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Revision 0

Development of the 3D Hexavalent Chromium Groundwater Plume using Leapfrog for Southeast 200-UP-1

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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Richland, Washington 99352

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M. C. Weber
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Terms

3D	three-dimensional
CHPRC	CH2M HILL Plateau Remediation Company
ECF	environmental calculation file
HISI	Hanford Information Systems Inventory
OU	Operable Unit
RD/RAWP	Remedial Design/Remedial Action Work Plan
Rlm	Ringold Member of Wooded Island lower mud unit (Rlm)
Rwia	Ringold Member of Wooded Island Unit A
SSP&A	S.S. Papadopoulos and Associates
UCL_{95}	95th percentile upper confidence limit on the plume mean concentration

1 Purpose

A chromium plume is present in the unconfined aquifer in the southeastern portion of the 200-UP1 Operable Unit (OU) (DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*). The current remedial action planned for this plume is a combination of pump-and-treat and monitored natural attenuation. DOE/RL-2013-07, *200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan* stated that due to the limited characterization dataset available, the plume extent and configuration was uncertain and additional characterization was necessary. As a result, eleven characterization wells were drilled in and around the plume. Depth-discrete chromium samples were taken during drilling to characterize the three-dimensional (3D) nature of the plume. These samples, along with routine samples taken at the pre-existing wells at the site, were used as data in this environmental calculation file (ECF) to create a 3D interpretation of the chromium plume.

2 Background

Eleven new wells were drilled to better characterize the chromium plume (Figure 2-1). The eleven new wells were drilled using the air rotary method. The air rotary method was chosen over the cable tool drilling method because the cable tool drilling method can create temporary reducing conditions in the aquifer. The cable tool drilling method pulverizes the sediment, creating fresh sediment surfaces. Some of the minerals in the sediment contain ferrous iron, Fe(II), a reduced of iron. When a fresh surface is cut in sediment containing ferrous iron, it oxidizes using the available nearby elements. This reaction can reduce the soluble and mobile hexavalent chromium Cr(VI) in chromate or dichromate to the non-soluble trivalent chromium Cr(III) (Early and Rai, *Kinetics of chromate reduction by ferrous ions derived from hematite and biotite at 25° C*; PNNL-24705, *Assessment of hexavalent chromium natural attenuation for the Hanford site 100 Area*; White and Peterson, *Reduction of aqueous transition metal species on surfaces of Fe(II) containing oxides*). When mobile hexavalent chromium is reduced to the non-soluble trivalent chromium, the amount of mobile chromium available to be measured in a water sample decreases, and a misleadingly low chromium value is returned. To get a proper assessment of the chromium concentrations at depth, it was necessary to mitigate reducing conditions during drilling. It is thought that the air rotary method mitigates reducing conditions in two ways: it helps to maintain an oxygenated subsurface and it doesn't disturb the sediment as much during drilling. Keeping a constant air flow in the borehole may provide oxygen to react with the ferrous iron, to minimize the reduction of chromium. The air rotary method also doesn't disturb the sediment as much as the cable tool drilling method, and therefore exposes less ferrous iron.

Additional measures were taken during sample collection to improve the chances of obtaining representative chromium results. Water was purged from the boreholes prior to sampling, and field measurements of dissolved oxygen were used to evaluate the purge. Water was purged until dissolved oxygen readings stabilized at or above 7,000 μg/L. For some wells, field measurements of hexavalent chromium were obtained during the purge with the requirement that concentrations stabilize prior to collecting samples for laboratory analysis.

Laboratory analyses for manganese was also performed on the water samples. Manganese is an indicator of reducing conditions because it is insoluble under the normal oxidizing conditions of the aquifer. Thus, the presence of substantial manganese in the sample results indicates reducing conditions.

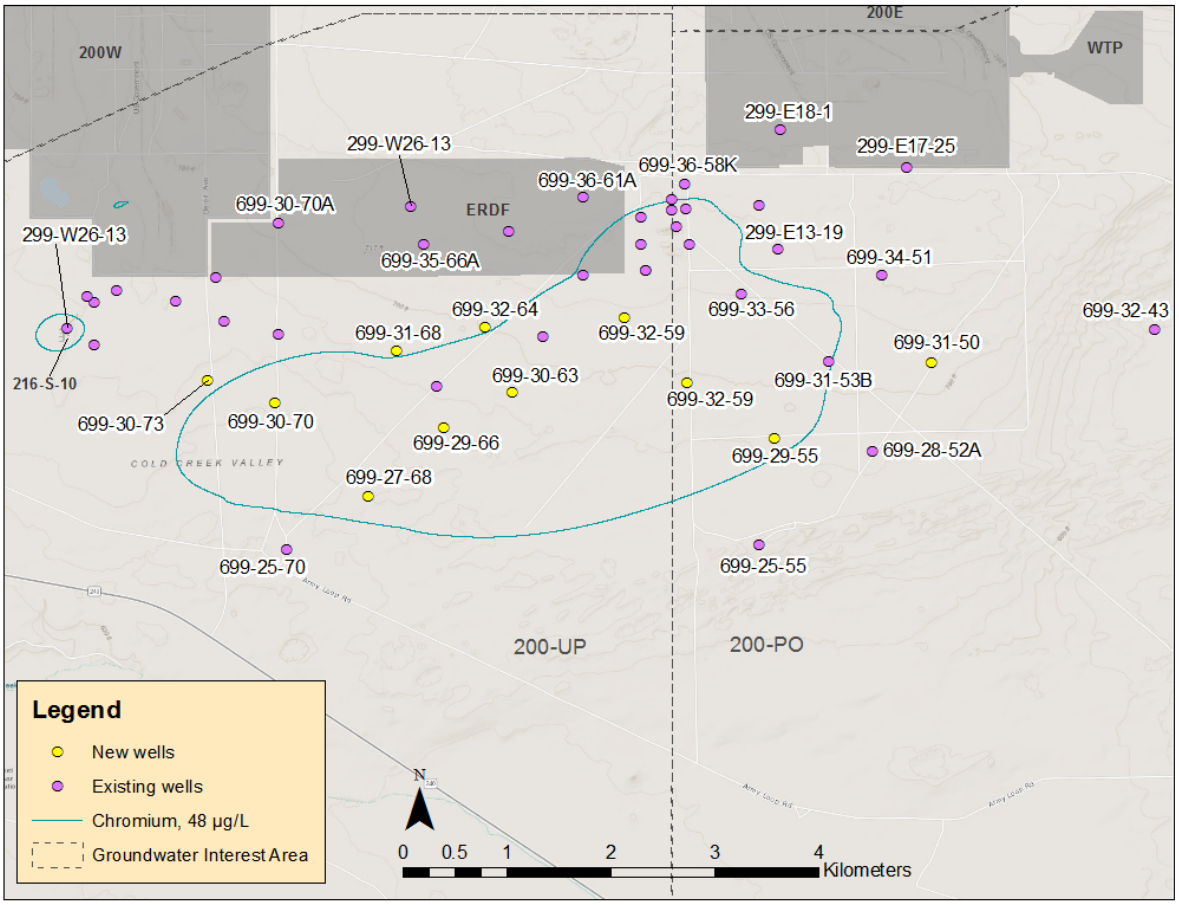

Figure 2-1. Overview of New and Existing Wells used for Characterization of the Chromium Plume

3 Methodology

The 3D chromium plume model was built using two kinds of data: well data and control data. The model was constrained using boundary data. The following section outlines the curation and use of each of these types of data, and their use in building the model.

3.1 Well Data

Two types of well data were used to build this model: the depth-discrete data taken during drilling of the eleven new wells, and the routine samples taken from the pre-existing wells in the area. Figure 2-1 has a map of the wells used in this model.

3.1.1 Depth-discrete Data

Depth-discrete well data were collected during drilling. Table 3-1 lists all the depth-discrete values used in the model. The sample data were evaluated to determine if chromium reduction had occurred during drilling, resulting in an underrepresentation of the contamination of the plume. Reduction was determined to have occurred in two types of cases: if a depth-discrete sample had an anomalously low concentration when compared to the samples taken above and below it, or if the routine post-development sample was higher than the highest depth-discrete sample taken during drilling. Sample results for manganese were also used in this evaluation. A sample with an anomalously low chromium value measured between two

high values was considered to have been reduced during drilling, especially if elevated manganese occurred in the sample. Two examples of this are present in 699-27-68. A sample value of 22.9 µg/L was taken below a sample of 55.5 µg/L and above a sample of 60.1 µg/L. A sample value of 10.9 µg/L was taken below the sample of 60.1 µg/L and above a sample of 69.8 µg/L. Manganese concentrations in the same samples as the low chromium values were 2 to 3 times higher than in the other samples, consistent with reducing conditions. The chromium results of 22.9 µg/L and 10.9 µg/L were determined to be anomalously low compared to the surrounding samples and were removed from the data set. Samples were also removed from well 699-29-55 for being anomalously low. The removed samples are listed in Table 3-2.

After drilling, chromium samples were taken quarterly at the new wells. If these routine samples had chromium concentrations significantly higher than the samples taken during drilling, then the well data were scaled up. Well 699-29-66 is the only well which required scaling. The routine sample taken on July 7th, 2017, approximately a month and a half after the last depth-discrete sample was taken, had a concentration of 94.9 µg/L. The highest concentration measured during drilling was 56 µg/L. The samples were scaled by dividing 94.9 by the result of 56 multiplied by the sample value. The scaled values are seen in Table 3-3.

