SGW-60584
Revision 0

ENGINEERING EVALUATION REPORT FOR LOW-LEVEL BURIAL GROUNDS WASTE MANAGEMENT AREA-4 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

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APPROVED
By Julia Raymer at 10:17 am, Aug 23, 2018

Release Approval Date

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-4 Green Islands Groundwater Monitoring, SGW-60584, 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).

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

August 16, 2018
Date

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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
DWS	drinking water standard
Ecology	Washington State Department of Ecology
ECF	engineering calculation file
EPA	U.S. Environmental Protection Agency
FY	fiscal year
K_d	distribution coefficient
LLBG	Low-Level Burial Grounds
MLLW	mixed low-level waste
MT3DMS	Modular 3-D Transport Multispecies
OU	operable unit
P&T	pump and treat
PFP	Plutonium Finishing Plant
RCRA	*Resource Conservation and Recovery Act of 1976*
SVOC	semivolatile organic compound
TCE	trichloroethylene
TOC	total organic carbon
TOX	total organic halogens
TPH	total petroleum hydrocarbon
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)-4 based on evaluation of contaminants associated with LLBG WMA-4 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-4 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-4 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-4 comprises two burial grounds: 218-W-4B and 218-W-4C (Figure 1-1). LLBG WMA-4 received miscellaneous mixed waste from Hanford and non-Hanford sources; 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 WAC 173-303-110(3)(c) and (7), "Dangerous Waste Regulations," "Sampling, Testing, Methods and Analytes," constituents 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 planning, scheduling, and construction for any new wells or revised groundwater monitoring networks that are approved by Ecology.

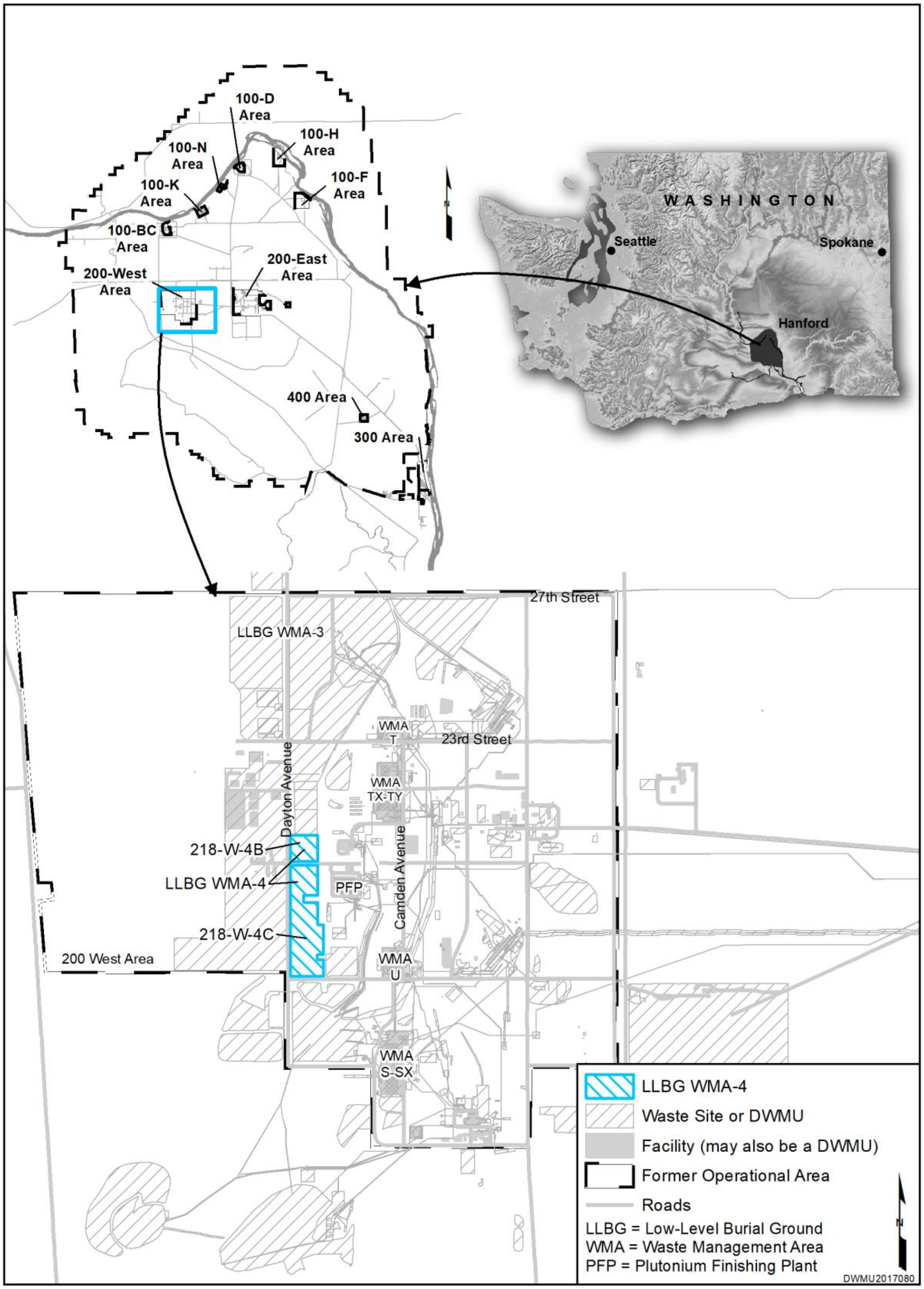

Figure 1-1. Location Map for LLBG WMA-4

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-4 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-4 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

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
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
WAC 173-303-645(9)(a) 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: (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.	Chapter 8 Chapter 9
WAC 173-303-645(9)(b) 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.	Chapter 9

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

b. WAC 173-303-645(8)(b) is not applicable because LLBG WMA-4 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-4. 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-4.
- 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-4 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-4.
- Appendix E contains well as-built diagrams and proposed well design information.
- 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-4 modeling ECF (ECF-200W-17-0073, *Groundwater Flow and Migration Calculation to Support Assessment of the LLBG WMA-4 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-4, its operations, regulatory basis, waste characteristics, and interim status groundwater monitoring history.

2.1 Background

LLBG WMA-4 is an inactive landfill located in the central portion of the 200 West Area, west of the Plutonium Finishing Plant (PFP) and WMA U. LLBG WMA-4 consists of the 218-W-4B and 218-W-4C Burial Grounds, which contain 28 unlined trenches that were used for disposal of low-level radioactive wastes and mixed low-level wastes (MLLW). At the southern end of the 218-W-4B Burial Ground, there are 12 below-grade caissons that contain remote-handled low-level waste and retrievable transuranic waste.

2.1.1 218-W-4B Burial Ground

The 218-W-4B Burial Ground is located in the central portion of the 200 West Area, about 150 m (500 ft) northwest of the 234-5Z Building (PFP) and directly west of the 231-Z Building (Figure 2-1). The burial ground covers approximately 3.5 ha (8.6 ac) and consists of 15 trenches that are approximately 177 m (580 ft) long and 3.1 to 3.7 m (10 to 12 ft) deep (Table 1-1 and Section 2.3.1.5 in DOE/RL-2004-60, *200-SW-2 Radioactive Landfills Group Operable Unit RCRA Facility Investigation/Corrective Measures Study/Remedial Investigation/Feasibility Study Work Plan*). 218-W-4B first received waste in 1967 and operated until 1995, at which time the remaining open trenches were backfilled and stabilized with clean gravel (Section 2.3.1.5 in DOE/RL-2004-60).

2.1.2 218-W-4C Burial Ground

The 218-W-4C Burial Ground comprises two separate areas (Figure 2-1). The larger of the areas is located west and southwest of PFP and measures 15 ha (37 ac) (Table 1-1 in DOE/RL-2004-60). A smaller, unused section of the burial ground that measures 4.3 ha (11 ac), referred to as the 218-W-4C Annex, is located directly south of the PFP (Table 1-1 and Section 2.3.1.6 in DOE/RL-2004-60). The 218-W-4C Annex will be removed from LLBG WMA-4 in the future Revision 9 of the Hanford Facility Dangerous Waste Permit. The 218-W-4C Annex is part of LLBG WMA-4 at the time of this engineering report; however, it will not be included for evaluation or discussed further as part of LLBG WMA-4.

The 218-W-4C Burial Ground was designed to contain up to 65 trenches; however, only 16 trenches were constructed. Of the constructed trenches, a total of 15 trenches, ranging from 91 to 219 m (300 to 719 ft) long, were used for waste storage and/or disposal (Table 1-1 in DOE/RL-2004-60, and Section 2.1.2 in DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*, Rev. 2). The burial ground received waste between 1978 and 2004 (Appendix D, p. D-59 in DOE/RL-2004-60).

The waste disposed to LLBG WMA-4 was generally low-level nondangerous waste, with some locations receiving retrievably stored waste. However, MLLW (waste with both a radioactive and dangerous waste component) was disposed to discrete areas within 218-W-4C after August 19, 1987, which is the effective date of RCRA regulation. The areas that received mixed waste were termed “Green Islands” because they were coded in green on the Hanford Facility RCRA Permit Part A application maps (WA7890008967, 2008, *Dangerous Waste Permit Application Part A Form – Low Level Burial Grounds 9/22/2008*) (Figure 2-2). The Green Islands do not include the entire trench, but only the portion of the trench where the regulated waste is buried.

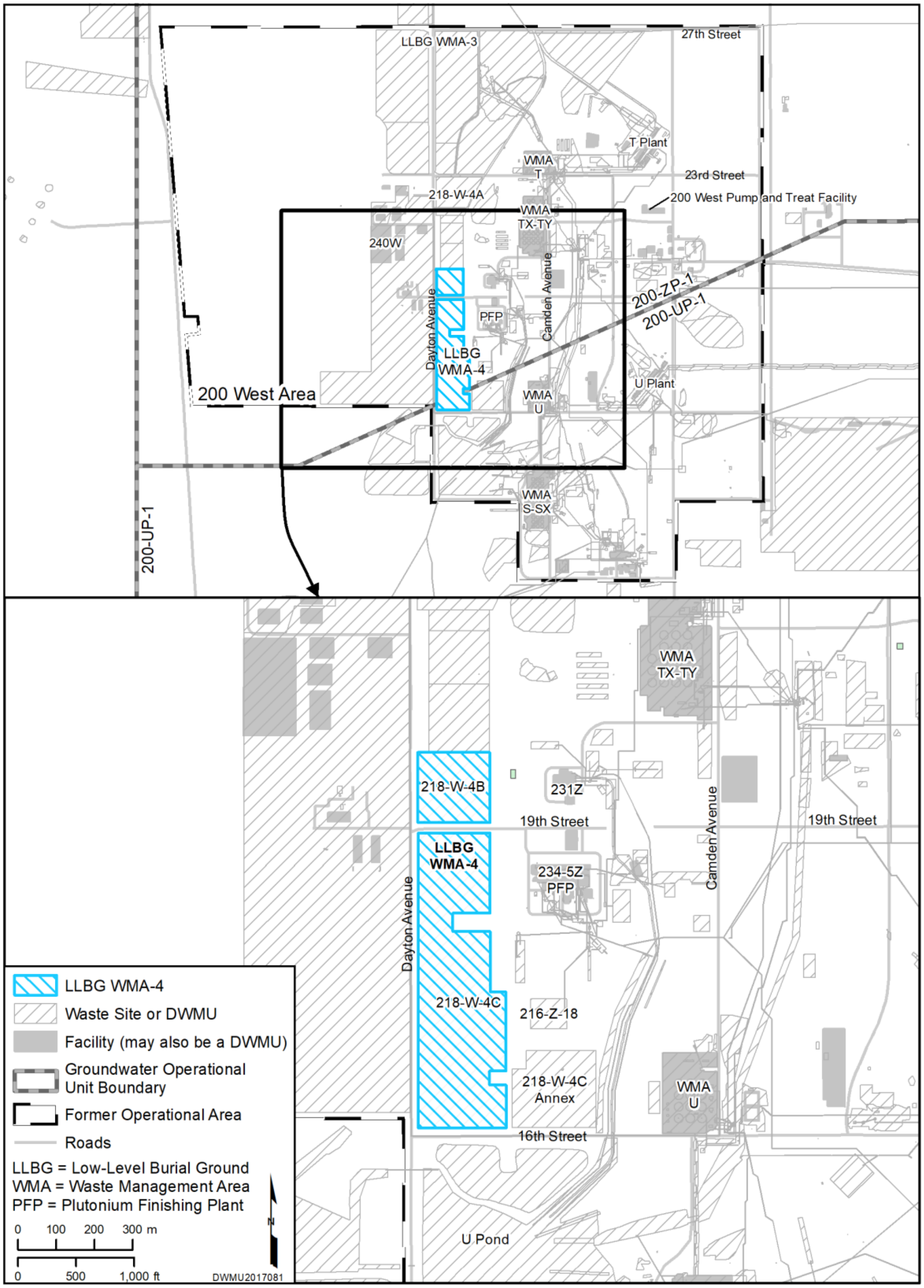

Figure 2-1. Location of LLBG WMA-4 Within the 200 West Area

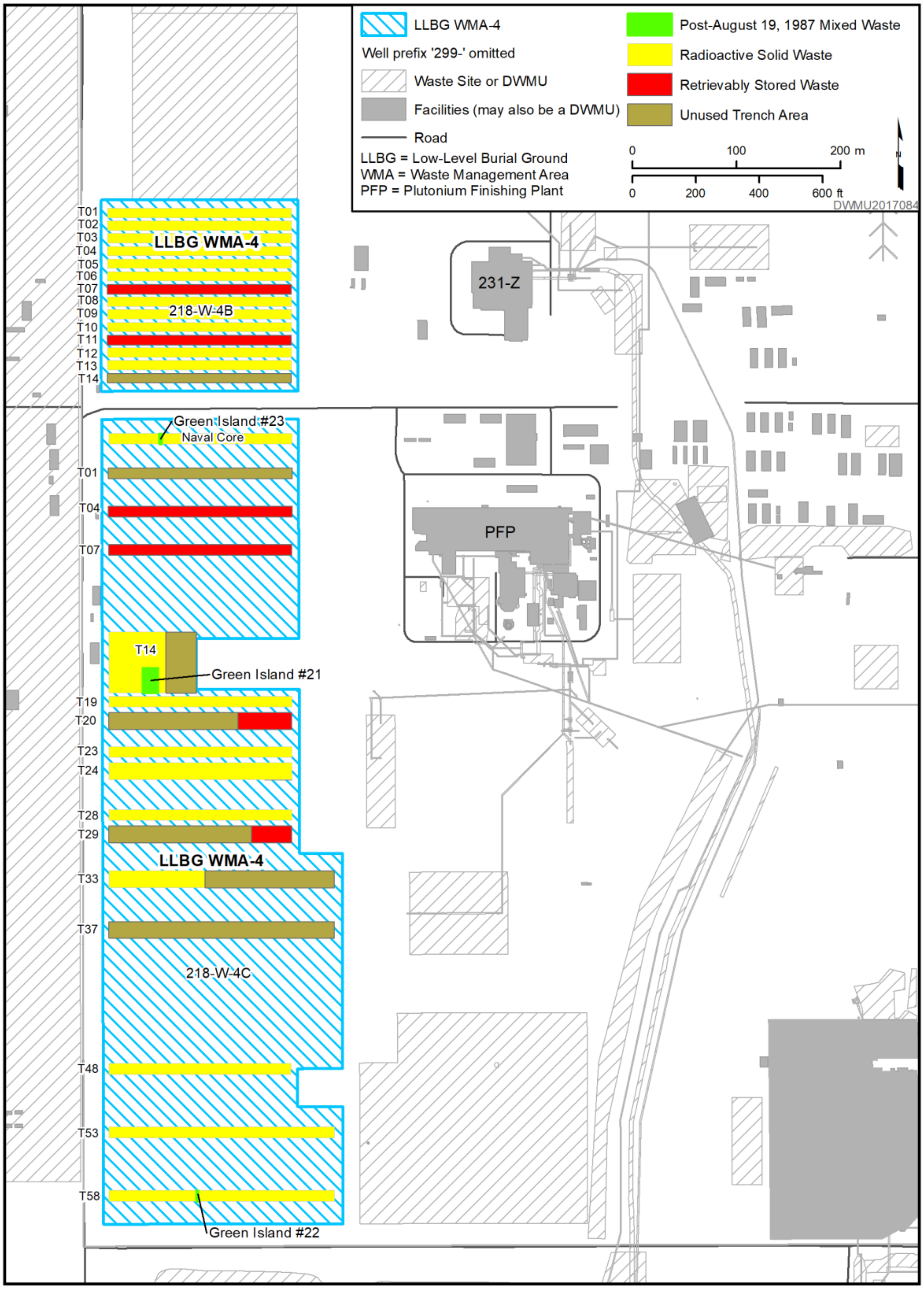

Figure 2-2. LLBG WMA-4 Trenches and Green Island Locations

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-4. Under interim status, groundwater monitoring at LLBG WMA-4 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-4 has an AEA component and is also 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-4 began in 1987 based on the indicator evaluation program requirements of 40 CFR 265, Subpart F (as referenced by WAC 173-303-400[3]). In 1999, the critical mean for total organic halogens (TOX) was exceeded at downgradient well 299-W15-16 (Section A.7.8 in PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). This well had previously been an upgradient monitoring well, and the exceedance was attributed to carbon tetrachloride from an upgradient source (Section A.7.8 in PNNL-13116). DOE reported the exceedance to Ecology and EPA in August 1999 (CCN 071519, "Quarterly Resource Conservation and Recovery Act (RCRA) Groundwater Monitoring Data for the Period January 1, 1999, through March 31, 1999"). Because the elevated TOX was caused by an upgradient source, no further action was taken and indicator parameter monitoring continued (CCN 071519).

In August 2008, total organic carbon (TOC) results in downgradient well 299-W15-224 exceeded the critical mean. Verification samples collected in October 2008 confirmed the results. On December 18, 2008, well 299-W15-224 was resampled again for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and total petroleum hydrocarbons (TPH) (Section 2.0 in SGW-40211, *First Determination RCRA Groundwater Quality Assessment Plan for the Low-Level Burial Grounds Low-Level Waste Management Area-4*). DOE notified Ecology of the exceedance at well 299-W15-224 prior to receiving the December 2008 sampling results (09-AMCP-0058, "Notification of Exceedance of Critical Mean Values for an Indicator Parameter at Non-Radioactive Dangerous Waste Landfill and Low-Level Burial Grounds, Low-Level Waste Management Area 4"). A groundwater quality assessment plan (SGW-40211) was submitted to Ecology in January 2009 (09-AMCP-0062, "First Determination Resource Conservation and Recovery Act Groundwater Quality Assessment Plans for the Non-Radioactive Dangerous Waste Landfill and the Low Level Burial Grounds Low Level Waste Management Area-4, SGW-40211, Revision 0"). Sampling was performed under SGW-40211 in March 2009. An assessment report (SGW-41903, *Groundwater Quality Assessment for the Low-Level*

Waste Management Area-4) was submitted to Ecology in July 2009. No organic compounds were identified to account for the elevated TOC, and the monitoring program returned to indicator parameter monitoring (Chapter 3 in SGW-41903).

A revised indicator parameter monitoring plan was issued in 2010 (DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for LLBG WMA-4*, Rev. 0), with the latest revision in 2012 (DOE/RL-2009-69, Rev. 2). Interim status monitoring has since continued under an indicator evaluation program.

In November 2015, DOE requested permission to remove the unused landfill areas, including the 218-W-4C Annex at LLBG WMA-4, from the LLBG Part A Application (16-AMRP-0031, "Request for Removal of Unused Landfill Areas from the Hanford Facility Resource Conservation and Recovery Act/Dangerous Waste Permit Application Part A Form for the Low-Level Burial Grounds Operating Unit Group"). Ecology concurred that the 218-W-4C Annex was unused and agreed to its removal from the LLBG unit during the permitting process (15-NWP-211, "Re: Request for Removal of Unused Landfill Areas from the Hanford Facility Resource Conservation and Recovery Act/Dangerous Waste Permit Application Part A Form for the Low-Level Burial Grounds Operating Unit Group"). Although the 218-W-4C Annex is part of LLBG WMA-4 at the time of this engineering report, it is not discussed further as it will not be included in the as part of LLBG WMA-4 in the next permit revision.

Under Revision 9 of the Hanford Facility Dangerous Waste Permit, the LLBG WMA-4 treatment, storage, and disposal (TSD) unit, will become a final status closure unit group. Part II, Condition II.F of 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-4 was designed for disposal of miscellaneous dry wastes from various operations at the Hanford Site and from offsite facilities.

2.3.1 218-W-4B Burial Ground

The 218-W-4B Burial Ground received miscellaneous radioactive waste from the 100, 200, and 300 Areas at the Hanford Site, and offsite generators (mainly national laboratories in the DOE complex) (Section 2.3.1.5 in DOE/RL-2004-60). Solid waste disposed at the site consisted of rags, paper, cardboard, plastic, pumps, tanks, process equipment, and other miscellaneous high-dose-rate and transuranic dry waste. The total volume of buried waste is estimated to be 7,300 m^3 (260,000 ft^3) (Table 1-1 in DOE/RL-2004-60). After August 19, 1987, RCRA and state-only designated MLLW was not disposed in the 218-W-4B Burial Ground.

2.3.2 218-W-4C Burial Ground

The 218-W-4C Burial Ground accepted packaged low-level waste, transuranic waste (some combustible), and mixed waste materials from 200 West Area and other Hanford Site areas, as well as offsite generators (Sections 2.1.2 and 2.3.2 in DOE/RL-2009-69, Rev. 2). The transuranic waste has been segregated from other burial ground waste since 1970 and placed in separate burial trenches where the packages are retrievably stored. The total volume of buried waste is estimated at 15,000 m^3 (530,000 ft^3) (Table 1-1 in DOE/RL-2004-60). Trenches 1, 4, 7, 20, 29, and the east end of Trench 24 contained retrievably stored waste, which has been fully retrieved (Section 2.3.1.6 in DOE/RL-2004-60).

The Naval reactor compartment trench (Trench NC); Trenches 14, 19, 23, 28, 33, 48, 53, and 58; and the remainder of Trench 24 received low-level waste (Section 2.4 in DOE/RL-2014-43, *Mixed Waste Disposed of in the Low-Level Burial Grounds*). The northernmost trench (Trench NC) contains core barrels that originated from the U.S. Department of the Navy. Trench 1 contains drums generated from mining the 216-Z-9 Crib and approximately 500 cans of ash received in the early 1980s. The ash was generated by the 232Z Waste Incinerator Facility, which incinerated miscellaneous waste such as rubber gloves, rags, paper, spent solvent, and cutting oils.

Trenches NC, 14, and 58 are identified as containing mixed waste that was disposed after the August 19, 1987 effective date of mixed waste regulation. Each of the trenches contains a Green Island as detailed in Table 2-1.

Table 2-1. Mixed Waste Disposed to the Green Islands in LLBG WMA-4

Green Island Number	Trench Number	Disposal Date	Description	Waste Volume (m^3 [yd^3])
218-W-4C Burial Ground				
21	14	4/15/1989	Self-contained reactor pressure vessel and neutron shield tank filled with lightweight concrete.	281.6 (368.3)
22	58	5/17/1988	Steel box with lead shielding containing contaminated equipment and decontamination debris.	9.3 (12.2)
23	NC	1/6/1995	Nine 208 L (55 gal) drums and twenty-three 568 L (150 gal) Enduropaks of Lawrence Berkeley Laboratory waste.	14.9 (19.5)

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

2.3.3 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 Permit Application (Operating Unit 17), last revised October 1, 2008 (Revision 14) (WA7890008967, 2008). The unit includes eight burial grounds. Dangerous wastes specifically associated with LLBG WMA-4 are not identified; therefore, LLBG WMA-4 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 Part A Application

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-
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

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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-trimethoxybenzo yl)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-

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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)

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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,-hex ahydro-, (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-hydroxy-, ethyl ester; Chlorobenzilate	P007	5-(Aminomethyl)-3-isoxazolol; 3(2H)-Isoxazolone, 5-(aminomethyl)-

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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-m ethoxy-, (8S-cis)-	P028	Benzene, (chloromethyl)-; Benzylchloride

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Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
U060	Benzene, 1,1'-(2,2-dichloroethylidene)bis [4-chloro-; DDD	P029	Coppercyanide; Copper cyanide Cu(CN)
U061	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis [4-chloro-; DDT	P030	Cyanides (soluble cyanide salts), not otherwise specified
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-o ctahydro-, (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

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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
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	Potassium cyanide; Potassium cyanide K(CN)
U121	Methane, trichlorofluoro-; Trichloromonofluoromethane	P099	Argentate(1-), bis(cyano-C)-, potassium; Potassium silver cyanide
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	Silver cyanide; Silver cyanide 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 Part A Application

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	Zinc cyanide; Zinc cyanide Zn(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

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

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
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-tri methylpyrrolo [2,3-b]indol-5-yl 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)-,methylcarbamate
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

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

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

Source: WA7890008967, 2008, *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-4. Figure 2-3 provides the locations of wells discussed in this section. A summary of the monitoring history for LLBG WMA-4 is presented in Appendix A. Appendix A also contains the interim status groundwater monitoring data collected at LLBG WMA-4 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*
PNNL-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* ECN 113805 ECN 144234 ECN 618165 ECN 618180	1989 1991 1991 1994 1995	Indicator Evaluation Program
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
SGW-40211, *First Determination RCRA Groundwater Quality Assessment Plan for the Low-Level Burial Grounds Low-Level Waste Management Area-4*	2009	Groundwater Quality Assessment Program
DOE/RL-2009-69, 2010, Rev. 0, *Interim Status Groundwater Monitoring Plan for LLBG WMA-4*	2010	Indicator Evaluation Program
DOE/RL-2009-69, 2010, Rev. 1, *Interim Status Groundwater Monitoring Plan for LLBG WMA-4*	2010	Indicator Evaluation Program
DOE/RL-2009-69, 2010, Rev. 2, *Interim Status Groundwater Monitoring Plan for LLBG WMA-4*	2012	Indicator Evaluation Program

* 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."

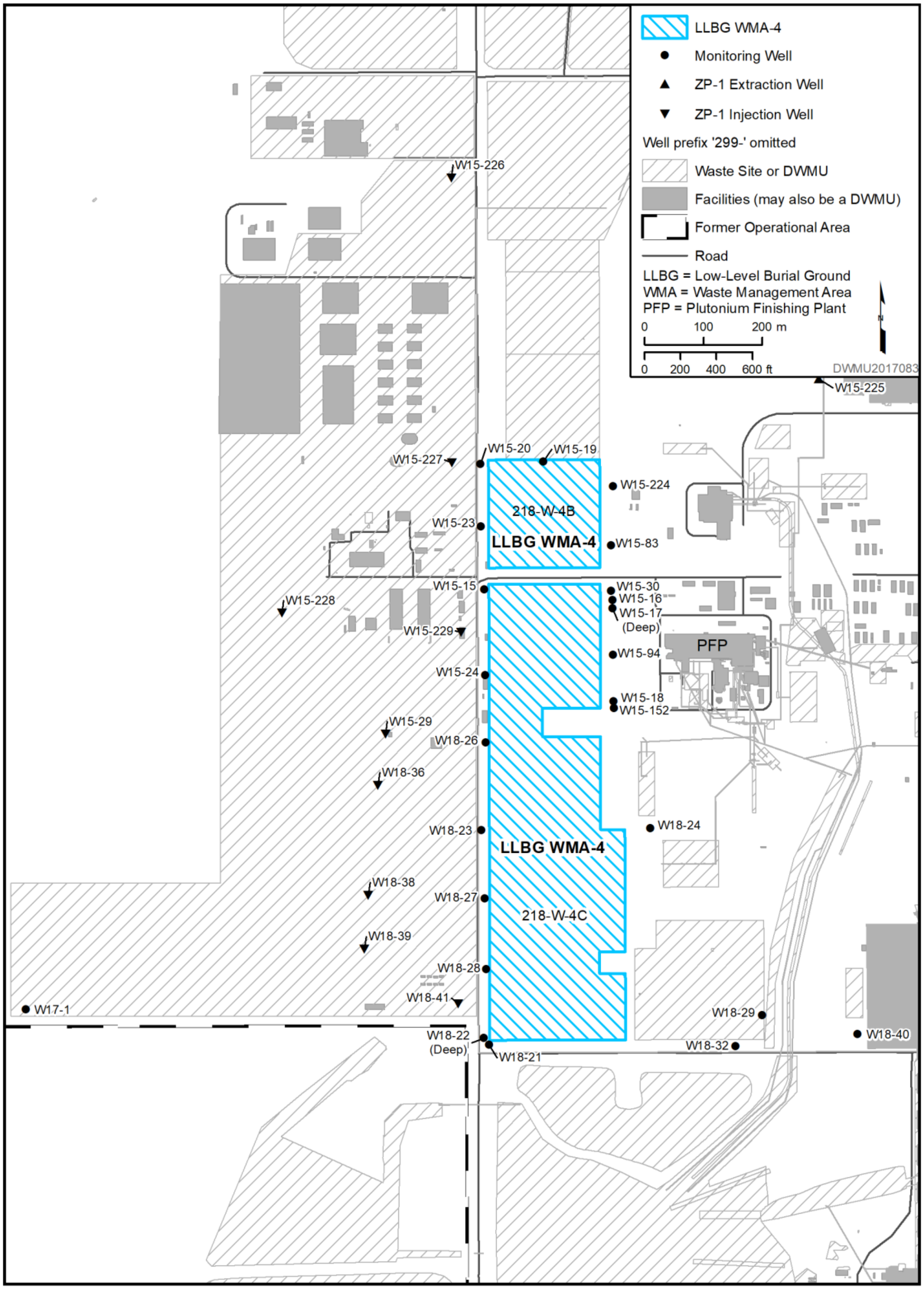

Figure 2-3. Wells Used During Interim Status Monitoring of LLBG WMA-4

In 1987, the DOE, Richland Operations Office, initiated an interim status groundwater monitoring program at LLBG WMA-4 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. Six new monitoring wells and two deep wells were planned at LLBG WMA-4 to characterize the hydrology at depth and to assess the hydraulic potential and quality of the 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-4 monitoring wells installed in 1987 included downgradient wells 299-W15-15, 299-W18-21, 299-W18-23, and 299-W18-22 (deep), and upgradient wells 299-W15-16, 299-W15-18, 299-W18-24, and 299-W15-17 (deep) (Figure 2-3).

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 with five planned downgradient wells. Three downgradient wells would be installed in 1989 and 1990 to monitor the new addition to the WMA: the 218-W-4B Burial Ground (Figure 2-3). The new wells would be located approximately 107 m (350 ft) apart along the western and northern boundaries of the WMA. The remaining two planned downgradient wells would be located along the western boundary of the 218-W-4C Burial Ground, between wells 299-W15-15 and 299-W18-23, to reduce well spacing from 427 m (1,400 ft), to 137 to 152 m (450 to 500 ft). Samples were to be collected for the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b). Ammonium, uranium, tritium, and VOCs (1,1-dichloroethane, 1,2-dichloroethane, trans-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, acetone, benzene, carbon tetrachloride, chloroform, p-dichlorobenzene, methyl ethyl ketone, methyl isobutyl ketone, methylene chloride, tetrachloroethylene, tetrahydrofuran, toluene, trichloroethylene [TCE], vinyl chloride, m-xylene, o-xylene, and p-xylene) were also included for sampling (Section 3.3.10 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, followed by annual sampling at selected wells (these wells were not identified in the plan) (Section 3.5 in WHC-SD-EN-AP-015). Groundwater at LLBG WMA-4 was considered to flow west and northwest (Section 2.3.3.4 in WHC-SD-EN-AP-015). The reported groundwater flow rate ranged from 0.0091 to 0.91 m/d (0.03 to 3 ft/d) (Section 2.3.3.4 in WHC-SD-EN-AP-015).

Downgradient wells 299-W15-20, 299-W15-19, 299-W15-24, and 299-W18-26 were installed in 1989, and downgradient well 299-W15-23 was installed in 1990. In 1990, groundwater was considered to flow primarily west, trending to the northwest in the northern portion of LLBG WMA-4 (Section 14.4.4 in DOE/RL-91-03).

Groundwater sampling was temporarily discontinued in June 1990 due to cancelation of the analytical laboratory contract. The Hanford Site 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*). Samples at LLBG WMA-4 were not collected until after the sampling program resumed in June 1991 (Introduction in DOE/RL-92-03).

In 1991, ECN 113805, *Engineering Change Notice To WHC-SD-EN-AP-015, Rev. 0, Revised Groundwater Monitoring Plan For Low-Level Burial Grounds,* was issued and included four new monitoring wells. Downgradient wells 299-W18-27 and 299-W18-28 were installed in 1991 followed by upgradient well 299-W18-32 in 1992. Upgradient well 299-W18-29 was drilled in 1991 as a monitoring well, but was completed as a perched well after intersecting a previously unknown perched water table (p. 3 in ECN 144234, *Engineering Change Notice To WHC-SD-EN-AP-015, Rev. 0, Revised Groundwater Monitoring Plan For Low-Level Burial Grounds*).

Beginning in 1991, elevated TOX levels were measured at upgradient LLBG WMA-4 monitoring wells and were attributed to the 200 West Area carbon tetrachloride plume (Section 15.4.3.1 in DOE/RL-92-03). Carbon tetrachloride exceeded the drinking water standard (DWS) in wells 299-W15-16, 299-W15-23, 299-W15-24, 299-W18-21, and 299-W18-26 (Section 15.4.3.1 in DOE/RL-92-03). In 1992, nitrate exceeded the DWS in wells 299-W15-15, 299-W15-16, 299-W15-18, and 299-W15-19 and was attributed to the nitrate plume in 200 West Area (Section 15.4.3 of DOE/RL-93-09, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1992*). Elevated concentrations of carbon tetrachloride, with subsequent elevated levels of TOX, and nitrate continued to be measured in LLBG WMA-4 wells throughout the interim status period.

