SGW-60583
Revision 0

ENGINEERING EVALUATION REPORT FOR LOW-LEVEL BURIAL GROUNDS WASTE MANAGEMENT AREA-3 GREEN ISLANDS GROUNDWATER MONITORING

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

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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CH2MHILL
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P.O. Box 1600
Richland, Washington 99352

APPROVED
By Julia Raymer at 10:40 am, Aug 21, 2018

Release Approval | Date

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Statement of certification:

I am a licensed Professional Engineer in the State of Washington, No. 41198, with a degree in Environmental Engineering. I have over 26 years of professional experience, including 15 years with groundwater systems. I reviewed the attached engineering study referenced as "Engineering Evaluation Report for Low-Level Burial Grounds Waste Management Area-3 Green Islands Groundwater Monitoring, SGW-60583, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington" and I certify that it demonstrates completeness in compliance with WAC 173-303-806(4)(a).

August 15, 2018

Date

Leonard D. Habel, P.E.
Sr. Principal Engineer
North Wind Infrastructure and Technology, LLC

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Terms

AEA	*Atomic Energy Act of 1954*
API	American Petroleum Institute
CCU	Cold Creek unit
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CPGWM	Central Plateau Groundwater Model
DOE	U.S. Department of Energy
DWMU	dangerous waste management unit
ECF	environmental calculation file
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FY	fiscal year
K_d	distribution coefficient
LLBG	Low-Level Burial Grounds
LLW	low-level waste
MT3DMS	Modular 3-D Transport Multispecies
OU	Operable Unit
P&T	pump and treat
RCRA	*Resource Conservation and Recovery Act of 1976*
RLM	Ringold lower mud
TOC	total organic carbon
TOX	total organic halides
VOC	volatile organic compound
WMA	waste management area

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1 Introduction

This engineering evaluation report provides information to support the proposed final status groundwater monitoring for the Low-Level Burial Grounds (LLBG) Waste Management Area (WMA)-3 based on evaluation of contaminants associated with LLBG WMA-3 and the expected migration behavior of contaminants in the WMA. This evaluation includes results of groundwater transport simulations conducted using the Central Plateau Groundwater Model (CPGWM) (CP-47631, *Model Package Report: Central Plateau Groundwater Model Version 8.3.4*). LLBG WMA-3 is an inactive burial grounds that will be incorporated into Revision 9 of WA7890008967, *Hanford Facility Dangerous Waste Permit (Site-Wide Permit)* (hereinafter referred to as the Hanford Facility Dangerous Waste Permit) as Closure Unit Group 26. This report provides supporting documentation regarding the protection of groundwater required by the *Resource Conservation and Recovery Act of 1976* (RCRA) permitting process for final status facilities.

LLBG WMA-3 is located in the 200 West Area of the Hanford Site in Washington State and overlies the 200-ZP-1 Groundwater Operable Unit (OU) (Figure 1-1). LLBG WMA-3 comprises three burial grounds; 218-W-3A, 218-W-3AE, and 218-W-5 (Figure 1-1). The WMA specifically excludes LLBG Trenches 31 and 34 and LLBG Trenches 31 and 34 Waste Storage and Treatment Pads, which are located within 218-W-5 Burial Ground, but will be permitted separately. LLBG WMA-3 received primarily non-dangerous, low-level radiological waste, however, there are discrete areas within the LLBG, referred to as 'Green Islands', where regulated mixed waste (waste with both a radioactive and dangerous waste component) was disposed in unlined trenches.

This report addresses the additional information for groundwater monitoring requested in Washington State Department of Ecology (Ecology) Letter 16-NWP-143, "Groundwater Engineering Report and Final Status Groundwater Monitoring Plan Requirements for the Integrated Disposal Facility, Nonradioactive Dangerous Waste Landfill, Low Level Burial Grounds Trench 94, and Low Level Burial Grounds "Green Islands" Dangerous Waste Management Units." The letter requests that the U.S. Department of Energy (DOE) develop engineering reports in advance of the complete permit application for the unit groups, with an associated groundwater monitoring plan developed for the final status permit application. The enclosure to the letter requires submittal of an engineering report with the following information included:

1. Information necessary to support the design of the groundwater monitoring well network, such that it is capable of yielding representative samples of groundwater potentially impacted by releases from the dangerous waste management units (DWMUs) resulting from changes in groundwater flow direction, declining water tables, and/or degrading wells that may be causing sample or groundwater contamination.

2. Information supporting design of the groundwater monitoring program that is capable of detecting significant statistical increases in groundwater contamination at the earliest practicable time.

3. Uncertainty in groundwater flow direction so that the appropriate number of wells can be located and drilled. This includes 1 year of background monitoring for constituents listed in WAC 173-303-110(3)(c) and (7), "Dangerous Waste Regulations," "Sampling, Testing, Methods and Analytes," unless previously performed to Ecology's satisfaction. Given the 3-year schedule for drilling and installing new wells, there should be at least 2 years minimum of groundwater monitoring for any new wells or revised groundwater monitoring networks.

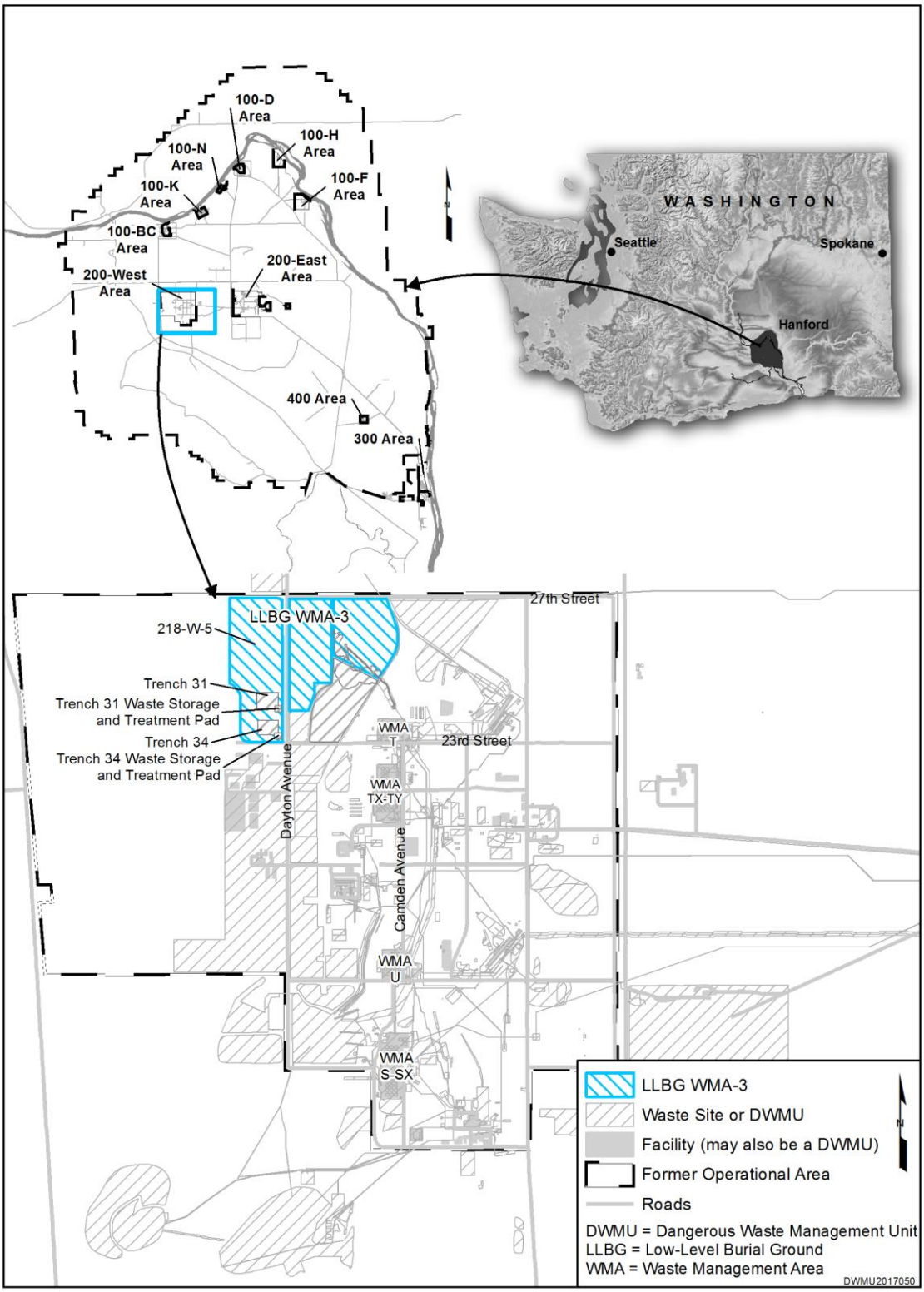

Figure 1-1. Location Map for LLBG WMA-3

4. Descriptions of the approach, input data, any additional information needs, and analysis proposed to evaluate and respond to changes listed in 1. Submit a full report of the complete analysis supporting the proposed approaches, including the methodology and results of validation of any modeling. Modifications of the groundwater monitoring network(s) may be needed to ensure they will continue to yield representative samples of groundwater potentially impacted by releases from DWMUs.

While 16-NWP-143 requested an engineering report for the "Green Islands" portion of LLBG, it was later agreed by Ecology and DOE that the entire LLBG WMA-3 (less LLBG Trenches 31 and 34) would be the subject of the engineering evaluation report and subsequent final status permit application.

The analysis documented in this report complies with WAC 173-303-806, "Final Facility Permits," which outlines the contents of the Part B permit application pertinent to the protection of groundwater. WAC 173-303-806(4)(a)(xx)(E) and (F)(I) and (II) require the preparation of detailed plans and an engineering report describing the proposed monitoring program to meet the requirements of WAC 173-303-645(8), "Releases from Regulated Units," "General Groundwater Monitoring Requirements," WAC 173-303-645(8) requires a groundwater monitoring system consisting of a sufficient number of wells installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer. These samples are intended to represent the quality of background groundwater that has not been affected by the leakage from a regulated unit, represent the quality of groundwater passing the point of compliance, and allow for the detection of contamination when dangerous waste constituents have migrated from the WMA to the uppermost aquifer.

WAC 173-303-806(4)(a)(xx)(E) and (F)(I) and (II) specify that a detailed plan describing the proposed groundwater monitoring program be included in the Part B application with this engineering evaluation report. This engineering evaluation report provides the technical basis for the groundwater monitoring that will be described in that plan. As groundwater monitoring under the detection monitoring program (WAC 173-303-645(9)) will be performed along with the general monitoring requirements (WAC 173-303-645(8)), this engineering evaluation report also provides the supporting information for the detection monitoring requirements. When the groundwater monitoring plan associated with this network is incorporated into the Hanford Facility Dangerous Waste Permit, it will replace any other groundwater monitoring plans associated specifically with LLBG WMA-3 under interim status.

In addition, this report provides information required by WAC 173-303-806(4)(a)(xx)(C) (topographic map), WAC 173-303-806(4)(a)(xx)(A) (summary of interim status groundwater monitoring data), and WAC 173-303-806(4)(a)(xx)(B) (hydrogeological information). Plume maps of regional contaminants in the area of the regulated unit are also provided.

Applicable groundwater monitoring requirements of WAC 173-303-645 and WAC 173-303-806(4)(a)(xx) are detailed in Table 1-1.

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-806(4)(a)(xx)(A) A summary of the groundwater monitoring data obtained during the interim status period under 40 C.F.R. 265.90 through 265.94, where applicable	Appendix A
WAC 173-303-806(4)(a)(xx)(B) Identification of the uppermost aquifer and aquifers hydraulically interconnected beneath the facility property, including groundwater flow direction and rate, and the basis for such identification (that is, the information obtained from hydrogeologic investigations of the facility area)	Section 3.2 Section 3.3
WAC 173-303-806(4)(a)(xx)(C) On the topographic map required under (a)(xviii) of this subsection, a delineation of the waste management area, the property boundary, the proposed "point of compliance" as defined under WAC 173-303-645(6), the proposed location of groundwater monitoring wells as required under WAC 173-303-645(8), and, to the extent possible, the information required in (a)(xx)(B) of this subsection	Appendix C
WAC 173-303-806(4)(a)(xx)(D)[a] A description of any plume of contamination that has entered the groundwater from a regulated unit at the time that the application was submitted that: (I) Delineates the extent of the plume on the topographic map required under (a)(xviii) of this subsection; (II) Identifies the concentration of each constituent throughout the plume or identifies the maximum concentrations of each constituent in the plume.	Appendix D
WAC 173-303-806(4)(a)(xx)(E) Detailed plans and an engineering report describing the proposed groundwater monitoring program to be implemented to meet the requirements of WAC 173-303-645(8)	Chapter 9
WAC 173-303-806(4)(a)(xx)(F) If the presence of dangerous constituents has not been detected in the groundwater at the time of permit application, the owner or operator must submit sufficient information, supporting data, and analyses to establish a detection monitoring program which meets the requirements of WAC 173-303-645(9). This submission must address the following items specified under WAC 173-303-645(9): (I) A proposed list of indicator parameters, waste constituents, or reaction products that can provide a reliable indication of the presence of dangerous constituents in groundwater (II) A proposed groundwater monitoring system	Section 2.3 Chapter 8 Chapter 9 Appendix A

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-645(2)(a) Owners and operators subject to this section must conduct a monitoring and response program as follows: (iv) In all other cases, the owner or operator must institute a detection monitoring program under subsection (9) of this section.	Chapter 9
WAC 173-303-645(6)(a) The department will specify in the facility permit the point of compliance...at which monitoring must be conducted. The point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units.	Section 9.2
WAC 173-303-645(8)(a) The groundwater monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer that: (i) Represent the quality of background groundwater that has not been affected by leakage from a regulated unit; (ii) Represent the quality of groundwater passing the point of compliance. (iii) Allow for the detection of contamination when dangerous waste or dangerous constituents have migrated from the waste management area to the uppermost aquifer	Section 9.3
WAC 173-303-645(8)(c) All monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must allow collection of representative groundwater samples. Wells must be constructed in such a manner as to prevent contamination of the samples, the sampled strata, and between aquifers and water bearing strata. Wells must meet the requirements applicable to resource protection wells, which are set forth in chapter WAC 173-160, “Minimum standards for construction and maintenance of wells.”	Section 9.3 Appendix E
WAC 173-303-645(8)(h) The owner or operator will specify one of the following statistical methods to be used in evaluating groundwater monitoring data for each hazardous constituent which, upon approval by the department, will be specified in the unit permit. The statistical test chosen must be conducted separately for each dangerous constituent in each well. Where practical quantification limits (pqls) are used in any of the following statistical procedures to comply with (i)(v) of this subsection, the pql must be proposed by the owner or operator and approved by the department. Use of any of the following statistical methods must be protective of human health and the environment and must comply with the performance standards outlined in (i) of this subsection.	Appendix H
WAC 173-303-645(8)(i) Any statistical method chosen under (h) of this subsection for specification in the unit permit must comply with [standards provided in WAC 173-303-645(8)(i)(i), (ii), (iii), (iv), (v), and (vi)] as appropriate.	Appendix H

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-645(9)(a)	Chapter 8
The owner or operator must monitor for indicator parameters (e.g., pH, specific conductance, total organic carbon (TOC), total organic halogen (TOX), or heavy metals), waste constituents, or reaction products that provide a reliable indication of the presence of dangerous constituents in groundwater. The department will specify the parameters or constituents to be monitored in the facility permit, after considering the following factors:	Chapter 9
(i) The types, quantities, and concentrations of constituents in wastes managed at the regulated unit;	
(ii) The mobility, stability, and persistence of waste constituents or their reaction products in the unsaturated zone beneath the waste management area;	
(iii) The detectability of indicator parameters, waste constituents, and reaction products in groundwater; and	
(iv) The concentrations or values and coefficients of variation of proposed monitoring parameters or constituents in the groundwater background.	
WAC 173-303-645(9)(b)[b]	Chapter 9
The owner or operator must install a groundwater monitoring system at the compliance point, as specified under subsection (6) of this section. The groundwater monitoring system must comply with subsection (8)(a)((ii), (b) [b] , and (c) of this section.	

a. WAC 173-303-806(4)(a)(xx)(D) is not applicable because LLBG WMA-3 has not contaminated the groundwater. However, plume maps of regional contaminants that are in the vicinity of LLBG WMA-3 are included in Appendix D.

b. WAC 173-303-645(8)(b) is not applicable because LLBG WMA-3 Green Islands is one regulated unit. It is not being monitored as part of a group of regulated units.

Documented releases to groundwater have not occurred at LLBG WMA-3. Details of the operational, regulatory, and groundwater monitoring history can be found in Chapter 2.

This report is organized as follows:

- Chapter 2 includes historical information to support the final status groundwater monitoring program determination.
- Chapter 3 describes the geology and hydrogeology of LLBG WMA-3.
- Chapter 4 describes the contaminant migration conceptual model.
- Chapter 5 describes groundwater flow simulations for the 200 West Area.
- Chapter 6 describes calculations performed to evaluate wells for the proposed LLBG WMA-3 monitoring well network.
- Chapter 7 presents conclusions from the calculations performed in Chapters 5 and 6.
- Chapter 8 identifies the groundwater monitoring constituents of interest.

- Chapter 9 describes the proposed final status groundwater monitoring program.
- Chapter 10 describes how the monitoring well network will be maintained.
- Chapter 11 lists the references cited in this report.
- Appendix A contains the interim status groundwater monitoring data summary.
- Appendix B contains the identification of site-specific monitoring constituents environmental calculation file (ECF) (ECF-HANFORD-17-0233, *Identification of Site-Specific Monitoring Constituents for the Low-Level Burial Grounds*).
- Appendix C contains the topographic map.
- Appendix D contains regional plume maps in the vicinity of LLBG WMA-3.
- Appendix E contains well as-built diagrams and proposed well designs.
- Appendix F contains the 200 West Area modeling ECF (ECF-200W-17-0070, *Groundwater Flow and Migration Calculations to Support Assessment of the Hanford Central Plateau 200 West Area Facilities Monitoring Network*).
- Appendix G contains the LLBG WMA-3 modeling ECF (ECF-200W-17-0072, *Groundwater Flow and Migration Calculations to Support Assessment of the LLBG WMA-3 Monitoring Network*).

Appendix H contains the process for defining the groundwater monitoring statistical method.

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2 Supporting Historical Information

This chapter describes LLBG WMA-3, its operations, regulatory basis, waste characteristics, and interim status groundwater monitoring history.

2.1 Background

The LLBG WMA-3 is located in the northwest corner of the 200 West Area (Figure 2-1) and consists of the following burial grounds:

- 218-W-3A Burial Ground
- 218-W-3AE Burial Ground
- 218-W-5 Burial Ground
- 200-W-254 Burial Ground

The 200-W-254 Burial Ground comprises LLBG Trenches 31 and 34 and LLBG Trenches 31 and 34 Waste Storage and Treatment Pads, which are operating DWMUs that are used for treatment, storage, and disposal of mixed wastes (wastes with both a radioactive and dangerous waste component). The trenches were initially part of the 218-W-5 Burial Ground. In 2014, the 200-W-254 site code was created in the Waste Information Data System specifically to identify and separate the operating units (i.e., active areas) of 218-W-5 from the nonoperating areas. An engineering evaluation for LLBG Trenches 31 and 34 is in preparation to support final status permitting of the trenches that will be separate from LLBG WMA-3. 200-W-254 is part of LLBG WMA-3 at the time of this engineering report; however, it will not be included for evaluation or discussed further as part of LLBG WMA-3.

The waste disposed to LLBG WMA-3 (218-W-3A, 218-W-3AE, and 218-W-5 Burial Grounds) was generally low-level nondangerous waste, with some locations receiving retrievably stored waste. However, low-level mixed waste was disposed to discrete areas within each of the three unlined burial grounds in LLBG WMA-3 (218-W-3A, 218-W-3AE, and 218-W-5) after August 19, 1987, which is the effective date of RCRA regulation. The areas that contain mixed waste were termed “Green Islands” because they were coded in green on the Part A Permit Application maps (WA7890008967, 2008, *Dangerous Waste Permit Application Part A Form - Low Level Burial Grounds 9/22/2008*).

2.1.1 218-W-3A Burial Ground

The 218-W-3A Burial Ground was placed into service in 1970, with a reported end date of 1998 (Section 2.2 in DOE/RL-2014-43, *Mixed Waste Disposed of in the Low-Level Burial Grounds*). The burial ground covers 21 ha (52 ac) and contains unsegregated waste, low-level waste (LLW), mixed waste, and retrievably stored waste . It is located northwest of T Plant on the southeast corner of the intersection of Dayton Avenue and 27th Street (Figure 2-1). The burial ground consists of 57 trenches of varying sizes. Portions of 13 trenches contain retrievably stored waste , which is not a dangerous waste.

Most of the waste in 218-W-3A originated from the 100 Areas, various facilities in the 200 West Area, the 300 Area, and the tank farms (Section 2.2 in DOE/RL-2014-43). A small portion of the waste originated from offsite facilities, and the remaining waste originated from Hanford Site facilities in the 200 East Area and other Hanford Site locations.

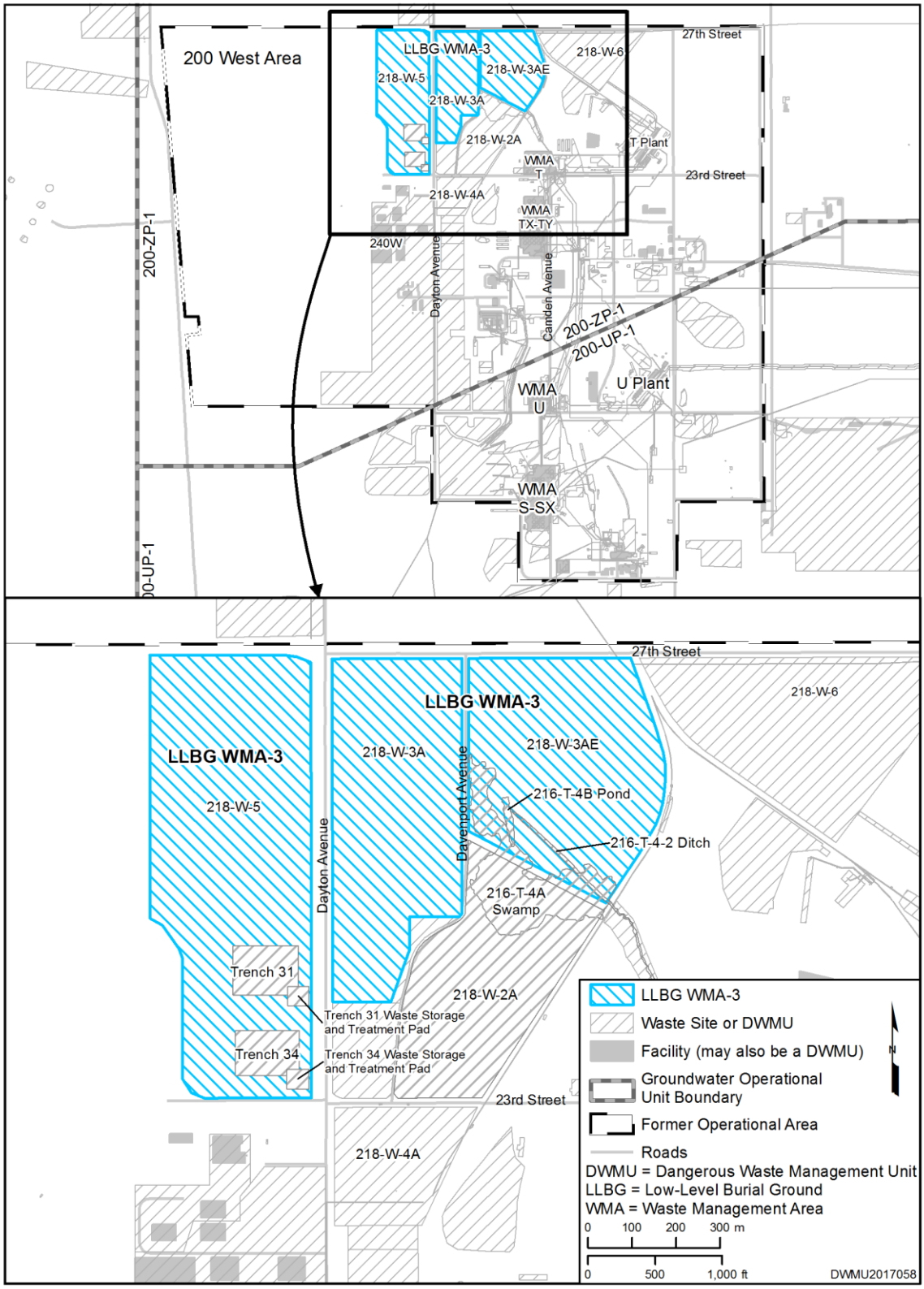


Figure 2-1. Location of LLBG WMA-3 within 200 West Area

2.1.2 218-W-3AE Burial Ground

The 218-W-3AE Burial Ground covers approximately 23 ha (57 ac) and received waste from 1981 until 2004 (Section 2.3 in DOE/RL-2014-43). The burial ground contains mixed waste and LLW, including large contaminated equipment. The 218-W-3AE Burial Ground is located directly east of, and adjacent to, 218-W-3A. The location designated as the 218-W-3AE Burial Ground includes areas that were previously used as portions of the 216-T-4A Swamp and the 216-T-4B Pond (Figure 2-1). The 218-T-4A Swamp received T Plant condensate effluent from 1944 until 1972, when it was exhumed to make room for the 218-W-2A Burial Ground (p. 1597 in RHO-CD-673, *Handbook 200 Areas Waste Sites*, Volume II). The 218-T-4B Seepage Pond also received T Plant condensate effluent and was constructed in 1972 to replace the 216-T-4A Swamp. The pond was often dry because the majority of the effluent was absorbed in the 216-T-4-2 Ditch (Section 2.3 in DOE/RL-2014-43). Part of the 218-W-3AE Burial Ground was constructed over the 216-T-4B Pond (Section 2.3 in DOE/RL-2014-43).

The 218-W-3AE Burial Ground is irregularly shaped and consists of eight trenches of varying sizes. Trenches 5 and 8 are wide-bottom, stacking trenches that contain large equipment such as portions of rail cars. Trench 26 was dug with a wide bottom to dispose of large tanks.

2.1.3 218-W-5 Burial Ground

In 1979, a large area adjacent to the northwest corner of the 200 West Area was annexed and designated as the Central Waste Complex, also known as the 218-W-5 Burial Ground (Section 2.5 in DOE/RL-2014-43). 218-W-5 is located in the southwest corner of the intersection of 27th Street and Dayton Avenue (Figure 2-1). The burial ground received waste from 1985 to 2004 and covers an area of 38.5 ha (95 ac). Within the large annex, 38 ha (94 ac) is permitted as a LLW burial ground. Original plans called for the area to contain 18 LLW trenches and 4 mixed waste trenches. The burial ground was expanded by annexing land to the west and north, and it was designed to contain 56 trenches, oriented east-west. Only 11 of the LLW trenches were constructed and received waste.

2.2 Regulatory Basis

In May 1987, DOE issued a final rule (10 CFR 962, “Byproduct Material”) stating that the hazardous waste components of mixed waste are subject to RCRA regulations. Ecology gained regulatory authority over the hazardous waste components of mixed waste on August 19, 1987.

In May 1989, DOE, the U.S. Environmental Protection Agency (EPA), and Ecology signed the Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement). This agreement established the roles and responsibilities of the agencies involved in regulating and controlling remedial restoration of the Hanford Site, which includes LLBG WMA-3. Under interim status, groundwater monitoring at LLBG WMA-3 has been conducted in accordance with WAC 173-303-400(3), “Interim Status Facility Standards” (and, by reference, 40 CFR 265, “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” Subpart F, “Ground-Water Monitoring”), which requires monitoring to determine whether dangerous waste constituents from the DWMU have entered the groundwater in the uppermost aquifer underlying the unit.

Dangerous waste is regulated under RCW 70.105, “Hazardous Waste Management,” and its Washington State implementing regulations (WAC 173-303). Radionuclides in mixed waste may include “source, special nuclear, and byproduct materials” as defined in the *Atomic Energy Act of 1954* (AEA). The AEA states that these radionuclide materials are regulated at DOE facilities, exclusively by DOE, acting pursuant to its AEA authority. Radionuclide materials are not hazardous/dangerous wastes and, therefore, are not subject to regulation by the State of Washington under RCRA or RCW 70.105. LLBG WMA-3

has an AEA component and is monitored for AEA under DOE/RL-2000-72, *Performance Assessment Monitoring Plan for the Hanford Site Low-Level Burial Grounds*.

Interim status groundwater monitoring at LLBG WMA-3 began in 1987 based on the indicator evaluation program requirements of 40 CFR 265, Subpart F (as referenced by WAC 173-303-400[3]). LLBG WMA-3 was monitored under an indicator evaluation program from 1987 to 1989, when it entered into assessment monitoring for an exceedance of the critical means for total organic halogens (TOX) and total organic carbon (TOC). In January 1994, a groundwater quality assessment report was issued and found that elevated TOX was not attributable to LLBG WMA-3, and elevated TOC results were due to laboratory error (Section 3.2 in WHC-SD-EN-EV-026, *Results of Groundwater Quality Assessment Program at Low-Level Waste Management Area 3 of the Low-Level Burial Grounds*). Groundwater monitoring subsequently returned to an indicator evaluation program.

A revised indicator parameter monitoring plan was issued in 2010 (DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*, Rev. 0) with the most recent revision occurring in 2012 (DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*, Rev. 2). Interim status monitoring has since continued under an indicator evaluation program.

Under Revision 9 of the Hanford Facility Dangerous Waste Permit, LLBG WMA-3 will become a final status closure unit group. Part II, Condition II.F of the WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Rev. 8c (hereinafter referred to as the Hanford Facility RCRA Permit) specifies that final status groundwater monitoring program requirements will comply with WAC 173-303-645. This engineering evaluation report is prepared in accordance with WAC 173-303-806(4)(a)(xx)(E) and (F)(I) and (II) to implement the detection monitoring program requirements of WAC 173-303-645.

This engineering evaluation report also provides supporting information for Part B application general requirements of WAC 173-303-806(4)(a)(xx)(C) (topographic map), WAC 173-303-806(4)(a)(xx)(A) (summary of interim status groundwater monitoring data), and WAC 173-303-806(4)(a)(xx)(B) (hydrogeological information). Plume maps of regional contaminants in the vicinity of the regulated unit are provided.

2.3 Waste Characteristics

LLBG WMA-3 was designed for disposal of miscellaneous dry wastes from various operations at the Hanford Site and from offsite facilities. The following subsections describe the waste in the three burial grounds comprising LLBG WMA-3 and the wastes identified on the Part A Application for LLBG.

2.3.1 218-W-3A Burial Ground

The 218-W-3A Burial Ground received shipments described as miscellaneous transuranic and nontransuranic waste from the Three-Mile Island accident cleanup; irradiated fuel elements from the General Electric Company in Vallecitos, California; radioactive soil from a salt waste spill (encased in concrete burial boxes); and industrial waste (Section 2.3 in DOE/RL-2009-68, Rev. 2). Examples of waste disposed in this burial ground include ion-exchange resins, failed equipment, tanks, pumps, ovens, agitators, heaters, hoods, jumpers, vehicles, and accessories. Trenches 6S and 19 are identified as containing mixed waste that was disposed after the August 19, 1987 effective date of the mixed waste regulation (Section 2.2 in DOE/RL-2014-43). Trench 6S has eight Green Islands and Trench 19 has one Green Island, as detailed in Table 2-1 and shown in Figure 2-2.

Table 2-1. Waste Disposed to the Green Islands in LLBG WMA-3

Green Island Number	Trench Number	Disposal Date	Description	Waste Volume (m^3 [yd^3])
218-W-3A Burial Ground				
08	6S	8/21/1987	Metal shipping container of radioactively contaminated equipment. Bagged asbestos lagging was used to fill void space.	9.0 (11.8)
09	6S	9/9/1987	Five 208 L (55 gal) drums containing scintillation vials and absorbent pads.	1.1 (1.4)
10	6S	9/30/1987	Fifteen 341 L (90 gal) fiberglass drums of sludge from decommissioning of the 1608-DR effluent pumping station.	5.1 (6.7)
11	6S	10/8/1987	Two 208 L (55 gal) drums containing scintillation vials and kitty litter. One 208 L (55 gal) drum containing contaminated hydraulic oil and absorbent.	0.6 (0.8)
12	6S	10/28/1987	Nineteen 341 L (90 gal) fiberglass drums of sludge from decommissioning of the 1608-H effluent pumping station.	6.1 (8.0)
13	6S	10/20/1987	One 208 L (55 gal) drum containing amalgamated mercury from a spill kit.	0.2 (0.3)
14	6S	10/28/1987	Twelve 208 L (55 gal) drums of laboratory-packed chemicals.	2.5 (3.3)
15	6S	10/30/1987	Two 208 L (55 gal) drums containing lead.	0.4 (0.5)
			Six 208 L (55 gal) drums containing scintillation vials and absorbent pads.	1.3 (1.7)
16	19	10/20/1989	Thirty 208 L (55 gal) drums of Lawrence Berkeley Laboratory waste.	6.2 (8.1)
218-W-3AE Burial Ground				
17	8	9/30/1994	Sixty-three 208 L (55 gal) drums listed waste.	13.1 (17.1)
18	5*	9/28/1987	Forty-three 208 L (55 gal) drums of uranium.	9.0 (11.8)
19	5*	10/28/1987	Two 208 L (55 gal) drums of aluminum nitrate and diatomaceous earth.	0.4 (0.5)
20	5*	11/9/1987	One 208 L (55 gal) drum containing lead.	0.2 (0.3)
			One 208 L (55 gal) drum containing beryllium.	0.2 (0.3)
218-W-5 Burial Ground				
24	22	8/10/1990	Twenty-four 208 L (55 gal) drums of Lawrence Berkeley Laboratory waste.	5 (6.5)

Source: Table 2 in DOE/RL-2014-43, *Mixed Waste Disposed of in the Low-Level Burial Grounds*.

*Table 2 in DOE/RL-2014-43 refers to this Trench as 5E, however, the Part A Permit application refers to this as Trench 5.

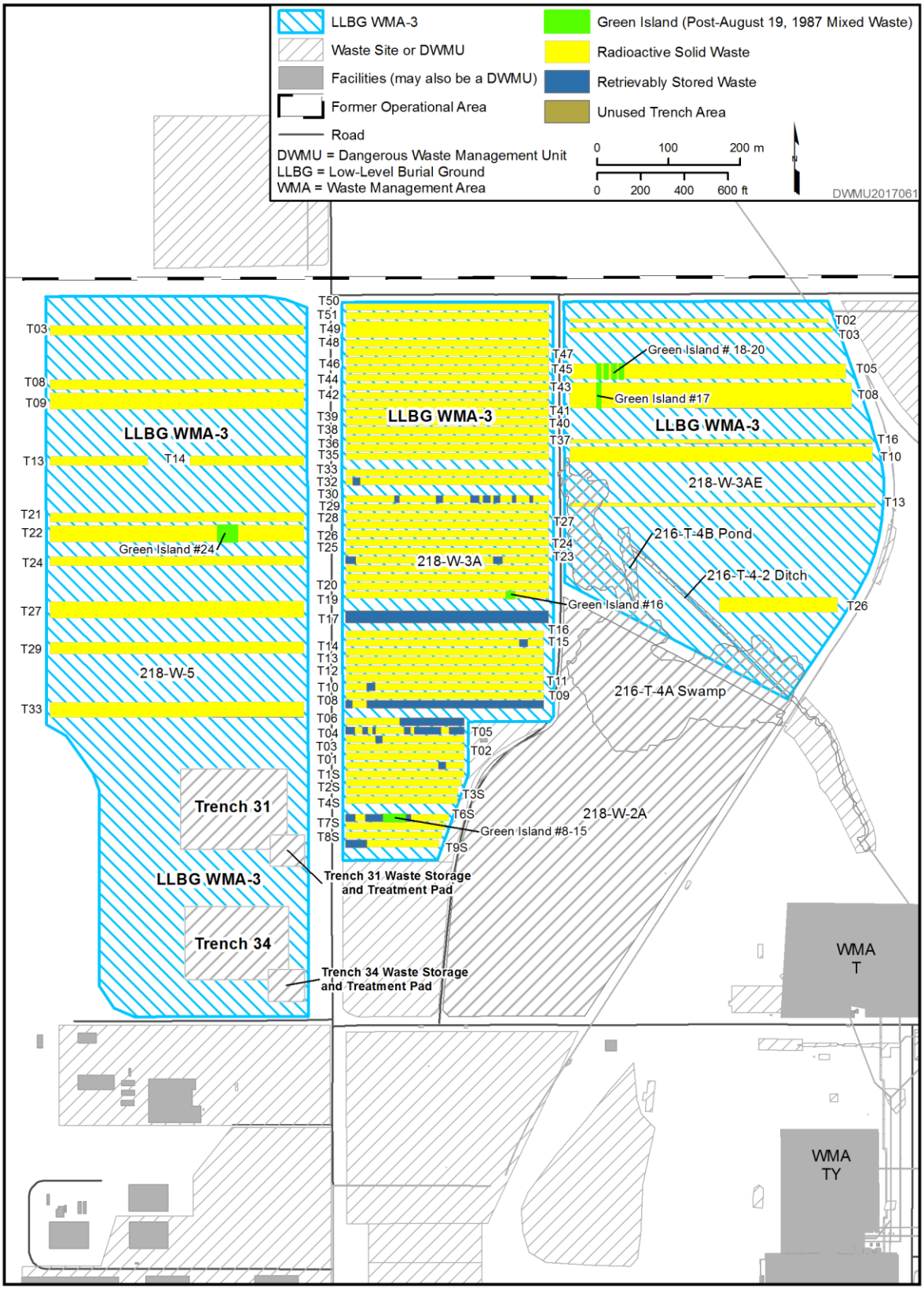


Figure 2-2. LLBG WMA-3 Trenches and Green Island Locations

2.3.2 218-W-3AE Burial Ground

The 218-W-3AE Burial Ground received miscellaneous waste such as rags, paper, rubber gloves, disposable supplies, and broken tools as well as industrial waste such as failed equipment, tanks, pumps, ovens, agitators, heaters, hoods, jumpers, and accessories (Section 2.3 in DOE/RL-2014-43). Each of the trenches received remote-handled LLW. The waste were primarily from the 100 Area, 200 East and West Areas, 300 Area, and other Hanford Site areas and facilities such as the tank farms and the 1100 Area. The remaining portion of the waste is from offsite generators, with Energy Systems Group, Argonne National Laboratory, Fermi National Accelerator Laboratory, and Battelle Columbus being the major contributors (Section 2.3 in DOE/RL-2014-43). Trenches 5 and 8 at 218-W-3AE are identified as containing mixed waste that was disposed after the August 19, 1987 effective date of the mixed waste regulation. Trench 8 has one Green Island and Trench 5E has three Green Islands, as detailed in Table 2-1 and shown in Figure 2-2.

2.3.3 218-W-5 Burial Ground

The 218-W-5 Burial Ground received packaged waste materials from 200 West Area operations as well as other wastes from the Hanford Site and offsite (Section 2.3 in DOE/RL-2009-68, Rev. 2). Examples of waste disposed to this burial ground include rags, paper, rubber gloves, disposable supplies, and broken tools. Trench 22 is identified as containing mixed waste that was disposed after the August 19, 1987 effective date of the mixed waste regulation (Section 2.5 in DOE/RL-2014-43). Trench 22 has one Green Island, as detailed in Table 2-1 and shown in Figure 2-2.

2.3.4 Dangerous Wastes Identified on Part A Permit Application

The dangerous wastes managed at the LLBG unit (which includes eight burial grounds in the 200 East and 200 West Areas) are from the Hanford Facility RCRA Permit Part A Application for the LLBG (Operating Unit 17), last revised October 1, 2008 (Revision 14) (WA7890008967, 2008). Dangerous wastes specifically associated with LLBG WMA-3 are not identified; therefore, LLBG WMA-3 may manage any of the identified dangerous wastes (Table 2-2).

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
D004	Arsenic	U162	Methyl methacrylate (I,T); 2-Propenoic acid, 2-methyl-,methyl ester (I,T)
D005	Barium	U163	Guanidine, -methyl-N'-nitro-N-nitroso-; MNNG
D006	Cadmium	U164	Methylthiouracil; 4(1H)-Pyrimidinone, 2,3-dihydro-6-methyl-2- thioxo-
D007	Chromium	U165	Naphthalene
D008	Lead	U166	1,4-Naphthalenedione; 1,4-Naphthoquinone
D009	Mercury	U167	1-Naphthalenamine; alpha-Naphthylamine
D010	Selenium	U168	2-Naphthalenamine; beta-Naphthylamine
D011	Silver	U169	Benzene, nitro-; Nitrobenzene (I,T)
D012	Endrin	U170	p-Nitrophenol; Phenol, 4-nitro-

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
D013	Lindane	U171	2-Nitropropane (I,T); Propane, 2-nitro- (I,T)
D014	Methoxychlor	U172	1-Butanamine, N-butyl-N-nitroso-; N-Nitrosodi-n-butylamine
D015	Toxaphene	U173	Ethanol, 2,2'- (nitrosoimino)bis-; N-Nitrosodiethanolamine
D016	2,4-D	U174	Ethanamine, -ethyl-N-nitroso-; N-Nitrosodiethylamine
D017	2,4,5-TP Silvex	U176	N-Nitroso-N-ethylurea; Urea, N-ethyl-N-nitroso-
D018	Benzene	U177	N-Nitroso-N-methylurea; Urea, N-methyl-N-nitroso-
D019	Carbon tetrachloride	U178	Carbamic acid, methylnitroso-,ethyl ester; N-Nitroso-N-methylurethane
D020	Chlordane	U179	N-Nitrosopiperidine; Piperidine, 1-nitroso-
D021	Chlorobenzene	U180	N-Nitrosopyrrolidine; Pyrrolidine,1-nitroso-
D022	Chloroform	U181	Benzenamine, 2-methyl-5-nitro-; 5-Nitro-o-toluidine
D023	o-Cresol	U182	1,3,5-Trioxane, 2,4,6-trimethyl-; Paraldehyde
D024	m-Cresol	U183	Benzene, pentachloro-; Pentachlorobenzene
D025	p-Cresol	U184	Ethane, pentachloro-; Pentachloroethane
D026	Cresol	U185	Benzene, pentachloronitro-; Pentachloronitrobenzene (PCNB)
D027	1,4-Dichlorobenzene	U186	1-Methylbutadiene(I); 1,3-Pentadiene(I)
D028	1,2-dichloroethane	U187	Acetamide, -(4-ethoxyphenyl)-; Phenacetin
D029	1,1-dichloroethylene	U188	Phenol
D030	2,4-dinitrotoluene	U189	Phosphorus sulfide (R); Sulfur phosphide (R)
D031	Heptachlor (and its epoxide)	U190	1,3-Isobenzofurandione; Phthalic anhydride
D032	Hexachlorobenzene	U191	2-Picoline; Pyridine, 2-methyl-
D033	Hexachlorobutadiene	U192	Benzamide, 3,5-dichloro-N-(1,1-dimethyl-2- propynyl)-; Pronamide
D034	Hexachloroethane	U193	1,2-Oxathiolane, 2,2-dioxide; 1,3-Propane sultone
D035	Methyl ethyl ketone	U194	1-Propanamine (I,T); n-Propylamine (I,T)
D036	Nitrobenzene	U196	Pyridine

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
D037	Pentachlorophenol	U197	p-Benzoquinone; 2,5-Cyclohexadiene-1,4-dione
D038	Pyridine	U200	Reserpine; Yohimban-16-carboxylic acid, 11,17-dimethoxy-18-[(3,4,5-trimethoxybenzoyl)oxy]-, methylester,(3beta,16beta,17alpha, 18beta,20alpha)-
D039	Tetrachloroethylene	U201	1,3-Benzenediol; Resorcinol
D040	Trichlorethylene	U203	1,3-Benzodioxole, 5-(2-propenyl)-; Safrole
D041	2,4,5-Trichlorophenol	U204	Selenious acid; Selenium dioxide
D042	2,4,6-Trichlorophenol	U205	Selenium sulfide; Selenium sulfide SeS2 (R,T)
D043	Vinyl chloride	U206	Glucopyranose, 2-deoxy-2-(3-methyl-3- nitrosoureido)-, D-; D-Glucose, 2-deoxy-2-[[(methylnitrosoamino)-carbonyl]amino]-; Streptozotocin
WSC2	Solid or semi-solid corrosive wastes - dangerous waste	U207	Benzene, 1,2,4,5-tetrachloro-; 1,2,4,5-Tetrachlorobenzene
WT01	Toxic dangerous wastes - extremely hazardous waste	U208	Ethane, 1,1,1,2-tetrachloro-; 1,1,1,2-Tetrachloroethane
WT02	Toxic dangerous wastes - dangerous waste	U209	Ethane, 1,1,2,2-tetrachloro-; 1,1,2,2-Tetrachloroethane
WP01	Persistent dangerous wastes halogenated organic compounds - extremely hazardous waste	U210	Ethene, tetrachloro-; Tetrachloroethylene
WP02	Persistent dangerous wastes halogenated organic compounds - dangerous waste	U211	Carbon tetrachloride; Methane, tetrachloro-
WP03	Polycyclic aromatic hydrocarbons - extremely hazardous waste	U213	Furan, tetrahydro-(I); Tetrahydrofuran (I)
WPCB	Washington polychlorinated biphenyls - dangerous waste	U214	Acetic acid, thallium(1+)salt; Thallium(I) acetate
F001	Spent halogenated solvents (T)	U215	Carbonic acid, dithallium(1+) salt; Thallium(I) carbonate
F002	Spent halogenated solvents (T)	U216	Thallium(I) chloride; Thallium chloride TlCl
F003	Spent nonhalogenated solvents (I)	U217	Nitric acid, thallium(1+) salt; Thallium(I) nitrate

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
F004	Spent nonhalogenated solvents (T)	U218	Ethanethioamide; Thioacetamide
F005	Spent non-halogenated solvents (I,T)	U219	Thiourea
F006	Wastewater treatment sludges (T)	U220	Benzene, methyl-; Toluene
F007	Spent cyanide plating bath solutions (R,T)	U221	Benzenediamine, ar-methyl-; Toluenediamine
F008	Plating bath residues (R,T)	U222	Benzenamine, 2-methyl-, hydrochloride; o-Toluidine hydrochloride
F009	Spent stripping and cleaning bath solutions (R,T)	U223	Benzene, 1,3-diisocyanatomethyl-(R,T); Toluene diisocyanate (R,T)
F010	Quenching bath residues (R,T)	U225	Bromoform; Methane, tribromo-
F011	Spent cyanide solutions (R,T)	U226	Ethane, 1,1,1-trichloro-; Methyl chloroform; 1,1,1-Trichloroethane
F012	Quenching wastewater treatment sludges (T)	U227	Ethane, 1,1,2-trichloro-; 1,1,2-Trichloroethane
F019	Wastewater treatment sludges (T)	U228	Ethene, trichloro-; Trichloroethylene
F027	Discarded unused formulations containing tri-, tetra-, or pentachlorophenol or discarded unused formulations containing compounds derived from chlorophenols (H)	U234	Benzene, 1,3,5-trinitro-; 1,3,5-Trinitrobenzene (R,T)
F039	Leachate (T)	U235	1-Propanol, 2,3-dibromo-, phosphate (3:1); Tris(2,3-dibromopropyl) phosphate
U001	Acetaldehyde (I); Ethanal (I)	U236	2,7-Naphthalenedisulfonicacid, 3,3'-[(3,3'- dimethyl[1,1'-biphenyl]-4,4'-diyl) bis(azo)bis [5-amino-4-hydroxy]-, tetrasodium salt; Trypan blue
U002	Acetone (I); 2-Propanone (I)	U237	2,4-(1H,3H)-Pyrimidinedione, 5-[bis (2-chloroethyl)amino]-; Uracil mustard
U003	Acetonitrile (I,T)	U238	Carbamic acid, ethyl ester; Ethyl carbamate (urethane)
U004	Acetophenone; Ethanone, 1-phenyl-	U239	Benzene, dimethyl- (I); Xylene (I)
U005	Acetamide, -9H-fluoren-2-yl-; 2-Acetylaminofluorene	U240	Acetic acid, (2,4-dichlorophenoxy)-, salts & esters; 2,4-D, salts & esters
U006	Acetyl chloride (C,R,T)	U243	Hexachloropropene; 1-Propene, 1,1,2,3,3,3-hexachloro-
U007	Acrylamide; 2-Propenamide	U244	Thioperoxydicarbonic diamide [(H2N)C(S)]2S2, tetramethyl-; Thiram
U008	Acrylic acid (I); 2-Propenoic acid (I)	U246	Cyanogen bromide(CN)Br

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U009	Acrylonitrile; 2-Propenenitrile	U247	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis [4-methoxy-; Methoxychlor
U010	Azirino[2',3':3,4]pyrrolo[1,2-a]indole-4,7-dione, 6-amino-8-[[(aminocarbonyl)oxy]methyl] -1,1a,2,8,8a,8b-hexahydro-8a-methoxy-5- methyl-, [1aS-(1aalpha,8beta,8aalpha,8balpha)]-; Mitomycin C	U248	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1- phenyl-butyl)-, & salts, when present at concentrations of 0.3% or less; Warfarin, & salts, when present at concentrations of 0.3% or less
U011	Amitrole; 1H-1,2,4-Triazol-3-amine	U249	Zinc phosphide Zn3 P2, when present at concentrations of 10% or less
U012	Aniline (I,T); Benzenamine (I,T)	U271	Benomyl; Carbamic acid, [1-[(butylamino)carbonyl]-1H-benzimidazol -2-yl]-, methylester
U014	Auramine; Benzenamine, 4,4'-carbonimidoylbis [N,N-dimethyl-	U278	Bendiocarb; 1,3-Benzodioxol-4-ol, 2,2-dimethyl-, methyl carbamate
U015	Azaserine; L-Serine, diazoacetate (ester)	U279	Carbaryl; 1-Naphthalenol, methylcarbamate
U016	Benz[c]acridine	U280	Barban; Carbamic acid, (3-chlorophenyl)-, 4-chloro-2- butynyl ester
U017	Benzal chloride; Benzene, (dichloromethyl)-	U328	Benzenamine, 2-methyl-; o-Toluidine
U018	Benz[a]anthracene	U353	Benzenamine, 4-methyl-; p-Toluidine
U019	Benzenesulfonic acid chloride(C,R)	U359	Ethanol,2-ethoxy-; Ethyleneglycol monoethylether
U020	Benzenesulfonyl chloride(C,R)	U364	Bendiocarb phenol; 1,3-Benzodioxol-4-ol, 2,2-dimethyl-,
U021	Benzidine; [1,1'-Biphenyl]-4,4'-diamine	U367	7-Benzofuranol, 2,3-dihydro-2,2-dimethyl-; Carbofuran phenol
U022	Benzo[a]pyrene	U372	Carbamic acid, 1H-benzimidazol-2-yl, methylester; Carbendazim
U023	Benzene, (trichloromethyl)-; Benzotrichloride (C,R,T)	U373	Carbamic acid, phenyl-, 1-methylethyl ester; Propham
U024	Dichloromethoxy ethane; Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro -	U387	Carbamothioic acid, dipropyl-, S-(phenylmethyl) ester; Prosulfocarb
U025	Dichloroethyl ether; Ethane, 1,1'-oxybis[2-chloro-	U389	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3,3-trichloro-2-propenyl) ester; Triallate

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U026	Chlornaphazin; Naphthalenamine, N,N'-bis(2-chloroethyl)-	U394	A2213; Ethanimidothioic acid, 2-(dimethylamino)-N- hydroxy-2-oxo-, methyl ester
U027	Dichloroisopropyl ether; Propane, 2,2'-oxybis[2-chloro-	U395	Diethylene glycol, dicarbamate; Ethanol, 2,2'-oxybis-,dicarbamate
U028	1,2-Benzenedicarboxylic acid,bis(2-ethylhexyl) ester; Diethylhexyl phthalate	U404	Ethanamine, N,N-diethyl-; Triethylamine
U029	Methane, bromo-; Methyl bromide	U409	Carbamic acid, [1,2-phenylenebis (iminocarbonothioyl)]bis, dimethyl ester; Thiophanate-methyl
U030	Benzene, 1-bromo-4-phenoxy-; 4-Bromophenyl phenyl ether	U410	Ethanimidothioic acid, N,N'-[thiobis [(methylimino)carbonyloxy]]bis-, dimethyl ester; Thiodicarb
U031	1-Butanol (I); n-Butyl alcohol (I)	U411	Phenol, 2-(1-methylethoxy)-, methylcarbamate; Propoxur
U032	Calcium chromate; Chromic acid H2 CrO4, calcium salt	P001	2H-1-Benzopyran-2-one, 4-hydroxy-3-(3-oxo-1- phenylbutyl)-, & salts, when present at concentrations greater than 0.3%; Warfarin, & salts, when present at concentrations greater than 0.3%
U033	Carbonic difluoride	P002	Acetamide, -(aminothioxomethyl)-; 1-Acetyl-2-thiourea
U034	Acetaldehyde, trichloro-; Chloral	P003	Acrolein; 2-Propenal
U035	Benzenebutanoic acid, 4-[bis(2-chloroethyl) amino]-; Chlorambucil	P004	Aldrin; 1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro-1,4,4a,5,8,8a,-he xahydro-, (1alpha,4alpha,4abeta,5alpha,8alpha,8abeta)
U036	Chlordane, alpha & gamma isomers; 4,7-Methano-1H- indene,1,2,4,5,6,7,8,8-octachloro-2,3 ,3a,4,7,7a- hexahydro-	P005	Allyl alcohol; 2-Propen-1-ol
U037	Benzene, chloro-; Chlorobenzene	P006	Aluminum phosphide (R,T)
U038	Benzeneacetic acid, 4-chloro- alpha-(4-chlorophenyl)-alpha-hydro xy-, ethyl ester; Chlorobenzilate	P007	5-(Aminomethyl)-3-isoxazolol; 3(2H)-Isoxazolone, 5-(aminomethyl)-
U039	p-Chloro-m-cresol; Phenol, 4-chloro-3-methyl-	P008	4-Aminopyridine; 4-Pyridinamine
U041	Epichlorohydrin; Oxirane, (chloromethyl)-	P009	Phenol, 2,4,6-trinitro-, ammonium salt (R)
U042	2-Chloroethyl vinyl ether; Ethene, (2-chloroethoxy)-	P010	Arsenic acid H3 AsO4

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U043	Ethene, chloro-; Vinyl chloride	P011	Arsenic oxide As2 O5; Arsenic pentoxide
U044	Chloroform; Methane, trichloro-	P012	Arsenic oxide As2 O3; Arsenic trioxide
U045	Methane,chloro- (I,T); Methyl chloride (I,T)	P013	Barium cyanide
U046	Chloromethylmethyl ether; Methane, chloromethoxy-	P014	Benzenethiol; Thiophenol
U047	beta-Chloronaphthalene; Naphthalene, 2-chloro-	P015	Beryllium powder
U048	o-Chlorophenol; Phenol, 2-chloro-	P016	Dichloromethyl ether; Methane, oxybis[chloro-
U049	Benzenamine, 4-chloro-2-methyl-, hydrochloride; 4-Chloro-o-toluidine, hydrochloride	P017	Bromoacetone; 2-Propanone, 1-bromo-
U050	Chrysene	P018	Brucine; Strychnidin-10-one, 2,3-dimethoxy-
U051	Creosote	P020	Dinoseb; Phenol, 2-(1-methylpropyl)-4,6-dinitro-
U052	Cresol (Cresylic acid); Phenol, methyl-	P021	Calcium cyanide; Calcium cyanide Ca(CN)2
U053	2-Butenal; Crotonaldehyde	P022	Carbon disulfide
U055	Benzene, (1-methylethyl)-(I); Cumene (I)	P023	Acetaldehyde, chloro-; Chloroacetaldehyde
U056	Benzene, hexahydro-(I); Cyclohexane (I)	P024	Benzenamine, 4-chloro-; Chloroaniline
U057	Cyclohexanone (I); Cyclophosphamide	P026	1-(o-Chlorophenyl)thiourea; Thiourea, (2-chlorophenyl)-
U058	2H-1,3,2-Oxazaphosphorin-2-amine, N,N-bis (2-chloroethyl)tetrahydro-, 2-oxide	P027	3-Chloropropionitrile; Propanenitrile, 3-chloro-
U059	Daunomycin; 5,12-Naphthacenedione, 8-acetyl-10- [(3-amino-2,3,6-trideoxy)-alpha-L-lyxo- hexopyranosyl)oxy]-7,8,9,10-tetrahydro-6,8,11- trihydroxy-1-methoxy-, (8S-cis)-	P028	Benzene, (chloromethyl)-; Benzylchloride
U060	Benzene, 1,1'-(2,2-dichloroethylidene)bis [4-chloro-; DDD	P029	Coppercyanide; Copper cyanideCu(CN)
U061	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis [4-chloro-; DDT	P030	Cyanides (soluble cyanide salts), not otherwise specified