Table 3-1. Depth-discrete Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
699-27-68	C9632	569324.68	131676.28	124.8	B3B044	6/5/2017	55.5
				112.95	B3B060	6/12/2017	60.1
				100.48	B3B076	6/20/2017	69.8
				96	B3B084	6/21/2017	46.6
699-29-55	C9634	573241.90	132230.30	118.78	B3B0C9	7/12/2017	48.4
				112.69	B3B0D7	7/13/2017	34.3
				97.45	B3B0H3	7/20/2017	78.6
699-29-66	C9413	580053.53	132336.94	121.87	B34TD0	5/12/2017	22.03
				103.74	B34TD5	5/16/2017	94.9
				82.77	B34TD8	5/17/2017	2.54
				55.67	B35N83	5/23/2017	2.71
699-30-57	C9417	572394.41	132770.78	114.2	B34TP4	6/14/2017	110
				98.12	B34TP9	6/15/2016	28
699-30-63	C9602	570716.90	132674.86	121.51	B37C55	11/28/2016	46.5
				115.33	B37C68	11/29/2016	126
				109.31	B37C81	11/30/2016	105
				103.19	B37C93	12/1/2016	81.5
				97.15	B37CB6	12/7/2016	92.1

Table 3-1. Depth-discrete Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
				92	B37JL9	12/13/2016	49.5
699-30-70	C9635	568429.06	132581.36	126.33	B3B0P5	5/23/2017	47
				120.26	B3B0R4	5/24/2017	68.4
				114.16	B3B0T2	5/25/2017	85.1
				108.05	B3B0V0	5/31/2017	176
				102.01	B3B0V8	6/1/2017	142
				95.91	B3B0W5	6/5/2017	160
				90.06	B3B0X5	6/20/2017	8.5
				83.96	B3B0Y3	6/21/2017	18.7
699-30-73	C9636	567781.87	132789.36	127.62	B3F9W1	10/17/2017	20.9
				121.55	B3F9W9	10/18/2017	11.3
				115.55	B3F9X7	10/18/2017	4
				109.37	B3F9Y5	10/19/2017	9.6
				103.36	B3FB03	10/23/2017	12
				97.19	B3FB11	10/24/2017	12.4
				91.15	B3FB21	10/25/2017	7
				85.03	B3FB29	10/25/2017	7.6
699-31-50	C9737	574750.00	132960.00	116.58	B3B127	9/12/2017	4
				110.9	B3B138	9/13/2017	4
				104.48	B3B143	9/18/2017	4
				98.75	B3B151	9/19/2017	4
				92.35	B3B159	9/20/2017	4
				86.41	B3B167	9/21/2017	4
				80.46	B3B175	9/26/2017	4
699-31-68	C9416	569598.00	133080.60	117.19	B34TH6	3/28/2016	18
				105.06	B34TJ1	3/29/2016	4.2
				83.66	B34WM8	3/31/2016	23
699-32-59	C9603	571800.08	133400.32	114.73	B386N9	1/31/2017	115
				108.84	B386R0	2/1/2017	81
				102.46	B386T5	2/2/2017	98.7

Table 3-1. Depth-discrete Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
				99.5	B386X1	2/7/2017	41.8
699-32-64	C9601	570451.01	133304.04	118.09	B37BT2	10/27/2017	31.7
				115.04	B37BT9	10/31/2016	29
				109.33	B37BV6	11/1/2016	7.6
				102.85	B37BW4	11/2/2016	1.5
				96.71	B37BX0	11/3/2016	4
Easting and northing are in NAV83(91); Elevation is in NAVD88							

Table 3-2. Depth-discrete Data Removed due to Anomalously Low Values

Well Name	Well ID	Elevation (m)	Sample Number	Sample Date	Chromium concentration (µg/L)
699-29-55	C9634	103.57	B3B0F5	07/19/17	17.2
699-29-55	C9634	91.35	B3B0J1	07/24/17	22.9
699-29-55	C9634	85.25	B3B0J9	07/26/17	15.9
699-27-68	C9632	118.89	B3B052	06/07/17	22.6
699-27-68	C9632	106.29	B3B068	06/15/17	10.9

Table 3-3. Scaled Depth-discrete Data

Well Name	Well ID	Elevation of Sample NAVD88 (m)	Sample Number	Sample Date	Measured Chromium Concentration (µg/L)	Scaled Chromium Concentration (µg/L)
699-29-66	C9413	121.87	B34TD0	5/12/2017	13	22.03
699-29-66	C9413	103.74	B34TD5	5/16/2017	56	94.90
699-29-66	C9413	82.77	B34TD8	5/17/2017	1.5	2.54
699-29-66	C9413	55.67	B35N83	5/23/2017	1.6	2.71
699-29-66	C9413	N/A	B3BLJ6	7/7/2017	94.9[a]	N/A
[a] Routine sample						

Two wells, 699-30-63 and 699-27-68, have samples which were taken just below the pick of the top of the Ringold Member of Wooded Island lower mud unit (Rlm). The transition of the Ringold Member of

Wooded Island Unit E to the Rlm is gradual enough in this location that the samples were judged to be representative of the concentration at the top of the Rlm. Therefore, the elevations of these samples were adjusted upwards to be slightly above the top of the Rlm, instead of beneath the top of the Rlm. Table 3-4 shows the measured elevations of the samples at 699-30-63 and 699-27-68, the approximate elevation of the top of the Rlm surface from Revision 5 of ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*, the picks of the top of the Rlm in those wells, and the adjusted elevations.

Table 3-4. Depth-discrete Samples with Adjusted Elevations

Well Name	Measured Elevation	Approximate top of Rlm in the model[a]	Top of Rlm in the well	Adjusted Elevation
699-30-63	91.08	91.789	91.95	92
699-27-68	94.37	95.6	95.78	96

[a] Value of the top of the Ringold Member of Wooded Island lower mud unit (Rlm) is from Appendix A of ECF-HANFORD-13-0029, Revision 5

3.1.2 Routine Data

The chromium data taken from the already-existing wells are routine samples. Routine sample data can be seen in Table 3-5. Routine data draw water from the length of their screens. To represent the length of the screen, three data points represent the routine samples: in Leapfrog®[1] these are represented with one sample each at the top (or top of the water table, whichever is lower), middle, and bottom of the screen. Screen data are found in Table 3-6.

Table 3-5. Routine Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
299-E13-14	A4726	573087.497	134474.132	121.87	B34TL7	4/6/2017	23
299-E13-14	A4726	573087.497	134474.132	121.5	B34TL7	4/6/2017	23
299-E13-14	A4726	573087.497	134474.132	121.68	B34TL7	4/6/2017	23
299-E13-19	A5864	573277.657	134061.013	121.89	B3B6W5	7/24/2017	19
299-E13-19	A5864	573277.657	134061.013	114.1	B3B6W5	7/24/2017	19
299-E13-19	A5864	573277.657	134061.013	117.99	B3B6W5	7/24/2017	19
299-E17-25	C3926	574515.185	134845.567	121.72	B37X24	7/17/2017	10.3
299-E17-25	C3926	574515.185	134845.567	111.8	B37X24	7/17/2017	10.3
299-E17-25	C3926	574515.185	134845.567	116.76	B37X24	7/17/2017	10.3
299-E18-1	A4743	573296.567	135200.161	121.76	B37X29	1/17/2017	6.7

[1] Leapfrog, Leapfrog Hydro, and Leapfrog Geo are registered trademarks of ARANZ Ltd., Christchurch, New Zealand.

Table 3-5. Routine Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
299-E18-1	A4743	573296.567	135200.161	119.2	B37X29	1/17/2017	6.7
299-E18-1	A4743	573296.567	135200.161	120.48	B37X29	1/17/2017	6.7
299-W26-13	B8817	566424.387	133293.598	133.84	B39BV2	5/2/2017	160
299-W26-13	B8817	566424.387	133293.598	126.7	B39BV2	5/2/2017	160
299-W26-13	B8817	566424.387	133293.598	130.27	B39BV2	5/2/2017	160
299-W26-14	B8828	566682.69	133539.21	133.24	B39BW2	5/2/2017	3.8
299-W26-14	B8828	566682.69	133539.21	125.9	B39BW2	5/2/2017	3.8
299-W26-14	B8828	566682.69	133539.21	129.57	B39BW2	5/2/2017	3.8
699-25-55	A5098	573089.05	131212.146	124.47	B3BWY0	9/15/2017	6.1
699-25-55	A5098	573089.05	131212.146	112.6	B3BWY0	9/15/2017	6.1
699-25-55	A5098	573089.05	131212.146	118.53	B3BWY0	9/15/2017	6.1
699-25-70	A5099	568544.855	131171.718	131	B3BWY5	9/15/2017	16
699-25-70	A5099	568544.855	131171.718	127.3	B3BWY5	9/15/2017	16
699-25-70	A5099	568544.855	131171.718	129.15	B3BWY5	9/15/2017	16
699-28-52A	A5111	574187.625	132109.32	122.23	B3BWY8	9/15/2017	1
699-28-52A	A5111	574187.625	132109.32	118.4	B3BWY8	9/15/2017	1
699-28-52A	A5111	574187.625	132109.32	120.31	B3BWY8	9/15/2017	1
699-29-55	C9634	573241.9	132230.3	97.45	B3B0H3	7/20/2017	78.6
699-30-66	C4298	569990.98	132739.19	92.4	B37B70	11/7/2016	110
699-30-66	C4298	569990.98	132739.19	89.3	B37B70	11/7/2016	110
699-30-66	C4298	569990.98	132739.19	90.85	B37B70	11/7/2016	110
699-31-53B	A8507	573758.382	132975.114	121.96	B3BX03	9/15/2017	45
699-31-53B	A8507	573758.382	132975.114	108.3	B3BX03	9/15/2017	45
699-31-53B	A8507	573758.382	132975.114	115.13	B3BX03	9/15/2017	45
699-32-43	A5127	576902.127	133278.606	121.69	B37XJ0	2/24/2017	10.1
699-32-43	A5127	576902.127	133278.606	121	B37XJ0	2/24/2017	10.1
699-32-43	A5127	576902.127	133278.606	121.34	B37XJ0	2/24/2017	10.1
699-32-62	A5128	571009.564	133215.925	127.57	B39308	4/5/2017	130
699-32-62	A5128	571009.564	133215.925	125.4	B39308	4/5/2017	130

Table 3-5. Routine Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
699-32-62	A5128	571009.564	133215.925	126.49	B39308	4/5/2017	130
699-32-70B	A5129	568461.999	133242.245	130.94	B39313	4/10/2017	21
699-32-70B	A5129	568461.999	133242.245	128.9	B39313	4/10/2017	21
699-32-70B	A5129	568461.999	133242.245	129.92	B39313	4/10/2017	21
699-32-72B	A9525	567935.006	133362.095	131.27	B0DJ01	1/9/1995	9.3
699-32-72B	A9525	567935.006	133362.095	129.7	B0DJ01	1/9/1995	9.3
699-32-72B	A9525	567935.006	133362.095	130.48	B0DJ01	1/9/1995	9.3
699-32-76	C4975	566683.94	133137.73	133	B39BX4	5/2/2017	6.6
699-32-76	C4975	566683.94	133137.73	123.3	B39BX4	5/2/2017	6.6
699-32-76	C4975	566683.94	133137.73	128.15	B39BX4	5/2/2017	6.6
699-33-56	A5133	572922.693	133627.235	121.94	B37XJ4	2/26/2017	76.9
699-33-56	A5133	572922.693	133627.235	94.5	B37XJ4	2/26/2017	76.9
699-33-56	A5133	572922.693	133627.235	108.22	B37XJ4	2/26/2017	76.9
699-33-74	C4973	567472.65	133552.16	131.6	B30XT6	5/11/2015	8.1
699-33-74	C4973	567472.65	133552.16	124.6	B30XT6	5/11/2015	8.1
699-33-74	C4973	567472.65	133552.16	128.1	B30XT6	5/11/2015	8.1
699-33-75	C4974	566907.78	133662.48	132.51	B39BY1	5/2/2017	1.5
699-33-75	C4974	566907.78	133662.48	124.3	B39BY1	5/2/2017	1.5
699-33-75	C4974	566907.78	133662.48	128.4	B39BY1	5/2/2017	1.5
699-33-76	C4976	566621.21	133600.43	133.37	B39BY8	5/2/2017	1.5
699-33-76	C4976	566621.21	133600.43	125	B39BY8	5/2/2017	1.5
699-33-76	C4976	566621.21	133600.43	129.18	B39BY8	5/2/2017	1.5
699-34-51	A5137	574269.887	133808.476	121.77	B39TP7	6/23/2017	26.2
699-34-51	A5137	574269.887	133808.476	112.8	B39TP7	6/23/2017	26.2
699-34-51	A5137	574269.887	133808.476	117.29	B39TP7	6/23/2017	26.2
699-34-58	C6065	572003.4	133850.1	115.6	B2PCP6	10/19/2009	90
699-34-58	C6065	572003.4	133850.1	106.8	B2PCP6	10/19/2009	90
699-34-58	C6065	572003.4	133850.1	111.2	B2PCP6	10/19/2009	90
699-34-58B	C6066	571995.7	133849.6	123.2	B2PCP4	10/19/2009	80