By 1992, the monitoring network consisted of 17 wells; 6 upgradient (299-W15-16, 299-W15-17 [deep], 299-W15-18, 299-W18-24, 299-W18-29 [perched], and 299-W18-32) and 11 downgradient (299-W15-15, 299-W15-19, 299-W15-20, 299-W15-23, 299-W15-24, 299-W18-21, 299-W18-22 [deep], 299-W18-23, 299-W18-26, 299-W18-27, and 299-W18-28) (Table 15-6 of DOE/RL-93-09). Groundwater flow direction continued primarily west, trending to northwest in the northern portion of LLBG WMA-4 and slightly southwest in the extreme southern portion of the WMA (Section 4.12.4.5.1 of DOE/RL 93-88, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1993*).

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-4 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. Flow direction continued west in 1995, with a northwestern trend in the northern portion, and a southwestern trend in the southern portions of the WMA (Section 4.10.4.5.1 in DOE/RL-96-01, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1995*). Considerable changes in hydraulic flow were expected when the 200 West Pump and Treat (P&T) facility began operation.

In 1996, downgradient well 299-W15-30 was added to the network while upgradient well 299-W18-29 (perched) became sample dry (Table 6.1-10 in PNNL-11470, *Hanford Site Groundwater Monitoring for Fiscal Year 1996*). In 1997, network wells were not identified as upgradient or downgradient as groundwater flow direction was affected by the P&T and declining water elevations (Table A.16 in PNNL-11793, *Hanford Site Groundwater Monitoring for Fiscal Year 1997*). The eastern wells were still used as upgradient wells because the source of groundwater beneath LLBG WMA-4 was from the east (Section 5.9.3.6 in PNNL-11470). The 200 West P&T operations extracted water on the east side of LLBG WMA-4 and injected it on the west side, essentially reversing the flow direction. The flow rate had steadily fallen over the years and was reported at 0.25 m/d (0.82 ft/d) in 1997 (Table 3.3-1 in PNNL-11793).

In January 1997, TOC exceeded the critical mean at 299-W15-23 (Section 5.9.2.7 in PNNL-11793). However, the sampling at the well was performed by bailing due to low water levels, and the quadruplicate samples showed wide variability. The well could not be resampled due to the low water level and the TOC result was attributed to poor sample quality and analytical difficulties.

Groundwater flow direction had become east by 1998 (Table 3.3-1 in PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*). Due to the change in flow direction, upgradient/downgradient comparisons were not meaningful and comparison values were to be reestablished the next year (Section 5.9.2.7 in PNNL-12086). In 1998, six of the upgradient monitoring wells at LLBG WMA-4 became sample dry (299-W15-19, 299-W15-20, 299-W15-23, 299-W15-24, 299-W18-26, and 299-W18-32) (Table A.15 in PNNL-12086). TCE exceeded the maximum contaminant level in downgradient well 299-W15-16 (Section 5.9.3.6 in PNNL-12086).

In 1999, background values for contamination indicator parameters were re-established (in response to the reversal in groundwater flow direction caused by the 200 West P&T) (Sections A.7.8 and 2.8.1.6 in PNNL-13116). The network was considered marginally adequate due to declining water levels and consisted of four downgradient wells (299-W15-16, 299-W15-18, 299-W18-24, and 299-W15-17 [deep]) and five upgradient wells (299-W15-15, 299-W18-21, 299-W18-23, 299-W18-27, and 299-W18-28) (Section A.7.8 in PNNL-13116). Downgradient well 299-W15-16 continued to slightly exceed the maximum contaminant level for TCE (Table A.3 in PNNL-13116). In January and July 1999, well 299-W15-16 exceeded the critical mean for TOX (Section A.7.8 in PNNL-13116). This well was previously considered upgradient and the exceedance was attributed to carbon tetrachloride from an upgradient source (Section A.7.8 in PNNL-13116). DOE reported the TOX exceedance to EPA and Ecology in August 1999 (CCN 071519).

In 2000 the groundwater flow direction changed from east to east by northeast (Table A.2 in PNNL-13404, *Hanford Site Groundwater Monitoring for Fiscal Year 2000*). One upgradient well (299-W18-26) and one downgradient well (299-W15-18) were identified as dry, and two upgradient monitoring wells (299-W18-27 and 299-W18-28) were not included for monitoring due to declining water levels (Table A-19 in PNNL-13404). Previously reported dry wells (299-W15-19, 299-W15-20, 299-W15-23, 299-W15-24, 299-W18-29, and 299-W18-32) were removed from the monitoring network (Table A-19 in PNNL-13404).

By 2002 the network consisted of four upgradient (299-W15-15, 299-W18-21, 299-W18-22 [deep], and 299-W18-23) and three downgradient wells (299-W15-16, 299-W15-17 [deep], and 299-W18-26). Downgradient well 299-W15-17 was screened across the bottom of the aquifer; therefore, the network comprised only two downgradient wells screened at the top of the aquifer. The monitoring network was not compliant with CFR 265.91(a)(2) and required upgrading (Section A.1.15 in PNNL-14187, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*). The northeastern flow direction was largely affected by the 200 West P&T, which had extraction wells to the east and injection wells to the west of LLBG WMA-4 (Section 2.8.1.6 and Figure A.13 in PNNL-14187).

In 2003, well 299-W15-16 continued to exceed the TOX critical mean, which was attributed to carbon tetrachloride from PFP (Section B.16 in PNNL-14548, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*). Also in 2003, downgradient well 299-W18-24 became sample dry, leaving only downgradient wells 299-W15-16 and 299-W15-18 (deep) in the network (Section 2.8.3.4 in PNNL-14548).

In 2004, a new groundwater monitoring plan was issued (PNNL-14859, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 to 4, RCRA Facilities, Hanford, Washington*). The downgradient wells in PNNL-14859 included 299-W15-17 (deep), 299-W15-30 (drilled in 2004), 299-W18-21 (previously an upgradient well), with nine new downgradient wells to be drilled (Table A.10). Three upgradient wells (299-W15-15, 299-W18-22 [deep], and 299-W18-23) were included. Monitoring constituents included contamination indicator parameters and groundwater quality parameters required by 40 CFR 265.92(b), VOCs (carbon tetrachloride, chloroform, trichloroethene, tetrachloroethene, benzene, toluene, ethylbenzene, xylene [total]), alkalinity, lead (filtered), mercury (filtered), dissolved oxygen, temperature, and turbidity (Section 3.1 and Table A.5 in PNNL-14859).

In February 2005, downgradient well 299-W15-30 (a replacement for well 299-W15-16 that had previously exceeded the TOX critical mean) exceeded the TOX critical mean (Section 2.8.3.2 in PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*). Three new downgradient monitoring wells (299-15-83, 299-W15-94, and 299-W15-152) were drilled in calendar year 2005 (Table B.25 in PNNL-15670). Another new downgradient well, 299-W15-224, was planned for fiscal year (FY) 2006 (Section 2.8.3.2 in PNNL-15670). Increasing nitrate concentrations that were not associated with the 200 West Area plume were measured in upgradient well 299-W18-21 (southwest portion of LLBG WMA-4) (Section 2.9.1.8 in PNNL-15670).

By 2006, the LLBG WMA-4 network consisted of seven downgradient wells (299-W15-17 [deep], 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, 299-W15-224, 299-W18-21) and three upgradient wells (299-W15-15, 299-W18-22 [deep], and 299-W18-23) (Table B.25, PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*). In July 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) revised the sampling list to include the contamination indicator parameters and groundwater quality parameters required by 40 CFR 265.92(b), VOCs (carbon tetrachloride, chloroform, trichloroethene, tetrachloroethene, benzene, toluene, ethylbenzene, xylene [total]), alkalinity, lead (filtered), mercury (filtered), dissolved oxygen, temperature, and turbidity (Table A.10).

In January 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, updated network well designations, changing 299-W18-21 from downgradient to upgradient (Table A.4 in PNNL-14859-ICN-2). Other new downgradient well locations were identified in 2007 and prioritized under Tri-Party Agreement Milestone M-24 (Ecology et al. 1989); however, drilling activities were postponed in the 200 West Area until the effects of the proposed 200 West P&T expansion were evaluated (Section 2.8.3.2 in DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*). Wells 299-W15-30, 299-W15-83, 299-W15-94, and 299-W15-224 continued to exceed the TOX critical mean, which was attributed to the carbon tetrachloride regional plumes (Section 2.8.3.2 in DOE/RL-2008-01).

In 2008 upgradient wells 299-W15-15 and 299-W18-23 became sample dry (Table B-25 in DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*). In February, two downgradient wells (299-W15-30 and 299-W15-224) exceeded the critical mean for TOC; however, resample results were below the critical mean. Well 299-W15-224 exceeded the TOC critical mean again in August 11, 2008, with a concentration between 1,090 and 1,300 µg/L. The well was resampled on October 21, 2008 and TOC results (2,100 and 2,200 µg/L) again exceeded the critical mean, indicating that LLBG WMA-4 may be impacting groundwater (Introduction in SGW-40211).

On December 18, 2008, well 299-W15-224 was sampled for the VOCs and SVOCs identified in Appendix IX of 40 CFR 264 and TPH (Section 2.0 in SGW-40211). DOE notified Ecology of the exceedance at well 299-W15-224 (09-AMCP-0058) prior to receiving the December 2008 sampling results. Results from this sampling were not yet available during preparation of the groundwater quality assessment plan (SGW-40211), submitted to Ecology on January 30, 2009 (09-AMCP-0062). Therefore, SGW-40211 specified that if the December 18 sample did not explain the elevated TOC, then wells 299-W15-30, 299-W15-83, and 299-W15-244 would be sampled for organics identified in Appendix IX of 40 CFR 264: TPH, oil and grease, TOC, coliform, and chemical oxygen demand (Section 2.0 and Table 2 in SGW-40211).

In March 2009, groundwater was sampled at the three wells and analyzed for coliform bacteria, oil and grease, chemical oxygen demand, TPH (gasoline, diesel, and kerosene), pesticides, herbicides, dioxins, polychlorinated biphenyls, and the VOCs and SVOCs listed in Appendix IX of 40 CFR 264. No organic compounds were identified to account for the elevated TOC at well 299-W15-224; therefore, the unit returned to indicator evaluation monitoring (Chapter 3 in SGW-41903).

A new groundwater monitoring plan was issued in 2010 (DOE/RL-2009-69, Rev. 0) that removed dry wells 299-W15-15 and 299-W18-23 from the network and revised the monitoring constituents. The revised network included two upgradient (299-W18-21 and 299-W18-22 [deep]) and six downgradient (299-W15-17 [deep], 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, and 299-W15-224) wells (Table 3-1 in DOE/RL-2009-69, Rev. 0). However, 299-W18-21 was not considered truly upgradient to LLBG WMA-4 due to flow direction changes caused by injection wells. Several options were under consideration to address the upgradient well compliance issue including (1) deepening existing upgradient wells; (2) using a well (699-39-79) that was not constructed to WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells," standards; (3) using alternative statistics not requiring an upgradient well; or (4) temporarily using a planned, new injection well as an upgradient well (prior to its use as an injection well) (Section 3.2 in DOE/RL-2009-69, Rev. 0). No new upgradient wells were planned because the 200 West P&T expansion was expected to further disrupt the groundwater flow direction when it came online in 2011 (Sections 3.2 and 4.4 in DOE/RL-2009-69, Rev. 0). Groundwater flow direction was to the east and the groundwater flow rate was calculated at 0.05 to 0.2 m/d (0.16 to 0.66 ft/d (Sections 2.4 and 2.6.3 in DOE/RL-2009-69, Rev. 0). The monitoring constituents included contamination indicator parameters and groundwater quality parameters required by 40 CFR 265.92(b): alkalinity, dissolved oxygen, temperature, turbidity, anions (chloride, fluoride, nitrate, nitrite, and sulfate), and metals (calcium, chromium, iron, magnesium, manganese, potassium, and sodium) (filtered and unfiltered) (Table 3-1 in DOE/RL-2009-69, Rev. 0). Mercury and lead were removed from sampling because 20 years of monitoring had shown that neither was a problem at LLBG WMA-4 (Section 3.4 in DOE/RL-2009-69, Rev. 0).

In 2010 well 299-W18-21 became dry, leaving the network without an upgradient monitoring well screened at the top of the unconfined aquifer (Section 12.4.2.2, DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010)*. Deep well 299-W18-22, located at the southwestern corner of LLBG WMA-4, was no longer considered upgradient because the 200 West P&T injection wells located west of LLBG WMA-4 had caused groundwater to flow toward the southeast. No new wells were planned until the effects of the P&T expansion on groundwater flow direction were better understood (Section 12.4.2.2 in DOE/RL-2011-01). Although now a dry well, the previous results from upgradient well 299-W18-21 were used for critical mean evaluations (Section 12.4.2.3 in DOE/RL-2011-01).

The groundwater monitoring plan for LLBG WMA-4 was revised later in 2010 to remove dry well 299-W18-21 (Section 3.4 in DOE/RL-2009-69, *Interim Status Groundwater Monitoring Plan for the LLBG WMA-4*, Rev. 1). The plan was revised again in 2012 to specify that samples for metals would be collected as unfiltered samples (Table 3-1 in DOE/RL-2009-69, Rev. 2).

Although well 299-W18-21 had become sample dry and was removed from the network in 2010 (DOE/RL-2009-69, Rev. 1), water levels rose sufficiently for it to be sampled in 2014 (Table B-63 and Section 12.11.4 in DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*). However, well 299-W18-21 was considered downgradient rather than an upgradient, so the network remained without an upgradient well screened at the top of the aquifer (Table B.59 in DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*).

In 2015, results from deep upgradient well 299-W18-22 were used with data from 299-W18-21 (now considered an upgradient well) to establish 2015 critical mean values (Table 2-54 in DOE/RL-2016-12, *Hanford Site RCRA Groundwater Monitoring Report 2015*; Section 12.11.4 in DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*). Well 299-W18-21 was not included as a network well in DOE/RL-2009-69, Rev. 2 because it became sample dry; however, the water level had risen to a level sufficient for sampling.

In July 2016, the water level in upgradient well 299-W18-21 was too low to sample with a pump, so the pump was removed and the well bailed (Section 2.14 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*). Data from well 299-W18-21 were again used in conjunction with data from deep upgradient well 299-W18-22 to establish critical means for LLBG WMA-4 (Table 2-53 in DOE/RL-2016-66). P&T injection wells upgradient of LLBG WMA-4 have caused the water table to rise and the hydraulic gradient to increase since injections began in 2012. DOE/RL-2016-66 reported the general groundwater flow direction for LLBG WMA-4 is east, with an estimated flow rate of 0.13 to 0.50 m/d (0.43 to 1.6 ft/d) (Table 2-52 in DOE/RL-2016-66). The monitoring network comprised two upgradient wells (299-W18-21 and 299-W18-22 [deep]) and six downgradient wells (299-W15-17 [deep], 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, and 299-W15-224) (Table 2-51 in DOE/RL-2016-66).

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3 Geology and Hydrogeology

This chapter describes the geology and hydrogeology beneath the LLBG WMA-4 area. This information is summarized from PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington,* and BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site*, and is included to provide a brief overview of the current understanding of the site.

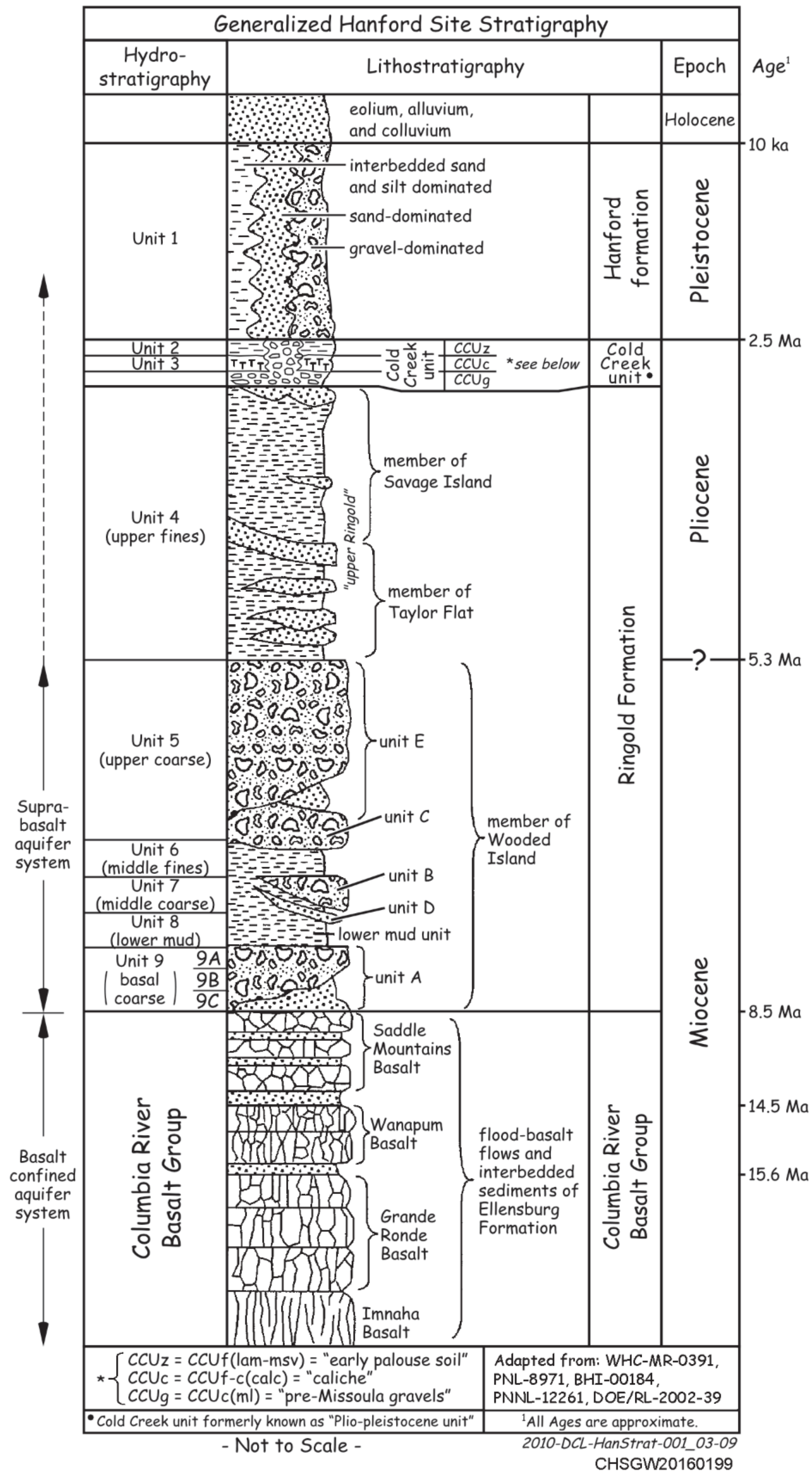
3.1 Stratigraphy

The generalized stratigraphy of the Hanford Site is shown in Figure 3-1. The local stratigraphy beneath LLBG WMA-4 consists of unconsolidated to semi-consolidated sediments overlying basalt bedrock of the Columbia River Basalt Group. Geologic cross sections are shown in Figures 3-2 and 3-3. The sedimentary units present (in descending sequence) are as follows:

- Sand and gravel backfill
- Sand and gravel of the Hanford formation
- Fine-grained Cold Creek unit (CCU)
- Sand and silt of the Ringold Taylor Flat (localized unit)
- Sand and gravel of the Ringold Unit E
- Fine-grained Ringold lower mud unit
- Sand and gravel of Ringold Unit A (which overlies the basalt)

LLBG WMA-4 is underlain by approximately 169 to 175 m (554 to 574 ft) of suprabasalt sediment. The major sedimentary units underlying the WMA are the near-surface Hanford formation which is underlain by the CCU about midway through the vadose zone. The Ringold Formation is encountered beneath the CCU with the Ringold Formation Unit E uppermost and underlain by the Ringold Formation Lower Mud unit and then the Ringold Formation Unit A atop the basalt. The Ringold Formation Taylor Flat unit is present beneath the CCU and above the Ringold Formation E unit; however, is localized and only present within the central portion of LLBG WMA-4. The uppermost unconfined aquifer unit is encountered within the Ringold Formation Unit E beneath LLBG WMA-4.

The Hanford formation is an informal stratigraphic unit made up of uncemented gravel, sand, and silt deposited by the late Pleistocene Missoula glacial floods. The Hanford formation can be described in terms of three gradational facies: gravel dominated, sand dominated, and silt dominated. At LLBG WMA-4 the upper portion of the Hanford formation is gravel dominated, and the lower portion is sand and silt dominated. At LLBG WMA-4, the upper gravel-dominated unit is approximately 16 m (53 ft) thick, and the Hanford formation has a total thickness of approximately 39 to 44 m (128 to 144 ft).



Note: Complete reference citations are provided in Chapter 11.

Figure 3-1. General Stratigraphy at the Hanford Site

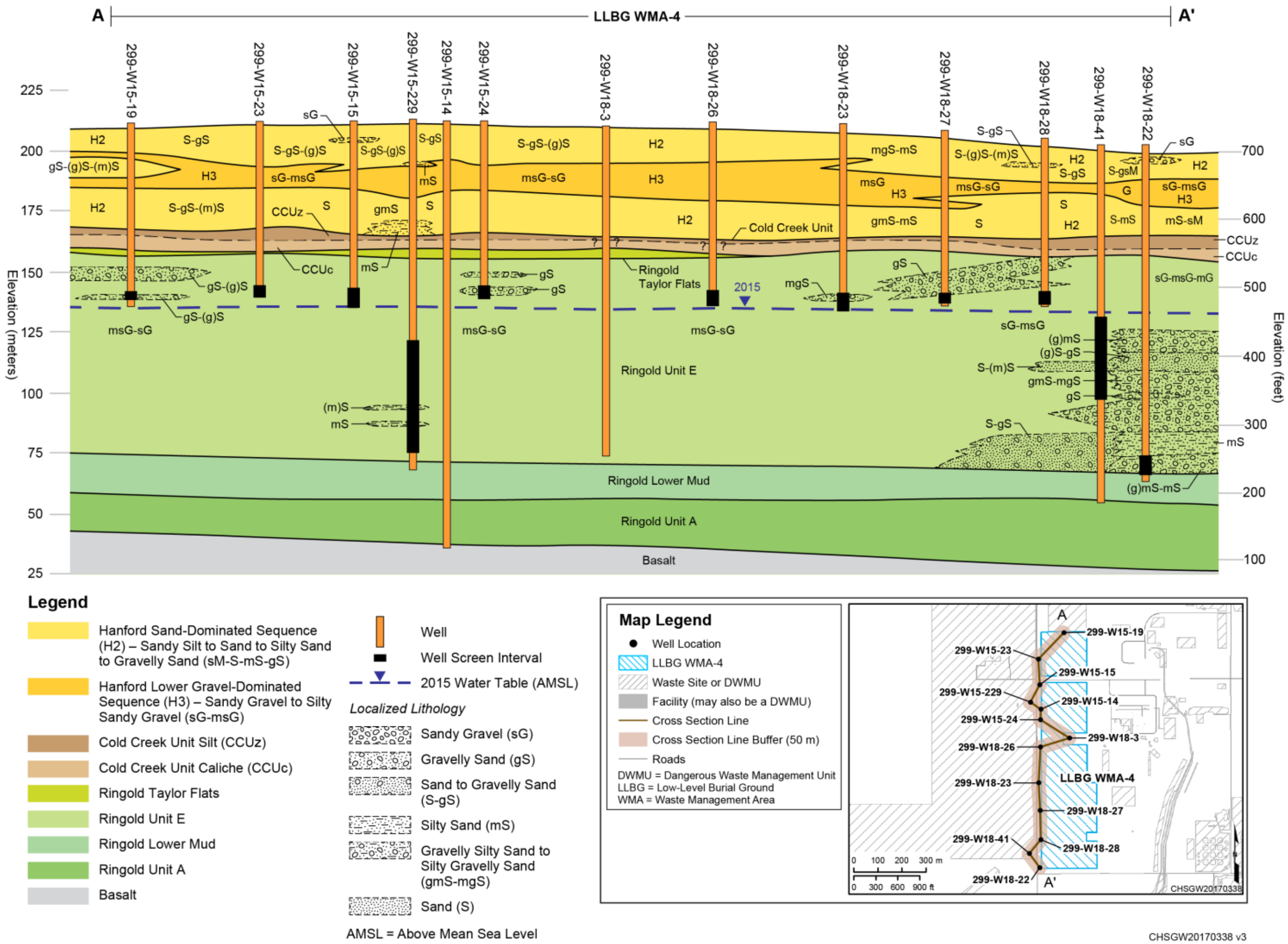


Figure 3-2. North to South Geologic Cross Section through LLBG WMA-4

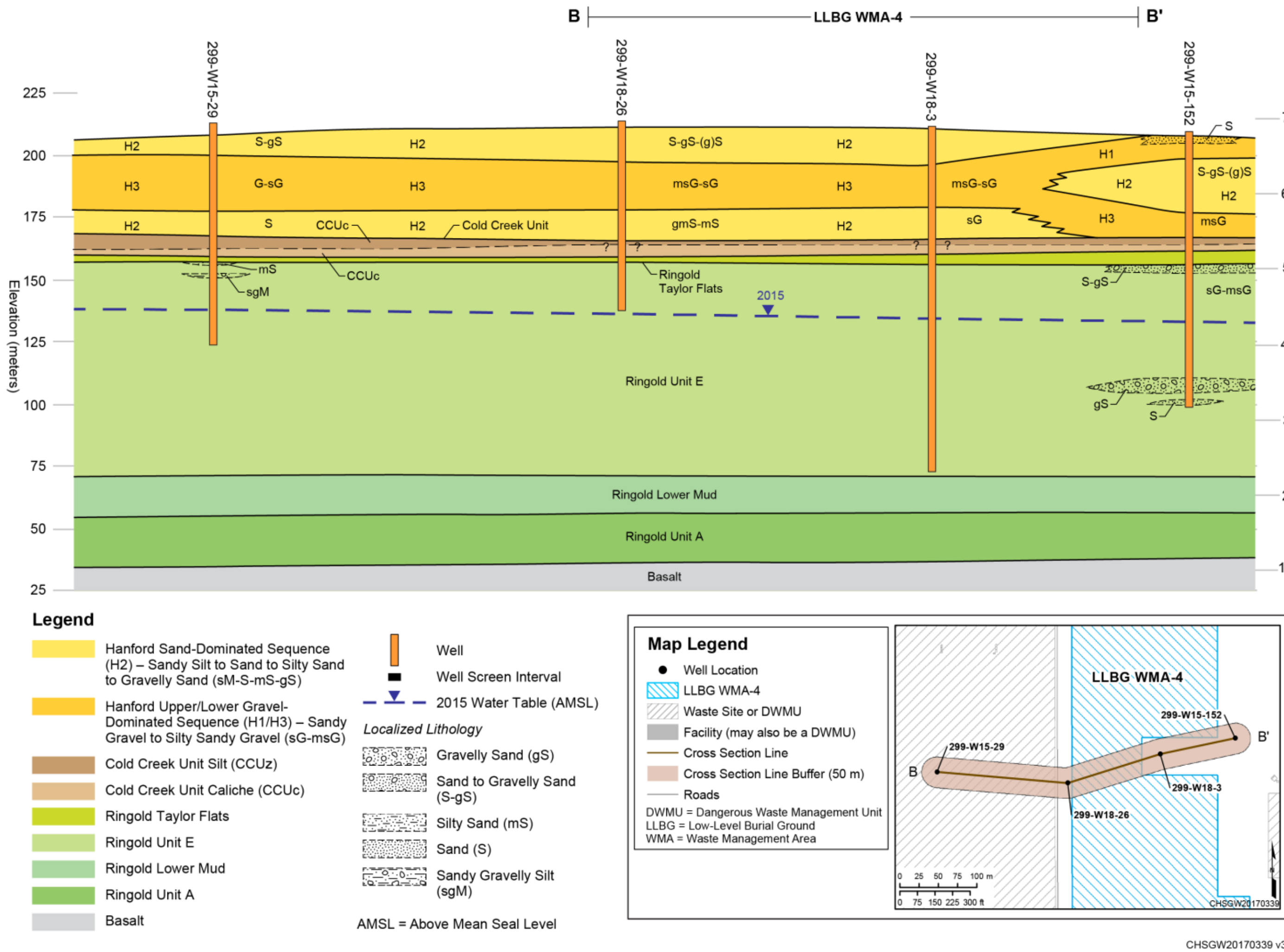


Figure 3-3. West to East Geologic Cross Section through LLBG WMA-4

The CCU, which separates the Ringold Formation from the Hanford formation, is divided into two distinct sequences at LLBG WMA-4. The upper sequence of thinly laminated silts was identified as lacustrine deposits. Calcium carbonate-rich strata characterize the lower sequence. This lower interval consists of locally derived basaltic detritus, silt-rich eolian deposits, reworked Ringold material, and calcium carbonate-rich paleosols. The calcium carbonate occurs as thin (<2.5 cm [1.0 in.]) layers, nodules, and coatings on clasts. The CCUg, pre-Missoula gravels, sequence of the CCU is not present at LLBG WMA-4 (Section 3.1.3 in PNNL-13858).

The Ringold Formation consists of Miocene-Pliocene fluvial and lacustrine clastic sediment deposited by the ancestral Columbia River system. The sediment rests unconformably on the Miocene-age Columbia River Basalt Group. In BHI-00184, using a depositional environment approach, a number of facies were identified within the Ringold Formation. Using facies associations, the Ringold Formation was divided into three informal members (BHI-00184). The Ringold Formation underlying LLBG WMA-4 belongs to the Member of Taylor Flats (upper Ringold); and Member of Wooded Island, the lowest member of the formation. The Member of Wooded Island was divided into five gravel-dominated fluvial depositional units, separated by widespread overbank, paleosol, and lacustrine deposits (BHI-00184). The lower mud unit, a thick lacustrine deposit, separates gravel Unit A from the overlying deposits.

3.2 Hydrogeology

Groundwater beneath the Central Plateau flows generally from west to east, although the 200 West P&T system disrupts this pattern locally. Natural recharge to the unconfined aquifer comes from the Cold Creek Valley, Dry Creek Valley, Rattlesnake Hills, and infiltrating precipitation. Groundwater velocity generally ranges from a few millimeters to tenths of a meter per day.

Groundwater beneath LLBG WMA-4 occurs as an unconfined aquifer and deeper confined aquifers. The water table occurs in the Ringold Formation Member of Wooded Island. Depth to water ranges from 71.6 to 75.5 m (235 to 248 ft) to 74.9 m (246 ft). The uppermost confined aquifer occurs in Ringold Unit A and is confined above by the lower mud unit and below by basalt. Deeper confined aquifers occur between the basalt flows.

The base of the unconfined aquifer is the fine-grained Ringold lower mud unit. The lower mud unit is at least partly confining and is continuous beneath WMA U (Section 3.2 in ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington: Fiscal Year 2016 Update*) isolating the confined aquifers from potential releases from LLBG WMA-4. The unconfined aquifer is approximately 62 to 66 m (202 to 217 ft) thick.

The saturated hydraulic conductivity of the Ringold E unit underlying LLBG WMA-4 is 5 m/d (16.4 ft/d) (Table 4-9 in CP-47631). 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 0.3 m/d (1 ft/d) in Table 2 to 61.0 m/d (200 ft/d) in Table 1 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. The Ringold lower mud and basalt are considered aquitards relative to other sediments beneath LLBG WMA-4 because of the units' very low hydraulic conductivities (Section 5.0 in PNNL-13858).

The contact between the Hanford formation and the underlying CCU presents a substantial discontinuity in hydraulic conductivity within the vadose zone. The CCU, located about 40 to 43 m (131 to 141 ft) below ground surface, would slow the downward movement of water and may divert it to the southwest, the direction the top of the unit is dipping beneath LLBG WMA-4. Releases of large volumes of water that reach the CCU may result in perching of water atop the CCU, with subsequent migration laterally along the top of the CCU. The downward migration of water and waste water released at, or near, the ground surface is largely a function of the volume of the release and its persistence (i.e., larger volumes and longer duration releases will migrate larger vertical distances). Although the infiltration and downward movement of natural meteoric water from the ground surface is small and slow in the Hanford Site, there is expected to be a small fraction of annual recharge to the groundwater. It is this downward movement of water in the vadose zone that carries waste contaminants to the water table. Water movement velocity in the unsaturated zone is a function of hydraulic conductivity of the geologic formation and the relative wetness of the formation (a function of the volume of water migrating). Small releases will normally migrate vertically at a slow rate. Large volumes and chronic releases will wet the vadose zone more thoroughly and will migrate faster.