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U062	Carbamothioic acid, bis(1-methylethyl)-, S-(2,3-dichloro-2-propenyl) ester; Diallate	P031	Cyanogen; Ethanedinitrile
U063	Dibenz[a,h]anthracene	P033	Cyanogen chloride; Cyanogen chloride (CN)Cl
U064	Benzo[rst]pentaphene; Dibenzo[a,i]pyrene	P034	Cyclohexyl-4,6- dinitrophenol; Phenol, 2-cyclohexyl-4,6-dinitro-
U066	1,2-Dibromo-3-chloropropane; Propane, 1,2-dibromo-3-chloro-	P036	Arsonous dichloride, phenyl-; Dichlorophenylarsine
U067	Ethane, 1,2-dibromo-; Ethylene dibromide	P037	Dieldrin; 2,7:3,6-Dimethanonaphth[2,3-b] oxirene, 3,4,5,6,9,9-hexachloro- 1a,2,2a,3,6,6a,7,7a-octahydro-, (1aalpha,2beta,2aalpha,3beta,6beta, 6aalpha,7beta, 7aalpha)-
U068	Methane, dibromo-; Methylene bromide	P038	Arsine, diethyl-; Diethylarsine
U069	1,2-Benzenedicarboxylic acid, dibutyl ester; Dibutyl phthalate	P039	Disulfoton; Phosphorodithioic acid, O,O-diethyl S-[2-(ethylthio) ethyl]ester
U070	Benzene, 1,2-dichloro-; o-Dichlorobenzene	P040	O,O-Diethyl O-pyrazinyl phosphorothioate; Phosphorothioic acid, O,O-diethyl O-pyrazinyl ester
U071	Benzene, 1,3-dichloro-; m-Dichlorobenzene	P041	Diethyl-p-nitrophenyl phosphate; Phosphoric acid, diethyl 4-nitrophenyl ester
U072	Benzene, 1,4-dichloro-; p-Dichlorobenzene	P042	1,2-Benzenediol, 4-[1-hydroxy-2-(methylamino) ethyl]-, (R)-; Epinephrine
U073	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro-; 3,3'-Dichlorobenzidine	P043	Diisopropylfluorophosphate (DFP); Phosphorofluoridic acid, bis(1-methylethyl) ester
U074	2-Butene, 1,4-dichloro-(I,T); 1,4-Dichloro-2-butene (I,T)	P044	Dimethoate; Phosphorodithioic acid, O,O-dimethyl S-[2-(methyl amino)-2-oxoethyl] ester
U075	Dichlorodifluoromethane; Methane, dichlorodifluoro-	P045	2-Butanone, 3,3-dimethyl-1-(methylthio)-, O-[(methylamino)carbonyl]oxime; Thiofanox
U076	Ethane, 1,1-dichloro-; Ethylidene dichloride	P046	Benzeneethanamine,alpha,alpha-dimethyl-; alpha,alpha-Dimethylphenethylamine
U077	Ethane, 1,2-dichloro-; Ethylene dichloride	P047	4,6-Dinitro-o-cresol, & salts; Phenol, 2-methyl-4,6-dinitro-, & salts

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U078	1,1-Dichloroethylene; Ethene, 1,1-dichloro-	P048	2,4-Dinitrophenol; Phenol, 2,4-dinitro-
U079	1,2-Dichloroethylene; Ethene, 1,2-dichloro-, (E)-	P049	Dithiobiuret; Thioimidodicarbonic diamide[(H2 N)C(S)]2 NH
U080	Methane, dichloro-; Methylene chloride	P050	6,9-Methano-2,4,3-benzodioxathiepin,6,7,8, 9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro -, 3-oxide
U081	2,4-Dichlorophenol; Phenol, 2,4-dichloro-	P051	2,7:3,6-Dimethanonaphth [2,3-b]oxirene, 3,4,5,6,9,9- hexachloro-1a,2,2a,3,6,6a,7,7a- octahydro-, (1aalpha,2beta,2abeta, 3alpha,6alpha,6abeta,7beta, 7aalpha)-, & metabolites; Endrin; Endrin, & metabolites
U082	2,6-Dichlorophenol; Phenol, 2,6-dichloro-	P054	Aziridine; Ethyleneimine
U083	Propane, 1,2-dichloro-; Propylene dichloride	P056	Fluorine
U084	1,3-Dichloropropene; 1-Propene, 1,3-dichloro-	P057	Acetamide, 2-fluoro-; Fluoroacetamide
U085	2,2'-Bioxirane; 1,2:3,4-Diepoxybutane (I,T)	P058	Acetic acid, fluoro-, sodium salt; Fluoroacetic acid, sodium salt
U086	N,N'-Diethylhydrazine; Hydrazine, 1,2-diethyl-	P059	Heptachlor; 4,7-Methano-1H-indene,1,4,5,6,7,8,8-heptachloro- 3a,4,7,7a-tetrahydro-
U087	O,O-Diethyl S-methyldithiophosphate; Phosphorodithioic acid, O,O-diethyl S- methyl ester	P060	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexa- chloro-1,4,4a,5,8,8a-hexahydro-, (1alpha,4alpha,4abeta,5beta,8beta,8abeta)-; Isodrin
U088	1,2-Benzenedicarboxylic acid, diethyl ester; Diethyl phthalate	P062	Hexaethyl tetraphosphate; Tetraphosphoric acid, hexaethyl ester
U089	Diethylstilbesterol; Phenol, 4,4'-(1,2-diethyl-1,2-ethenediyl)bis-, (E)	P063	Hydrocyanic acid; Hydrogen cyanide
U090	1,3-Benzodioxole, 5-propyl-; Dihydrosafrole	P064	Methane, isocyanato-; Methyl isocyanate
U091	[1,1'-Biphenyl]-4,4'-diamine, 3,3'- dimethoxy-; 3,3'-Dimethoxybenzidine	P065	Fulminic acid, mercury(2+) salt (R,T); Mercury fulminate (R,T)
U092	Dimethylamine (I); Methanamine, -methyl-(I)	P066	Ethanimidothioic acid, N-[[(methylamino)carbonyl] oxy]-, methyl ester; Methomyl

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U093	Benzenamine, N,N-dimethyl-4- (phenylazo)-; p-Dimethylaminoazobenzene	P067	Aziridine, 2-methyl-; 1,2-Propylenimine
U094	Benz[a]anthracene, 7,12-dimethyl-; 7,12-Dimethylbenz[a]anthracene	P068	Hydrazine, methyl-; Methyl hydrazine
U095	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dimethyl-; 3,3'-Dimethylbenzidine	P069	2-Methyllactonitrile; Propanenitrile, 2-hydroxy-2-methyl-
U096	alpha,alpha-Dimethylbenzylhydroperoxide (R); Hydroperoxide, 1-methyl-1-phenylethyl-(R)	P070	Aldicarb; Propanal, 2-methyl-2-(methylthio)-, O-[(methylamino)carbonyl]oxime
U097	Carbamic chloride, dimethyl-; Dimethylcarbamoyl chloride	P071	Methylparathion; Phosphorothioic acid, O,O,-dimethyl O-(4-nitrophenyl)ester
U098	1,1-Dimethylhydrazine; Hydrazine, 1,1-dimethyl-	P072	alpha-Naphthylthiourea; Thiourea, 1-naphthalenyl-
U099	1,2-Dimethylhydrazine; Hydrazine, 1,2-dimethyl-	P073	Nickel carbonyl; Nickel carbonyl Ni(CO)4, (T-4)-
U101	2,4-Dimethylphenol; Phenol, 2,4-dimethyl-	P074	Nickel cyanide; Nickel cyanide Ni(CN)2
U102	1,2-Benzenedicarboxylicacid, dimethyl ester; Dimethylphthalate	P075	Nicotine, & salts; Pyridine, 3-(1-methyl-2-pyrrolidinyl)-, (S)-, & salts
U103	Dimethyl sulfate; Sulfuric acid, dimethyl ester	P076	Nitric oxide; Nitrogen oxide NO
U105	Benzene, 1-methyl-2,4-dinitro-; 2,4-Dinitrotoluene	P077	Benzenamine, 4-nitro-; p-Nitroaniline
U106	Benzene, 2-methyl-1,3-dinitro-; 2,6-Dinitrotoluene	P078	Nitrogen dioxide; Nitrogen oxide NO2
U107	1,2-Benzenedicarboxylic acid, dioctyl ester; Di-n-octylphthalate	P081	Nitroglycerine (R); 1,2,3-Propanetriol, trinitrate (R)
U108	1,4-Diethyleneoxide; 1,4-Dioxane	P082	Methanamine, -methyl-N-nitroso-; N-Nitrosodimethylamine
U109	1,2-Diphenylhydrazine; Hydrazine, 1,2-diphenyl-	P084	N-Nitrosomethylvinylamine; Vinylamine, -methyl-N-nitroso-
U110	Dipropylamine(I); 1-Propanamine, N-propyl-(I)	P085	Diphosphoramide, octamethyl-; Octamethylpyrophosphoramide
U111	Di-n-propylnitrosamine; 1-Propanamine,N-nitroso-N- propyl-	P087	Osmium oxide OsO4, (T-4)-; Osmium tetroxide
U112	Acetic acid ethyl ester(I); Ethyl acetate (I)	P088	Endothall; 7-Oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U113	Ethyl acrylate(I); 2-Propenoic acid, ethyl ester (I)	P089	Parathion; Phosphorothioic acid, O,O-diethyl O-(4-nitrophenyl) ester
U114	Carbamodithioic acid, 1,2-ethanediylbis-, salts & esters; Ethylenebisdithiocarbamic acid, salts & esters	P092	Mercury, (acetato-O)phenyl-; Phenylmercury acetate
U115	Ethylene oxide (I,T); Oxirane (I,T)	P093	Phenylthiourea; Thiourea, phenyl-
U116	Ethylenethiourea; 2-Imidazolidinethione	P094	Phorate; Phosphorodithioic acid, O,O-diethyl S-[(ethylthio) methyl]ester
U117	Ethane, 1,1'-oxybis-(I); Ethyl ether (I)	P095	Carbonic dichloride; Phosgene
U118	Ethyl methacrylate; 2-Propenoic acid, 2-methyl-,ethyl ester	P096	Hydrogen phosphide; Phosphine
U119	Ethyl methanesulfonate; Methanesulfonic acid, ethyl ester	P097	Famphur; Phosphorothioic acid, O-[4-[(dimethylamino)sulfonyl]phenyl]O,O -dimethyl ester
U120	Fluoranthene	P098	Potassiumcyanide; Potassium cyanide K(CN)
U121	Methane, trichlorofluoro-; Trichloromonofluoromethane	P099	Argentate(1-), bis(cyano-C)-, potassium; Potassium silvercyanide
U122	Formaldehyde	P101	Ethyl cyanide; Propanenitrile
U123	Formic acid (C,T)	P102	Propargyl alcohol; 2-Propyn-1-ol
U124	Furan (I); Furfuran (I)	P103	Selenourea
U125	2-Furancarboxaldehyde (I); Furfural (I)	P104	Silvercyanide; Silvercyanide Ag(CN)
U126	Glycidylaldehyde; Oxiranecarboxyaldehyde	P105	Sodium azide
U127	Benzene, hexachloro-; Hexachlorobenzene	P106	Sodium cyanide; Sodium cyanide Na(CN)
U128	1,3-Butadiene, 1,1,2,3,4,4-hexachloro-; Hexachlorobutadiene	P108	Strychnidin-10-one, & salts; Strychnine, & salts
U129	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1alpha,2alpha,3beta,4alpha, 5alpha,6beta)-; Lindane	P109	Thiodiphosphoric acid,tetraethyl ester
U130	1,3-Cyclopentadiene, 1,2,3,4,5,5-hexachloro-; Hexachlorocyclopentadiene	P110	Plumbane, tetraethyl-; Tetraethyl lead

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U131	Ethane, hexachloro-; Hexachloroethane	P111	Diphosphoric acid, tetraethylester; Tetraethyl pyrophosphate
U132	Hexachlorophene; Phenol, 2,2'-methylenebis[3,4,6-trichloro-	P112	Methane, tetranitro-(R); Tetranitromethane (R)
U133	Hydrazine (R,T)	P113	Thallic oxide; Thallium oxide Tl2 O3
U134	Hydrofluoric acid (C,T); Hydrogen fluoride (C,T)	P114	Selenious acid,dithallium(1+) salt; Thallium(I) selenite
U135	Hydrogen sulfide; Hydrogen sulfide H2S	P115	Sulfuric acid, dithallium(1+) salt; Thallium(I) sulfate
U136	Arsinic acid, dimethyl-; Cacodylic acid	P116	Hydrazinecarbothioamide; Thiosemicarbazide
U137	Indeno[1,2,3-cd]pyrene	P118	Methanethiol, trichloro-; Trichloromethanethiol
U138	Methane, iodo-; Methyl iodide	P119	Ammonium vanadate; Vanadic acid, ammonium salt
U140	Isobutyl alcohol (I,T); 1-Propanol, 2-methyl- (I,T)	P120	Vanadium oxide V2O5; Vanadium pentoxide
U141	1,3-Benzodioxole, 5-(1-propenyl)-; Isosafrole	P121	Zinccyanide; Zinc cyanideZn(CN)2
U142	Kepone; 1,3,4-Metheno-2H-cyclobuta[cd]pentalen-2-one, 1,1a,3,3a,4,5,5,5a,5b,6-decachlorooctahydro-	P122	Zinc phosphide Zn3 P2, when present at concentrations greater than 10% (R,T)
U143	2-Butenoic acid, 2-methyl-, 7-[[2,3-dihydroxy-2-(1-methoxyethyl)-3-methyl-1-oxobutoxy] methyl]-2,3,5,7a-tetrahydro-1H-pyrrolizin-1-yl ester, [1S-[1alpha(Z),7(2S*,3R*),7aalpha]]-; Lasiocarpine	P123	Toxaphene
U144	Acetic acid,lead(2+) salt; Lead acetate	P127	7-Benzofuranol, 2,3-dihydro-2,2- dimethyl-, methylcarbamate; Carbofuran
U145	Lead phosphate; Phosphoric acid, lead(2+)salt (2:3)	P128	Mexacarbate; Phenol, 4-(dimethylamino)-3,5-dimethyl-, methylcarbamate(ester)
U146	Lead, bis(acetato-O)tetrahydroxytri-; Lead subacetate	P185	1,3-Dithiolane-2-carboxaldehyde, 2,4-dimethyl-, O-[(methylamino)-carbonyl]oxime; Tirpate
U147	2,5-Furandione; Maleic anhydride	P188	Benzoic acid, 2-hydroxy-,compd. with (3aS-cis)-1,2,3,3a,8,8a-hexahydro-1,3a,8-trimethylpyrrolo [2,3-b]indol-5-yl

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
			methylcarbamate ester (1:1); Physostigmine salicylate
U148	Maleic hydrazide; 3,6-Pyridazinedione, 1,2-dihydro-	P189	Carbamic acid,[(dibutylamino)-thio]methyl-,2,3-dihydro-2,2-dimethyl-7-benzofuranyl ester; Carbosulfan
U149	Malononitrile; Propanedinitrile	P190	Carbamic acid, methyl-, 3-methylphenyl ester; Metolcarb
U150	L-Phenylalanine, 4-[bis(2-chloroethyl)amino]-	P191	Carbamic acid, dimethyl-, 1-[(dimethyl-amino) carbonyl]-5-methyl-1H-pyrazol-3-yl ester; Dimetilan
U151	Mercury	P192	Carbamic acid, dimethyl-, 3-methyl-1-(1-methylethyl)-1H-pyrazol-5-yl ester; Isolan
U152	Methacrylonitrile (I,T); 2-Propenenitrile, 2-methyl- (I,T)	P194	Ethanimidthioic acid, 2-(dimethylamino)-N-[[(methylamino)carbonyl]oxy]-2-oxo-, methylester; Oxamyl
U153	Methanethiol (I,T); Thiomethanol (I,T)	P196	Manganese,bis(dimethylcarbamodithioato-S,S')-,; Manganesedimethyldithiocarbamate
U154	Methanol (I); Methyl alcohol (I)	P197	Formparanate; Methanimidamide, N,N-dimethyl-N'-[2-methyl-4-[[(methylamino)carbonyl]oxy]phenyl]-
U155	1,2-Ethanediamine, N,N-dimethyl-N'-2- pyridinyl-N'-(2-thienylmethyl)-; Methapyrilene	P198	Formetanate hydrochloride; Methanimidamide, N,N-dimethyl- N'-[3-[[(methylamino)-carbonyl]oxy]phenyl] -monohydrochloride
U156	Carbonochloridic acid, methylester (I,T); Methyl chlorocarbonate (I,T)	P199	Methiocarb; Phenol, (3,5-dimethyl-4-(methylthio)-,methyl-carbamate
U157	Benz[j]aceanthrylene, 1,2-dihydro-3-methyl-; 3-Methylcholanthrene	P201	Phenol, 3-methyl-5-(1-methylethyl)-, methylcarbamate; Promecarb
U158	Benzenamine, 4,4'-methylenebis[2-chloro-; 4,4'-Methylenebis(2-chloroaniline)	P202	m-Cumenyl methylcarbamate; 3-Isopropylphenyl N-methylcarbamate
U159	2-Butanone (I,T); Methyl ethyl ketone (MEK) (I,T)	P203	Aldicarb sulfone; Propanal, 2-methyl-2-(methyl-sulfonyl)-, O-[(methylamino)carbonyl]oxime
U160	2-Butanone, peroxide (R,T); Methyl ethyl ketone peroxide (R,T)	P204	Physostigmine; Pyrrolo[2,3-b]indol-5-ol,1,2,3,3a,8,8a- hexahydro-1,3a,8- trimethyl-,methylcarbamate (ester), (3aS-cis)-

Table 2-2. Dangerous Wastes Identified for LLBG in the Hanford Facility RCRA Permit Application Part A Form

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U161	Methyl isobutyl ketone (I); 4-Methyl-2-pentanone (I); Pentanol, 4-methyl-	P205	Zinc, bis (dimethylcarbamodithioato-S,S')-,; Ziram

Source: WA7890008967, *Dangerous Waste Permit Application Part A Form - Low Level Burial Grounds 9/22/2008*

* Dangerous waste code contaminant descriptions from WAC 173-303-090, "Dangerous Waste Regulations," "Dangerous Waste Characteristics"; WAC 173-303-104, "State-Specific Dangerous Waste Numbers"; WAC 173-303-9903, "Discarded Chemical Products List"; and WAC 173-303-9904, "Dangerous Waste Sources List."

C = corrosive waste
E = toxicity characteristic waste
H = acute hazardous waste
I = ignitable waste
R = reactive waste
T = toxic waste

2.4 Groundwater Monitoring and Sampling History

Table 2-3 identifies the interim status groundwater monitoring plans implemented at LLBG WMA-3. Figure 2-3 provides the locations of wells discussed in this section. A summary of the monitoring history for LLBG WMA-3 is presented in Appendix A. Appendix A also contains the interim status groundwater monitoring data collected at LLBG WMA-3 network wells and meets the requirement of WAC 173-303-806(4)(a)(xx)(A). The status of the monitoring wells through the plans indicated in Table 2-3 is provided in Appendix A.

Table 2-3. Interim Status Monitoring Plans

Document	Date Issued	Monitoring Program[a]
PNL-6772, *A Detection-Level Hazardous Waste Ground-Water Monitoring Compliance Plan for the 200 Areas Low-Level Burial Grounds and Retrievable Storage Units*	1987	Indicator Evaluation Program
WHC-SD-EN-AP-015, *Revised Ground-Water Monitoring Plan for the 200 Areas Low-Level Burial Grounds*	1989	Indicator Evaluation Program
ECN 113805	1991	
ECN 144234	1991	
ECN 618165	1994	
ECN 618180	1995	
WHC-SD-EN-AP-022, *Interim-Status Ground-Water Quality Assessment Plan for Waste Management Area 3 of the 200 Areas Low-Level Burial Grounds*	1990	Groundwater Quality Assessment[b]

Table 2-3. Interim Status Monitoring Plans

Document	Date Issued	Monitoring Program[a]
PNNL-14859, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington* PNNL-14859-ICN-1 PNNL-14859-ICN-2	2004 2006 2007	Indicator Evaluation Program
DOE/RL-2009-68, Rev. 0, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*	2010	Indicator Evaluation Program
DOE/RL-2009-68, Rev. 1, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*	2011	Indicator Evaluation Program
DOE/RL-2009-68, Rev. 2, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*	2012	Indicator Evaluation Program

a. The indicator evaluation program satisfies the requirements of 40 CFR 265.92(b)(2), (b)(3), (d)(1), (d)(2) and (e), "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis." The groundwater quality assessment program's first determination satisfies the requirements of 40 CFR 265.93(d)(4) and (d)(6), "Preparation, Evaluation, and Response."

b. LLBG WMA-3 entered a groundwater quality assessment program in 1990 due to an exceedance of total organic halogen and total organic carbon. In January 1994, a groundwater quality assessment report was issued and found that elevated total organic halogens was not attributable to LLBG WMA-3 and elevated total organic carbon results were due to laboratory error (Section 3.2 in WHC-SD-EN-EV-026, *Results of Groundwater Quality Assessment Program at Low-Level Waste Management Area 3 of the Low-Level Burial Grounds*). Groundwater monitoring subsequently returned to an indicator evaluation program under WHC-SD-EN-AP-015.

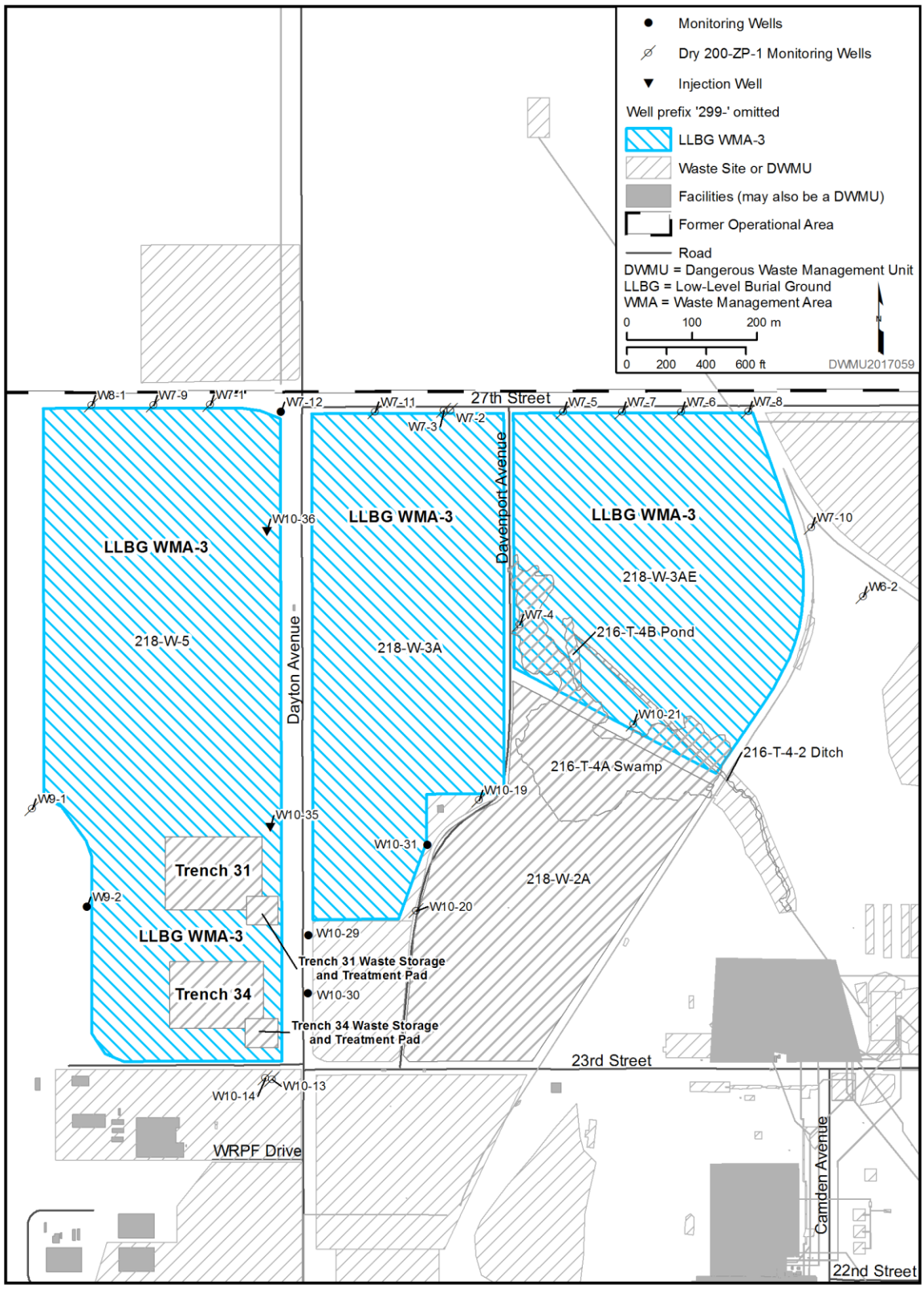


Figure 2-3. Wells Used during Interim Status Monitoring of LLBG WMA-3

In 1987, DOE-RL initiated an interim status groundwater monitoring program at LLBG WMA-3 in accordance with PNL-6772, *A Detection-Level Hazardous Waste Ground-Water Monitoring Compliance Plan for the 200 Areas Low-Level Burial Grounds and Retrievable Storage Units*, based on the interim status indicator evaluation program requirements of 40 CFR 265, Subpart F, and WAC 173-303-400. PNNL-6772 identified a total of 35 wells to be drilled amongst the burial grounds. LLBG WMA-3 was to have both an upgradient and downgradient deep monitoring well drilled to characterize the hydrogeology at depth and to assess the hydraulic potential and quality of groundwater near the base of the unconfined aquifer. A shallow well was to be located adjacent to each deep well. Samples were to be collected for the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b), "Sampling and Analysis." Ammonium, calcium, magnesium, potassium, and total dissolved solids were also included for sampling. The LLBG WMA-3 monitoring wells installed in 1987 included downgradient wells 299-W6-2, 299-W7-1, 299-W7-2, 299-W7-3 (deep well), 299-W7-4, 299-W7-5, 299-W7-6, and 299-W8-1 and upgradient wells 299-W9-1, 299-W10-13, and 299-W10-14 (deep well) (Figure 2-3). Two additional downgradient wells were installed in 1989 (299-W7-7 and 299-W7-8).

The groundwater monitoring plan was revised in 1989 (WHC-SD-EN-AP-015, *Revised Ground-Water Monitoring Plan for the 200 Areas Low-Level Burial Grounds*) and included an updated network for LLBG WMA-3 with four planned downgradient wells. The new wells were sited between existing wells to reduce the well spacing to between 91 and 137 m (300 to 450 ft) along the northern boundary of the 218-W-5 Burial Ground and to 152 m (500 ft) along the northern and northeastern boundaries of the 218-W-3A-E Burial Ground. Samples were to be collected for the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b), and ammonium, uranium, tritium, and volatile organic compounds (VOCs) (Section 3.5 in WHC-SD-EN-AP-015). The dangerous wastes listed in 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Appendix IX, "Ground-Water Monitoring List," were included for the first sample from each well and then annual sampling at selected wells (these wells were not identified in the plan) (Section 3.5 in WHC-SD-EN-AP-015). The two deep wells (299-W7-3 and 299-W10-14), which are screened at the bottom 6 m (20 ft) of the unconfined aquifer, were used to monitor for any dense nonaqueous-phase liquids from LLBG WMA-3 (Section 3.3.5.3 in WHC-SD-EN-AP-015). Groundwater at LLBG WMA-3 was considered to flow to the north-northeast at a velocity of 0.00003 to 0.2 m/d (0.001 to 0.6 ft/d) (Section 2.3.3.2 in WHC-SD-EN-AP-015).

In 1990, a groundwater quality assessment program was initiated (WHC-SD-EN-AP-022, *Interim-Status Ground-Water Quality Assessment Plan for Waste Management Area 3 of the 200 Areas Low-Level Burial Grounds*) due to sampling results from September 1989 in which TOX at downgradient well 299-W7-4 and TOC at downgradient wells 299-W7-5 and 299-W8-1 and upgradient well 299-W10-13 exceeded the statistical comparison value. Resampling confirmed the TOX exceedance; however, the TOC resampling could not exclude that the TOC results were not a result of a laboratory error (Section 3.0 in WHC-SD-EN-AP-022).

The groundwater quality assessment plan (WHC-SD-EN-AP-022) included quarterly sampling for VOCs and contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b) at the 11 existing and 4 planned network wells (Sections 4.2 and 4.4 in WHC-SD-EN-AP-022). Additionally, the four wells that triggered the assessment (299-W7-4, 299-W7-5, 299-W8-1, and 299-W10-13) were to be sampled for the dangerous wastes listed in Appendix IX of 40 CFR 264 at least once. Sampling was temporarily discontinued in June 1990 due to cancelation of the laboratory contract. The sampling program resumed in June 1991 (Introduction in DOE/RL-92-03, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1991*).

Four new wells were drilled in 1990 (299-W7-9 and 299-W7-10) and 1991 (299-W7-11 and 299-W7-12) (Figure 2-3) bringing the network total to 3 upgradient and 14 downgradient. Additional upgradient wells were drilled in 1992 (299-W10-19) and 1993 (299-W10-20 and 299-W10-21), bringing the upgradient network to six wells (including deep well 299-W10-14, which was used for information only).

In 1991, ECN 113805, *Engineering Change Notice To WHC-SD-EN-AP-015, Rev. 0 Revised Groundwater Monitoring Plan For Low-Level Burial Grounds*, provided locations for 32 additional monitoring wells for LLBG and well numbers for 16 newly installed wells. Two new wells were proposed for LLBG WMA-3 (Table 3 in ECN 113805). ECN 144234, *Engineering Change Notice To WHC-SD-EN-AP-015, Rev. 0 Revised Groundwater Monitoring Plan For Low-Level Burial Grounds*, was also issued in 1991 but was specific to a LLBG WMA-4 well change that did not affect LLBG WMA-3.

A groundwater quality assessment report was prepared in January 1994 (WHC-SD-EN-EV-026). Results from three additional upgradient monitoring wells (299-W10-19, 299-W10-20, and 299-W10-21) indicated that the elevated TOX originated from the carbon tetrachloride plume in the 200 West Area and not from LLBG WMA-3 (Section 3.2 in WHC-SD-EN-EV-026). Chloroform and trichloroethylene plumes in the 200 West Area were also contributing to elevated TOX results (Section 3.2 in WHC-SD-EN-EV-026). Sampling for TOC in wells 299-W7-5 and 299-W8-1 indicated that the September 1989 values were erroneous and that the critical mean for TOC was not exceeded. Indicator evaluation monitoring subsequently resumed at LLBG WMA-3 under WHC-SD-EN-AP-015.

Due to the addition of three upgradient wells to the network, background values were reestablished for the contamination indicator parameters. Two sets of critical means were determined for LLBG WMA-3. One set included wells 299-W9-1 and 299-W10-13 and was used for comparisons with wells north of 218-W-3A and 218-W-5. The other set included wells 299-W10-19, 299-W10-20, and 299-W10-21 and was used for comparisons with wells to the north and east of 218-W-3AE (Section 4.10.3.4.2 in DOE/RL-96-01, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1995*). DOE/RL-96-01 also reported that trichloroethylene exceeded the drinking water standard in upgradient wells 299-W10-19, 299-W10-20, and 299-W10-21 but was not attributable to LLBG WMA-3 (Section 4.10.3.4.1 in DOE/RL-96-01).

ECN 618165, *Engineering Change Notice To WHC-SD-EN-AP-015, Rev. 0 Revised Groundwater Monitoring Plan For Low-Level Burial Grounds*, and ECN 618180, *Engineering Change Notice To WHC-SD-EN-AP-015, Rev. 0 Revised Groundwater Monitoring Plan For Low-Level Burial Grounds*, revised the constituents required for sampling after the first year of monitoring. The revised constituents for LLBG WMA-3 included the contamination indicator parameters and groundwater quality parameters required by 40 CFR 265.92(b), gross alpha, gross beta, tritium, anion, metals, lead, mercury, VOCs, turbidity, and alkalinity.

Declining water elevations and changes in groundwater flow direction began to affect the network. Water elevation and flow direction changes were due to the dissipation of the groundwater mound caused by past disposal practices. In 1997, downgradient well 299-W7-2 became dry (Table A.15 in PNNL-11793, *Hanford Site Groundwater Monitoring for Fiscal Year 1997*) and was no longer sampled. Downgradient well 299-W7-10 and upgradient well 299-W9-1 became dry in 2000 (Section 2.8.2.13 and Table A.16 in PNNL-13404, *Hanford Site Groundwater Monitoring for Fiscal Year 2000*) followed by downgradient wells 299-W7-6, 299-W7-9, and 299-W7-11 in 2001 (Table A.24 in PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*) and downgradient well 299-W7-8 and upgradient well 299-W10-13 in 2002 (Section 2.8.2.13 in PNNL-14187, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*). In 2001, the groundwater flow direction determination was revised to east-northeast

(previous flow direction was toward the north-northeast) (Table A.2 in PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). By 2002, upgradient wells 299-W10-19 and 299-W10-20 remained upgradient of the east portion of LLBG WMA-3, but were downgradient from the southwest part of the WMA (Section 2.8.2.13 in PNNL-14187). In 2004, downgradient wells 299-W7-1 and 299-W7-7 and upgradient well 299-W10-19 became dry (Table B.23 in PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*).

In 2004, dry wells were removed from the network with the issuance of a revised groundwater monitoring plan (PNNL-14859, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington*). Due to the groundwater flow direction change, the designations for wells 299-W10-20 and 299-W10-21 changed from upgradient to downgradient, leaving no upgradient wells monitoring the upper portion of the aquifer. Statistical evaluations for indicator parameters were suspended until new upgradient wells were installed and new background values could be established (Section 5.3 in PNNL-14859). The well network in PNNL-14859 comprised downgradient wells 299-W7-3 (deep well), 299-W7-4, 299-W7-5, 299-W7-12, 299-W8-1, 299-W10-20, and 299-W10-21 and upgradient well 299-W10-14 (deep well) (Table A.9 in PNNL-14859). Thirteen new wells were proposed, of which eight were prioritized for installation in 2005 and 2006 (Section 3.2.2, in PNNL-14859). The sampling constituents for LLBG WMA-3 included the contamination indicator parameters and groundwater quality parameters required by 40 CFR 265.92(b), alkalinity, anions, metals, lead, mercury, and VOCs (Table A.9 in PNNL-14859).

In 2005, wells 299-W7-5 and 299-W10-21 became dry (Table B.24 in PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*). In 2006, PNNL-14859-ICN-1, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington*, Interim Change Notice 1, was issued and removed dry wells 299-W7-5, 299-W7-12, and 299-W10-21 from the network. New downgradient wells 299-W10-29, 299-W10-30, and 299-W10-31 were added to the network.

In 2006, well 299-W10-20 became dry (Table B.24 in PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*). In 2007, PNNL-14859-ICN-2, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington*, Interim Change Notice 2, was issued and removed 299-W10-20 from the network. In 2008, well 299-W7-4 was removed from monitoring due to safety concerns associated with cave-in potential (Section 2.8.3.1 in DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*).

In 2010, a new groundwater monitoring plan was issued (DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*, Rev. 0) to remove deep wells 299-W7-3 and 299-W10-14 and remove 299-W8-1, which became cross-gradient to LLBG WMA-3 due to changes in flow direction. Well 299-W7-4 was included as a downgradient well but was not able to be sampled due to access and safety issues (Table 3-1 in DOE/RL-2009-68, Rev. 0). The network included four downgradient wells (299-W7-4, 299-W10-29, 299-W10-30, and 299-W10-31), but no upgradient wells were available. The analyte list was revised to remove reduction-oxidation potential, mercury, and lead.

In 2011, well 299-W7-4 went dry (Section 3.2.10.3 in DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*). DOE/RL-2009-68, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-3*, Rev. 1, was issued in 2011 and revised the monitoring network by removing dry downgradient well 299-W7-4 and adding a new planned upgradient well 299-W9-2. The downgradient wells included 299-W10-29, 299-W10-30, and 299-W10-31. Upgradient well 299-W9-2 was drilled in 2011 and was scheduled for quarterly sampling to support calculation of critical means for indicator parameters (Section 3.2.10.3 in DOE/RL-2011-118). In 2012, DOE/RL-2009-68, *Interim Status Groundwater*

Monitoring Plan for the LLBG WMA-3, Rev. 2, was issued with updated information on newly drilled well 299-W9-2.

Elevated TOC was measured in new well 299-W9-2 in September 2012 (average 12,000 µg/L) and was attributed to vegetable grease. DOE/RL-2013-22, *Hanford Site Groundwater Monitoring Report for 2012*, p. ZP-33, provided that vegetable grease was used during well construction to lubricate casing connections. TOC sample results subsequently declined to an average 4,390 µg/L in December 2012, which suggested the vegetable grease was the source of the elevated TOC.

Beginning in 2013, critical means were re-established for LLBG WMA-3 and comparisons were again reported (Table B.55 in DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). Due to the elevated TOC values in upgradient well 299-W9-2 measured in 2012, the critical means for the downgradient wells were determined and compared on an intrawell basis for 2013 and 2014 (Table B.56 and p. ZP-35 in DOE/RL-2014-32; Section 12.11.3 and Table B-59 in DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*). The 2015 TOC critical mean was based on 2014 results in which TOC levels had decreased substantially from the 2012 levels. The TOC results in 299-W9-2 had decreased to less than detection in 2015, which supports the explanation that vegetable grease had been the source of elevated TOC (Section 12.11.3 in DOE/RL-2015-07).

Beginning in 2013, specific conductance exceeded the critical mean at one or more downgradient wells (299-W10-30 and 299-W10-31) and was attributed to increasing nitrate concentrations from the regional plume (Table B.55 and p. ZP-35 in DOE/RL-2014-32; Table B-58 in DOE/RL-2015-07). Specific conductance measurements for downgradient wells are also affected by treated groundwater that is injected upgradient of the downgradient wells (Section 12.11.3 in DOE/RL-2016-09, *Hanford Site RCRA Groundwater Monitoring Report for 2015*; Section 2.13 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*).

Beginning in 2014, TOX exceeded the critical mean in one or more downgradient wells (Table B-58 in DOE/RL-2015-07; Table B-52 in DOE/RL-2016-09). However, the elevated TOX concentrations at 299-W10-31 are consistent with observed levels of carbon tetrachloride in the area (Section 12.11.3 in DOE/RL-2016-09).

The influences from the regional nitrate and carbon tetrachloride plumes continued to lead to downgradient well results exceeding the critical means for specific conductance and TOX. Also, treated effluent from the 200 West Area Pump and Treat (P&T) is injected downgradient of the upgradient well that is used to establish LLBG WMA-3 background. The treated effluent has higher specific conductance and TOC than the background data set. The regional carbon tetrachloride and nitrate plumes and influence from nearby 200 West P&T injection wells create spatial variability, potentially leading to false positive exceedances at the LLBG WMA-3 downgradient wells, based on comparisons to upgradient monitoring well concentrations (Section 2.13 in DOE/RL-2016-66).

To account for spatial variability in the specific conductance, TOC, and TOX indicator parameters, statistical comparisons for 2016 were evaluated on an intrawell basis (Section 2.13 in DOE/RL-2016-66). No indicator parameters exceeded critical means that were calculated on an intrawell basis. For 2016, the reported groundwater flow is predominantly to the east but is locally affected by injection wells 299-W10-35 and 299-W10-36 that are within the LLBG WMA-3 boundary.

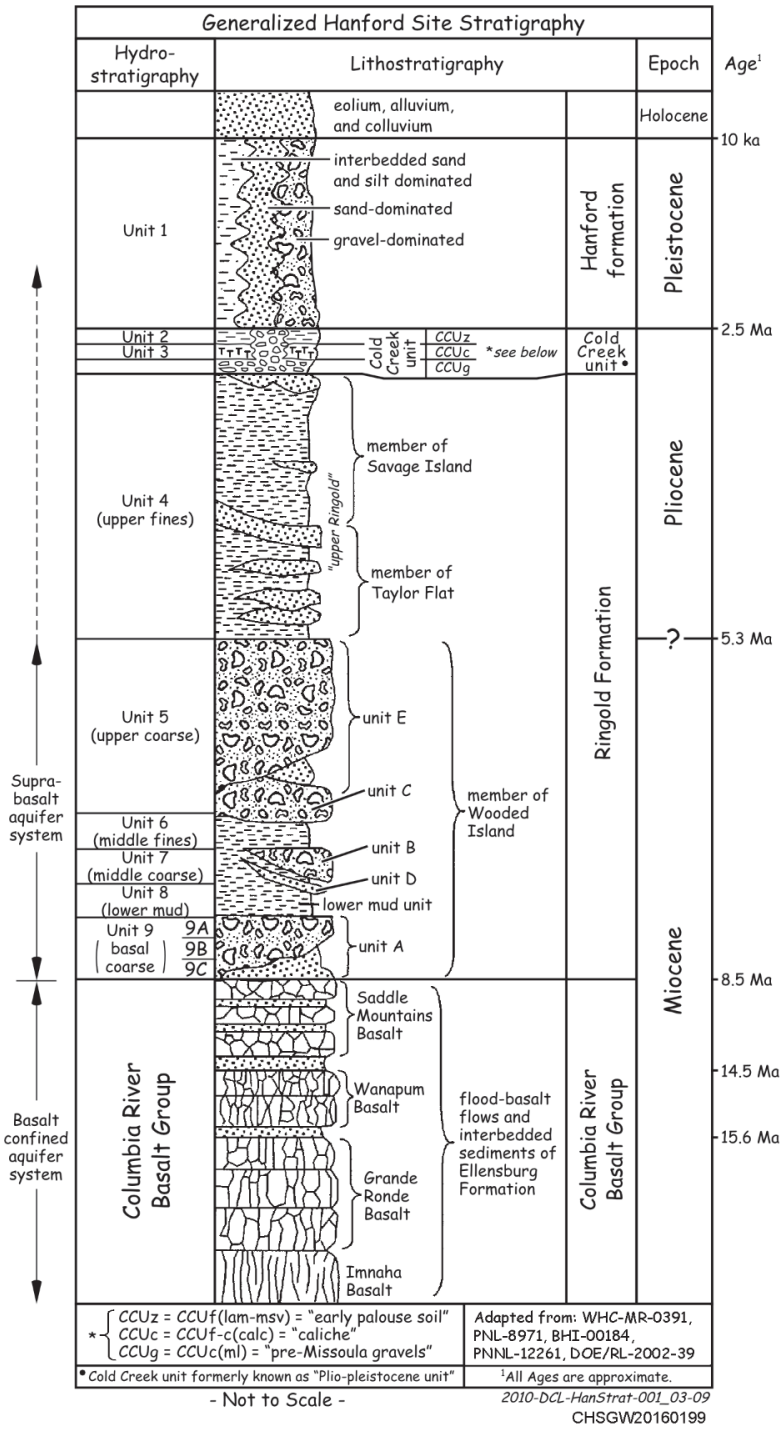
3 Geology and Hydrogeology

This chapter describes the geology and hydrogeology beneath the LLBG WMA-3 area. This information is summarized from PNNL-13858, *Revised Hydrogeology For the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington;* PNL-6820, *Hydrogeology of the 200 Areas Low Level Burial Grounds—An Interim Report: Volume 1: Text*; PNL-7336, *Geohydrology of the 218-W-5 Burial Ground, 200-West Area, Hanford Site;* PNNL-16887, *Geologic Descriptions for the Solid-Waste Low Level Burial Grounds*; WHC-SD-EN-AP-015*;* and WHC-SD-EN-TI-290, *Geologic Setting of the Low-Level Burial Grounds* and is included to provide a brief overview of the current understanding of the site.

3.1 Stratigraphy

The generalized stratigraphic column for the Hanford Site is shown in Figure 3-1. The geology beneath LLBG WMA-3 includes a basalt basement overlain by an approximately 140 to 170 m (460 to 560 ft) thick sedimentary sequence. Geologic cross sections prepared in the vicinity of LLBG WMA-3 are shown in Figures 3-2 and 3-3. The geologic sequence below LLBG WMA-3 from top to bottom includes the following:

- Surficial deposits at LLBG WMA-3 consist of Holocene eolian sand and silt. These windblown soils are not continuous across the site and are up to several feet thick (Section 2.0 in PNNL-16887).
- Basalt-rich glaciofluvial unconsolidated gravel and sand of the Hanford formation are present at the surface where surficial deposits are absent at the site. These sediments were deposited by Pleistocene cataclysmic floodwaters 13,000 years to 1 million years before present (Section 3.1.5 in PNL-7336). The gravel-dominated sequence consists of uncemented, matrix poor, cross-stratified, coarse-grained sands and granule to boulder size gravel. The sand-dominated sequence consists of well-stratified fine to coarse sand with less gravel. Silt in these lithologies is variable. A silt-dominated sequence is also associated with the Hanford formation but does not appear to be present beneath LLBG WMA-3. The Hanford formation is 9 to 32 m (30 to 105 ft) thick, and thins to the north beneath LLBG WMA-3.
- The Cold Creek unit (CCU), formerly known as the Plio-Pleistocene Unit/Early Palouse Soil, underlies the Hanford formation beneath LLBG WMA-3 (Section 3.1.3 in PNL-7336). This unit was deposited 1 to 3.9 million years before present. The CCU consists of two sequences, a carbonate cemented sand and gravel unit that formed during soil development as precipitation evaporated and left behind minerals forming pedogenic $CaCO_3$ (i.e., caliche) (Section 2.2 in PNNL-16887), and an overlying fine-textured unit of unconsolidated muddy fine sand to fine sandy mud. In the 200 West Area, the CCU is 0 to 20 m (0 to 66 ft) thick. Beneath LLBG WMA-3, the CCU is about 9 to 14 m (30 to 45 ft) thick and dips to the southwest (Section 3.1.3 in PNL-7336) and includes both the cemented unit and the overlying fine-textured unconsolidated unit. The contact between the top of the CCU and the overlying Hanford formation is the primary contact of interest with respect to potential for flow direction modification within the vadose zone. The CCU upper surface in the vicinity of LLBG WMA-3 exhibits a generally south-southwest strike direction with a dip angle of about 1.4%. In an unsaturated flow condition, such as may be expected under a hypothetical release scenario from LLBG WMA-3, fluid migration should be primarily vertical, and this condition should not produce substantial lateral movement of migrating water.



Note: Complete reference citations are provided in Chapter 11.

Figure 3-1. General Stratigraphy at the Hanford Site

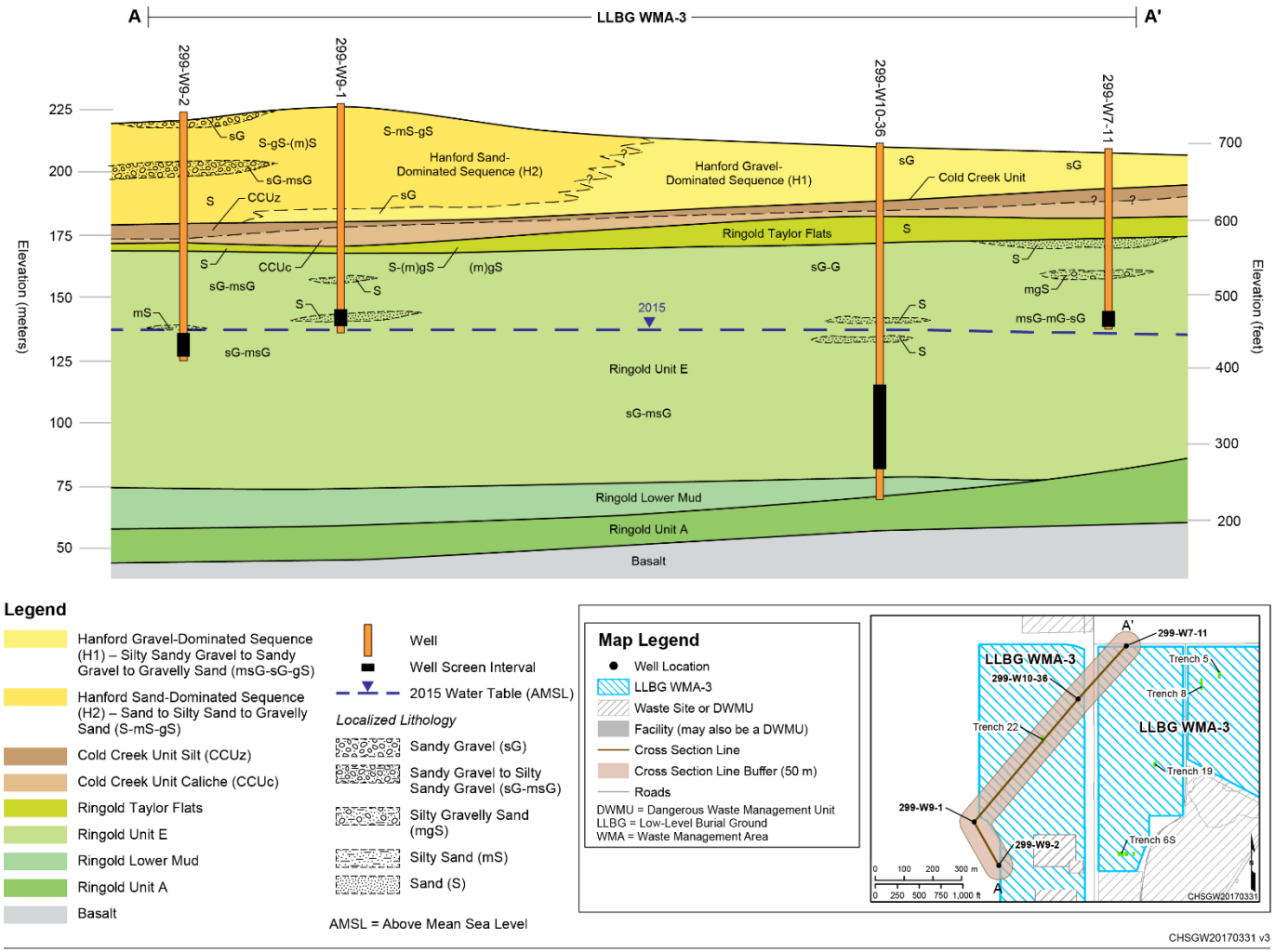


Figure 3-2. Geologic Cross Section through Western Portion of LLBG WMA-3

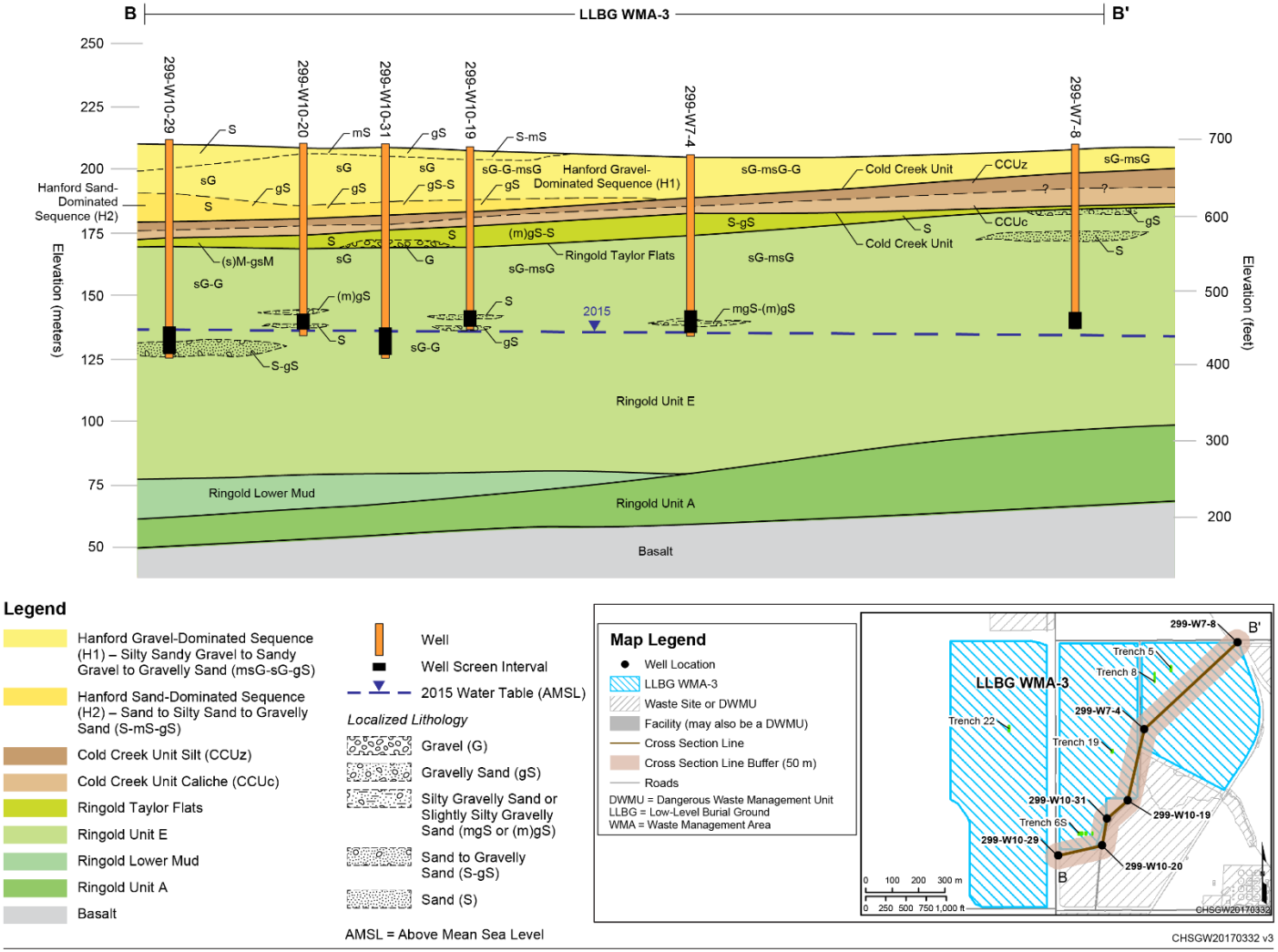
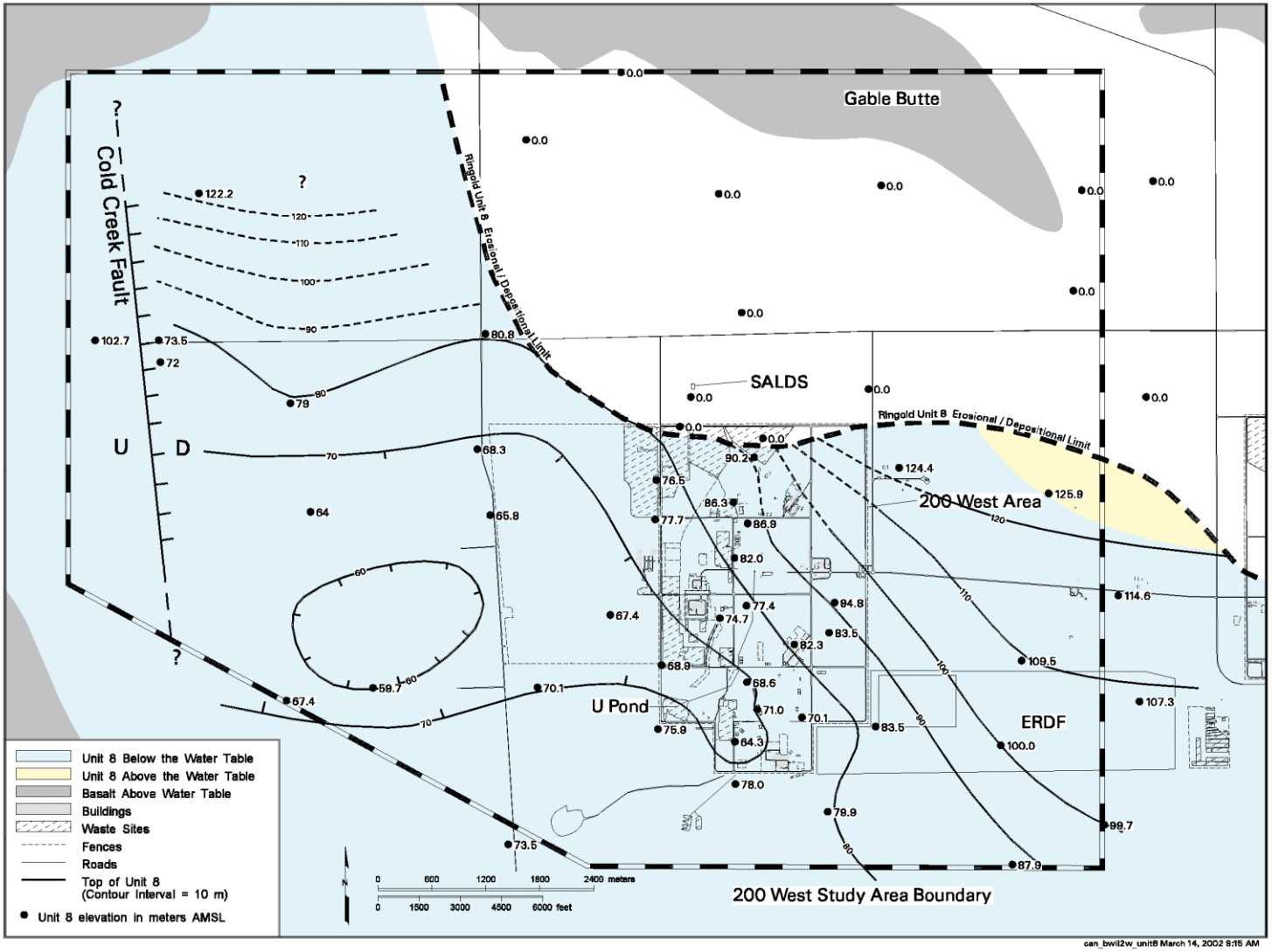


Figure 3-3. Geologic Cross Section through Mid and Eastern Portions of LLBG WMA-3

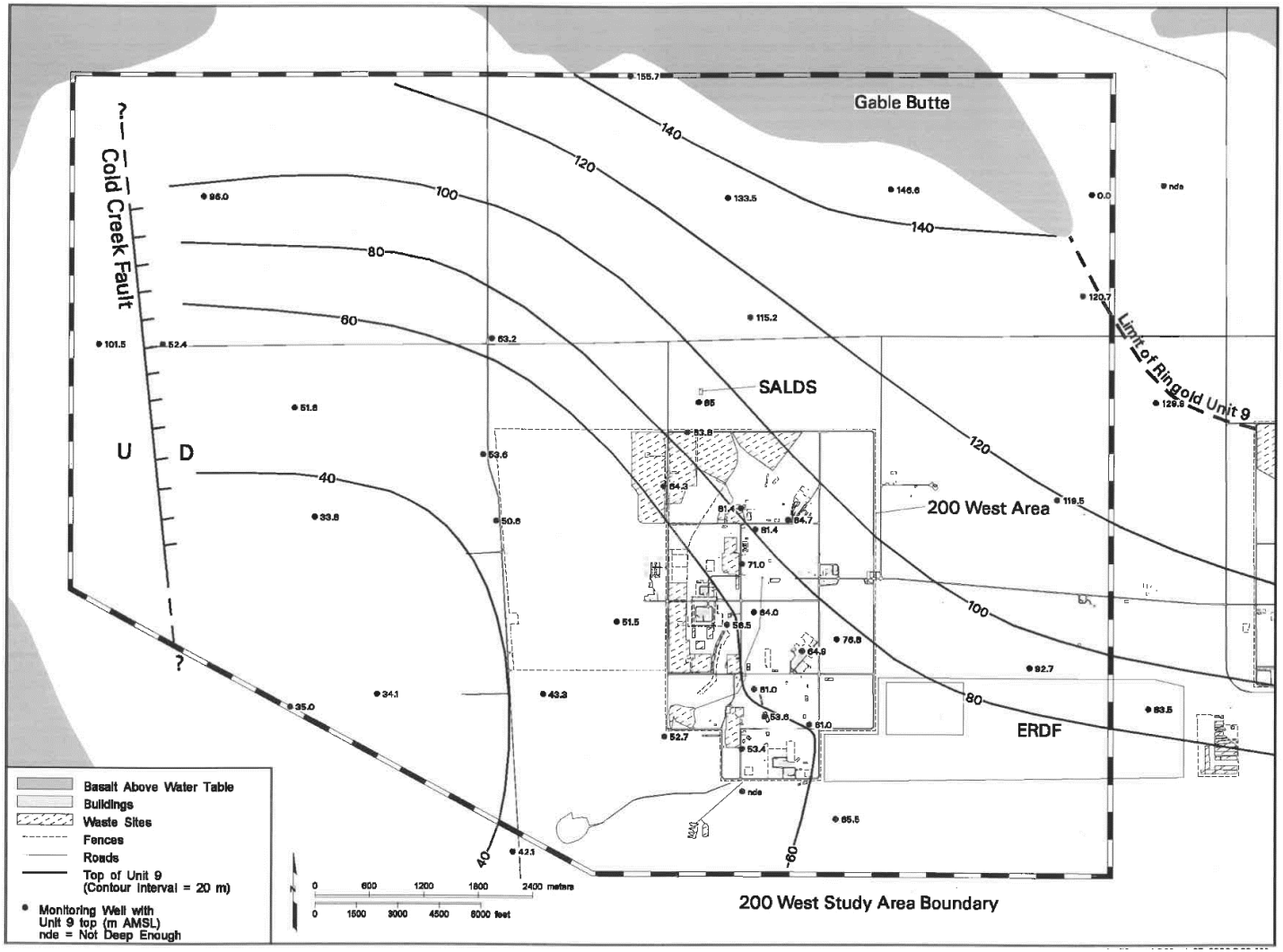
The Ringold Formation underlies the CCU and overlies basalt beneath LLBG WMA-3. This formation consists of fluvial lacustrine sediments deposited by the ancestral Columbia River about 3.9 to 10.5 million years before present (Section 2.1 in PNNL-16887). These semi-consolidated sediments consist of an intercalated mix of gravel, sand, and silts to silt-rich paleosols and lake deposits. Beneath LLBG WMA-3, the Ringold Formation is subdivided into the four units in descending order: Member of Taylor Flat (upper Ringold), Unit E, the Ringold lower mud (RLM), and Unit A. The Ringold Formation is up to 122 m (400 ft) thick beneath LLBG WMA-3 and dips to the south. A brief description of each unit is provided below.