Table 3-5. Routine Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
699-34-58B	C6066	571995.7	133849.6	114.4	B2PCP4	10/19/2009	80
699-34-58B	C6066	571995.7	133849.6	118.8	B2PCP4	10/19/2009	80
699-34-61	A5463	571395.863	133809.862	125.81	B38RC7	3/17/2017	63.2
699-34-61	A5463	571395.863	133809.862	122.3	B38RC7	3/17/2017	63.2
699-34-61	A5463	571395.863	133809.862	124.05	B38RC7	3/17/2017	63.2
699-34-72	C4972	567859.97	133785.33	131.1	B343V3	2/22/2016	20
699-34-72	C4972	567859.97	133785.33	123.1	B343V3	2/22/2016	20
699-34-72	C4972	567859.97	133785.33	127.1	B343V3	2/22/2016	20
699-35-57	A8556	572422.612	134106.712	122.06	B2PCR3	10/21/2009	105
699-35-57	A8556	572422.612	134106.712	114.6	B2PCR3	10/21/2009	105
699-35-57	A8556	572422.612	134106.712	118.33	B2PCR3	10/21/2009	105
699-35-58	A8557	572300.422	134272.86	122.02	B2PCP9	10/20/2009	90
699-35-58	A8557	572300.422	134272.86	114.1	B2PCP9	10/20/2009	90
699-35-58	A8557	572300.422	134272.86	118.06	B2PCP9	10/20/2009	90
699-35-58D	C9427	571951.778	134365.554	122.92			61
699-35-58D	C9427	571951.778	134365.554	112.7			61
699-35-58D	C9427	571951.778	134365.554	117.81			61
699-35-59	A8558	571956.4	134096.2	123.38	B2PCL3	2/10/2009	74.2
699-35-59	A8558	571956.4	134096.2	114.8	B2PCL3	2/10/2009	74.2
699-35-59	A8558	571956.4	134096.2	119.09	B2PCL3	2/10/2009	74.2
699-35-66A	A5139	569857.861	134099.244	129.38	B38RX1	3/9/2017	20.2
699-35-66A	A5139	569857.861	134099.244	128	B38RX1	3/9/2017	20.2
699-35-66A	A5139	569857.861	134099.244	128.69	B38RX1	3/9/2017	20.2
699-36-58A	A8571	572251.672	134536.248	121.91	B2PCR2	10/21/2009	46.2
699-36-58A	A8571	572251.672	134536.248	115	B2PCR2	10/21/2009	46.2
699-36-58A	A8571	572251.672	134536.248	118.46	B2PCR2	10/21/2009	46.2
699-36-58B	A8572	572253.483	134431.185	121.95	B2PCR1	10/20/2009	60
699-36-58B	A8572	572253.483	134431.185	115.1	B2PCR1	10/20/2009	60
699-36-58B	A8572	572253.483	134431.185	118.53	B2PCR1	10/20/2009	60

Table 3-5. Routine Chromium Data used in the Model

Well Name	Well ID	Easting	Northing	Elevation (m)	Sample Number	Sample Date	Sample Result (Total Cr or Cr6+) (µg/L)
699-36-58J	C9426	572386.368	134437.639	121.88			64
699-36-58J	C9426	572386.368	134437.639	111.8			64
699-36-58J	C9426	572386.368	134437.639	116.84			64
699-36-58K	C9428	572376.288	134678.157	121.89			25
699-36-58K	C9428	572376.288	134678.157	113.7			25
699-36-58K	C9428	572376.288	134678.157	117.8			25
699-36-61A	A5144	571395.472	134557.106	123.89	B39TR2	6/19/2017	12.9
699-36-61A	A5144	571395.472	134557.106	120.5	B39TR2	6/19/2017	12.9
699-36-61A	A5144	571395.472	134557.106	122.19	B39TR2	6/19/2017	12.9
699-36-63B	C9593	570683.53	134228.69	127.31	B39TR8	6/19/2017	14.6
699-36-63B	C9593	570683.53	134228.69	104.6	B39TR8	6/19/2017	14.6
699-36-63B	C9593	570683.53	134228.69	115.95	B39TR8	6/19/2017	14.6
699-36-66B	C6219	569731.34	134469.01	129.48	B3BT10	9/27/2017	3.6
699-36-66B	C6219	569731.34	134469.01	120.2	B3BT10	9/27/2017	3.6
699-36-66B	C6219	569731.34	134469.01	124.84	B3BT10	9/27/2017	3.6
699-36-70A	A9901	568466.679	134308.839	130.53	B3BT17	9/27/2017	3
699-36-70A	A9901	568466.679	134308.839	127.5	B3BT17	9/27/2017	3
699-36-70A	A9901	568466.679	134308.839	129.01	B3BT17	9/27/2017	3

Easting and northing data are in NAV83(91)
Elevation data are in NAVD88

Table 3-6. Screen Data for Routine Samples

Well Name	Elevation of Top of Open Interval (m)	Elevation of Bottom of Open Interval (m)
299-E13-14	129.8	121.5
299-E13-19	128.2	114.1
299-E17-25	122.4	111.8
299-E18-1	125.5	119.2
299-W26-13	137.4	126.7
299-W26-14	136.6	125.9

Table 3-6. Screen Data for Routine Samples

Well Name	Elevation of Top of Open Interval (m)	Elevation of Bottom of Open Interval (m)
699-25-55	127.7	112.6
699-25-70	139.2	127.3
699-28-52A	125.4	118.4
699-30-66	92.4	89.3
699-31-53B	126.3	108.3
699-32-43	124.1	121
699-32-62	132.2	125.4
699-32-70B	140.7	128.9
699-32-72B	140.4	129.7
699-32-76	134.8	123.3
699-33-56	123.1	94.5
699-33-74	134.4	124.6
699-33-75	135	124.3
699-33-76	135.5	125
699-34-51	124.4	112.8
699-34-58	115.6	106.8
699-34-58B	123.2	114.4
699-34-61	128.5	122.3
699-34-72	133.7	123.1
699-35-57	126.8	114.6
699-35-58	126.3	114.1
699-35-58D	124.9	112.7
699-35-59	127	114.8
699-35-66A	142.5	128
699-36-58A	127.2	115
699-36-58B	127.3	115.1
699-36-58J	124	111.8
699-36-58K	125.9	113.7
699-36-61A	128	120.5
699-36-63B	138.2	104.6
699-36-66B	130.9	120.2

Table 3-6. Screen Data for Routine Samples

Well Name	Elevation of Top of Open Interval (m)	Elevation of Bottom of Open Interval (m)
699-36-70A	136.7	127.5

3.2 Control Data

3.2.1 Outer edge of Two-dimensional Plume

The raster of chromium concentrations in groundwater produced for DOE/RL-2016-67 was updated with data from the characterization wells for use in this model (M. Aye, personal communication, November 9th, 2017). The maximum concentration taken from each well was used as the input value for that well in the raster. The maximum concentration may have occurred during drilling or as a routine sample after drilling. Two rasters were produced for use in this ECF: one for the main body of the plume and one for the plume at the 216-S-10 pond and ditch. The plume raster around 216-S-10 was interpolated using the same process as the main plume, but with a different variogram (M. Aye, personal communication, November 9th, 2017). This was done to reflect the difference in the historical flow pattern of the plume at 216-S-10 and the historical flow pattern of the main plume.

Lines representing the 24 µg/L concentration contours in these two rasters were extracted and used as control lines to bound and generally shape the 3D plume. The contour lines were extracted from the rasters using the following steps:

1. Import the "Chromium_200UP1_Ave.asc" file.
2. Navigate to "Spatial Analyst Tools" → "Surface" → "Contour"
3. In the Contour tool, set the inputs thusly:
    a. Set "Input raster" to "Chromium_200UP1_Ave.asc"
    b. Set "Output polyline features" to the location desired, with the desired name.
    c. Set "Contour interval" to 24
    d. Set "Base contour (optional)" to 0
    e. Leave "Z factor (optional)" as its default value, 1
4. Add the new layer to the map.
5. Right-click the layer and select "Display Attribute Table".
6. Select all three of the polylines with a contour value of 24 and close the attribute table.
7. Right-click on the layer and select "Export Data" to export the contours of 24mg/L.
8. In the Export Data tool, set the inputs thusly:
    a. Export: Selected features
    b. Use the same coordinate system as: this layer's source data
    c. Output feature class: (set this to the location and file name desired).

3.2.2 Control Lines

Control lines are lines used to constrain and shape the 3D plume in Leapfrog. The lines are assigned numerical values, and the plume shape adjusts to respect those values. Control lines can be constructed in Leapfrog or calculated outside of Leapfrog and imported. The control lines in this model were all calculated outside of Leapfrog and imported. Aside from the control lines which were created from plume contours, the control lines used in this model consist of straight lines connecting sample values from one well to another. In most cases, these lines are broken up into quarters, and each of the quarters has a concentration representing a linear change in values from one sample to the next. Table 3-7 lists the name

and purpose and calculation method of each control line. Appendix A contains the x,y,z data of each control line, and the concentration value assigned to each line.

