ECF-100BC5-15-0123
Revision 0

Estimating Chromium Migration Rate by Correlating Concentration Peaks

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

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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APPROVED
By Janis D. Aardal at 11:08 am, May 11, 2016

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ENVIRONMENTAL CALCULATION COVER PAGE

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	Name /Position	Signature	Date
Preparer:	Mary J Hartman	Mary J Hartman	11/30/15
Checker:	Travis Hammond	[illegible]	11/25/15
Senior Reviewer:	Greg Ruskauff	[illegible]	11/30/15
Responsible Manager:	Robert Evans/Cost Account Manager	Robert T. Evans	12/15/15

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1 Purpose

During remediation at the 100-C-7:1 waste site in southern 100-BC, hexavalent chromium was mobilized and entered groundwater, creating a concentration peak in nearby monitoring well 199-B4-14 (Section 6.2.2 of PNNL-21845). Subsequent concentration peaks in downgradient wells were used to estimate the rate of movement of the chromium contamination.

2 Background

Impacts of the recent hexavalent chromium release from 100-C-7:1 are observed in the upper portion of the unconfined aquifer (PNNL-21845; Appendix A). Groundwater flows to the northeast and east beneath southern 100-BC, turning toward the north as it approaches the Columbia River.

3 Methodology

All graphs and calculations were created in an Excel workbook. The following steps describe the basic method:

1. Excel charts of hexavalent chromium concentration vs time were created for wells 199-B4-14, 199-B4-7, 199-B4-8, 199-B4-1, and 199-B5-2 (locations shown in Figure 1).
2. For each well, the maximum observed hexavalent chromium concentration and the date it occurred were identified.
3. Because sample frequency was not sufficient to identify the actual concentration peak with certainty, the following rationale was used to identify bounds on time:
    a. 199-B4-14: Samples were collected frequently and the peak concentration was very clear, so boundaries were set at the sample date immediately before and after the peak.
    b. 199-B4-1: Sampling frequency was low and the maximum concentration (in December 2013) was only nominally higher than the concentrations in 2011, 2012, and October 2014. The early time boundary was set midway between the preceding sample (which had lower concentration) and the peak sample. The late time boundary was set at October 2014. Estimates based on this well have high uncertainty.
    c. 199-B4-7: The maximum observed concentration was October 2013, and the data define clear, broad, rising and falling limbs. The actual peak is assumed to have been between the January 2013 and 2014 sample dates.
    d. 199-B4-8: The maximum observed concentration was October 2013 and there are few preceding data to define the trend. The early time boundary was selected to be a little later than the early bound of 199-B4-7, because 199-B4-8 is farther from the source. Because of the paucity of early data, there is high uncertainty in estimates based on this well.
    e. 199-B5-2: The maximum observed concentration was from a June 2014 sample and rising and falling limbs are clearly defined. Time boundaries were set to preceding and succeeding sample dates.
4. To calculate travel times between 199-B4-14 and downgradient wells, the peak date for 199-B4-14 was subtracted from the peak date for each downgradient well. For minimum migration times, the latest upgradient peak boundary was subtracted from the earliest downgradient peak boundary. Similarly, for the maximum migration times, the earliest upgradient peak date was

subtracted from the latest downgradient peak date. Travel times between 199-B4-7 and 199-B5-2 were calculated the same way.

5. Distance between wells was calculated from the horizontal coordinates.
6. To calculate velocity, travel times from step 4 were divided by the distance between wells from step 5.

4 Assumptions and Inputs

Hexavalent chromium data and sample dates were extracted from the HEIS database.

The primary assumption was that the concentration peak observed in each downgradient well represented the same peak seen in 199-B4-14 in 2012, apparently a release from the 100-C-7:1 waste site during remediation. This assumption is supported by comparing contaminant plume maps from 2012 through 2015 (Appendix A), and by estimated groundwater flow directions based on water-level measurements (Section 3.2.3 of SGW-58308; Section 2.1 of DOE/RL-2015-07).

Section 3 includes a discussion of limitations and uncertainties in defining concentration peaks.

Travel distance was assumed to be the straight line between wells. Actual groundwater flow paths are somewhat longer, which would result in higher velocity estimates.

5 Software Applications

Microsoft Excel® was used to perform the calculations.[1]

6 Calculations and Results

Figures 2 through 5 illustrate hexavalent chromium trends in well 199-B4-14 and four wells located downgradient, used to estimate flow rates from southern 100-BC to central and northern 100-BC. Figure 6 illustrates hexavalent chromium trends in 199-B4-7 and 199-B5-2 to estimate flow rate between central and northern 100-BC.