- The Ringold Formation member of Taylor Flat consists of an abundance of well sorted sand to muddy sand and gravelly sand. Deposition of this unit represents transition to a lower energy fluvial environment compared to Unit E. Beneath LLBG WMA-3, this unit is about 0 to 9 m (0 to 30 ft) and thins to the south.
- Ringold Formation Unit E makes up over 75% of the Ringold Formation and intersects the water table surface at an elevation of about 136 m (446 ft). Unit E consists mostly of coarse-grained gravel and sand deposited in a high-energy fluvial environment and it is general more consolidated than Hanford formation sands and gravels (Section 3.1.2 in PNL-7336). This unit is about 83 to 94 m (272 to 308 ft) thick near LLBG WMA-3.
- The Ringold Formation lower mud unit represents the base of the unconfined aquifer within the southern portions of LLBG WMA-3. This unit consists predominantly of silt with approximately equal amounts of sand and clay. Beneath LLBG WMA-3 this unit is about 0 to 16 m (0 to 52 ft) thick and thins to north where it pinches out within the northern portion of LLBG WMA-3 (Plate 5 in PNNL-13858) (Figure 3-4).
- Ringold Formation Unit A is similar in texture to Ringold Formation Unit E. Where the Ringold formation lower mud is not present, it is difficult to differentiate between Unit E. Beneath LLBG WMA-3 this unit is about 10 to 30 m (33 to 98 ft) thick and directly overlies basalt of the Elephant Mountain Member. Regional mapping of the top of Unit A shows a dip to the southwest (Figure 3-5).
- The Saddle Mountain Basalt is the uppermost formation of the Columbia River Basalt Group beneath LLBG WMA-3. The uppermost basalt unit is Elephant Mountain Member dated about 10.5 million years before present (Section 3.1.1 in PNL-7336). The surface of the basalt slopes gently to the south at an elevation of 44 to 67 m (144 to 220 ft). Where the RLM unit is not present beneath LLBG WMA-3, the unconfined aquifer extends to the basalt unit. Regional mapping of the Saddle Mountain Basalt surface indicates a dip to the southwest into the Cold Creek syncline (Figure 3-6).



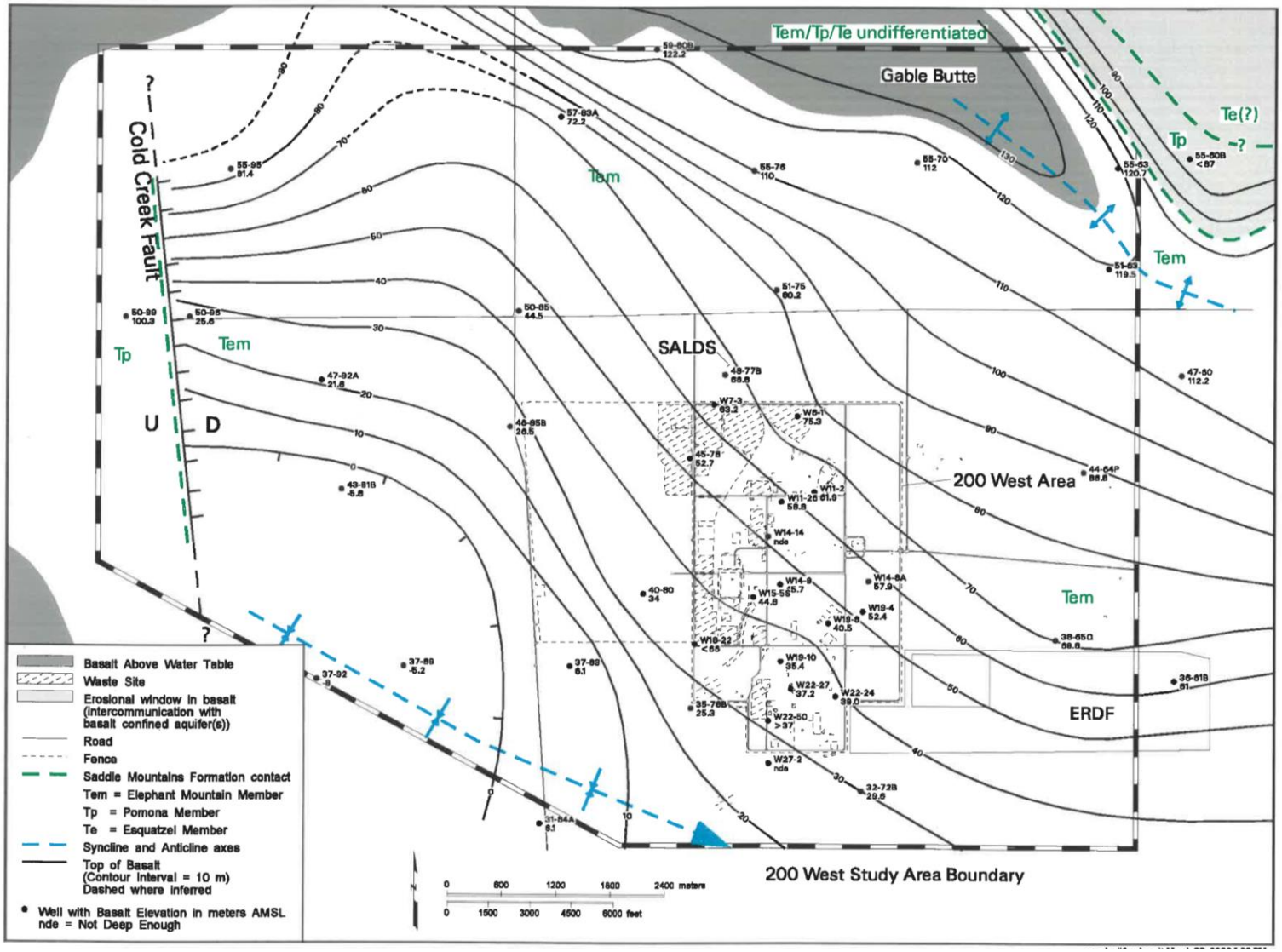
Source: PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*.

Figure 3-4. Isopach Map Showing Extent of the Ringold Lower Mud (Unit 8) in the Vicinity of the 200 West Area and Underlying LLBG WMA-3



Source: PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington.*

Figure 3-5. Structure Contour Map Showing Dip Direction for the Top of the Ringold Unit A in the Vicinity of 200 West Area and Underlying LLBG WMA-3



Source: PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington.*

Figure 3-6. Structure Contour Map Showing Dip Direction of the Saddle Mountain Basalt Surface in the Vicinity 200 West Area and Underlying LLBG WMA-3

3.2 Hydrogeology

This section describes the local geology and hydrology beneath LLBG WMA-3. The geology of the 200 West Area is discussed in PNNL-13858. The geology specific to LLBG WMA-3 also described in PNL-6820, PNL-7336, PNNL-16887, WHC-SD-EN-AP-015, and WHC-SD-EN-TI-290.

Groundwater beneath LLBG WMA-3 occurs as an unconfined aquifer and deeper confined aquifers. The water table occurs entirely in the Ringold Formation Unit E. Depth to water ranges from 71.8 m (235.6 ft) to 86.5 m (283.8 ft). The RLM serves as a confining or semiconfining layer separating the unconfined aquifer from a confined, or partly confined, aquifer in the underlying Ringold Formation Unit A (Figures 3-2, 3-3, and 3-4), where RLM is present beneath LLBG WMA-3. Within the northern portions of LLBG WMA-3, RLM is absent and the unconfined aquifer extends to the underlying basalt. The unconfined aquifer increases in thickness towards the southwest and is estimated to range in thickness from approximately 59 to 63 m (194 to 207 ft) based on water levels and the depth of the RLM unit. Where the RLM is not present in the northern portion of LLBG WMA-3, the aquifer thickness ranges from approximately 65 to 75 m (213 to 246 ft) based on the depth of basalt (Figure 3-6). The uppermost confined aquifer beneath the RLM occurs in Ringold Unit A and is confined above by the lower mud unit and below by basalt (Figures 3-2, 3-3, 3-4, and 3-6). Deeper confined aquifers occur between the basalt flows.

Additional descriptions of the hydrogeology of LLBG WMA-3 are provided in Section 4.0 in PNL-6820 and Section 4.0 in PNL-7336. Section 3.1 in PNNL-13858 describes the hydrogeology of the entire 200 West Area and vicinity.

The saturated hydraulic conductivity of the Ringold E unit underlying LLBG WMA-3 is 5 m/d (16.4 ft/d) (Table 4-9 in CP-47631). Table 1 in PNL-8337, *Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System*, gives a range of saturated hydraulic conductivities ranging from 0.05 to 4.9 m/d (0.16 to 16 ft/d) based on field measurements. Soil properties of the CCU indicate that this horizon will likely slow the rate of downward movement and promote lateral spreading in the vadose zone; however, under a hypothetical release scenario, fluid migration should be primarily vertical and this condition should not produce substantial lateral movement of migrating water.

Most recently, hydraulic property values for the 200 West Area have been evaluated and incorporated into the CPGWM, documented in CP-47631. A hydraulic conductivity value of 5 m/d (16.4 ft/d) was calibrated for the unconfined aquifer in the Ringold E unit (Table 4-7 in CP-74631). A current groundwater elevation map for LLBG WMA-3 is presented in Section 3.3.2.

A major stratigraphic change is the top of the CCU. This unit, located between 8 and 53 m (26 and 174 ft) below ground surface, would slow the downward movement of water and divert it to the southwest, the direction that the top of the unit is dipping beneath the WMA. Water from a waste release may reach the water table at a time, location, and concentration depending on its volume, depth of release, and diversion from downward movement at a stratigraphic change. Over time, waste water released to the sediment column near ground surface will evaporate or be driven downward to the water table by new inputs of water to the sediment column from above. It is this downward movement of water in the vadose zone that carries waste contaminants to the water table. Water movement in the unsaturated zone is relatively slow compared to groundwater flow below the water table, delaying the observed impact of a near-surface waste release on groundwater quality.

Possible interconnection between the unconfined and confined aquifers beneath the site does exist. A large erosional window in the RLM located to the east of the site, within the northeast portion of the 200 West Area, and provides a pathway for groundwater movement between the two aquifers

(Section 4.2.4 in PNNL-13858). This interconnection is further exemplified by the presence of an extensive carbon tetrachloride plume in both the unconfined and confined aquifers within the 200 West Area (Figure 3-37 in DOE/RL-2015-06).

3.3 Groundwater Flow

The hydrologic conditions at LLBG WMA-3 have changed over time. This section describes the groundwater flow system of the region before and during Hanford Site operations and current conditions resulting from the operation of the 200 West P&T system.

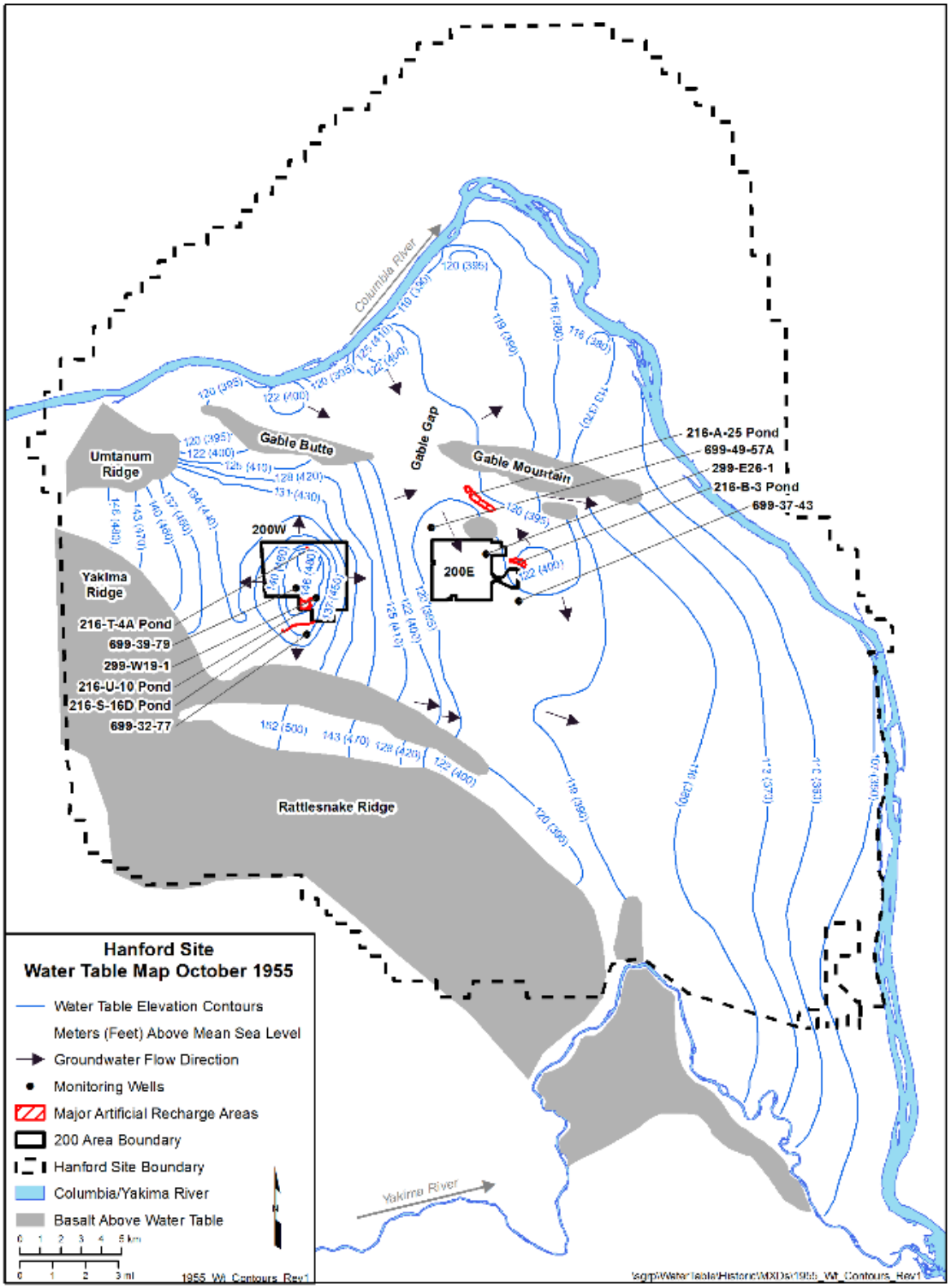
3.3.1 Groundwater Flow Prior to 200 West P&T Operations

The groundwater flow direction prior to Hanford Site operations was toward the east in the 200 West Area (Figure 4 in BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973*). After Hanford Site operations began in 1944, the water table beneath the 200 West Area and LLBG WMA-3 was affected by disposal of large volumes of liquid effluent to various facilities. Discharges to liquid waste receiving sites that reached groundwater caused increases in the elevation of the water table and changes in groundwater flow direction. Radial groundwater flow away from groundwater recharge mounds was documented in the 200 West Area from 1948 to 1955. In 1955, groundwater flow in the area of LLBG WMA-3 was to the west and south away from a groundwater mound located beneath the 216-T-4 Pond (Figure 3-7). The 216-T-4 Pond was located immediately south and extended into the southern portion of the 218-W-3AE boundary of LLBG WMA-3.

By 2000, most discharges of effluent to the ground in the 200 Areas had ceased. After year 2000 and prior to the startup of 200 West Area P&T operations the groundwater flow direction was predominantly eastward; however, the elevation of the water table declined, but remained elevated beneath the 200 West Area (Section 2.1.1.2 in PNNL-13404 and Section 2.1.1.2 in PNNL-15670).

Phase I of the 200-ZP-1 OU interim P&T system was installed in 1994 and was expanded with Phases II and III in 1996 and 1997, respectively. The three phases included a total of six extraction wells. In 2005, Phase IV of the 200-ZP-1 OU interim P&T system was installed and included converting wells located upgradient of WMA TX-TY, located southeast of LLBG WMA-3 to extraction wells (299-W15-40, 299-W15-42, 299-W15-43, and 299-W15-765) (Section 2.8.1.1 in PNNL-15670). Conversion of monitoring wells to extraction wells included installation of high capacity pumps and plumbing of extraction water from the well head to the treatment system. The water table map prior to the start of the full-scale 200 West P&T remedy in 2012 is presented in Figure 3-8. Groundwater flow at 200-ZP-1 OU interim P&T does not indicate significant impact to groundwater flow at LLBG WMA-3.

Figure 3-9 depicts available groundwater elevation data for wells 299-W9-1, 299-W10-13, and 299-W10-20 within the vicinity of LLBG WMA-3 collected from 1985 until dry in 2010, and through the implementation of the 200-ZP-1 OU interim P&T system. Figure 3-8 indicates continued decreasing elevation trends at LLBG WMA-3. Additionally, Figure 3-9 depicts available groundwater elevation data for wells 299-W9-2, 299-W10-31, and 299-W6-12 between 2005 and 2017. Figure 3-9 depicts a continued declining water table elevation until implementation of the 200 West P&T system in 2012 as discussed in Section 3.3.2.



Modified from BNWL-B-360, *Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973.*

Figure 3-7. 1955 Hanford Site Water Table Map

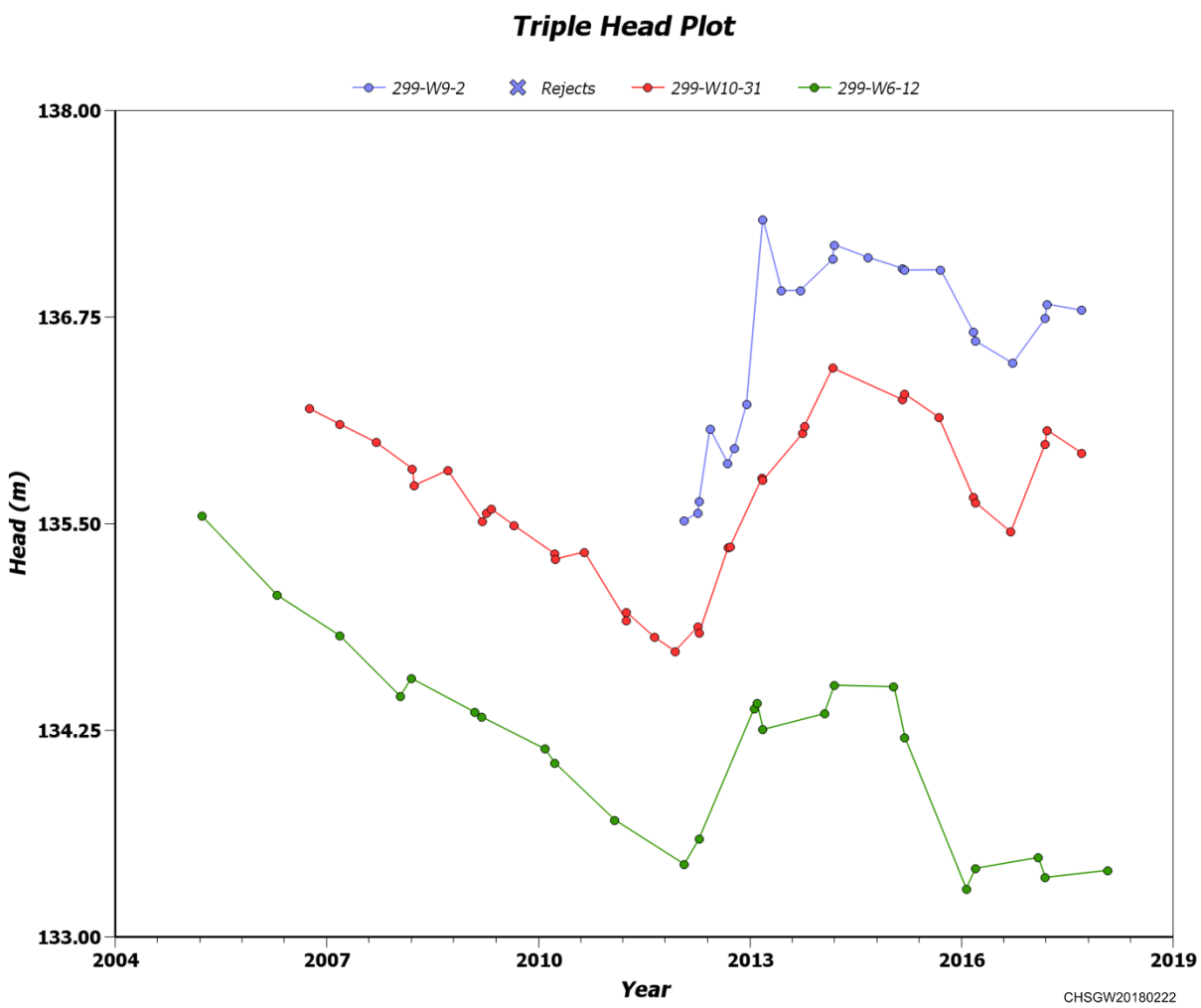


Figure 3-8. Groundwater Elevation Trends for Wells 299-W9-2, 299-W10-31, and 299-W6-12 Between 2005 and 2017

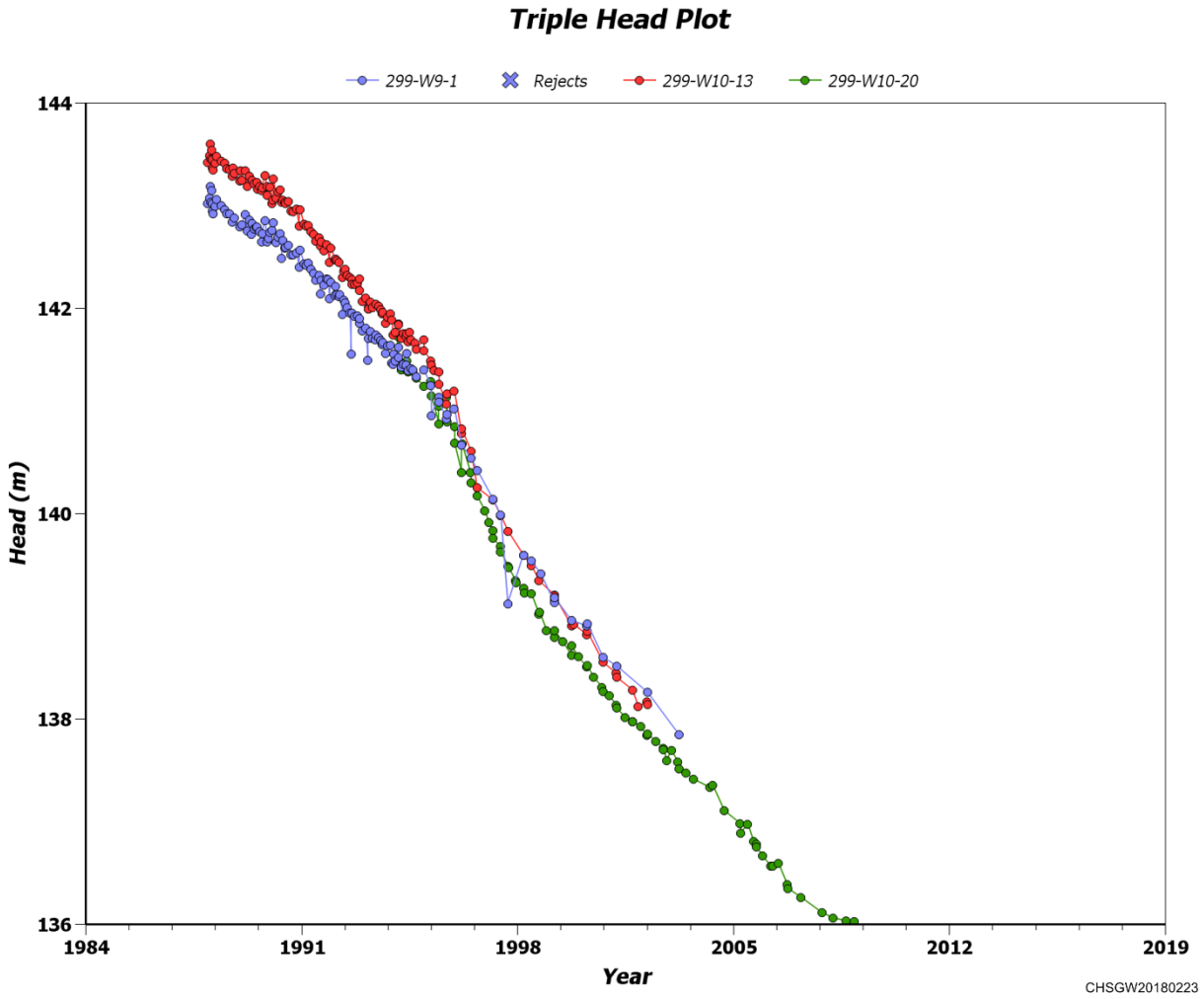


Figure 3-9. Groundwater Elevation Trends for Wells 299-W9-1, 299-W10-13, and 299-W10-20 Between 1985 and 2010

3.3.2 Groundwater Flow Due to Operations of the P&T Remedy

The 200 West P&T system came online in 2012 and is designed to capture and treat contaminated groundwater. The groundwater P&T technology is an element of the selected final remedy for the 200-ZP-1 Groundwater OU (EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*) and the interim remedy for the 200-UP-1 OU (EPA et al., 2012, *Record of Decision for Interim Remedial Action Hanford 200 Area Superfund Site 200-UP-1 Operable Unit*). At the 200 West P&T facility, the groundwater extracted from the 200-ZP-1 and 200-UP-1 OUs is combined and treated. Following treatment, water is reinjected into the aquifer to serve as a recharge source and as the flow-path control component of the remedy. According to DOE/RL-2009-124, *200 West Pump and Treat Operations and Maintenance Plan*, the facility can treat up to 9,464 L/min (2,500 gal/min). The 200 West P&T system currently operates at 8,725 L/min (2,305 gal/min). With modifications to the system, the treatment capacity can be increased to 14,194 L/min (3,750 gal/min) if required; however, there are currently no plans for operating at this capacity. Figure 3-10 shows the locations of 200 West P&T system extraction and injection wells.

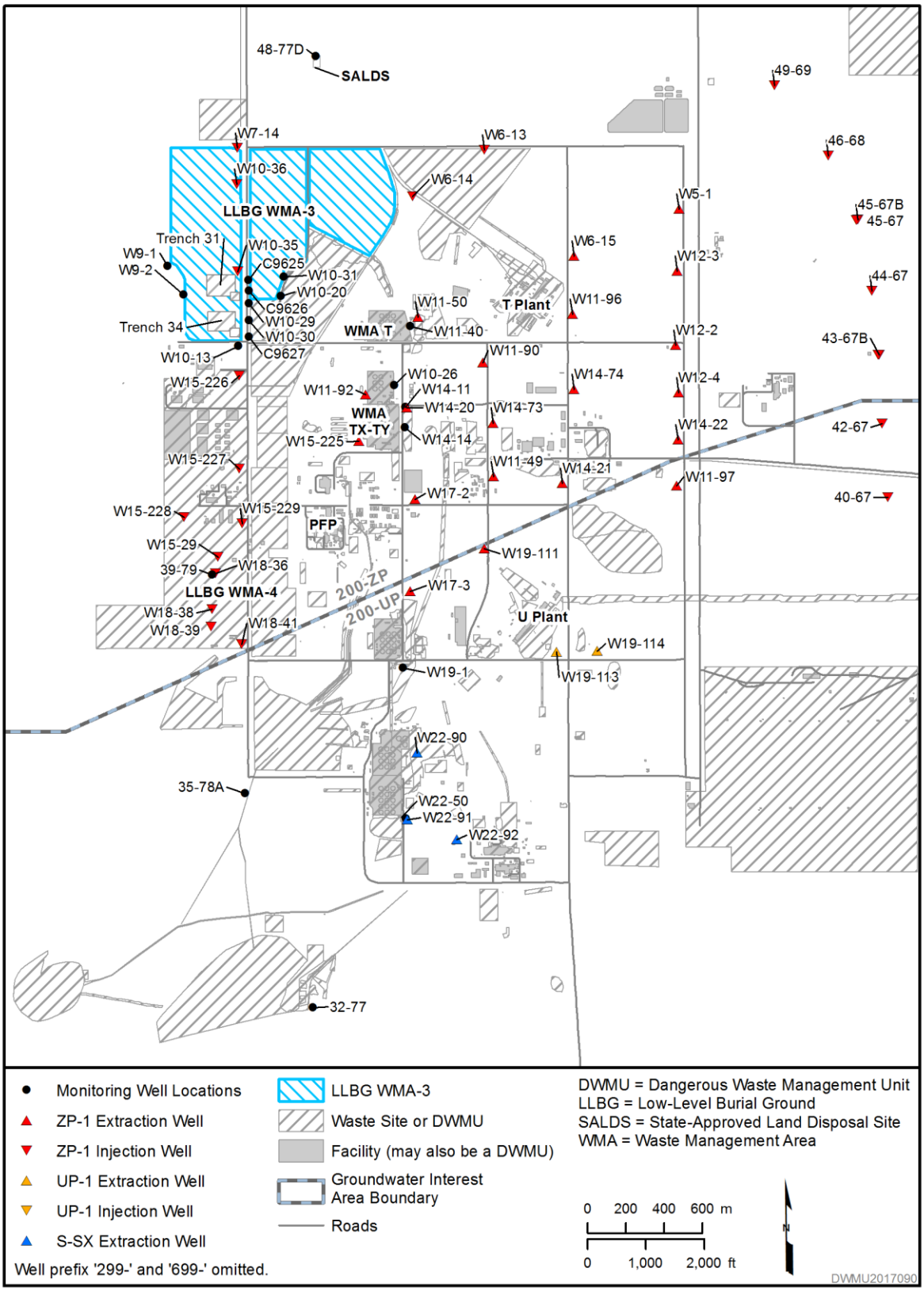


Figure 3-10. 200 West P&T System Well Location Map (as of June 2016)

The impacts to site groundwater flow from the operations of the 200 West P&T system can be illustrated by comparing water table maps from prior to the start of operations to current conditions (Figures 3-11 and 3-12). Figure 3-11, a 2012 water table map, represents groundwater elevations prior to 200 West P&T operations. Water-level data obtained during June 2012 were evaluated by interpolation. During this time, groundwater flow direction was to the east-northeast near WMA-3. The hydraulic gradient is estimated to be 1.5×10^{-3} m/m in 2012 with an average linear velocity of 0.04 to 0.15 m/d (0.13 to 0.49 ft/d) (Table 3-1 in SGW-55438, *Hanford Site Groundwater Monitoring for 2012: Supporting Information*).

Water levels at LLBG WMA-3 increased beginning in 2012 due injection of treated water at LLBG WMA-3 and as depicted in Figure 3-9. Water levels declined about 0.6 m to 0.8 m (2 to 2.6 ft) between 2015 and 2016 (Section 12.10.3 in DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*). The decline is primarily due to two factors simulated within the CPGWM:

1. The substantial reduction of waste water discharges to the soil column associated with the cessation of discharges in the mid-1990s.

2. Commencement of operation of the 200 West P&T system in 2012. Water level changes associated with the start-up (SGW-50907, *Predicted Impact of Future Water-Level Declines on Groundwater Well Longevity within the 200 West Area, Hanford Site*, and ECF-200ZP1-12-0074, *Presentation & Initial Evaluation of Water-Level & Pumping Data for the Hanford 200-ZP-1 Groundwater Pump-and-Treat Remedy*).

The March 2016 Hanford Site water table map (Figure 3-12) shows groundwater flow direction generally to the east beneath LLBG WMA-3, with flow predominantly to the north-northeast within the western portions affected by injection wells under current operating conditions of the 200 West P&T system. Several injection wells (299-W6-14, 299-W6-16, 299-W7-14, 299-W10-35, 299-W10-36, and 299-W15-226) are located near LLBG WMA-3, which inject treated water into the aquifer below the water table. Injection and extraction wells are shown on the 2016 water table map (Figure 3-10). The hydraulic gradient beneath LLBG WMA-3 is estimated to be 7.0×10^{-3} m/m based on the 2016 water table map, with an average linear velocity of 0.18 to 0.70 m/d (0.59 to 2.3 ft/d) (Table 2-47 in DOE/RL-2016-66). The groundwater flow rate and direction are further described in Section 4.3.

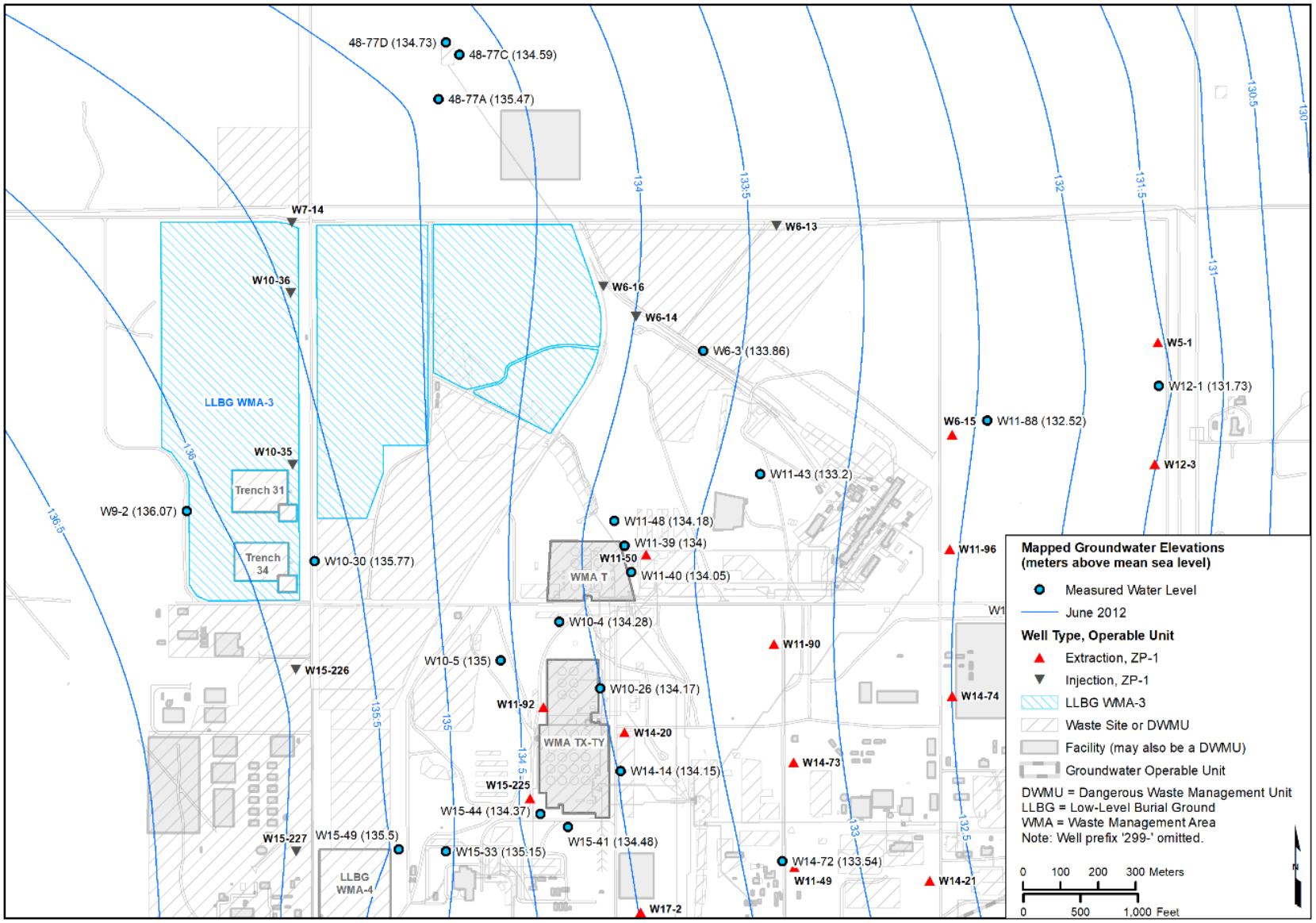


Figure 3-11. Groundwater Elevation Contours Computed Using Water-Level Mapping, June 2012

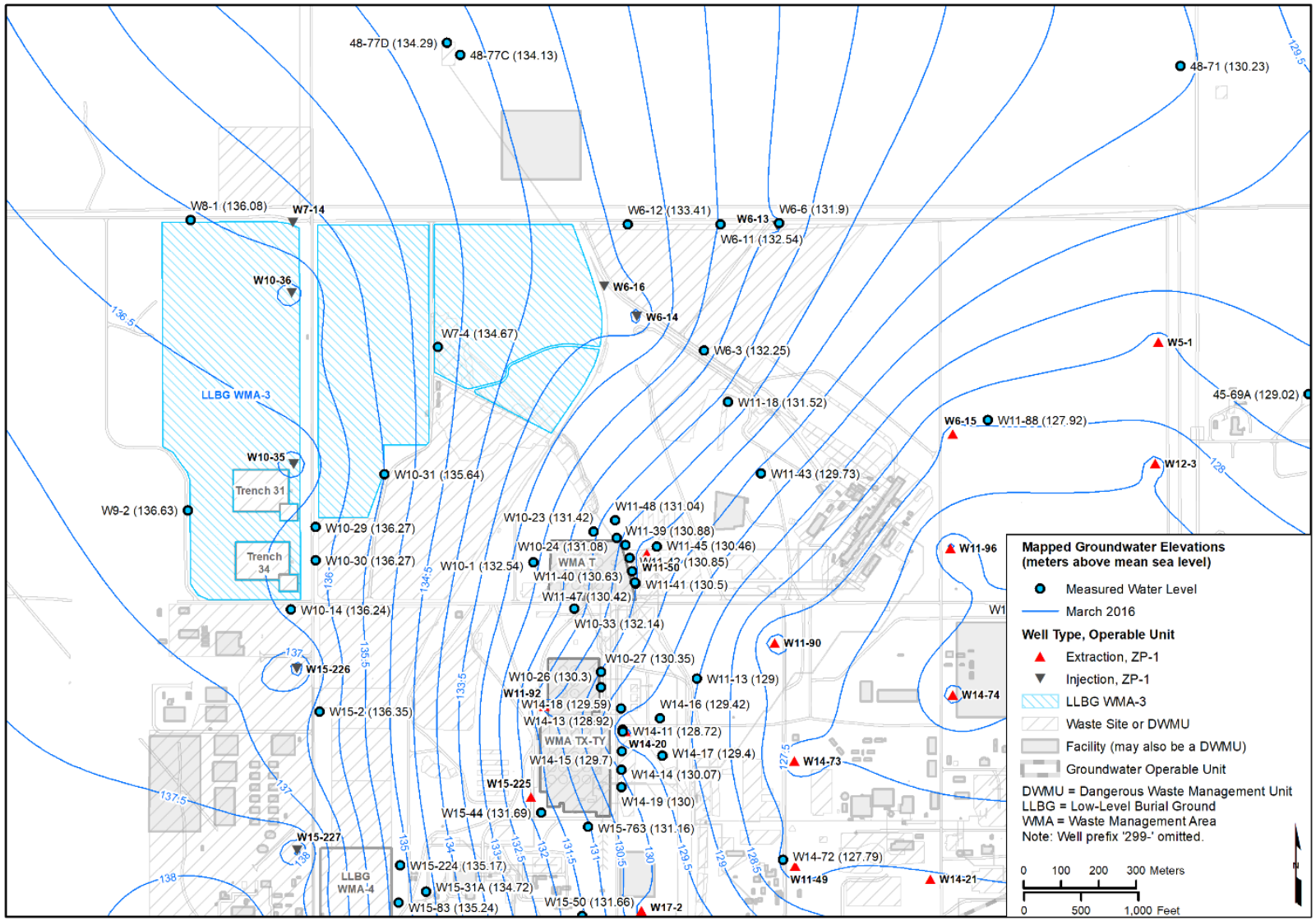


Figure 3-12. Groundwater Elevation Contours Computed Using Water-Level Mapping, March 2016

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4 Contaminant Migration Conceptual Model

The conceptual model for contaminant release and transport through the vadose zone to groundwater is based on the following assumptions:

- Average precipitation of about 17 cm/yr (~7 in./yr) has prevailed over the timeframe of interest (operational lifespan and post-closure monitoring period) (PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*, Section 4.5.2.2).
- Net infiltration is assumed to occur directly to the vadose zone from the unlined trenches.
- Leaching of mobile contaminants from buried waste in damaged/degraded sealed containers or contaminated soils in direct contact with the trenches is assumed to be the major potential source for contamination to soils underlying the unlined trenches.
- Artificial sources of water (e.g., leaking potable or raw water lines) are not present based on Hanford Site drawings.
- Extreme conditions or accidental releases are recognized as possibilities but would be addressed under emergency response/corrective actions.

4.1 Vadose Zone

The vadose zone at LLBG WMA-3 ranges from approximately 71.8 to 86.5 m (235.6 to 283.8 ft) thick and consists of (from top to bottom) the Hanford formation, the CCU, and the Ringold Formation. The finer textured sediment and caliche cementing that characterize the CCU in the vadose zone account for its relatively low hydraulic conductivity, which is likely to slow downward movement of moisture and contaminants

A finer grained lithologic unit lies below the CCU within the stratigraphic framework under LLBG WMA-3. The Taylor Flat member of the Ringold Formation (shown in Figures 3-1 through 3-3) is interpreted from geologic logs for wells constructed in LLBG WMA-3. It is a fine-grained sequence consisting of interstratified, well-bedded, fine to coarse sand to silt and is equivalent to the upper Ringold Formation unit mentioned in previous documents (e.g., PNNL-16887). The combined moisture retention properties for the CCU and Taylor Flat member of the Ringold Formation within the vadose zone have high capacity to absorb and retain moisture.

4.2 Soil Moisture Factors

Direct precipitation contacting waste materials in the trenches is the primary driver for hypothetical leaching of waste constituents from the burial trenches to the vadose zone.

Stratigraphic features in the soil column beneath LLBG WMA-3 can also influence or slow the downward migration by spreading soil moisture laterally. Direct observational evidence to assess this effect at LLBG WMA-3 is lacking, with no perched water zones in the vicinity. Under the gravity drainage assumption, only a small to moderate component of horizontal gradient is likely to be available to produce lateral spreading of infiltrating water.

It is estimated that recharge rates in the northern portion of the 200 West Area in the vicinity of LLBG WMA-3 range from 4 mm/yr (0.2 in./yr) in a shrub-steppe vegetated area to 44 mm/yr (1.7 in./yr) at a gravel-covered, nonvegetated site (Table 4.15 in PNNL-14702).

No perched water has been observed during drilling of recent wells that intersected the CCU in the vicinity of LLBG WMA-3, although the CCU has historically supported perched water units under conditions of long-term, high-volume surface discharges. Present conditions beneath LLBG WMA-3 reflect unsaturated flow conditions in the vadose driven primarily by natural infiltration of meteoric water. There is no current injection of water into the vadose zone in the vicinity of LLBG WMA-3, and none is anticipated. A hypothetical release from the trenches would result in unsaturated flow through the vadose; unsaturated flow is not expected to produce substantial lateral migration along the contact between the CCU and the overlying Hanford formation.

4.3 Hydrogeologic Considerations

Prior to startup of the 200 West P&T system in 2012, the groundwater flow direction under LLBG WMA-3 was east-northeast at a calculated rate (using the Darcy relationship) of 0.04 to 0.15 m/day (0.13 to 0.49 ft/d). The water table elevation in the vicinity of LLBG WMA-3 has increased in response to local groundwater injection (200 West P&T injection wells) (Figure 3-8), and the groundwater flow direction beneath the area of the burial ground is now generally east as a result of groundwater extraction and injection for the 200 West P&T with a calculated groundwater velocity of 0.18 to 0.70 m/d (0.59 to 2.3 ft/d) (Table 2-47 in DOE/RL-2016-66).

P&T operations are expected to continue in this region until 2037. After active groundwater remediation is completed and the 200 West P&T system is shut down, groundwater flow is anticipated to return to pre-200 West P&T startup conditions. The changing groundwater flow directions and gradients will be considered when evaluating the groundwater monitoring network. These factors are assessed in evaluating impacts to groundwater beneath LLBG WMA-3 in the simulations described in Chapters 5 through 7 of this report.

4.4 Groundwater Chemistry

The solubility and subsequent mobility of waste constituents in pore fluid depend on the chemical nature of the waste constituents, the volume of water and water contact time with the waste, and natural subsurface geochemical conditions.

Pore fluid and groundwater in the unsaturated and saturated zones beneath LLBG WMA-3 is slightly alkaline ($7<pH<9$), with appreciable amounts of bicarbonate and very little natural organic material. Vadose soil and groundwater are generally well aerated. The dissolved oxygen concentrations fall into the higher range for groundwater (7 to 10 mg/L). These general conditions favor sorption or retardation of many heavy metals (e.g., lead) and also favor stability of oxy anionic species, which enhance mobility for other metals (e.g., hexavalent chromium). Laboratory sorption studies have documented these effects and related mobility issues in Hanford Site media. These conditions tend to allow chlorinated solvents (e.g., carbon tetrachloride) to remain persistent, as these compounds normally degrade more rapidly in reduced groundwater environments.

Regional groundwater contaminant sources are identified through *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation activities at the 200-ZP-1 OU. The 200-ZP-1 OU includes the groundwater beneath an area in the northern portion of the 200 West Area. Monitoring results for the 200-ZP-1 OU have shown that historically groundwater beneath much of the 200 West Area, including beneath LLBG WMA-3, has been contaminated from other sources including the Plutonium Finishing Plant, 216-Z Trenches and Cribs, WMA T, and WMA TX-TY (Sections 12.1, 12.4, and 12.5 in DOE/RL-2016-09).

The principal contaminant plume from the 200 West Area that is present in the saturated zone under LLBG WMA-3 is carbon tetrachloride. The footprint of LLBG WMA-3 is located immediately adjacent to or within the northwestern edges of this large regional plume of carbon tetrachloride. In this area of the plume, the carbon tetrachloride concentrations exceed the drinking water standard (5 μg/L).

Nitrate is another contaminant from the 200 West Area that is found at elevated concentrations beneath LLBG WMA-3. The footprint of LLBG WMA-3 is located immediately adjacent to, or within the edges of, this large regional nitrate plume. In this area of the plume, the concentrations range from 5.75 to 44.3 mg/L in groundwater samples collected in 2016, and close to the drinking water standard for nitrate (45 mg/L).

Additional regional plumes include nonregulated radionuclides that are monitored under AEA.

4.5 Summary of Vertical Contaminant Distribution

Dangerous waste constituents specific to release from LLBG WMA-3 are not present in groundwater. Evaluation of available vertically distributed groundwater data is limited to the location of LLBG WMA-3 within the context of regional plumes present in 200-ZP-1 OU. Available vertical distribution data is limited to nine completed wells in the vicinity of LLBG-3 collected during drilling and special studies. The identified wells (299-W10-31, 299-W10-35, 299-W10-36, 299-W15-226, 299-W6-13, 299-W6-14, 299-W6-16, and 299-W7-13) are located near the perimeter of LLBG-3; and 299-W11-43, located distally from LLBG WMA-3. See Figure 4-1 for general well locations in relation to LLBG WMA-3. These wells were installed between 2005 and 2017 and have varying quantities of measurements, collected samples, and depths of characterization. The temporal separation in observations and measurements introduces substantial uncertainty in interpreting correlation between individual well data and the LLBG WMA-3 operation. In addition, a CERCLA P&T remedial action is currently in operation in the vicinity of these wells.

Evaluated constituents were limited to available nonradiological vertical data associated with the surrounding wells and limited to the following: carbon tetrachloride, nitrate, and hexavalent chromium, representing wide spread contaminants in 200-ZP-1 OU and present near LLBG-3. During drilling of the wells, groundwater samples were collected from the boreholes at selected depths and analyzed by field and/or laboratory methods. Laboratory data were selected where both field and laboratory data were available for each of the vertical contaminant distribution plots.

Limited vertical characterization data are available for well 299-W10-31, were collected during special study and included: carbon tetrachloride, chloroform, tetrachloroethene, and trichloroethene. Additionally, limited vertical characterization data is available for 299-W7-13 collected during drilling and included volatile organic compounds collected at three recorded elevations. Carbon tetrachloride results for well 299-W7-13 ranged from 3.7 to 17 ug/L. Due to the limited available data, wells 299-W10-31 and 299-W7-13 are not further evaluated.

Where duplicate samples were collected at a given interval, resulting values were averaged.
See Figures 4-2 through 4-8 for observed vertical distribution of identified contaminants. Vertical zones of increased contaminant concentrations are provided within the figures and are based on visual observation of the vertical trends and are for visual reference only.