Table 3-7. List of Control Lines and their use in the Model

Name of the Control Line	Purpose of the Control Line
29_55_to_30_57_78	This line increases the connectivity of the portion of the plume with a concentration >72 μg/L between wells 699-30-57 and 699-29-55. The concentration on this line is 78.6 μg/L, which is a value of a sample in 699-29-55. Well 699-30-57 has two values: 110 μg/L at 114 m, and 28 μg/L at 98 m. These values were too high or too low for the necessary connection value of 78.6 μg/L. Wells with depth-discrete data (specifically 699-30-63 and 699-30-70) indicate that after peaking about midway between the water table and top of the Rlm, chromium concentrations decrease as elevation decreases. Therefore, in well 699-30-57 a linear decay in chromium concentration was assumed. Assuming a linear decay, the elevation of a value of 78 μg/L between the sample of 110 μg/L and the sample of 28 μg/L was calculated and used as the endpoint of the polyline.
57_to_57 Quarters 1-4	This line series connects the 105 μg/L value at 699-35-57 to the 110 μg/L value at 699-30-57. This was done to increase the connectivity of the high values (>100 μg/L) of the plume. This line series has four sections, each of which represents a linear change in values from one sample to the other.
62_to_57 Quarters 1-4	This line series connects the 130 μg/L value at 699-32-62 to the 110 μg/L value at 699-30-57. This was done to increase the connectivity of the high values (>100 μg/L) of the plume. This line series has four sections, each of which represents a linear change in values from one sample to the other.
63_to_62 Quarters 1-4	This line series connects the 126 μg/L value at 699-30-63 to the 130 μg/L value at 699-32-62. This was done to increase the connectivity of the high values (>100 μg/L) of the plume and create a verticality in plume concentrations based on the elevations of these concentrations and the decrease in concentrations below the 130 μg/L sample in 699-30-63. This line series has four sections, each of which represents a linear change in values from one sample to the other.
66_to_62 Quarters 1-4	This line series connects the 110 μg/L value at 699-30-66 to the 130 μg/L value at 699-32-62. This was done to increase the connectivity of the high values (>100 μg/L) of the plume. This line series has four sections, each of which represents a linear change in values from one sample to the other.

Table 3-7. List of Control Lines and their use in the Model

Name of the Control Line	Purpose of the Control Line
66_to_63 Quarters 1-4	This line series connects the 110 μg/L value at 699-30-66 to the 126 μg/L value at 699-30-63. This was done to increase the connectivity of the high values (>100 μg/L) of the plume and create a verticality in plume concentrations based on the elevations of these concentrations and the decrease in concentrations below the 130 μg/L sample in 699-30-63. This line series has four sections, each of which represents a linear change in values from one sample to the other.
70_to_63 Quarters 1-4	This line series connects the ~47 μg/L values in 699-30-70 and 699-30-63. This is done to connect the plume between the two values and create a verticality in plume concentrations based on the elevations of these concentrations. This line series has four sections, each of which represents a linear change in values from one sample to the other.
70_to_66 Quarters 1-4	This line series connects the 176 μg/L value in 699-30-70 to the 110 μg/L value in 699-30-66. This was done to increase the connectivity of the high values (>100 μg/L) of the plume and create a verticality in plume concentrations based on the elevations of the high concentrations in the plume. This line series has four sections, each of which represents a linear change in values from one sample to the other.
Chromium_200UP1_W26_13_Ave_24	This line series represents the contour of 24 μg/L around 216-S-10 as defined by the raster from SSP&A[2] outlined in Section 3.2.1. This line was used to constrain the plume and get a general shape of its interior, without relying too heavily on the SSP&A interpretation.
new_chrome_24_contour_only	This line series represents the contour of 24 μg/L of the main body of the chromium plume and the plume as defined by the raster from SSP&A outlined in Section 3.2.1. This line was used to constrain the plume and get a general shape of its interior, without relying too heavily on the SSP&A interpretation.

3.2.2.1 Control Points

Control points are used to constrain and shape the 3D plume in Leapfrog. The points are assigned numerical values and spatial locations, and the plume shape adjusts to respect those values. Control points must be imported into Leapfrog-Geo. Table 3-8 lists the name and purpose and calculation method of each set of control points. Appendix A contains the x,y,z data of each control point, and the concentration value assigned to each line.

[2] S.S. Papadopoulos and Associates, Bethesda, Maryland.

Table 3-8: List of Control Point Sets and their use in the Model

Name of the Control Point set	Purpose of the Control Point Set
control_points	These points increase the connectivity of the >72 µg/L portion of the plume with the high concentration value (94.9 µg/L) in well 699-29-66. Their locations are approximately along planes which connect well 699-29-66 to well 699-30-70 and well 699-30-63, as those wells also have high concentrations.
control_points_south_70	These points increase the connectivity of the ~70 µg/L concentrations in wells 699-27-68 and 699-29-55. These points were chosen along a plane connecting the two wells.

3.2.3 Boundary Data

The model is bounded on top by the water table and on bottom by the interpolated surface of the top of the Rlm and the top of the basalt. The water table grid used in this model came from a grid interpolated from the sitewide water table map for 2016 (ECF-HANFORD-16-0080, *Preparation of the March 2016 Hanford Site Water Table and Potentiometric Surface Maps*. The method for creating the top of basalt raster is described in ECF-HANFORD-16-0128, *Development of Continuous Top of Basalt Surface for use in Development of Site Geoframeworks*. The interpolated surface of the top of the Rlm was exported from the Leapfrog model in Revision 5 of ECF-HANFORD-13-0029 according to the following steps:

1. Open the Hanford South Geoframework Leapfrog model.
2. In the Project Tree, navigate to the surface of the Rlm in the correct fault block by following these steps: "Geological Models" → "GM" → "GM fault block 7" → "Rlm contacts".
3. Right-click on "Rlm contacts" and select "Export". Leave all the settings as the default settings. Export the file as a mesh (*.msh) file.

3.3 Creating a 3D Leapfrog Plume

3.3.1 Import the Data

The chromium plume was built using three types of data: boundary data, well data, and control data. The methods for importing these types of data are outlined below.

1. Open a new Leapfrog-Geo 3.0.0 file
2. Ensure the clipping boundary is set. In the Project Tree, right-click on "Topographies". Select "Set clipping boundaries". Set the clipping boundaries thusly:
    a. X (East) minimum: 548000.0
    b. X (East) maximum: 604300.0
    c. Y (North) minimum: 100200.0
    d. Y (North) maximum: 144000.0
3. Import the water table data by right-clicking on the "Meshes" folder in the Project Tree and selecting "Import Elevation Grid". Navigate to "2016wt.tif" and select it. Leave the surface resolution set to 50 and ensure the box next to "Clip data to bounding box" is checked and import the surface.

a. Ensure all the surfaces are facing the correct direction: the water table should serve as the upper boundary and the top of basalt and top of Rlm should serve as the bottom boundary of the interpolant. If an interpolant is calculated and the result is outside these boundaries, right-click on the incorrect-facing boundary and select "Swap Inside".

4. Import the top of basalt file. Right-click on the "Meshes" folder in the Project Tree and selecting "Import Elevation Grid". Navigate to "final_tob_ecf.asc" and select it. Leave the surface resolution set to 150 and ensure the box next to "Clip data to bounding box" is checked and import the surface.

   a. The top of basalt used to create this plume is the same file that was used in Revision 5 of ECF-HANFORD-13-0029. The bounding box used when this file was originally imported for a previous revision of the Hanford South Geoframework Model is different than that of the current bounding box; as a result, the dimensions of the top of basalt surface are slightly different when the model is recreated than the version that was produced for this ECF.

5. Import the interpreted surface of the top of the Rlm by right-clicking on the "Meshes" folder in the Project Tree and selecting "Import Mesh". Navigate to the exported surface of the Rlm, "Rlm_surface.msh", select it, and in the "Cleanup mesh" window that pops up, accept all the defaults and import the mesh.

6. Import the well data by right-clicking on the "Points" folder in the Project Tree and selecting "Import Points". Navigate to the point dataset, "chromium dataset.csv", which should be saved in a comma-separated file. Open the file, and in the Import window that pops up, import the column values thusly:

   a. Well Name: Text

   b. Well ID: Text

   c. Easting: East (X)

   d. Northing: North (Y)

   e. Elevation: Elev (Z)

   f. Sample Number: Text

   g. Sample Date: Date

   h. Value: Numeric

   i. Units: Text

7. Import the control lines by right-clicking on "Polylines" in the Project Tree and selecting "Import Polyline". The control lines used in this step are listed in Table 3-7. Navigate to the polyline to be imported and select it. In the "Polyline Import" pop-up window, set the column values thusly:

   a. First column (contains point name data): Not Imported

   b. East (X): Easting

   c. North (Y): Northing

d. Elev (Z): Elevation

8. Import the 24 μg/L contour lines created in Section 3.2.1 (Chromium_200UP1_W26_13_Ave_24 and new_chrome_24_contour_only) and convert them into a format which can be used as a control line.

   a. Right-click on the "GIS Data, Maps and Photos" folder in the Project Tree and select "Import Vector data". Navigate to the contour file to be imported and select it. In the "Import GIS Vector Data" pop-up window, leave everything set to the default—Do not set an elevation field, and filter data to the clipping boundary.

   b. Set the elevation of the contours to the water table by right-clicking on the newly-imported contour file and select "Set Elevation". In the "Set Elevation" pop-up window, check the radio button next to "From surface" and select "2016wt" from the drop-down menu.

      i. Note: the elevation of the contour around the 216-S-10 pond and ditch was set approximately 0.2 meters above the water table.

   c. Extract the polylines from the contours to be used in the model by right-clicking on the contours and selecting "Extract Polyline".

9. Import the control points by right-clicking on the "Points" folder in the Project Tree and selecting "Import Points". The list of control point files can be seen in Table 3-8. Navigate to the control points files and select one for import. Open the file, and in the Import Points pop-up window, set the columns thusly:

   a. East (X): Easting

   b. North (Y): Northing

   c. Elev (Z): Elevation

   d. Conc: Numeric

   e. All other columns are not imported

   Repeat this process with the remaining control point file.

3.3.2 Build the Interpolant

Now that all the data have been loaded into Leapfrog, the 3D chromium plume model, referred to in Leapfrog as an interpolant, is ready to be built. The model is built according to the following instructions:

1. Right-click on the "Interpolants" folder in the project tree and select "New Interpolant". In the "New Interpolant" pop-up window, set the options thusly (see Figure 3-1 for a visual representation):

   a. Under "Values To Interpolate" set "Numeric values" to the "Value" field of the well data (Points > chromium_dataset).

   b. Check the box next to "Surface Filter" and of the filter options below, set the radio button to "Interpolant Boundary"

   c. Under "Interpolant Boundary", set the radio button to "Custom" and set the boundaries to the following values:

i. X (East) Minimum: 563797.59

ii. X (East) Maximum: 580173.29

iii. Y (North) Minimum: 126634.56

iv. Y (North) Maximum: 139167.59

v. Z (Elev) Minimum: -150

vi. Z (Elev) Maximum: 167.15

d. Under "General" set the surface resolution to 50, and "Volumes enclose" to "Intervals".

e. The interpolant can be named anything, but for this walkthrough it is named "Chromium Plume".