Best estimates of groundwater velocity based on chromium peak migration from well 199-B4-14 to the northeast ranged from 0.77 to 1.23 m/d (Table 1). These estimates are in general agreement with those based on tracer studies in the 100-C-7:1 site (PNNL-21845) and based on changes in the chromium plume. The estimated velocity between wells 199-B4-7 and 199-B5-2 was higher, 2.4 m/d. This is consistent with the observation that the hydraulic gradient steepens in northern 100-BC.

[1] Microsoft Excel® is a registered trademark of the Microsoft Corporation in the United States.

Table 1. Average Linear Velocity

Well	Distance (m)	Peak Cr(VI) µg/L	Measured Peak Date	Earliest Peak Date	Latest Peak Date	Estimated Velocity (m/d)		
						Best Estimate	Minimum	Maximum
Flow Paths from Well 199-B4-14 to the Northeast								
199-B4-14	--	179	4/5/2012	2/11/2012	5/1/2012	--	--	--
199-B4-7	435.1	60.2	10/23/2013	1/3/2013	1/17/2014	0.77	0.62	1.76
199-B4-8	697.6	62.0	10/23/2013	4/1/2013	6/10/2014	1.23	0.82	2.08
199-B4-1	575.2	42.0	12/12/2013	7/1/2013	7/31/2015	0.93	0.45	1.35
199-B5-2	762.7	55.0	6/12/2014	10/25/2013	10/9/2014	0.96	0.79	1.41
Flow Path from Well 199-B4-7 to the North								
199-B4-7	--	60.2	10/23/2013	1/3/2013	1/17/2014	--	--	--
199-B5-2	556.9	55.0	6/12/2014	10/25/2013	10/9/2014	2.40	0.86	See note

Note: Maximum velocity between 199-B4-7 and 199-B5-2 not calculated because early time boundary in 199-B5-2 is before the late time boundary in 199-B4-7