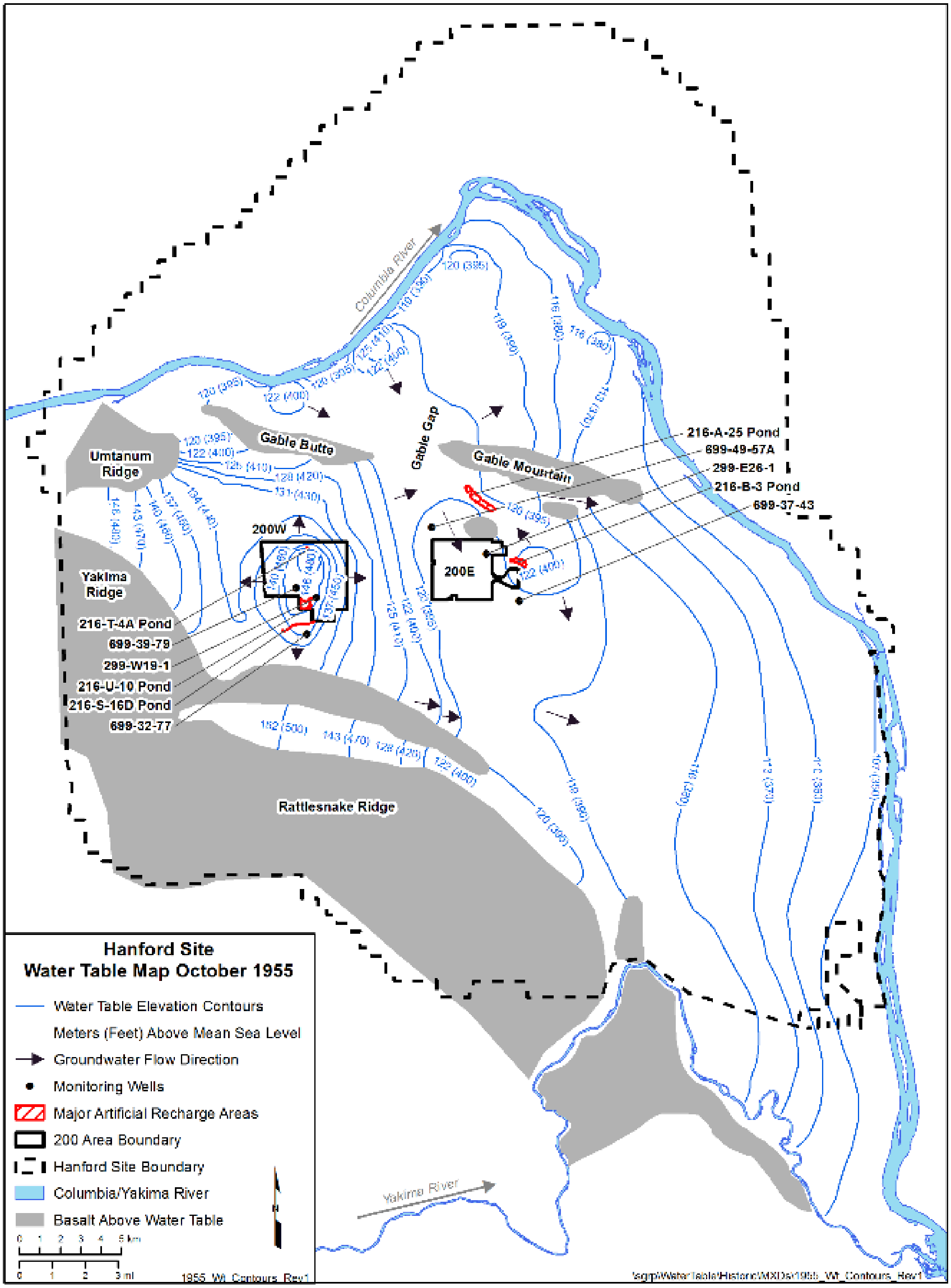
3.3 Groundwater Flow System

Elements of the groundwater flow system beneath LLBG WMA-4 are described in the following subsections. These elements include the effects of historical anthropogenic discharges to ground in the 200 West Area, resulting changes in groundwater elevation and flow direction and velocity, and more recently, implementation of groundwater remediation using P&T systems that remove, treat, and replace water into the aquifer.

3.3.1 Hydrologic Conditions Prior to 200 West Pump and Treat Operations

Groundwater flow conditions at LLBG WMA-4 have varied greatly over the past several decades due to changing wastewater disposal in areas surrounding LLBG WMA-4. Between 1950 and 1970, the groundwater flow direction beneath LLBG WMA-4 varied between south, southwest, west, northwest, northeast, and east, depending on effluent disposal volumes to the former 216-T-4 Pond to the north of LLBG WMA-4 and the former 216-U-10 Pond to the south (Sections 3 and 4 in PNNL-16069, *Development of Historical Water Table Maps of the 200 West Area of the Hanford Site (1950-1970)*) (Figure 3-4). During the 1980s, the flow direction changed from northeast to east in response to the decommissioning of the 216-U-10 Pond in 1985. In the late 1980s and early 1990s, nearby effluent discharges were occurring at the 216-Z-20 Crib and the 216-U-14 Ditch, both to the east of LLBG WMA-4 (Section 3.8 in SGW-60338, *Historical Changes in Water Table Elevation and Groundwater Flow Direction at Hanford: 1944 to 2014*). The effluent volume discharged to the 216-Z-20 Crib declined in 1992, and the flow direction beneath LLBG WMA-4 reversed to west because discharges to the 216-U-14 Ditch became dominant. Discharges to both sites ceased by 1996, and the flow direction has been toward the east-northeast since that time.

In 1994, Phase I of the 200-ZP-1 OU interim P&T system was implemented and included installation of extraction wells near WMA TX-TY, northeast of LLBG WMA-4. Between 1995 and 1996, five injection wells were installed west and upgradient of LLBG WMA-4 as a portion of the 200-ZP-1 OU interim P&T system. The installation of the five injection wells modified flow to the southeast within the southwest portion of LLBG WMA-4 where the injections wells are positioned. Figure 3-5 depicts continued decreasing groundwater elevation trends for wells 299-W15-17, 299-W18-1, and 299-W18-21 located in the vicinity of LLBG WMA-4 between 1987 and 2017. However, impact of the injection wells located upgradient of LLBG WMA-4 and near 299-W18-21 is evident beginning in approximately 1997 as the decreasing groundwater trend is lessened in this well. In 2010, one additional injection well was installed west and upgradient of LLBG WMA-4.



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

Figure 3-4. 1955 Hanford Site Water Table Map

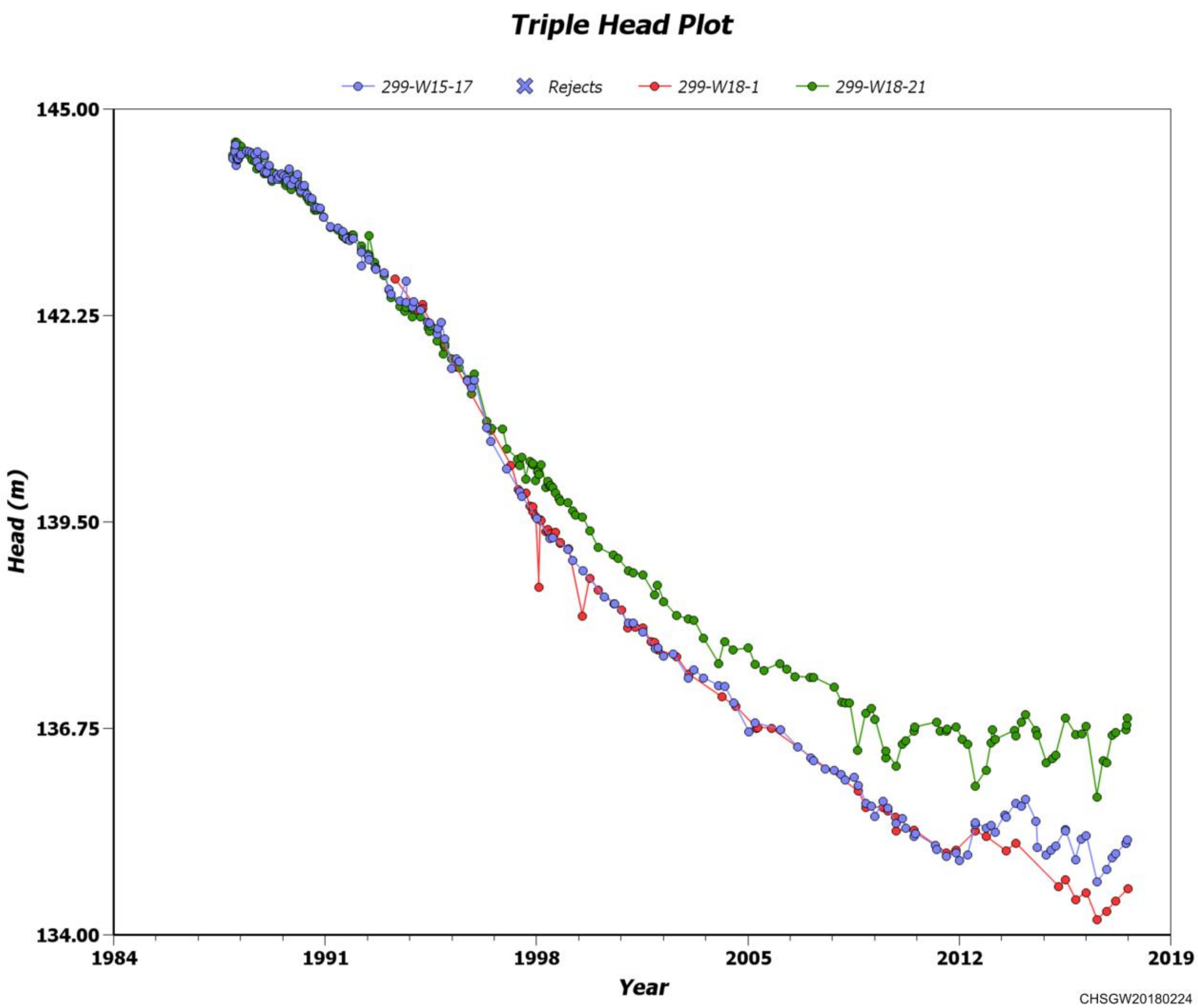


Figure 3-5. Groundwater Elevation Trend Plot for Wells 299-W15-17, 299-W18-1, and 299-W18-21 between 1987 and 2017

Baseline groundwater levels were evaluated in two dimensions by interpolating water-level data obtained during June 2012, prior to implementation of the 200 West P&T system. Figure 3-6 shows the 2012 water table map prior to the start of the 200 West P&T remedy. During this time, groundwater flow direction was to the east-northeast. The hydraulic gradient was estimated to be 2.7×10^{-3} m/m in 2012 with an average linear velocity of 0.07 to 0.27 m/d (0.23 to 0.89 ft/d) (Table 3-1 in SGW-55438, *Hanford Site Groundwater Monitoring for 2012: Supporting Information*).

3.3.2 Hydrologic Conditions Due to Operations of the Pump and Treat Remedy

Between 2014 and 2017, six additional P&T injection wells were installed upgradient and west of LLBG WMA-4 operations and influenced groundwater gradients (Figure 3-7). Between July 2015 and July 2016, water levels in the monitoring wells declined 0.14 to 1.1 m (0.54 to 3.4 ft) in seven LLBG WMA-4 wells and increased 0.54 m (1.8 ft) in one well (Section 12.10.4 in DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*). The decline is primarily due to two factors which are simulated with the CPGWM.

1. The substantial reduction of wastewater 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 (which replaced the interim 200-ZP-1 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 shows groundwater flow direction to the east and southeast beneath LLBG WMA-4 (Figure 3-8). Groundwater flow is affected by the 200 West P&T remedy. The system extracts and treats contaminated groundwater and injects treated water both upgradient and downgradient of the 200 West groundwater plumes. Twelve injection wells are located near LLBG WMA-4 to the west; however, each well has varying injection capacity and operational history. Groundwater mounding around these wells accounts for the increased gradient at LLBG WMA-4. The wells are shown on the March 2016 water table map (Figure 3-8). The hydraulic gradient beneath LLBG WMA-4 is estimated to be 5.0×10^{-3} m/m based on a trend surface analyses performed at LLBG WMA-4 during 2016. The average groundwater flow rate during 2016 ranged from 0.13 to 0.50 m/d (0.43 to 1.6 ft/d) (Section 12.10.4 in DOE/RL-2016-67). The groundwater flow rate and direction are further described in Section 4.3.

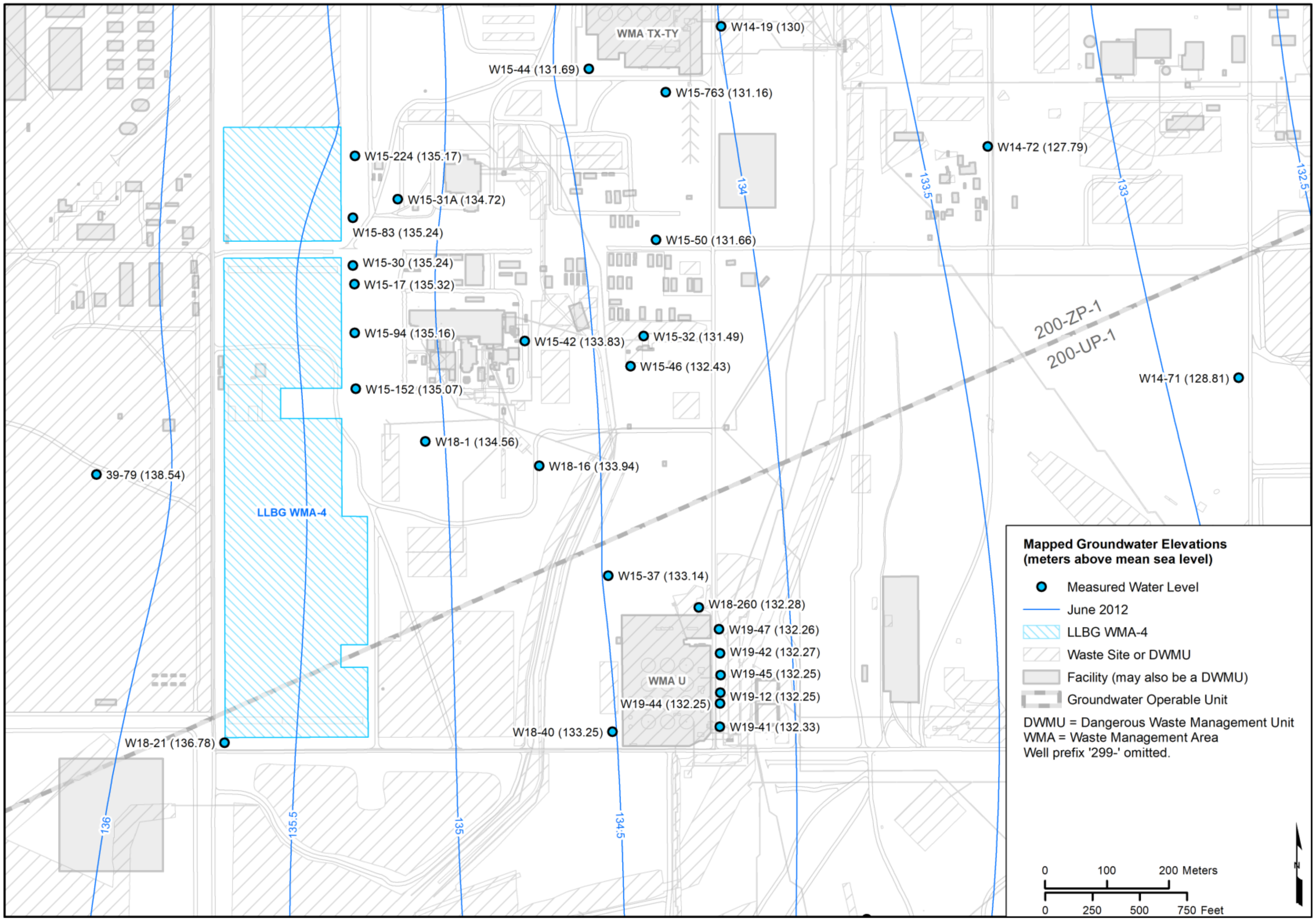


Figure 3-6. Water Elevation Contours in June 2012 Prior to Startup of the 200 West P&T

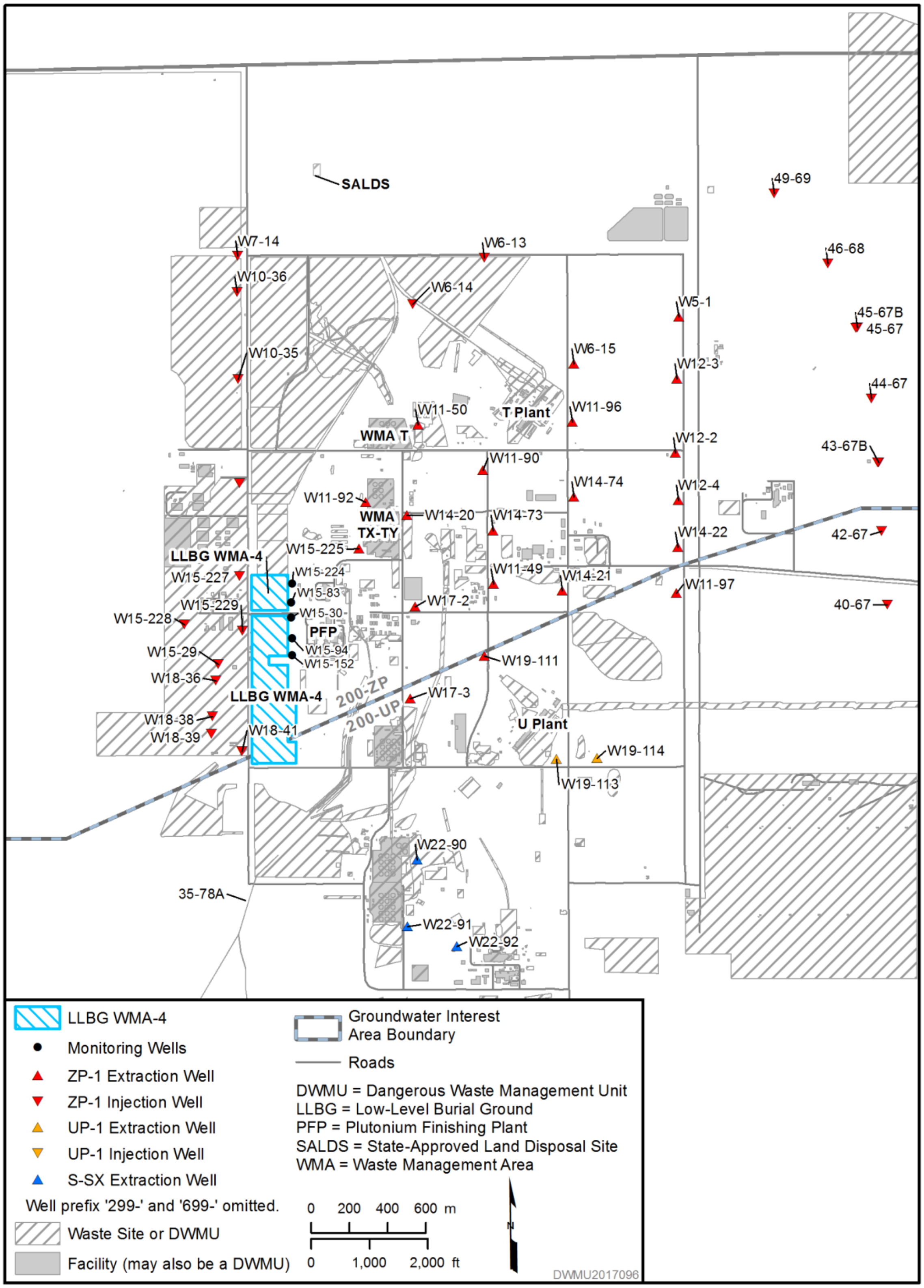


Figure 3-7. 200 West P&T System Well Location Map (as of June 2016)

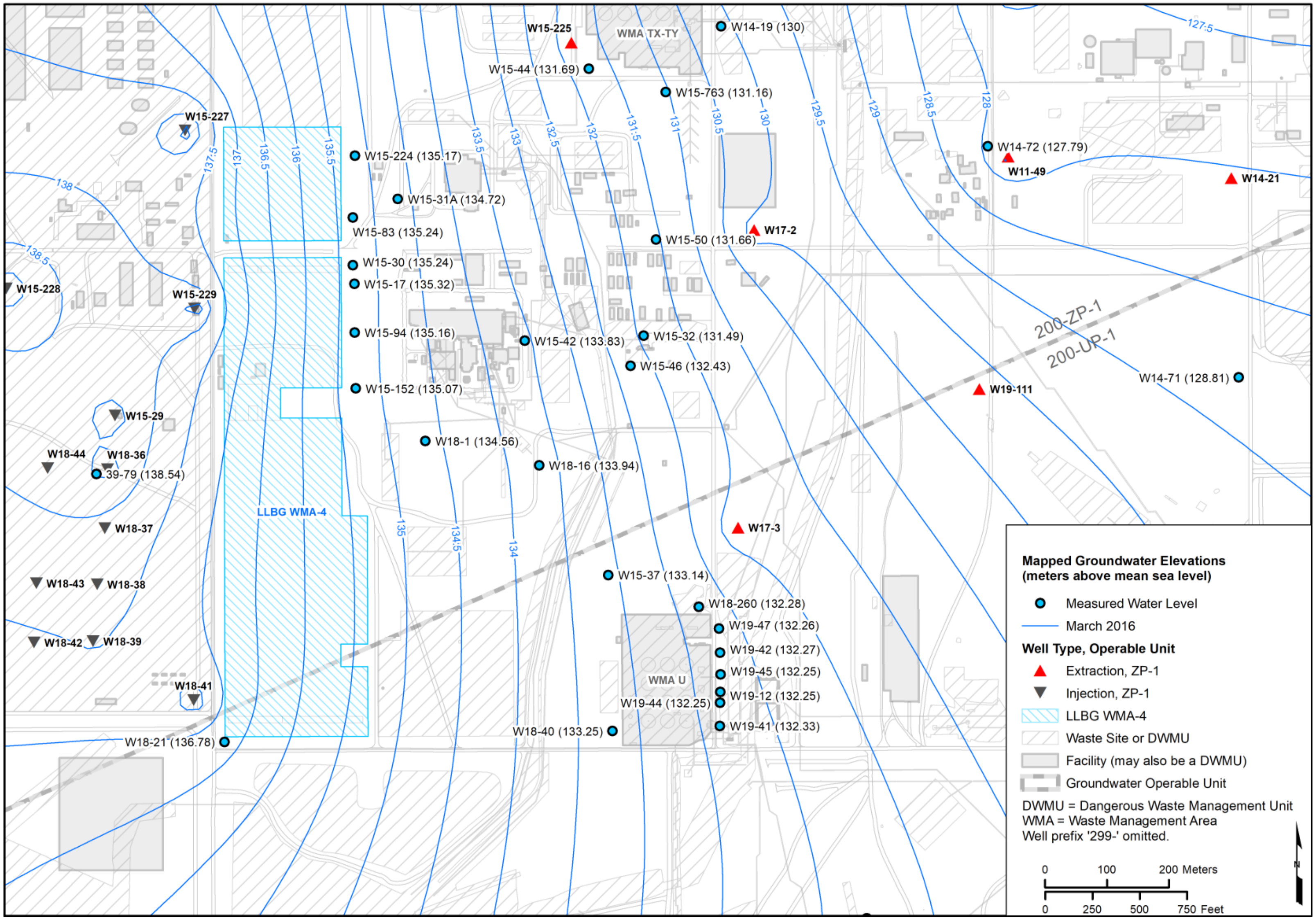


Figure 3-8. Water Elevation Contours in March 2016 During 200 West P&T Operations

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) (Section 4.5.2.2 in PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*).
- Net infiltration is assumed to occur directly to the vadose zone within 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 factors, but would be addressed under emergency response/corrective actions.

4.1 Vadose Zone

The vadose zone at LLBG WMA-4 is approximately 71.6 to 75.5 m (235 to 248 ft) thick and consists of (from top to bottom) the Hanford formation, the CCU, and the Ringold Formation. The finer textured sediment and associated calcium carbonate cementation that characterize the CCU account for its relatively low hydraulic conductivity, which is likely to slow downward movement of moisture and contaminants. Although the CCU is clearly a restriction to vertical migration of water (and associated dissolved contaminants) beneath LLBG WMA-4, it is not impermeable and contaminated water can eventually reach the underlying groundwater.

A finer grained lithologic unit lies below the CCU within the stratigraphic framework under the central portion of LLBG WMA-4. The Taylor Flat member of the Ringold Formation (shown in Figures 3-2 and 3-3) is interpreted from geologic logs for well construction in LLBG WMA-4. 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 earlier documents (e.g., PNNL-16887, *Geologic Descriptions for the Solid-Waste Low Level Burial Grounds*). 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-4 can also influence or slow the downward migration by spreading soil moisture laterally. Direct observational evidence to assess this effect at LLBG WMA-4 is lacking, with no perched water zones in the vicinity. Under the gravity drainage assumption, only a small to moderate horizontal gradient component is likely to be available to produce lateral spreading of infiltrating water.

It is estimated that recharge rates in the southern portion of the 200 West Area in the vicinity of LLBG WMA-4 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 recent wells that intersected the CCU in the vicinity of LLBG WMA-4, although the CCU has historically supported perched water units under conditions of long-term, high-volume surface discharges. Present conditions beneath LLBG WMA-4 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-4 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-4 was east-northeast at a calculated rate (using the Darcy relationship) of 0.07 to 0.27 m/d (0.23 to 0.89 ft/d). The water table elevation in the vicinity of LLBG WMA-4 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 grounds is now generally east and east-southeast as a result of groundwater injection for the 200 West P&T with a calculated groundwater velocity of 0.13 to 0.50 m/d (0.43 to 1.6 ft/d) (Table 2-52 in DOE/RL-2016-66).

P&T operations are expected to continue in this region until 2037. After completion of active groundwater remediation 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 impact to groundwater beneath LLBG WMA-4 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-4 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 incorporates 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 the groundwater beneath much of the 200 West Area, including beneath portions of LLBG WMA-4, has been contaminated from other sources including PFP, 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-4 is carbon tetrachloride. The footprint of LLBG WMA-4 is located immediately adjacent to or within the southwestern edges of this large regional plume of carbon tetrachloride. In this area of the plume, the concentrations exceed the DWS for carbon tetrachloride (5 µg/L).

A contaminate plume of nitrate from the 200 West Area also is found beneath LLBG WMA-4. The footprint of LLBG WMA-4 is located immediately adjacent to or within the edges of this large regional plume. In this area of the plume, the concentrations range from 22.6 to 111 mg/L in groundwater samples collected in 2016, and close to the DWS for nitrate (45 mg/L) (Table 2-54 and DOE/RL-2016-66).

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-4 are not present in groundwater based on historical monitoring. Evaluation of vertically distributed groundwater data is limited to the location of LLBG WMA-4 within the context of regional plumes present in 200-ZP-1 OU. Available vertical distribution data are limited to six wells completed in the vicinity of LLBG WMA-4 collected during drilling and special studies. The identified wells (299-W15-10, 299-W15-152, 299-W15-227, 299-W15-229, 299-W15-49, and 299-W18-41) are located near the perimeter of LLBG WMA-4. See Figure 4-1 for general well locations in relation to LLBG WMA-4. These wells were installed between 1996 and 2014 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-4 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 and nitrate representing widespread contaminants in 200-ZP-1 OU, and present near LLBG WMA-4. 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 select wells, consisting of VOCs for wells 299-W15-152 and 299-W15-229; and carbon tetrachloride, chloroform, and trichloroethene for well 299-W15-10. Carbon tetrachloride samples collected from 299-W15-152 included four sample depths collected at elevations between 6 m (21 ft) and 37 m (121 ft) below the 2017 water table elevation and range from 12 µg/L at 6 m (21 ft) to 390 µg/L at 37 m (121 ft). Results for wells 299-W15-229 and 299-W15-10 are limited to three elevations only. Limited vertical characterization data for wells 299-W15-152, 299-W15-229, and 299-W15-10, where available, are generally consistent with results from remaining evaluated wells.

Where duplicate samples were collected at a given interval, resulting values were averaged; non-detect results were included at the reported detection limit. See Figures 4-2 through 4-4 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.