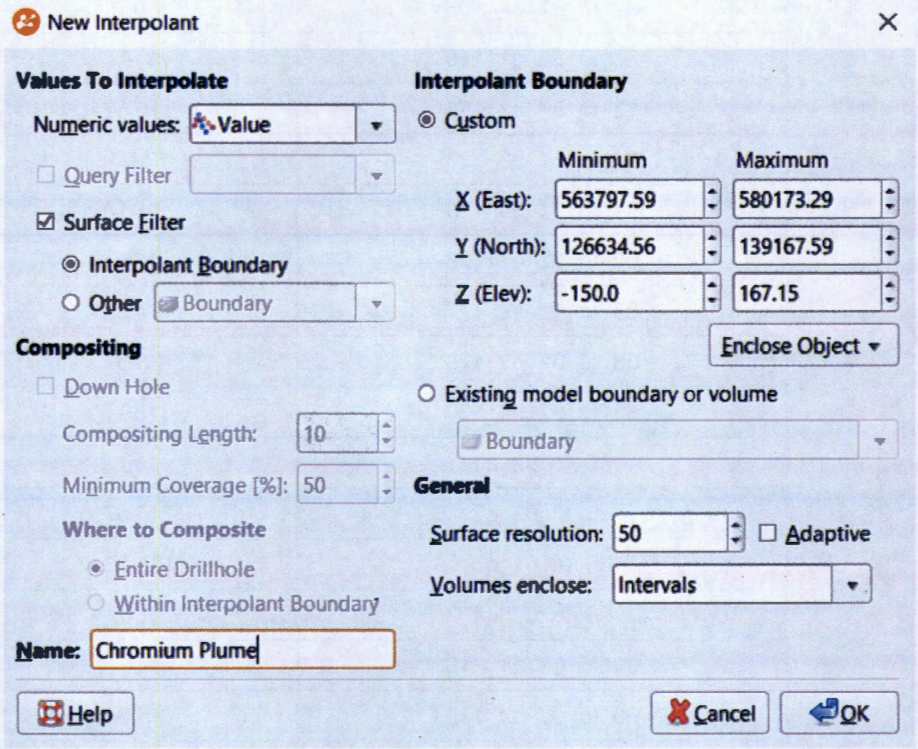

Figure 3-1. New Interpolant Setup

2. Set the boundaries:

   a. Expand the new interpolant and right-click on "Boundary". Under "New Lateral Extent" select "From Surface". Do this for the water table, the Rlm, and the top of basalt.

      i. When the water table is set as a lateral extent, a pop-up will appear saying "The boundary surface '2016wt' is too small. Select "Use '2016wt' Vertices".

      ii. If the resulting plume uses the top of the water table as the bottom of the plume, expand the Boundary menu in the interpolant menu, right-click on "2016wt", and select "Swap Inside".

3. Import the control lines into the interpolant:

a. In the expanded interpolant, right-click on "Chromium Plume values" and select "New Contour Polyline". In the pop-up window, set the radio button to "Existing Polyline", select a polyline, and set the "Value On Contour" to the concentration indicated in Table 3-9.

Table 3-9. Control Line Concentrations

Control line name	Concentration (µg/L)
29_55_to_30_57_78	78.6
57_to_57_q1_110	110
57_to_57_q2_108	108.3
57_to_57_q3_106	106.67
57_to_57_q4_105	105
62_to_57_q1_110	110
62_to_57_q2_116	116.67
62_to_57_q3_123	123.3
62_to_57_q4_130	130
63_to_62_q1_126	126
63_to_62_q2_127	127.33
63_to_62_q3_128	128.67
63_to_62_q4_130	130
66_to_62_q1	110
66_to_62_q2	116.67
66_to_62_q3	123.33
66_to_62_q4	130
66_to_63_q1_110	110
66_to_63_q2_115	115.33
66_to_63_q3_120	120.67
66_to_63_q4_126	126
70_to_63_q1_47	47
70_to_63_q2_47	46.83
70_to_63_q3_47	46.67
70_to_63_q4_46	46.5
70_to_66_q1	176
70_to_66_q2	154
70_to_66_q3	132

Table 3-9. Control Line Concentrations

Control line name	Concentration (µg/L)
70_to_66_q4	110
chromium_200up1_w26_13_ 24_only	24
new_chrome_24_contour_only	24

4. Import the control points:
    a. In the expanded interpolant, right-click on "Chromium Plume values" and select "Add Values". In the "Select Values" pop-up window, select the "Conc" value for one set of control points. Repeat this process for the other set of control points.
5. Edit the interpolant:
    a. Double-click on the interpolant and an "Edit Interpolant" window will pop up. Edit data in the following tabs:
        i. In the "Trend" tab, set the Global Trend thusly:
            1. Directions:
                a. Dip: 0
                b. Dip Azimuth: 0
                c. Pitch: 0
            2. Ellipsoid Ratios:
                a. Maximum: 6
                b. Intermediate: 3
                c. Minimum: 0.5
        ii. In the "Interpolant" tab, set the values thusly:
            1. Interpolant: Linear
            2. Sill: 1000
            3. Nugget: 0
            4. Base Range: 4000
            5. Drift: Constant
            6. Accuracy: 0.400
        iii. In the "Outputs" tab, set the values thusly:
            1. Evaluation limits: check the box next to "Minimum" and set the value to 0.0. Leave "Maximum" unchecked.

2. Isosurfaces: set "Default resolution" to 50, ensure the box next to "adaptive" is unchecked, and check the box next to "Exact clipping".
    a. In the table showing Iso Value and Surface Resolution, leave the surface resolutions for all iso values at 50, and set the following iso values: 12, 24, 48, 72, 100.
3. Volumes: set "Enclose" to "Intervals".

4 Assumptions and Inputs

The inputs to this model are the well data, the control data, and the boundary data. The well data are seen in Table 3-1 and Table 3-5. The x,y,z coordinates of the control line data are in Appendix A, while their reasons for use are in Table 3-7. The x,y,z and value data of the control points are listed in Appendix A, and the reasons for their use are in Table 3-8. The GIS data, the water table surface, the surface of the top of the Rlm, and the top of basalt surface are all packaged with this document.

The assumptions made in building this model are as follows:

1. The borehole data were assumed to be representative of the contamination. When the depth-discrete borehole data were anomalously low when compared to other values in the borehole or the routine sample taken later, we assumed this was due to reduction of Cr(VI) into the less-mobile Cr(III). Anomalously low values in a borehole with otherwise acceptable data were deleted. A well with low values when compared to the routine sample taken after drilling had its concentrations scaled up relative to the routine sample.
2. The routine data taken from the pre-existing wells were assumed to represent the concentrations over the whole screened area. This was represented by placing a data point with the measured value at the top (or top of the water table, whichever is lower), middle, and bottom of the screen.
3. The plume in general was assumed to be continuous, and control lines and points were used to increase continuity. This especially applied to the >100 μg/L areas. Control lines were used to increase the continuity of the 100 μg/L portion of the plume.

5 Software Applications

Software used for this calculation is applicable in accordance with a controlled software use procedure that implements the requirements of DOE O 414.1d, *Quality Assurance.*

5.1 Approved Software

The software identified below was used to perform this calculation and was approved and used compliant with controlled software use procedure that implements the requirements of DOE O 414.1d, *Quality Assurance.*

5.1.1 Description

The following approved software was used to perform this calculation:

- Software Title: Leapfrog-Geo

- Software Version: 3.0.0
- Hanford Information Systems Inventory (HISI) Identification Number: 3592 (Safety Software S3, graded to Level C)
- Workstation type and property number (from which software is run): INTERA workstation, Property Tag INTERA-00857 (INTERA owned; non-HLAN)

This approved software is managed under the following software quality assurance documents:

- CHPRC-01753, *Leapfrog-Hydro and Leapfrog-Geo Software Management Plan*
- CHPRC-01754, *Leapfrog-Hydro and Leapfrog-Geo Software Test Plan*
- CHPRC-01755, *Leapfrog-Hydro and Leapfrog-Geo Acceptance Test Report: Leapfrog-Hydro Version 2.3.2 and Leapfrog-Geo Version 4.2.1*

5.1.2 Software Installation and Checkout

A copy of the *Software Installation and Checkout Form* for Leapfrog-Geo is provided in Appendix B to this ECF.

5.1.3 Statement of Valid Software Application

Leapfrog-Geo software identified was used consistent with intended use for CH2M HILL Plateau Remediation Company (CHPRC) as identified in CHPRC-01753. This software was used within the limitations defined in CHPRC-01753 for CHPRC applications.

5.2 Support Software

The following software was used for limited purposes to support the use of Leapfrog-Geo in this calculation.

ArcMap®[3]

ArcMap® was used to create contours using the "Contour" tool in "Spatial Analyst Tools"

1. Software Title: ArcMap®
2. Software Version: 10.5.1
3. HISI Identification Number: 3402 (graded to Level E)

Microsoft Excel®[4]

Microsoft Excel was used to perform the calculations and as a spreadsheet tool.

6 Results/Conclusions

The final product of the work in this ECF is two chromium plumes: a small plume at 216-S-10 and a much larger plume to the east. The plume at the 216-S-10 pond and ditch formed later than the large

[3] ArcMap is a registered trademark of ESRI, Inc., Redlands, California.

[4] Excel is a registered trademark of Microsoft Corporation in the United States and in other countries.

plume, and under a different flow regime (Aye, personal communication). This discussion will henceforth be solely about the large chromium plume, which will be referred to as "the chromium plume".

The chromium plume is a continuous plume with three-dimensional characteristics. Concentrations of chromium above 72 μg/L are located deeper in the aquifer in the western portion of the plume than in the eastern part of the plume, where high chromium concentrations reach the water table. More vertical variability can be seen in the cross-sections (Figure 6-2 through Figure 6-6).

Cross-section 1 (Figure 6-2) cuts a section through the two plumes from northwest to southeast. It showcases the low concentrations of two of the wells between the small plume and the large plume. Well 699-30-73, which has depth-discrete data, shows a consistently low concentration of chromium over the entirety of the well. The progression of chromium concentrations in well 699-30-70 begin near the water table with a concentration of nearly 48 μg/L and generally increase with depth until the concentration drops from 160 μg/L to 8.5 μg/L at the bottom of the aquifer. Well 699-29-66 also features a low chromium concentration near the water table and a higher concentration at depth. This well also drilled past the Rlm into the Ringold Member of Wooded Island Unit A (Rwia) (also referred to as the Ringold Confined Aquifer). The low concentrations of chromium in the Rwia indicate that the Rlm serves as an aquiclude in this portion of the Hanford Site, and has prevented the chromium contamination from reaching the Rwia.