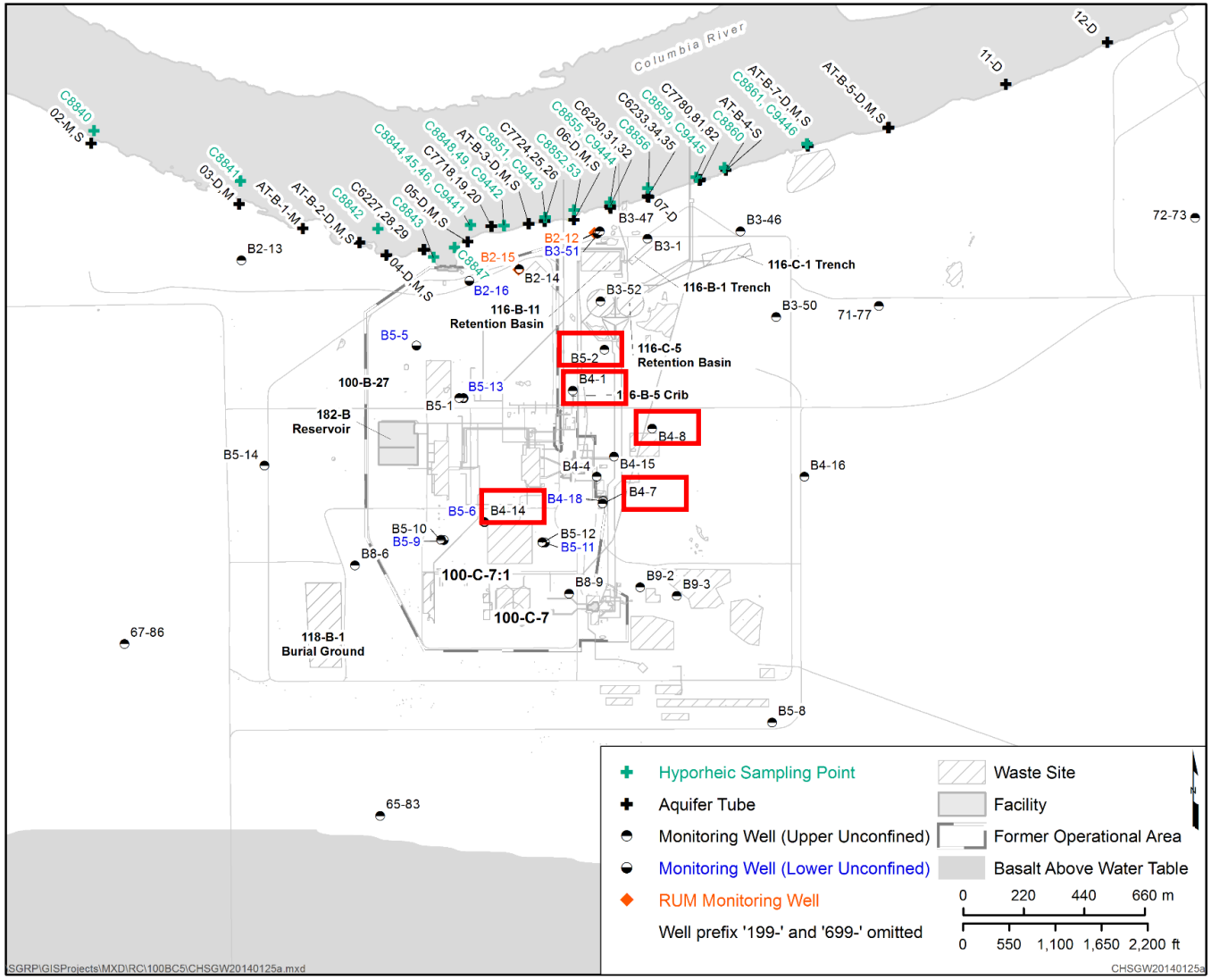

Figure 1. Locations of Wells Used in Velocity Estimates

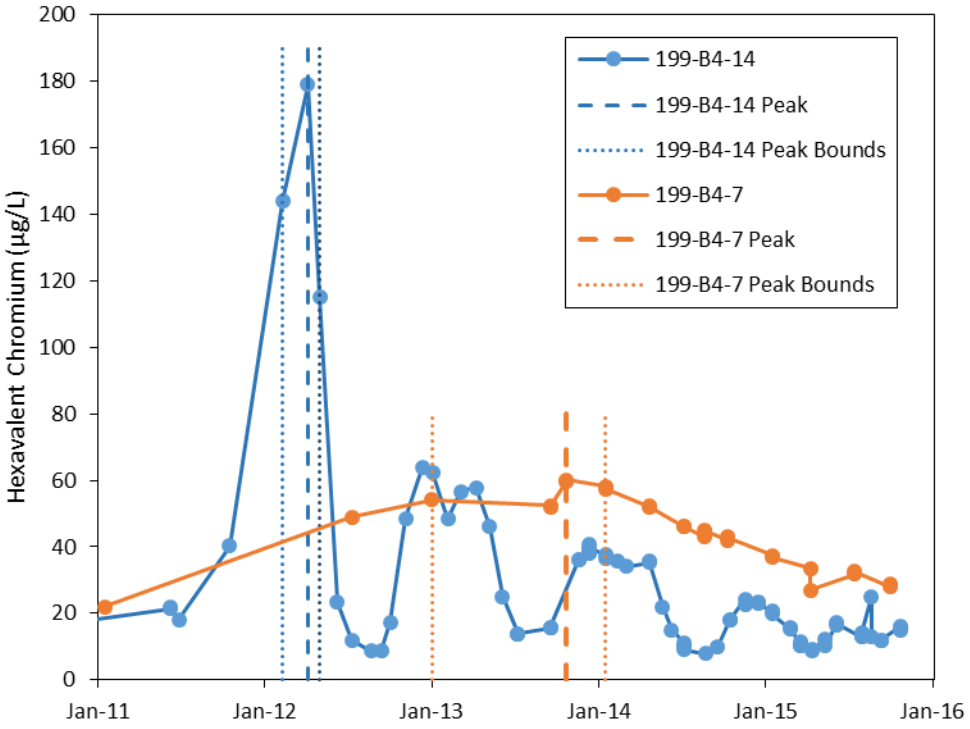

Figure 2. Hexavalent Chromium in Wells 199-B4-14 and 199-B4-7

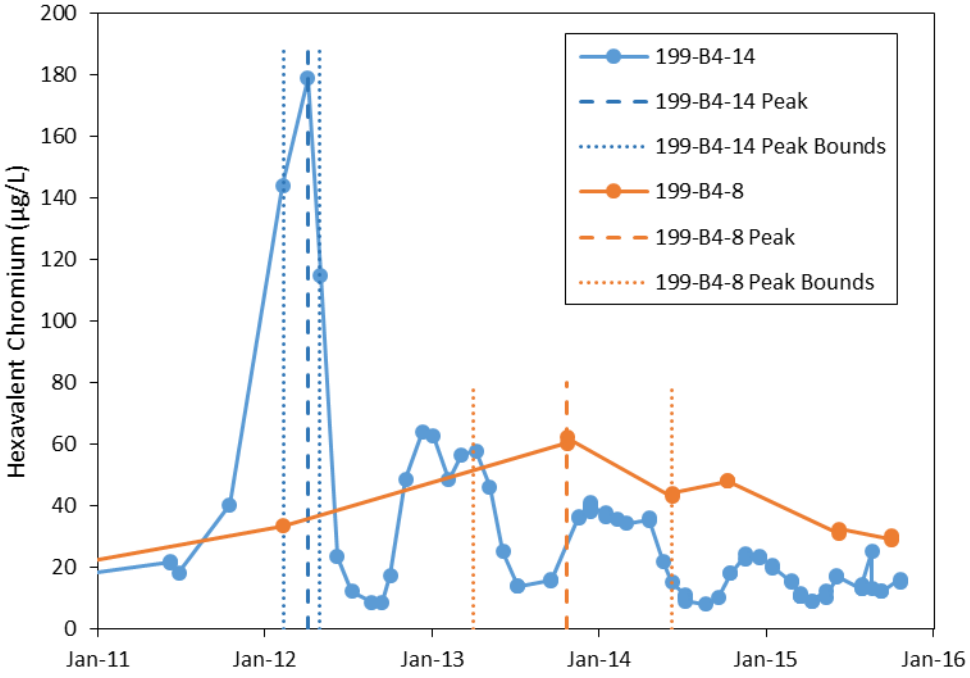