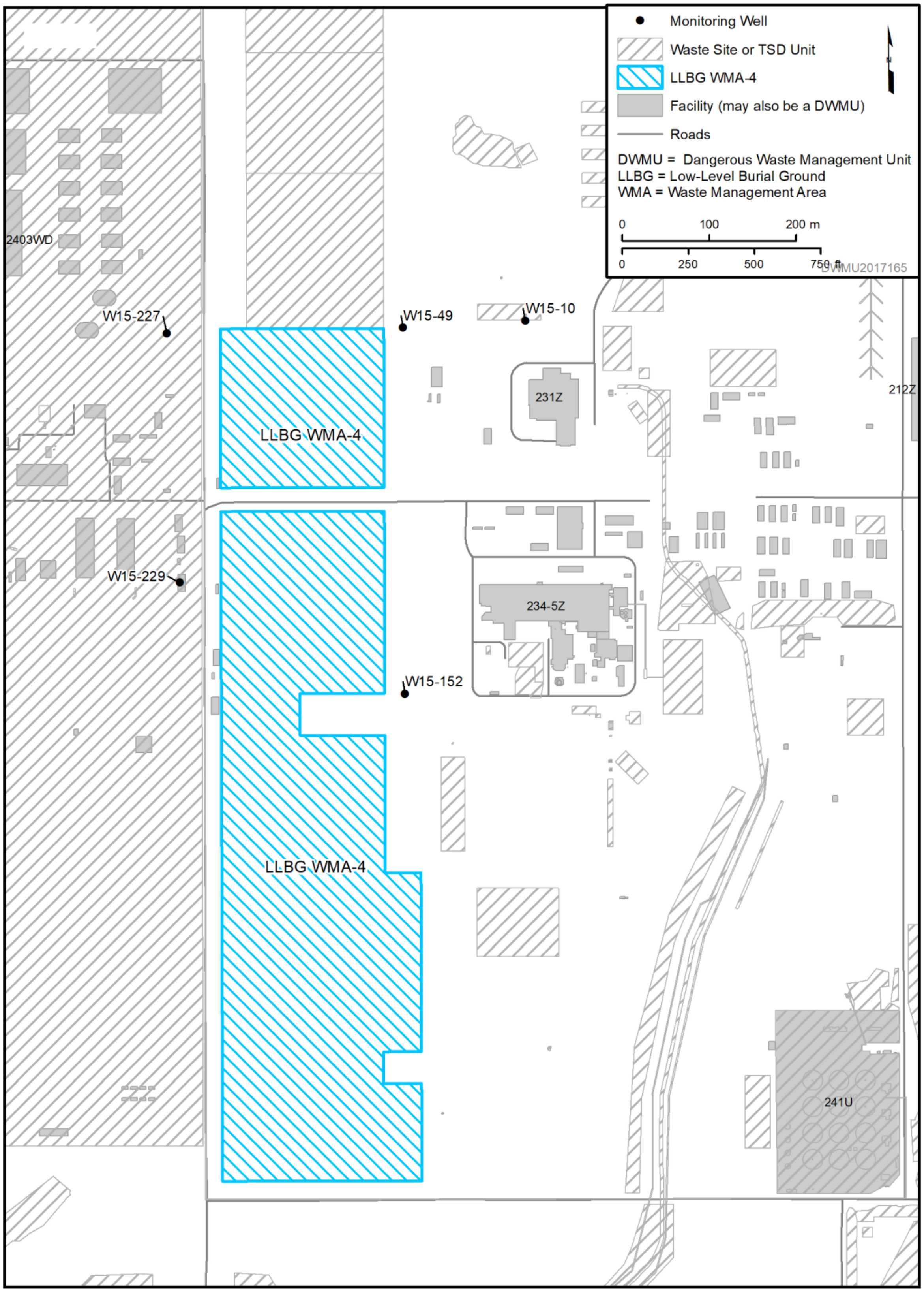


Figure 4-1. Vertical Contaminant Characterization Well Location Map

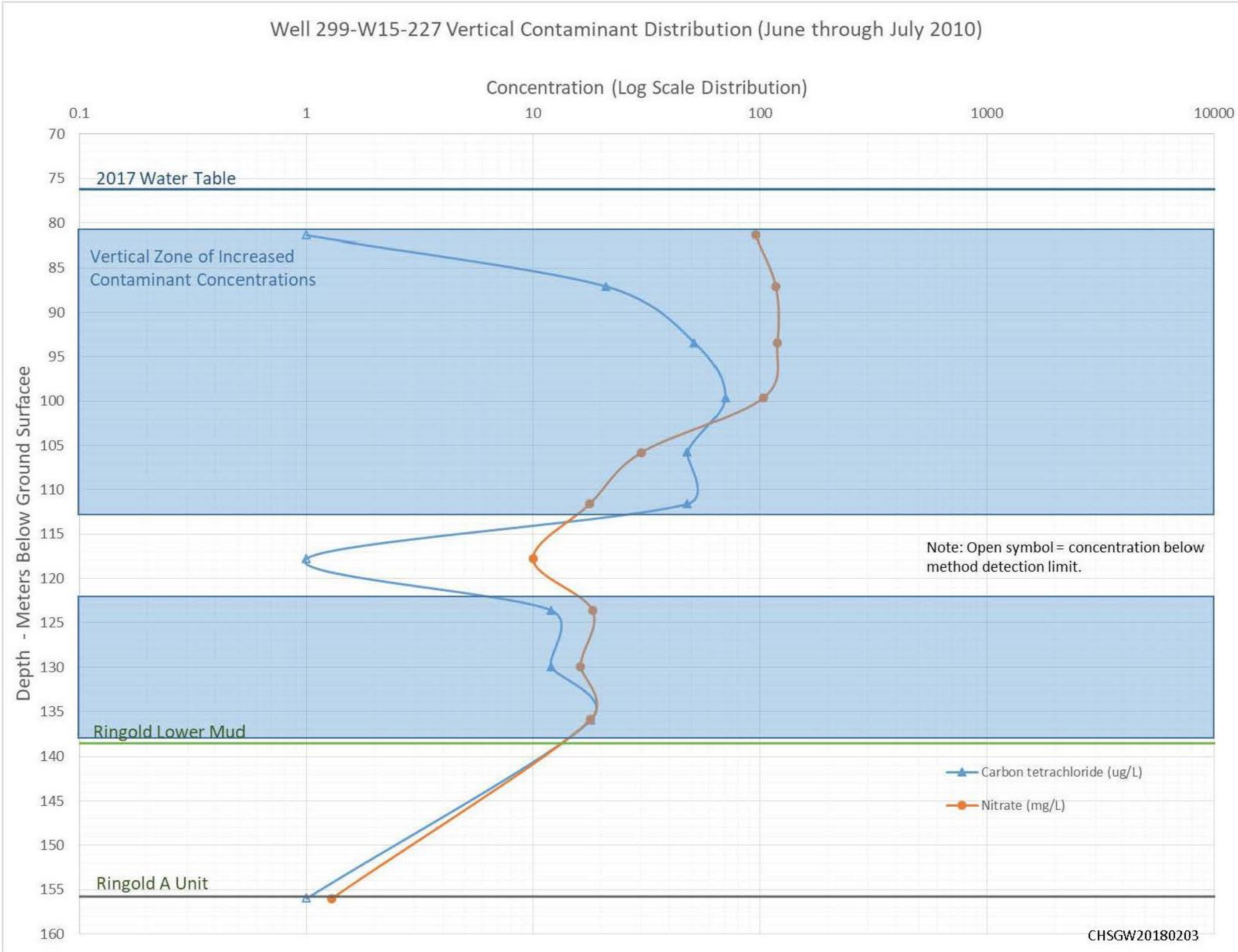


Figure 4-2. Vertical Contaminant Distribution Well 299-W15-227

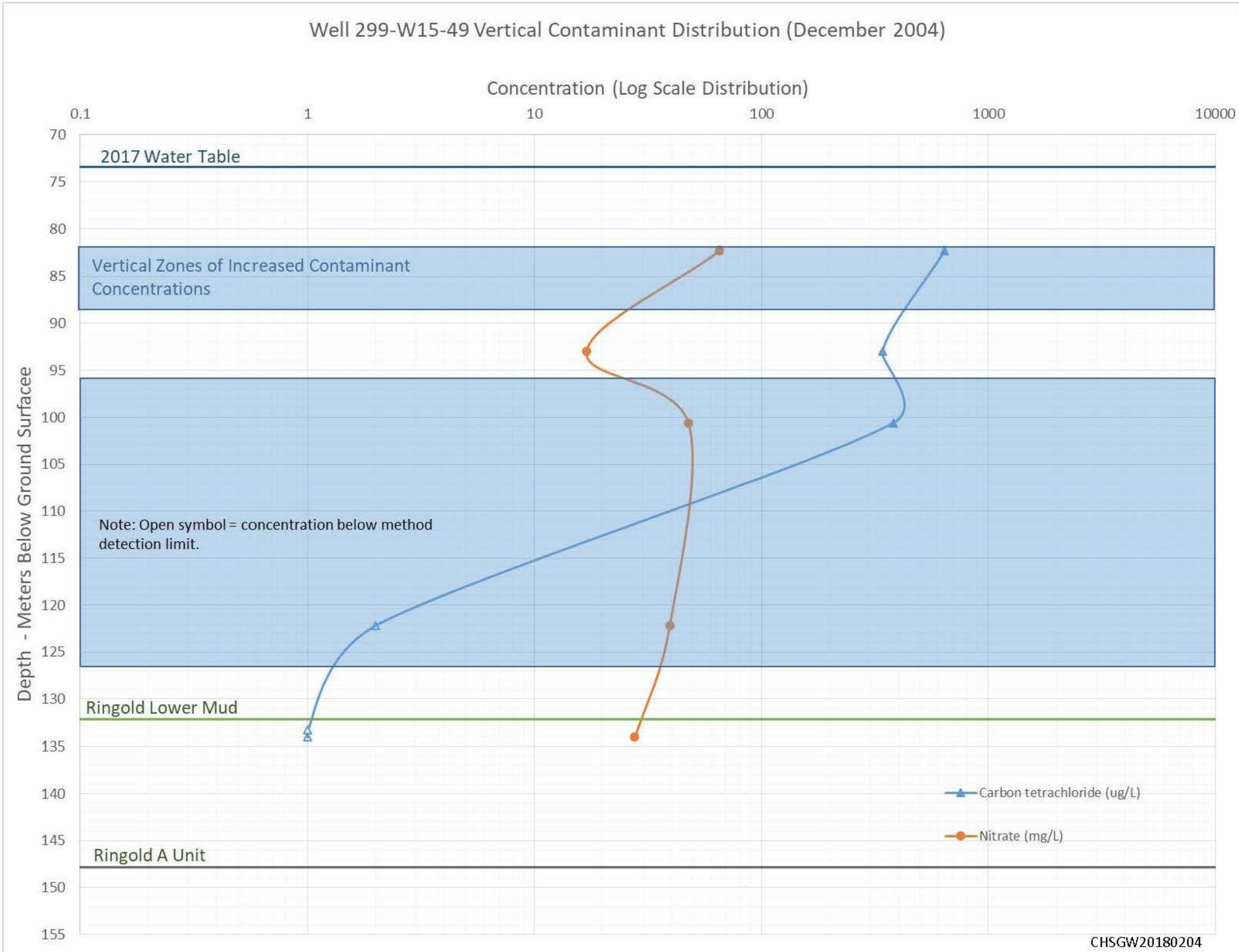


Figure 4-3. Vertical Contaminant Distribution Well 299-W15-49

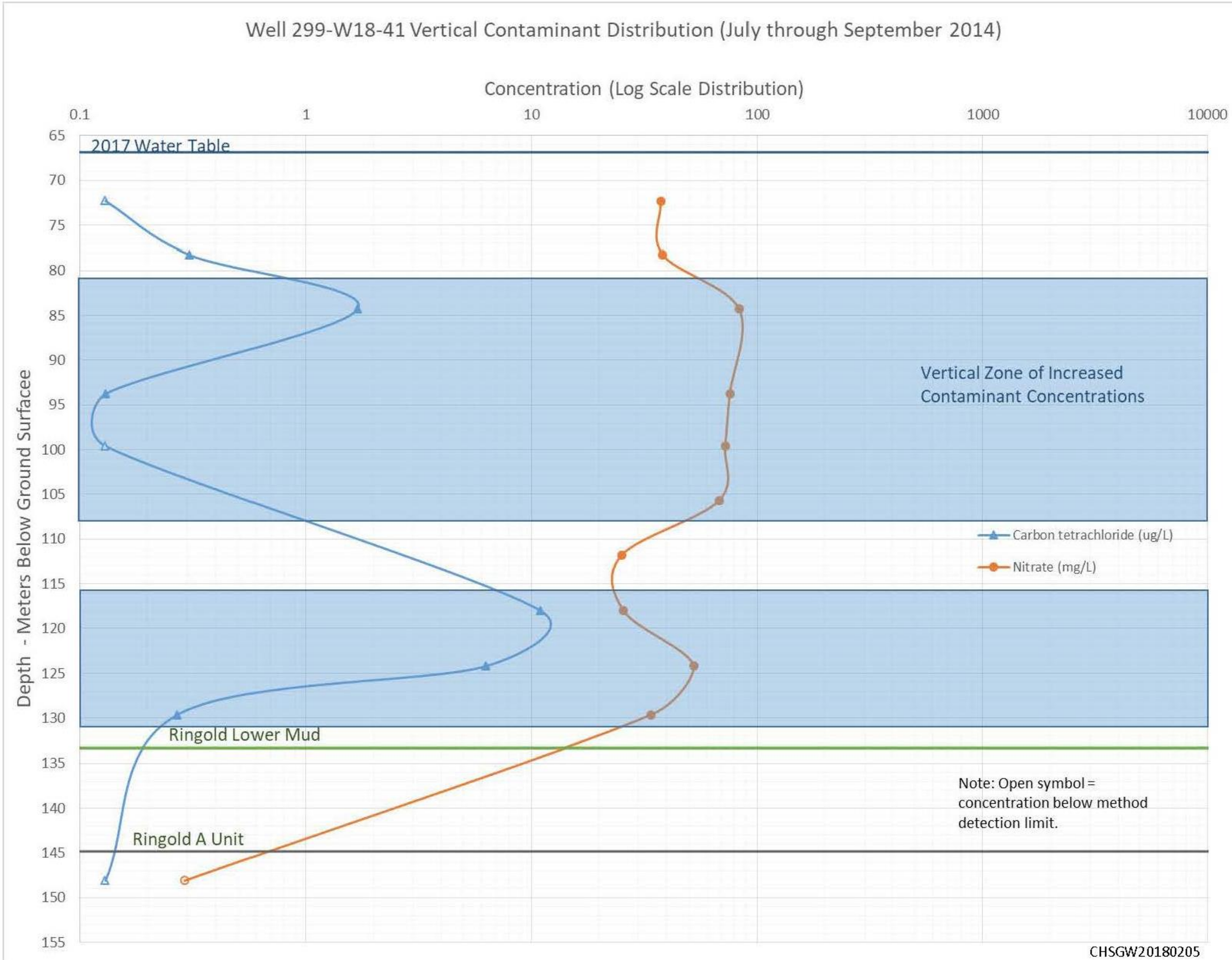


Figure 4-4. Vertical Contaminant Distribution Well 299-W18-41

Based on vertical characterization data, contaminants are present throughout the unconfined aquifer; consistent with the presence of multiple historical sources and extents of regional plumes. However, vertical zones of increased contaminant concentrations are evident to varying degrees within the wells. Evaluated wells show indications of highest contaminant concentrations within the upper portion of the unconfined aquifer within wells 299-W15-227 and 299-W15-49 and approximately 37 m (121 ft) and 16 m (51 ft) below the 2017 water table elevation, respectively. These wells indicate a general decreasing trend in concentrations with depth to the Ringold Lower Mud.

Well 299-W18-41 is an active injection well located within an area of active injection wells associated with the 200 West P&T system and about 180 m (590 ft) southeast of injection well 299-W18-39. Vertical profile samples were collected during drilling of this well. Based on 2017 water table mapping, the area of injection wells, including 299-W18-41 have an artificially increased water table elevation. Samples collected during drilling show elevated concentrations of carbon tetrachloride and nitrate beginning approximately 13 m (43 ft) below the water table and extending to approximately 39 m (128 ft) below the 2017 water table elevation. Well 299-W18-41 exhibits a general decreasing concentration of nitrate with depth; however, the highest concentration of carbon tetrachloride (11 µg/L) was collected approximately 6 m (20 ft) above the Ringold Lower Mud.

In summary, the LLBG WMA-4 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-4. Available data for the wells are not sufficiently representative to evaluate vertical plume migration from a hypothetical release from LLBG WMA-4.

5 Groundwater Flow Simulations

Groundwater flow simulations were conducted to evaluate the groundwater monitoring network for LLBG WMA-4 (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 2-51 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-4.

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.

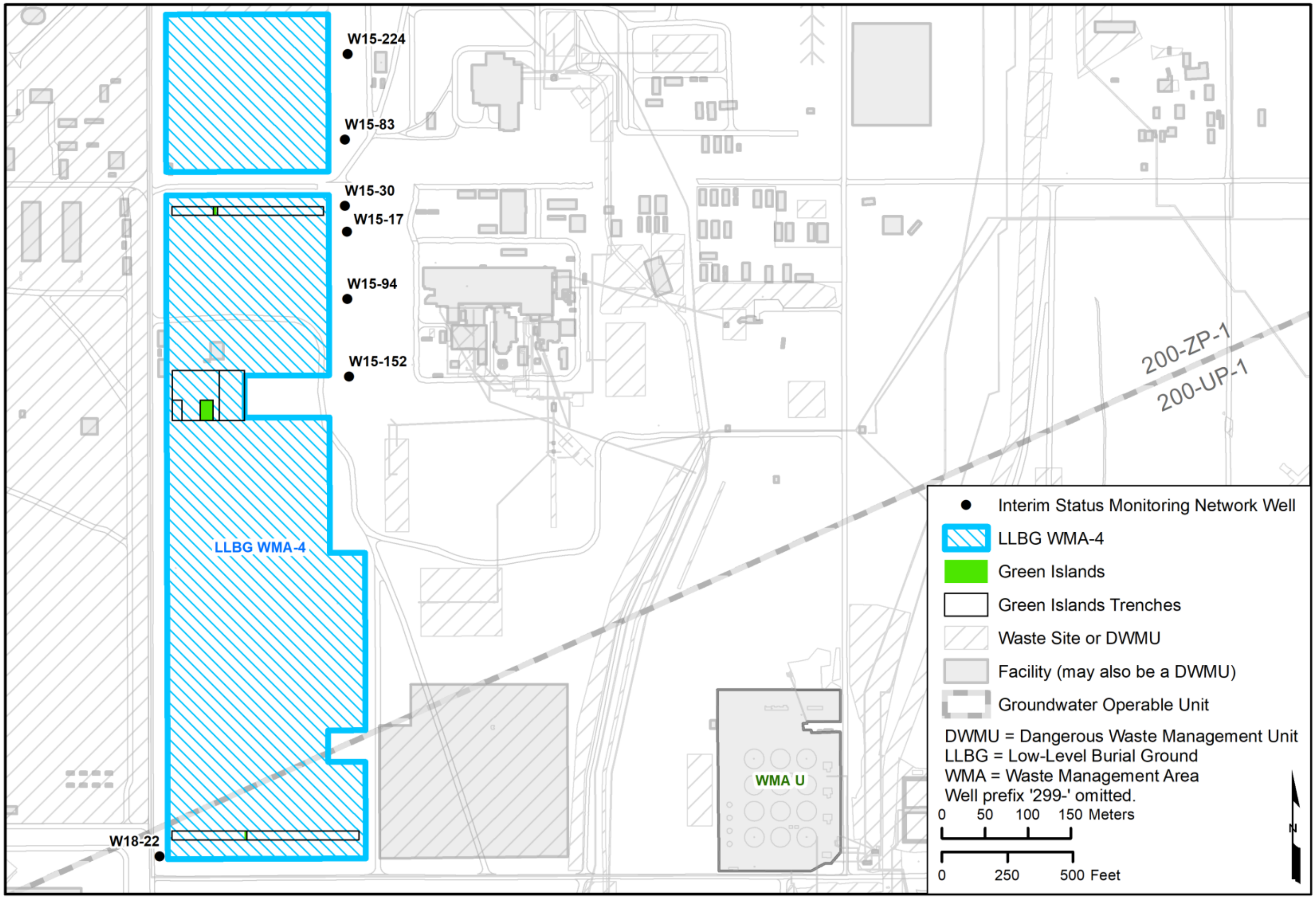
Contaminant transport is simulated using the Modular Three-Dimensional Multi-Species Transport Model (MT3DMS) code. MT3DMS was developed specifically for use with MODFLOW to simulate contaminant advection, dispersion, sources and sinks, and chemical reactions in groundwater systems.

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 2-51 of 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.

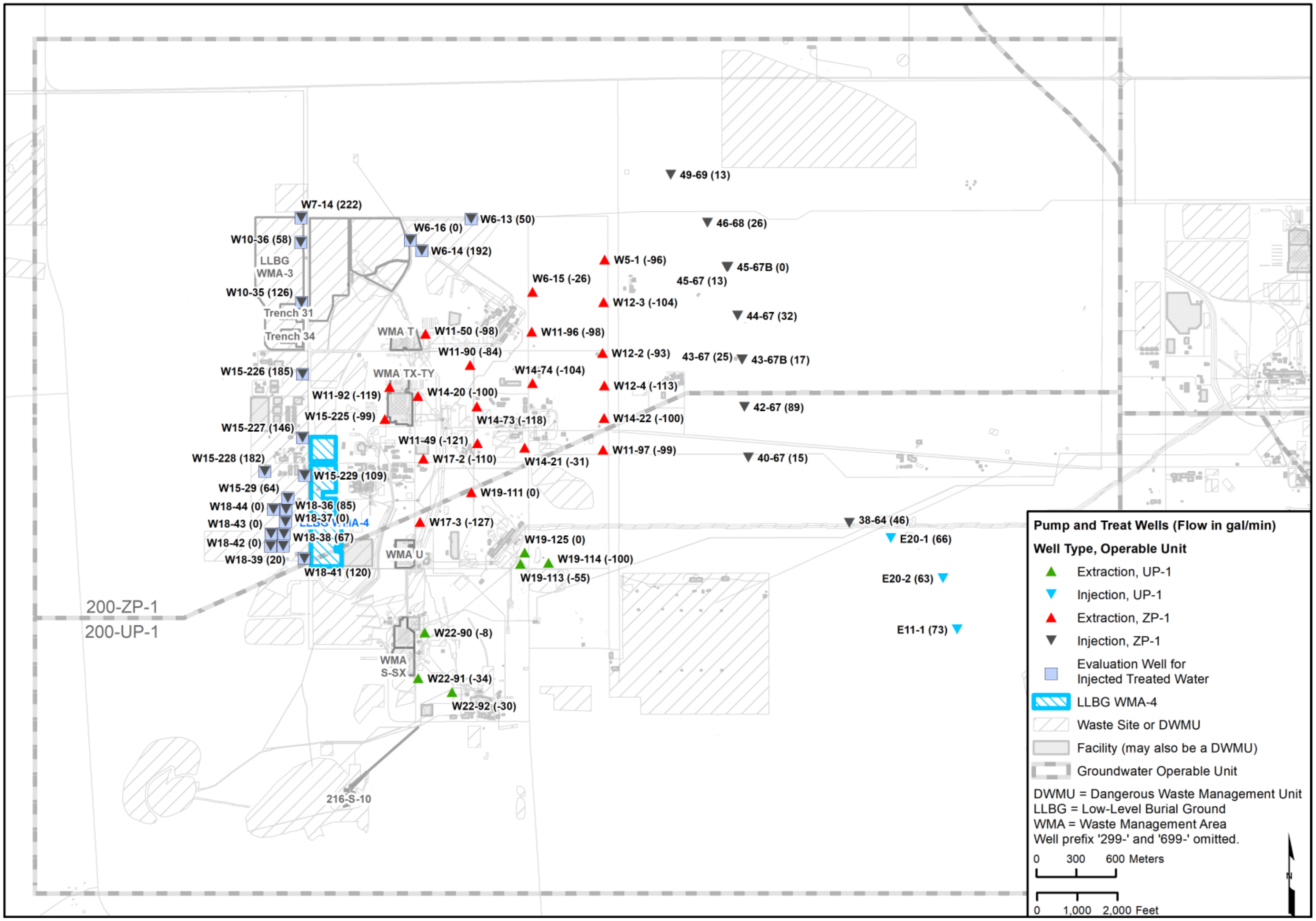


Figure 5-2. Locations and Average Pumping Rates (for December 2016) of 200 West P&T System Wells

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-4 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, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*.

Simulations were run for each scenario to examine dilution from injection of treated water and particle pathlines of hypothetical releases from LLBG WMA-4. The results of those simulations were used to evaluate the efficacy of the groundwater monitoring network to detect hypothetical releases from LLBG WMA-4.

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-4. 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 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-4 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-4 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-4, 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 located in LLBG WMA-4. The Green Islands are locations within certain LLBG WMA-4 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 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.

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-4 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-4 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-4 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.

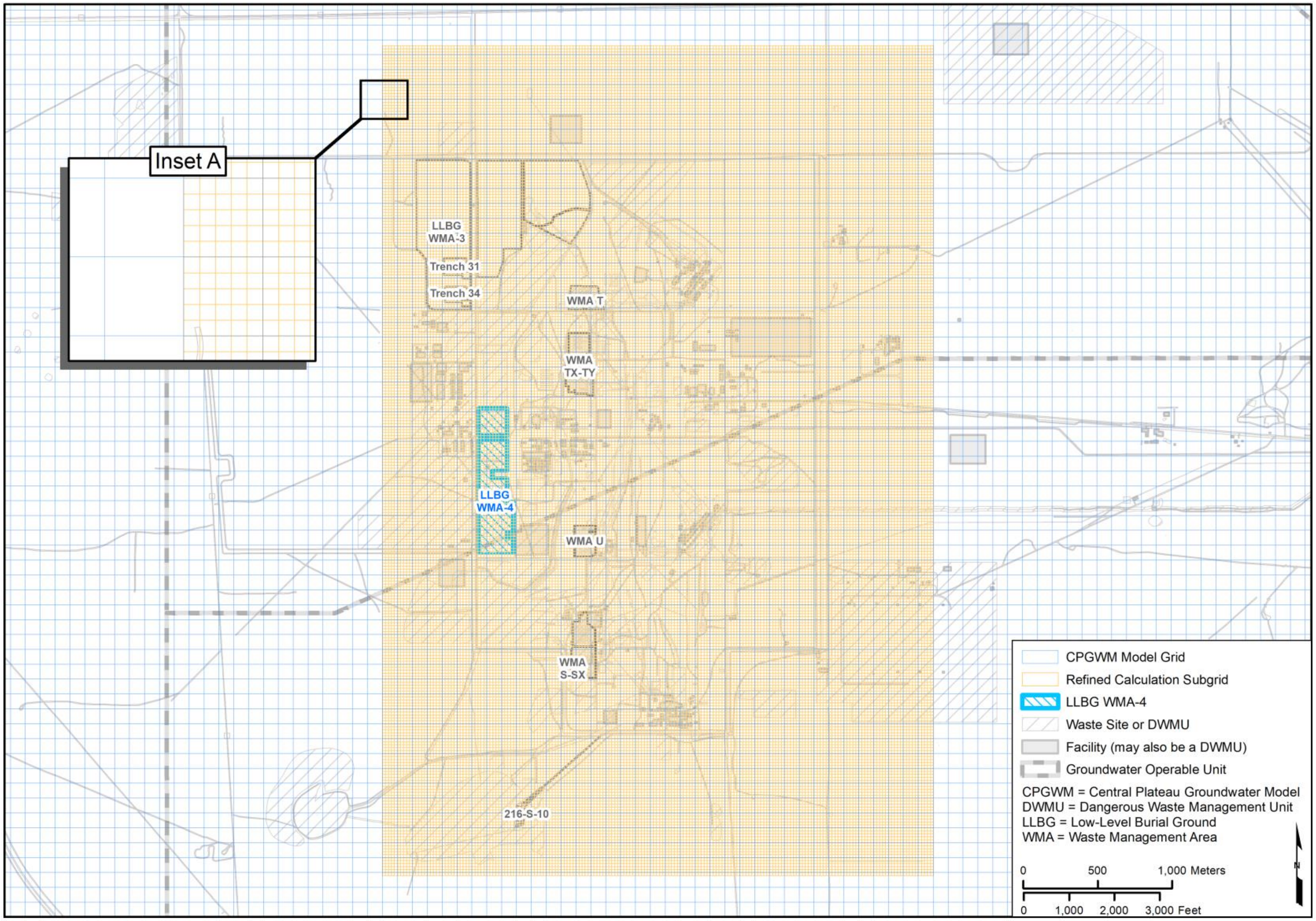


Figure 6-1. Location of Calculation Subgrid in Relation to 200 West Area Facilities Evaluated in Appendix F

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-4 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-4, unit concentrations representing the hypothetical contaminant were released at the water table in three model grid cells representing LLBG WMA-4 (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-4 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 includes 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-4's 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 the facility.

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 the facility. 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 are likely to have higher dilutions from injected treated water and which are likely to 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-4 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-W15-17, 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, 299-W15-224, and 299-W18-22 (Figure 5-1) 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 7-7 show the injected treated water dilution breakthrough curves for monitoring wells 299-W15-17, 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, 299-W15-224, and 299-W18-22, 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 that the injected treated water arrives at the monitoring wells quickly. The curves also show some variability among the different sub-scenarios, suggesting that varying injection well operations influences the concentrations of treated water observed at the LLBG WMA-4 monitoring network wells. The results for downgradient wells are bounded on the high end (higher unit concentrations of injected treated water) by sub-scenario N. Sub-scenario N results in nearly 100% injected treated water at the monitoring wells. Wells 299-W15-152 and 299-W15-224 are bounded on the low end (lower unit concentrations) by sub-scenarios P and O, respectively, while all others are bounded by sub-scenario M. The results for scenario 2 (included in Appendix G) were similar to those for scenario 1.