Cross-section 2 (Figure 6-3) cuts a section that begins further to the south and ends further to the north than cross-section 1. Cross-section 2 is located approximately 100 meters closer to well 699-29-66 than cross-section 1. Over this approximate 100-meter distance, the shape of the >100 μg/L portion of the plume has changed, its upper limit increasing in elevation to respect the nearly 100 μg/L value at 699-29-66.

Cross-section 3 (Figure 6-4) cuts through the approximate center of the plume. In this cross-section, the change from east to west in the shape of the >100 μg/L portion of the plume is visible. Between 699-30-70 and 699-30-66, the >100 μg/L portion of the plume dips, before rising to the west of 699-30-66. The dip in the top of the >100 μg/L portion of the plume is partially due to sample results of < 24 μg/L near the water table at nearby wells 699-29-66 and 699-31-68, which are not featured on the cross-section. The low elevation of the samples in well 699-30-66 also contributed to the dip in the top of the >100 μg/L portion of the plume. Routine samples at 699-30-66 had high concentrations in a small screened area at the bottom of the aquifer. Nearby well 699-32-59 has depth-discrete data which decrease in concentration with depth. Accordingly, the bottom of the >100 μg/L portion of the plume increased in elevation to respect this data. The 72-100 μg/L portion of the plume extends to 699-33-56.

Cross-section 4 (Figure 6-5) also cuts along the approximate center of the plume. It begins slightly more to the north and ends slightly more to the south than cross-section 3. It shows another depth-discrete well, well 699-30-57, which has a concentration of >100 μg/L and a concentration of 28 μg/L deeper in the well, which, along with well 699-32-59, contribute to the rise of the bottom of the 100 μg/L. The low concentration of 28 μg/L in 699-30-57 also contributed to the rise of the bottom of the 72-100 μg/L portion of the plume around that well. This rise was not seen in the nearby cross-section 3. It also shows two wells with chromium concentrations less than 48 μg/L: 699-31-53B and 699-31-50.

Cross-section 5 (Figure 6-6) cuts the plume from southwest to northeast and showcases the vertical changes in the plume at a different angle than cross-sections 3 and 4. Well 699-27-68 bounds the southern edge of the plume, with three depth-discrete samples above 42 µg/L but below 72 µg/L. Well 699-30-63 is being projected onto the cross-section from more than 50 meters away, and chromium concentrations decrease to the south of 699-30-63, so it looks as though the values are not being respected when they are. The impact on the plume of the decrease in concentrations at depth-discrete samples at 699-32-59 can be better seen in this cross-section than cross-section 3 (Figure 6-4).