Figure 3. Hexavalent Chromium in Wells 199-B4-14 and 199-B4-8

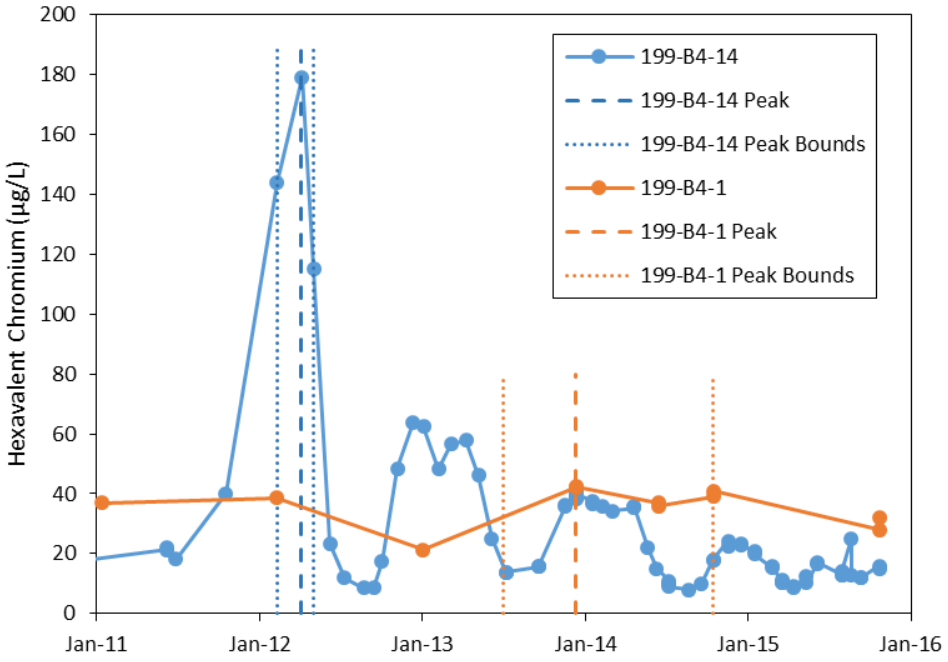

Figure 4. Hexavalent Chromium in Wells 199-B4-14 and 199-B4-1

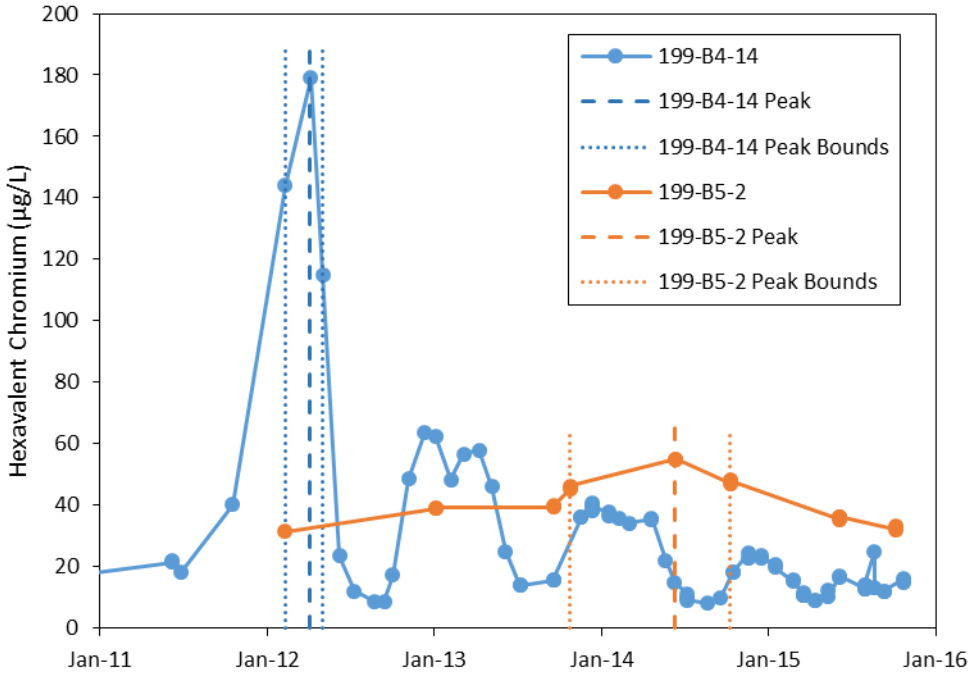

Figure 5. Hexavalent Chromium in Wells 199-B4-14 and 199-B5-2