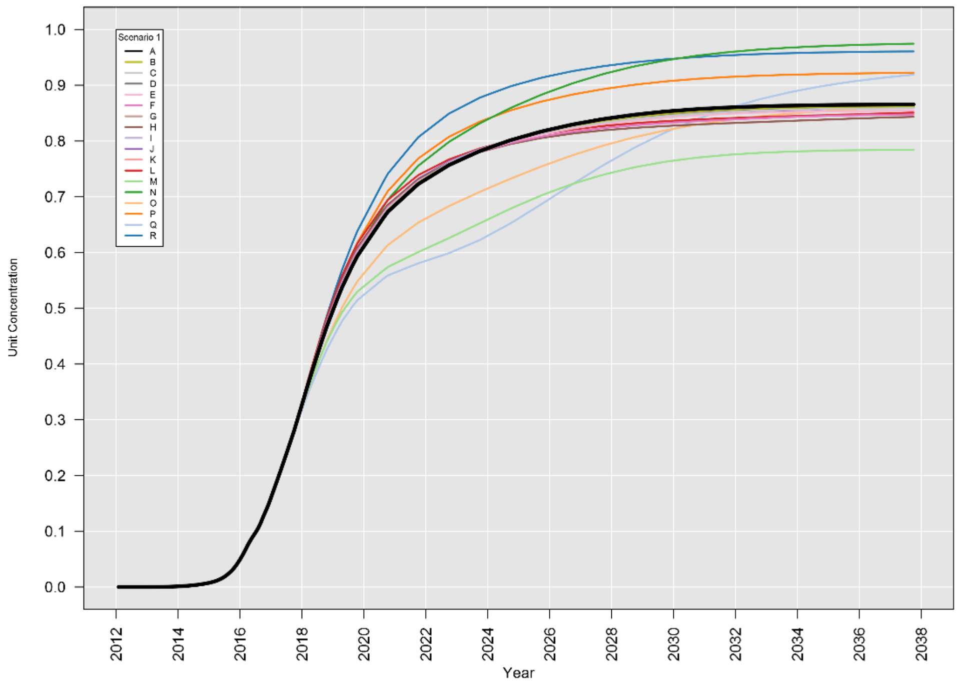


Figure 7-1. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-17

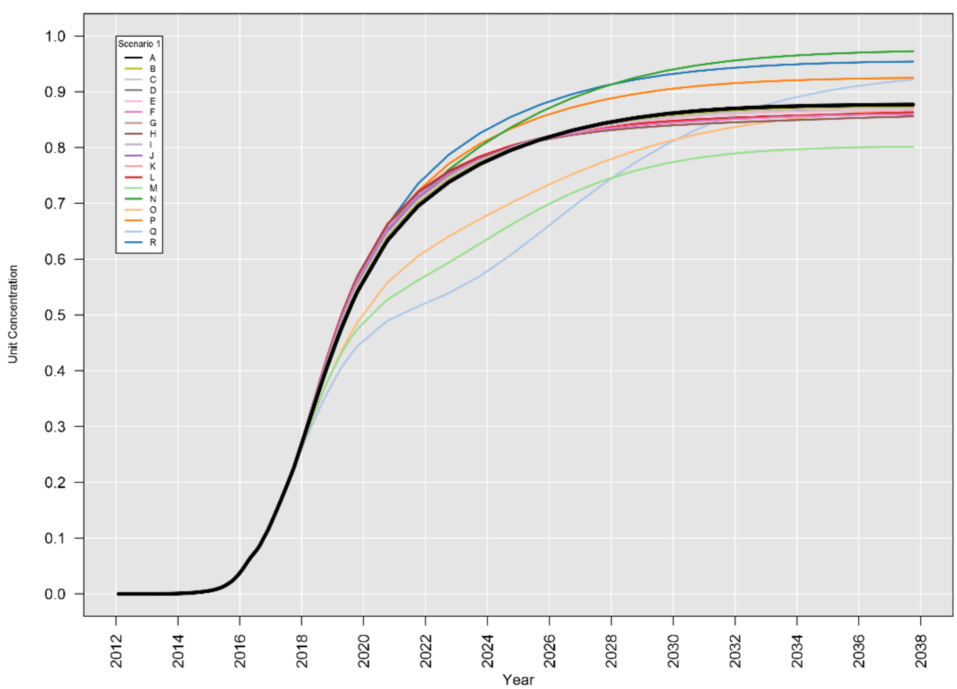


Figure 7-2. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-30

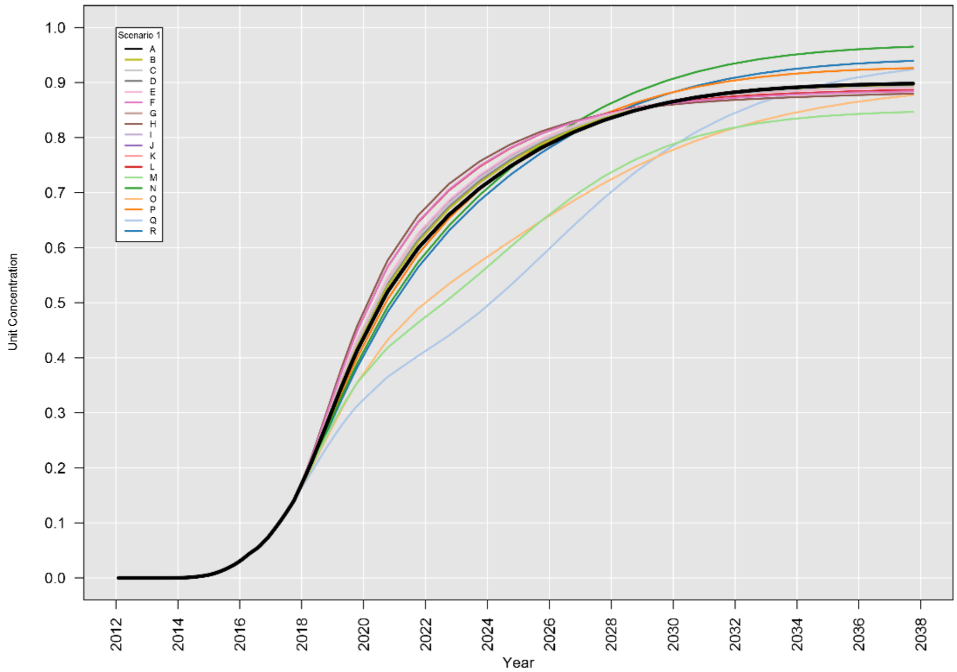


Figure 7-3. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-83

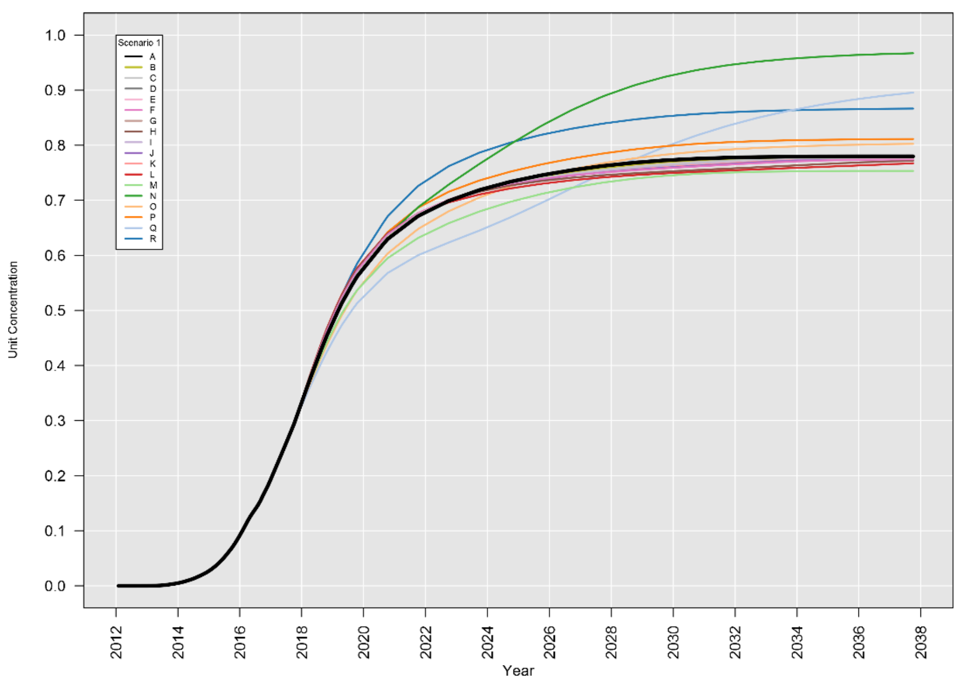


Figure 7-4. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-94

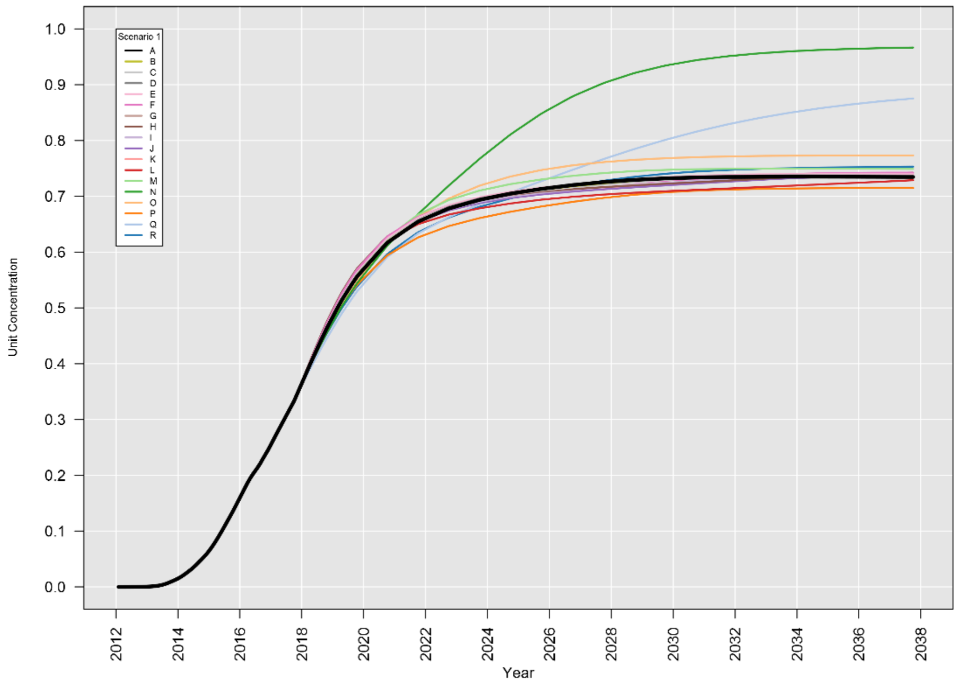


Figure 7-5. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-152

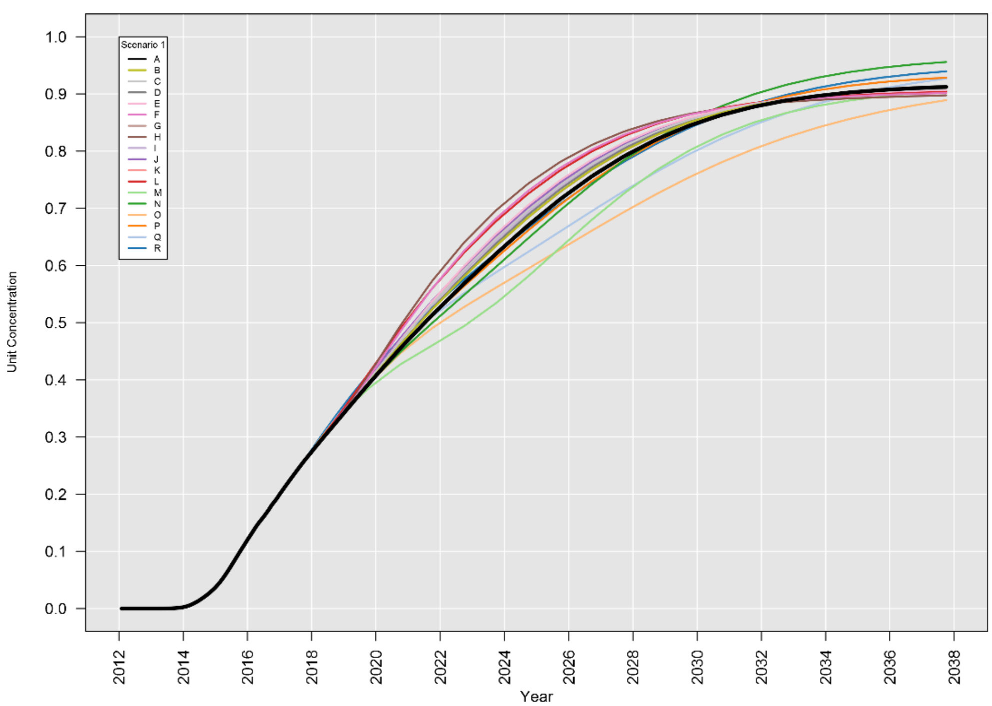


Figure 7-6. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-224

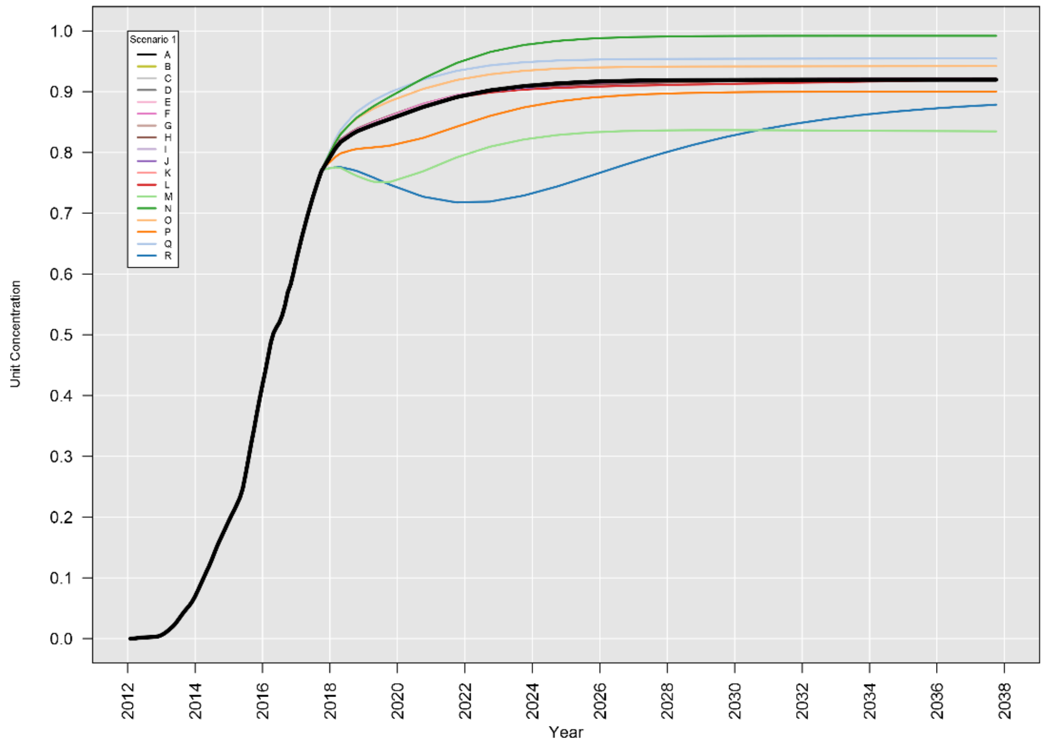


Figure 7-7. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W18-22

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-W15-17	1	0.784	0.974	0.870
	2	0.785	0.978	0.871
299-W15-30	1	0.802	0.973	0.880
	2	0.802	0.976	0.882
299-W15-83	1	0.847	0.965	0.899
	2	0.848	0.970	0.901
299-W15-94	1	0.753	0.967	0.789
	2	0.754	0.971	0.793
299-W15-152	1	0.715	0.967	0.745
	2	0.716	0.971	0.751
299-W15-224	1	0.889	0.956	0.913
	2	0.895	0.964	0.916
299-W18-22	1	0.835	0.992	0.920
	2	0.835	0.993	0.922

The release concentration breakthrough curves for monitoring wells 299-W15-17, 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, 299-W15-224, and 299-W18-22 for all sub-scenarios in scenario 1 are shown in Figures 7-8 through 7-14, respectively. These figures, which depict the simulated breakthrough of a unit source release to the groundwater table from LLBG WMA-4, 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.

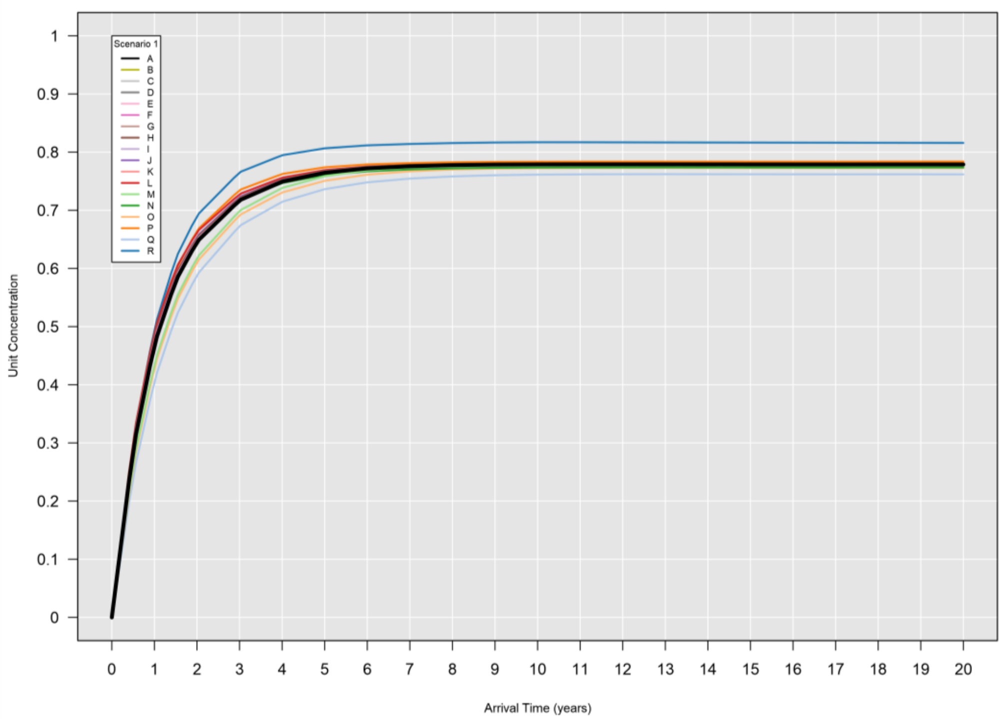


Figure 7-8. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-17

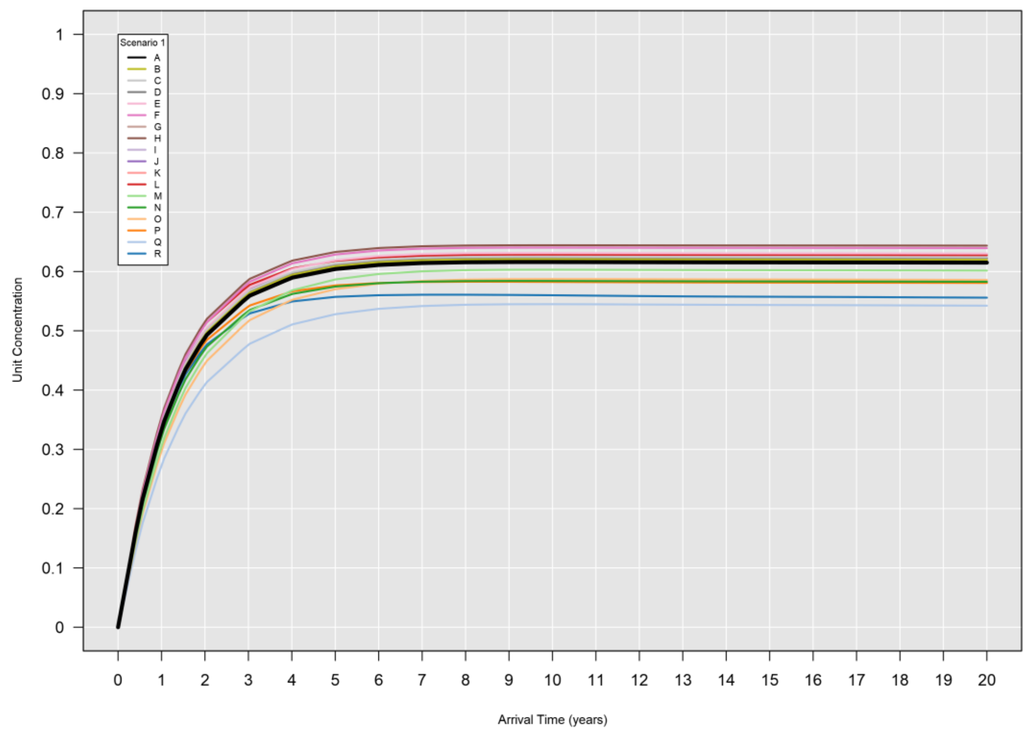


Figure 7-9. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-30

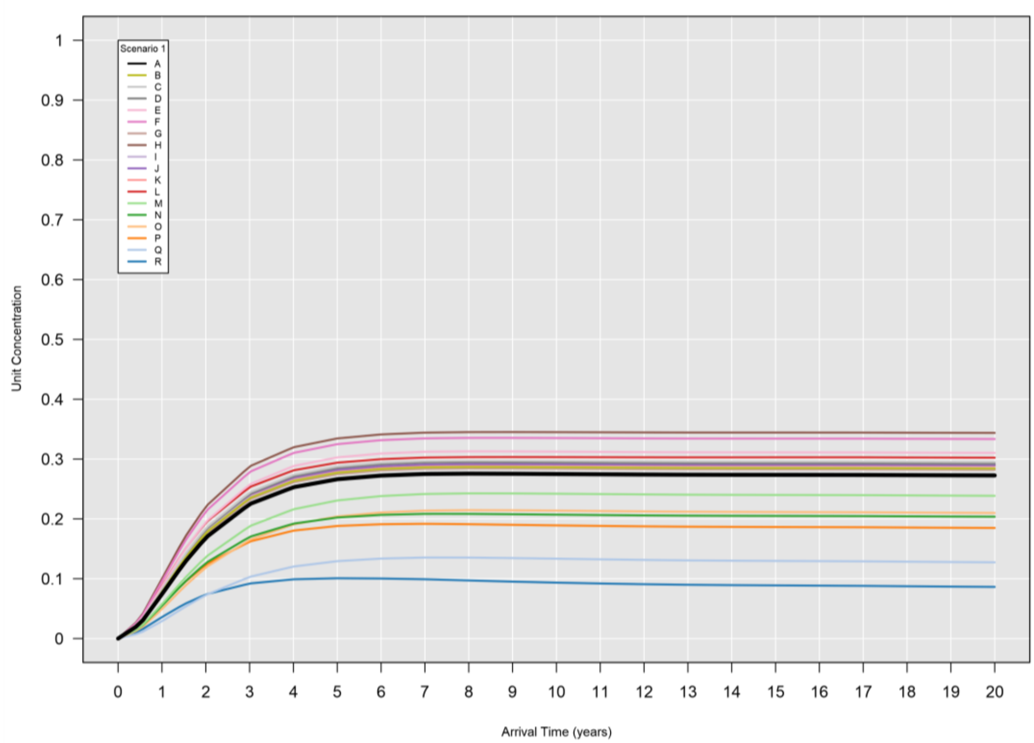


Figure 7-10. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-83

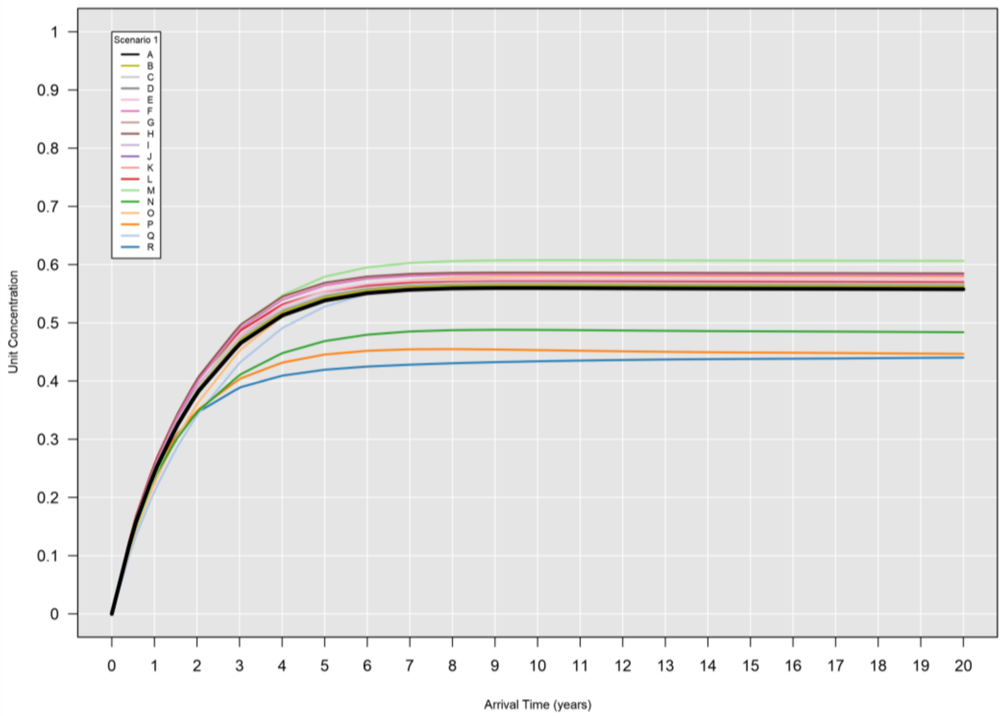


Figure 7-11. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-94

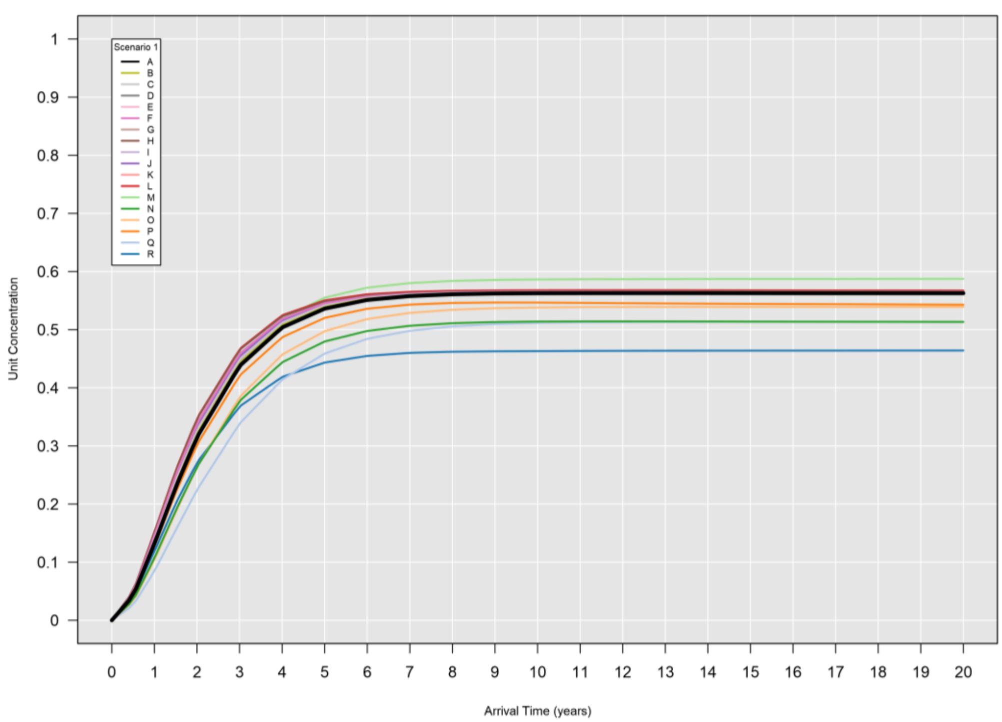


Figure 7-12. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-152

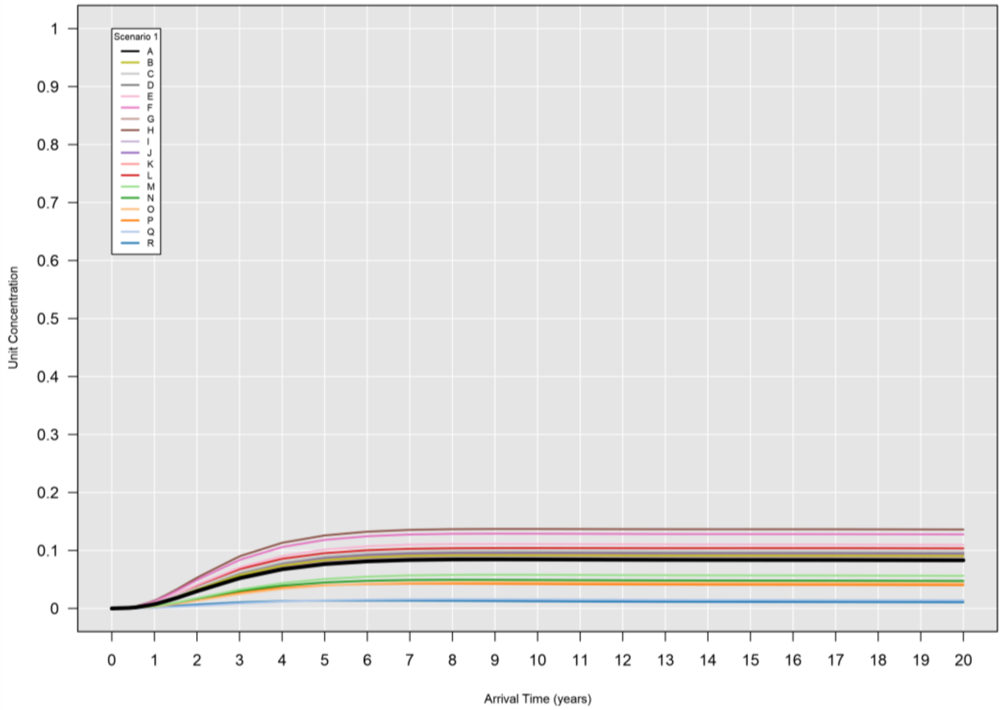


Figure 7-13. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W15-224

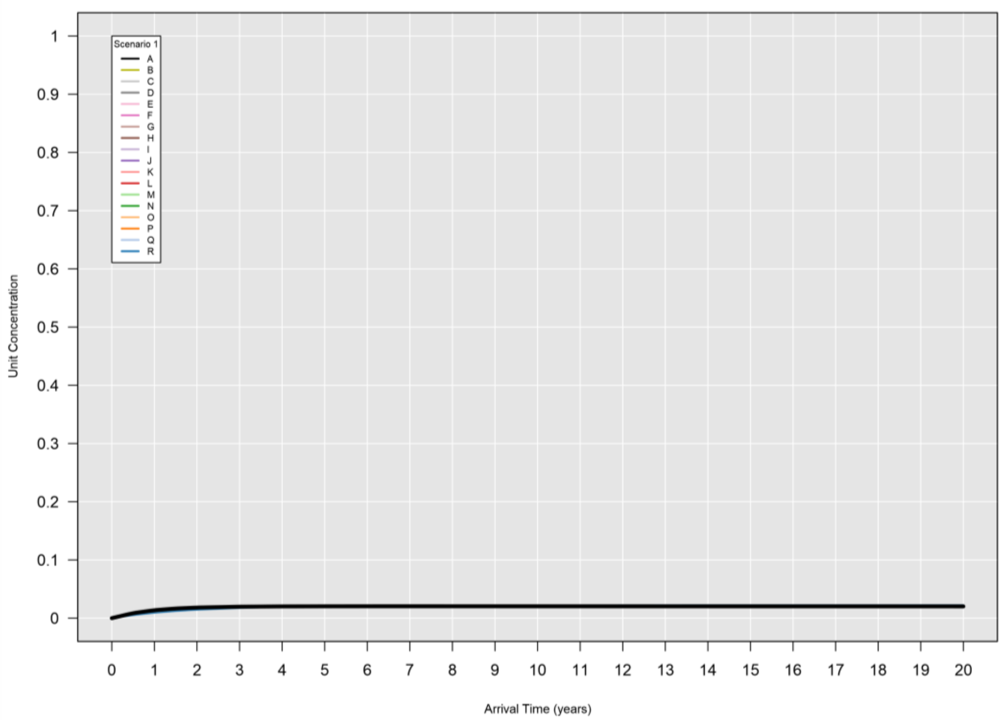


Figure 7-14. Release Concentration Breakthrough Curves, Scenario 1, Monitoring Well 299-W18-22

Figures 7-8 through 7-14 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 very sensitive to changes in the 200 West P&T system operating conditions. Compared to other monitoring well locations, the release concentration breakthrough curves for northernmost well 299-W15-83, indicate the most variation and, therefore most sensitivity to changes for all the operating scenarios. Curves for several monitoring wells (299-W15-17, 299-W15-30, 299-W15-94, and 299-W15-152) show medium to high unit concentrations, which indicate those monitoring network wells are located in areas having high potential for detecting releases from LLBG WMA-4. 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-W15-17	1	0.762	0.816	0.779	0.716
	2	0.762	0.816	0.779	
299-W15-30	1	0.542	0.644	0.612	0.518
	2	0.544	0.645	0.613	
299-W15-83	1	0.086	0.344	0.265	0.073
	2	0.086	0.347	0.269	
299-W15-94	1	0.440	0.606	0.553	0.469
	2	0.440	0.608	0.556	
299-W15-152	1	0.464	0.587	0.559	0.238
	2	0.464	0.588	0.559	
299-W15-224	1	0.011	0.136	0.080	0.013
	2	0.011	0.139	0.082	
299-W18-22	1	0.020	0.022	0.020	0.012
	2	0.020	0.022	0.020	

The release concentration breakthrough curves for scenario 3 (Figure 7-15) indicate that wells 299-W15-17, 299-W15-30, and 299-W15-94 have medium to high unit concentrations similar to the range of unit concentrations for those wells in scenarios 1 and 2. This result is discussed in detail in relation to the release unit plume maps. The unit concentration for well 299-W15-224 is 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.

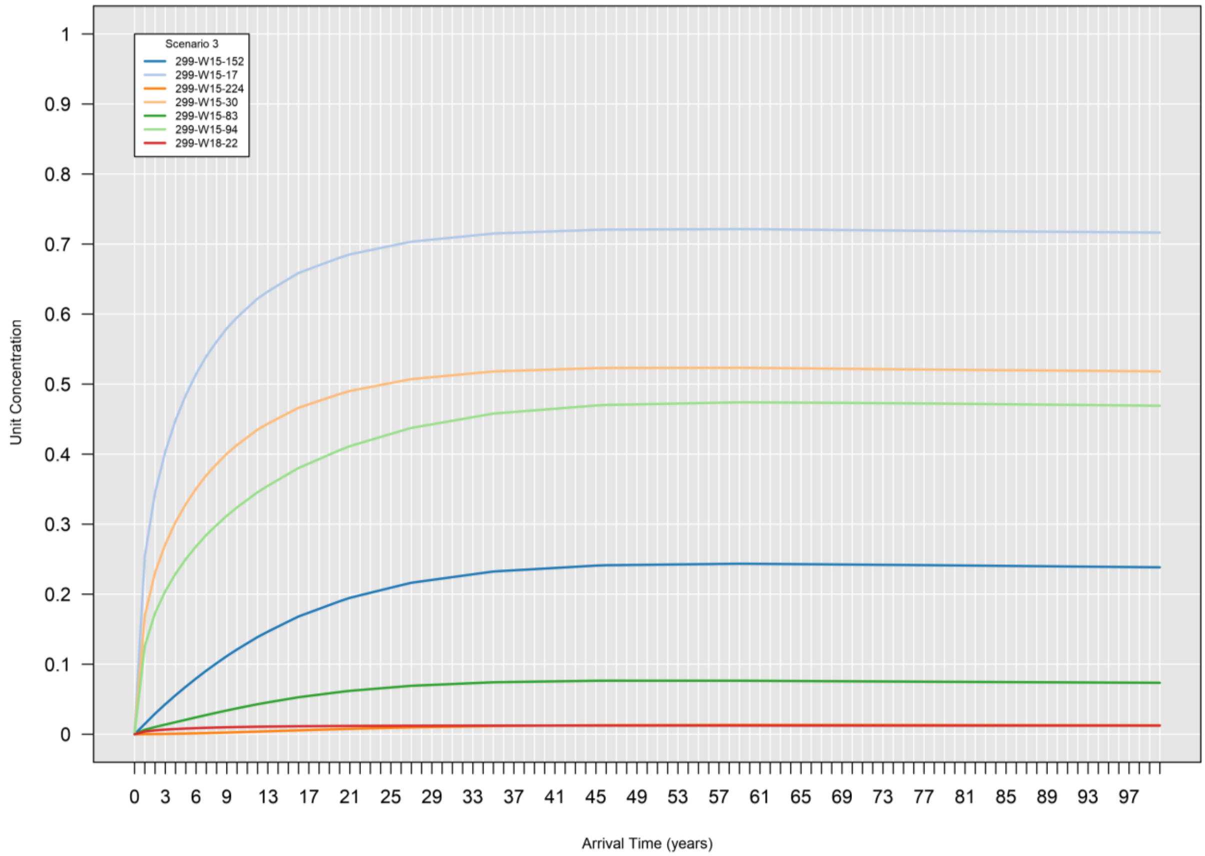


Figure 7-15. Release Concentration Breakthrough Curves at Monitoring Wells, Scenario 3

Figures 7-16 through 7-18 show plume maps of release unit concentrations based on transport modeling representing conditions at the end of 200 West P&T system operations in 2037 for scenarios 1 and 2 and in 2137 for scenario 3. Figures 7-16 and 7-17 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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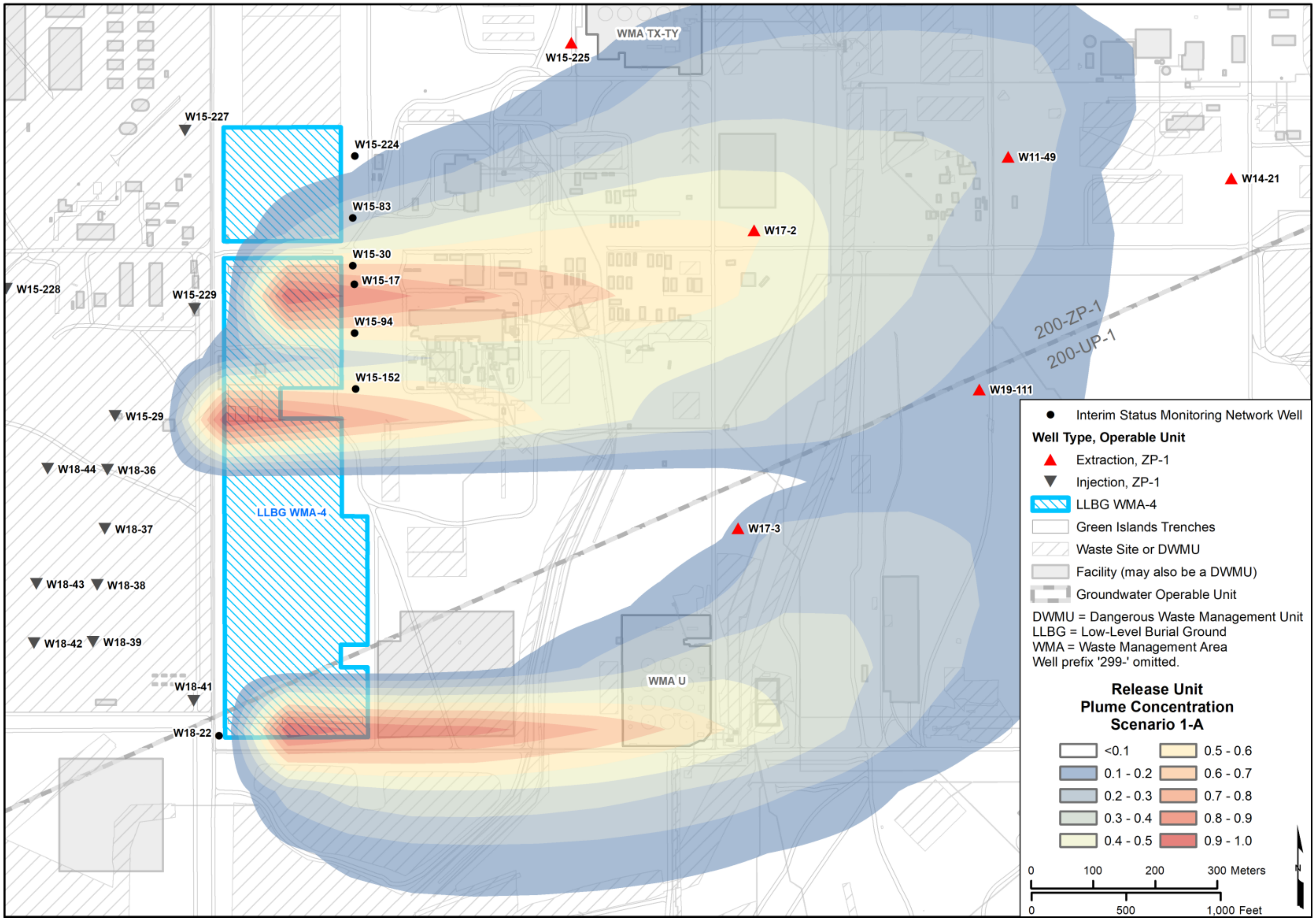