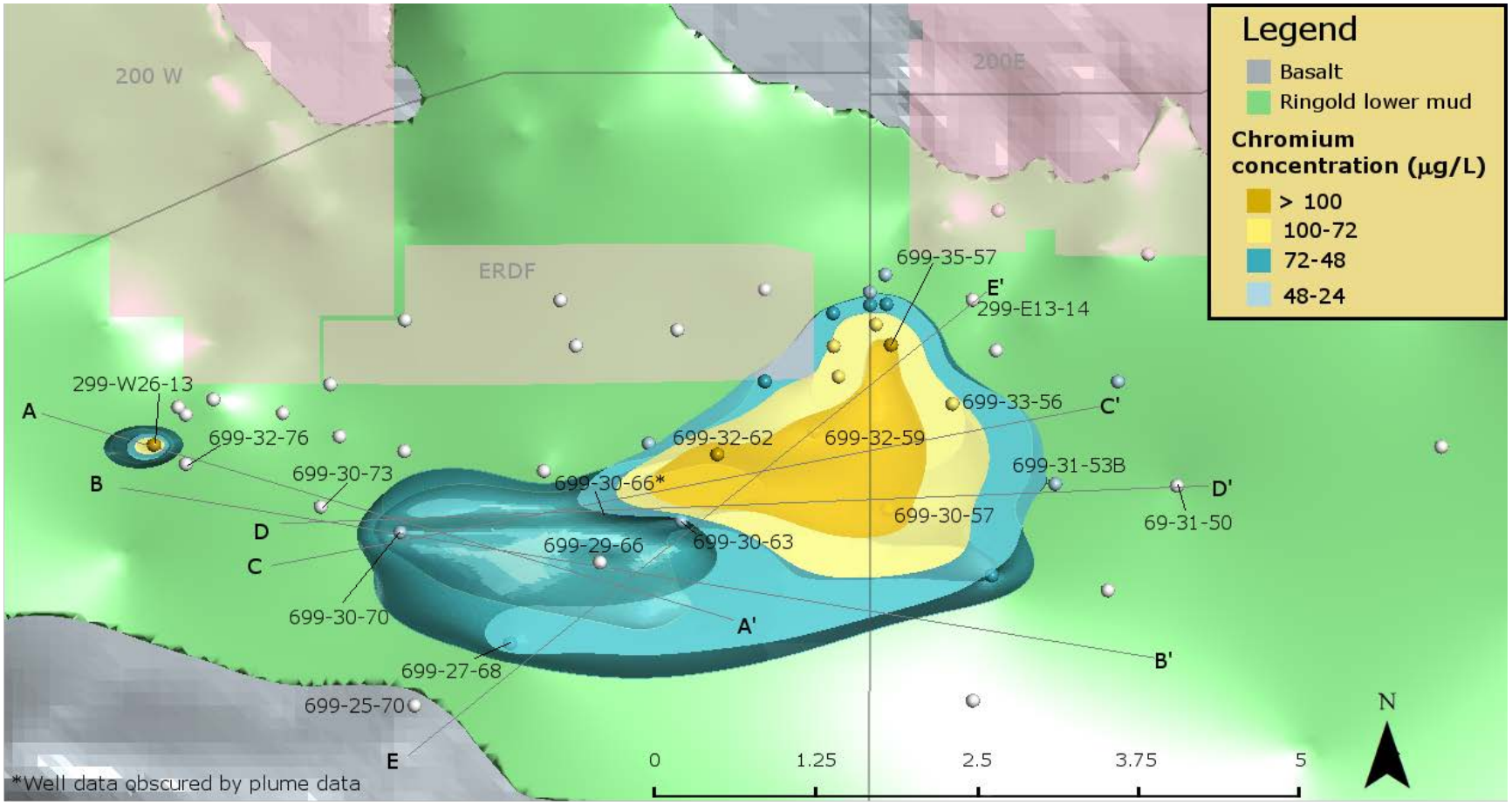

Figure 6-1. Map of Chromium Plume and Cross-section Locations

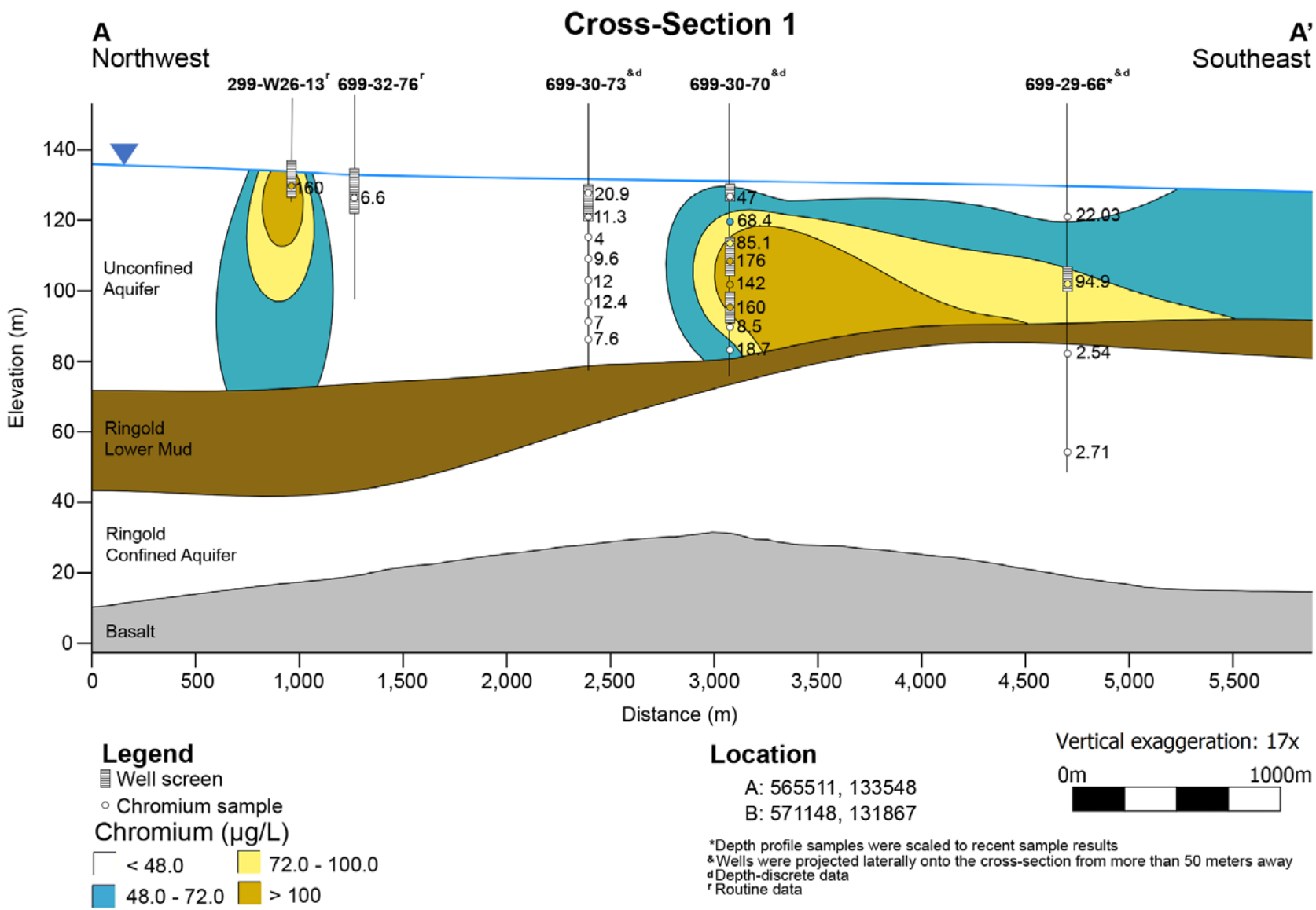

Figure 6-2. Cross-section 1

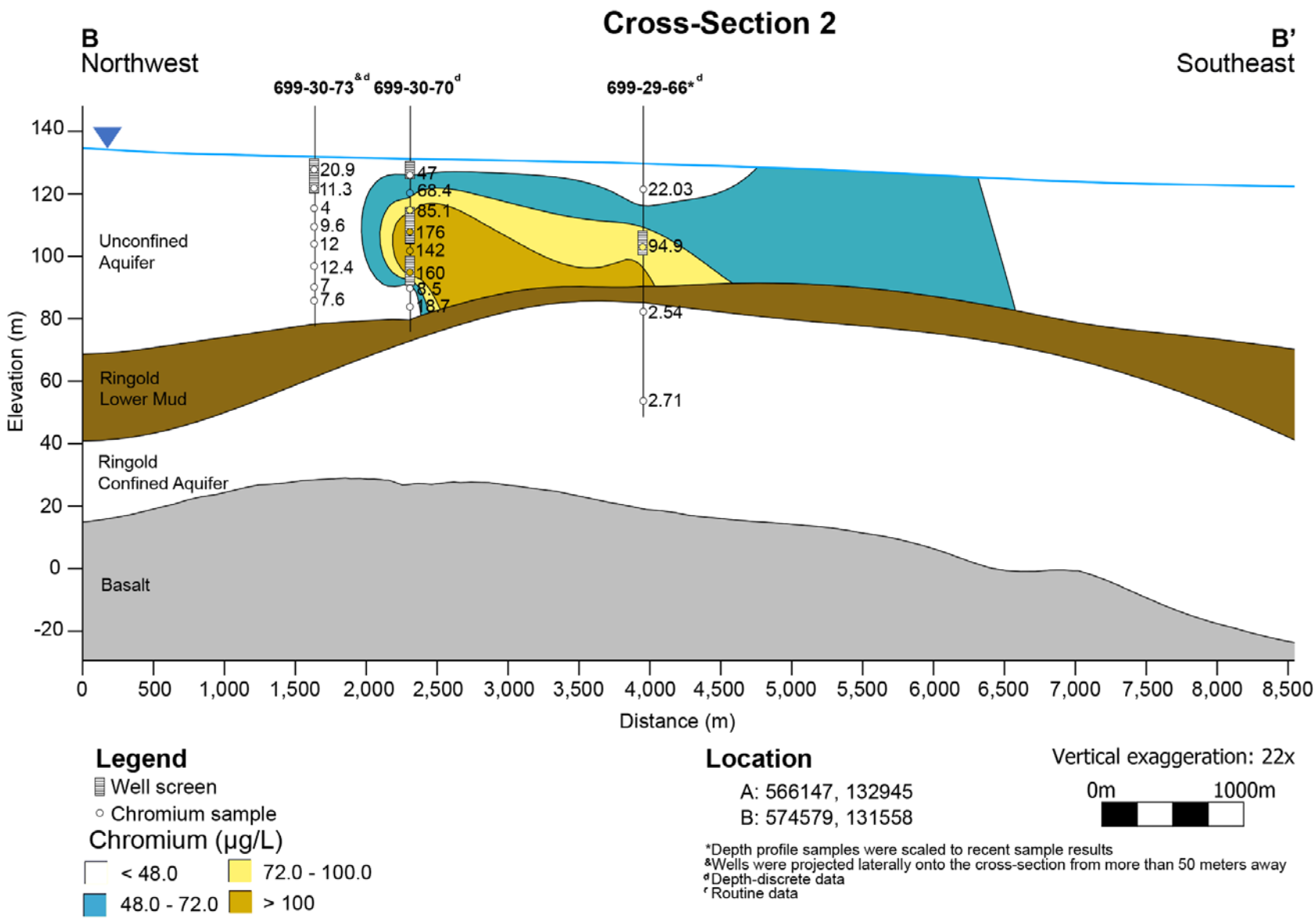

Figure 6-3. Cross-section 2

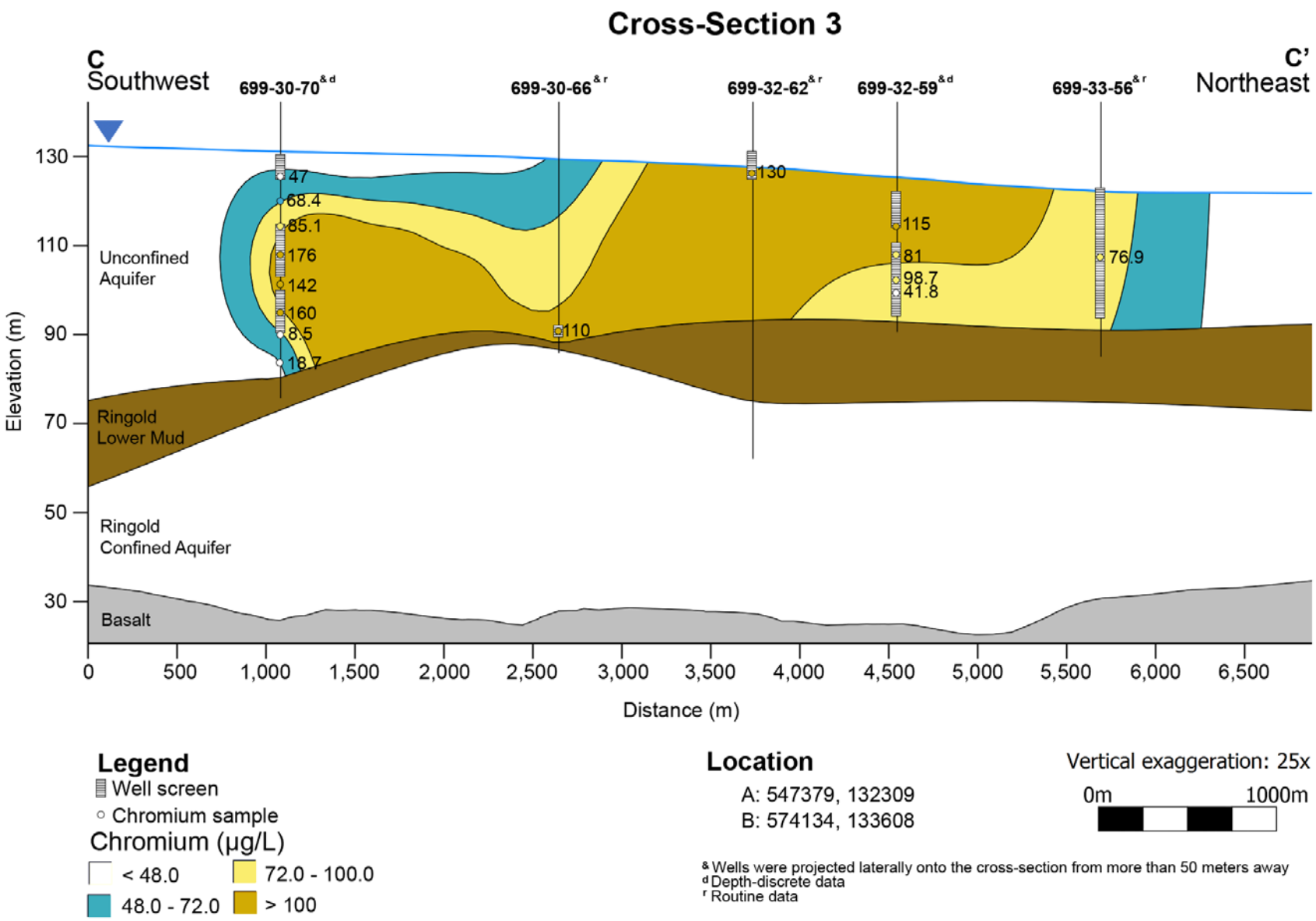

Figure 6-4. Cross-section 3

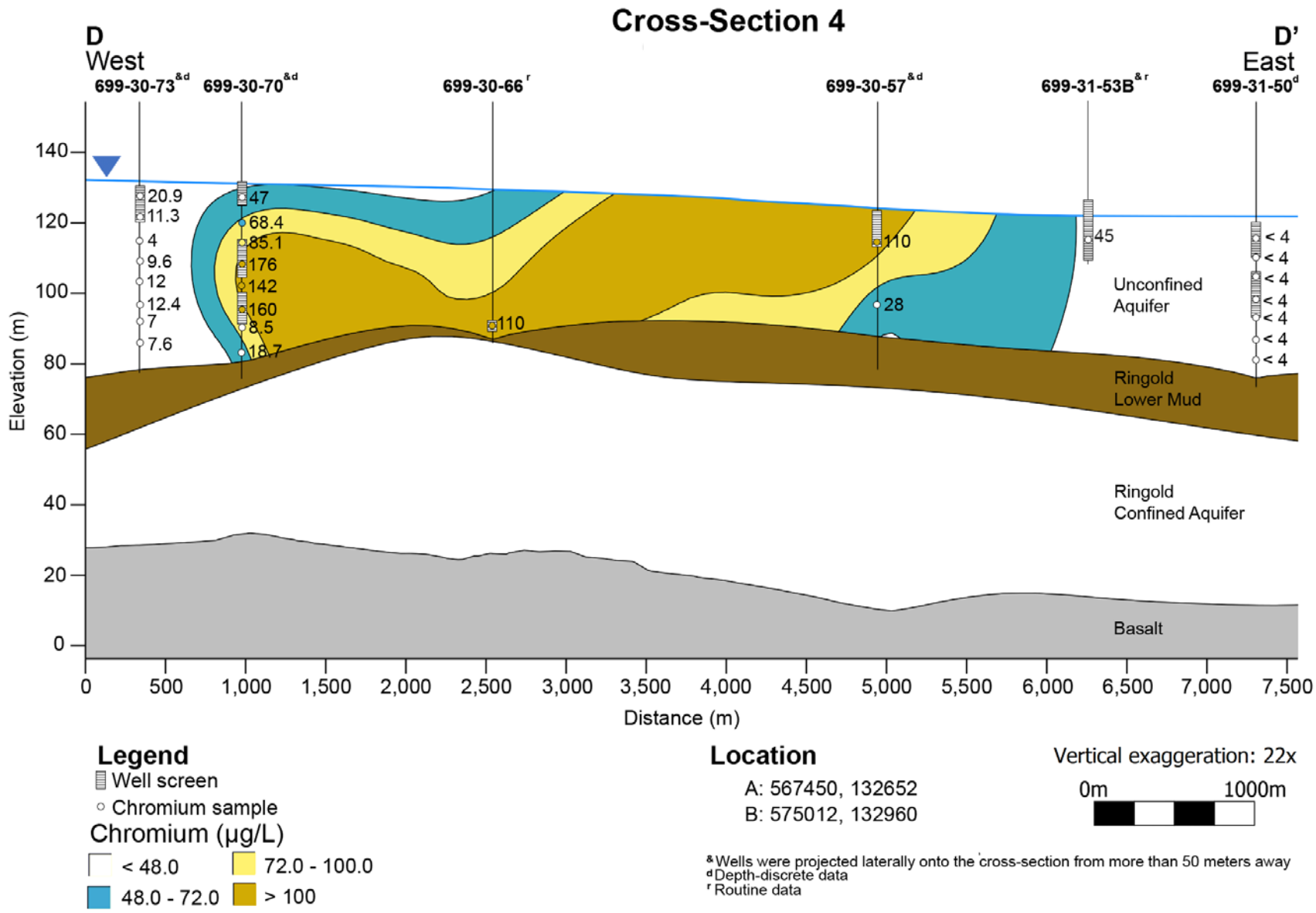

Figure 6-5. Cross-section 4

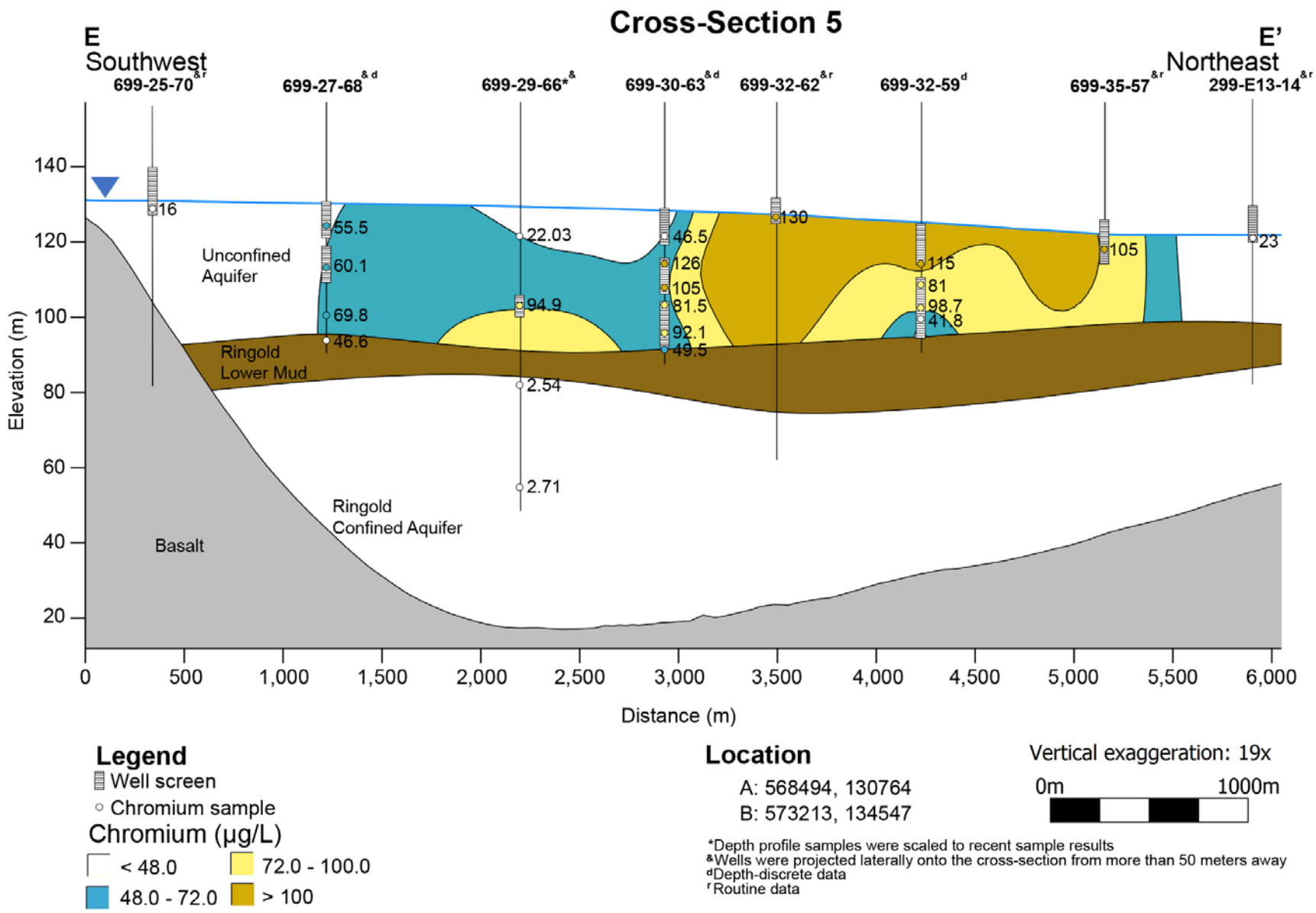

Figure 6-6. Cross-section 5

7 References

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Appendix A

Control Data

Table A-1. Control line *x, y, z* Data

Line Name	Line point type	Easting	Northing	Elevation
29_55_to_30_57_78	Start	573241.9	132230.3	97.45
29_55_to_30_57_78	Finish	572394.4	132770.8	108.04
57_to_57_q1	Q1 start	572394.4	132770.8	114.2
57_to_57_q1	Q1 finish	572401.5	133104.8	115.233
57_to_57_q2	Q2 start	572401.5	133104.8	115.233
57_to_57_q2	Q2 finish	572408.5	133438.7	116.2659
57_to_57_q3	Q3 start	572408.5	133438.7	116.2659
57_to_57_q3	Q3 finish	572415.6	133772.7	117.2989
57_to_57_q4	Q4 start	572415.6	133772.7	117.2989
57_to_57_q4	Q4 finish	572422.6	134106.7	118.3318
62_to_57_q1	Q1 start	571009.6	133215.9	126.4866
62_to_57_q1	Q1 finish	571355.8	133104.6	123.4149
62_to_57_q2	Q2 start	571355.8	133104.6	123.4149
62_to_57_q2	Q2 finish	571702	132993.4	120.3433
62_to_57_q3	Q3 start	571702	132993.4	120.3433
62_to_57_q3	Q3 finish	572048.2	132882.1	117.2716
62_to_57_q4	Q4 start	572048.2	132882.1	117.2716
62_to_57_q4	Q4 finish	572394.4	132770.8	114.2
63_to_62_q1	Q1 start	570716.9	132674.9	115.33
63_to_62_q1	Q1 finish	570790.1	132810.1	118.1191
63_to_62_q2	Q2 start	570790.1	132810.1	118.1191
63_to_62_q2	Q2 finish	570863.2	132945.4	120.9083
63_to_62_q3	Q3 start	570863.2	132945.4	120.9083
63_to_62_q3	Q3 finish	570936.4	133080.7	123.6974
63_to_62_q4	Q4 start	570936.4	133080.7	123.6974
63_to_62_q4	Q4 finish	571009.6	133215.9	126.4866
66_to_62_q1	Q1 start	569991	132739.2	90.85
66_to_62_q1	Q1 finish	570245.6	132858.4	99.75914
66_to_62_q2	Q2 start	570245.6	132858.4	99.75914
66_to_62_q2	Q2 finish	570500.3	132977.6	108.6683
66_to_62_q3	Q3 start	570500.3	132977.6	108.6683
66_to_62_q3	Q3 finish	570754.9	133096.7	117.5774
66_to_62_q4	Q4 start	570754.9	133096.7	117.5774
66_to_62_q4	Q4 finish	571009.6	133215.9	126.4866
66_to_63_q1	Q1 start	569991	132739.2	90.85
66_to_63_q1	Q1 finish	570172.5	132723.1	96.97
66_to_63_q2	Q2 start	570172.5	132723.1	96.97
66_to_63_q2	Q2 finish	570353.9	132707	103.09
66_to_63_q3	Q3 start	570353.9	132707	103.09
66_to_63_q3	Q3 finish	570535.4	132690.9	109.21

Table A-1. Control line *x, y, z* Data

Line Name	Line point type	Easting	Northing	Elevation
66_to_63_q4	Q4 start	570535.4	132690.9	109.21
66_to_63_q4	Q4 finish	570716.9	132674.9	115.33