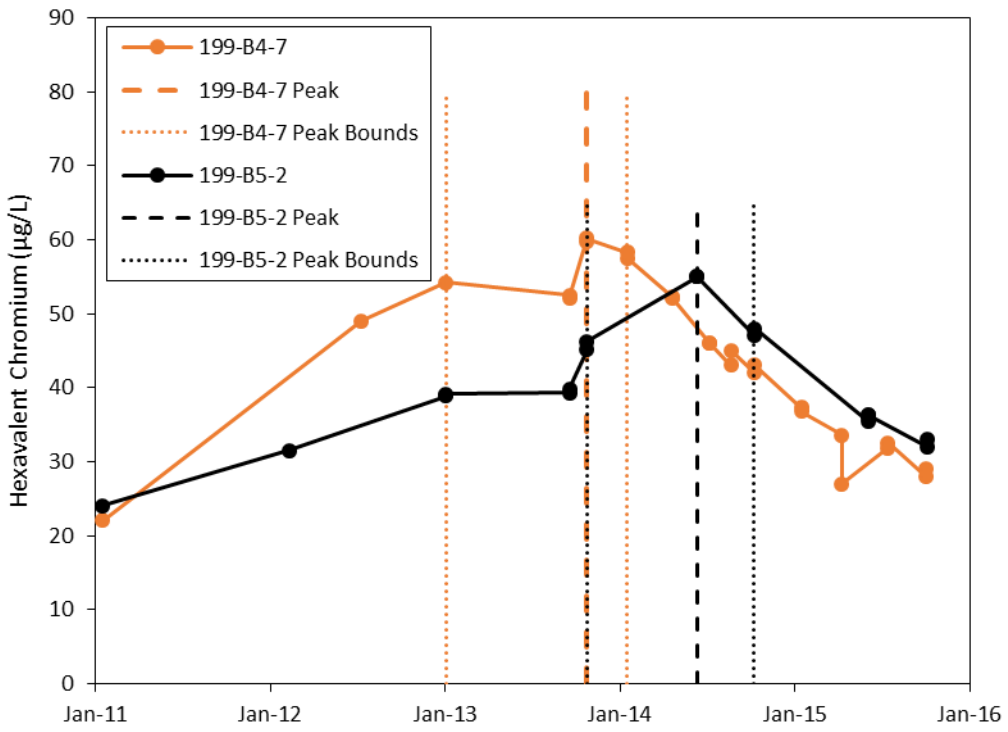

Figure 6. Hexavalent Chromium in Wells 199-B4-7 and 199-B5-2

7 Reference

DOE/RL-2015-07, 2015, Hanford Site Groundwater Monitoring Report for 2014, U.S. Department of Energy, Richland, Washington.