Figure 7-16. Release Unit Plume Map, Scenario 1, Sub-Scenario A

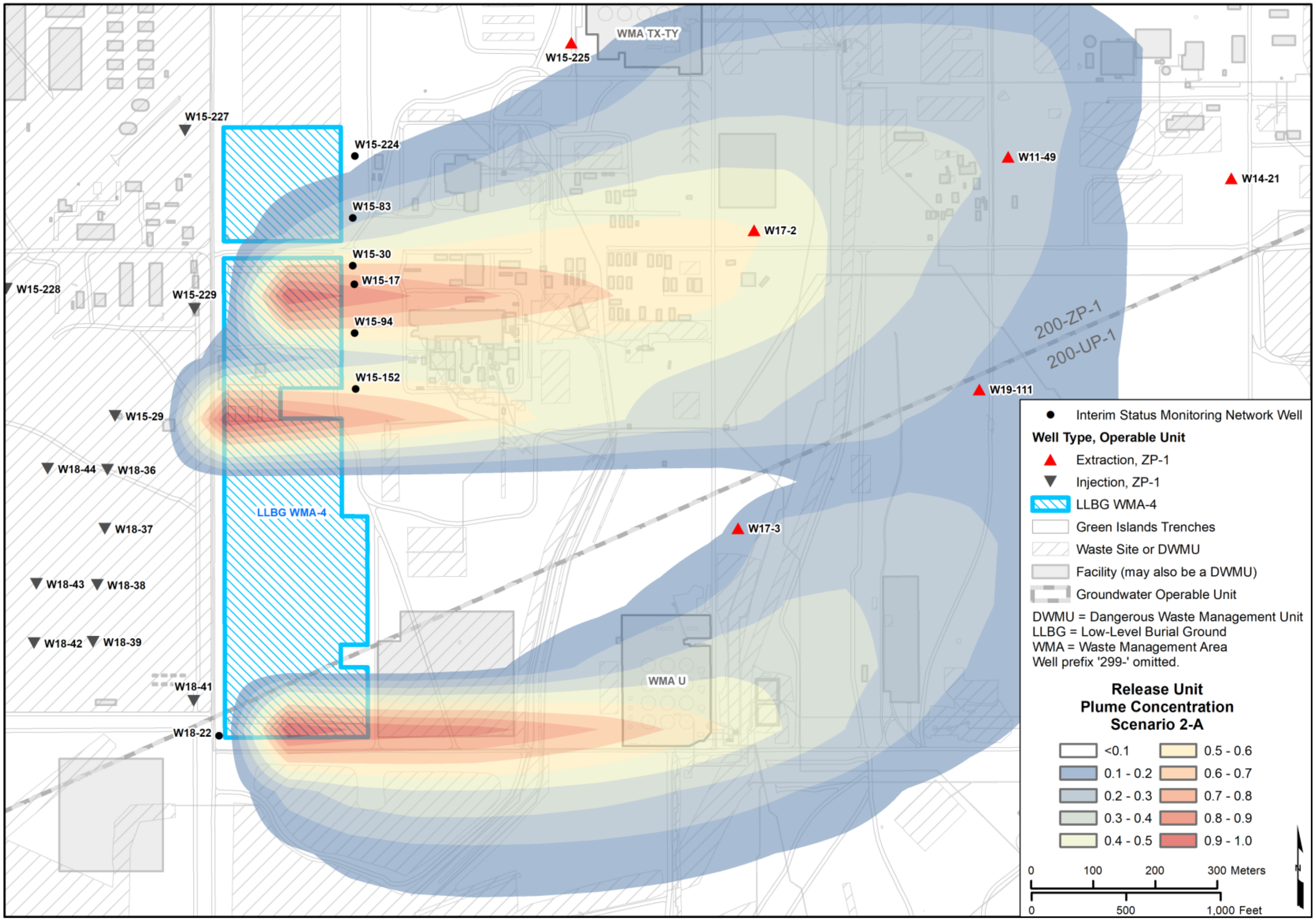

Figure 7-17. Release Unit Plume Map, Scenario 2, Sub-Scenario A

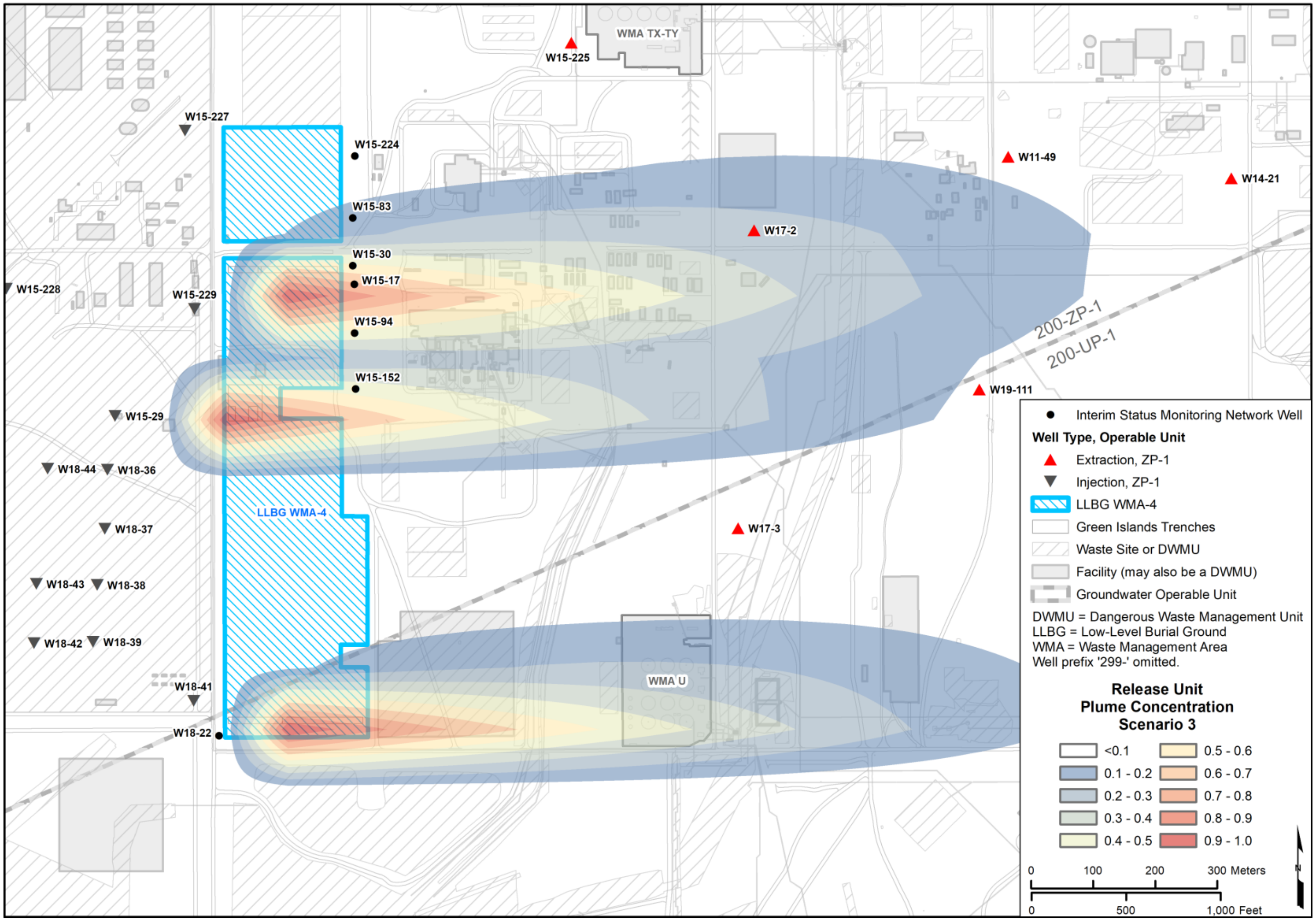

Figure 7-18. Release Unit Plume Map, Scenario 3

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 7-16 through 7-18 show that all downgradient wells except 299-W15-224 are within the unit plume for the scenarios evaluated. Well 299-W15-224 is located outside of the release unit plume for scenario 3. 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-4. 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 7-19 and 7-20 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 7-21) 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 well located for detecting releases from the facility with the exception of wells 299-W15-94 and 299-W15-224, which are located to the north of and between the extents of the release particle pathlines. In scenario 3, well 299-W15-83 also falls to the north of the particle pathlines.

Maps of relative detectability identify areas of the aquifer where a hypothetical release that impacts the water table beneath LLBG WMA-4 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.

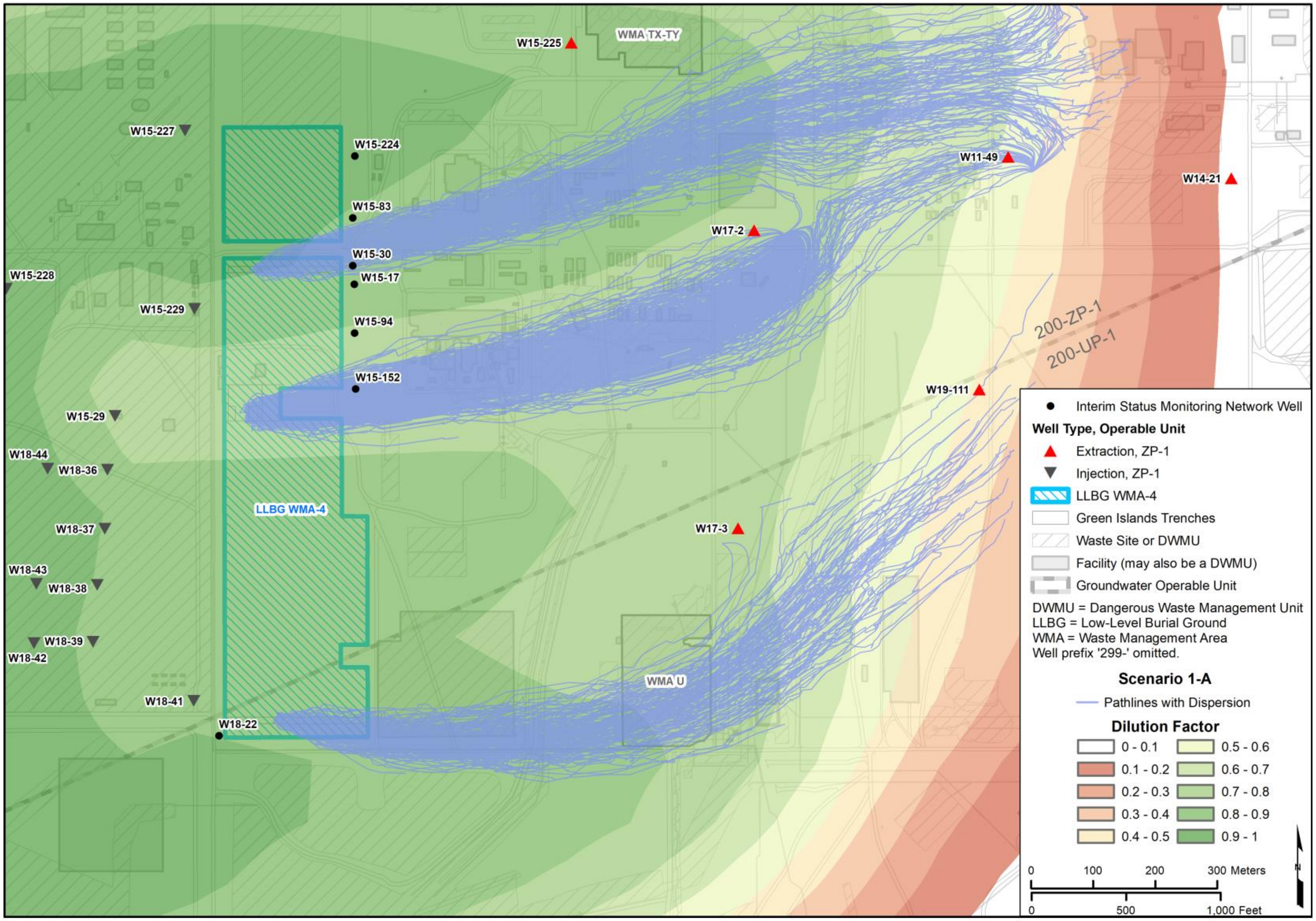

Figure 7-19. Particle Pathlines Superimposed on Injected Treated Water Dilution Plumes, Scenario 1, Sub-Scenario A

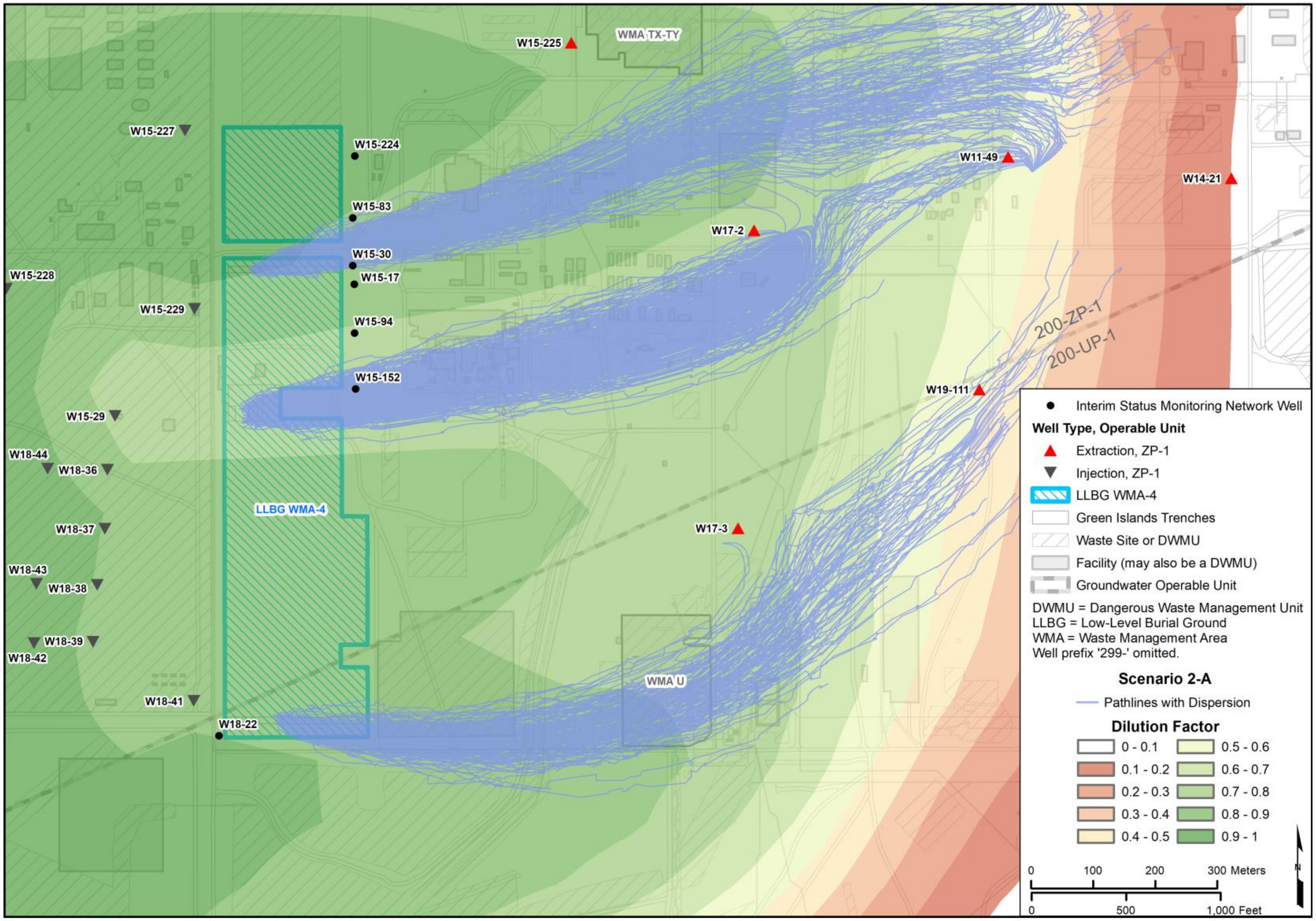

Figure 7-20. Particle Pathlines Superimposed on Injected Treated Water Dilution Plumes, Scenario 2, Sub-Scenario A

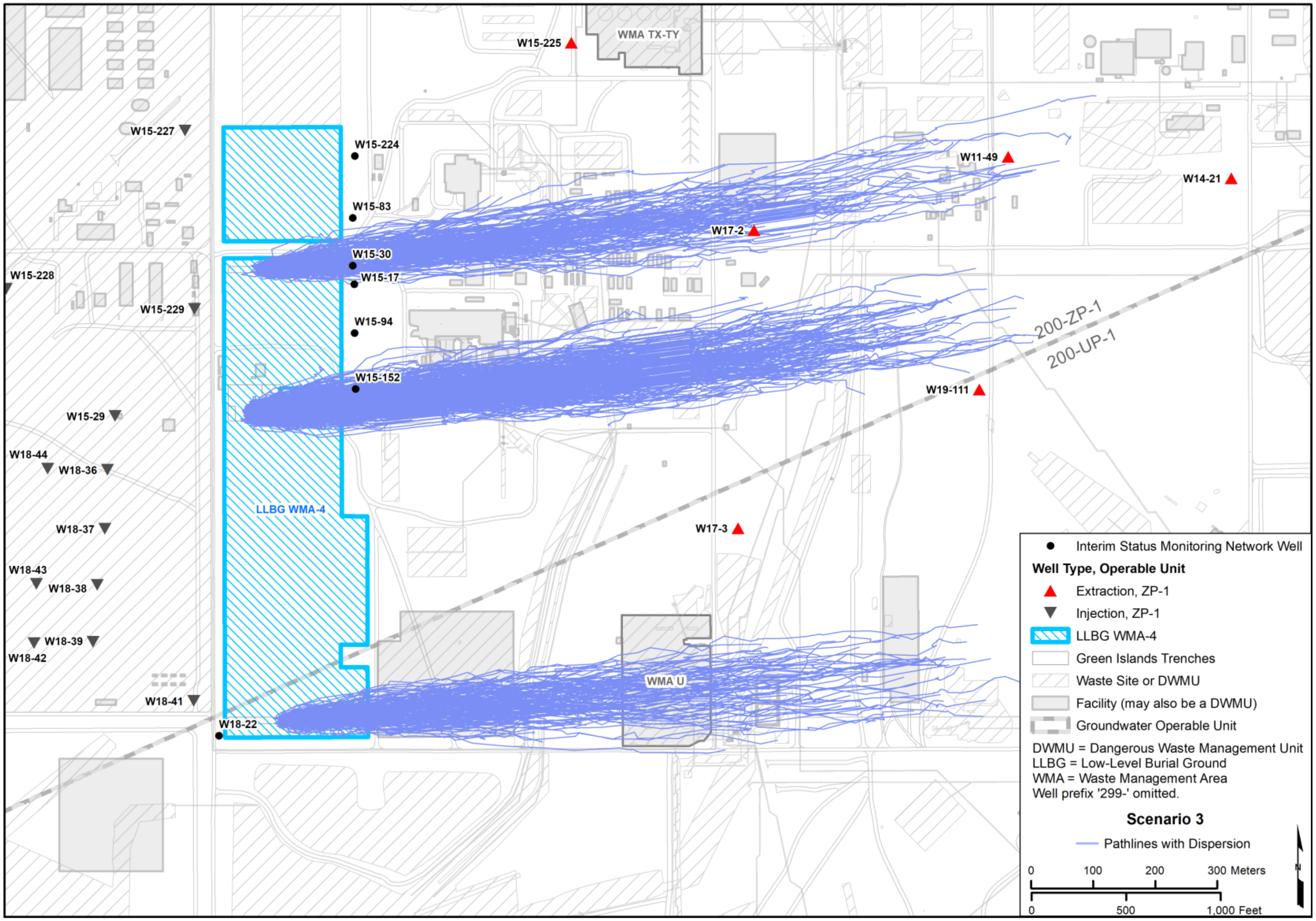

Figure 7-21. Particle Pathlines, Scenario 3

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.

Figures 7-22 through 7-24 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 for scenarios 1 and 2 show that downgradient groundwater monitoring wells 299-W15-30 and 299-W15-152 generally are located in areas of high relative detectability for particle releases from LLBG WMA-4. Monitoring wells 299-W15-17, 299-W15-83, 299-W15-94, and 299-W15-224 are located on the edge or outside of the relative detectability area. After the cessation of 200 West P&T system operations, the groundwater flow will shift from a northeastern to an eastern direction, however, there is little change to the results for scenario 3. Because no monitoring wells are located in the particle pathlines from the southernmost Green Island and the central Green Island only had one downgradient monitoring well, three new downgradient monitoring wells (WMA-4_PW1, WMA-4_PW2, and WMA-4_PW_6) are proposed for the final status monitoring well network.
The proposed locations for these wells are shown in Figures 7-22 through 7-24. In addition, three new upgradient wells are proposed. One is proposed to replace 299-W18-22, which is a deep well, and the other two are proposed along the western side of the facility. These new upgradient wells, WMA-4_PW3, WMA-4_PW4, and WMA-4_PW5 are also shown in Figures 7-22 through 7-24.

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-4_PW1, WMA-4_PW2, WMA-4_PW3, WMA-4_PW4, WMA-4_PW5, and WMA-4_PW6. Figures 7-25 through 7-30 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 7-31 through 7-36 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 the proposed wells for scenario 2 are included in Appendix G.

The injected treated water breakthrough curves for the proposed wells indicate some sensitivity to variations in 200 West P&T system injection operations. The curves also indicate high unit concentrations of injected treated water at the well locations, with sub-scenario N approaching 100% injected treated water at the well locations. For each proposed well location except WMA-4_PW5 and WMA-4_PW6, sub-scenario M is the lower boundary condition, having a unit concentration of more than 0.8. Results for scenario 2 were similar to the results for scenario 1.