70_to_63_q1	Q1 start	568429.1	132581.4	126.33
70_to_63_q1	Q1 finish	569001	132604.7	125.125
70_to_63_q2	Q2 start	569001	132604.7	125.125
70_to_63_q2	Q2 finish	569573	132628.1	123.92
70_to_63_q3	Q3 start	569573	132628.1	123.92
70_to_63_q3	Q3 finish	570144.9	132651.5	122.715
70_to_63_q4	Q4 start	570144.9	132651.5	122.715
70_to_63_q4	Q4 finish	570716.9	132674.9	121.51
70_to_66_q1	Q1 start	568429.1	132581.4	108.05
70_to_66_q1	Q1 finish	568819.5	132620.8	103.75
70_to_66_q2	Q2 start	568819.5	132620.8	103.75
70_to_66_q2	Q2 finish	569210	132660.3	99.45
70_to_66_q3	Q3 start	569210	132660.3	99.45
70_to_66_q3	Q3 finish	569600.5	132699.7	95.15
70_to_66_q4	Q4 start	569600.5	132699.7	95.15
70_to_66_q4	Q4 finish	569991	132739.2	90.85

Table A-2. Control Point Data

Control point data set name	Easting	Northing	Elevation	Chromium concentration (µg/L)
control_points	569953.53	132336.9	103.74	94.9
control_points	570153.53	132436.9	103.74	94.9
Control_points_south_70	570414.8186	131809.4	105	70
Control_points_south_70	571396.037	131943.6	105	70

Appendix B

Software Installation and Checkout Form

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:
Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:
Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: Leapfrog Geo — Software Version No.: 3.0.0

EXECUTABLE INFORMATION:

2. Executable Name (include path):

[redacted]geo.exe

3. Executable Size (bytes):

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

Vendor supplied

5. Operating System (include version number):

Windows (Vendor supplied)

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

INTERA-00857

7. Operating System (include version number):

Windows 10 Pro

8. Open Problem Report? (●) No ( ) Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]eapfrog\

10. Procedure(s):

per CHPRC-01754 Rev 1, Leapfrog-Hydro and Leapfrog-Geo Software Test Plan

11. Libraries:

N/A

12. Input Files:

per CHPRC-01754 Rev 1, Leapfrog-Hydro and Leapfrog-Geo Software Test Plan

13. Output Files:

per CHPRC-01754 Rev 1, Leapfrog-Hydro and Leapfrog-Geo Software Test Plan

14. Test Cases:

TC-1, TC-2, TC-3, TC-4, TC-5, TC-6

15. Test Case Results:

Pass

16. Test Performed By: Mary Weber

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update):

Accepted; installation added to Hanford Off-Site user list

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: Leapfrog Geo — Software Version No.: 3.0.0

Prepared By:

19.	WE Nichols	5 MAY 2018
Software Owner (Signature)	Print	Date

20. Test Personnel:

Mary Weber	MC Weber	5-3-2018
Sign	Print	Date
Sign	Print	Date
Sign	Print	Date

Approved By:

21.	N/R per SMP	
Software SME (Signature)	Print	Date

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