PNNL-21845, 2012. Investigation of Hexavalent Chromium Flux to Groundwater at the 100-C-7:1 Excavation Site. Pacific Northwest National Laboratory, Richland, Washington.

SGW-58308, 2015. 100-BC-5 Remedial Investigation: 2014 Status Report. CH2M HILL Plateau Remediation Company, Richland, Washington.

Appendix A
Hexavalent Chromium Plume Maps

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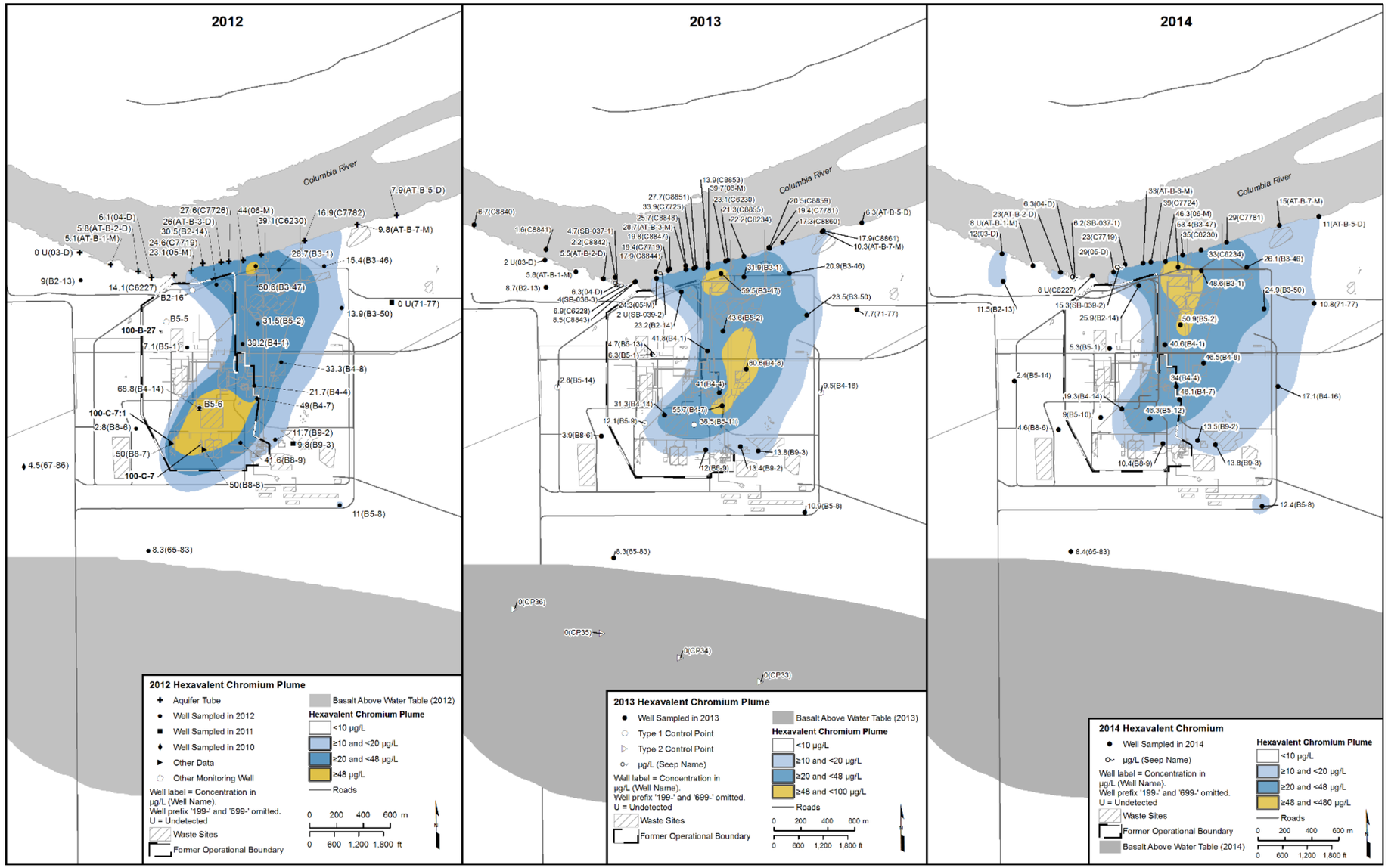