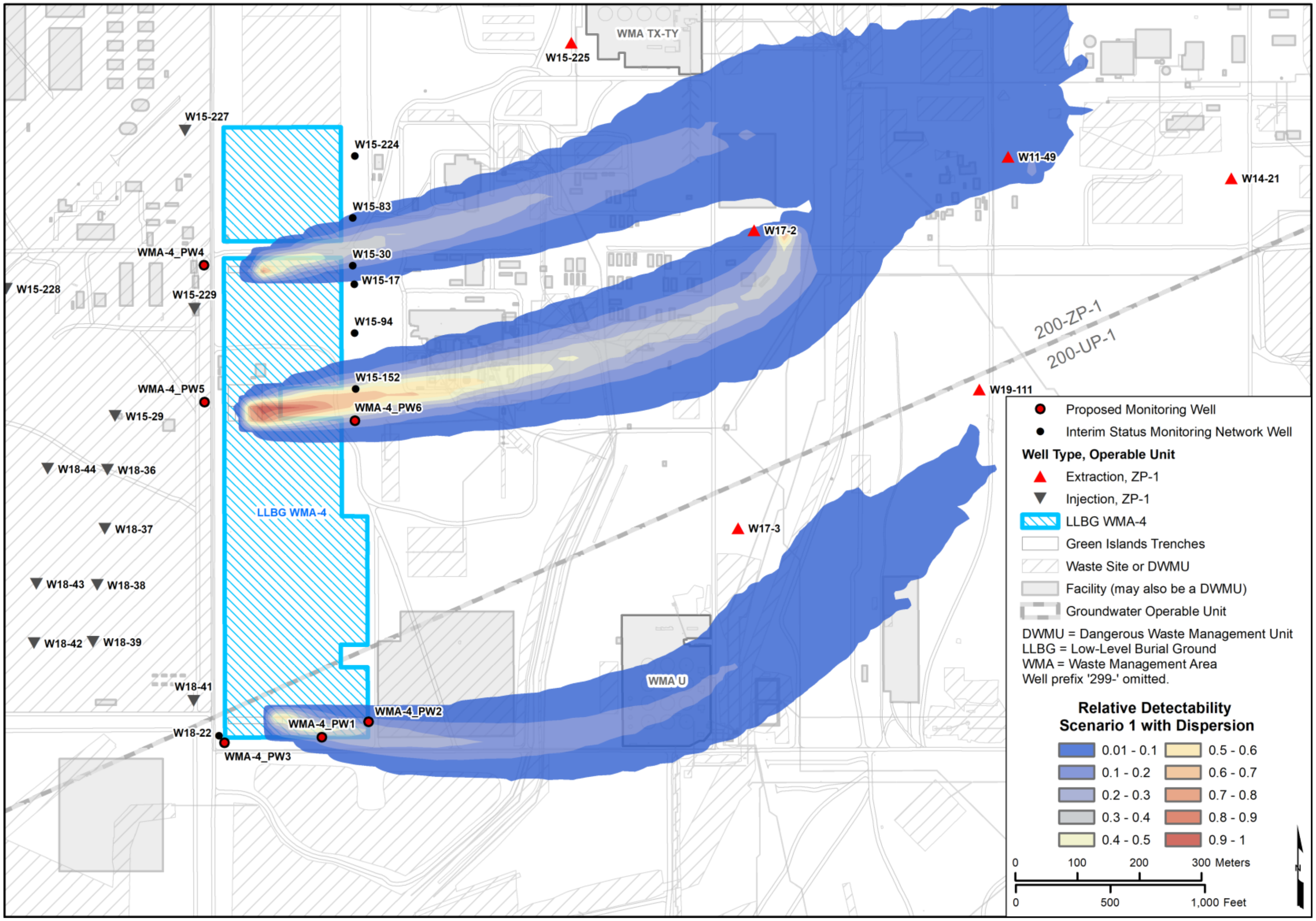

Figure 7-22. Relative Detectability of Release, Scenario 1

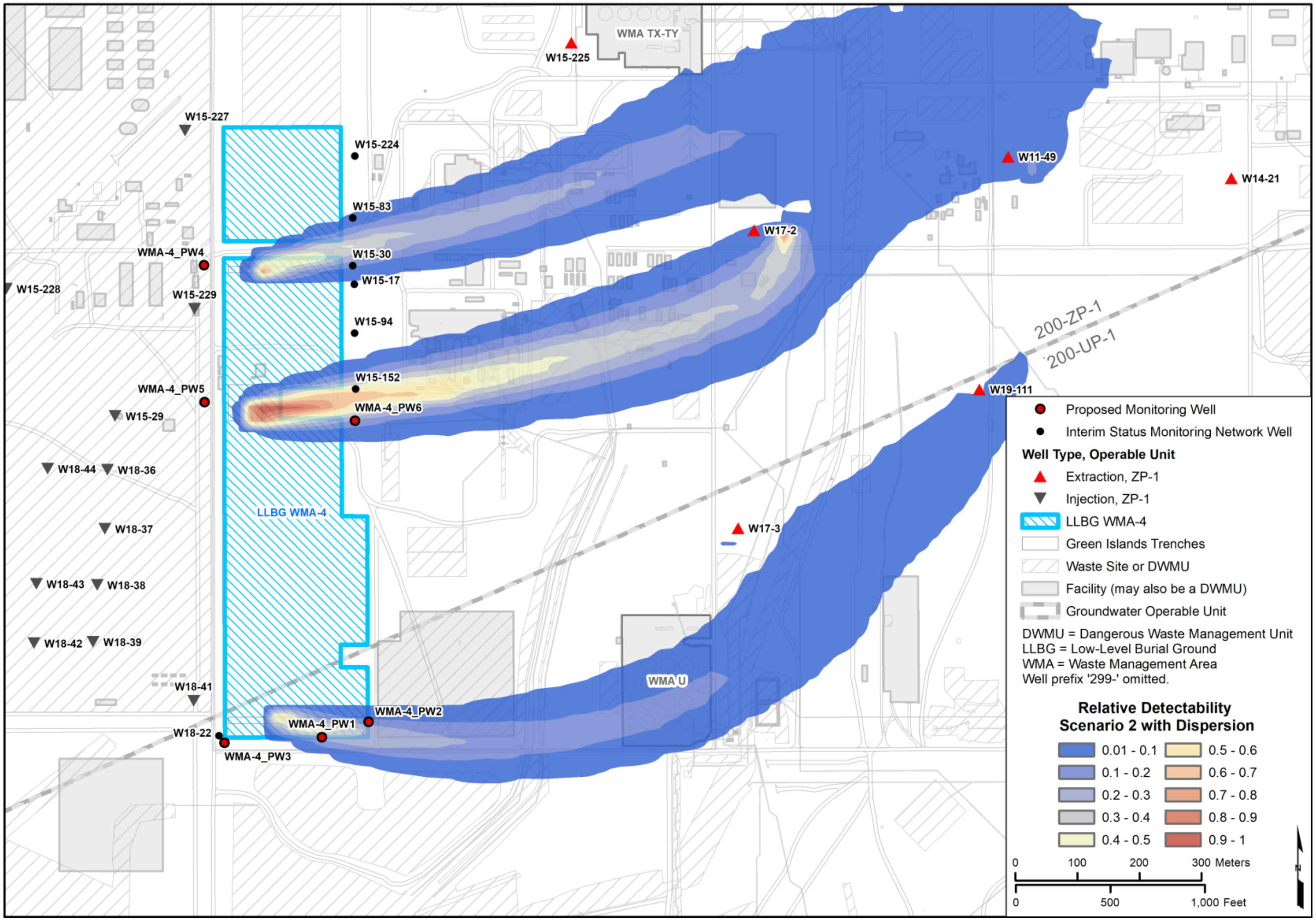

Figure 7-23. Relative Detectability of Release, Scenario 2

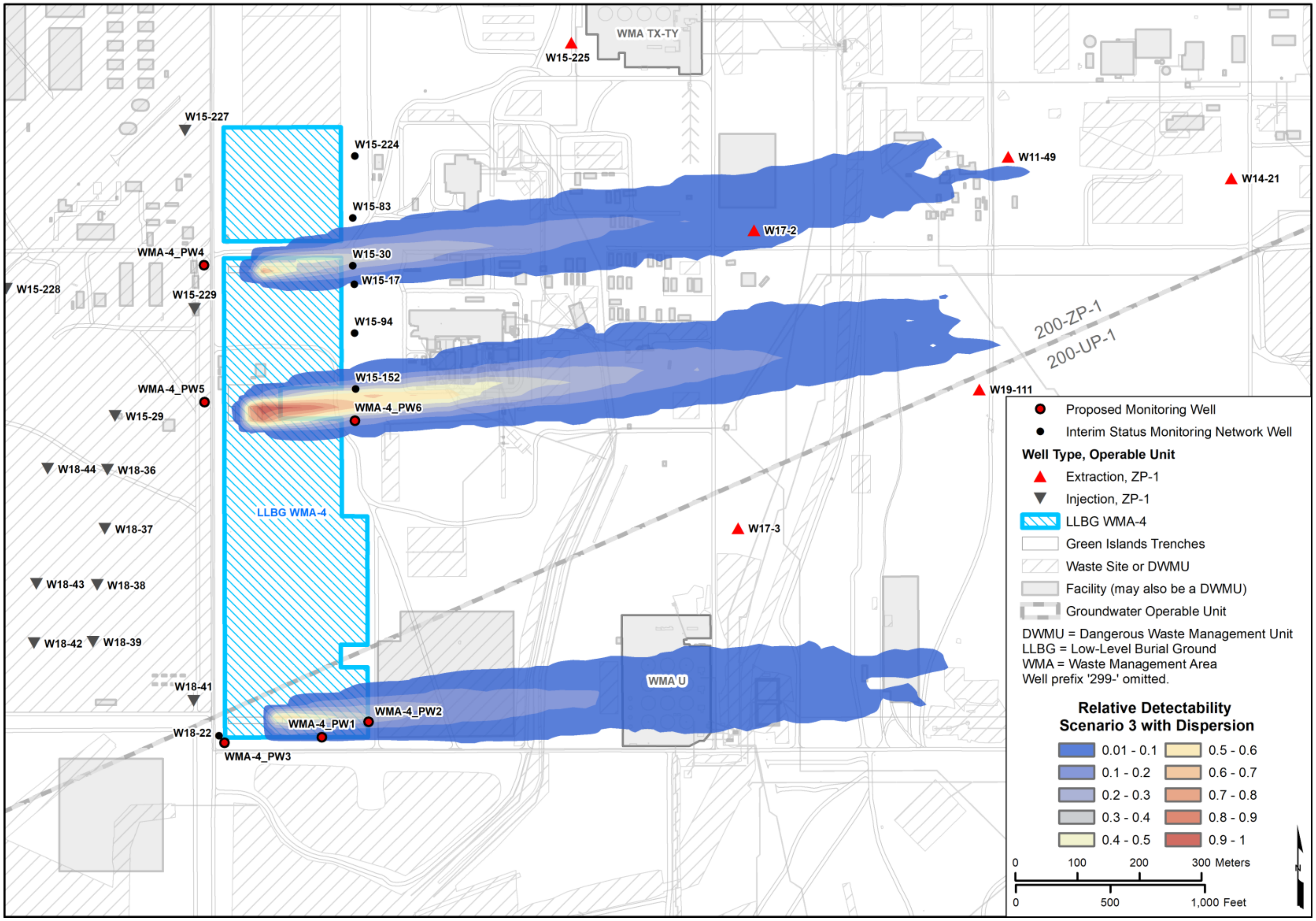

Figure 7-24. Relative Detectability of Release, Scenario 3

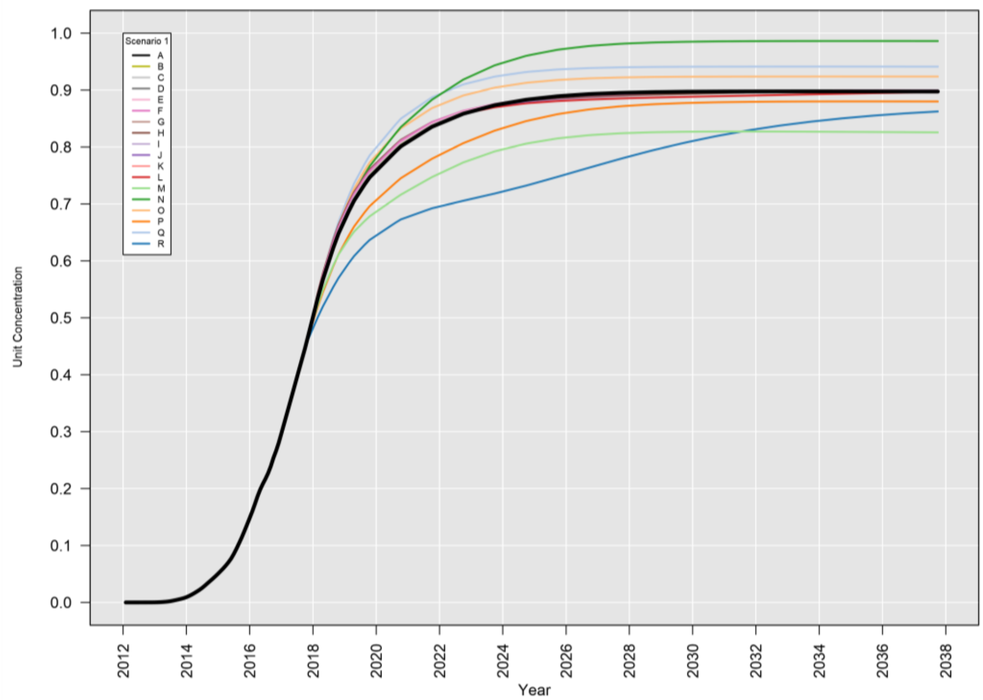

Figure 7-25. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW1

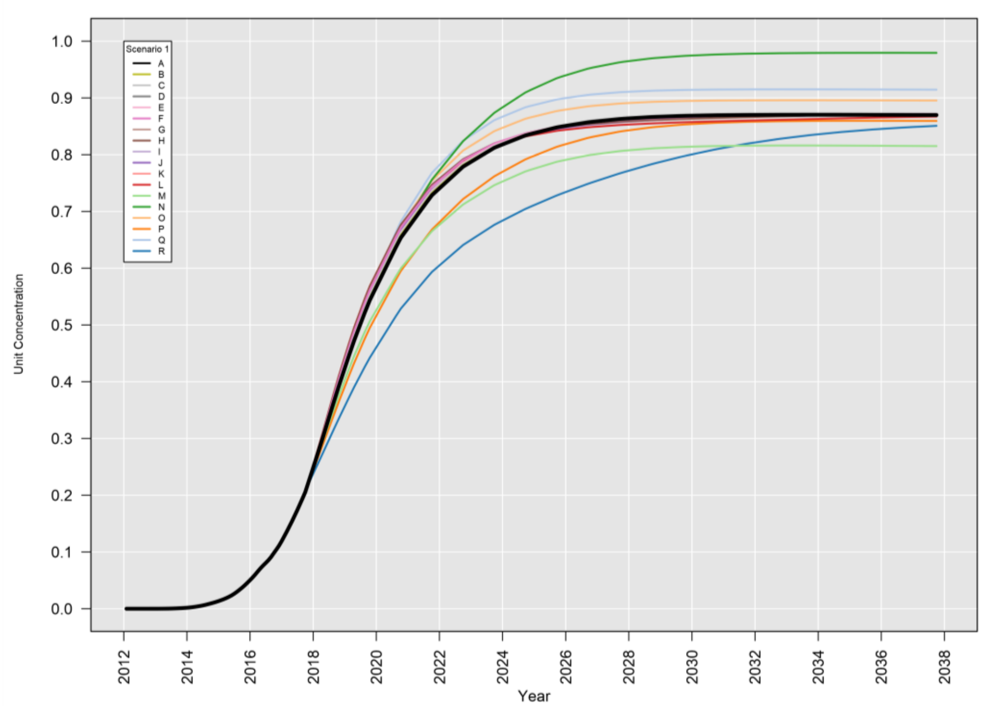

Figure 7-26. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW2

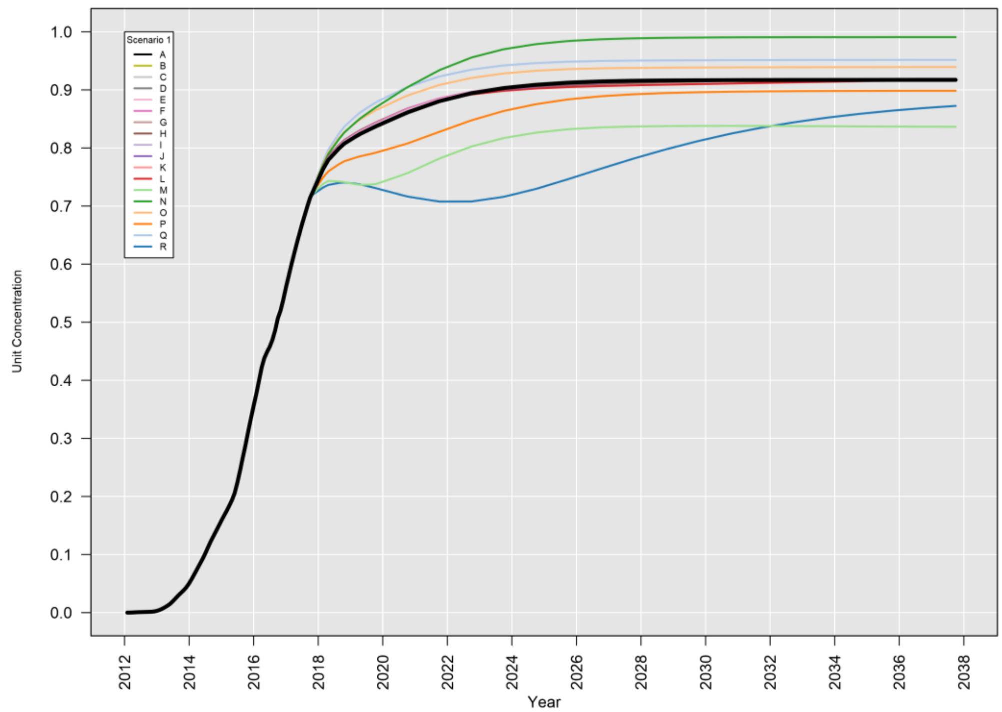

Figure 7-27. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW3

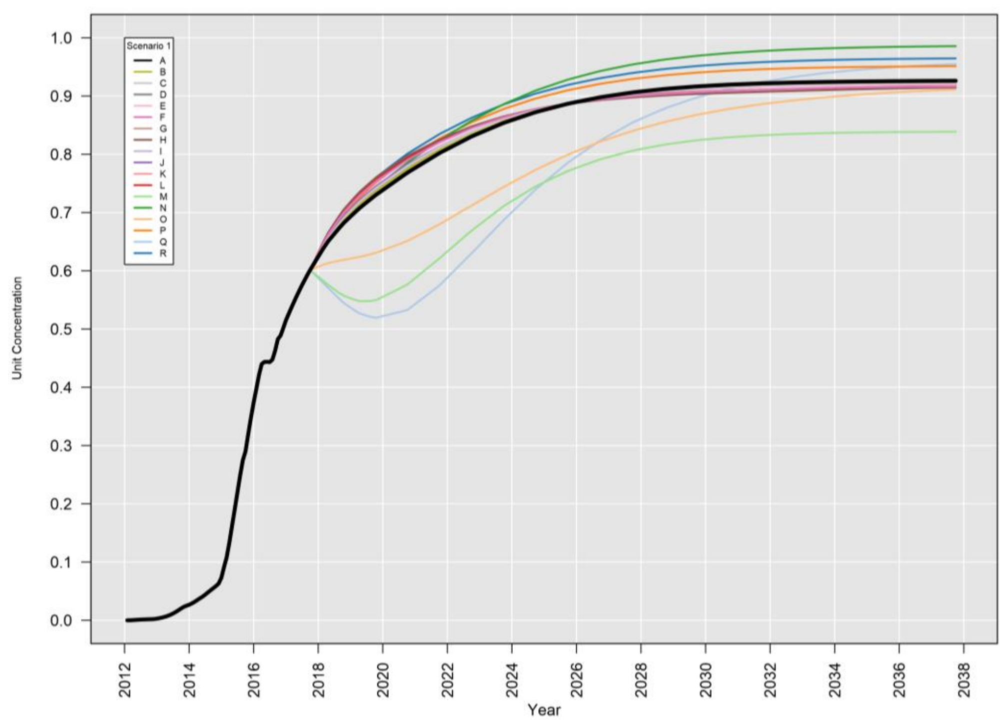

Figure 7-28. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW4

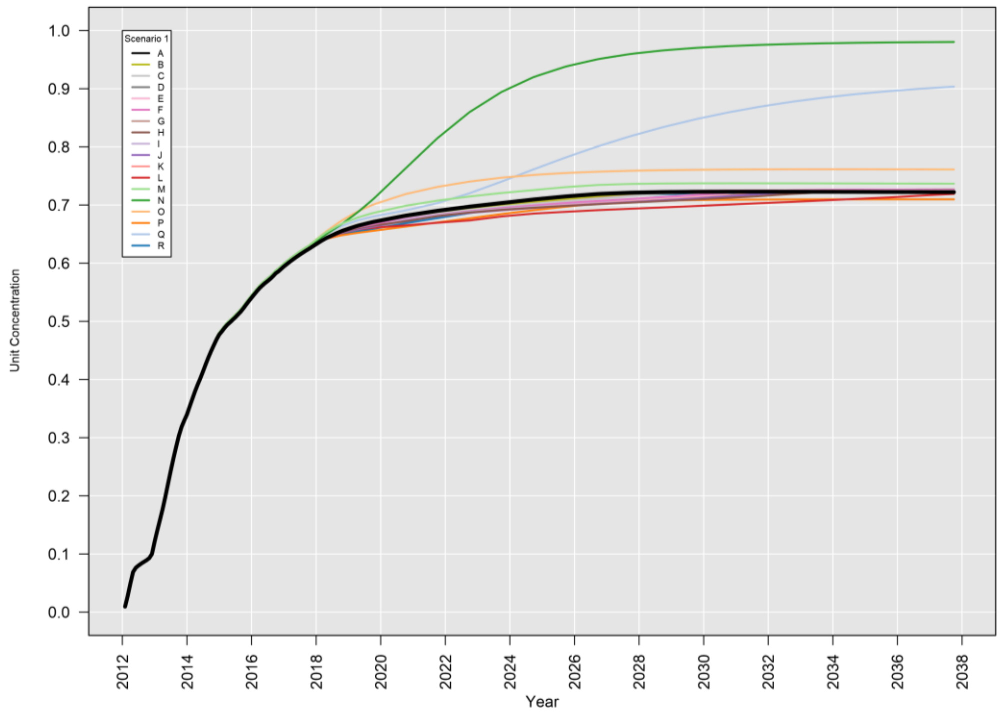

Figure 7-29. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW5

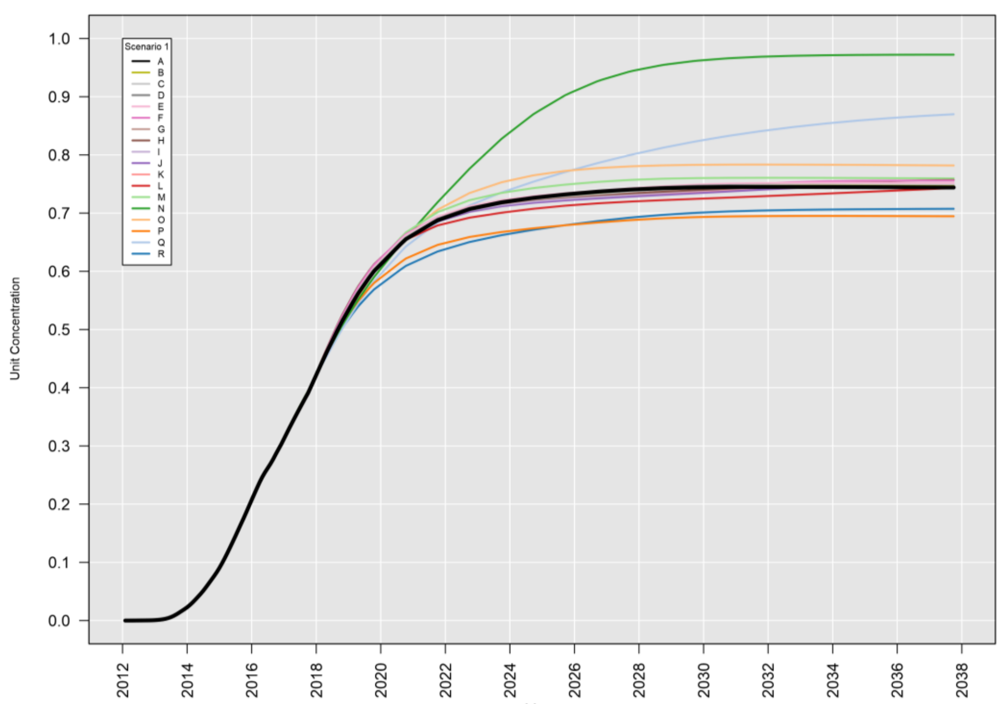

Figure 7-30. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW6

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

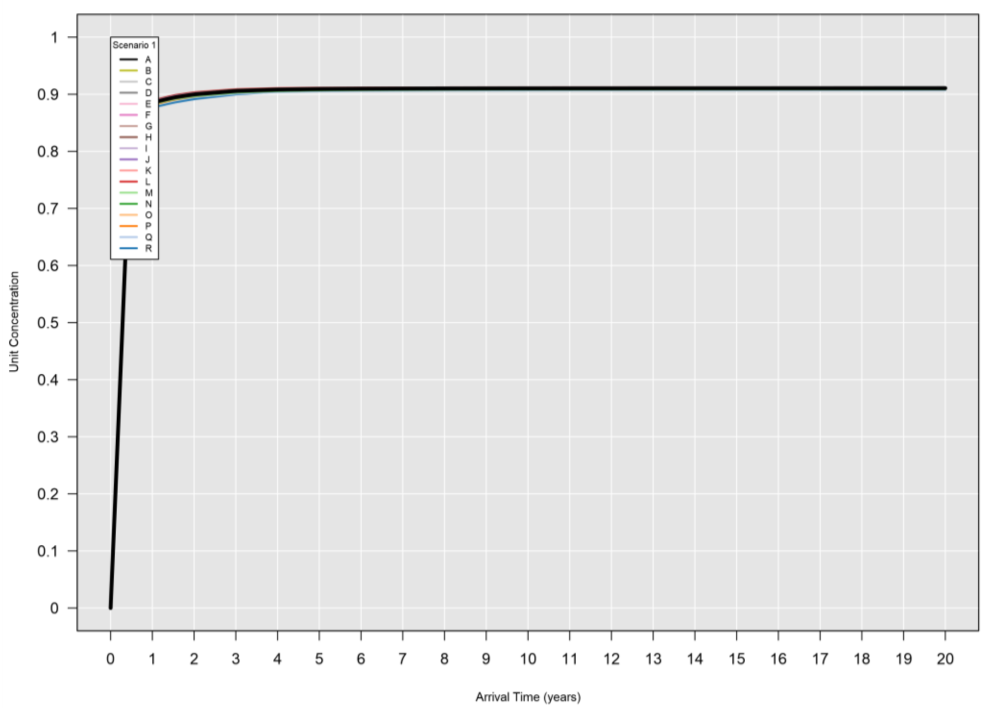

Figure 7-31. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW1

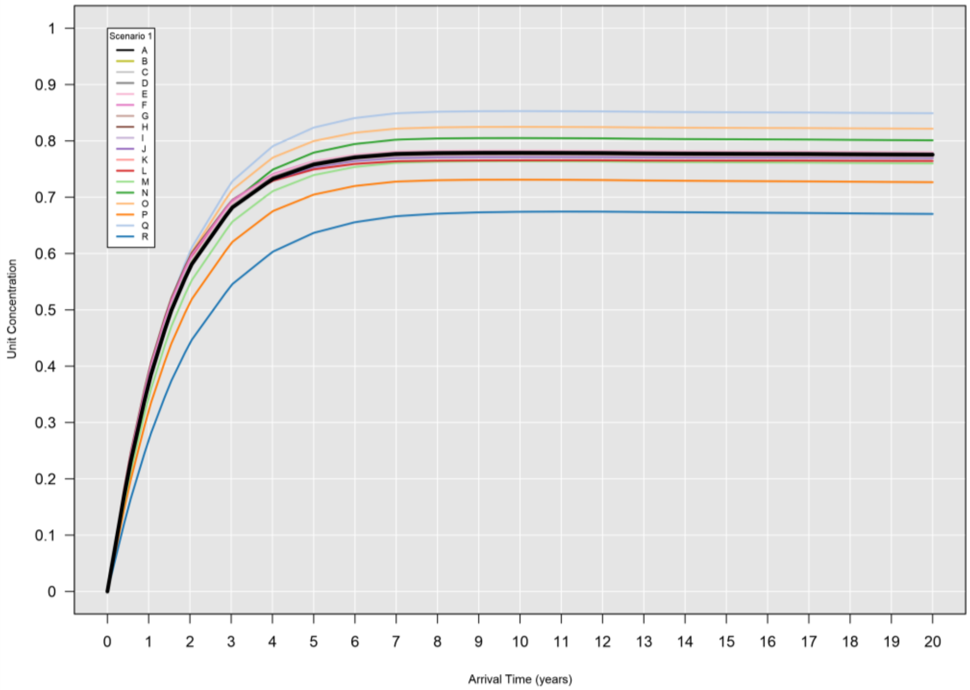

Figure 7-32. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW2

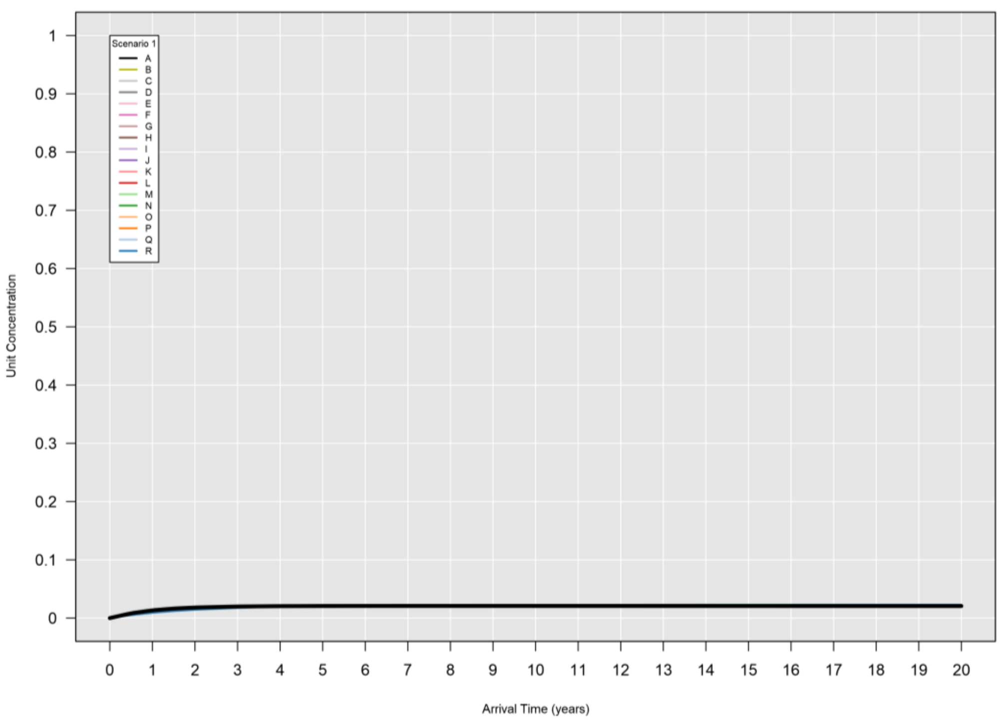

Figure 7-33. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW3

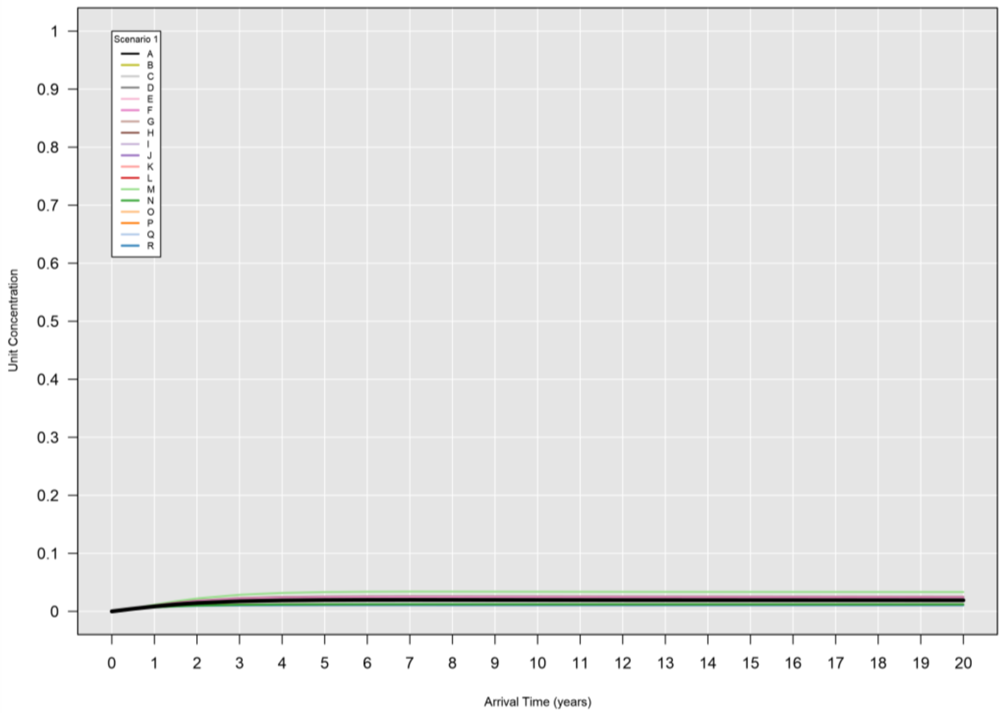

Figure 7-34. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW4

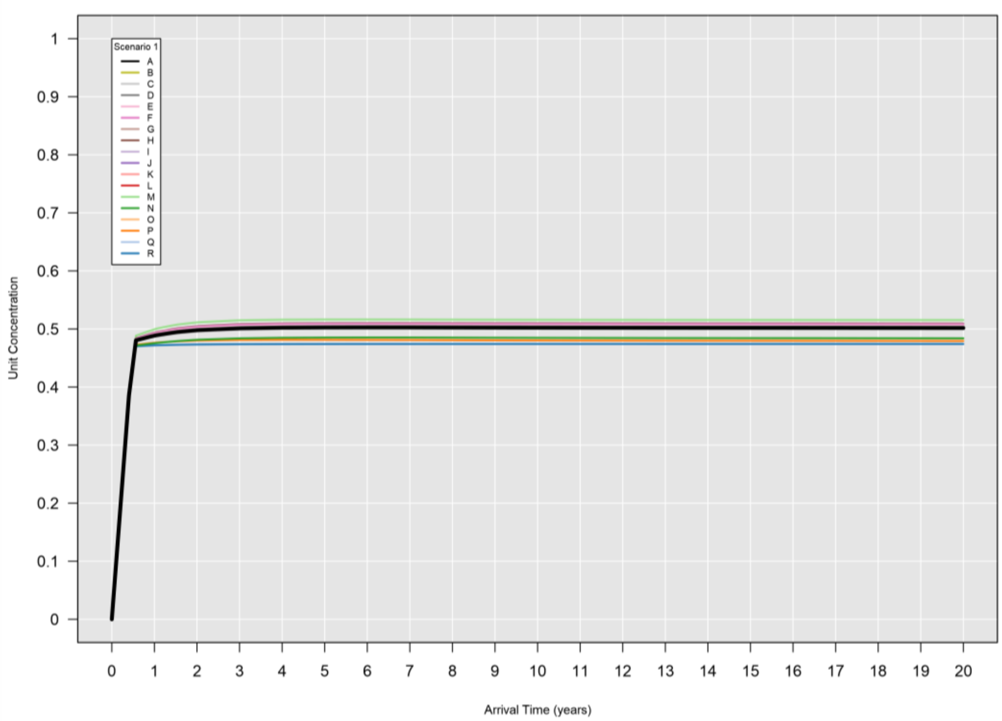

Figure 7-35. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW5

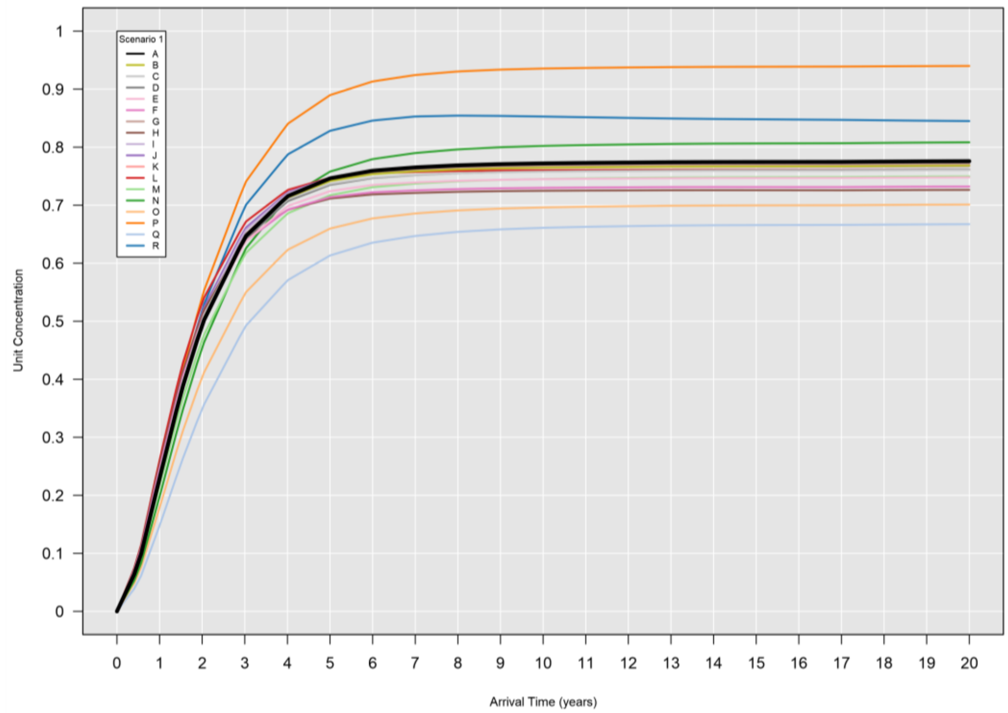

Figure 7-36. Release Concentration Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-4_PW6

The release concentration breakthrough curves indicate that the potential for detecting releases from the facility are minimally influenced by 200 West P&T system operations. Proposed downgradient wells WMA-4_PW1 and WMA-4_PW2 show minimal sensitivity to 200 West P&T system operating conditions, whereas WMA-4_PW6 shows some sensitivity. The wells generally are well-located for detecting releases from the facility to the water table. The release concentration breakthrough curves for WMA-4_PW5 indicate that the proposed upgradient well location is within the spread of the interpolated unit concentrations. The unit concentration reflects that the location of the upgradient well is within one of the CPGWM grid cells that represents the central Green Islands trench (in which the unit concentration of 1 was released). The unit concentration from this grid cell is interpolated as described above between the nodes of this grid cell and the upgradient grid cell, which has a simulated unit concentration near zero resulting in this well location being within an area of significant release unit concentration. The relative detectability maps (Figures 7-22 through 7-24), however, indicate that the well is upgradient of hypothetical releases. Table 7-4 shows the range of the release concentration breakthrough curves for the proposed wells for scenarios 1, 2, and 3.

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-4_PW1	1	0.907	0.912	0.911	0.882
	2	0.907	0.912	0.911	
WMA-4_PW2	1	0.670	0.849	0.775	0.746

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
	2	0.670	0.852	0.777	
WMA-4_PW3	1	0.020	0.023	0.021	0.012
	2	0.020	0.023	0.021	
WMA-4_PW4	1	0.011	0.033	0.019	0.015
	2	0.011	0.034	0.020	
WMA-4_PW5	1	0.474	0.515	0.501	0.242
	2	0.474	0.516	0.502	
WMA-4_PW6	1	0.667	0.940	0.776	0.680
	2	0.663	0.929	0.773	

The release concentration breakthrough curves for scenario 3 for the proposed wells are shown in Figure 7-37. The curves indicate that proposed wells WMA-4_PW1, WMA-4_PW2, and WMA-4_PW6 likely will be able to detect releases from the facility after cessation of P&T system operations as wells as during 200 West P&T system operations. Unit concentrations for the wells range from 0.68 to 0.88 for scenario 3.

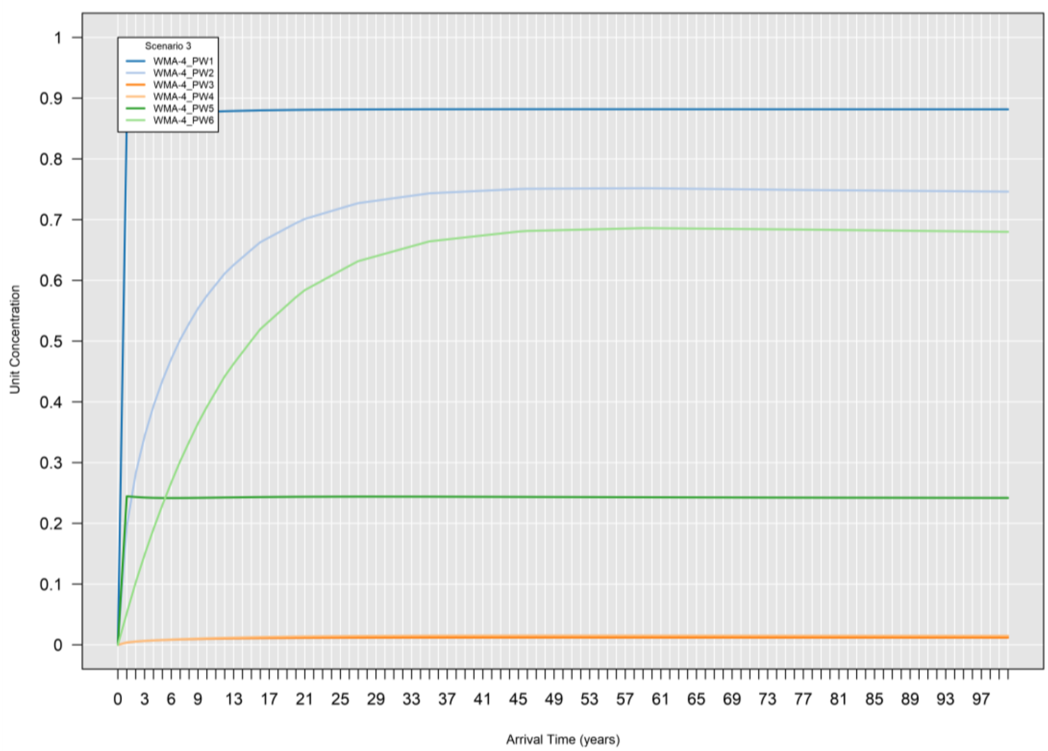

Figure 7-37. Release Concentration Breakthrough Curves, Scenario 3, Proposed Monitoring Wells

7.4 Modeling Conclusions

The proposed final status groundwater monitoring network for LLBG WMA-4 includes retaining existing downgradient wells 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, and 299-W15-224. Wells not included in the final status monitoring network are existing upgradient well, 299-W18-22, and existing downgradient well 299-W15-17. Those wells are deep wells that are not retained for the LLBG WMA-4 final status monitoring network. New monitoring wells (WMA-4_PW1, WMA-4_PW2, WMA-4_PW3, WMA-4_PW4, WMA-4_PW5, and WMA-4_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 wells WMA-4_PW3, WMA-4_PW4, and WMA-4_PW5, along with the eight downgradient groundwater monitoring wells, 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, 299-W15-224, WMA-4_PW1, WMA-4_PW2, and WMA-4_PW6 are shown to be in locations spanning the range of particle distribution as released from LLBG WMA-4. The well placement is suitable for detecting releases to the water table from LLBG WMA-4 under the evaluated range of conditions.

Figure 7-38 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.

The release concentration breakthrough curves for the recommended downgradient monitoring network wells indicate a range of dilution of approximately 6%[1] to 98%[2]. After cessation of the 200 West P&T system operations (scenario 3), this dilution range becomes approximately 12% to approximately 98%[3]. Additional discussion regarding each well is provided in Section 9.3.

[1] 6% dilution corresponds to a release unit concentration of approximately 0.94 at monitoring well WMA-4_PW6 for sub-scenario P of scenario 1 (Figure 7-36).

[2] 98% dilution corresponds to a release unit concentration of lapproximately 0.02 at monitoring well 299-W15-224 for sub-scenario R of scenario 1 (Figure 7-13).

[3] 12% to 98% dilution for scenario 3 corresponds to a release unit concentration of approximately 0.88 and of approximately 0.02 for wells WMA-4_PW1 and 299-W15-224, respectively (Figures 7-37 and 7-15).

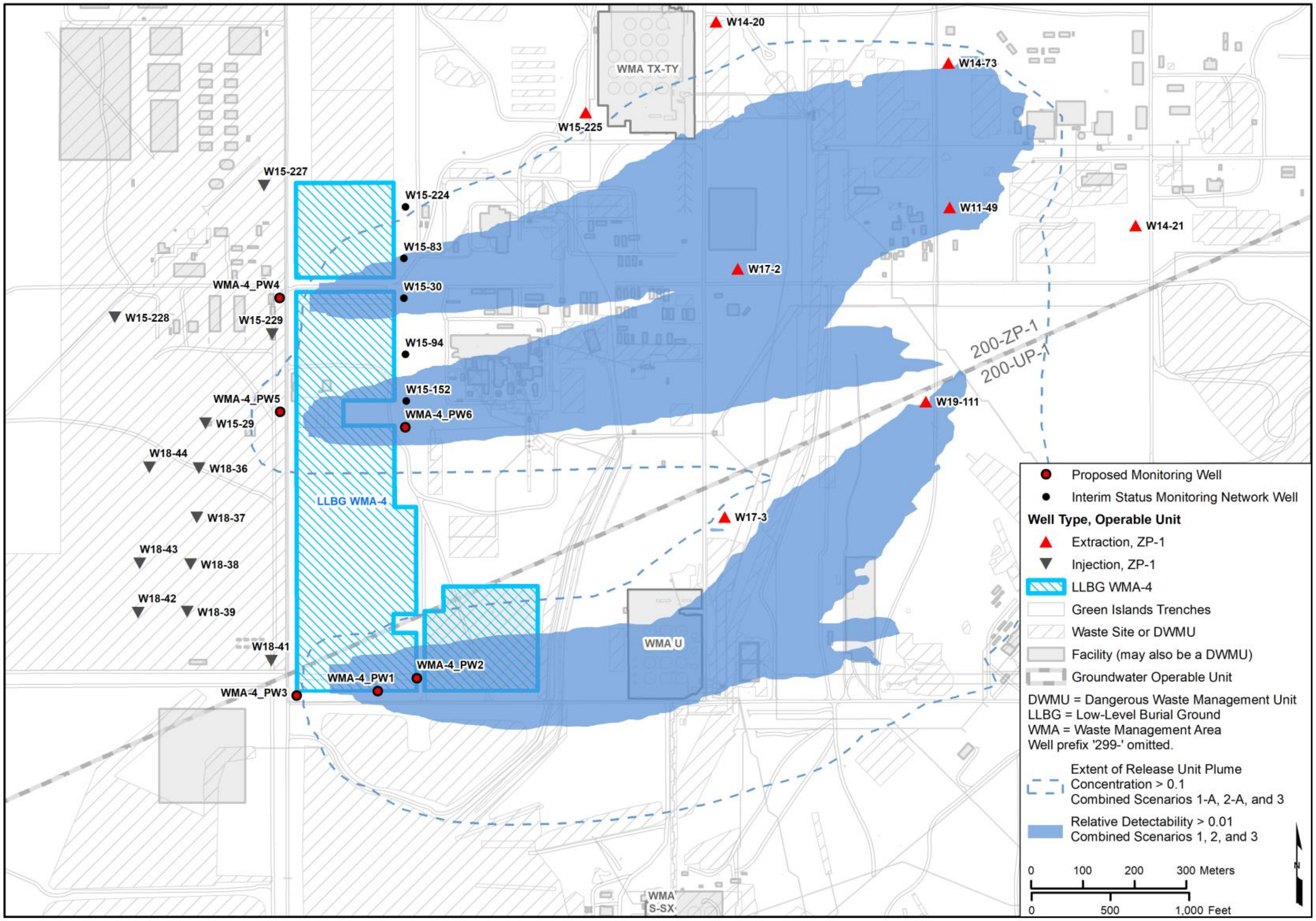

Figure 7-38. Proposed Final Status Groundwater Monitoring Network with Combined Relative Detectability and Release Unit Plume Results

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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-4, 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-4 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-4. 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 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-4 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 WMA-4 (Table 8-1). 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-4

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

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
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
3-Methylphenol (m-Cresol)	108-39-4

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
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
Cyclohexane	110-82-7

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
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 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

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

Table 8-1. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
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-4. Therefore, LLBG WMA-4 will be in detection monitoring under WAC 173-303-645(9) when LLBG WMA-4 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 eight downgradient wells proposed for the monitoring well network (existing wells 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, and 299-W15-224, and proposed wells WMA-4_PW1, WMA-4_PW2, and WMA-4_PW6) span the range of particle distribution as released from LLBG WMA-4. The well placement is suitable for detecting releases to the water table from LLBG WMA-4 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 as appropriate.