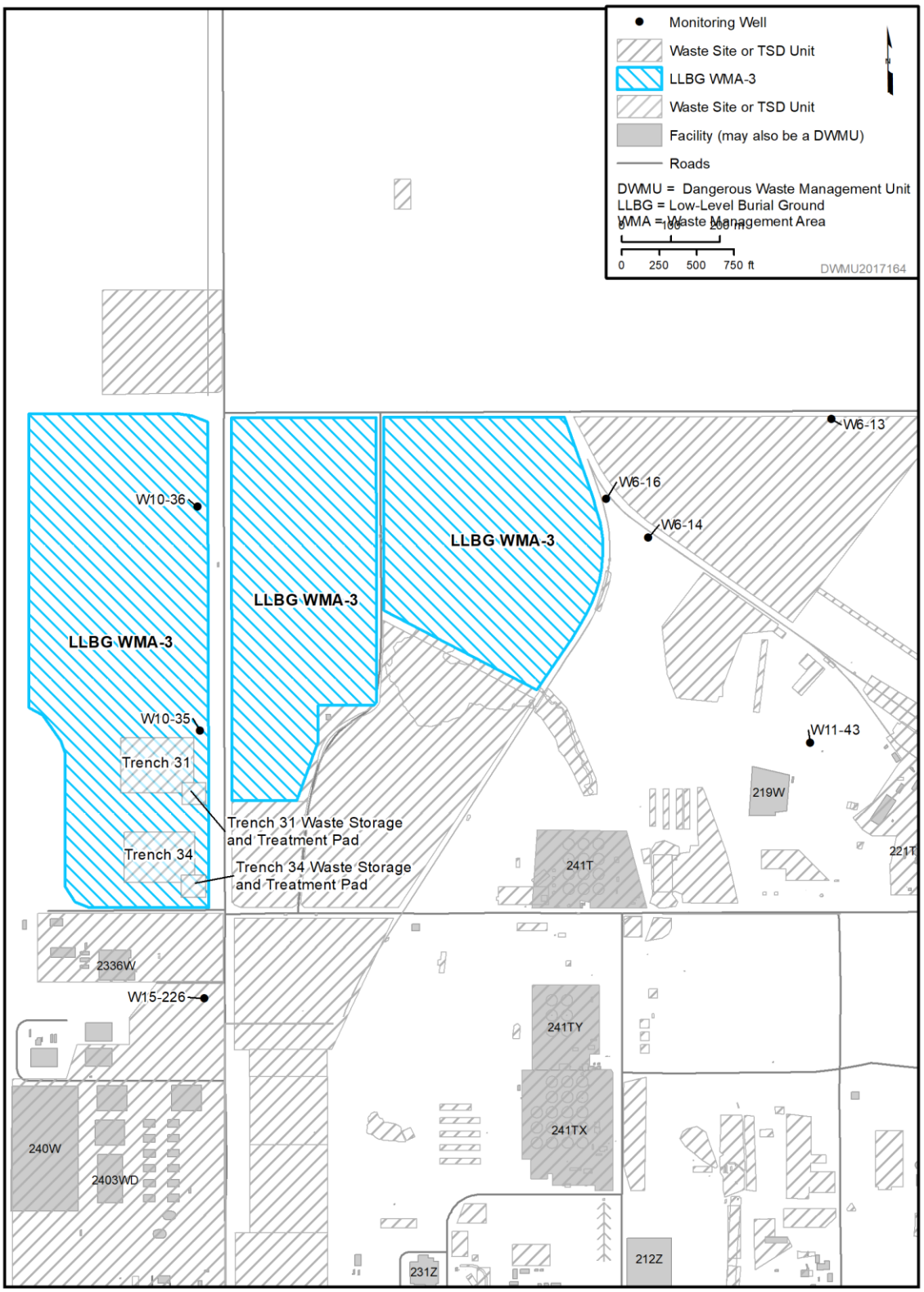


Figure 4-1. Vertical Contaminant Characterization Well Location Map

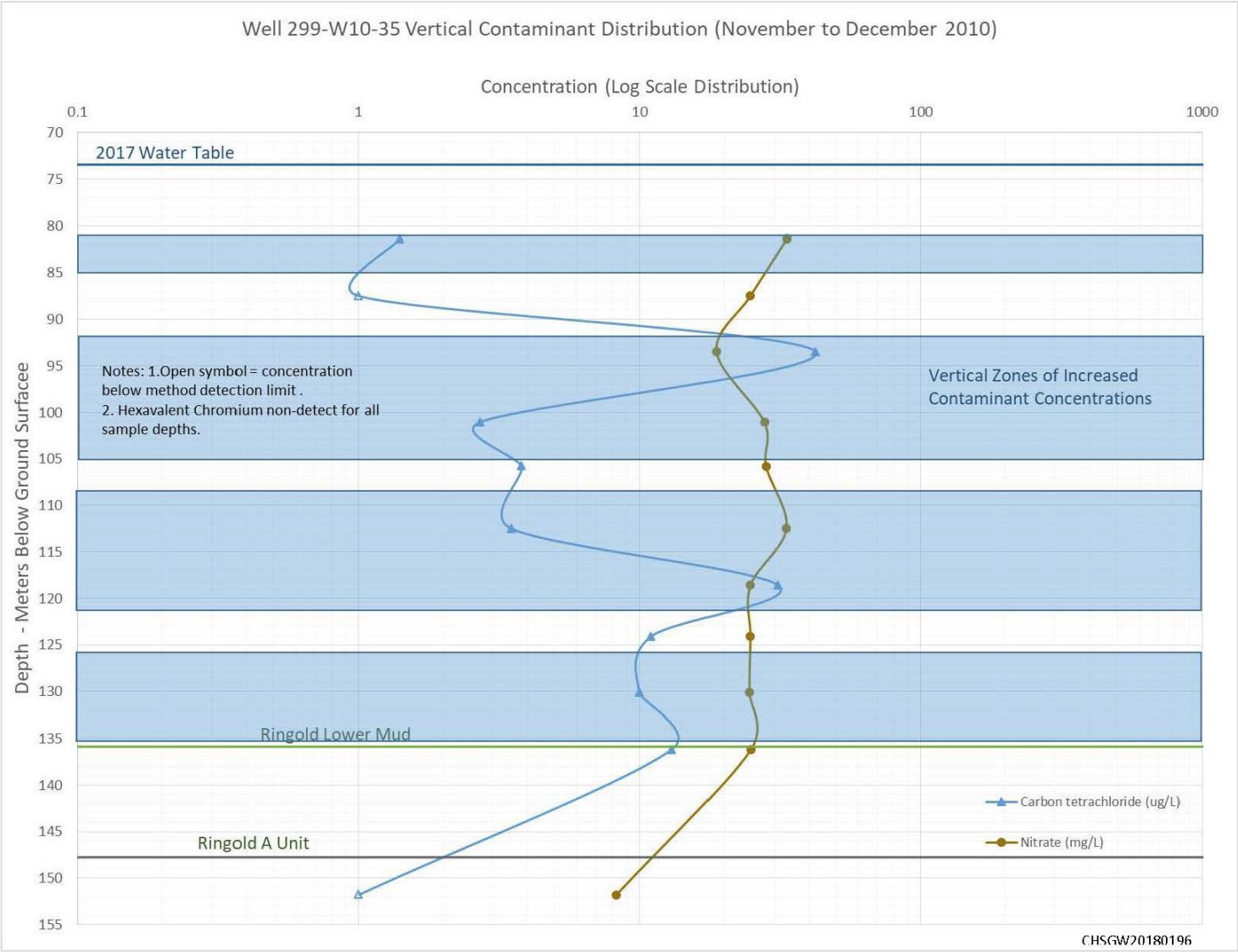


Figure 4-2. Vertical Contaminant Characterization Well 299-W10-35

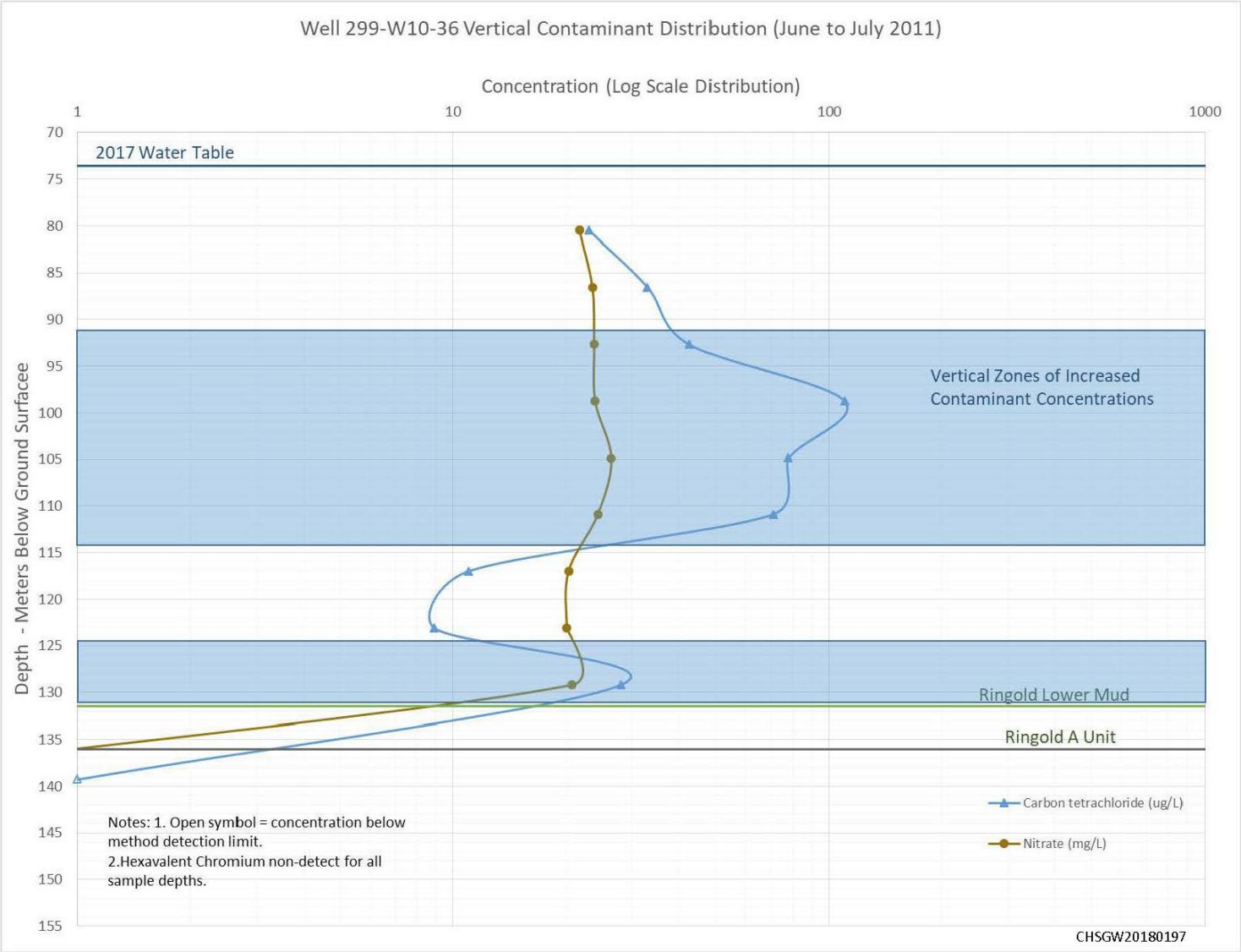


Figure 4-3. Vertical Contaminant Characterization Well 299-W10-36

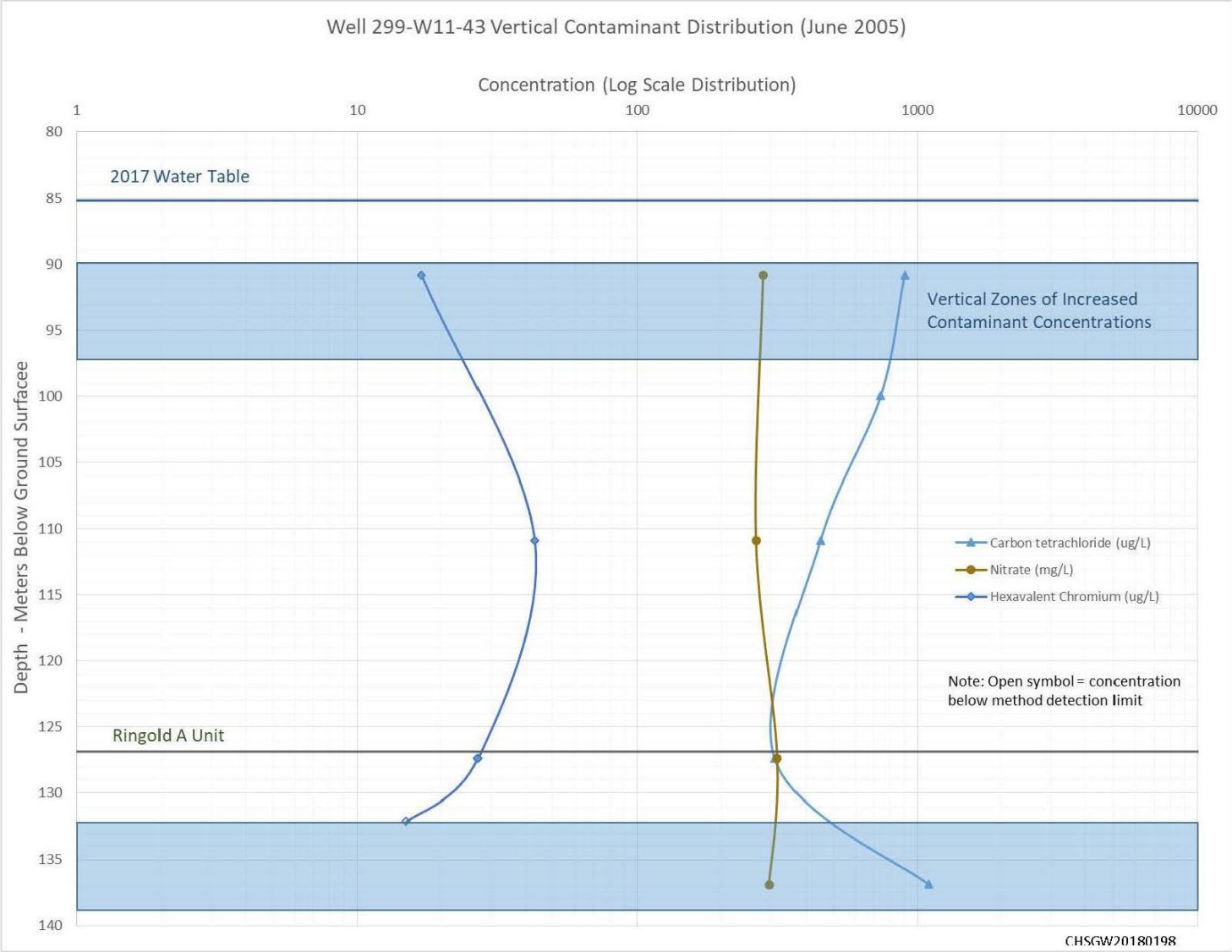


Figure 4-4. Vertical Contaminant Characterization Well 299-W11-43

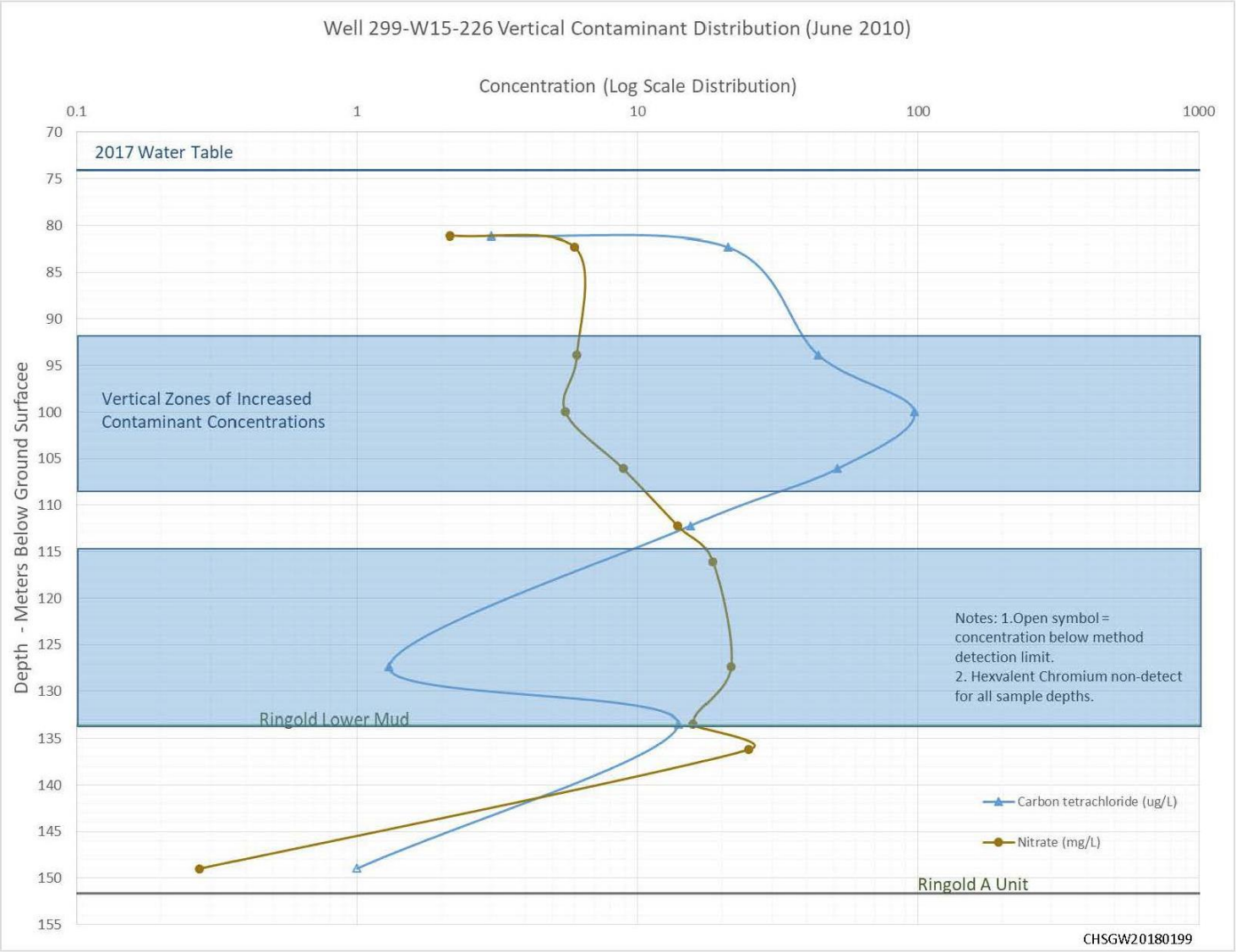


Figure 4-5. Vertical Contaminant Characterization Well 299-W15-226

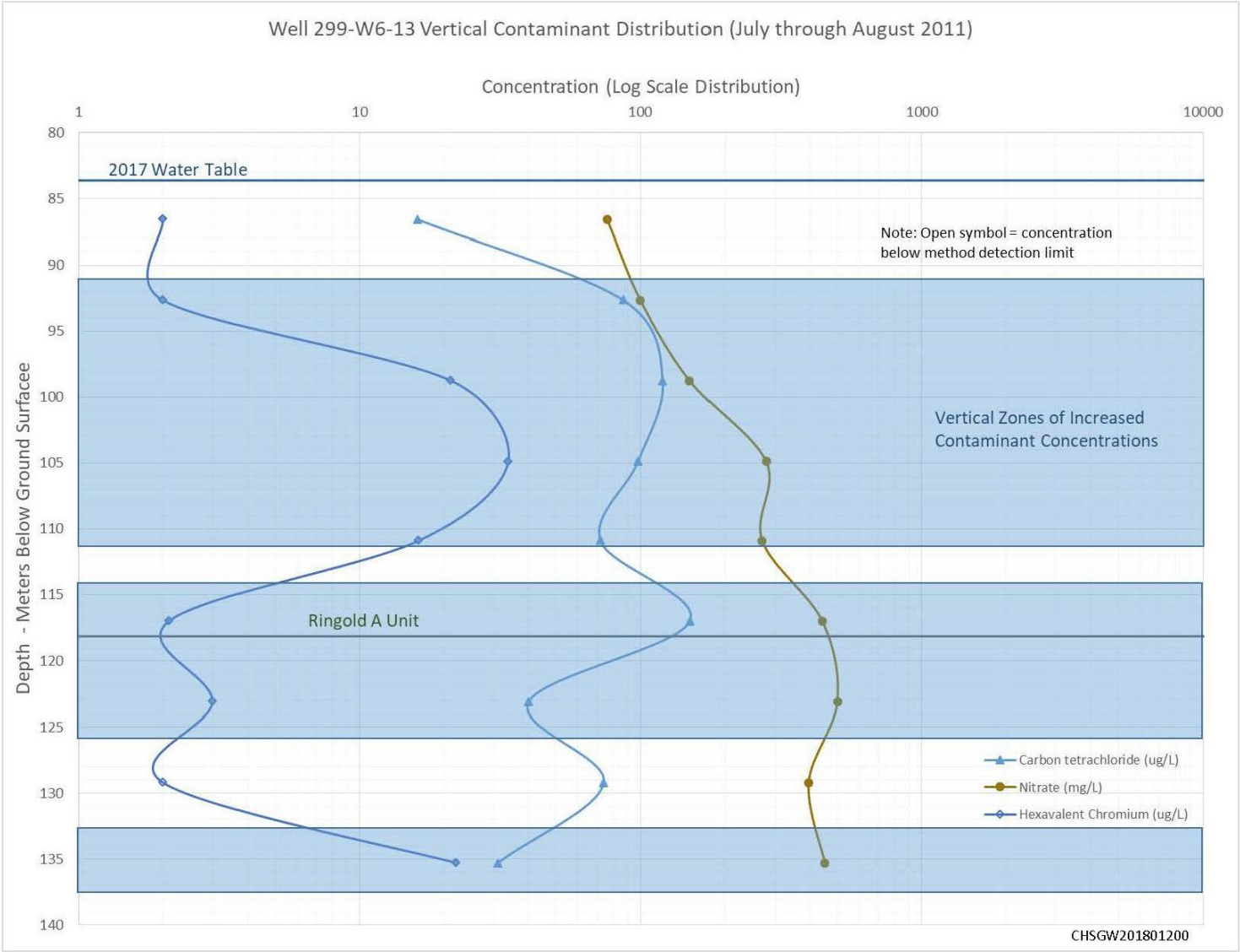


Figure 4-6. Vertical Contaminant Characterization Well 299-W6-13

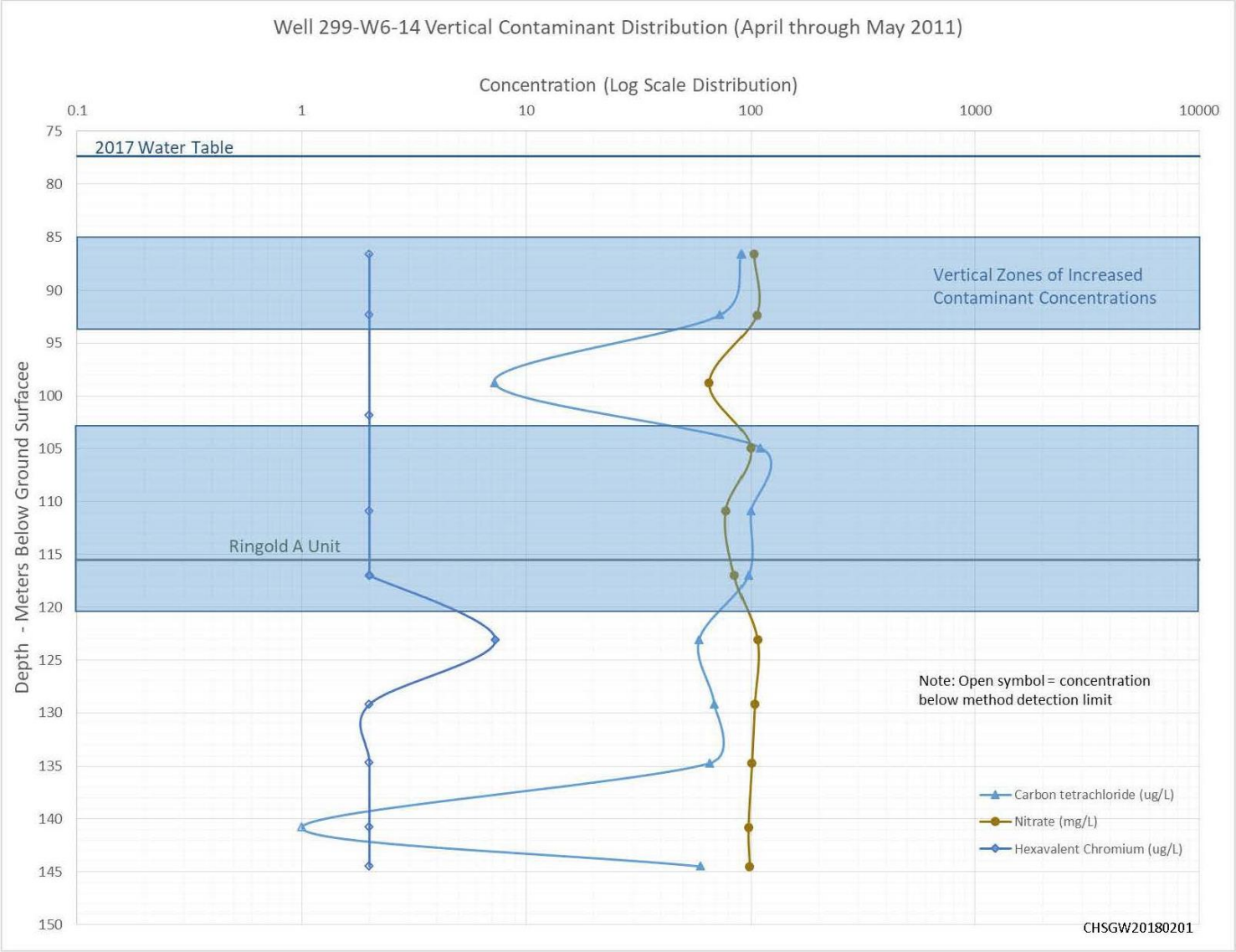


Figure 4-7. Vertical Contaminant Characterization Well 299-W6-14

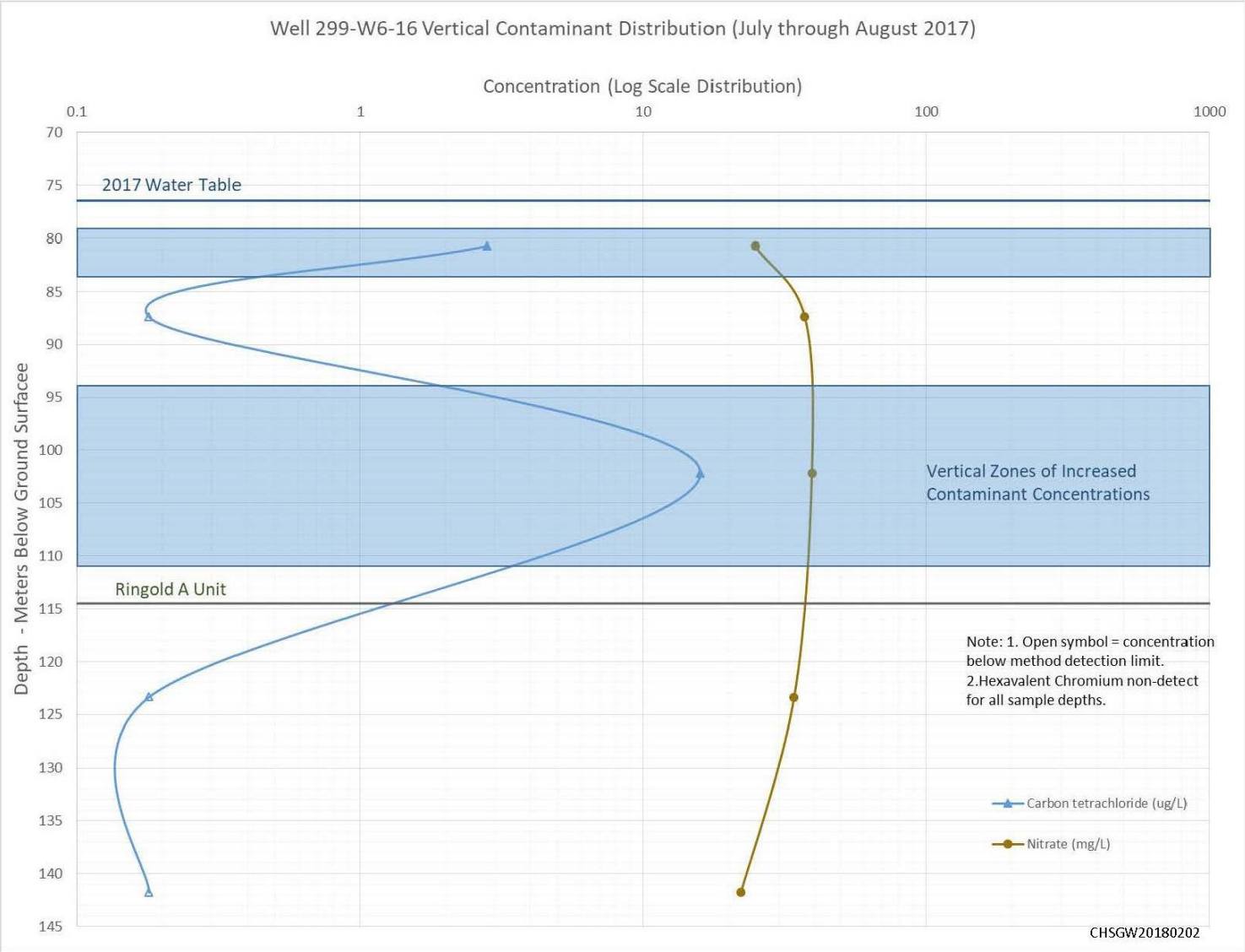


Figure 4-8. Vertical Contaminant Characterization Well 299-W6-16

Based on vertical characterization data, contaminants are present throughout the unconfined aquifer; consistent with the presence of multiple sources and extents of regional plumes. However, vertical zones of increased contaminant concentrations are evident to varying degrees within the wells. Evaluated wells show highest concentrations of carbon tetrachloride and/or nitrate at depths below the upper most portion of the aquifer. Wells 299-W15-226 and 299-W6-13 additionally indicate a general increasing concentration of nitrate with depth. The increase in concentrations at depth within wells is consistent with active 200 West P&T injection well operations in the vicinity of LLBG WMA-3 and general locations at the periphery of the regional plumes.

In summary, the LLBG WMA-3 is located within the periphery of the regional 200-ZP-1 OU plumes and is additionally impacted by nearby former 200-ZP P&T and current 200 West P&T injection well networks. Evaluated wells indicate varying concentration trends with depth in wells near LLBG WMA-3. Available data for the wells is not sufficient to evaluate plume migration from a hypothetical release from LLBG WMA-3.

5 Groundwater Flow Simulations

Groundwater flow simulations were conducted to evaluate the groundwater monitoring network for LLBG WMA-3 (Figure 5-1) for its ability to detect increases in groundwater contamination due to hypothetical releases from the facility both under the influence of the 200 West P&T system and after cessation of P&T operations. The wells included in the interim status groundwater monitoring network are documented in Table 2-46 in DOE/RL-2016-66 and shown in Figure 5-1. The CPGWM is the principal computational tool used to simulate groundwater flow and evaluate the performance of the 200 West P&T groundwater remedy (CP-47631). The CPGWM and the scenarios that were simulated to evaluate the monitoring network are described briefly in this chapter. The modeling effort was aimed at potential future releases, and is not intended to address the effect of pre-existing contamination. A more detailed summary is included in Appendix F. Two simulation approaches were used: (1) a plume migration (transport modeling) analysis that provides insight into the dilution of groundwater contaminant concentrations at monitoring locations, and (2) a particle-tracking analysis that indicates the potential travel paths for contaminants released under hypothetical conditions. Both approaches are based on the continuous release of a hypothetical unit source at the water table beneath LLBG WMA-3.

5.1 Central Plateau Groundwater Model

The model package report describing the CPGWM (version 8.3.4) was released in 2016 (CP-47631). The CPGWM simulates groundwater flow using the U.S. Geological Survey modular three-dimensional, finite-difference groundwater flow model, MODFLOW.

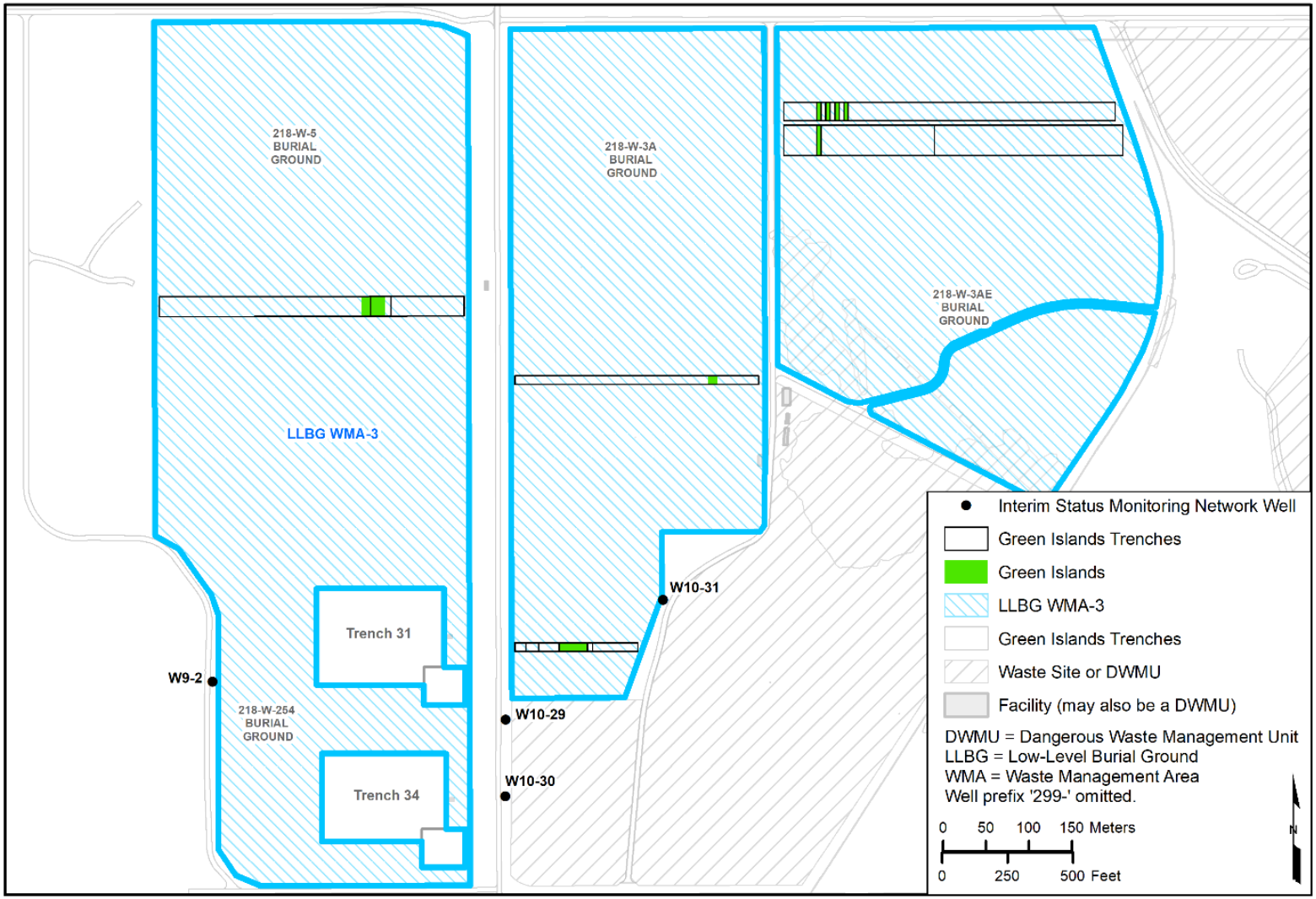
Contaminant transport is simulated using the Modular Three-Dimensional Multi-Species Transport Model (MT3DMS) code. MT3DMS was developed specifically for use with MODFLOW to simulate contaminant advection, dispersion, sources and sinks, and chemical reactions in groundwater systems.

Both particle-tracking and transport modeling calculations were performed to evaluate the monitoring well network. For particle tracking, the post-processor ModPath3DU was used to compute pathlines based on results obtained from the CPGWM flow simulations. Additional information on the model and processing, including a more detailed description of the model, time discretization, calibration, and software, is included in Appendix F.

5.2 Simulation Scenarios

Using the CPGWM, groundwater flow simulations were performed to evaluate a range of possible 200 West P&T system operating conditions, referred to as “scenarios” and “sub-scenarios.” These scenarios reflect the potential range of groundwater flow and contaminant migration directions that could result from varying the adjacent 200 West P&T system extraction rates and injection well operations. Three scenarios were evaluated:

- Scenario 1: 200 West P&T system operating at an expected capacity of 8,725 L/min (2,305 gal/min).
- Scenario 2: 200 West P&T system operating at the planned expanded capacity of 9,464 L/min (2,500 gal/min).
- Scenario 3: 200 West P&T system shut down. These conditions would apply when the remedy is complete.



Source: Table 2-46 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*

Figure 5-1. Interim Status Groundwater Monitoring Network

Scenarios 1 and 2 both include 18 sub-scenarios (A through R) that evaluate how changes in the operation of injection wells could impact the effectiveness of the monitoring network. Extraction well pumping rates were not varied because the pumping within the plume is expected to continue at rates that maintain hydraulic capture until the P&T system operation is shut down in 30 years. Descriptions of the scenarios and sub-scenarios are provided in Table 5-1. The locations of the 200 West P&T system injection and extraction wells are shown in Figure 5-2. Average pumping rates for December 2016 are shown in parentheses next to the wells.

Table 5-1. Simulation Scenarios

Scenario	P&T System Capacity[a]	Sub-Scenario	Description	Scenario Weight (%)
1	2,305 gal/min (8,725 L/min)	A	Current conditions.[b]	55
		B	Injection well 299-W10-35 operating at 50%.	5
		C	Injection well 299-W10-35 not operating.	3
		D	Injection well 299-W15-226 operating at 50%.	3
		E	Injection well 299-W15-226 not operating.	3
		F	Injection wells 299-W10-35 and 299-W15-226 not operating.	1
		G	Injection well 299-W10-36 not operating.	2
		H	Injection wells 299-W10-36, 299-W10-35, and 299-W15-226 not operating.	1
		I	Injection well 299-W6-14 not operating.	3
		J	Injection well 299-W6-16 not operating.	3
		K	Injection wells 299-W6-14 and 299-W6-16 operating at 50%.	3
		L	Injection wells 299-W6-14 and 299-W6-16 not operating.	1
		M	Injection wells 299-W18-41 and 299-W15-229 not operating.	2
		N	Injection wells 299-W15-29, 299-W18-36, 299-W18-38, and 299-W18-39 not operating.	3
		O	Injection wells 299-W15-228, 299-W15-229, 299-W15-29, 299-18-44, 299-W18-36, and 299-W15-29 operating at 50%.	5
		P	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 operating at 50%.	5
		Q	Injection wells 299-W15-229, 299-W15-29, 299-18-44, and 299-W18-36 not operating.	1
		R	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 not operating.	1

Table 5-1. Simulation Scenarios

Scenario	P&T System Capacity[a]	Sub-Scenario	Description	Scenario Weight (%)
2	2,500 gal/min (9,464 L/min)	A	2,500 gal/min, injection rates rebalanced.	55
		B	Injection well 299-W10-35 operating at 50%.	5
		C	Injection well 299-W10-35 not operating.	3
		D	Injection well 299-W15-226 operating at 50%.	3
		E	Injection well 299-W15-226 not operating.	3
		F	Injection wells 299-W10-35 and 299-W15-226 not operating.	1
		G	Injection well 299-W10-36 not operating.	2
		H	Injection wells 299-W10-36, 299-W10-35, and 299-W15-226 not operating.	1
		I	Injection well 299-W6-14 not operating.	3
		J	Injection well 299-W6-16 not operating.	3
		K	Injection wells 299-W6-14 and 299-W6-16 operating at 50%.	3
		L	Injection wells 299-W6-14 and 299-W6-16 not operating.	1
		M	Injection wells 299-W18-41 and 299-W15-229 not operating.	2
		N	Injection wells 299-W15-29, 299-W18-36, 299-W18-38, and 299-W18-39 not operating.	3
		O	Injection wells 299-W15-228, 299-W15-229, 299-W15-29, 299-18-44, 299-W18-36, and 299-W15-29 operating at 50%.	5
		P	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 operating at 50%.	5
		Q	Injection wells 299-W15-229, 299-W15-29, 299-18-44, and 299-W18-36 not operating.	1
		R	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 not operating.	1
3	0		System shutdown following active P&T.	100

Notes: For injected treated water dilution calculations, unit concentrations released at injection wells correspond with initiation of each injection well (i.e., using actual dates/timing).

For release calculations, unit concentrations released at the facility assumed a late 2017 release date for scenarios 1 and 2 and 2037 for scenario 3.

a. Scenario 1 pumping rate = 2,305 gal/min (comprised of 305 gal/min from 200-UP-1 extraction wells and 2,000 gal/min from 200-ZP-1 extraction wells); Scenario 2 pumping rate = 2,500 gal/min (comprised of 305 gal/min from 200-UP-1 extraction wells and 2,195 gal/min from 200-ZP-1 extraction wells). In both cases, an extraction rate of 60 gal/min at well 299-E33-268, located in the 200-BP-5 operable unit, is included in the extraction total for 200-ZP-1.

b. Current conditions as defined in Appendix G.

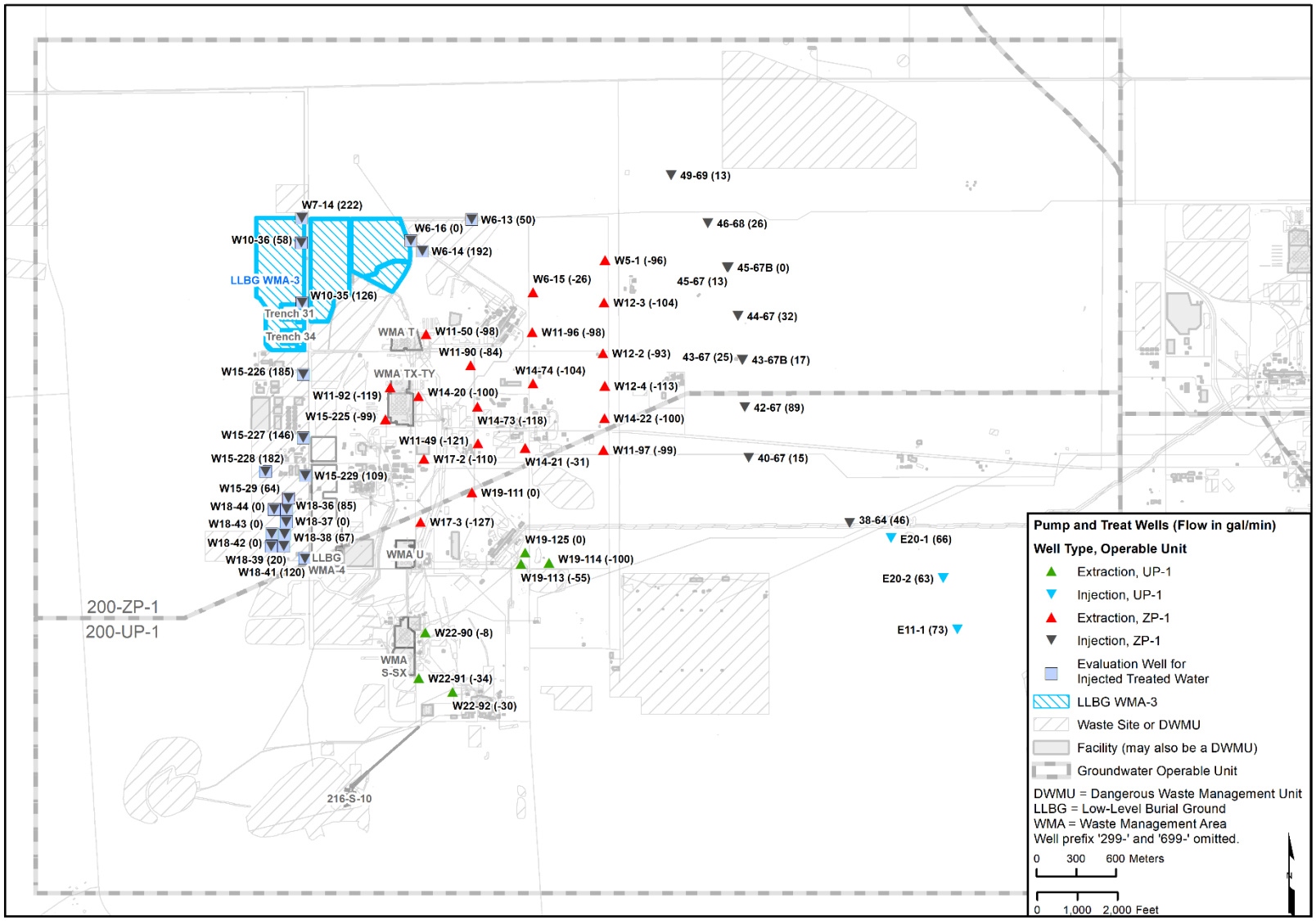


Figure 5-2. Locations and Average Pumping Rates (for December 2016) of 200 West P&T System Wells

The scenarios and sub-scenarios were selected to describe a range of conditions near the facilities evaluated within the 200 West Area. Some sub-scenarios were selected to examine conditions under typical, current, or likely injection well operating conditions, whereas others were selected to represent extreme or unlikely operating conditions. These extreme operating conditions, or bounding scenarios, are included to provide a bounding set of resultant groundwater flow and contaminant migration directions that can be used to evaluate the locations of the interim status monitoring network wells for LLBG WMA-3 and to assist in determining whether adjustment to the monitoring network is needed.

As described in Appendix F, a weight, in terms of a percentage, was assigned to each sub-scenario to reflect the relative probability of each operating condition. Those weights, shown in Table 5-1, are normalized on a scale of 0% to 100%. The highest weight is assigned to the most likely operating conditions, represented by sub-scenario A, while the extreme or boundary conditions are given low weights. The weights are used, as described in Section 6.2.2, in calculations that combine the results for all the sub-scenarios to identify areas where a hypothetical release to the water table would be most likely to migrate and be detectable.

Appendix A in Appendix F provides pumping rates for the 200 West P&T system extraction and injection wells for scenarios 1 and 2; scenario 3 evaluates conditions with no active extraction or injection well operations. The CPGWM represents the “as-built” screened intervals (i.e., top and bottom elevations) for extraction and injection wells (Konikow et al., 2009, *Revised Multi-Node Well (MNW2) Package for MODFLOW Ground-Water Flow Model*) and hence the depth below the water table at which injection (or extraction) at each well is focused. The monitoring wells were assumed to be screened across the water table, so that sampling from them focuses on the quality of water at or close to the water table. The P&T operations were assumed to end in year 2037, which is the end date of P&T operations per EPA et al., 2008.

Simulations were run for each scenario to examine dilution from the injection of treated water and particle pathlines of hypothetical releases from LLBG WMA-3. The results of those simulations were used to evaluate the efficacy of the groundwater monitoring network to detect hypothetical releases from LLBG WMA-3.

6 Calculations

Particle-tracking and transport simulations were performed to evaluate the efficacy of the groundwater monitoring network to detect significant increases in groundwater contamination that might occur from a hypothetical release from LLBG WMA-3. The simulations also account for the hydraulic influence of the 200 West P&T system extraction and injection wells. The simulations performed and output produced during the evaluation of the monitoring well network are described briefly in this chapter. Additional details about the modeling, including software used, inputs, and assumptions, are described in Appendix F and in Appendix G.

Particle tracking was performed first on a regional scale and then on a facility-specific scale. The regional-scale particle-tracking simulations presented in Appendix F included an analysis of the pathlines of injected treated water from 200 West P&T system injection wells for each scenario that considered advection only. Particle tracking using both advection and dispersion was then performed on a facility-specific scale to simulate a hypothetical release from the facility.

Similarly, transport modeling was performed on a regional scale to represent the migration, mixing, and dilution of treated water injected at the 200 West P&T system injection wells for each of the scenarios. On a facility-specific scale, transport modeling was performed to evaluate the migration, mixing, and dilution of groundwater impacted by a hypothetical release to the water table beneath the facility.

Particle-tracking and transport modeling calculations and the output produced for LLBG WMA-3 are described in the following sections and discussed in more detail in Appendix G.

6.1 Principal Assumptions and Inputs

The principal inputs to the modeling performed to evaluate the monitoring network for LLBG WMA-3 are the assumed extraction rates and injection well operations for the 200 West P&T system, model boundary conditions, and the assumed transport parameters of a hypothetical conservative contaminant release to groundwater beneath the facility. The parameters of the groundwater flow component of the CPGWM have been formally calibrated to historical data and conditions. As discussed in Appendices F and G, the outputs of the flow model (i.e., heads and flow fields) correspond in general with measured data throughout the area of interest. The parameters of the transport component of the CPGWM have not been formally calibrated to historical data and conditions. The transport parameters, however, have been qualitatively corroborated via simulations conducted as part of the work to simulate tritium concentrations in monitoring wells adjacent to the State-Approved Land Disposal Site. Tritium is a conservative contaminant with respect to migration in groundwater.

Analysis presented in Section 7.4 of Appendix F shows that, based on present conditions, no significant vertical migration is expected in the 200 West Area. The vertical movement that is likely to occur is limited to areas near extraction wells. Section 7.4 of Appendix F also concludes that the American Petroleum Institute (API) calculator can be used to verify the appropriateness of the depths of the well screens for monitoring wells. In addition to confirming the use of the API calculator, the results of the analysis of particle vertical distribution agrees with the conclusion of Hantush, 1964, “Hydraulics of Wells,” that the flows at locations that are a distance greater than approximately 1.5 to 2 times the saturated thickness from extraction wells are predominately horizontal. The facility-specific results of the API calculator are presented in Section 7.5 of Appendix G. Transport parameters used in the simulations are unchanged from the transport parameters used in modeling performed for annual reports of the 200 West P&T operations (Section 3.5 in DOE/RL-2016-20, *Calendar Year 2015 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations*). Since these parameters are fundamental to the calculations, they are listed in Table 6-1, and references are provided in

the table footnotes. Additional details on the inputs to and assumptions used in the calculations are included in Appendices F and G.

Table 6-1. Properties Assumed for Transport Calculations Using the CPGWM

Assumed Properties for Purposes of Conservative Dilution Calculations					
Distribution Coefficient (mL/g)	**Half-Life (yr)**	**Half-Life (d)**	**Degradation Rate (one/d)**	**Reference for Distribution Coefficient**	**Reference for Degradation Rate**
0.0	None assumed	None assumed	None assumed	None assumed	None assumed
Aquifer-Dependent Transport Parameter Values for the Central Plateau Model					
Property	**Value**	**Comments**			
Effective porosity	0.15	Approximate central value (Table D-2 of DOE/RL-2007-28)			
Longitudinal dispersivity	3.5 m	Introduced for stability of the transport calculations based on recommendation from the MT3DMS manual (Zheng and Wang, 1999)			
Transverse dispersivity	0.7 m	20% of longitudinal (DOE/RL-2008-56)			
Vertical dispersivity	0.0 m	DOE/RL-2008-56			
Molecular diffusion constant	0.0 m^2/d	Negligible term			

References: DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*.

DOE/RL-2008-56, *200 West Area Pre-Conceptual Design for Final Extraction/Injection Well Network: Modeling Analyses*.

Zheng and Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*.

6.2 Particle Tracking

To evaluate the efficacy of the groundwater monitoring network to detect hypothetical increases in concentrations in groundwater due to releases from LLBG WMA-3, facility-specific particle-tracking calculations were performed for each sub-scenario in scenarios 1 and 2 and for scenario 3. Particles were released to the water table annually and tracked forward, with initial release in 2017 along the Green Islands within LLBG WMA-3. The Green Islands are locations within certain LLBG WMA-3 trenches that contain mixed waste subject to regulation under WAC 173-303. The particle release locations are shown in Figure 6-1 in Appendix G. These "focused releases" reflect hypothetical leaks from the Green Islands that reach the water table. This release scenario does not incorporate any aspects of transport through the overlying vadose zone. Once released to the water table, the particle movement is then predominantly horizontal, with minor components of vertical migration in response to very limited infiltration from groundwater recharge and the operation of nearby extraction and injection wells.

In all sub-scenarios for scenarios 1 and 2, particles were released annually and tracked through to the end of fiscal year (FY) 2037, which is when the 200-ZP-1 groundwater P&T remedy component is expected to cease operation in accordance with EPA et al., 2008. For scenario 3, which evaluates conditions after cessation of P&T system operations, the initial release to the water table is the end of FY 2037, and the particles are released every 5 years thereafter for 100 years.

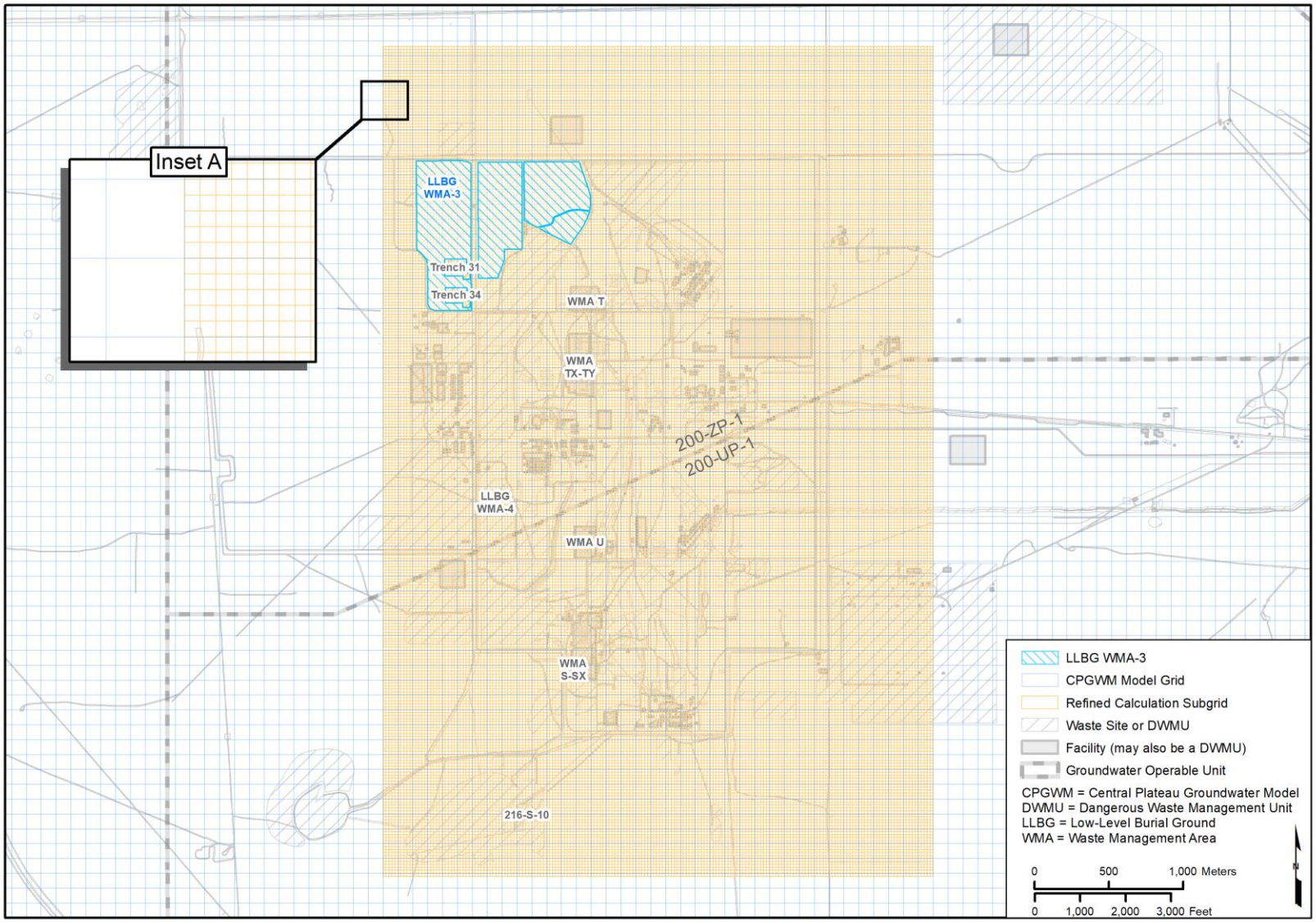


Figure 6-1. Location of Calculation Subgrid in Relation to 200 West Area Facilities Evaluated in Appendix F

6.2.1 Particle Pathlines

The particle-tracking post-processor ModPath3DU was executed to track particles using both advection and dispersion. To simulate dispersion within particle tracking, the Random-Walk tracking option within ModPath3DU was used as discussed in Appendix F. The results were post-processed and superimposed upon figures showing injection and monitoring wells. These particle-tracking maps indicate if monitoring locations lie in the migration pathway of any hypothetical releases from the facility.

Particles were tracked for hypothetical releases from LLBG WMA-3 Green Islands for each of the simulation scenarios identified in Table 5-1. Details on generation of the input files, particle tracking, and post-processing of the output data are provided in Appendices F and G.

6.2.2 Relative Detectability Calculations

For each scenario, a calculation was performed to identify areas of the aquifer where a hypothetical release from LLBG WMA-3 to the water table would be most likely to migrate and be detectable. There is no assumption of a concentration, allowing a comparison between scenarios and also geographically between wells as the relative detectability stays the same. The effects of the spreading and reduction of detectability as the result of injection are not applied as a specific element. In each scenario, the groundwater flow rates and resulting migration directions all explicitly include the effects of injection. Across scenarios modeled, the relative detectability calculation allows for the placement of wells in the most likely locations to detect a potential release. This calculation of “relative detectability” was performed on a finer spatial resolution than provided by the discretization of the CPGWM simulation grids. This refined calculation subgrid, shown in Figure 6-1, comprises 20 by 20 m (66 by 66 ft) cells, resulting in 25 calculation cells within each CPGWM simulation cell (100 by 100 m [328 by 328 ft], also shown in Figure 6-1). The relative detectability was calculated as follows:

- As described for particle tracking, particles are released to the water table within the focused release area for the conditions in each sub-scenario. A particle count map is then produced for each sub-scenario by counting the number of particles that pass through each pre-defined calculation subgrid cell, which enables development of a contour map of the particle count for each grid cell.
- For each scenario, the relative detectability was then determined by calculating the weighted sum of all the particles that traversed each refined calculation subgrid cell over all the sub-scenarios within that scenario. The weights given to the sub-scenarios are shown in Table 5-1. The weighted sum of these counts was computed as described in Appendix G. This method produces a relative detectability map for each scenario that gives more weight to the more likely scenarios and less weight to the more extreme and less likely scenarios. The relative detectability map for scenario 3 is equivalent to the particle count map because scenario 3 has no sub-scenarios.

The resulting maps of relative detectability for each scenario show the overall distribution for a release from LLBG WMA-3 considering both advection and dispersion. The release distributions are color-coded to reflect the weighted percent distributions of particle counts throughout the release pathline. Where the weighted percent distribution of particle counts is higher, the probability of release detection is also higher.

6.3 Transport Calculations

Transport calculations were performed to evaluate the impact of the injection of treated water at injection wells as well as the impact of hypothetical releases from the facility to the underlying water table. Treated water injected at the 200 West P&T system injection wells will mix with ambient groundwater, resulting in dilution of the ambient groundwater to varying degrees at different locations and times. A release of

contamination from LLBG WMA-3 that ultimately reaches the underlying water table will be diluted as a result of this same mixing process.

The potential effects of dilution were evaluated using a "unit-plume" approach to transport simulation. When using a unit-plume approach, the unit concentration can represent a single contaminant, a combination of contaminants, or treated water. In each case, for purposes of the analysis performed, the unit concentration is referred to as a "unit source." The objective is to use the concept of a unit source to simulate in relative rather than absolute terms the likely fate (i.e., migration and mixing) of the injected treated water or of a particular release of contaminant(s) in the subsurface.

For this analysis, a unit concentration (C = 1.0) is used to represent either the treated water that is injected at the 200 West P&T system injection wells or water that is impacted by a release from a DWMU that mixes continuously with groundwater over an area immediately beneath the facility. Consistent with the unit-plume concept, the ascribed value of 1.0 at the unit source, whether an injection well or the impacted water table beneath the facility, denotes that the water at the location of interest comprises 100% of the quantity of interest (i.e., it has not yet undergone any mixing with other water sources). The effects of mixing and dispersion within the aquifer are simulated as water migrates away from the location of the unit source. As a result, over time and throughout space, the simulated concentration represents that fraction of the original water present that remains out of the water released or injected at the unit source location. For example, a concentration of 0.5 indicates that at that time and location, 50% of the water comprises water that was released at the unit source location, and 50% of the water comprises other water, typically, ambient groundwater with which the water originating from the unit source has mixed and migrated. The simulated concentrations from these calculations can be interpreted in terms of a dilution factor.

- If the unit source represents injection of treated water, then the simulated concentration at any point or time represents the fraction of the water at that location that comprises injected treated water, demonstrating how that fraction has been reduced via the processes of advection and dispersion. This calculation was performed only for scenarios 1 and 2 because scenario 3 assumes cessation of 200 West P&T system operations.
- If the unit source represents a contaminant release or water table impact, then the simulated concentration at any point or time can be interpreted two ways:
  - First, as representing the fraction of the water at that location that comprises the originally impacted groundwater from beneath the facility where the release occurred. That value, 1.0 minus the concentration, thus represents the fraction of other water (typically, a combination of ambient groundwater and injected treated water from the P&T system) with which the water originating from the unit source has mixed and migrated.
  - Second, as representing a dilution factor or ratio to which the concentration at the source has been reduced via the processes of advection and dispersion.

The following "unit plume" transport calculations were performed to illustrate the potential effects of dilution via mixing.

- To represent the migration, mixing, and dilution of treated, injected water, unit concentrations representing injected water were released to the water table from injection wells to simulate the injected water migration and transport through FY 2037.

- To represent the migration, mixing, and dilution of groundwater impacted by a continuous release from a hypothetical contaminant source at LLBG WMA-3, unit concentrations representing the hypothetical contaminant were released at the water table in five model grid cells representing LLBG WMA-3 (shown in Figure 6-1 in Appendix G). The migration and transport of the release in groundwater were simulated through FY 2037 for scenarios 1 and 2. Scenario 3 was simulated from 2037 through 2137.