Figure A.1. Hexavalent Chromium in the Upper Part of the Unconfined Aquifer in 2012, 2013, and 2014

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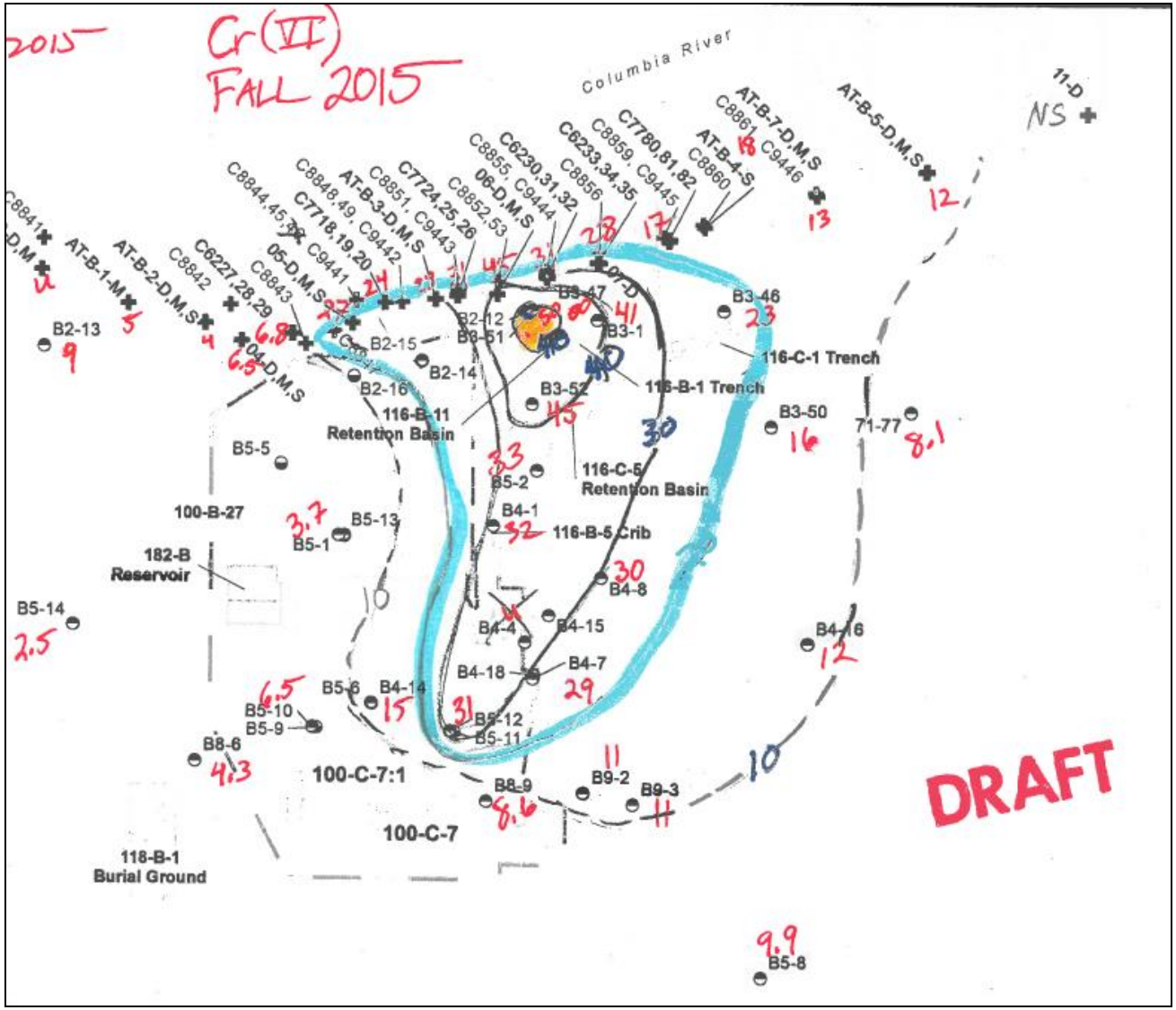

Figure A.2. Rough Sketch of Hexavalent Chromium Plume in the Upper part of the Unconfined Aquifer in Fall 2015

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