In each case, two sets of outputs from these dilution calculations were prepared. These comprise time-series plots of concentrations at selected spatial locations and spatial "snapshots" of concentrations at the water table throughout the aquifer at certain times.

- The interpretation and thus the descriptor of the figures that plot the simulated concentrations over time at selected spatial locations differ depending on the type of unit source that was simulated:
  - In the case of treated water injection as the unit source, the time-series plots are referred to as "injected treated water dilution breakthrough curves."
  - In the case of a simulated release to the water table being the unit source, the time-series plots are referred to as "release concentration breakthrough curves."
- The figures that depict the simulated concentrations at the water table throughout the 200 West Area at a selected time are similarly referred to as:
  - "Injected treated water dilution plumes" for the cases where the unit source is the injected water entering the aquifer via the 200 West P&T system injection wells. Those figures indicate the fraction of the water at those locations that comprises treated water injected at the 200 West P&T system injection wells.
  - "Release unit plume maps" for the cases where the unit source is the release to the water table from the facility. Those figures indicate the fraction of the water at those locations that comprises the originally impacted groundwater from beneath the facility where the release occurred.

7 Simulation Results and Conclusions

This chapter presents the simulation results and conclusions regarding the groundwater monitoring network's ability to detect hypothetical releases from LLBG WMA-3 under various 200 West P&T system operating conditions. The interim status groundwater monitoring network wells that were evaluated are shown in Figure 5-1. The results presented here (conclusions can be found in Section 7.4) derive from the calculations described in Chapter 6, which were performed for the various scenarios described in Chapter 5. Throughout this chapter, sub-scenario A represents current operating conditions as defined in Appendix G.

Both transport and particle-tracking calculations accounted for advection and dispersion processes, and both types of calculations were considered in the evaluation of the monitoring well network. As described in Chapter 6, the output of transport calculations include the following:

- Injected treated water dilution breakthrough curves – Time-series plots for each monitoring well of simulated treated water concentrations from treated water injected at 200 West P&T system injection wells.
- Release concentration breakthrough curves – Time-series plots for each monitoring well of simulated unit contaminant concentrations from the hypothetical release in the CPGWM model grid cell(s) beneath the LLBG WMA-3 defined release area.
- Injected treated water dilution plumes – Maps that indicate, at a selected point in time, the relative fraction of the groundwater that comprises the treated water injected at 200 West P&T system injection wells.
- Release unit plume maps – Maps that indicate, at a selected point in time, the relative fraction of the groundwater that comprises the hypothetical release to groundwater beneath LLBG WMA-3.

Outputs of the particle-tracking calculations include the following:

- Particle-tracking maps – Maps that show the particle pathlines of a hypothetical release to groundwater.
- Particle count maps – Maps that show the count of particles that traverse each cell of the refined calculation subgrid over a selected time-frame.
- Relative detectability maps – Maps that show the distribution of a release from LLBG WMA-3. The relative detectability map combines all the particle count maps within each scenario, assigning greater weight to the results for more likely scenarios and less weight to scenarios that are characterized by unlikely or extreme operating conditions.

For each existing downgradient well location, breakthrough curves for injected treated water dilution and release concentrations can be compared to evaluate which well locations will likely have higher dilutions from injected treated water and which will likely have more detectable concentrations from releases from the facility. The breakthrough curves for the existing monitoring wells are discussed in Section 7.1.

Differences between transport modeling and particle-tracking methods can result in variations in outputs. Those variations are apparent when comparing the release unit plume maps created using transport modeling and the particle-tracking maps created using particle tracking. Each type of map shows the results of each calculation method for the same selected point in time for the hypothetical release to the groundwater table beneath the facility for each sub-scenario. Selected release unit plume and particle-tracking maps are included in Sections 7.1 and 7.2, respectively. The maps represent conditions at the end of the operation of the 200 West P&T system in 2037 for scenarios 1 and 2 and in 2137 for scenario 3.

Maps of relative detectability for scenarios 1, 2, and 3 identify where a hypothetical release to the groundwater table beneath LLBG WMA-3 would most likely migrate and be detectable. The relative detectability maps are discussed in Section 7.2. Section 7.3 presents an evaluation of proposed monitoring wells, and Section 7.4 presents the conclusions to the evaluation of the monitoring well network.

7.1 Breakthrough Curves and Release Unit Plume Maps

Transport modeling was used to create breakthrough curves for unit concentrations of injected treated water and release concentrations for each monitoring well location. It was also used to create spatial snapshots of the release unit concentration plumes, or release unit plume maps.

Injected treated water dilution breakthrough curves and release concentration breakthrough curves for monitoring wells 299-W9-2, 299-W10-29, 299-W10-30, and 299-W10-31 were prepared for each sub-scenario under scenarios 1 and 2 and for scenario 3. For both types of breakthrough curves, bold black lines are used to indicate sub-scenario A, which is considered to represent the most likely future operating scenario.

The injected treated water dilution breakthrough curves indicate, for each sub-scenario, the estimated dilution at the monitoring well from the treated water injected at the 200 West P&T system injection wells and the relative time of arrival of the treated water at the monitoring well. The start of the simulation represents 2012, the year of startup of the 200 West P&T operations. The simulations assume the operating conditions for the 200 West P&T system stipulated for sub-scenario A continue until October 1, 2017, at which time the operating conditions for each separate sub-scenario are assumed to start. This assumption is reflected in the breakthrough curves by the single trend line for injected treated water dilution until October 2017, followed by diverging curves representing adjustments to the injection well operations for each sub-scenario. Figures 7-1 through 7-4 show the injected treated water dilution breakthrough curves for monitoring wells 299-W9-2, 299-W10-29, 299-W10-30, and 299-W10-31, respectively, for scenario 1. Table 7-1 shows the range of the injected treated water dilution breakthrough curves for the monitoring wells for scenarios 1 and 2.

Each well and each sub-scenario has a unique injected treated water dilution breakthrough curve. The treated water dilution breakthrough curves for each downgradient monitoring well indicate significant variability among the different sub-scenarios, suggesting that varying injection well operations influences the treated water observed at the LLBG WMA-3 monitoring network wells. The results for downgradient wells are bounded on the high end (higher unit concentrations of injected treated water) by sub-scenario R and on the low end (lower unit concentrations) by sub-scenario H. In sub-scenario R, the more southern injection wells (299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43) are not operating, while in sub-scenario H, the injection wells in the vicinity of LLBG WMA-3 (299-W10-36, 299-W10-35, and 299-W15-226) are not operating. The results for scenario 2 (included in Appendix G) were similar to those for scenario 1.

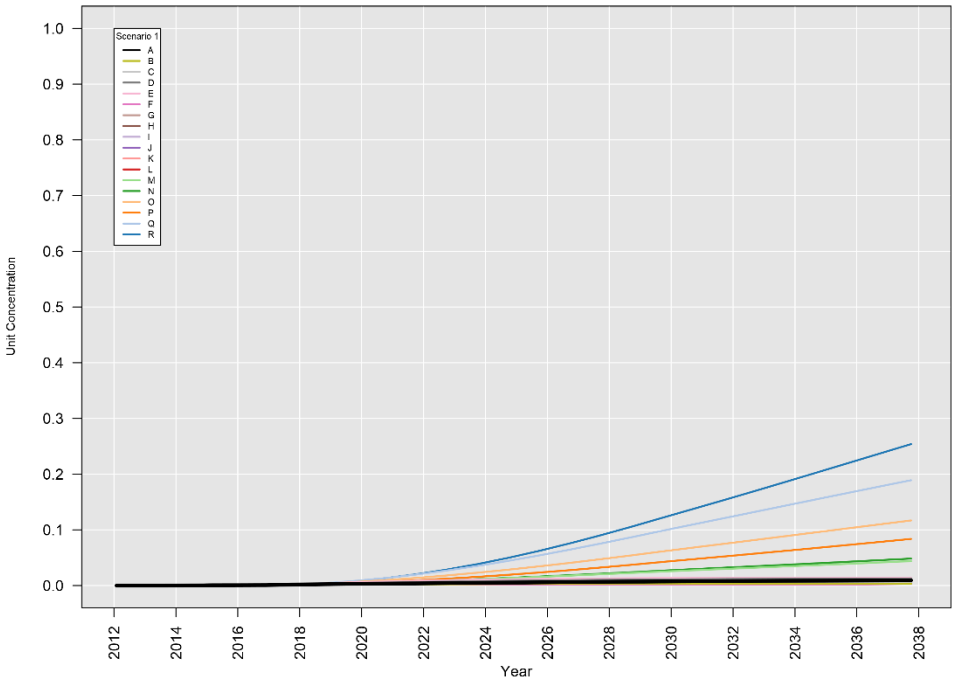


Figure 7-1. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W9-2

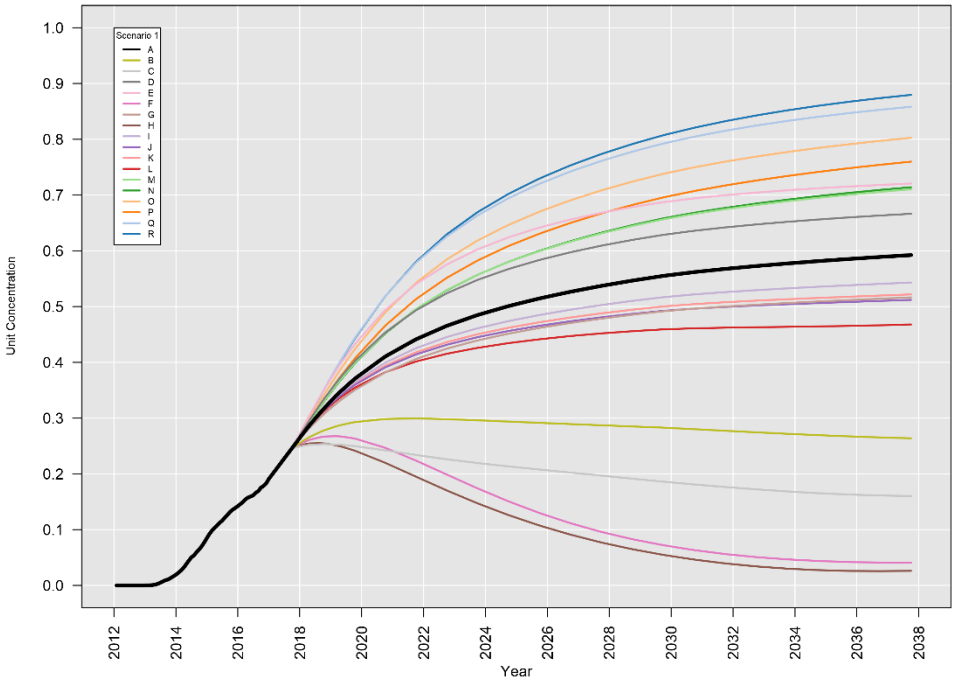


Figure 7-2. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W10-29

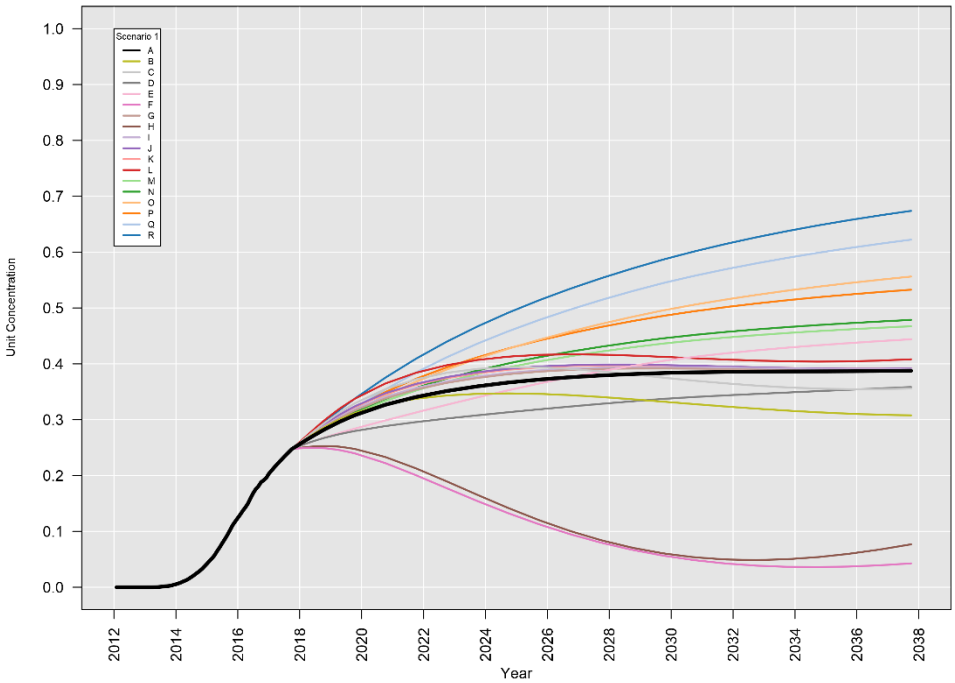


Figure 7-3. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W10-30

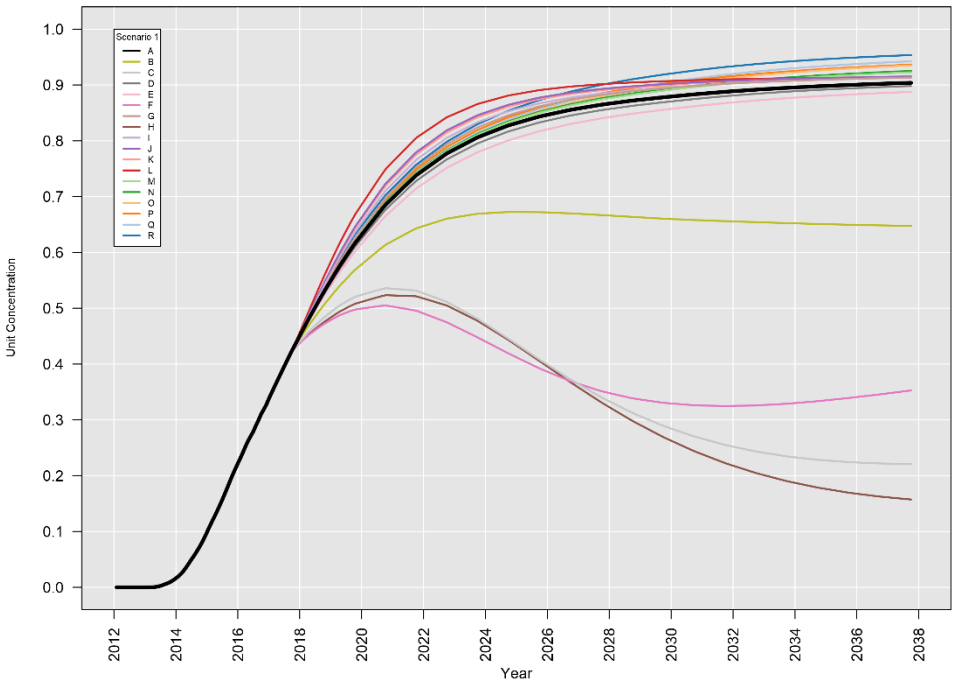


Figure 7-4. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W10-31

Table 7-1. Range of Unit Concentrations of Injected Treated Water Dilution Breakthrough Curves

Well Name	Scenario	Minimum Unit Concentration	Maximum Unit Concentration	Weighted Average
299-W9-2	1	0.003	0.254	0.024
	2	0.004	0.254	0.030
299-W10-29	1	0.026	0.880	0.580
	2	0.030	0.880	0.599
299-W10-30	1	0.043	0.674	0.403
	2	0.053	0.674	0.420
299-W10-31	1	0.157	0.954	0.863
	2	0.167	0.954	0.870

The release concentration breakthrough curves for monitoring wells 299-W9-2, 299-W10-29, 299-W10-30, and 299-W10-31 for the sub-scenarios in scenario 1 are shown in Figures 7-5 through 7-8, respectively. These figures, which depict the simulated breakthrough of a unit source release to the groundwater table from LLBG WMA-3, provide for a relative comparison of the monitoring well locations. The plotted unit concentrations are the ratios of the simulated concentration that would be observed at a downgradient monitoring well location to the original concentration of the release. A unit concentration of 1 represents the original concentration of the release reaching the monitoring well. The breakthrough curves show the relative time of arrival of the release concentration at the monitoring well in terms of years after release to groundwater beneath the facility. The release time (represented on the figures as arrival time year 0) corresponds to October 1, 2017. The unit concentrations and arrival times consider advection and dispersion but do not include chemical-specific, predictive calculations for more complex, constituent-dependent processes such as sorption and degradation (decay) that would decrease the concentration or delay arrival time at the wells.

In general, release concentration breakthrough curves displaying higher unit concentrations for a larger range of operating conditions (different sub-scenarios) and, in particular, displaying higher unit concentrations for sub-scenario A, indicate well locations that are effective for monitoring releases from the facility. Wells for which breakthrough curves display high variation among different operating scenarios are sensitive to changes in the 200 West P&T system operating conditions. Wells for which breakthrough curves display lower unit concentrations (in particular, for the most likely operating conditions) indicate less optimal well locations.

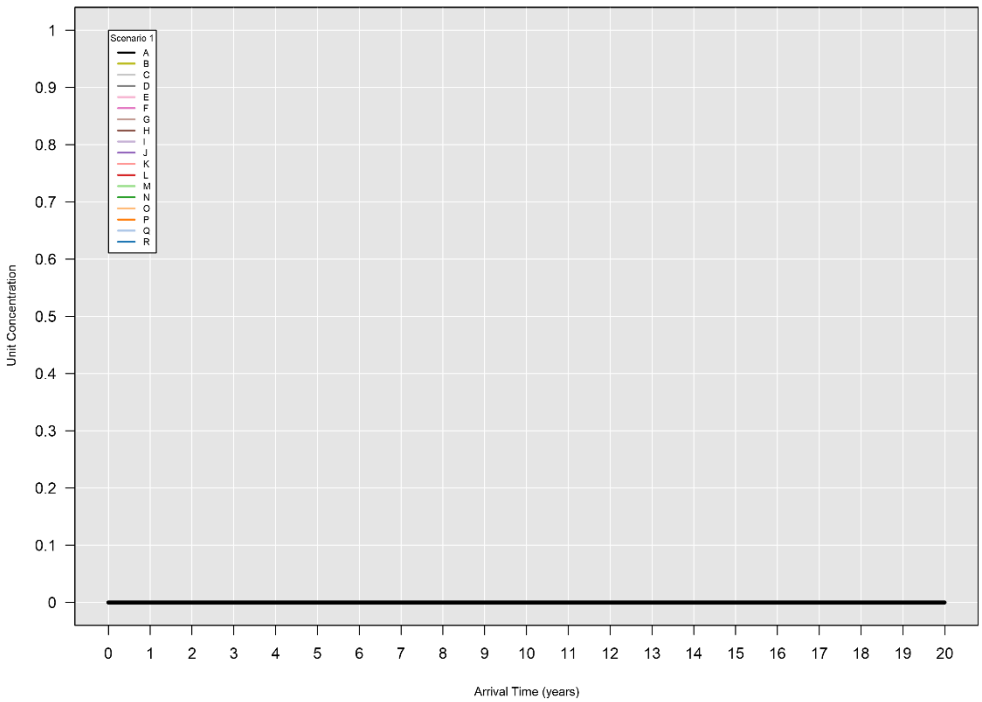


Figure 7-5. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W9-2

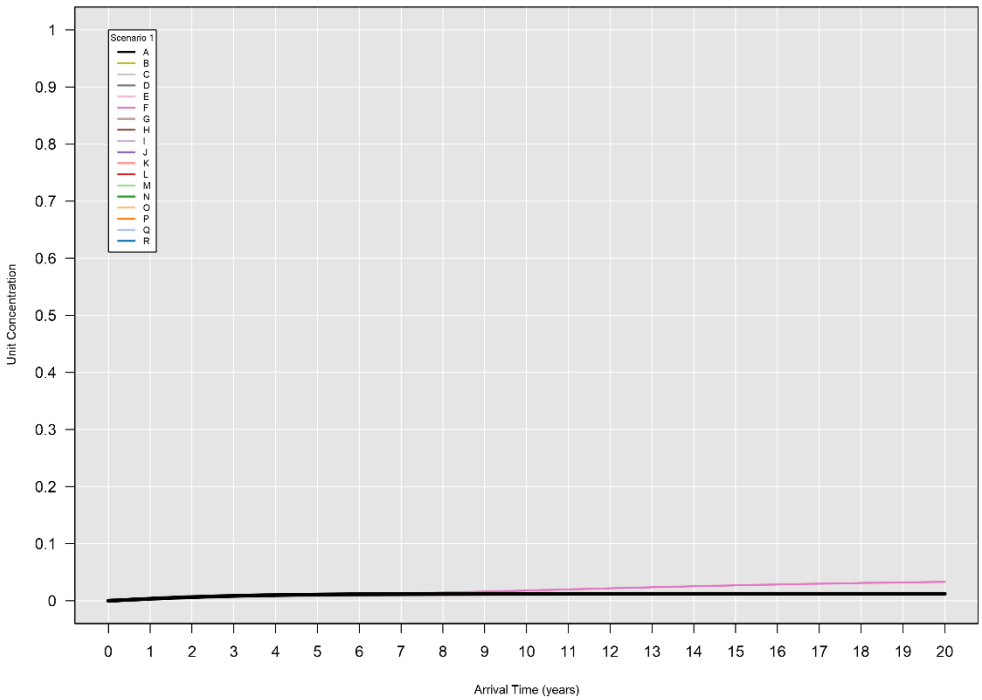


Figure 7-6. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W10-29

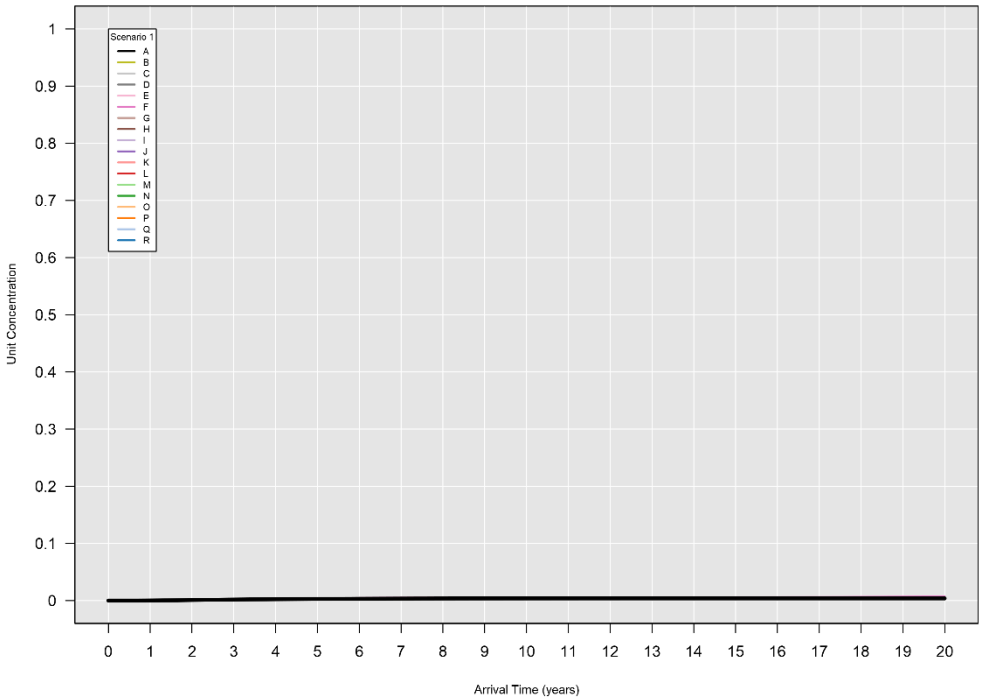


Figure 7-7. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W10-30

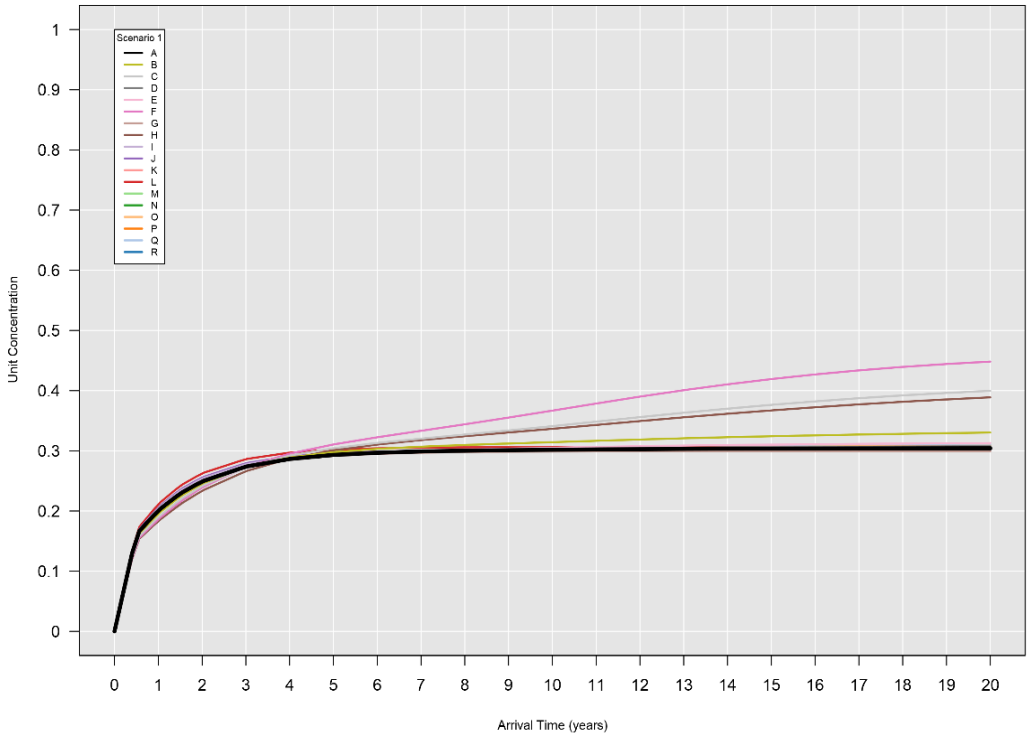


Figure 7-8. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W10-31

Figures 7-5 through 7-8 show some variation in the breakthrough curves for the 200 West P&T system operating scenarios evaluated, indicating that detection of releases at the well locations will differ but is not significantly sensitive to changes in the 200 West P&T system operating conditions. Release concentration breakthrough curves for well 299-W9-2 indicate a unit concentration of near zero due to the location of the well upgradient of the Green Islands. The curves for wells 299-W10-29 and 299-W10-30, located south of the Green Islands locations, also indicate near zero unit concentrations. Therefore, those well locations are less likely to detect releases for the various operating scenarios relative to other monitoring well locations. None of the curves for the monitoring wells indicate high unit concentrations. Though the curves for well 299-W10-31 do indicate adequate unit concentrations, the results, in general, indicate the monitoring network wells are not located in areas having high potential for detecting releases from LLBG WMA-3. The results for scenario 2 (included in Appendix G) are similar to those for scenario 1. Table 7-2 shows the range of the release concentration breakthrough curves for the monitoring wells for scenarios 1, 2, and 3.

Table 7-2. Range of Unit Concentrations of Release Concentration Breakthrough Curves

Well Name	Scenario	Minimum Unit Concentration	Maximum Unit Concentration	Weighted Average	Scenario 3
299-W9-2	1	0.000	0.000	0.000	0.000
	2	0.000	0.000	0.000	
299-W10-29	1	0.010	0.033	0.012	0.008
	2	0.010	0.036	0.012	
299-W10-30	1	0.001	0.007	0.004	0.001
	2	0.001	0.008	0.004	
299-W10-31	1	0.299	0.448	0.311	0.407
	2	0.299	0.457	0.313	

The release concentration breakthrough curves for scenario 3 (Figure 7-9) indicate that well 299-W10-31 has unit concentrations within the range of the unit concentrations detected in scenarios 1 and 2. The unit concentrations for wells 299-W9-2, 299-W10-29, and 299-W10-30 are at or near zero for scenario 3. The release time for scenario 3 (represented on the figure as arrival time year 0) corresponds to October 1, 2037.

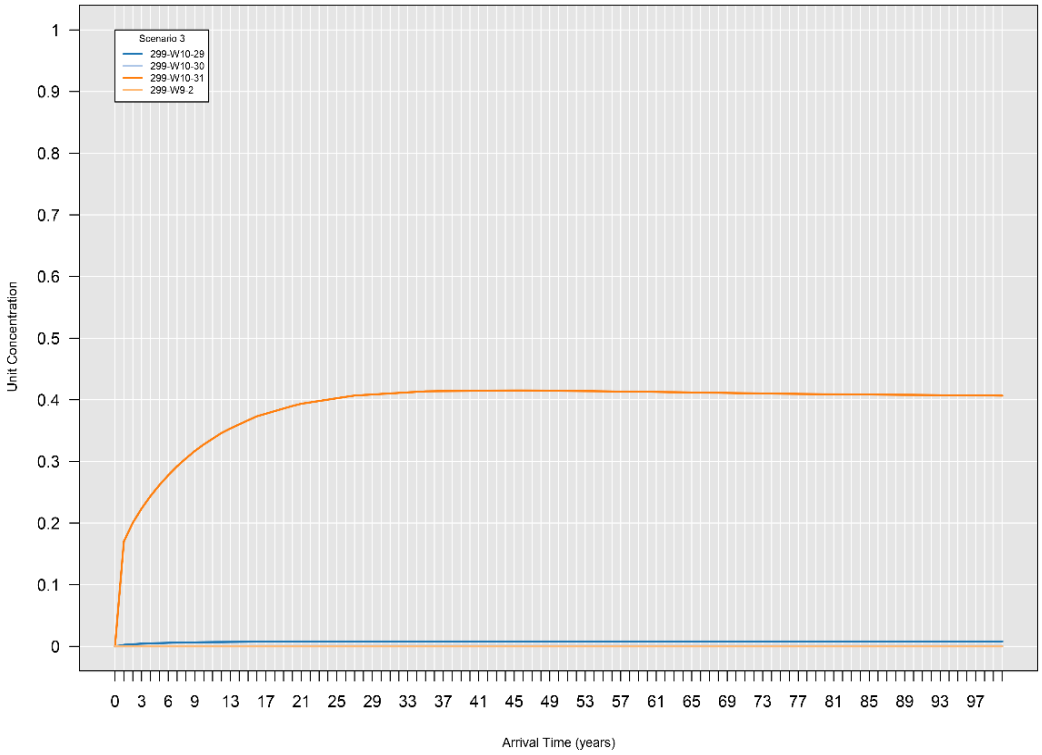


Figure 7-9. Release Concentration Breakthrough Curves at Monitoring Wells, Scenario 3

Figures 7-10 through 7-12 show plume maps of release unit concentrations based on transport modeling representing conditions at the end of the 200 West P&T system operations in 2037 for scenarios 1 and 2 and in 2137 for scenario 3. Figures 7-10 and 7-11 depict sub-scenario A for scenarios 1 and 2, which corresponds to the bold black lines on the breakthrough curves. Release unit plume maps for all sub-scenarios in scenarios 1 and 2 are included in Appendix B in Appendix G.

The release unit plume maps provide a visual representation of the release dispersion predicted by the transport modeling results. The release plumes are produced using a bilinear interpolation process within ArcGIS™ to smooth the grid block modeling results that are calculated on the 100 by 100 m (328 by 328 ft) CPGWM grid cells. This interpolation process is performed to depict a visually smooth transition between concentrations calculated for the model grid cells; the unit plume maps would have a blocky appearance if they represented only the outputs obtained directly from the model. This interpolation process does, however, result in some spread of the unit plumes, particularly at the margins, and some differences in the visual representation of the transport modeling results when compared to results of particle-tracking calculations. Differences between the results shown in the release concentration breakthrough curves and the release unit plume maps generally are a result of this interpolation.

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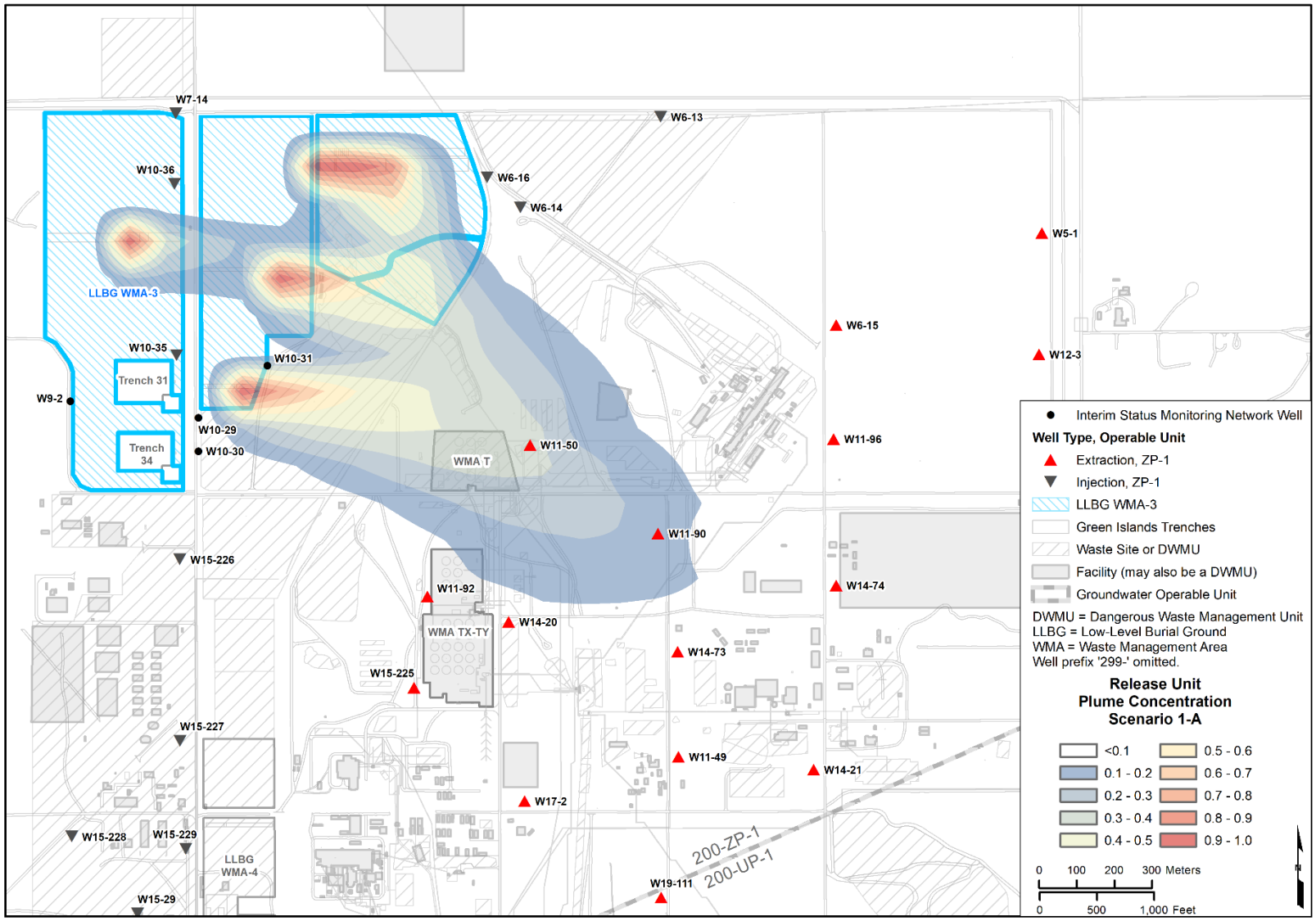

Figure 7-10. Release Unit Plume Map, Scenario 1, Sub-Scenario A

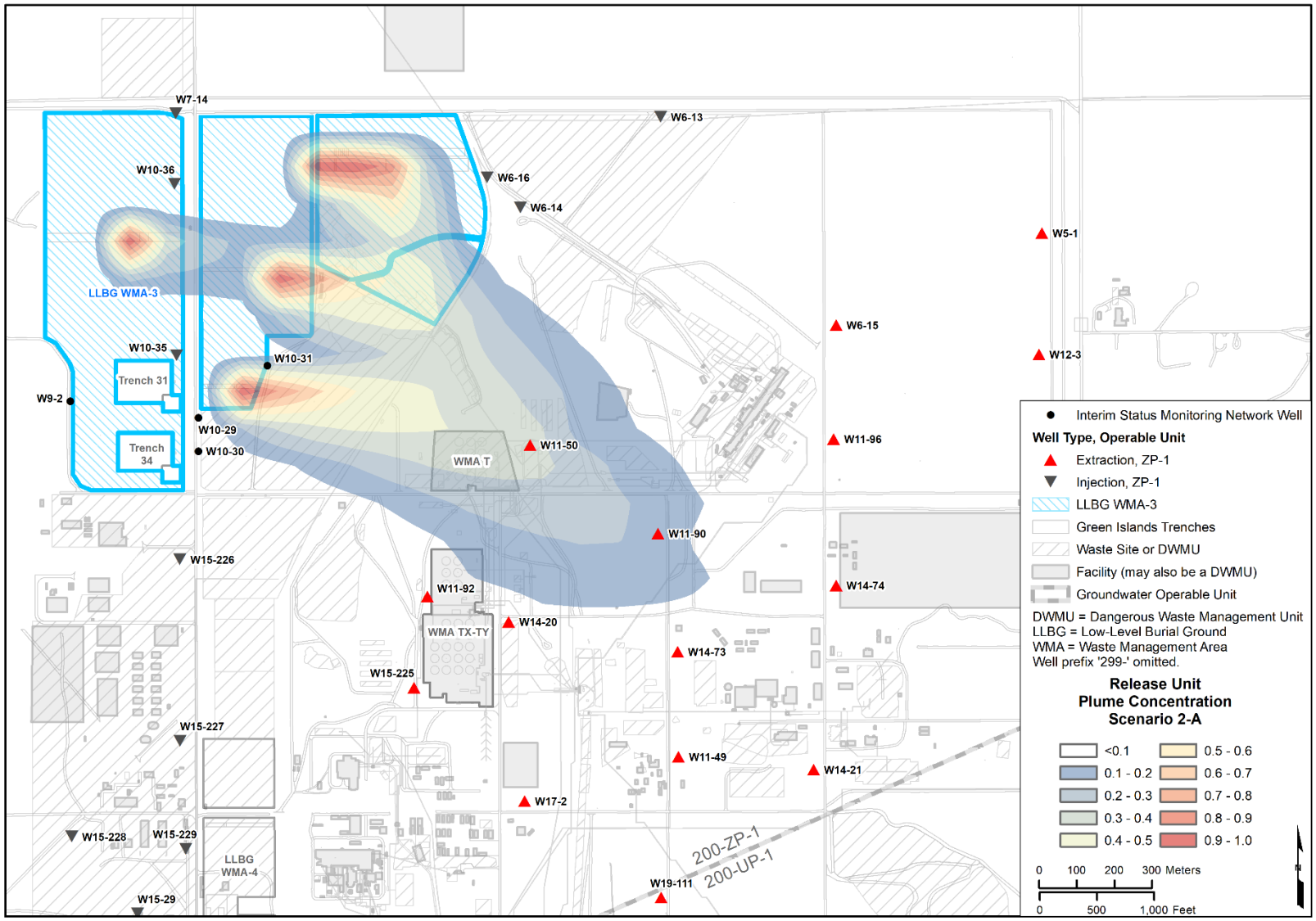

Figure 7-11. Release Unit Plume Map, Scenario 2, Sub-Scenario A

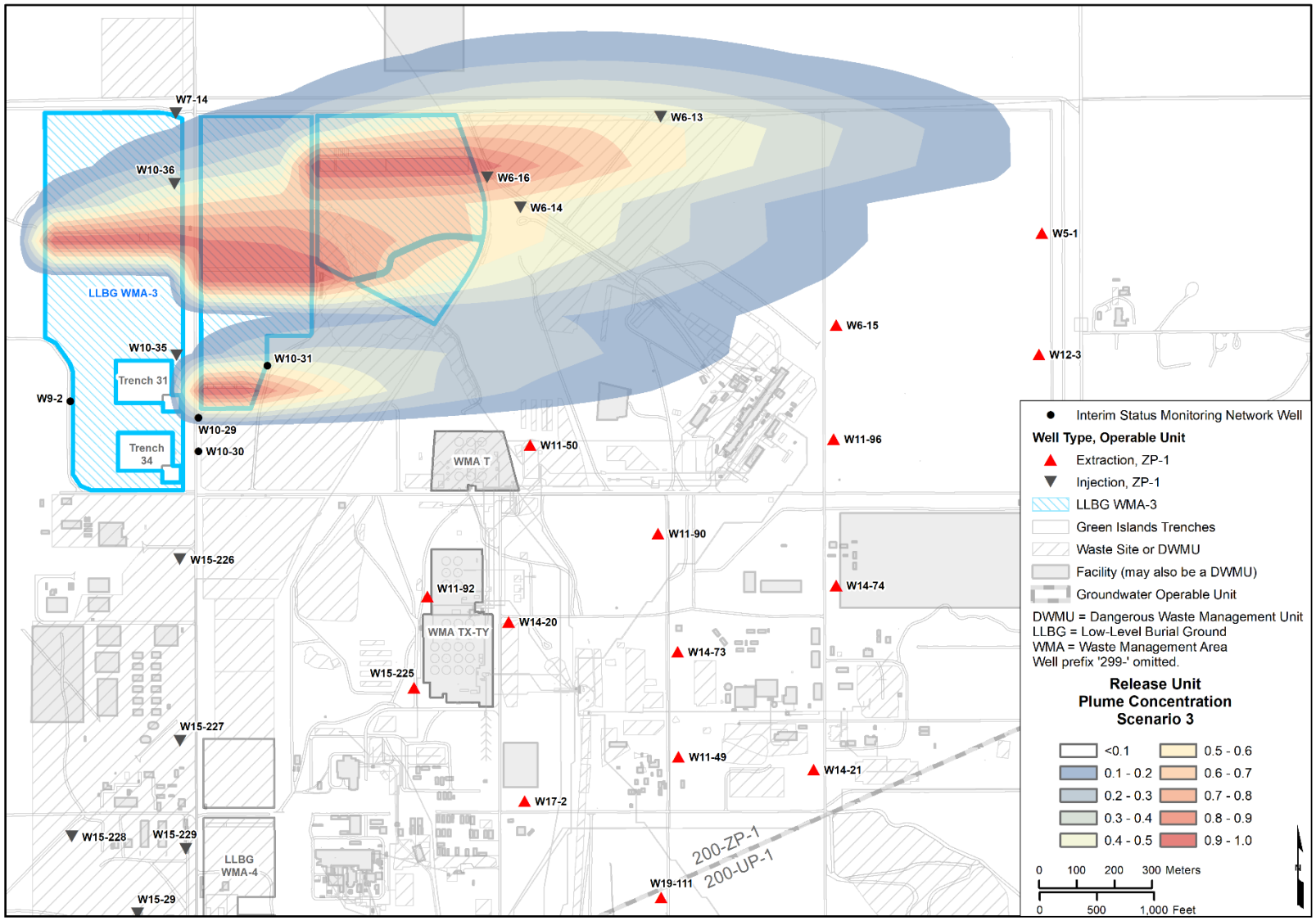

Figure 7-12. Release Unit Plume Map, Scenario 3

The release unit plume maps are one of the methods used in evaluating the robustness of the monitoring well network for coverage of the interpolated plume spread. However, because of the size of the model grid used in transport modeling and the plume spread caused by the interpolation between the nodes (centers) of the model cells, particle-tracking results are used in conjunction with the release unit plume maps for proper interpretation of model results.

Figures 7-10 through 7-12 show that well 299-W10-31 is generally within the unit plume but located in areas of low unit concentrations whereas wells 299-W-10-29 and 299-W10-30 are located outside or on the outer edges of the release unit plume. These conclusions are consistent with the conclusions based on the breakthrough curves.

7.2 Particle-Tracking and Relative Detectability Maps

Particle-tracking and relative detectability maps generated using particle-tracking calculations show for each scenario the overall distribution, given advection and dispersion, of a hypothetical release to the water table below LLBG WMA-3. For scenarios 1 and 2, the maps represent conditions in 2037; for scenario 3, the maps represent conditions in 2137.

Based on the calculations, particles released to the water table exhibited predominantly horizontal migration, with minor components of vertical migration in response to very limited infiltration from groundwater recharge and the operation of nearby extraction and injection wells.

Figures 7-13 and 7-14 show particle pathlines superimposed upon injected treated water dilution plume maps (created using transport modeling) for sub-scenario A of scenarios 1 and 2 (the most likely operating conditions). The dilution factor represents the simulated relative fraction of injected water from injection wells. Similar figures for all sub-scenarios in scenarios 1 and 2 are included in Appendix G. The particle-tracking map for scenario 3 (Figure 7-15) represents conditions after cessation of the 200 West P&T system operations and therefore has no injected treated water component.

The particle tracking indicates that the downgradient monitoring wells generally are beyond the extent of the release particle pathlines for all scenarios, although 299-W10-31 is within the pathlines after cessation of the 200 West P&T system operations (scenario 3). Well 299-W9-2 is upgradient in all scenarios.

Maps of relative detectability identify areas of the aquifer where a hypothetical release that impacts the water table beneath LLBG WMA-3 would be most likely to migrate and be detectable. Whereas particle-tracking maps present the results for each sub-scenario separately, the relative detectability maps evaluate the sub-scenarios together while accounting for the weighting (estimated relative probability) of the various operating scenarios.

As described in Section 6.2.2, the relative detectability was determined by first calculating, for each sub-scenario, the number of released particles that traversed each calculation subgrid cell. Particle count maps generated for each sub-scenario are included as Appendix A in Appendix G. Using the particle counts, relative detectability for each scenario was determined by computing a weighted sum of the particle counts for each individual cell for all sub-scenarios within each scenario using the weights shown in Table 5-1 to account for the estimated relative probability of each sub-scenario.

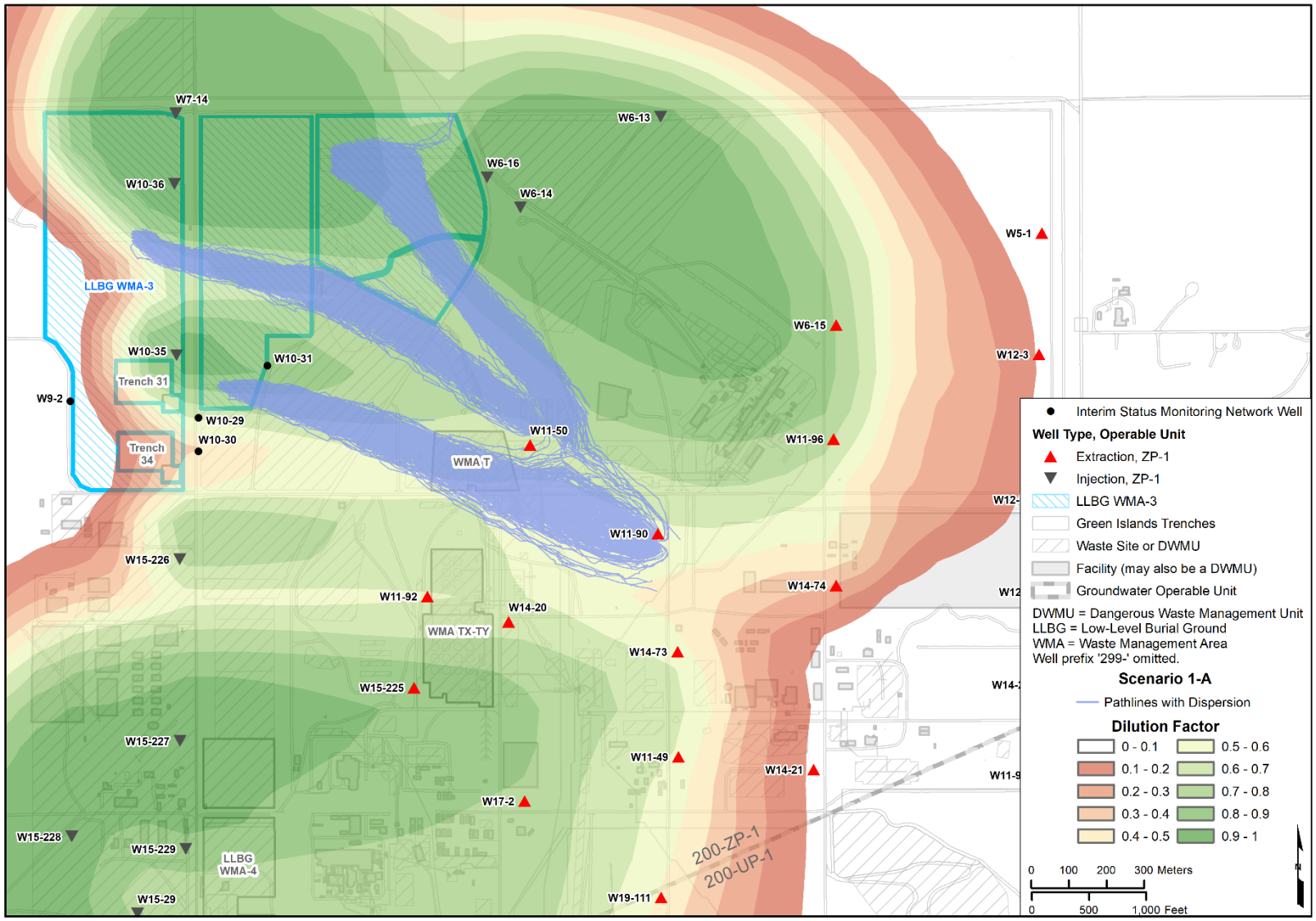

Figure 7-13. Particle Pathlines Superimposed on Injected Treated Water Dilution Plumes, Scenario 1, Sub-Scenario A

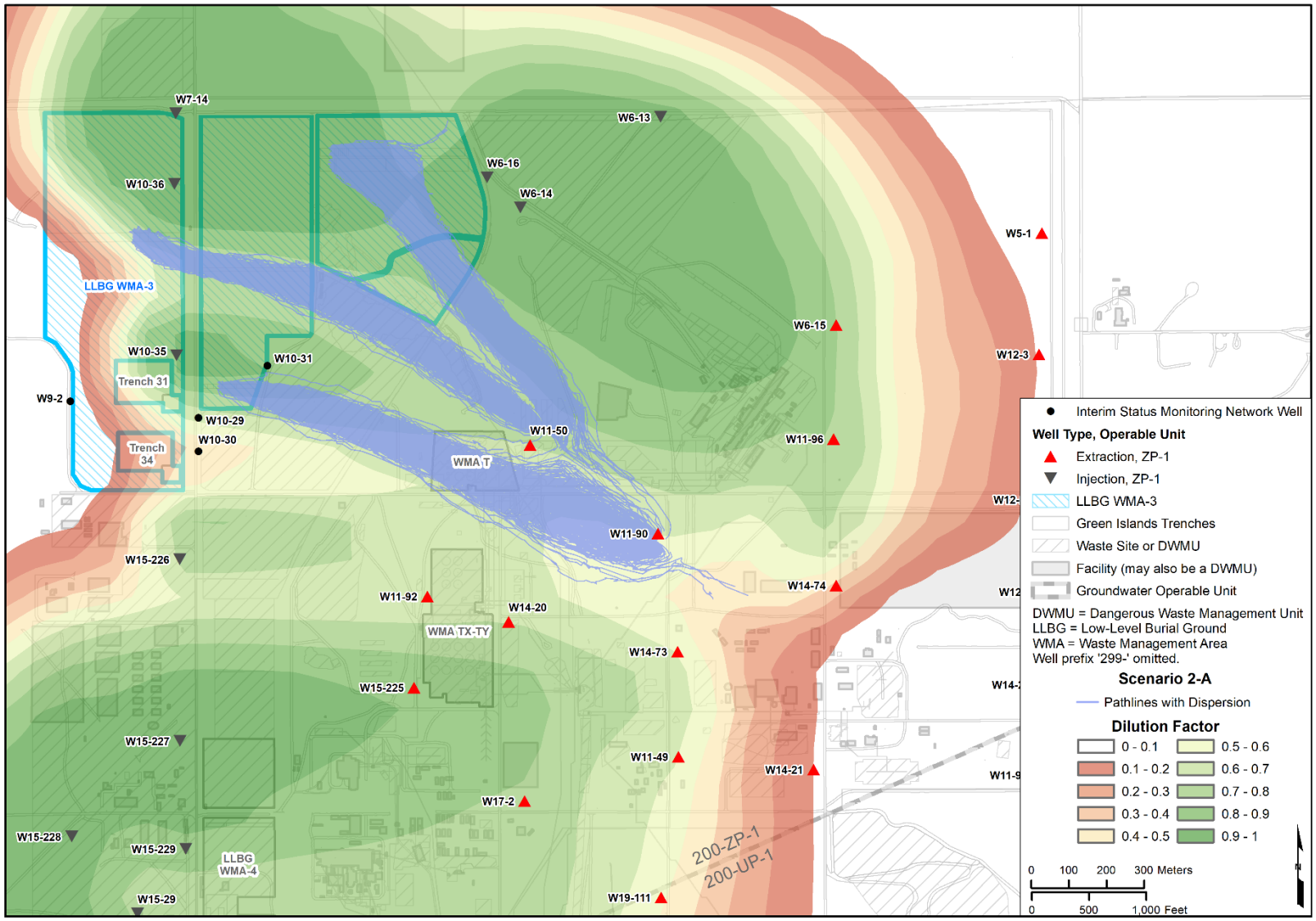

Figure 7-14. Particle Pathlines Superimposed on Injected Treated Water Dilution Plumes, Scenario 2, Sub-Scenario A

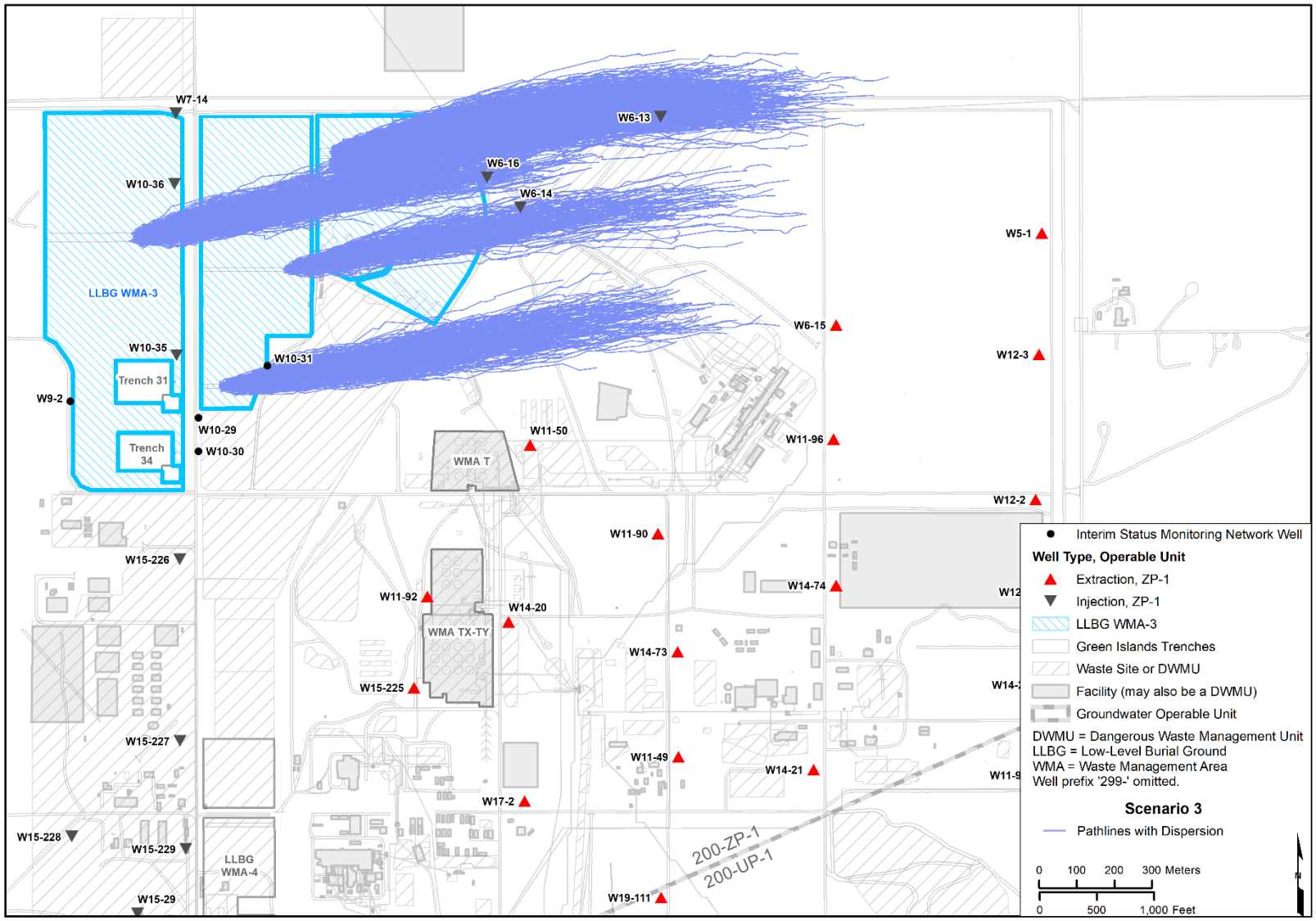

Figure 7-15. Particle Pathlines, Scenario 3

Figures 7-16 through 7-18 depict the relative detectability distribution for releases to the water table beneath the facility for scenarios 1, 2, and 3, respectively. The release distribution is color-coded to reflect the results of the weighted percent distribution of particle counts throughout the release pathline. Where the weighted percent distribution of particle counts is higher, the probability of release detection is also higher.

The relative detectability maps show existing downgradient groundwater monitoring wells are located beyond the extents of the detectable areas for all scenarios, with the exception of 299-W10-31, which is within the detectable area after the cessation of 200 West P&T system operations (scenario 3).
The relative detectability maps (as well as release unit plume maps [Figures 7-10 through 7-12] and particle-tracking maps [Figures 7-13 through 7-15]) show significant detectable areas where there are no downgradient monitoring wells, indicating the need for six new downgradient monitoring wells to monitor the full range of the detectable areas. Wells WMA-3_PW1, WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, WMA-3_PW5, and WMA-3_PW6 are proposed for the final status monitoring well network. The proposed locations for the wells are shown in Figures 7-16 through 7-18.

7.3 Breakthrough Curves for Proposed Wells

Using transport calculations, injected treated water dilution breakthrough curves and release concentration breakthrough curves were generated for each scenario and sub-scenario to evaluate the proposed wells, WMA-3_PW1, WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, WMA-3_PW5, and WMA-3_PW6. Figures 7-19 through 7-24 show injected treated water dilution breakthrough curves for the proposed wells for scenario 1. Table 7-3 shows the range of the injected treated water dilution breakthrough curves for the proposed well for scenarios 1 and 2. Figures 7-25 through 7-30 show release concentration breakthrough curves for the proposed wells for scenario 1. The injected treated water dilution breakthrough curves and release concentration breakthrough curves for scenario 2 for the proposed wells are included in Appendix G.

Results for scenario 2 were similar to the results for scenario 1. Similar to the curves for existing wells, the injected treated water breakthrough curves for the proposed wells indicate sensitivity to variations in 200 West P&T system injection operations. The release concentration breakthrough curves also indicate the potential for detecting releases from the facility are influenced by 200 West P&T system operations. Well WMA-3_PW1 shows significant sensitivity to 200 West P&T system operating conditions with unit concentrations ranging from almost 0.96 for sub-scenario R down to approximately 0.09 for sub-scenario H. The wells, in general are well located for detecting releases to the water table from the facility.

The release concentration breakthrough curves for scenario 3 for the proposed wells are shown in Figure 7-31. These curves indicate that proposed wells WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, and WMA-3_PW6 will be less likely to detect releases from the facility after cessation of the P&T system operations compared to during 200 West P&T system operations. Well WMA-3_PW5 will also be less likely to detect releases, although the decrease is not as significant. Table 7-4 shows the range of the release concentration breakthrough curves for the proposed wells for scenarios 1, 2, and 3.

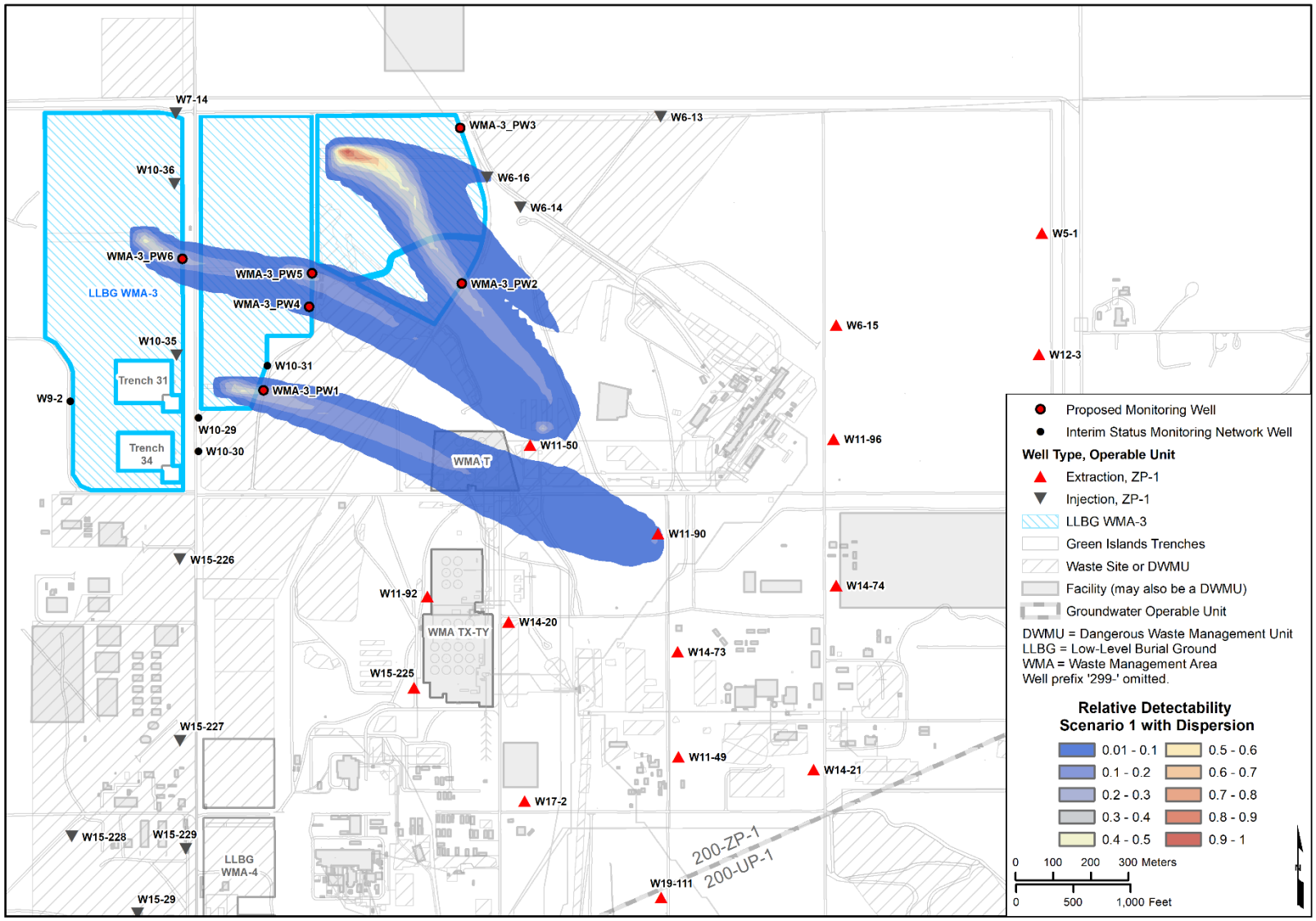

Figure 7-16. Relative Detectability of Release, Scenario 1

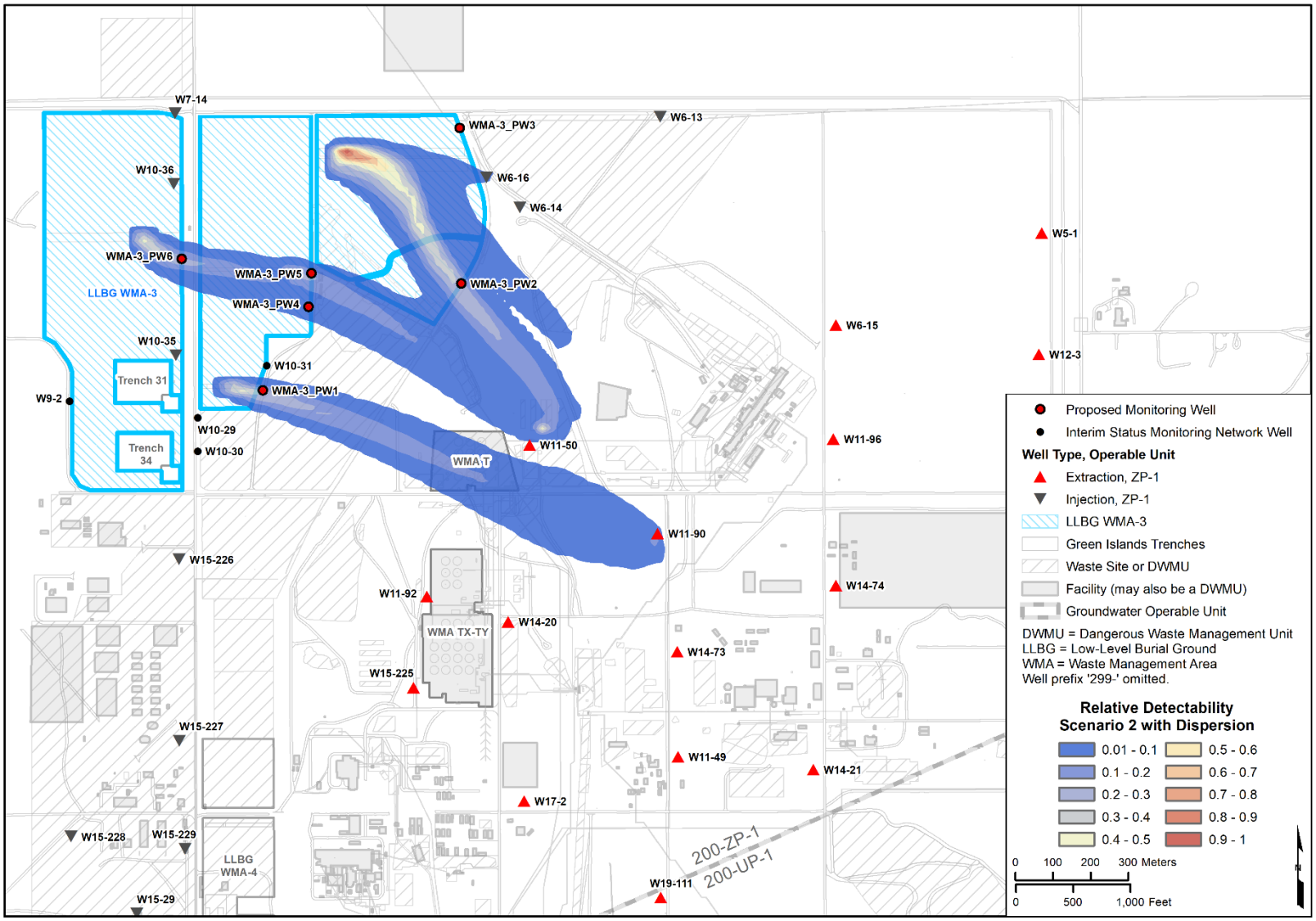

Figure 7-17. Relative Detectability of Release, Scenario 2

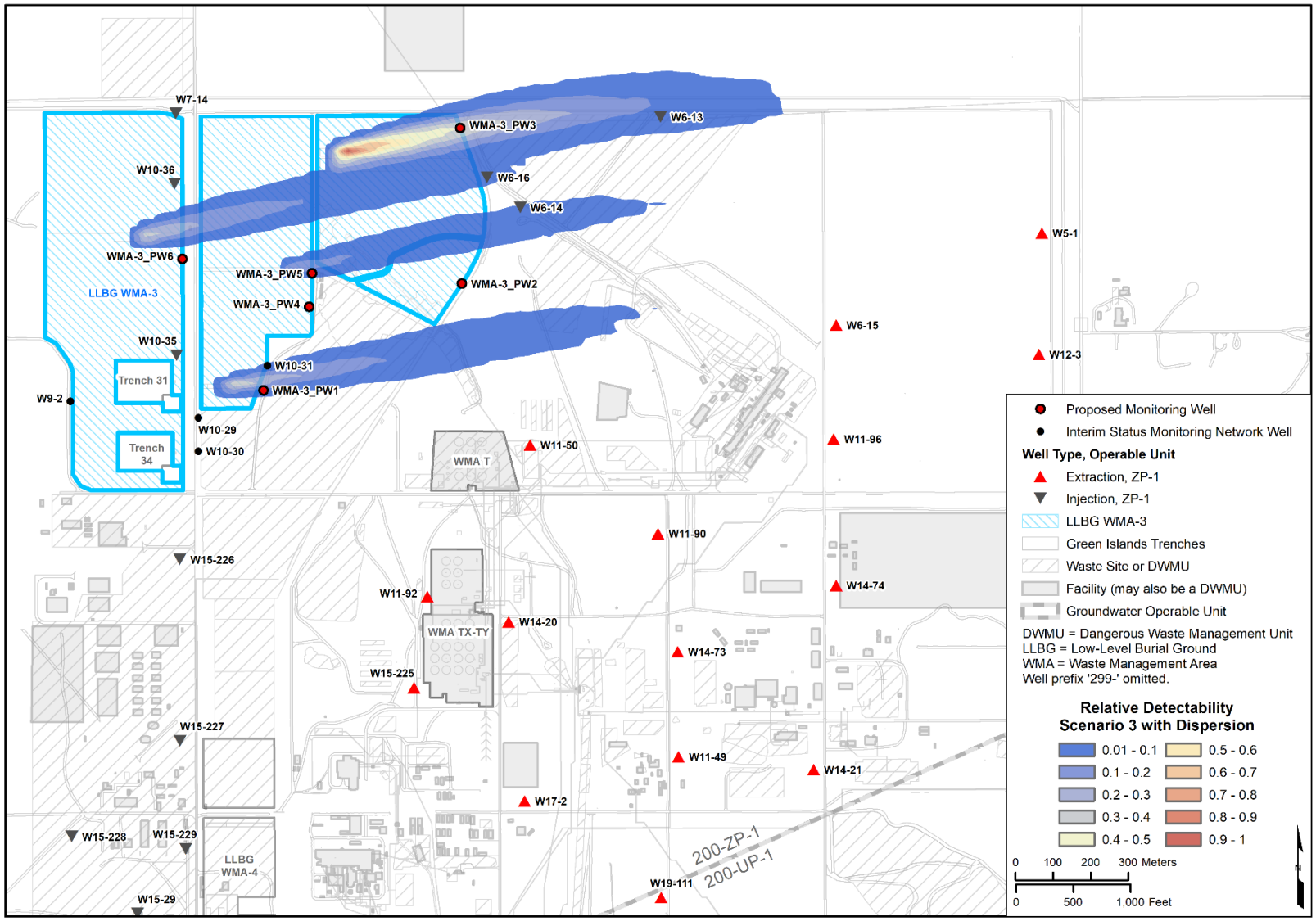

Figure 7-18. Relative Detectability of Release, Scenario 3

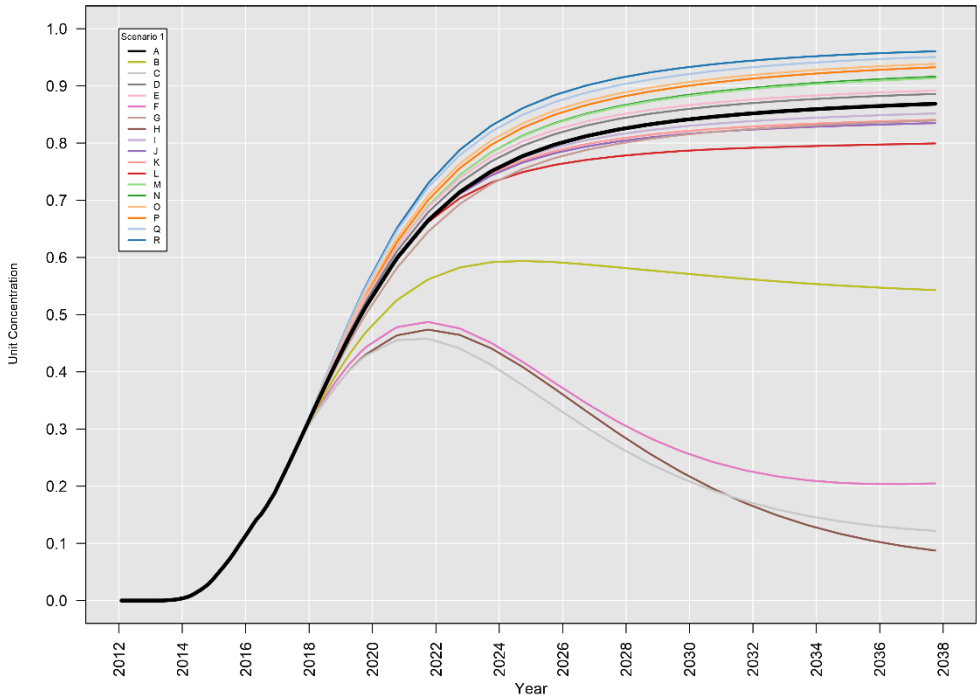

Figure 7-19. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW1

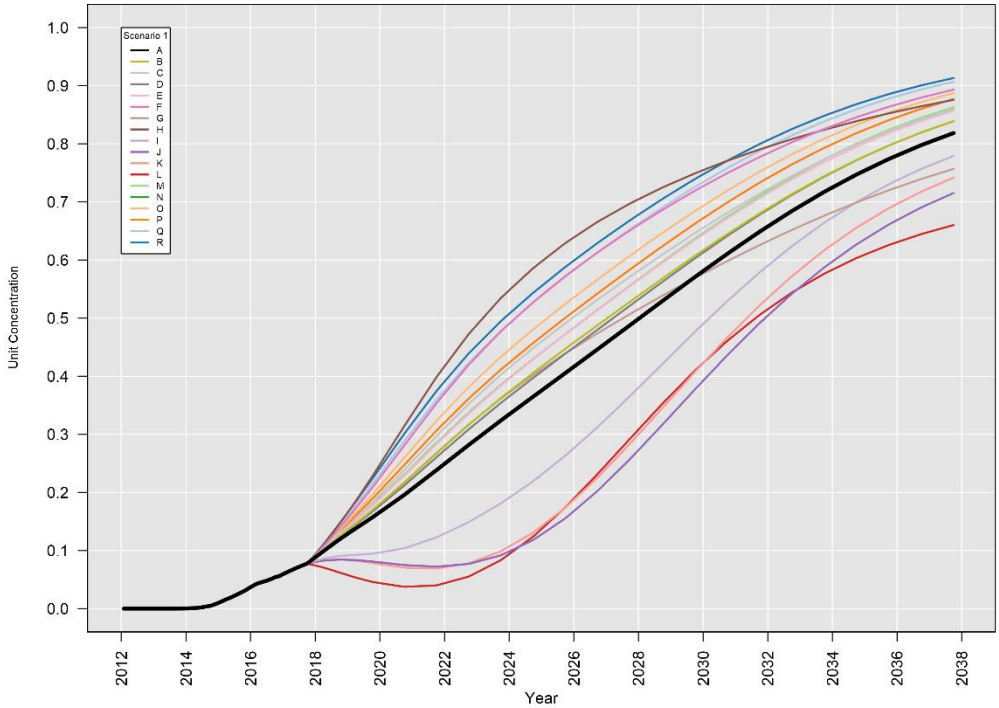

Figure 7-20. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW2

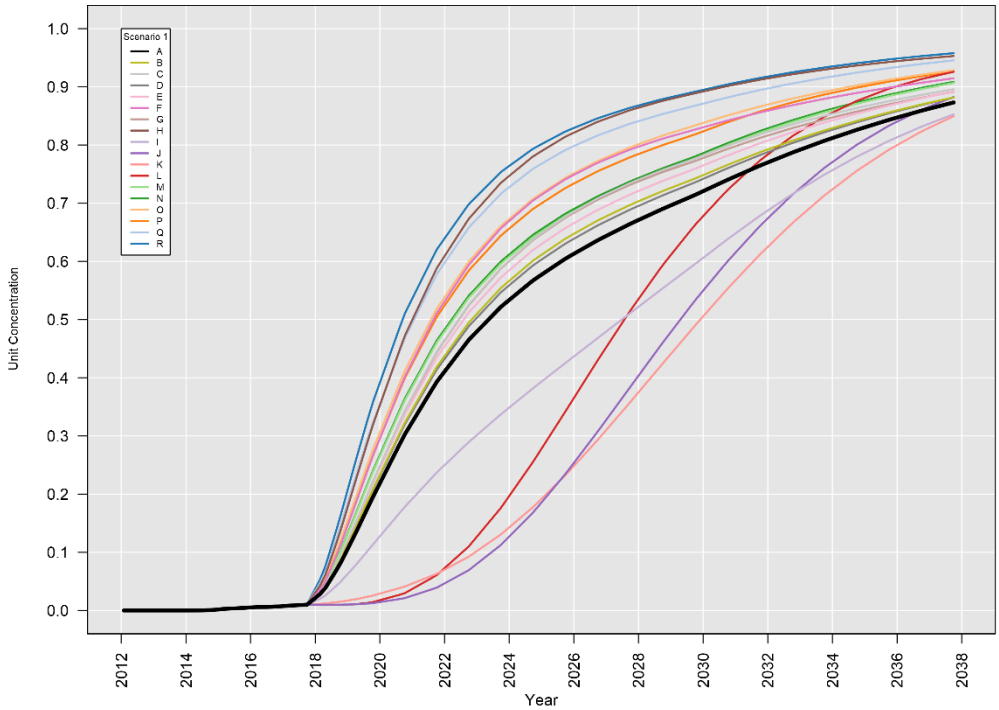

Figure 7-21. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW3

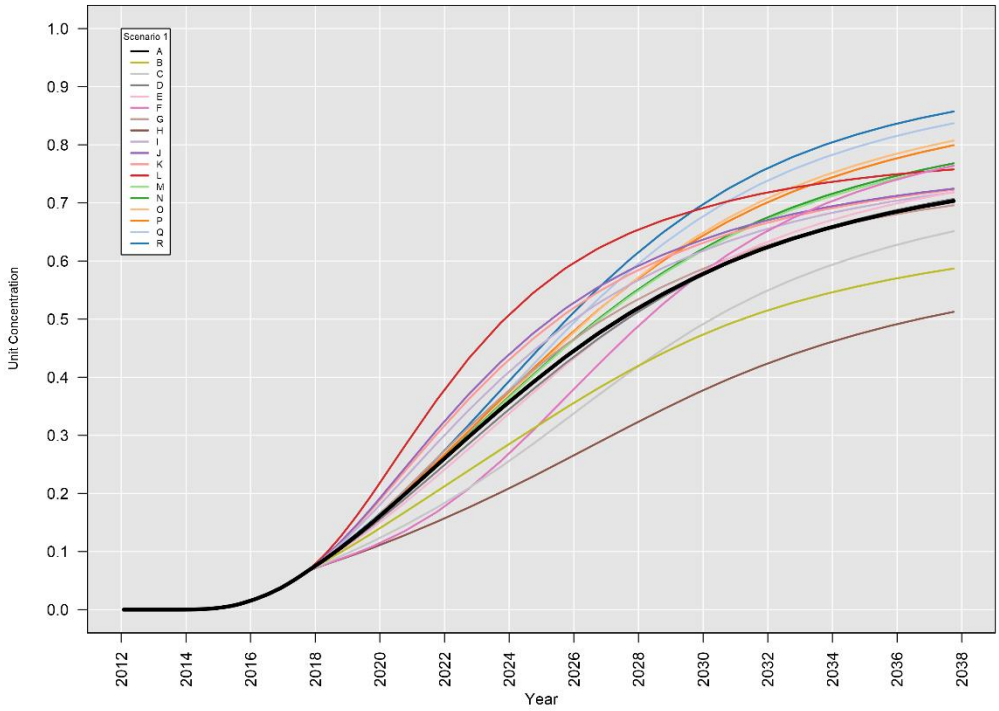

Figure 7-22. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW4

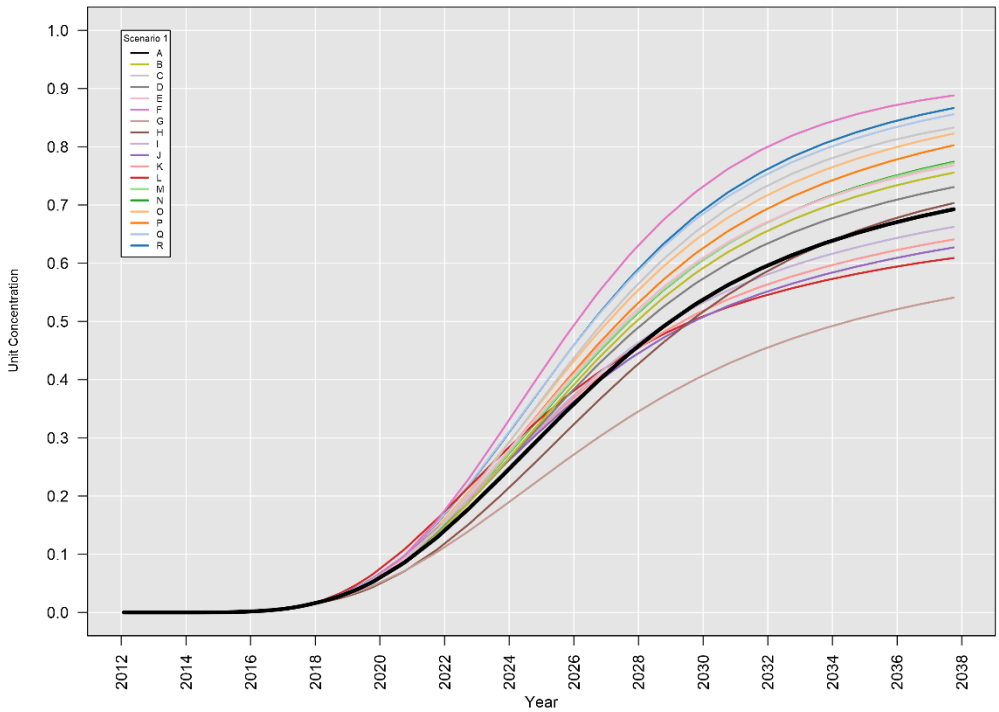

Figure 7-23. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW5

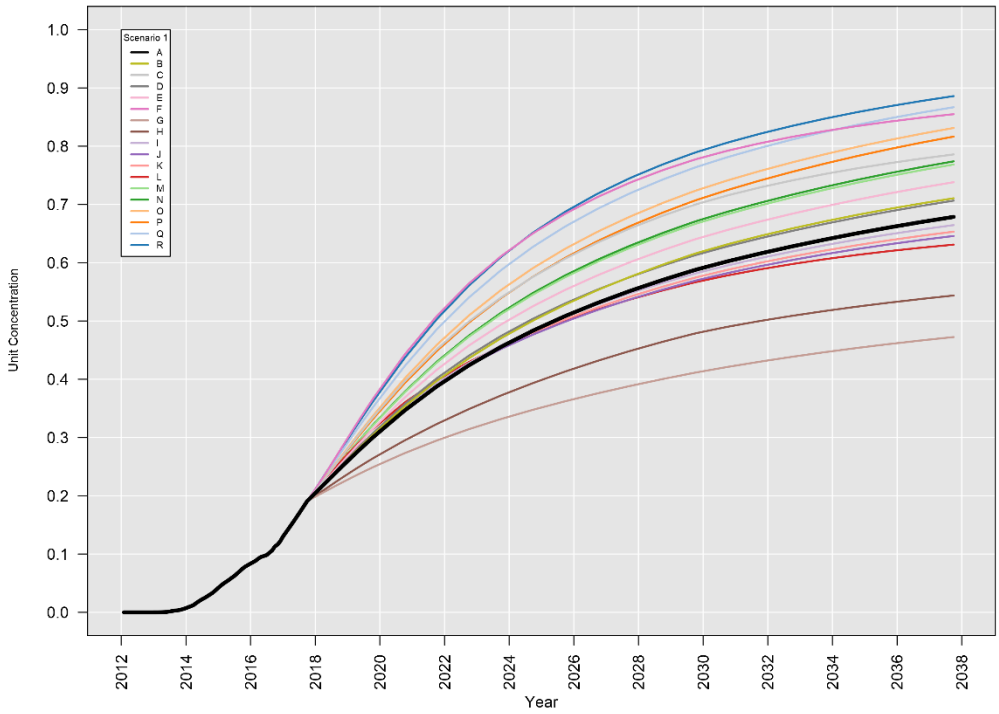

Figure 7-24. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW6

Table 7-3. Range of Unit Concentrations of Injected Treated Water Dilution Breakthrough Curves

Well Name	Scenario	Minimum Unit Concentration	Maximum Unit Concentration	Weighted Average
WMA-3_PW1	1	0.087	0.961	0.824
	2	0.087	0.961	0.834
WMA-3_PW2	1	0.660	0.913	0.825
	2	0.703	0.927	0.861
WMA-3_PW3	1	0.850	0.958	0.885
	2	0.878	0.964	0.902
WMA-3_PW4	1	0.513	0.857	0.713
	2	0.557	0.863	0.744
WMA-3_PW5	1	0.541	0.888	0.717
	2	0.577	0.907	0.754
WMA-3_PW6	1	0.472	0.886	0.703
	2	0.503	0.889	0.737

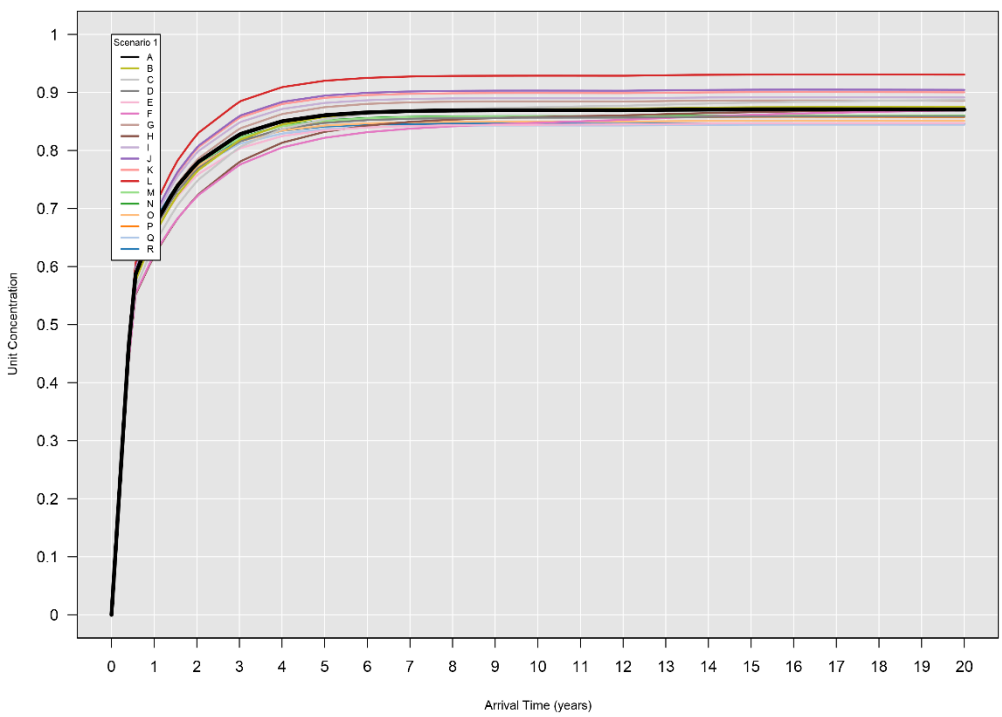

Figure 7-25. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW1

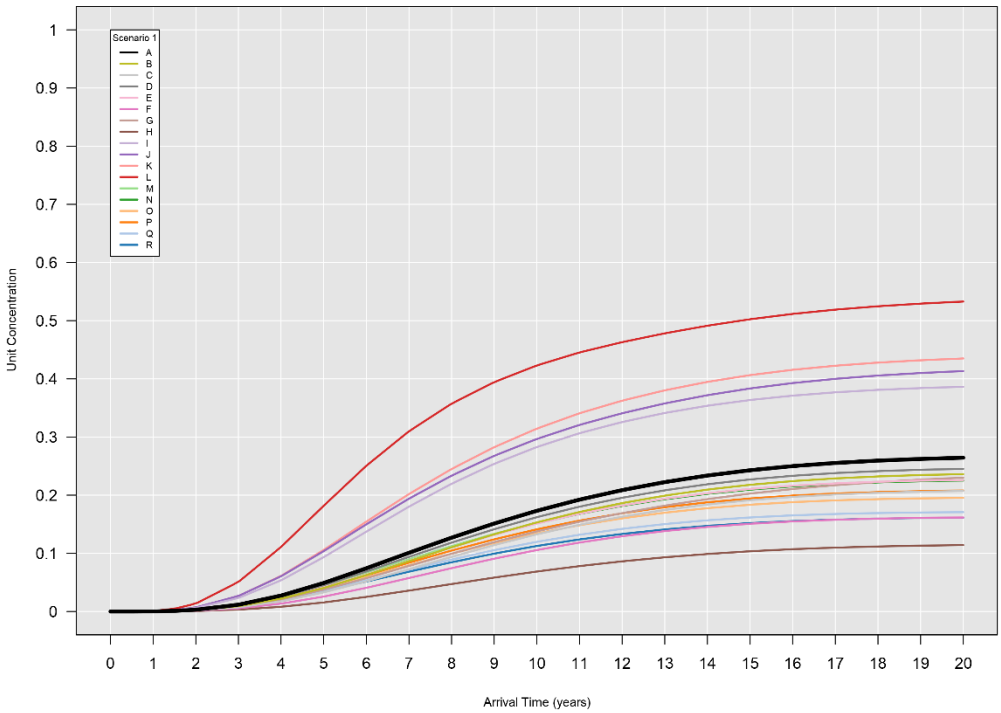

Figure 7-26. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA 3_PW2

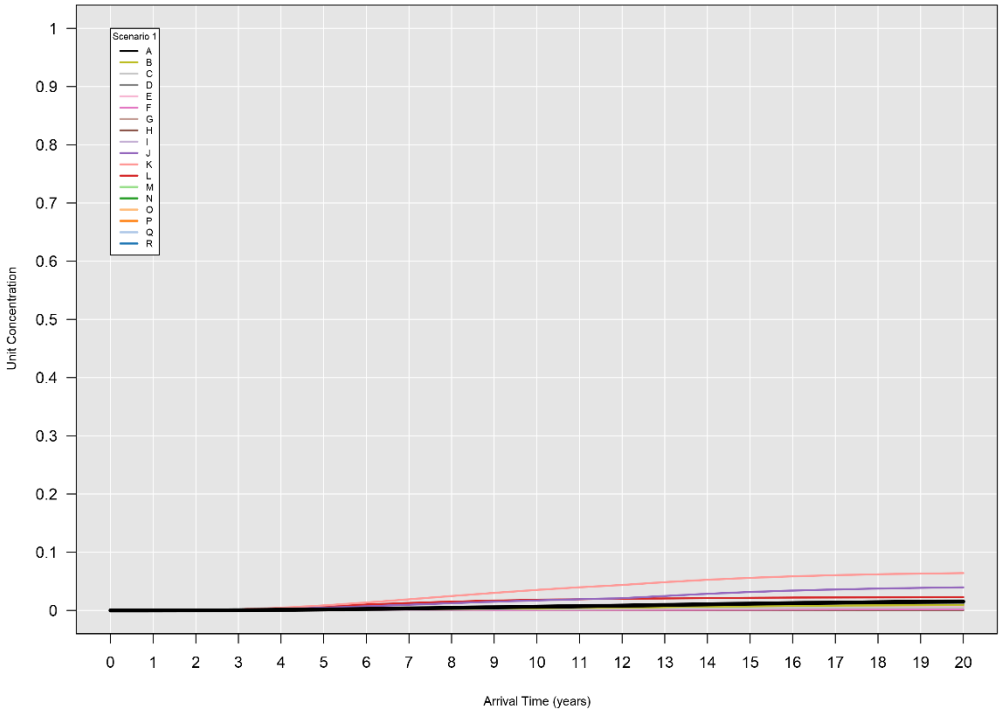

Figure 7-27. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW3

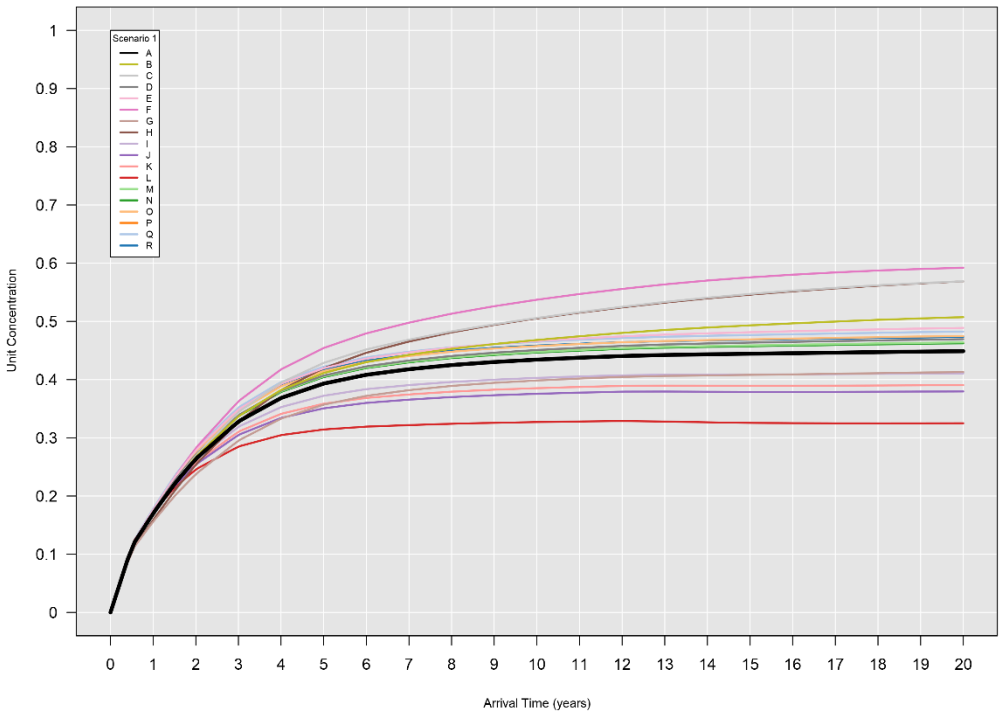

Figure 7-28. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW4

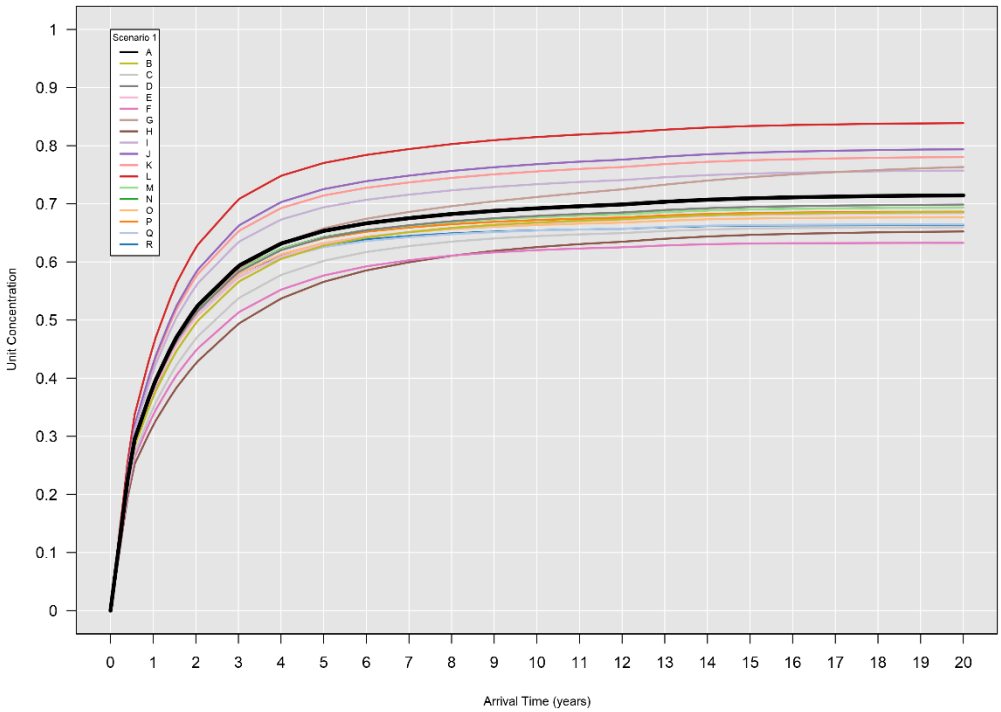

Figure 7-29. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW5

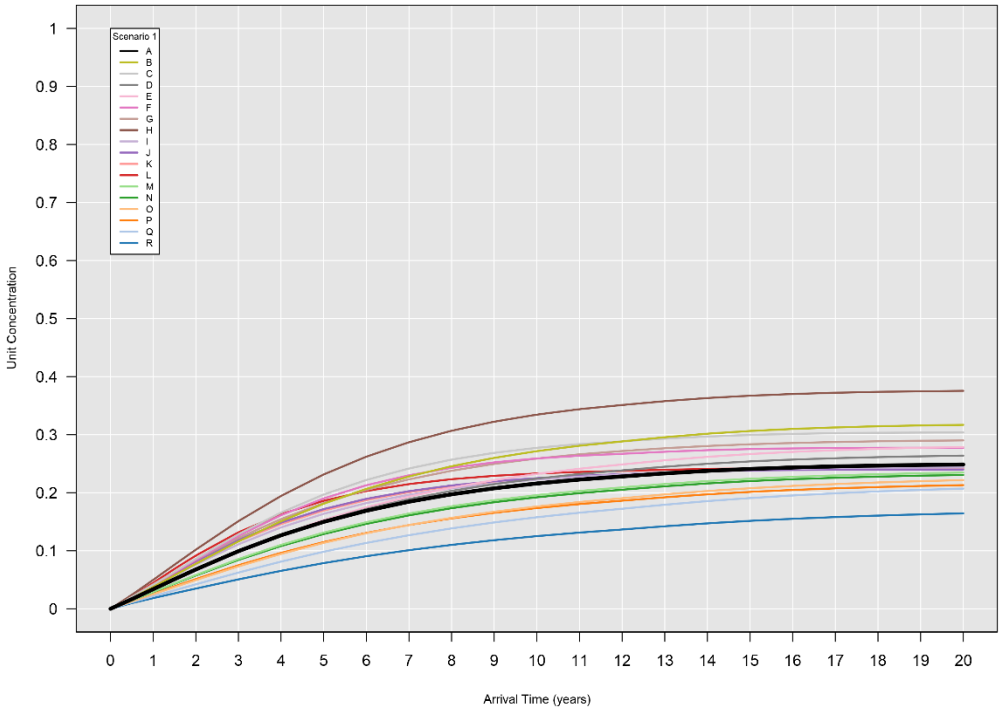

Figure 7-30. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-3_PW6

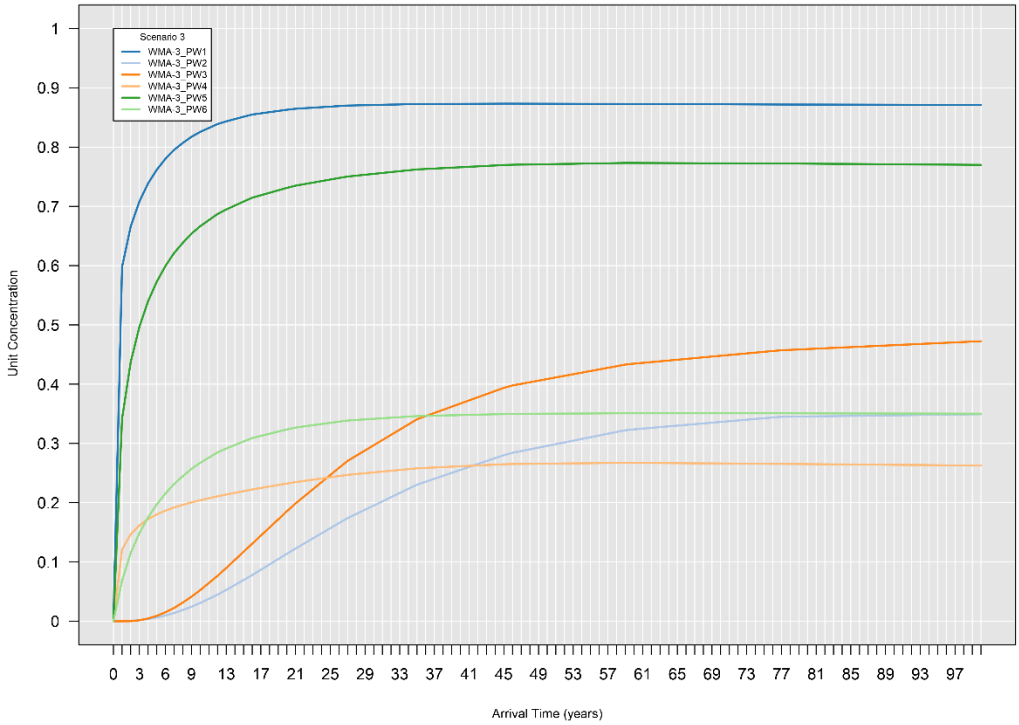

Figure 7-31. Release Concentration Breakthrough Curves, Scenario 3, Proposed Monitoring Wells WMA-3_PW1, WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, WMA-3_PW5 and WMA-3_PW6

Table 7-4. Range of Unit Concentrations of Release Concentration Breakthrough Curves

Well Name	Scenario	Minimum Unit Concentration	Maximum Unit Concentration	Weighted Average	Scenario 3
WMA-3_PW1	1	0.845	0.931	0.871	0.871
	2	0.844	0.930	0.870	
WMA-3_PW2	1	0.114	0.533	0.262	0.349
	2	0.108	0.532	0.257	
WMA-3_PW3	1	0.000	0.064	0.015	0.472
	2	0.000	0.061	0.013	
WMA-3_PW4	1	0.325	0.592	0.456	0.263
	2	0.328	0.596	0.460	
WMA-3_PW5	1	0.633	0.839	0.711	0.770
	2	0.630	0.836	0.708	
WMA-3_PW6	1	0.164	0.375	0.252	0.350
	2	0.164	0.372	0.249	

7.4 Modeling Conclusions

The proposed final status groundwater monitoring network for LLBG WMA-3 includes retaining existing upgradient well 299-W9-2 and existing downgradient well 299-W10-31. Wells not included in the final status monitoring network include existing downgradient wells 299-W10-29 and 299-W10-30. These wells are specific to the monitoring network for Trenches 31 and 34 and are not retained for the LLBG WMA-3 final status monitoring network. Six new monitoring wells (WMA-3_PW1, WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, WMA-3_PW5, and WMA-3_PW6) are proposed for the final status monitoring well network. The proposed final status monitoring network is based on the results of the simulation scenarios presented in Appendix G and summarized herein.

The simulations indicate that, under the scenarios evaluated, upgradient monitoring well 299-W9-2 along with the seven downgradient groundwater monitoring wells (299-W10-31, WMA-3_PW1, WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, WMA-3_PW5, and WMA-3_PW6) are well placed for detection of a release to the water table from LLBG WMA-3.

Figure 7-32 shows the final status monitoring network wells compared to the combined extents of relative detectability greater than 0.01 for scenarios 1, 2, and 3 from particle tracking and the combined extents of release unit plumes greater than 0.1 for sub-scenario A of scenarios 1 and 2, and scenario 3 from transport modeling.

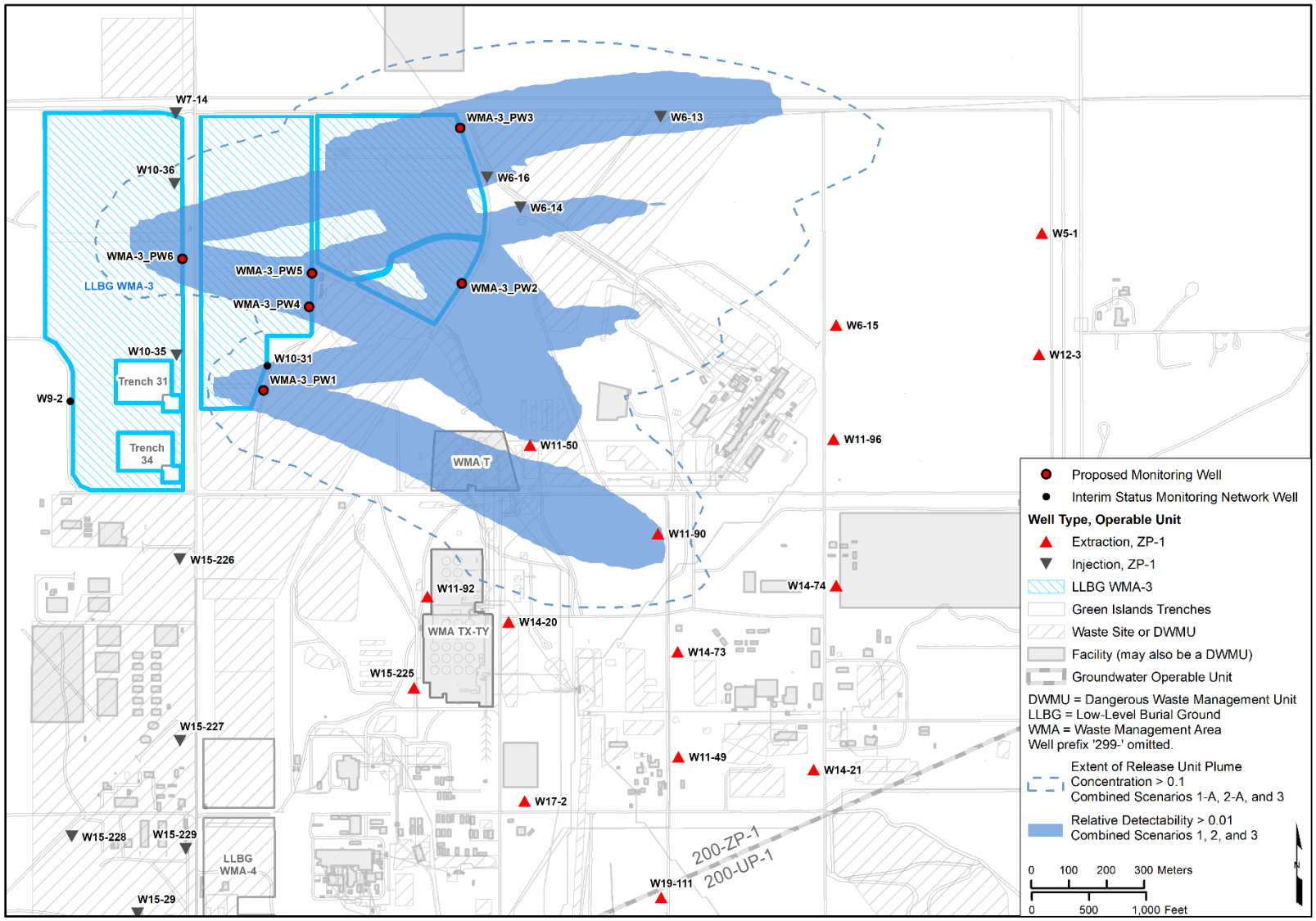

Figure 7-32. Proposed Final Status Groundwater Monitoring Network with Combined Results for Relative Detectability and Release Unit Plume

The release concentration breakthrough curves for the recommended downgradient monitoring network wells indicate a range of dilution of approximately 7%[1] to 100%[2] for release unit concentrations. After cessation of the 200 West P&T system operations (scenario 3), this dilution range becomes less than 13% to approximately 74%[3]. Additional discussion regarding each well is provided in Section 9.3.

[1] 7% dilution corresponds to a release unit concentration of approximately 0.93 at monitoring well WMA-3_PW1 for sub-scenario L of scenario 1 (Figure 7-25).

[2] Approximately 100% dilution corresponds to a release unit concentration of 0.00 at monitoring well WMA-3_PW3 for sub-scenario H of scenario 1 (Figure 7-27).

[3] 13%-74% dilution for scenario 3 corresponds to a release unit concentration of more than 0.87 and of approximately 0.26 for wells WMA-3_PW1 and WMA-3_PW4, respectively (Figure 7-31).

8 Identification of Site-Specific Monitoring Constituents

An evaluation of the waste constituents associated with the LLBG unit group (Operating Unit 17), which includes LLBG WMA-3, was performed to identify the proposed groundwater monitoring constituents to include in the final status groundwater monitoring program. The evaluation process and proposed monitoring constituents are summarized in this chapter and detailed in ECF-HANFORD-17-0233 (Appendix B).

8.1 Selection Process for Monitoring Constituents

The waste constituents associated with LLBG WMA-3 are the dangerous wastes that are identified in the Hanford Facility RCRA Permit Part A Permit Application for LLBG. These wastes were used to identify potential monitoring constituents. Potential monitoring constituents underwent evaluation to identify the proposed monitoring constituents to be monitored under the final status permit.

The evaluations were performed in accordance with the summary descriptions provided in Sections 8.1 and 8.2. Additional details of the methodology are provided in Chapter 3 of Appendix B with assumptions documented in Chapter 4 of Appendix B.

8.1.1 Hanford Facility RCRA Permit Part A Form Dangerous Wastes

The Hanford Facility RCRA Permit Part A Application for LLBG identifies the dangerous waste codes associated with the unit, which includes LLBG WMA-3. A list of dangerous wastes and their corresponding Chemical Abstracts Service numbers was compiled using the waste codes presented in Table 2-2.

The specified dangerous wastes were screened to identify mobile constituents by comparing literature reference values for constituent distribution coefficients (K_d) to a Hanford Site-derived K_d value of 0.8 mL/g that was developed and applied to a known mobile constituent in Hanford Site vadose soils (hexavalent chromium) (Section 6.1 in ECF-Hanford-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area*). Constituents with a $K_d \leq 0.8$ mL/g were identified as mobile constituents and further evaluated as potential monitoring constituents (Tables 1 and 3 in Appendix B). If no reference K_d value was available for a constituent, the constituent was conservatively retained for further evaluation as a potential monitoring constituent.

8.1.2 Identification of Potential Monitoring Constituents Already Prescribed for Monitoring at LLBG

Ecology Letter 16-NWP-143 provided direction for preparation of documents to support the final status permit revision at LLBG units containing dangerous wastes. The letter directed that monitoring for WAC 173-303-110(3)(c) and (7) constituents would be performed for 1 year. WAC 173-303-110(3)(c) references Ecology Publication No. 97-407, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*, and WAC 173-303-110(7) references Appendix 5 of Ecology Publication No. 97-407. Because the waste constituents identified in Appendix 5 of Ecology Publication No. 97-407 will be included for background monitoring at the LLBG under the final status permit, the potential monitoring constituents that are also listed in Appendix 5 of Ecology Publication No. 97-407 were identified as proposed monitoring constituents without evaluation or screening.

8.1.3 Final Monitoring Constituent Evaluation

The constituents retained as potential monitoring constituents in Sections 8.1.1 and 8.1.2 were compiled for the final evaluation described in this section. A final evaluation identified potential monitoring

constituents to be included as proposed monitoring constituents to detect and monitor wastes from LLBG WMA-3 that impact groundwater. The evaluation was performed as follows:

- Evaluation of physical properties. Potential monitoring constituents that are gases were removed from consideration.
- Identification of related chemicals (e.g., parent compounds and isomers) that were already identified as proposed monitoring constituents. Such potential monitoring constituents were evaluated on a case-by-case basis.
- Availability of analysis. The potential monitoring constituents that are not routinely analyzed by commercial laboratories were removed from consideration.

Potential monitoring constituents that were not excluded due to physical property, analysis by related chemicals, or unavailability of analysis were identified as proposed monitoring constituents. These proposed monitoring constituents, combined with the proposed monitoring constituents from the evaluation in Section 8.1.2, comprise the proposed monitoring constituents for the LLBG unit, as applicable.

8.2 Results of Selection of Groundwater Monitoring Constituents

Based on the evaluation of the dangerous wastes identified from the LLBG Part A Permit Application, 140 waste constituents are identified as proposed monitoring constituents to detect and monitor any groundwater impacts from hypothetical dangerous waste releases at LLBG (Table 8-1). LLBG WMA-3 was part of the LLBG; therefore, the identified waste constituents will be monitored at LLBG WMA-3. Details of the constituent screening and selection process outcomes are provided in Chapter 7 of Appendix B of this document.

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
1-Butanol (n-Butyl alcohol)	71-36-3
1-Naphthylamine	134-32-7
1,1-Dichloroethane	75-34-3
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4
1,1,1-Trichloroethane	71-55-6
1,1,1,2-Tetrachloroethane	630-20-6
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
1,1,2-Trichloroethane	79-00-5
1,1,2,2-Tetrachloroethane	79-34-5
1,2-Dibromo-3-chloropropane	96-12-8
1,2-Dibromoethane	106-93-4
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
1,2-Dichloroethane	107-06-2
1,2-Dichloropropane	78-87-5
1,2-Diphenylhydrazine	122-66-7
1,2,4,5-Tetrachlorobenzene	95-94-3
1,4-Dichlorobenzene	106-46-7
1,4-Dioxane	123-91-1
1,4-Naphthoquinone	130-15-4
2-Acetylaminofluorene	53-96-3
2-Butanone (Methyl ethyl ketone)	78-93-3
2-Chloroethyl vinyl ether	110-75-8
2-Chlorophenol	95-57-8
2-Methylphenol (o-Cresol)	95-48-7
2-Naphthylamine	91-59-8
2-Nitropropane	79-46-9
2-Picoline	109-06-8
2-Propanone (Acetone)	67-64-1
2,3,4,6-Tetrachlorophenol	58-90-2
2,4-D (2,4-Dichlorophenoxyacetic acid)	94-75-7
2,4-Dichlorophenol	120-83-2
2,4-Dimethylphenol	105-67-9
2,4-Dinitrophenol	51-28-5
2,4-Dinitrotoluene	121-14-2
2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)	93-76-5
2,4,5-TP Silvex (2-(2,4,5-trichlorophenoxy)propionic acid)	93-72-1
2,4,6-Trichlorophenol	88-06-2
2,6-Dichlorophenol	87-65-0
2,6-Dinitrotoluene	606-20-2
3-Methylcholanthrene	56-49-5

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
3-Methylphenol (m-Cresol)	108-39-4
3,3′-Dichlorobenzidine	91-94-1
3,3′-Dimethylbenzidine	119-93-7
4,4'-Methylenebis (2-chloroaniline)	101-14-4
4,6-Dinitro-o-cresol (4,6-Dinitro-2-methyl phenol)	534-52-1
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	59-50-7
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1
4-Methylphenol (p-cresol)	106-44-5
5-Nitro-o-toluidine	99-55-8
7,12-Dimethylbenz[a]anthracene	57-97-6
Acetonitrile (Methyl cyanide)	75-05-8
Acetophenone	98-86-2
Acrolein	107-02-8
Acrylamide	79-06-1
Acrylonitrile	107-13-1
alpha, alpha-Dimethylphenethylamine	122-09-8
Aniline	62-53-3
Benzene	71-43-2
Benzyl chloride	100-44-7
Bis(2-chloro-1-methylethyl) ether (2,2'-Oxybis(1-chloropropane))	108-60-1
Bis(2-chloroethoxy)methane	111-91-1
Bis(2-chloroethyl)ether	111-44-4
Bromoform	75-25-2
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chlorobenzilate	510-15-6
Chloroform	67-66-3

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
Cyclohexane	110-82-7
Cyclohexanone	108-94-1
Diallate	2303-16-4
Dichlorodifluoromethane	75-71-8
Diethyl phthalate	84-66-2
Dimethoate	60-51-5
Dimethyl phthalate	131-11-3
Disulfoton	298-04-4
Ethyl acetate	141-78-6
Ethyl ether	60-29-7
Ethyl methacrylate	97-63-2
Ethyl methanesulfonate	62-50-0
Ethylbenzene	100-41-4
Famphur	52-85-7
Formaldehyde	50-00-0
Formic acid	64-18-6
Hexachlorophene	70-30-4
Hexachloropropene	1888-71-7
Hydrazine	302-01-2
Isobutanol (Isobutyl alcohol)	78-83-1
Isodrin	465-73-6
Isopropylbenzene	98-82-8
Isosafrole	120-58-1
Kepone	143-50-0
m-Dichlorobenzene	541-73-1
Methacrylonitrile	126-98-7
Methanol	67-56-1
Methapyrilene	91-80-5
Methyl bromide (Bromomethane)	74-83-9

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
Methyl chloride (Chloromethane)	74-87-3
Methyl iodide (Iodomethane)	74-88-4
Methyl methacrylate	80-62-6
Methyl parathion	298-00-0
Methylene bromide (Dibromomethane)	74-95-3
Methylene chloride	75-09-2
Nitrobenzene	98-95-3
Nitroglycerine	55-63-0
n-Nitrosodiethylamine	55-18-5
n-Nitrosodimethylamine	62-75-9
n-Nitrosodi-n-butylamine	924-16-3
n-Nitroso-di-n-dipropylamine (n-Nitrosodipropylamine)	621-64-7
n-Nitrosopiperidine	100-75-4
n-Nitrosopyrrolidine	930-55-2
O,O-Diethyl-O-pyrazinylthiophosphate	297-97-2
o-Toluidine	95-53-4
p-(Dimethylamino)azobenzene	60-11-7
Parathion	56-38-2
p-Chloroaniline (4-Chloroaniline)	106-47-8
Pentachlorobenzene	608-93-5
Pentachloroethane	76-01-7
Pentachloronitrobenzene	82-68-8
Pentachlorophenol	87-86-5
Phenacetin	62-44-2
Phenol	108-95-2
Phorate	298-02-2
p-Nitroaniline (4-Nitroaniline)	100-01-6
p-Nitrophenol (4-Nitrophenol)	100-02-7

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
Pronamide	23950-58-5
Propionitrile (Ethyl cyanide)	107-12-0
Pyridine	110-86-1
Safrole	94-59-7
sym-Trinitrobenzene	99-35-4
Tetrachloroethene	127-18-4
Tetraethyl dithiopyrophosphate	3689-24-5
Tetrahydrofuran	109-99-9
Thiophenol	108-98-5
Toluene	108-88-3
trans-1,2-Dichloroethylene	156-60-5
Trichloroethene (TCE)	79-01-6
Trichlorofluoromethane	75-69-4
Vinyl chloride (Chloroethene)	75-01-4
Xylenes (total)	1330-20-7

CAS = Chemical Abstracts Service

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9 Groundwater Monitoring

This chapter includes a description of the proposed final status groundwater monitoring program and identifies the monitoring network, constituents to be sampled and analyzed, and the sample frequency. A detailed groundwater monitoring plan will include corresponding details (e.g., sampling protocols, quality assurance project plan) necessary to meet the requirements of WAC 173-303-806(4)(xx)(E) and (F)(I) and (II).

9.1 Final Status Groundwater Monitoring Program Determination

The appropriate groundwater monitoring program (i.e., detection monitoring, compliance monitoring, corrective action monitoring) is determined using the requirements in WAC 173-303-645(2)(a). If there is no statistically significant evidence of a release (contamination) at the point of compliance, the DWMU is monitored under WAC 173-303-645(9), "Detection Monitoring Program." If groundwater monitoring has shown statistically significant evidence of a release (contamination) at the point of compliance, the DWMU is monitored under WAC 173-303-645(10), "Compliance Monitoring Program." If the groundwater protection standard (which may be defined at the time of permit issuance, or when dangerous constituents from a regulated unit have been detected [WAC 173-303-645(3)]) is exceeded, a corrective action program is implemented and the DWMU is monitored under WAC 173-303-645(11), "Corrective Action Program."

To date, a release to the environment (statistically significant evidence of contamination at the point of compliance) has not been observed at LLBG WMA-3. Therefore, LLBG WMA-3 will be in detection monitoring under WAC 173-303-645(9) when LLBG WMA-3 becomes a final status closure unit group in Revision 9 of the Hanford Facility Dangerous Waste Permit.

9.2 Point of Compliance Monitoring

The point of compliance is defined in WAC 173-303-645(6)(a) as "…a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units." WAC 173-303-645(6)(b) further states, "The waste management area is the limit projected in the horizontal plane of the area on which waste will be placed during the active life of a regulated unit. The waste management area includes horizontal space taken up by any liner, dike, or other barrier designed to contain waste in a regulated unit. If the facility contains more than one regulated unit, the waste management area is described by an imaginary line circumscribing the several regulated units."

The results of the modeling described in Chapter 7 indicate that the locations of the seven downgradient wells proposed for the monitoring well network (existing well 299-W10-31 and proposed wells WMA-3_PW1, WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, WMA-3_PW5, and WMA-3_PW6) span the range of particle distribution as released from the LLBG WMA-3. The well placement is suitable for detecting releases to the water table from LLBG WMA-3 under the evaluated range of conditions. The proposed well locations comply with the intent of WAC 173-303-645(6), which is to detect releases of waste constituents from the facility that would pose a potential risk to ground and surface water. The downgradient wells are proposed as the point of compliance wells. Additional details regarding selection of these wells are presented in Chapter 7. In order to monitor the vertical contamination distribution at the point of compliance, data from available deep wells will be evaluated from other groundwater monitoring programs in the immediate area of the DWMU. These additional wells will be defined in the groundwater monitoring plan and added to the monitoring well network for the DWMU.

9.3 Proposed Groundwater Monitoring Network

The proposed groundwater monitoring network for LLBG WMA-3 consists of one background (upgradient) and seven point of compliance (downgradient) wells to monitor for releases to the water table from LLBG WMA-3 (Figure 9-1). The monitoring well locations were evaluated under a range of 200 West P&T system operating conditions, or scenarios, presented in Table 5-1, including conditions after shutdown of P&T operations. Results of the simulations of the various scenarios are presented in Chapter 7.

Well attributes are summarized in Table 9-1 and Appendix E. Each of the proposed network wells have been, or will be, constructed according to WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." Each well is, or will be, screened in the upper unconfined aquifer in order to yield sufficient groundwater for representative sampling. Sections 9.3.1 through 9.3.8 provide details supporting the selection of each of the proposed locations. Based on the results of the API calculator (Section 7.5 of Appendix G), the depths of the monitoring wells, which are screened across the top of the water table, are appropriate.

Where possible, the groundwater monitoring network is intended to meet the requirements of WAC 173-303-645(8)(a). Groundwater conditions on the Central Plateau have been impacted in different ways throughout the history of the Hanford Site. A description of the impacts to groundwater flow direction pertaining to LLBG WMA-3 is presented in Section 3.3. WAC 173-303-645(8)(a)(i) states that wells must be appropriately sited to, "Represent the quality of background groundwater that has not been affected by leakage from a regulated unit." To meet the intent of WAC 173-303-645(8)(a)(i), a background (upgradient) well has been selected that would be representative of ambient conditions under the currently operating 200 West P&T remedy. It does not however, represent groundwater not affected by Hanford Site operations. Characterization of the contaminated groundwater, including concentrations of dangerous constituents and parameters, will be performed after sufficient samples have been collected in the first 2 years of monitoring to conduct statistical analyses.

WAC 173-303-645(8)(g), states, "In detection monitoring…data on each dangerous constituent specified in the permit will be collected from background wells and at the compliance point(s). The number and kinds of samples collected to establish background must be appropriate for the form of statistical test employed, following generally accepted statistical principles. The sample size must be as large as necessary to ensure with reasonable confidence that a contaminant release to groundwater from a facility will be detected…" However, WAC 173-303-645(8)(h)(v) allows that, "Another statistical test method may be submitted by the owner or operator and approved by the department." The process for selection of a statistical method is found in Appendix H. Selection of the statistical method for use in LLBG WMA-3 is discussed in Section 9.5.

Based on current groundwater flow direction to the east (Section 2.13 in DOE/RL-2016-66), the selected point of compliance wells will provide representative samples of the quality of groundwater passing the point of compliance (WAC 173-303-645(8)(a)(ii)). These locations allow for the detection of contamination when dangerous waste or dangerous constituents have migrated from the WMA to the uppermost aquifer (WAC 173-303-645(8)(a)(iii)). Using the API calculator to assess the vertical component of contaminant migration indicates that the wells, which are screened in the top of the uppermost unconfined aquifer are suitable for monitoring (Section 7.5 of Appendix G).

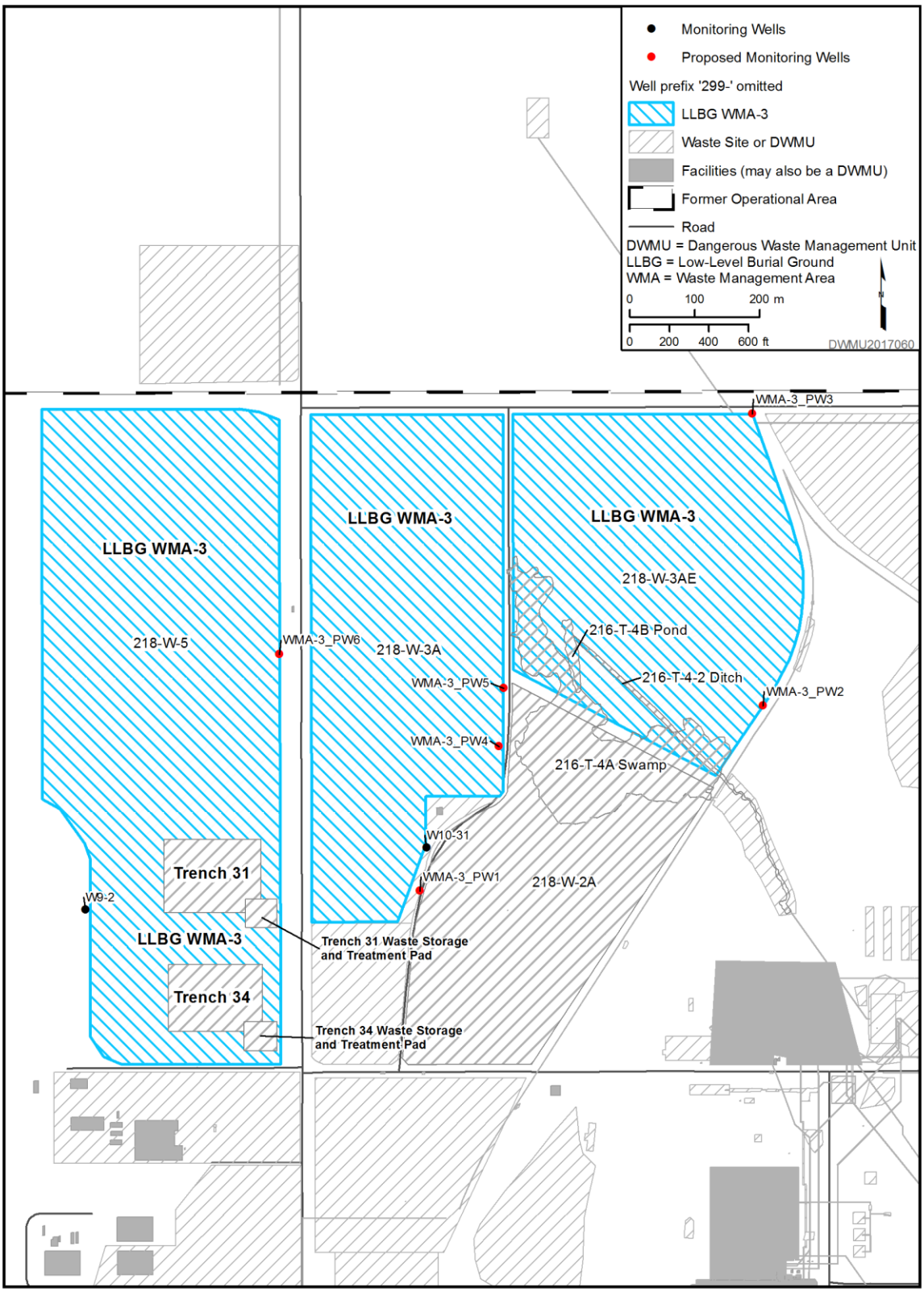

Figure 9-1. Proposed Final Status Groundwater Monitoring Network for LLBG WMA-3

Table 9-1. Attributes for Wells in the LLBG WMA-3 Groundwater Monitoring Network

Well Name	Completion Date	Northing* (m)	Easting* (m)	Top of Casing Elevation (m [ft]) (NAVD88)	Water Table Elevation (m [ft]) (amsl)	Water Depth (m [ft] bgs)	Depth of Water in Screen (m [ft])	Water-Level Date
299-W9-2	9/22/2011	136872.84	565742.21	223.77 (734.14)	136.79 (448.79)	86.11 (282.52)	11.59 (38.02)	9/13/2017
299-W10-31	5/10/2006	136968.34	566266.44	210.38 (690.24)	135.93 (445.95)	73.74 (241.93)	10.13 (33.22)	9/13/2017
WMA-3_PW1	TBD	136901.47	566256.03	TBD	136.12 (446.59)	73.84 (242.26)	TBD	TBD
WMA-3_PW2	TBD	137186.42	566784.13	TBD	134.01 (439.67)	73.45 (240.98)	TBD	TBD
WMA-3_PW3	TBD	137635.58	566767.69	TBD	134.57 (441.5)	74.67 (244.98)	TBD	TBD
WMA-3_PW4	TBD	137124.25	566377.71	TBD	135.53 (444.65)	71.08 (233.2)	TBD	TBD
WMA-3_PW5	TBD	137213.53	566385.08	TBD	135.53 (444.65)	70.83 (232.38)	TBD	TBD
WMA-3_PW6	TBD	137265.74	566040.35	TBD	136.81 (448.85)	73.8 (242.13)	TBD	TBD

Reference: NAVD88, *North American Vertical Datum of 1988.*

* Coordinates are in Washington State Plane (south zone), NAD83, *North American Datum of 1983*; 1991 adjustment.

Note: Proposed well coordinates, elevations, and projected well design are estimates and are subject to modification based on final well location survey and conditions encountered during drilling.

amsl = above mean sea level

bgs = below ground surface

TBD = to be determined. Information will be obtained after well construction.

9.3.1 Groundwater Monitoring Well 299-W9-2

Groundwater monitoring well 299-W9-2 is proposed as a background well. It was constructed in 2011 to the standards of WAC 173-160. This well is also used in the interim status groundwater monitoring network for LLBG WMA-3. The well is upgradient and screened from elevation 135.9 m (445.8 ft) to elevation 125.2 m (410.8 ft) (Appendix E). Based on 2017 water elevation data, well 299-W9-2 is screened across the upper 5.05 m (16.6 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Under 200 West P&T system operations in 2016, groundwater flow direction at well 299-W9-2 is predominantly to the east-northeast (Figure 3-12); however, future groundwater flow direction may be impacted by ongoing 200 West P&T operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release. The results of particle-tracking calculations (Figures 7-13 through 7-15) and the results of transport calculations (Figures 7-10 through 7-12) indicate that this well will remain upgradient of LLBG WMA-3 under the scenarios evaluated. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1, sub-scenario A) calculates that the injection of treated water associated with the final 200 West P&T system could dilute the water at this location by as much as 25% for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.25 shown on the injection injected treated water dilution breakthrough curve in Figure 7-1).

9.3.2 Groundwater Monitoring Well 299-W10-31

Groundwater monitoring well 299-W10-31 is proposed as a point of compliance well. It was constructed in 2006 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for LLBG WMA-3. The well is downgradient of LLBG WMA-3 and is screened from elevation 136.5 m (447.9 ft) to elevation 125.8 m (412.9 ft) (Appendix E). Based on 2017 water elevation data, well 299-W10-31 is screened across the upper 3.81 m (12.5 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the east at this well (Figure 3-12); however, future groundwater flow direction may be impacted by ongoing 200 West P&T system operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release.

The results of particle-tracking calculations (Figures 7-13 through 7-15) indicate this well is north of the area of particle tracks for scenarios 1 and 2 but is within the area of interest in scenario 3. The results of transport calculations (Figures 7-10 through 7-12) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-16 through 7-18) indicate that this well is located to the north of the detectable area for scenarios 1 and 2 and at the northern extent of the estimated area of detectability for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well for scenario 1 (Figure 7-8) indicate some dilution of the release concentration is expected at the well location during 200 West P&T

system operations. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1, sub-scenario A) calculates that a unit concentration released at the waste site would be reduced by approximately 70% (corresponding to a release unit concentration of approximately 0.30 as shown in Figure 7-8) through the processes of advection, dispersion, and recharge, by the time it arrives at the monitoring well. The modeling performed also calculates that the injection of treated water associated with the final 200 West P&T system could, over time, contribute as much as 90% of the water at the well location for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.90 shown on the injection injected treated water dilution breakthrough curve in Figure 7-4). This could result in further dilution of the release concentration by some amount up to but likely less than 90%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from LLBG WMA-3 under the range of operating conditions evaluated.

9.3.3 Groundwater Monitoring Well WMA-3_PW1

Groundwater monitoring well WMA-3_PW1 is a proposed point of compliance well. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of LLBG WMA-3. Conceptually, the well will be constructed with 10.7 m (35 ft) of screen placed from approximately 1.5 m (5 ft) above and extending to 9.1 m (30 ft) below the uppermost portion of the unconfined aquifer. The proposed screened interval is anticipated to yield sufficient groundwater for representative sampling when constructed.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the east southeast at this proposed well location; however, future groundwater flow direction may be impacted by ongoing 200 West P&T system operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release.

The results of the relative detectability evaluation (Figures 7-16 through 7-18) indicate that this well is centrally located in the estimated area of detectability for scenarios 1 and 2 and located at the southern edge of the estimated area of detectability for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well for scenario 1 (Figure 7-25) indicate minimal dilution of the release concentration is expected at the well location during 200 West P&T system operations. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1, sub-scenario A) calculates that a unit concentration released at the waste site would be reduced by approximately 13% (corresponding to a release unit concentration of approximately 0.87 as shown in Figure 7-25) through the processes of advection, dispersion, and recharge, by the time it arrives at the monitoring well. The modeling performed also calculates that the injection of treated water associated with the final 200 West P&T system could, over time, contribute as much as 87% of the water at the well location for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.87 shown on the injection injected treated water dilution

breakthrough curve in Figure 7-19). This could result in further dilution of the release concentration by some amount up to but likely less than 87%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from LLBG WMA-3 under the range of operating conditions evaluated.

9.3.4 Groundwater Monitoring Well WMA-3_PW2

Groundwater monitoring well WMA-3_PW2 is a proposed point of compliance well. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of LLBG WMA-3. Conceptually, the well will be constructed with 10.7 m (35 ft) of screen placed from approximately 1.5 m (5 ft) above and extending to 9.1 m (30 ft) below the uppermost portion of the unconfined aquifer. The proposed screened interval is anticipated to yield sufficient groundwater for representative sampling when constructed.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the southeast at this proposed well location; however, future groundwater flow direction may be impacted by ongoing 200 West P&T system operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release.

The results of the relative detectability evaluation (Figures 7-16 through 7-18) indicate that this well is located centrally in the estimated area of detectability for scenarios 1 and 2 and located south of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well for scenario 1 (Figure 7-26) indicate some dilution of the release concentration is expected at the well location during 200 West P&T system operations. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1, sub-scenario A) calculates that a unit concentration released at the waste site would be reduced by approximately 64% (corresponding to a release unit concentration of approximately 0.26 as shown in Figure 7-26) through the processes of advection, dispersion, and recharge, by the time it arrives at the monitoring well. The modeling performed also calculates that the injection of treated water associated with the final 200 West P&T system could, over time, contribute as much as 82% of the water at the well location for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.82 shown on the injection injected treated water dilution breakthrough curve in Figure 7-20). This could result in further dilution of the release concentration by some amount up to but likely less than 82%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the

detection of contamination and of increases in contamination should there be a release from LLBG WMA-3 under the range of operating conditions evaluated.

9.3.5 Groundwater Monitoring Well WMA-3_PW3

Groundwater monitoring well WMA-3_PW3 is a proposed point of compliance well. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of LLBG WMA-3. Conceptually, the well will be constructed with 10.7 m (35 ft) of screen placed from approximately 1.5 m (5 ft) above and extending to 9.1 m (30 ft) below the uppermost portion of the unconfined aquifer. The proposed screened interval is anticipated to yield sufficient groundwater for representative sampling when constructed.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the northeast at this proposed well location; however, future groundwater flow direction may be impacted by ongoing 200 West P&T system operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release.

The results of the relative detectability evaluation (Figures 7-16 through 7-18) indicate that this well is located in the north portion of the estimated area of detectability for scenarios 1 and 2 and located at the northern edge of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well for scenario 1 (Figure 7-27) indicate some dilution of the release concentration is expected at the well location during 200 West P&T system operations. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1, sub-scenario A) calculates that a unit concentration released at the waste site would be reduced by approximately 98% (corresponding to a release unit concentration of approximately 0.02 as shown in Figure 7-27) through the processes of advection, dispersion, and recharge, by the time it arrives at the monitoring well. The modeling performed also calculates that the injection of treated water associated with the final 200 West P&T system could, over time, contribute as much as 87% of the water at the well location for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.87 shown on the injection injected treated water dilution breakthrough curve in Figure 7-21). This could result in further dilution of the release concentration by some amount up to but likely less than 87%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from LLBG WMA-3 under the range of operating conditions evaluated.

9.3.6 Groundwater Monitoring Well WMA-3_PW4

Groundwater monitoring well WMA-3_PW4 is a proposed point of compliance well. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of LLBG WMA-3. Conceptually, the well will be constructed with 10.7 m (35 ft) of screen placed from approximately 1.5 m (5 ft) above and extending to 9.1 m (30 ft) below the uppermost portion

of the unconfined aquifer. The proposed screened interval is anticipated to yield sufficient groundwater for representative sampling when constructed.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the east at this proposed well location; however, future groundwater flow direction may be impacted by ongoing 200 West P&T system operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release.

The results of the relative detectability evaluation (Figures 7-16 through 7-18) indicate that this well is located in the estimated area of detectability for scenarios 1 and 2 and located south of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well for scenario 1 (Figure 7-28) indicate some dilution of the release concentration is expected at the well location during 200 West P&T system operations. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1, sub-scenario A) calculates that a unit concentration released at the waste site would be reduced by approximately 55% (corresponding to a release unit concentration of approximately 0.45 as shown in Figure 7-28) through the processes of advection, dispersion, and recharge, by the time it arrives at the monitoring well. The modeling performed also calculates that the injection of treated water associated with the final 200 West P&T system could, over time, contribute as much as 70% of the water at the well location for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.70 shown on the injection injected treated water dilution breakthrough curve in Figure 7-22). This could result in further dilution of the release concentration by some amount up to but likely less than 70%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from LLBG WMA-3 under the range of operating conditions evaluated.

9.3.7 Groundwater Monitoring Well WMA-3_PW5

Groundwater monitoring well WMA-3_PW5 is a proposed point of compliance well. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of LLBG WMA-3. Conceptually, the well will be constructed with 10.7 m (35 ft) of screen placed from approximately 1.5 m (5 ft) above and extending to 9.1 m (30 ft) below the uppermost portion of the unconfined aquifer. The proposed screened interval is anticipated to yield sufficient groundwater for representative sampling when constructed.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the east at this proposed well location; however, future groundwater flow direction may be impacted by ongoing 200 West P&T system operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations

evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release.

The results of the relative detectability evaluation (Figures 7-16 through 7-18) indicate that this well is located in the estimated area of detectability for scenarios 1 and 2 and located in the southern edge of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well for scenario 1 (Figure 7-29) indicate minimal dilution of the release concentration is expected at the well location during 200 West P&T system operations. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1, sub-scenario A) calculates that a unit concentration released at the waste site would be reduced by approximately 28% (corresponding to a release unit concentration of approximately 0.72 as shown in Figure 7-29) through the processes of advection, dispersion, and recharge, by the time it arrives at the monitoring well. The modeling performed also calculates that the injection of treated water associated with the final 200 West P&T system could, over time, contribute as much as 69% of the water at the well location for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.69 shown on the injection injected treated water dilution breakthrough curve in Figure 7-23). This could result in further dilution of the release concentration by some amount up to but likely less than 69%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from LLBG WMA-3 under the range of operating conditions evaluated.

9.3.8 Groundwater Monitoring Well WMA-3_PW6

Groundwater monitoring well WMA-3_PW6 is a proposed point of compliance well. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of LLBG WMA-3. Conceptually, the well will be constructed with 10.7 m (35 ft) of screen placed from approximately 1.5 m (5 ft) above and extending to 9.1 m (30 ft) below the uppermost portion of the unconfined aquifer. The proposed screened interval is anticipated to yield sufficient groundwater for representative sampling when constructed.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the east at this proposed well location; however, future groundwater flow direction may be impacted by ongoing 200 West P&T system operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed to evaluate the impacts on groundwater flow of various 200 West P&T system flow rates, including a scenario that assumed no flow through the 200 West P&T system (Appendix G and Chapter 7). Within each overall P&T system flow rate scenario, the simulations evaluated the impact of varying the injection rates at 200 West P&T system injection wells. Using this information, monitoring locations were evaluated against the ability to detect a release.

The results of the relative detectability evaluation (Figures 7-16 through 7-18) indicate that this well is centrally located in the estimated area of detectability for scenarios 1 and 2 and located south of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well for scenario 1 (Figure 7-30) indicate some dilution of the release concentration is expected at the well location during 200 West P&T system operations. The modeling performed for the most likely future 200 West P&T system operating conditions (scenario 1,

sub-scenario A) calculates that a unit concentration released at the waste site would be reduced by approximately 75% (corresponding to a release unit concentration of approximately 0.25 as shown in Figure 7-30) through the processes of advection, dispersion, and recharge, by the time it arrives at the monitoring well. The modeling performed also calculates that the injection of treated water associated with the final 200 West P&T system could, over time, contribute as much as 68% of the water at the well location for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.68 shown on the injection injected treated water dilution breakthrough curve in Figure 7-24). This could result in further dilution of the release concentration by some amount up to but likely less than 68%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from LLBG WMA-3 under the range of operating conditions evaluated.

9.4 Constituent List and Frequency

The proposed LLBG WMA-3 final status groundwater monitoring network detailed in this report consists of one upgradient (299-W9-2) and seven downgradient (existing wells 299-W10-31 and proposed wells WMA-3_PW1, WMA-3_PW2, WMA-3_PW3, WMA-3_PW4, WMA-3_PW5, and WMA-3_PW6) wells. The upgradient well (299-W9-2) and downgradient wells (299-W10-31) are part of the LLBG WMA-3 interim status groundwater monitoring network (Table 3-1 in DOE/RL-2009-68, Rev. 2) and are shown in Figure 9-1.

For a detection monitoring program, WAC 173-303-645(9)(a) requires, “The owner or operator must monitor for indicator parameters (e.g., pH, specific conductance, total organic carbon (TOC), total organic halogen (TOX), or heavy metals), waste constituents, or reaction products that provide a reliable indication of the presence of dangerous constituents in groundwater. The department will specify the parameters or constituents to be monitored in the facility permit…” Based on the analysis in Chapter 8, 140 waste constituents were selected to detect and monitor groundwater impacts from potential dangerous waste releases at LLBG WMA-3.

Table 9-2 identifies the proposed monitoring network and sampling frequency for LLBG WMA-3. The proposed site-specific monitoring constituents (Table 9-3) will be sampled quarterly for the first 2 years of monitoring. After background concentrations are determined, the proposed monitoring constituents will be sampled semi-annually. Field measurements (pH, dissolved oxygen, oxidation-reduction potential, specific conductance, temperature, and turbidity) will be collected each time a well is sampled. Water-level measurements at each monitoring well will be determined each time a sample is obtained (WAC 173-303-645(8)(f)). Analytical performance, data evaluation, reporting, sampling protocols, and quality assurance requirements will be specified in the final status groundwater monitoring plan to be prepared for LLBG WMA-3.

Table 9-2. Monitoring Wells and Sample Schedule for LLBG WMA-3

Well Name	Purpose	WAC Compliant	Water Level	Site-Specific Constituents to Detect Release from Regulated Unit[a]								Dangerous Wastes[b]	Field Parameters[f]
				Volatile Organic Compounds[c]	Semivolatile Organic Compounds[d]	Herbicides[e]	Formic acid	Formaldehyde	Hydrazine	Methanol	Nitroglycerine	Table 9-4	
299-W9-2	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
299-W10-31	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-3_PW1	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-3_PW2	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-3_PW3	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-3_PW4	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-3_PW5	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-3_PW6	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S

Note: Complete reference citations are provided in Chapter 11.

a. Monitoring constituents will be sampled quarterly for the first 2 years of monitoring to determine background concentrations. After background concentrations are determined, these constituents will be monitored semiannually.

b. To establish background concentrations in accordance with 16-NWP-143, and to support collection of sufficient samples to perform statistical testing (e.g., eight samples), quarterly sampling for Ecology Publication No. 97-407 Appendix 5 constituents will be performed for a 2-year period.

c. Volatile organic compounds are provided in Table 9-3 and include 1-butanol (n-butyl alcohol); 1,1-dichloroethane; 1,1-dichloroethene (1,1-dichloroethylene); 1,1,1-trichloroethane; 1,1,1,2-tetrachloroethane; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,1,2-trichloroethane; 1,1,2,2-tetrachloroethane; 1,2-dibromo-3-chloropropane; 1,2-dibromoethane; 1,2-dichloroethane; 1,2-dichloropropane; 1,4-dichlorobenzene; 2-butanone (methyl ethyl ketone); 2-chloroethyl vinyl ether; 2-nitropropane; 2-propanone (acetone); 4-methyl-2-pentanone (methyl isobutyl ketone); acetonitrile (methyl cyanide); acrolein; acrylamide; acrylonitrile; benzene; benzyl chloride; bromoform; carbon disulfide; carbon tetrachloride; chlorobenzene; chloroform, cyclohexane; cyclohexanone, dichlorodifluoromethane; ethyl acetate, ethyl ether, ethyl methacrylate; ethyl methanesulfonate; ethylbenzene, isobutanol (isobutyl alcohol); isopropylbenzene; methacrylonitrile; methyl bromide (bromomethane); methyl chloride (chloromethane); methyl iodide

Table 9-2. Monitoring Wells and Sample Schedule for LLBG WMA-3

Well Name	Purpose	WAC Compliant	Water Level	Site-Specific Constituents to Detect Release from Regulated Unit[a]								Dangerous Wastes[b]	Field Parameters[f]
				Volatile Organic Compounds[c]	Semivolatile Organic Compounds[d]	Herbicides[e]	Formic acid	Formaldehyde	Hydrazine	Methanol	Nitroglycerine	Table 9-4	

(iodomethane); methyl methacrylate; methylene bromide (dibromomethane); methylene chloride; propionitrile (ethyl cyanide); tetrachloroethene; tetrahydrofuran; toluene, trans-1,2-dichloroethylene; trichloroethylene (TCE), trichlorofluoromethane, vinyl chloride (chloroethene), and xylene (total).

d. Semivolatile organic compounds are provided in Table 9-3 and include 1-naphthylamine; 1,2-dichlorobenzene (o-dichlorobenzene); 1,2-diphenylhydrazine; 1,2,4,5-tetrachlorobenzene; 1,4-dioxane; 1,4-naphthoquinone; 2-acetylaminofluorene; 2-chlorophenol; 2-methylphenol (o-cresol); 2-naphthylamine; 2-picoline; 2,3,4,6-tetrachlorophenol; 2,4-dichlorophenol; 2,4-dimethylphenol; 2,4-dinitrophenol; 2,4-dinitrotoluene; 2,4,6-trichlorophenol; 2,6-dichlorophenol; 2,6-dinitrotoluene; 3-methylcholanthrene; 3-methylphenol (m-cresol); 3,3′-dichlorobenzidine; 3,3′-dimethylbenzidine; 4-methylphenol (p-cresol); 4,4'-methylenebis(2-chloroaniline); 4,6-dinitro-o-cresol (4,6-dinitro-2-methyl phenol); 4-chloro-3-methylphenol (p-chloro-m-cresol); 5-nitro-o-toluidine; 7,12-dimethylbenz[a]anthracene; acetophenone; alpha, alpha-Dimethylphenethylamine; aniline; bis(2-chloro-1-methylethyl) ether (2,2'-oxybis(1-chloropropane)); bis(2-chloroethoxy)methane; bis(2-chloroethyl)ether; chlorobenzilate; diallate; diethyl phthalate; dimethoate; dimethyl phthalate; disulfoton; famphur; hexachlorophene; hexachloropropene; isodrin; isosafrole; kepone; m-dichlorobenzene; methapyrilene; methyl parathion; nitrobenzene; n-nitrosodiethylamine; n-nitrosodimethylamine; n-nitrosodi-n-butylamine; n-nitroso-di-n-dipropylamine (n-nitrosodipropylamine); n-nitrosopiperidine; n-nitrosopyrrolidine; O,O-diethyl-O-pyrazinylthiophosphate; o-toluidine; p-(dimethylamino)azobenzene; parathion; p-chloroaniline (4-chloroaniline); pentachlorobenzene; pentachloroethane; pentachloronitrobenzene; pentachlorophenol; phenacetin; phenol; phorate; p-nitroaniline (4-nitroaniline); p-nitrophenol (4-nitrophenol); pronamide; pyridine; safrole; sym-trinitrobenzene; tetraethyl dithiopyrophosphate; and thiophenol.

e. Herbicides are provided in Table 9-3 and include 2,4-D (2,4-dichlorophenoxyacetic acid); 2,4,5-T (2,4,5-trichlorophenoxyacetic acid); and 2,4,5-TP Silvex (2-(2,4,5-trichlorophenoxy)propionic acid).

f. Field parameters include pH, dissolved oxygen, oxidation-reduction potential, specific conductance, temperature, and turbidity. Field parameters will be measured at each sample event (quarterly for the first 2 years of monitoring and semiannually thereafter).

A = annually

E = each time the well is sampled

Q = quarterly

S = semiannually

WAC = *Washington Administrative Code*

Y = well is, or will be, constructed as a resource protection well (WAC 173-160, “Minimum Standard for Construction and Maintenance of Wells”)

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
1-Butanol (n-Butyl alcohol)	71-36-3
1-Naphthylamine	134-32-7
1,1-Dichloroethane	75-34-3
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4
1,1,1-Trichloroethane	71-55-6
1,1,1,2-Tetrachloroethane	630-20-6
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
1,1,2-Trichloroethane	79-00-5
1,1,2,2-Tetrachloroethane	79-34-5
1,2-Dibromo-3-chloropropane	96-12-8
1,2-Dibromoethane	106-93-4
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1
1,2-Dichloroethane	107-06-2
1,2-Dichloropropane	78-87-5
1,2-Diphenylhydrazine	122-66-7
1,2,4,5-Tetrachlorobenzene	95-94-3
1,4-Dichlorobenzene	106-46-7
1,4-Dioxane	123-91-1
1,4-Naphthoquinone	130-15-4
2-Acetylaminofluorene	53-96-3
2-Butanone (Methyl ethyl ketone)	78-93-3
2-Chloroethyl vinyl ether	110-75-8
2-Chlorophenol	95-57-8
2-Methylphenol (o-Cresol)	95-48-7
2-Naphthylamine	91-59-8
2-Nitropropane	79-46-9
2-Picoline	109-06-8
2-Propanone (Acetone)	67-64-1
2,3,4,6-Tetrachlorophenol	58-90-2
2,4-D (2,4-Dichlorophenoxyacetic acid)	94-75-7
2,4-Dichlorophenol	120-83-2
2,4-Dimethylphenol	105-67-9
2,4-Dinitrophenol	51-28-5

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
2,4-Dinitrotoluene	121-14-2
2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)	93-76-5
2,4,5-TP Silvex (2-(2,4,5-trichlorophenoxy)propionic acid)	93-72-1
2,4,6-Trichlorophenol	88-06-2
2,6-Dichlorophenol	87-65-0
2,6-Dinitrotoluene	606-20-2
3-Methylcholanthrene	56-49-5
3-Methylphenol (m-Cresol)	108-39-4
3,3′-Dichlorobenzidine	91-94-1
3,3′-Dimethylbenzidine	119-93-7
4,4'-Methylenebis(2-chloroaniline)	101-14-4
4,6-Dinitro-o-cresol (4,6-Dinitro-2-methyl phenol)	534-52-1
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	59-50-7
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1
4-Methylphenol (p-cresol)	106-44-5
5-Nitro-o-toluidine	99-55-8
7,12-Dimethylbenz[a]anthracene	57-97-6
Acetonitrile (Methyl cyanide)	75-05-8
Acetophenone	98-86-2
Acrolein	107-02-8
Acrylamide	79-06-1
Acrylonitrile	107-13-1
alpha, alpha-Dimethylphenethylamine	122-09-8
Aniline	62-53-3
Benzene	71-43-2
Benzyl chloride	100-44-7
Bis(2-chloro-1-methylethyl) ether (2,2'-Oxybis(1-chloropropane))	108-60-1
Bis(2-chloroethoxy)methane	111-91-1
Bis(2-chloroethyl)ether	111-44-4
Bromoform	75-25-2
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
Chlorobenzene	108-90-7
Chlorobenzilate	510-15-6
Chloroform	67-66-3
Cyclohexane	110-82-7
Cyclohexanone	108-94-1
Diallate	2303-16-4
Dichlorodifluoromethane	75-71-8
Diethyl phthalate	84-66-2
Dimethoate	60-51-5
Dimethyl phthalate	131-11-3
Disulfoton	298-04-4
Ethyl acetate	141-78-6
Ethyl ether	60-29-7
Ethyl methacrylate	97-63-2
Ethyl methanesulfonate	62-50-0
Ethylbenzene	100-41-4
Famphur	52-85-7
Formaldehyde	50-00-0
Formic acid	64-18-6
Hexachlorophene	70-30-4
Hexachloropropene	1888-71-7
Hydrazine	302-01-2
Isobutanol (Isobutyl alcohol)	78-83-1
Isodrin	465-73-6
Isopropylbenzene	98-82-8
Isosafrole	120-58-1
Kepone	143-50-0
m-Dichlorobenzene	541-73-1
Methacrylonitrile	126-98-7
Methanol	67-56-1
Methapyrilene	91-80-5
Methyl bromide (Bromomethane)	74-83-9
Methyl chloride (Chloromethane)	74-87-3

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
Methyl iodide (Iodomethane)	74-88-4
Methyl methacrylate	80-62-6
Methyl parathion	298-00-0
Methylene bromide (Dibromomethane)	74-95-3
Methylene chloride	75-09-2
Nitrobenzene	98-95-3
Nitroglycerine	55-63-0
n-Nitrosodiethylamine	55-18-5
n-Nitrosodimethylamine	62-75-9
n-Nitrosodi-n-butylamine	924-16-3
n-Nitroso-di-n-dipropylamine (n-Nitrosodipropylamine)	621-64-7
n-Nitrosopiperidine	100-75-4
n-Nitrosopyrrolidine	930-55-2
O,O-Diethyl-O-pyrazinylthiophosphate	297-97-2
o-Toluidine	95-53-4
p-(Dimethylamino)azobenzene	60-11-7
Parathion	56-38-2
p-Chloroaniline (4-Chloroaniline)	106-47-8
Pentachlorobenzene	608-93-5
Pentachloroethane	76-01-7
Pentachloronitrobenzene	82-68-8
Pentachlorophenol	87-86-5
Phenacetin	62-44-2
Phenol	108-95-2
Phorate	298-02-2
p-Nitroaniline (4-Nitroaniline)	100-01-6
p-Nitrophenol (4-Nitrophenol)	100-02-7
Pronamide	23950-58-5
Propionitrile (Ethyl cyanide)	107-12-0
Pyridine	110-86-1
Safrole	94-59-7
sym-Trinitrobenzene	99-35-4

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-3

Waste Constituent	CAS Number
Tetrachloroethene	127-18-4
Tetraethyl dithiopyrophosphate	3689-24-5
Tetrahydrofuran	109-99-9
Thiophenol	108-98-5
Toluene	108-88-3
trans-1,2-Dichloroethylene	156-60-5
Trichloroethene (TCE)	79-01-6
Trichlorofluoromethane	75-69-4
Vinyl chloride (Chloroethene)	75-01-4
Xylenes (total)	1330-20-7

CAS = Chemical Abstracts Service

In accordance with 16-NWP-143, performing 1 year of background monitoring for WAC 173-303-110(3)(c) and (7) constituents was established for burial grounds containing dangerous waste. WAC 173-303-110(3)(c) references Ecology Publication No. 97-407, and WAC 173-303-110(7) references Appendix 5 of Ecology Publication No. 97-407. Accordingly, the constituents identified in Appendix 5 of Ecology Publication No. 97-407 (Table 9-4) will be sampled for background monitoring. However, to support collection of sufficient samples to perform statistical testing (e.g., eight samples) and establish background concentrations, sampling for Appendix 5 of Ecology Publication No. 97-407 constituents will be extended to a 2-year period and performed on a quarterly basis, after which sampling to establish background concentrations will be discontinued. Section 9.5 provides details on the number of sample data required to determine a statistical method.

Statistical evaluation of sampling results will be performed for site-specific monitoring constituents (Table 9-3) and the Appendix 5 dangerous wastes (Table 9-4), as appropriate. Information on the statistical method is provided in Section 9.7.

When the groundwater monitoring plan for LLBG WMA-3 is incorporated into the Hanford Facility Dangerous Waste Permit, it will replace any other groundwater monitoring plan(s) associated specifically with this DWMU under interim status.

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
Inorganic Constituents			
Antimony	7440-36-0	Mercury	7439-97-6
Arsenic	7440-38-2	Nickel	7440-02-0
Barium	7440-39-3	Selenium	7782-49-2
Beryllium	7440-41-7	Silver	7440-22-4

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
Cadmium	7440-43-9	Sulfide	18496-25-8
Chromium	7440-47-3	Thallium	7440-28-0
Cobalt	7440-48-4	Tin	7440-31-5
Copper	7440-50-8	Vanadium	7440-62-2
Cyanide	57-12-5	Zinc	7440-66-6
Lead	7439-92-1	--	--
Volatile Organic Compounds			
1,1-Dichloroethane	75-34-3	Carbon tetrachloride	56-23-5
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	Chlorobenzene	108-90-7
1,1,1-Trichloroethane	71-55-6	Chloroethane	75-00-3
1,1,1,2-Tetrachloroethane	630-20-6	Chloroform	67-66-3
1,1,2-Trichloroethane	79-00-5	Chloroprene	126-99-8
1,1,2,2-Tetrachloroethane	79-34-5	Dibromochloromethane	124-48-1
1,2-Dibromo-3-chloropropane	96-12-8	p-Dichlorobenzene (1,4-Dichlorobenzene)	106-46-7
1,2-Dibromoethane	106-93-4	Dichlorodifluoromethane	75-71-8
1,2-Dichloroethane	107-06-2	Ethylbenzene	100-41-4
1,2-Dichloropropane	78-87-5	Ethyl methacrylate	97-63-2
trans-1,2-Dichloroethylene	156-60-5	Isobutanol (Isobutyl alcohol)	78-83-1
1,2,3-Trichloropropane	96-18-4	Methacrylonitrile	126-98-7
cis-1,3-Dichloropropene	10061-01-5	Methyl bromide (Bromomethane)	74-83-9
trans-1,3-Dichloropropene	10061-02-6	Methyl chloride (Chloromethane)	74-87-3
trans-1,4-Dichloro-2-butene	110-57-6	Methyl iodide (Iodomethane)	74-88-4
2-Butanone (Methyl ethyl ketone; MEK)	78-93-3	Methyl methacrylate	80-62-6
2-Propanone (acetone)	67-64-1	Methylene bromide (Dibromomethane)	74-95-3
2-Hexanone (Methyl butyl ketone)	591-78-6	Methylene chloride	75-09-2
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1	Propionitrile (Ethyl cyanide)	107-12-0
Acetonitrile (Methyl cyanide)	75-05-8	Styrene	100-42-5
Acrolein	107-02-8	Tetrachloroethene	127-18-4
Acrylonitrile	107-13-1	Toluene	108-88-3
Allyl chloride	107-05-1	Trichloroethene (TCE)	79-01-6

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
Benzene	71-43-2	Trichlorofluoromethane	75-69-4
Bromodichloromethane	75-27-4	Vinyl acetate	108-05-4
Bromoform	75-25-2	Vinyl chloride (Chloroethene)	75-01-4
Carbon disulfide	75-15-0	Xylenes (total)	1330-20-7
Semivolatile Organic Compounds			
1-Naphthylamine	134-32-7	Dimethyl phthalate	131-11-3
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	Di-n-butyl phthalate	84-74-2
1,2,4-Trichlorobenzene	120-82-1	m-Dinitrobenzene	99-65-0
1,2,4,5-Tetrachlorobenzene	95-94-3	Di-n-octylphthalate	117-84-0
1,4-Dioxane	123-91-1	Dinoseb (2-sec-Butyl-4,6-dinitrophenol)	88-85-7
1,4-Naphthoquinone	130-15-4	Diphenylamine	122-39-4
2-Acetylaminofluorene	53-96-3	Disulfoton	298-04-4
2-Chloronaphthalene	91-58-7	Ethyl methanesulfonate	62-50-0
2-Chlorophenol	95-57-8	Famphur	52-85-7
2-Methylphenol (o-cresol)	95-48-7	Fluoranthene	206-44-0
2-Methylnaphthalene	91-57-6	9H-Fluorene (Fluorene)	86-73-7
2-Naphthylamine	91-59-8	Hexachlorobenzene	118-74-1
2-Nitrophenol (o-Nitrophenol)	88-75-5	Hexachlorobutadiene	87-68-3
2-Picoline	109-06-8	Hexachlorocyclopentadiene	77-47-4
2,3,4,6-Tetrachlorophenol	58-90-2	Hexachloroethane	67-72-1
2,4-Dichlorophenol	120-83-2	Hexachlorophene	70-30-4
2,4-Dimethylphenol	105-67-9	Hexachloropropene	1888-71-7
2,4-Dinitrophenol	51-28-5	Indeno(1,2,3-cd)pyrene	193-39-5
2,4-Dinitrotoluene	121-14-2	Isodrin	465-73-6
2,4,5-Trichlorophenol	95-95-4	Isophorone	78-59-1
2,4,6-Trichlorophenol	88-06-2	Isosafrole	120-58-1
2,6-Dichlorophenol	87-65-0	Kepone	143-50-0
2,6-Dinitrotoluene	606-20-2	Methapyrilene	91-80-5
3-Methylcholanthrene	56-49-5	Methyl methanesulfonate	66-27-3
3-Methylphenol (m-Cresol)	108-39-4	Methyl parathion	298-00-0
4-Methylphenol (p-cresol)	106-44-5	Naphthalene	91-20-3
3,3′-Dichlorobenzidine	91-94-1	Nitrobenzene	98-95-3

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
3,3′-Dimethylbenzidine	119-93-7	o-Nitroaniline (2-Nitroaniline)	88-74-4
4-Aminobiphenyl	92-67-1	m-Nitroaniline (3-Nitroaniline)	99-09-2
4-Bromophenyl phenyl ether	101-55-3	p-Nitroaniline (4-Nitroaniline)	100-01-6
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	59-50-7	p-Nitrophenol (4-Nitrophenol)	100-02-7
4-Chlorophenyl phenyl ether	7005-72-3	N-Nitrosodi-n-butylamine	924-16-3
4-Nitroquinoline 1-oxide	56-57-5	N-Nitrosodiethylamine	55-18-5
4,6-Dinitro-o-cresol (4,6-Dinitro-2-methyl phenol)	534-52-1	N-Nitrosodimethylamine	62-75-9
5-Nitro-o-toluidine	99-55-8	N-Nitrosodiphenylamine	86-30-6
7,12-Dimethylbenz[a]anthracene	57-97-6	n-Nitroso-di-n-dipropylamine (N-Nitrosodipropylamine; Di-n-propylnitrosamine)	621-64-7
Acenaphthene	83-32-9	N-Nitrosomethylethalamine	10595-95-6
Acenaphthylene	208-96-8	n-Nitrosomorpholine	59-89-2
Acetophenone	98-86-2	N-Nitrosopiperidine	100-75-4
Aniline	62-53-3	N-Nitrosopyrrolidine	930-55-2
Anthracene	120-12-7	Parathion	56-38-2
Aramite	140-57-8	Pentachlorobenzene	608-93-5
Benz[a]anthracene (Benzo[a]anthracene)	56-55-3	Pentachloroethane	76-01-7
Benz[e]acephenanthrylene (Benzo[b]fluoranthene)	205-99-2	Pentachloronitrobenzene	82-68-8
Benzo[k]fluoranthene	207-08-9	Pentachlorophenol	87-86-5
Benzo[ghi]perylene	191-24-2	Phenacetin	62-44-2
Benzo[a]pyrene	50-32-8	Phenanthrene	85-01-8
Benzyl alcohol	100-51-6	Phenol	108-95-2
Bis(2-chloroethoxy)methane	111-91-1	p-Phenylenediamine	106-50-3
Bis(2-chloroethyl)ether	111-44-4	Phorate	298-02-2
Bis(2-chloro-1-methylethyl) ether (2,2'-Oxybis(1-chloropropane))	108-60-1	Pronamide	23950-58-5
Bis(2-ethylhexyl) phthalate	117-81-7	Pyrene	129-00-0
Butylbenzylphthalate	85-68-7	Pyridine	110-86-1
p-Chloroaniline (4-Chloroaniline)	106-47-8	Safrole	94-59-7
Chlorobenzilate	510-15-6	Tetraethyl dithiopyrophosphate	3689-24-5

Table 9-4. Dangerous Waste Constituents for First 2 Years of Monitoring

Constituent	CAS Number	Constituent	CAS Number
Chrysene	218-01-9	o-Toluidine	95-53-4
Diallate	2303-16-4	O,O,O-Triethyl phosphorothioate	126-68-1
Dibenz[a,h]anthracene	53-70-3	sym-Trinitrobenzene	99-35-4
Dibenzofuran	132-64-9	Aroclor 1016	12674-11-2
m-Dichlorobenzene (1,3-Dichlorobenzene)	541-73-1	Aroclor 1221	11104-28-2
Diethyl phthalate	84-66-2	Aroclor 1232	11141-16-5
O,O-Diethyl O-2-pyrazinyl phosphorothioate	297-97-2	Aroclor 1242	53469-21-9
Dimethoate	60-51-5	Aroclor 1248	12672-29-6
p-(Dimethylamino)azobenzene	60-11-7	Aroclor 1254	11097-69-1
alpha, alpha-Dimethylphenethylamine	122-09-8	Aroclor 1260	11096-82-5
Pesticides			
4,4′-DDD	72-54-8	Endosulfan I	959-98-8
4,4′-DDE	72-55-9	Endosulfan II	33213-65-9
4,4′-DDT	50-29-3	Endosulfan sulfate	1031-07-8
Aldrin	309-00-2	Endrin	72-20-8
alpha-BHC	319-84-6	Endrin aldehyde	7421-93-4
beta-BHC	319-85-7	Heptachlor	76-44-8
delta-BHC	319-86-8	Heptachlor epoxide	1024-57-3
gamma-BHC (Lindane)	58-89-9	Methoxychlor	72-43-5
Chlordane	57-74-9	Toxaphene	8001-35-2
Dieldrin	60-57-1	--	--
Herbicides			
2,4-D; 2,4-Dichlorophenoxyacetic acid	94-75-7	Silvex; 2,4,5-TP	93-72-1
2,4,5-T; 2,4,5-Trichlorophenoxyacetic acid	93-76-5	--	--
Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans			
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	Polychlorinated dibenzofurans	N/A
Polychlorinated dibenzo-p-dioxins	N/A	--	--

Note: This table identifies the dangerous waste constituents listed in Appendix 5 of Ecology Publication No. 97-407, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*.

CAS = Chemical Abstracts Service

N/A = not applicable

9.5 Statistical Method

At this time, a specific statistical method for the determination of statistically significant evidence of contamination from LLBG WMA-3 cannot be determined. EPA 530/R-09-007, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, requires a minimum of eight samples to be able to define background. The proposed compliance wells for LLBG WMA-3 include one existing and six proposed downgradient wells. The existing proposed compliance well has not been part of the monitoring network since 2002. Given that six of the compliance wells are not yet drilled, there is insufficient data to assess baseline conditions and determine a statistical method.

An accelerated sampling program is recommended to obtain sufficient samples to define baseline and determine a statistical method. This accelerated sampling program will monitor each of the constituents in Table 9-2 at a quarterly frequency for 2 years. Quarterly monitoring will allow for sufficient time between samples so as to not cause a problem with autocorrelation of samples (i.e., resampling the same water). After 2 years of sampling is completed, the statistical test method can be determined using the decision matrix included as Appendix H. In addition this methodology, hydrogeology of the area also will be considered. Following this initial monitoring period and determination of the statistical method, the statistical method will be periodically reassessed.

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10 Routine Evaluation of the Monitoring Network

The groundwater flow regime will evolve over time. The scenarios that were simulated (as described in Chapters 5, 6, and 7) are intended to be representative of the range of plausible conditions, but actual conditions may differ from the scenarios evaluated. The CPGWM is updated and run annually as part of the 200 West P&T program. Because of this, the CPGWM is maintained up to date to reflect recent operating conditions and can be used to model proposed changes to the operating conditions.

Throughout the year, water-level measurements are also taken as part of routine sampling, and annually for water-level mapping. Analysis of groundwater elevation, using universal kriging for water-level maps, and hydraulic gradient mapping will be used to interpret changes in the groundwater flow regime. Additionally, re-evaluation of the monitoring network will be performed annually in conjunction with the WAC 173-303-645(10)(e) determination of groundwater flow direction and rate in the uppermost aquifer. If the analysis suggests a change in the flow regime (e.g., changes resulting from modifications to the 200 West P&T system operations) that indicates that the likely migration direction of any hypothetical release is outside of or on the margins of the monitoring network for a DWMU, then the model will be used to re-evaluate the monitoring network for that DWMU.

Results of the re-evaluation of the monitoring network may result in a proposal to add additional monitoring well locations. In a given year, the results may show that there is no impact to a DWMU, in which case no action would be taken. If an impact to a DWMU is shown, the network would be re-evaluated and documented in an update to this engineering evaluation report, shared with Ecology, and placed in the operating record. An update to the engineering report would not necessarily result in an update to the associated groundwater monitoring plan if there is no resulting change needed to the groundwater monitoring network. If a change in the groundwater monitoring network is determined, a permit modification with a revised groundwater monitoring plan would be performed in accordance with WAC 173-303-815, “Facility Specific Permit Conditions.”

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11 References

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Appendix A

Interim Status Data Summary

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1 Introduction

Section 2.4 of the main document summarizes the groundwater monitoring history at Low-Level Burial Grounds (LLBG) Waste Management Area (WMA)-3. An interim status indicator parameter groundwater monitoring program under 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" was initiated in 1987. The indicator parameter monitoring program continued until 1990 when LLBG WMA-3 was placed into a groundwater quality assessment monitoring program in accordance with 40 CFR 265.93(d), "Preparation, Evaluation, and Response." LLBG WMA-3 was monitored under a groundwater quality assessment program until 1994, afterwhich it reverted back to an indicator evaluation program where it continued through the remainder of interim status.

The interim status groundwater monitoring history of LLBG WMA-3 through 2016 was compiled. Information from annual reporting documents and groundwater monitoring plans were utilized to compile a summary of wells in the LLBG WMA-3 network, groundwater flow direction and rate, monitoring constituents, statistical comparison values (e.g., critical means), and a summary of comparison value exceedances or other contaminants (e.g., plumes from upgradient sources) in a Microsoft® Excel® workbook. Sampling data through December 31, 2016 for each well is presented in separate Microsoft Excel workbooks. Sample data for each well were retrieved from the Hanford Environmental Information System database. The workbooks are contained in electronic files to accompany this report.

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Appendix B

Identification of Site-Specific Monitoring Constituents for the Low-Level Burial Grounds - ECF-HANFORD-17-0233

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The calculation ECF-HANFORD-17-0233, *Identification of Site-Specific Monitoring Constituents for the Low-Level Burial Grounds*, was performed evaluate the waste constituents associated with the Low-Level Burial Grounds to identify proposed groundwater monitoring constituents. The calculation is available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065107H.

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Appendix C

Topographic Map

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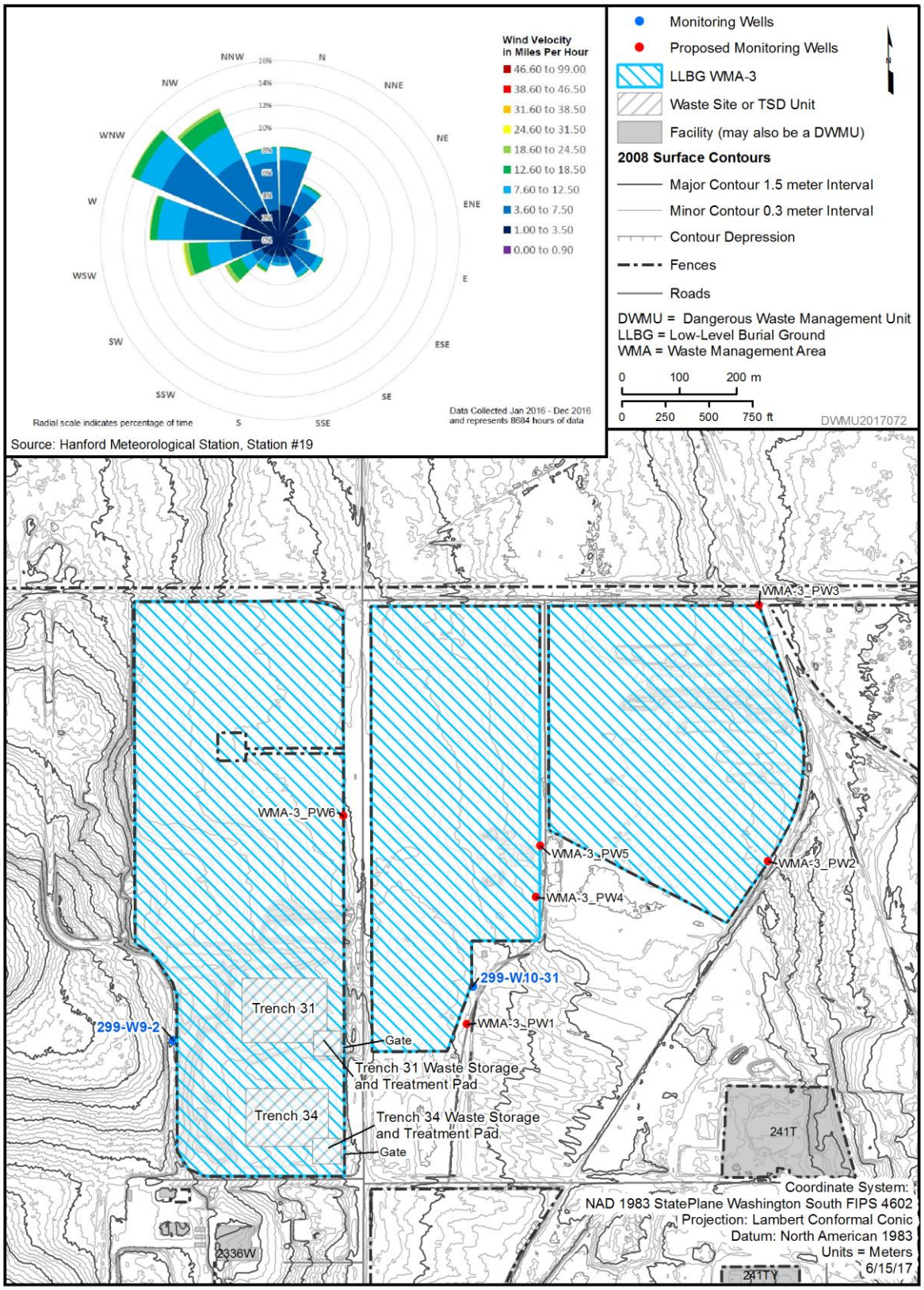

Figure C-1. Topographic Map

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Appendix D

Plume Maps

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This appendix presents regional plume maps in the vicinity of Low-Level Burial Ground (LLBG) Waste Management Area (WMA)-3. These plumes do not originate from LLBG WMA-3, but are regional plumes in the area of the unit.

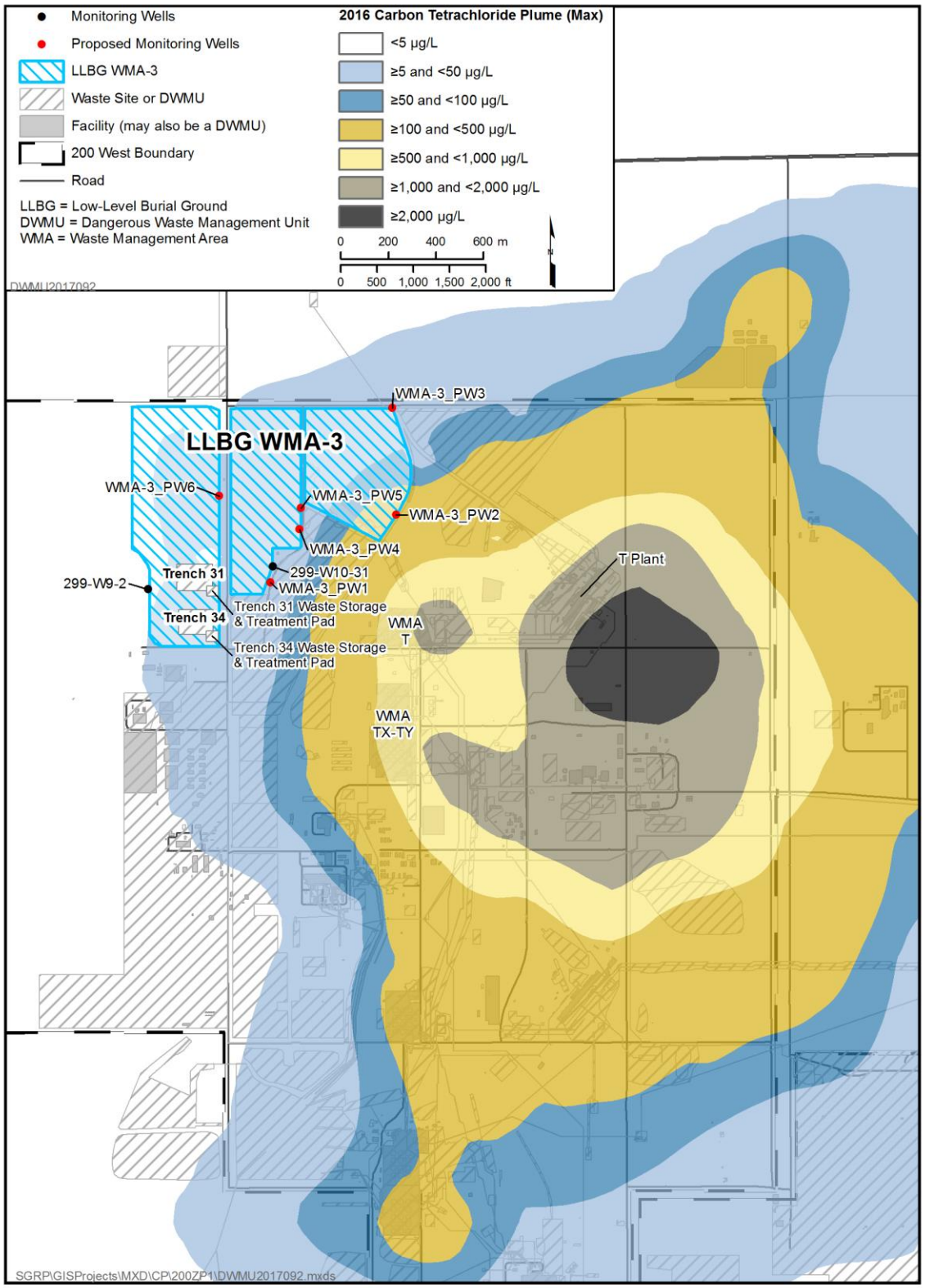

Figure D-1. Regional Carbon Tetrachloride Plume at Low-Level Burial Grounds Waste Management Area-3

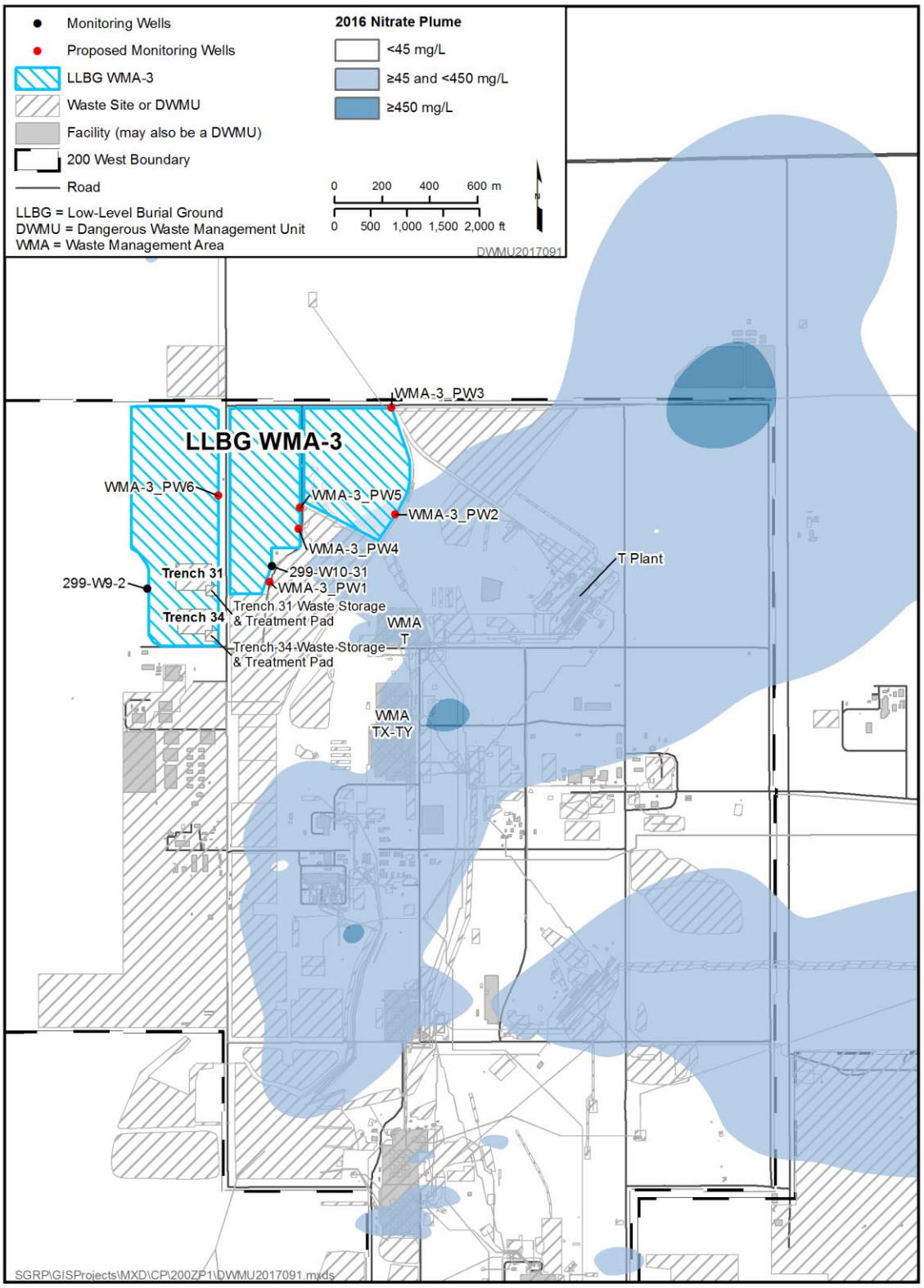

Figure D-2. Regional Nitrate Plume at Low-Level Burial Grounds Waste Management Area-3

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Appendix E

Well As-Built Diagrams and Proposed Well Design Information

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Table E-2. Sampling Interval Information for Wells within the LLBG WMA-3 Network E-1

Table E-3. Planned Location, Depth, and Screen Interval for Proposed Wells within the LLBG WMA-3 Network E-2

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E1 Introduction

This appendix provides the following information for the existing Low-Level Burial Grounds (LLBG) Waste Management Area (WMA)-3 groundwater monitoring wells:

- Well name
- Hydrogeologic unit monitored (the aquifer portion at the well screen-perforation) (Table E-1)
- The following sampling interval information, as provided in Table E-2:
  - Elevation at the top of the screen or perforated interval
  - Elevation at the bottom of the screen or perforated interval
  - Open interval length (i.e., difference between the top and bottom screen-perforation elevations)
  - Drilling method

For proposed wells, the following design information is provided in Table E-3:

- Well location
- Drill depth
- Well diameter
- Screen interval depth
- Sump and end cap interval

Figures E-1 and E-2 provide construction and completion summaries for the existing network wells.

Table E-1. Hydrogeologic Monitoring Unit Classification Scheme

Unit	Description
TU	**Top of Unconfined.** Screened across the water table or the top of the open interval is within 1.5 m (5 ft) of the water table, and the bottom of the open interval is no more than 10.7 m (35 ft) below the water table.

Table E-2. Sampling Interval Information for Wells within the LLBG WMA-3 Network

Well Name	Hydrogeologic Unit Monitored	Elevation Top of Open Interval (m [ft] NAVD88)	Elevation Bottom of Open Interval (m [ft] NAVD88)	Open Interval Length (m [ft])	Drilling Method
299-W9-2	TU	135.9 (445.87)	125.2 (410.76)	10.7 (35.0)	Auger/Cable Tool
299-W10-31	TU	136.5 (447.83)	125.8 (412.73)	10.7 (35.0)	Becker Hammer

Reference: NAVD88, *North American Vertical Datum of 1988*.

TU = Top of Unconfined, as described in Table E-1

Table E-3. Planned Location, Depth, and Screen Interval for Proposed Wells within the LLBG WMA-3 Network

Well ID	Northing (m)	Easting (m)	Surface Elevation (m [ft] NAVD88)	Water Table Elevation (m [ft] NAVD88)	Depth to Water (m [ft] bgs)	Drill Depth (m [ft] bgs)	Final Well Diameter (cm [in.])	Screen Interval (m [ft] bgs)	Sump and End Cap Interval (m [ft] bgs)
WMA-3_PW1	136901.47	566256.03	209.96 (688.85)	136.12 (446.59)	73.84 (242.26)	84.2 (276.26)	10.16 (4)	72.32 (237.26) to 82.98 (272.26)	82.98 (272.26) to 83.9 (275.26)
WMA-3_ PW2	137186.42	566784.13	207.46 (680.64)	134.01 (439.67)	73.45 (240.98)	83.81 (274.98)	10.16 (4)	71.93 (235.98) to 82.59 (270.98)	82.59 (270.98) to 83.51 (273.98)
WMA-3_ PW3	137635.58	566767.69	209.24 (686.48)	134.57 (441.5)	74.67 (244.98)	85.03 (278.98)	10.16 (4)	73.15 (239.98) to 83.81 (274.98)	83.81 (274.98) to 84.73 (277.98)
WMA-3_ PW4	137124.25	566377.71	206.61 (677.85)	135.53 (444.65)	71.08 (233.2)	81.44 (267.2)	10.16 (4)	69.56 (228.2) to 80.22 (263.2)	80.22 (263.2) to 81.14 (266.2)
WMA-3_ PW5	137213.53	566385.08	206.36 (677.03)	135.53 (444.65)	70.83 (232.38)	81.19 (266.38)	10.16 (4)	69.31 (227.38) to 79.97 (262.38)	79.97 (262.38) to 80.89 (265.38)
WMA-3_ PW6	137265.74	566040.35	210.61 (690.98)	136.81 (448.85)	73.8 (242.13)	84.16 (276.13)	10.16 (4)	72.28 (237.13) to 82.95 (272.13)	82.95 (272.13) to 83.86 (275.13)

Reference: NAVD88, *North American Vertical Datum of 1988*.

Note: Well coordinates, elevations, and projected well design are estimates and are subject to modification based on final well location survey and conditions encountered during drilling.

bgs = below ground surface

WELL SUMMARY SHEET	Start Date: 7/26/11 Finish Date: 9/22/11	Page 1 of 2
Well ID: C8201	Well Name: 299-W9-2	
Location: 350 meters NNW of WRAP Building	Project: 2 M-24 RCRA Groundwater Wells	
Prepared By: Patrick Cabbage — Date: 10/21/11	Reviewed By: RC Weekes — Date: 10/24/11	
Signature: Patrick Cabbage	Signature: RC Weekes	

CONSTRUCTION DATA

Stainless Steel Protective Casing: 3.33 ft above ground surface

Type I/II Portland Cement Grout: 0 - 10.2 ft bgs

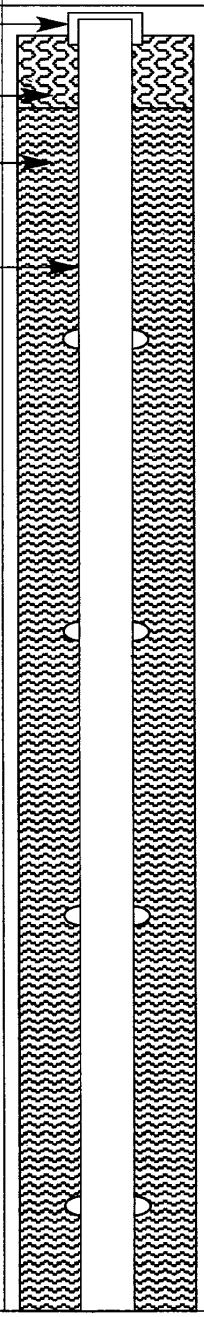
#8 Granular Bentonite Crumbles: 10.2 - 277.1 ft bgs

4-in I.D., Schedule 10, Type 304, Stainless Steel Permanent Casing: 2.35 ft ags - 284.69 ft bgs

All temporary drill casing was removed from the ground.

All depths are in feet below ground surface.

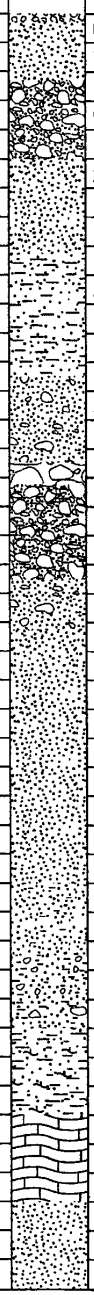
The borehole was drilled with 10 ¾-inch O.D. casing from 0.0 - 119.4 ft bgs and with 8 5/8-inch O.D. casing from 119.4 - 325.0 ft bgs.



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 20, 40, 60, 80, 100, 120, 140, 160

Graphic Log



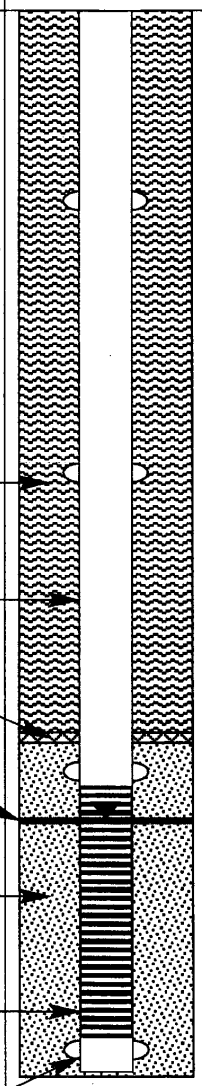
Lithologic Description/Groundwater Sample Depths (ft bgs)

- 0-1 Gravel Drill Pad (G)
- 1-9 Sand (S)
- 9-20 Sandy Gravel (sG)
- 20-33 Sand (S)
- 33-50 Slightly Silty Sand ((m)S)
- 50-62 Gravelly Sand (gS)
- 62-65 Gravel (G)
- 65-78 Silty Sandy Gravel (msG)
- 78-85 Gravelly Sand (gS)
- 85-120 Sand (S)
- 120-130 Sand (S)
- 130-140 Slightly Silty Gravelly Sand ((m)gS) with caliche
- 140-152 Slightly Silty Sand ((m)S) with caliche
- 152-164 Caliche
- 164-183 Sand (S)

Figure E-1. Well 299-W9-2 Construction and Completion Summary

WELL SUMMARY SHEET		Start Date: 7/26/11 Finish Date: 9/22/11	Page 2 of 2
Well ID: C8201		Well Name: 299-W9-2	
Location: 350 meters NNW of WRAP Building		Project: 2 M-24 RCRA Groundwater Wells	
Prepared By: Patrick Cabbage	Date: 10/21/11	Reviewed By: DC Weekes	Date: 10/24/11
Signature: Patrick Cabbage		Signature: DC Weekes	

CONSTRUCTION DATA

Description	Diagram
All temporary drill casing was removed from the ground. All depths are in feet below ground surface. The borehole was drilled with 10 ¾-inch O.D. casing from 0.0 - 119.4 ft bgs and with 8 5/8-inch O.D. casing from 119.4 - 325.0 ft bgs. #8 Granular Bentonite Crumbles: 10.2 - 277.1 ft bgs 4-in I.D., Schedule 10, Type 304, Stainless Steel Permanent Casing: 2.35 ft ags - 284.69 ft bgs 3/8-in Bentonite Pellets: 277.1 - 278.4 ft bgs Static Water Level: 289.4 ft bgs (9/12/11) Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 278.4 - 325.0 ft bgs 4-in I.D., Schedule 10, Type 304, Stainless Steel 20-slot Screen: 284.69 - 319.65 ft bgs 4-in I.D., Schedule 10, Type 304, Stainless Steel Sump: 319.65 - 324.57 ft bgs	

GEOLOGIC/HYDROLOGIC DATA

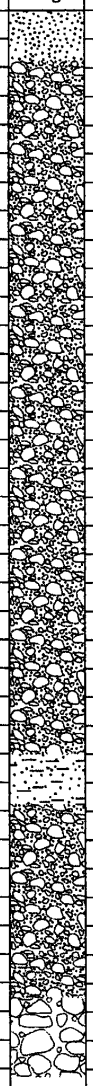
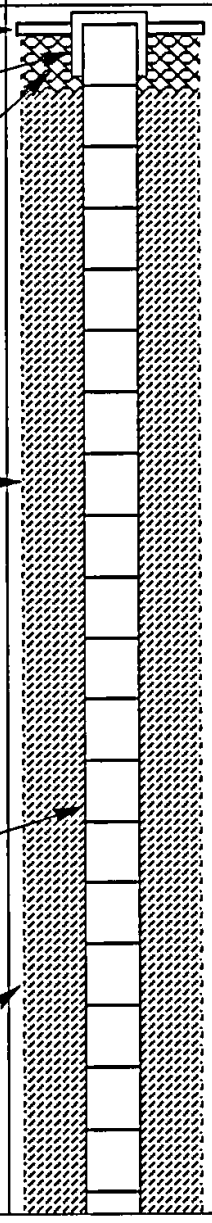
Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
180		164-183 Sand (S)
		183-280 Sandy Gravel (sG)
200		
220		
240		
260		
280		280-287 Silty Sand (mS)
		287-306 Sandy Gravel (sG)
300		
		306-314 Silty Sandy Gravel (msG)
320		314-325 Gravel (G)
		TD = 325.0 ft bgs (09-07-2011)
340		

Figure E-1. Well 299-W9-2 Construction and Completion Summary (continued)

WELL SUMMARY SHEET	Start Date: 4/20/2006 Finish Date: 5/10/2006	Page 1 of 2
Well ID: C5194	Well Name: 299-W10-31	
Location: Approx. 560 ft E Dayton Ave., 790 N 23rd St.	Project: CY06 LLBG Monitoring Wells	
Prepared By: Jeffrey Weiss — Date: 5/10/06	Reviewed By: L. D. Walker — Date: 5/31/06	
Signature: John Howch for Jeff Weiss	Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
6-in thick concrete pad 6-in I.D. stainless steel protective casing - top of casing is 2.35 ft above pad Concrete 0 -3.0 ft Portland Cement 3.0 - 10.8 ft Bentonite Crumbles 10.8 - 224.7 ft 4-in I.D. stainless steel, type 304, schedule 5 casing, flush threaded 1.45 ft above pad - 239.93 ft bgs Nominal 9-in borehole diameter	



GEOLOGIC/HYDROLOGIC DATA

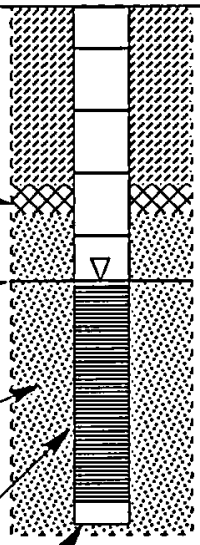
Depth in Feet	Graphic Log	Lithologic Description (ft bgs)
0		0-5 No Recovery
		5-14 Gravely Sand, gS
		14-23 Sandy Gravel, sG
		23-35 Gravel, G
25		35-45 Sandy Gravel, sG
		45-50 Gravel, G
50		50-72 Sandy Gravel, sG
		72-80 Gravely Sand, gS
75		80-95 Sand, S
		95-105 Silty Sand, mS
100		101-103 Caliche
		105-110 Gravely Sand, gS
		110-121 Sand, S
		121-130 Gravel, G
125		130-132 Gravely Sand, gS
		132-133.5 Gravel, G, basalt boulder
		133.5-142 Gravel, G
		142-157 Sandy Gravel, sG
150		157-194 Gravel, G
175		

Figure E-2. Well 299-W10-31 Construction and Completion Summary

WELL SUMMARY SHEET	Start Date: 4/20/2006 Finish Date: 5/10/2006	Page 2 of 2
Well ID: C5194	Well Name: 299-W10-31	
Location: Approx. 560 ft E Dayton Ave., 790 N 23rd St.	Project: CY06 LLBG Monitoring Wells	
Prepared By: Jeffrey Weiss — Date: 5/10/06	Reviewed By: L.D. Walker — Date: 5/31/06	
Signature: John Horch for Jeff Weiss	Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
1/4-in coated bentonite pellets 224.7 - 228.7	
Static water level = 239.95 (5/02/06)	
10-20 mesh Colorado silica sand 228.7 - ~~281.3~~ 279.8 LW 5-31-06	
4-in I.D. stainless steel, type 304, 20 slot (0.02-in) screen 239.93 - 275.01	
4-in I.D. stainless steel, type 304, schedule 5 sump w/ plate bottom 275.01 - 278.01	
All temporary casing removed from the ground	
All depths are feet below ground surface	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description (ft bgs)
200		194-195 Boulder 195-273 Sandy Gravel, sG
225		
250		273-279.8 (TD) Sandy GRAVEL, sG to Gravelly SAND, gS
275		Total depth drilled = 279.8 ft
300		
325		
350		
375		

Figure E-2. Well 299-W10-31 Construction and Completion Summary (continued)

E2 Reference

NAVD88, 1988, *North American Vertical Datum of 1988*, as revised, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: http://www.ngs.noaa.gov/.

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Appendix F

Groundwater Flow and Migration Calculations to Support Assessment of the Hanford Central Plateau 200 West Area Facilities Monitoring Network – ECF-200W-17-0070

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The calculation ECF-200W-17-0070, *Groundwater Flow and Migration Calculations to Support Assessment of the Hanford Central Plateau 200 West Area Facilities Monitoring Network*, was performed to evaluate the suitability of the current groundwater monitoring networks to detect hypothetical releases and, where appropriate, to evaluate the efficacy of the monitoring networks to detect the presence of, or significant increases in, groundwater contamination from the dangerous waste management units that are located in the 200 West Area of the Central Plateau. The calculation is available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065259H.

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Appendix G

Groundwater Flow and Migration Calculations to Support Assessment of the LLBG WMA-3 Monitoring Network – ECF-200W-17-0072

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The calculation ECF-200W-17-0072, *Groundwater Flow and Migration Calculations to Support Assessment of the LLBG WMA-3 Monitoring Network*, was performed to evaluate monitoring well locations for the Low-Level Burial Grounds Waste Management Area-3 groundwater monitoring network. The calculation is available at:
https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065098H.

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Appendix H

Statistical Method Determination

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Figure H-7. Equal Variance Evaluation H-8
Figure H-8. Chart Legend H-9

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H1 Introduction

An accelerated sampling program will be conducted to obtain a minimum of eight samples. The accelerated sampling program will monitor the constituents listed in Table 9-4 (Appendix 5 of Ecology Publication No. 97-407) of the main body at a quarterly frequency for 2 years. After 2 years of sampling is completed, the statistical test method can be determined using the flow charts presented in this appendix.

The flow charts (Figures H-1 through H-7) below represent a series of statistical analyses, consistent with EPA 530/R-09-007, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, that describe basic methodology for determining the type of statistical test that would be most appropriate for implementation in a groundwater monitoring plan for regulated waste. These flow charts guide the user through tests to identify potential outliers, and evaluate statistical distributions, spatial variance, temporal trends and equality of variance for background and compliance wells. EPA 530/R-09-007 should be consulted for conditional data handling requirements related to normality of distribution for Rosner's, Modified Dixson's, and ANOVA tests. Based on these series of tests, the user is directed towards the type of test, interwell or intrawell, that is most appropriate based on the available data. The flow charts do not proclaim to provide every detail of every process but are to be used as a guide.

Figure H-8 provides a chart legend applicable to Figures H-1 through H-7.

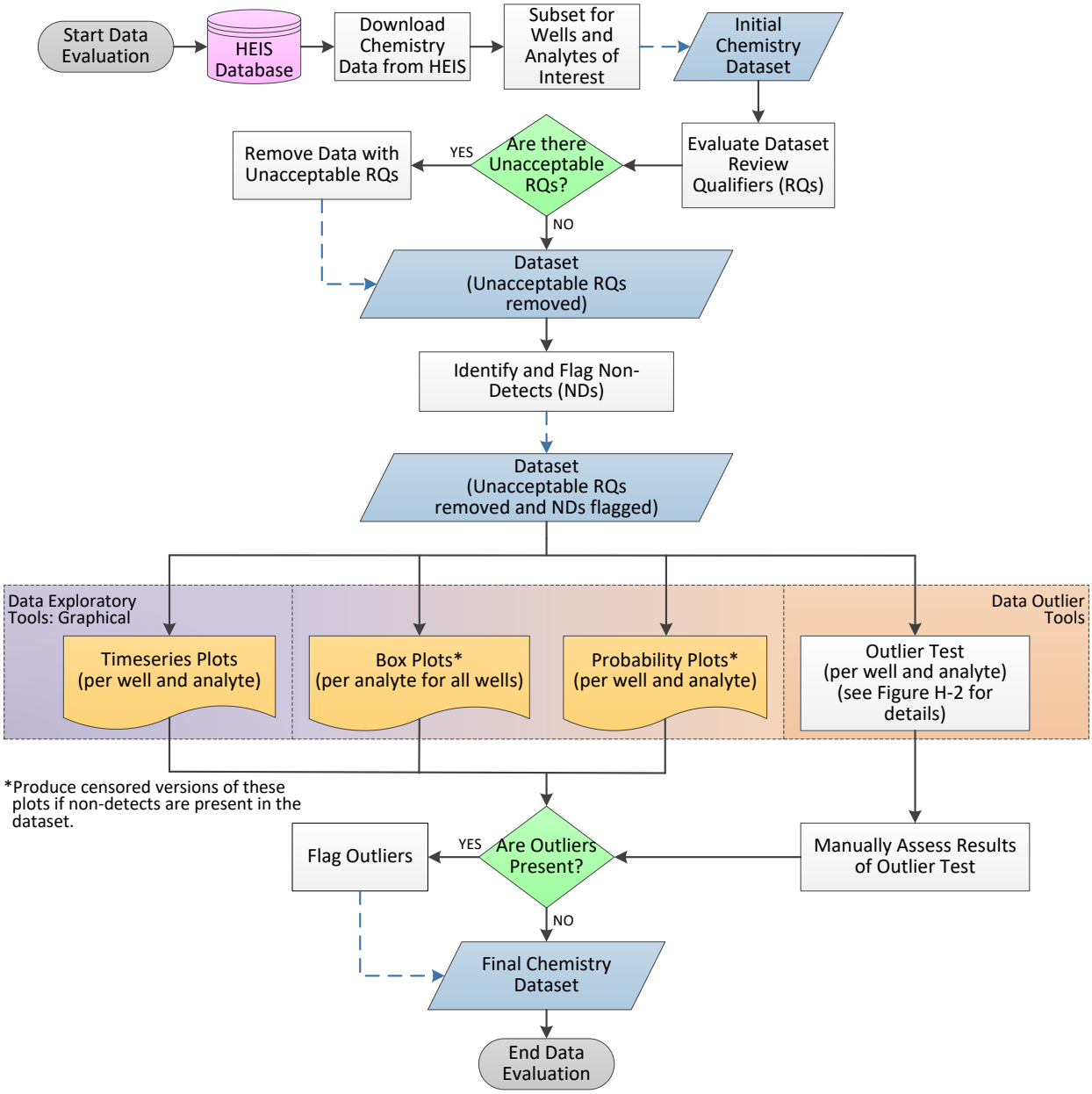

Figure H-1. Data Evaluation

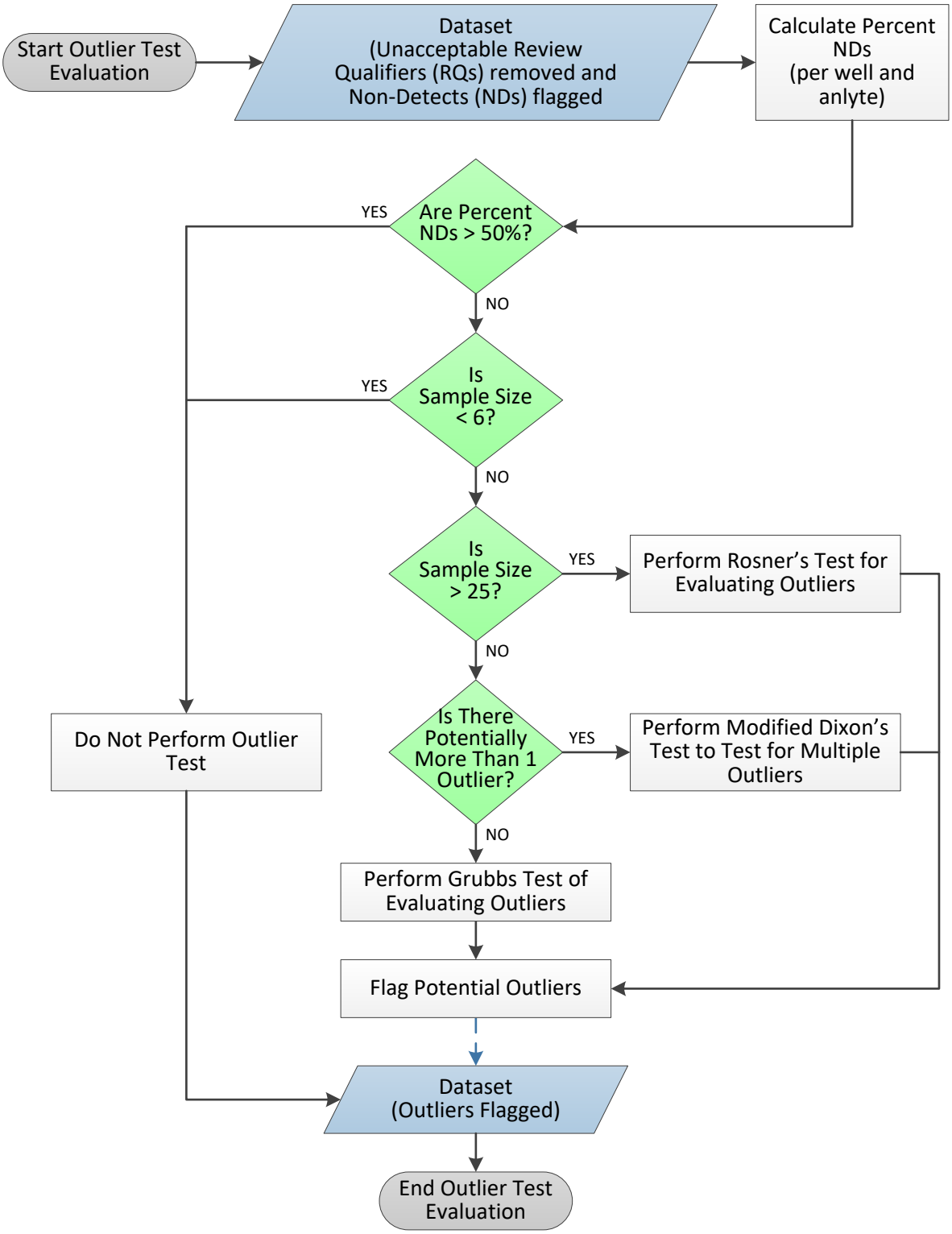

Figure H-2. Outlier Test Evaluation

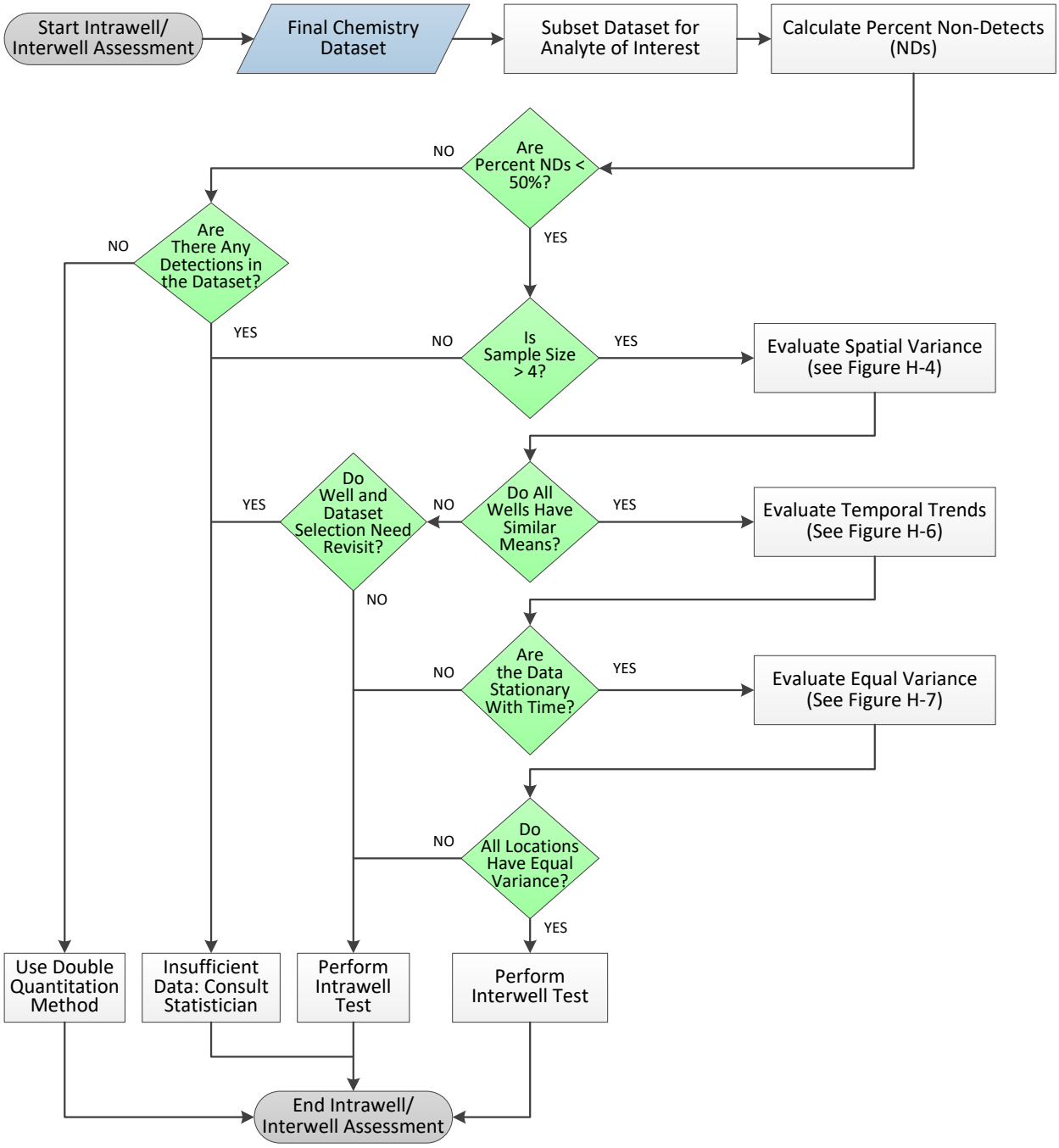

Figure H-3. Intrawell/Interwell Assessment

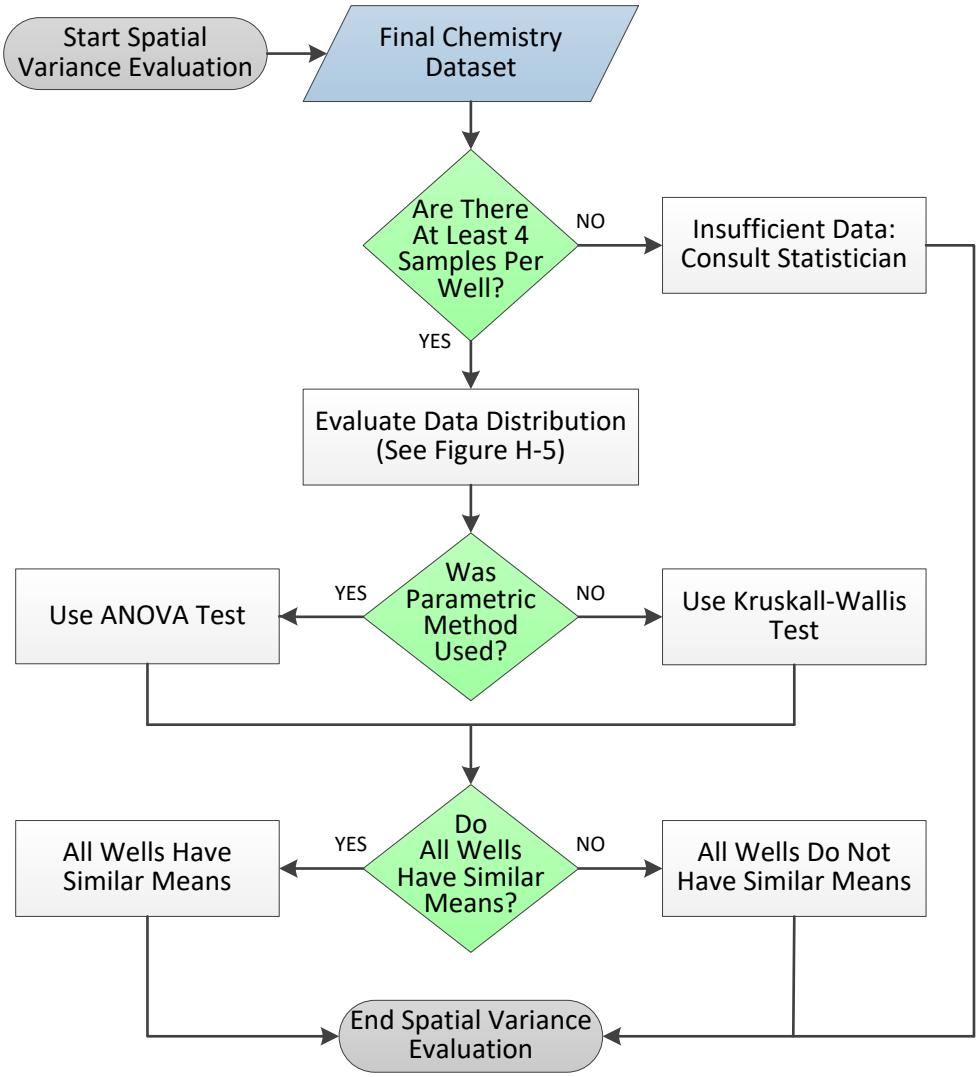

Figure H-4. Spatial Variance Evaluation

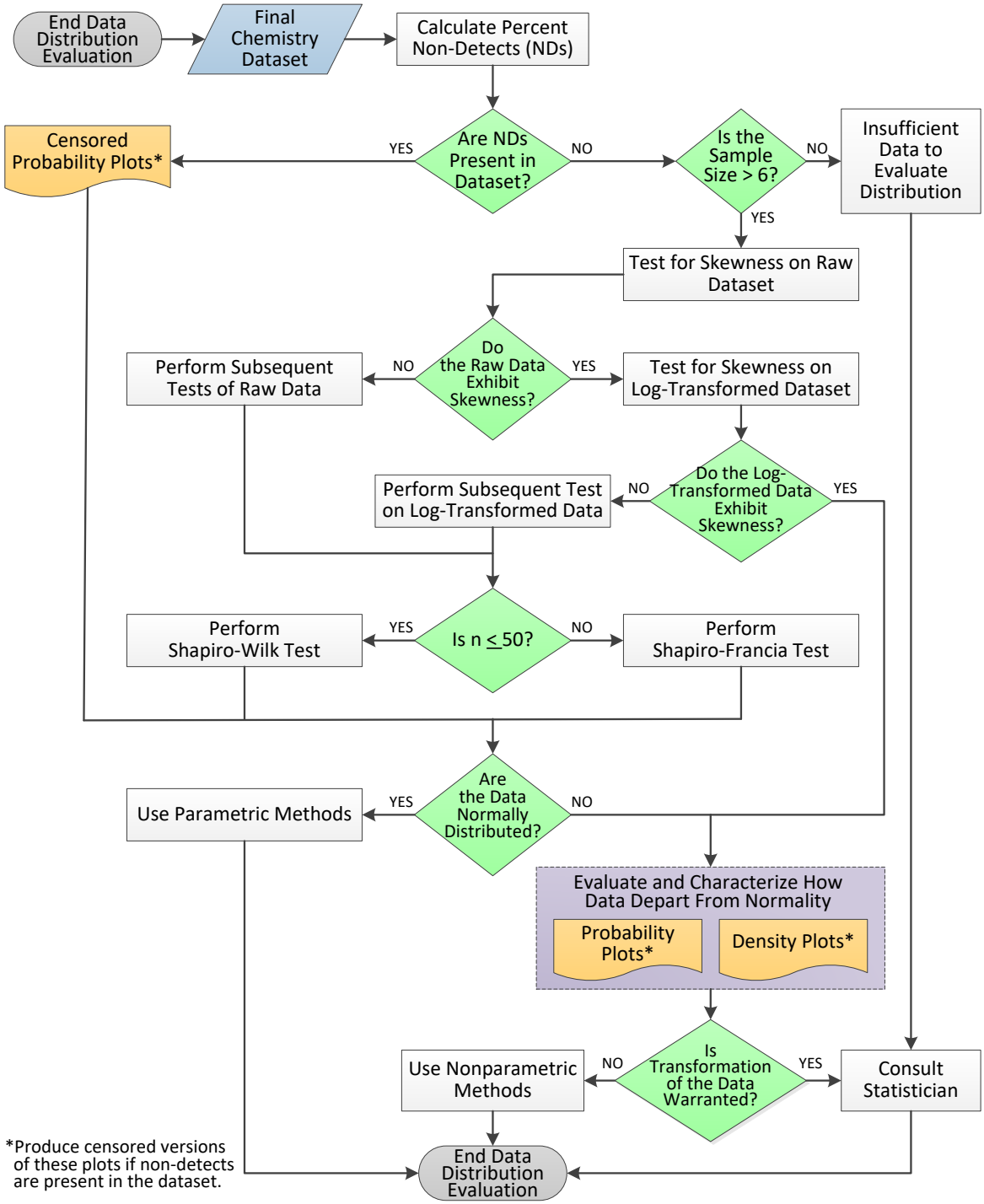

Figure H-5. Data Distribution Evaluation

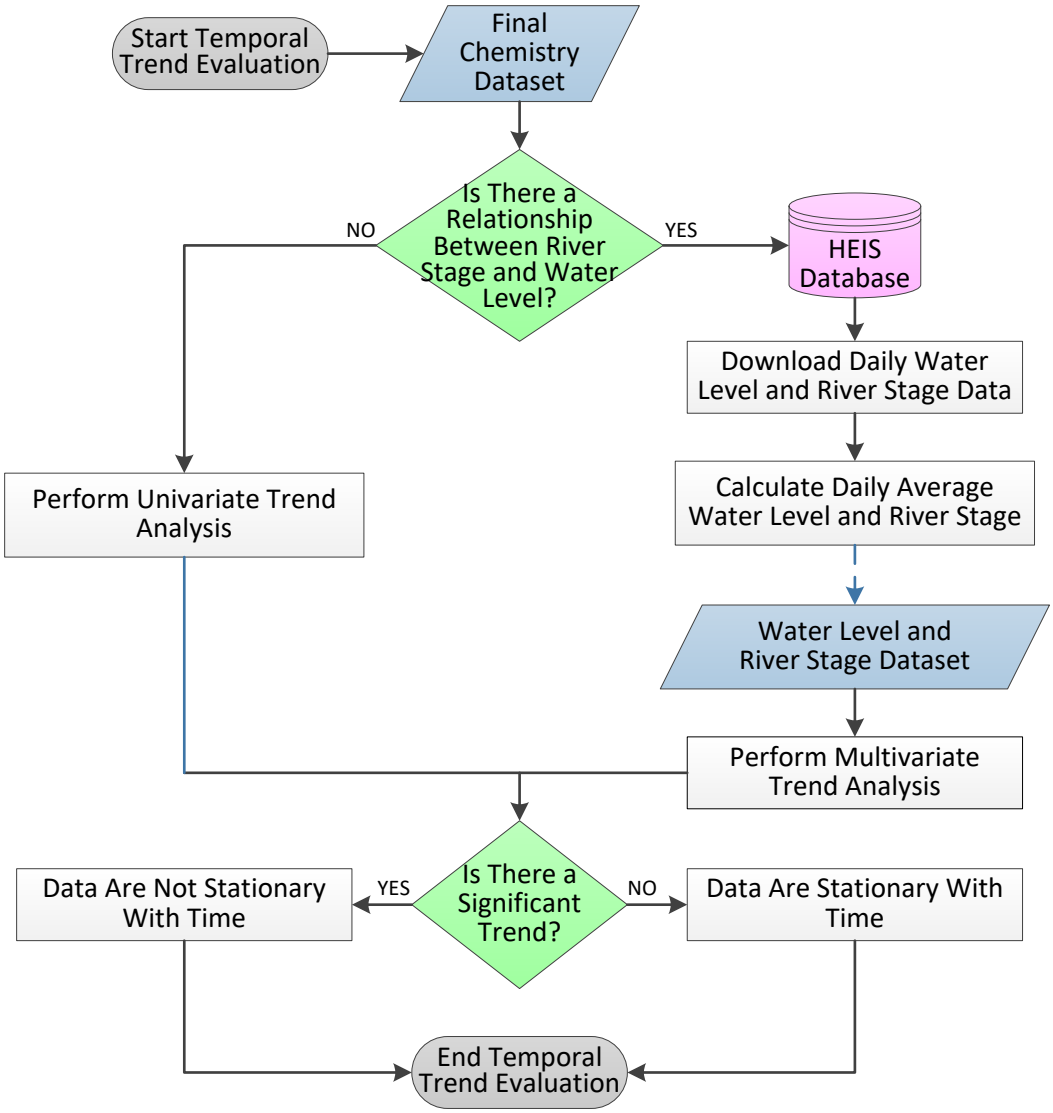

Figure H-6. Temporal Trend Analysis

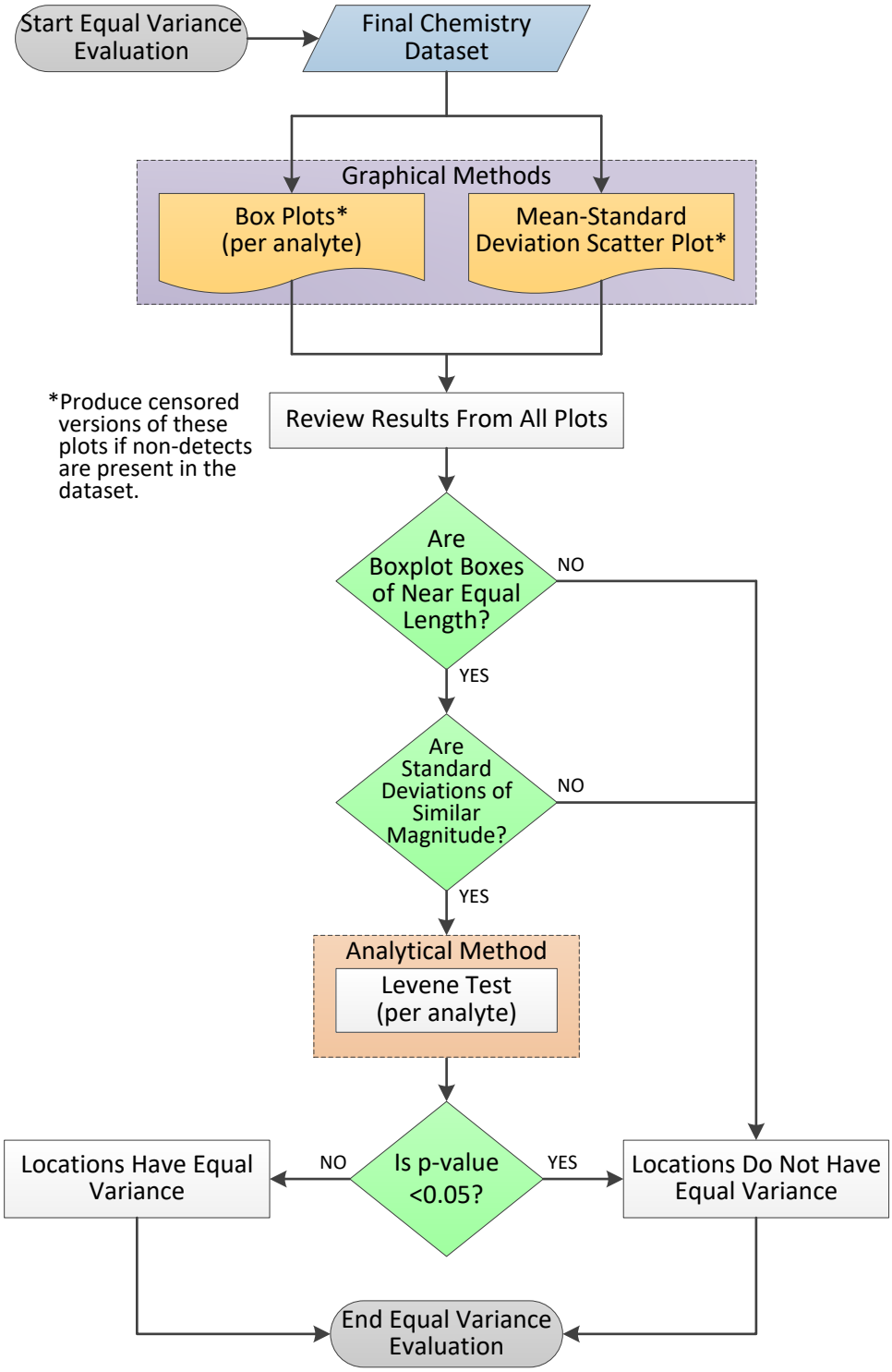

Figure H-7. Equal Variance Evaluation

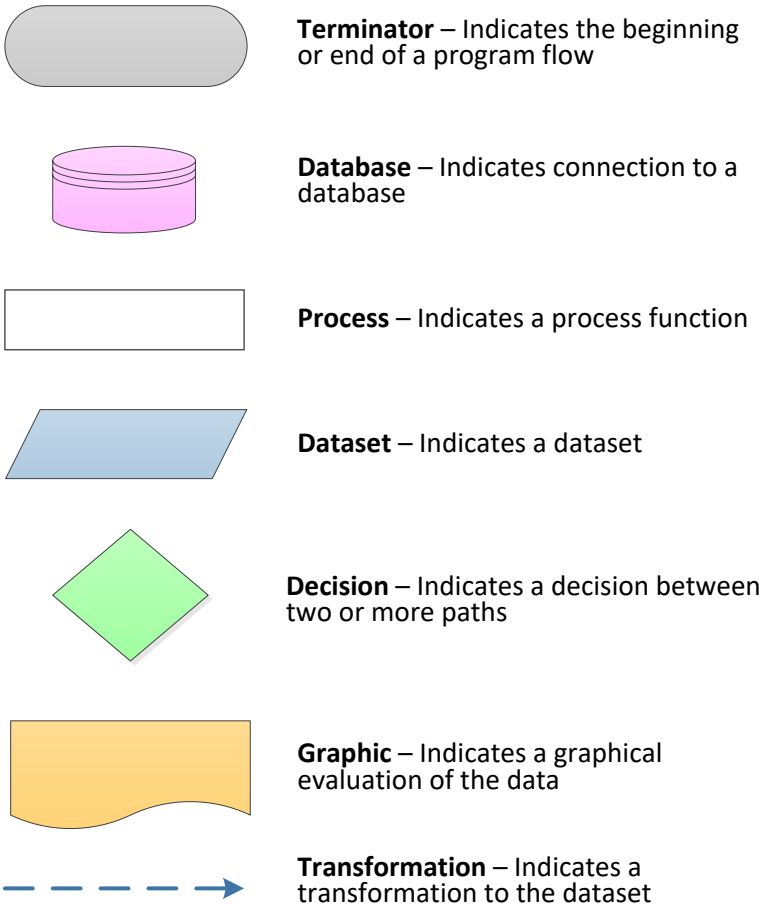

Figure H-8. Chart Legend

H2 Reference

EPA 530/R-09-007, 2009, *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*, Office of Resource Conservation and Recovery, U.S. Environmental Protection Agency, Washington, D.C. Available at: https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P10055GQ.TXT.