9.3 Proposed Groundwater Monitoring Network

The proposed groundwater monitoring network for LLBG WMA-4 consists of three background (upgradient) and eight point of compliance (downgradient) wells to monitor for releases to the water table from LLBG WMA-4 (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. 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 9.3.10 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-4 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), three background (upgradient) wells have been selected that would be representative of ambient conditions under the currently operating 200 West P&T remedy. They do 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)(h), 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, since 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-4 is discussed in Section 9.5.

Based on current groundwater flow direction to the east and predictions of future groundwater flow direction toward the east, 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).

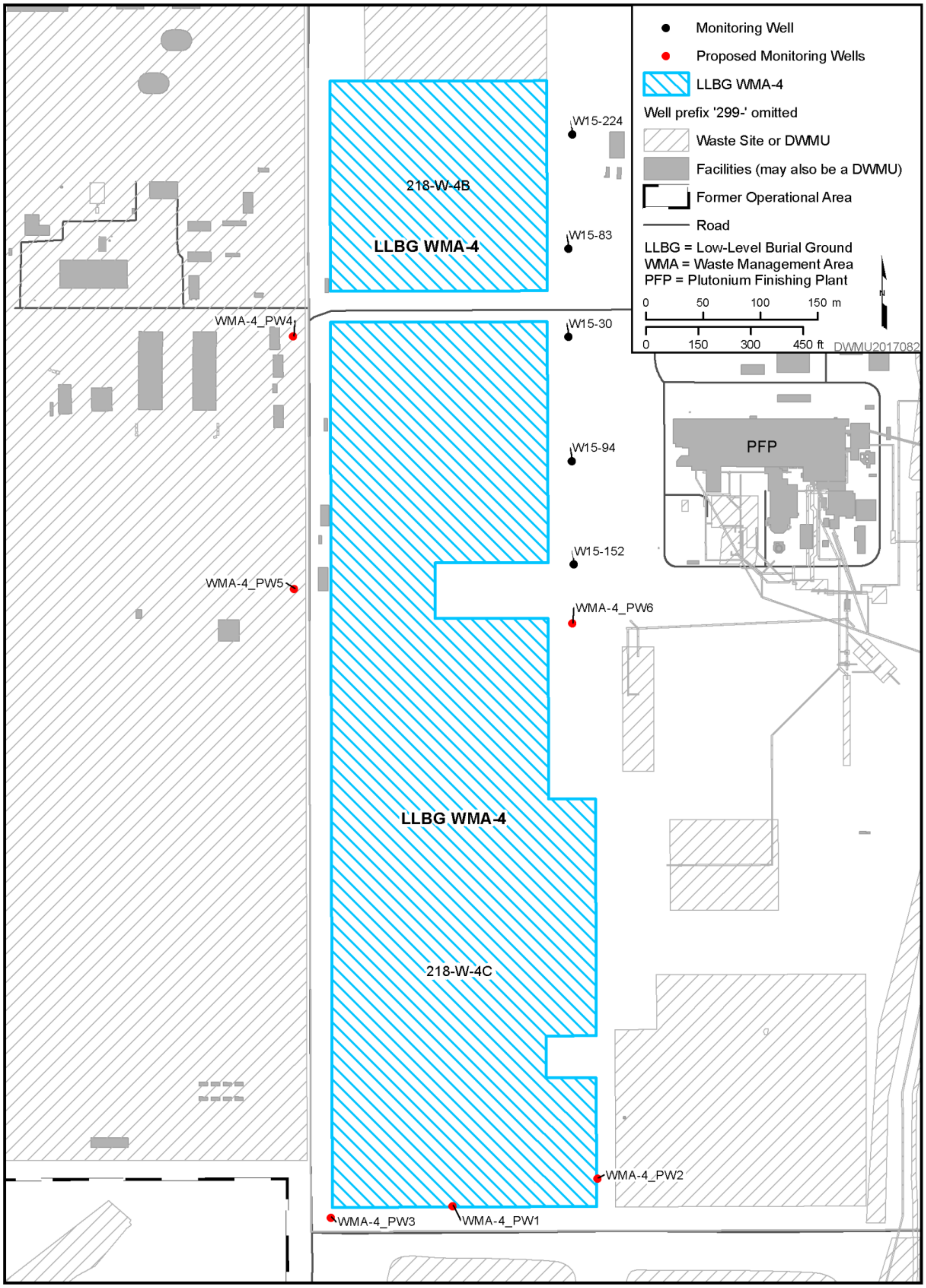

Figure 9-1. Proposed Final Status Groundwater Monitoring Network for LLBG WMA-4

Table 9-1. Attributes for Wells in the LLBG WMA-4 Groundwater Monitoring Network

Well Name	Completion Date	Northing[a] (m)	Easting[a] (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-W15-30	5/5/1995	135748.94	566304.62	210.13 (689.39)	135.21 (443.61)	74.06 (242.99)	4.61 (15.13)	7/28/2017
299-W15-83	9/21/2005	135826.24	566304.52	209.32 (686.76)	135.24 (443.7)	73.71 (241.84)	8.54 (28.02)	7/28/2017
299-W15-94	9/28/2005	135640.34	566307.58	209.86 (688.51)	135.08 (443.17)	74.33 (243.87)	8.28 (27.16)	7/28/2017
299-W15-152	9/28/2005	135550.00	566309.40	209.87 (688.55)	134.99 (442.87)	74.43 (244.19)	8.19 (26.86)	7/28/2017
299-W15-224	2/23/2006	135926.08	566307.89	209.19 (686.32)	135.23 (443.66)	73.09 (239.78)	9.33 (30.6)	7/28/2017
WMA-4_PW1	TBD	134988.53	566203.97	TBD	135.83 (445.64)[b]	71.36 (234.12)[b]	TBD	TBD
WMA-4_PW2	TBD	135012.60	566329.98	TBD	135.26 (443.77)[b]	73.86 (242.32)[b]	TBD	TBD
WMA-4_PW3	TBD	134978.69	566097.70	TBD	136.32 (447.24)[b]	68.08 (223.36)[b]	TBD	TBD
WMA-4_PW4	TBD	135749.31	566064.44	TBD	137.03 (449.57)[b]	76.3 (250.33)[b]	TBD	TBD
WMA-4_PW5	TBD	135528.62	566065.27	TBD	136.97 (449.38)[b]	75.85 (248.85)[b]	TBD	TBD
WMA-4_PW6	TBD	135498.50	566307.84	TBD	135.12 (443.31)[b]	74.46 (244.29)[b]	TBD	TBD

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

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

b. Water table elevation and water depths are estimates only and are based on projected surface and 2015 water table elevations at the proposed well locations utilizing Leapfrog® modeling software.

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.

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9.3.1 Groundwater Monitoring Well WMA-4_PW3

Groundwater monitoring well WMA-4_PW3 is a proposed background well to replace well 299-W18-21, which is going dry. If the well location is approved it will be constructed according to WAC 173-160. The proposed location for the well is upgradient of LLBG WMA-4. 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 particle-tracking calculations (Figures 7-19 through 7-21) indicate that this well will remain upgradient of LLBG WMA-4 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 92% for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.92 shown on the injection injected treated water dilution breakthrough curve in Figure 7-27).

9.3.2 Groundwater Monitoring Well WMA-4_PW4

Groundwater monitoring well WMA-4_PW4 is a proposed background well. If the well location is approved it will be constructed according to WAC 173-160. The proposed location for the well is upgradient of LLBG WMA-4. 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 particle-tracking calculations (Figures 7-19 through 7-21) indicate that this well will remain upgradient of LLBG WMA-4 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 93% for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.93 shown on the injection injected treated water dilution breakthrough curve in Figure 7-28).

9.3.3 Groundwater Monitoring Well WMA-4_PW5

Groundwater monitoring well WMA-4_PW5 is a proposed background well. If the well location is approved it will be constructed according to WAC 173-160. The proposed location for the well is upgradient of LLBG WMA-4. 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 particle-tracking calculations (Figures 7-19 through 7-21) indicate that this well will remain upgradient of LLBG WMA-4 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 72% for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.72 shown on the injection injected treated water dilution breakthrough curve in Figure 7-29).

9.3.4 Groundwater Monitoring Well 299-W15-30

Groundwater monitoring well 299-W15-30 is proposed as a point of compliance well. It was constructed in 1995 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for LLBG WMA-4. The well is downgradient of LLBG WMA-4 and is screened from elevation 142.8 m (468.6 ft) to elevation 130.6 m (428.6 ft) (Appendix E). Based on 2017 water elevation data, well 299-W15-30 is screened across the upper 4.61 m (15.13 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-northeast at this well (Figure 3-8); 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 transport calculations (Figures 7-16 through 7-18) and the results of particle-tracking calculations (Figures 7-19 through 7-21) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-22 through 7-24) indicate that this well is centrally located within of the detectable area for the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-9 and 7-15) indicate minimal dilution of the release concentration is expected at the well location. 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 38% (corresponding to a release unit concentration of approximately 0.62 shown in Figure 7-9) 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 7-2). 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.3.5 Groundwater Monitoring Well 299-W15-83

Groundwater monitoring well 299-W15-83 is proposed as a point of compliance well. It was constructed in 2005 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for LLBG WMA-4. The well is downgradient of LLBG WMA-4 and is screened from elevation 137.3 m (450.5 ft) to elevation 126.7 m (415.5 ft) (Appendix E). Based on 2017 water elevation data, well 299-W15-83 is screened across the upper 8.54 m (28.02 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-northeast at this well (Figure 3-8); 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 transport calculations (Figures 7-16 through 7-18) and the results of particle-tracking calculations (Figures 7-19 through 7-21) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-22 through 7-24) indicate that this well is located within the northern extent of the estimated area of detectability for scenarios 1 and 2 and located to the north, outside of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well (Figures 7-10 and 7-15) indicate some dilution of the release concentration is expected at the well location. 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 73% (corresponding to a release unit concentration of approximately 0.27 shown in Figure 7-10) 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 7-3). 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.3.6 Groundwater Monitoring Well 299-W15-94

Groundwater monitoring well 299-W15-94 is proposed as a point of compliance well. It was constructed in 2005 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for LLBG WMA-4. The well is downgradient of LLBG WMA-4 and is screened from elevation 137.5 m (451.0 ft) to elevation 126.8 m (416.0 ft) (Appendix E). Based on 2017 water elevation data, well 299-W15-94 is screened across the upper 8.28 m (27.16 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-northeast at this well (Figure 3-8); 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 transport calculations (Figures 7-16 through 7-18) and the results of particle-tracking calculations (Figures 7-19 through 7-21) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-22 through 7-24) indicate that this well is located within the northern extent of the estimated area of detectability for scenarios 1 and 2 and located outside of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well (Figures 7-11 and 7-15) indicate some dilution of the release concentration is expected at the well location. 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 44% (corresponding to a release unit concentration of approximately 0.56 shown in Figure 7-11) 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 78% 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 0.78 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 78%, 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.3.7 Groundwater Monitoring Well 299-W15-152

Groundwater monitoring well 299-W15-152 is proposed as a point of compliance well. It was constructed in 2005 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for LLBG WMA-4. The well is downgradient of LLBG WMA-4 and is screened from elevation 137.5 m (451.1 ft) to elevation 126.8 m (416.1 ft) (Appendix E). Based on 2017 water elevation data, well 299-W15-152 is screened across the upper 8.19 m (26.86 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-northeast at this well (Figure 3-8); 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 transport calculations (7-16 through 7-18) and the results of particle-tracking calculations (Figures 7-19 through 7-21) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-22 through 7-24) indicate that this well is centrally located within of the detectable area for the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-12 and 7-15) indicate some dilution of the release concentration is expected at the well location. 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 43% (corresponding to a release unit concentration of approximately 0.57 shown in Figure 7-12) 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 73% 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 0.73 shown on the injection injected treated water dilution breakthrough curve in Figure 7-5). This could result in further dilution of the release concentration by some amount up to but likely less than 73%, 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.3.8 Groundwater Monitoring Well 299-W15-224

Groundwater monitoring well 299-W15-224 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-4. The well is downgradient of LLBG WMA-4 and is screened from elevation 136.5 m (447.9 ft) to elevation 125.9 m (412.9 ft) (Appendix E). Based on 2017 water elevation data, well 299-W15-224 is screened across the upper 9.33 m (30.6 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 is predominantly to the east-northeast at this well (Figure 3-8); 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 transport calculations (Figures 7-16 through 7-18) and the results of particle-tracking calculations (Figures 7-19 through 7-21) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-22 through 7-24) indicate that this well is located to the north, outside of the extent of the estimated area of detectability for the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-13 and 7-15) indicate significant dilution of the release concentration is expected at the well location. 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 of approximately 92% (corresponding to a release unit concentration of approximately 0.08 shown in Figure 7-13) 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 92% 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 0.92 shown on the injection injected treated water dilution breakthrough curve in Figure 7-6). This could result in further dilution of the release concentration by some amount up to but likely less than 92%, 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.3.9 Groundwater Monitoring Well WMA-4_PW1

Groundwater monitoring well WMA-4_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-4. 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 7-22 through 7-24) indicate that this well is centrally located within of the detectable area for scenarios 1 and 2 and is located within the southern 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 (Figures 7-31 and 7-37) indicate minimal dilution of the release concentration is expected at the well location. 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 9% (corresponding to a release unit concentration of approximately 0.91 shown in Figure 7-31) 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 7-25). 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.3.10 Groundwater Monitoring Well WMA-4_PW2

Groundwater monitoring well WMA-4_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-4. 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 7-22 through 7-24) indicate that this well is centrally located within of the detectable area for the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-32 and 7-37) indicate minimal dilution of the release concentration is expected at the well location. 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 23% (corresponding to a release unit concentration of approximately 0.77 shown in Figure 7-32) 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 7-26). 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.3.11 Groundwater Monitoring Well WMA-4_PW6

Groundwater monitoring well WMA-4_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-4. 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 7-22 through 7-24) indicate that this well is centrally located within of the detectable area for the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-36 and 7-37) indicate minimal dilution of the release concentration is expected at the well location. 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 23% (corresponding to a release unit concentration of approximately 0.77 shown in Figure 7-36) 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 75% 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 0.75 shown on the injection injected treated water dilution breakthrough curve in Figure 7-30). This could result in further dilution of the release concentration by some amount up to but likely less than 75%, 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 should there be a release from LLBG WMA-4 under the range of operating conditions evaluated.

9.4 Constituent List and Frequency

The proposed LLBG WMA-4 final status groundwater monitoring network detailed in this report consists of three upgradient (WMA-4_PW3, WMA-4_PW4, and WMA-4_PW5) and eight downgradient (existing wells 299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, and 299-W15-224 and proposed wells WMA-4_PW1, WMA-4_PW2, and WMA-4_PW6) wells. The downgradient wells (299-W15-30, 299-W15-83, 299-W15-94, 299-W15-152, and 299-W15-224) are part of the LLBG WMA-4 interim status groundwater monitoring network (DOE/RL-2009-69, 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 groundwater impacts from potential dangerous waste releases at LLBG WMA-4.

Table 9-2 identifies the proposed monitoring network and sampling frequency for LLBG WMA-4. 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, specific conductance, dissolved oxygen, oxidation-reduction potential, 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-4.

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 Ecology Publication No. 97-407 Appendix 5 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.

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 9.5.

When the groundwater monitoring plan for LLBG WMA-4 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 9-2. Monitoring Wells and Sample Schedule for LLBG WMA-4

				Site-Specific Constituents to Detect Release from Regulated Unit[a]								Dangerous Wastes[b]	
Well Name	**Purpose**	**WAC Compliant**	**Water Level**	**Volatile Organic Compounds[c]**	**Semivolatile Organic Compounds[d]**	**Herbicides[e]**	**Formic acid**	**Formaldehyde**	**Hydrazine**	**Methanol**	**Nitroglycerine**	**Table 9-4**	**Field Parameters[f]**
WMA-4_PW3	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-4_PW4	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-4_PW5	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
299-W15-30	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
299-W15-83	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
299-W15-94	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
299-W15-152	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
299-W15-224	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-4_PW1	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-4_PW2	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q	Q/S
WMA-4_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

Table 9-2. Monitoring Wells and Sample Schedule for LLBG WMA-4

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

acetate, ethyl ether, ethyl methacrylate; ethyl methanesulfonate; ethylbenzene, isobutanol (isobutyl alcohol); isopropylbenzene; methacrylonitrile; methyl bromide (bromomethane); methyl chloride (chloromethane); methyl iodide (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-4

Waste Constituent	CAS Number
Dangerous Waste Constituents	
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

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
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
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

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
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
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

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
Methacrylonitrile	126-98-7
Methanol	67-56-1
Methapyrilene	91-80-5
Methyl bromide (Bromomethane)	74-83-9
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

Table 9-3. Proposed Groundwater Monitoring Constituents for LLBG WMA-4

Waste Constituent	CAS Number
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
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

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
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	--	--

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

Constituent	CAS Number	Constituent	CAS Number
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
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

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

Constituent	CAS Number	Constituent	CAS Number
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
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

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

Constituent	CAS Number	Constituent	CAS Number
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
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

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

Constituent	CAS Number	Constituent	CAS Number
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-4 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-4 include five existing and three new downgradient wells. Each of the three proposed background wells are new wells.

Given that each of the background wells and three 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 constituent in Table 9-4 at a quarterly frequency for 2 years. Quarterly monitoring will allow for 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 in Appendix H. In addition to 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(9)(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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Appendix A

Interim Status Data Summary

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A1 Introduction

Section 2.4 of the main document summarizes the groundwater monitoring history at Low-Level Burial Grounds (LLBG) Waste Management Area (WMA)-4. 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 January 2009 when LLBG WMA-4 was placed into a groundwater quality assessment monitoring program in accordance with 40 CFR 265.93(d), "Preparation, Evaluation, and Response." LLBG WMA-4 was monitored under a groundwater quality assessment program until later in 2009 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-4 through 2016 was compiled. Information from annual reporting documents and groundwater monitoring plans was utilized to compile a summary of wells in the LLBG WMA-4 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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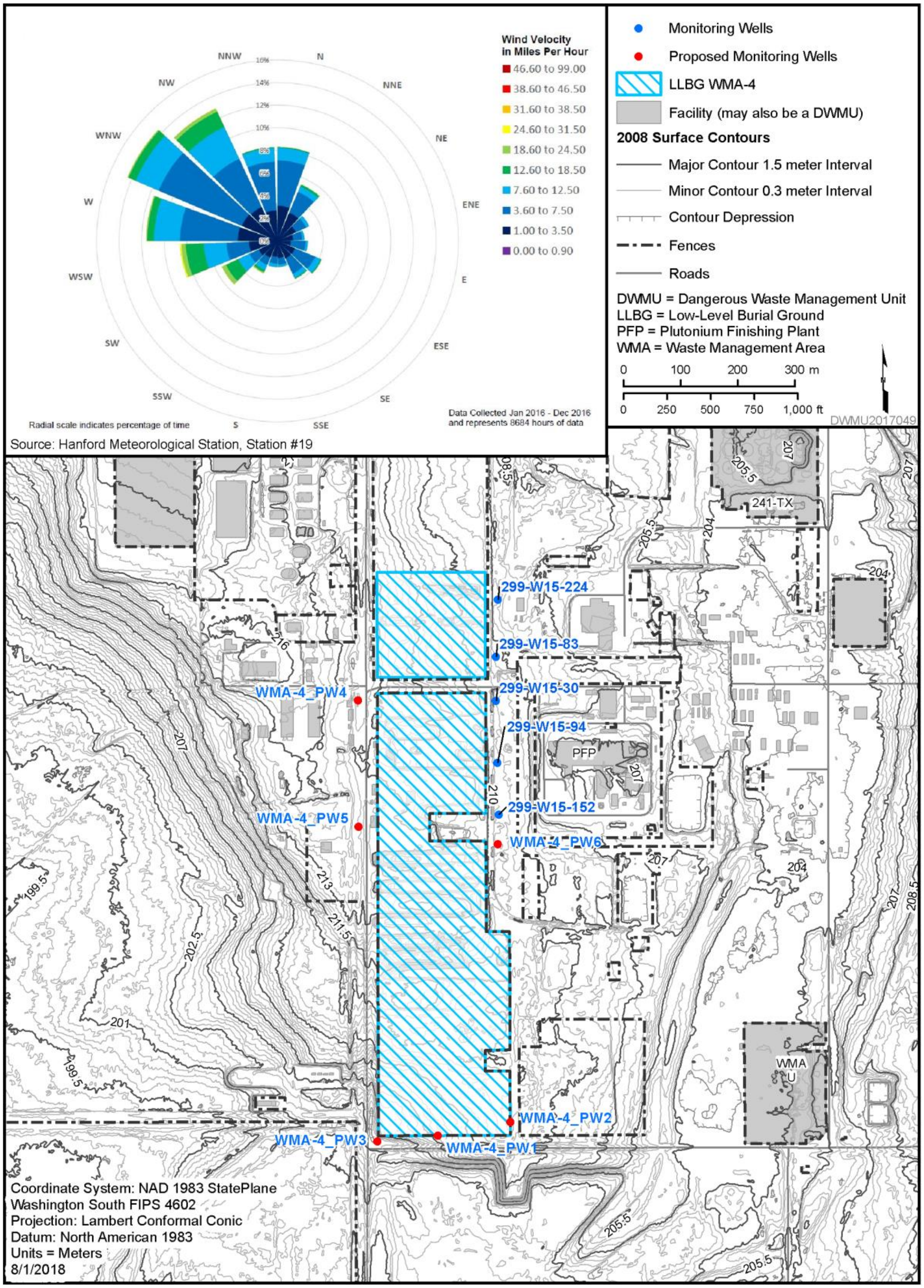

Figure C-1. Topographic Map

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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)-4. These plumes do not originate from LLBG WMA-4, but are regional plumes in the area of the unit.

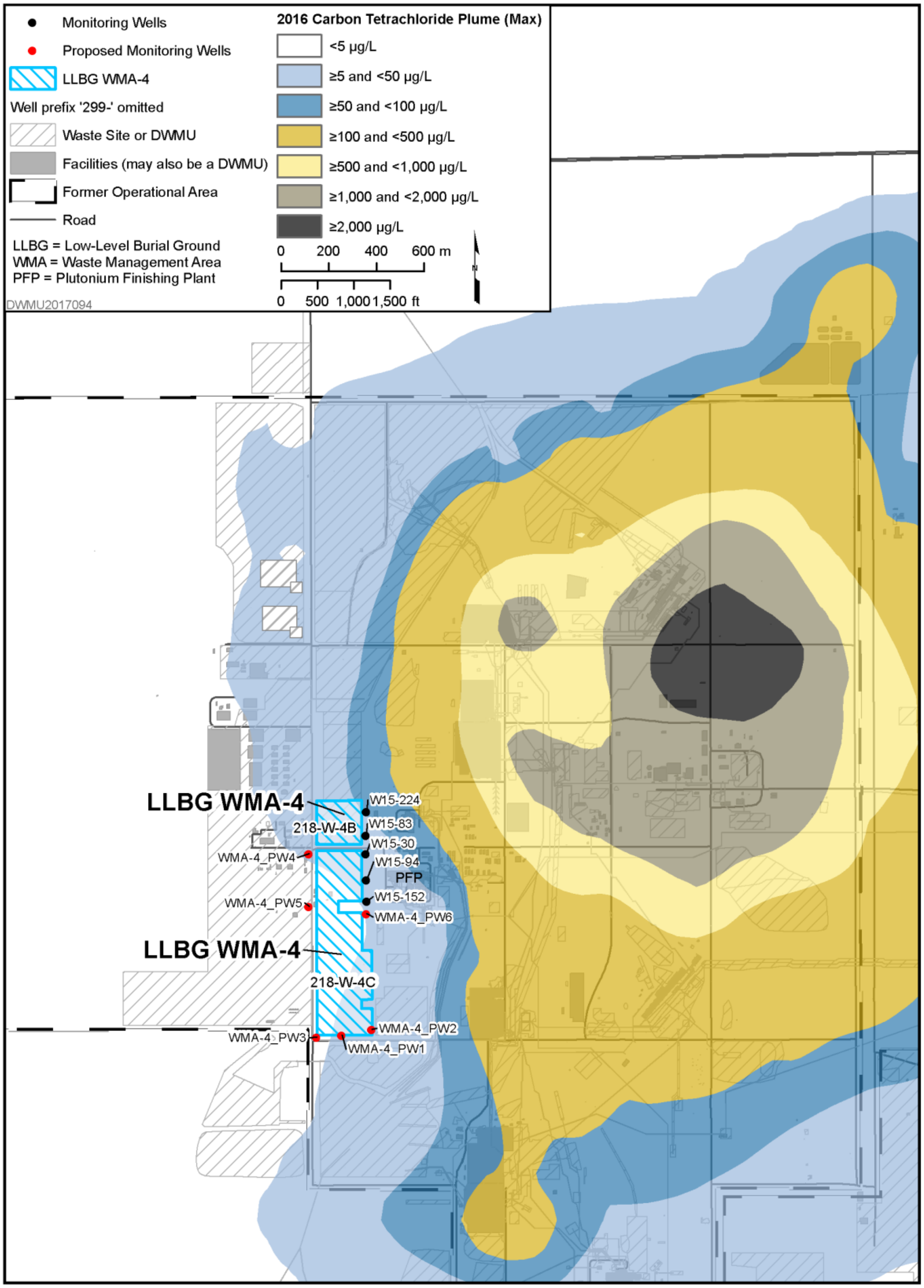

Figure D-1. Regional Carbon Tetrachloride Plume at LLBG WMA-4

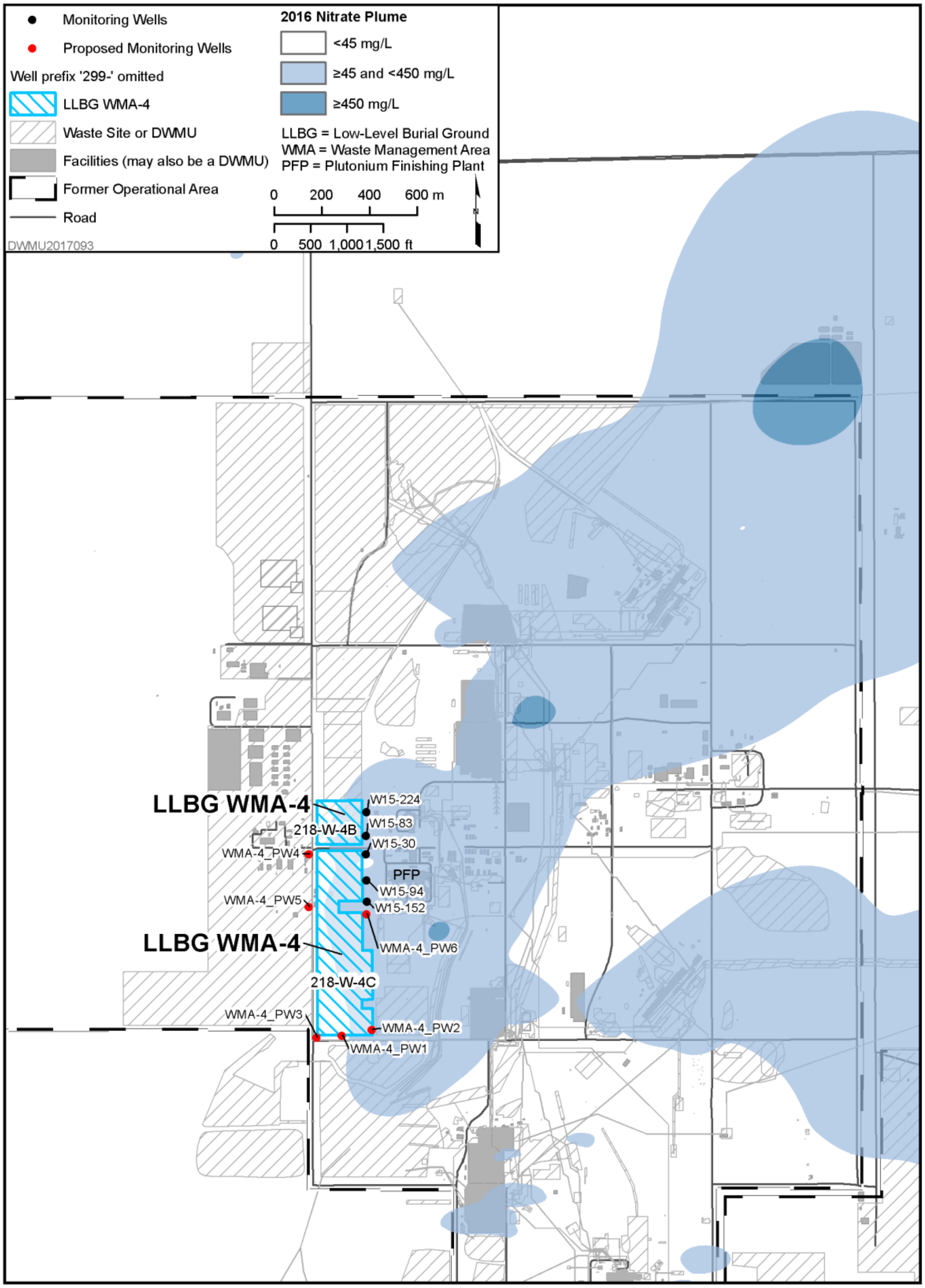

Figure D-2. Regional Nitrate Plume at LLBG WMA-4

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Appendix E

Well As-Built Diagrams and Proposed Well Design Information

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Contents

Figures

Tables

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E1 Introduction

This appendix provides the following information for the existing Low-Level Burial Grounds (LLBG) Waste Management Area (WMA)-4 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 through E-5 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-4 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-W15-30	TU	142.8 (468.5)	130.6 (428.48)	12.2 (40.0)	Rotary w/Sonic Assist
299-W15-83	TU	137.3 (450.46)	126.7 (415.68)	10.7 (35.0)	Becker Hammer
299-W15-94	TU	137.5 (451.12)	126.8 (416.01)	10.7 (35.0)	Becker Hammer
299-W15-152	TU	137.5 (451.12)	126.8 (416.01)	10.7 (35.0)	Becker Hammer
299-W15-224	TU	136.5 (447.83)	125.9 (413.06)	10.7 (35.0)	Becker Hammer

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

* Construction records for the wells are reported in standard units (ft), which are converted to metric elevatation (m) for this table. Due to rounding of the metric unit, the computed open interval length based on the top and bottom elevation differs slightly from the actual open interval length.

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-4 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-4_PW1	134988.53	566203.97	207.19 (679.76)	135.83 (445.64)	71.36 (234.12)	81.72 (268.12)	10.16 (4.00)	69.84 – 80.50 (229.12 – 264.12)	80.50 – 81.42 (264.12 – 267.12)
WMA-4_PW2	135012.60	566329.98	209.12 (686.09)	135.26 (443.77)	73.86 (242.32)	84.22 (276.32)	10.16 (4.00)	72.34 – 83.00 (237.32 – 272.32)	83.00 – 83.92 (272.32 – 275.32)
WMA-4_PW3	134978.69	566097.70	204.4 (670.60)	136.32 (447.24)	68.08 (223.36)	78.44 (257.36)	10.16 (4.00)	66.56 – 77.22 (218.36 – 253.36)	77.22 – 78.14 (253.36 – 256.36)
WMA-4_PW4	135749.31	566064.44	213.33 (699.90)	137.03 (449.57)	76.3 (250.33)	86.66 (284.33)	10.16 (4.00)	74.78 – 85.44 (245.33 – 280.33)	85.44 – 86.36 (280.33 – 283.33)
WMA-4_PW5	135528.62	566065.27	212.82 (698.23)	136.97 (449.38)	75.85 (248.85)	86.21 (282.85)	10.16 (4.00)	74.33 – 84.99 (243.85 – 278.85)	84.99 – 85.91 (278.85 – 281.85)
WMA-4_PW6	135498.50	566307.84	209.96 (688.85)	135.12 (443.31)	74.84 (245.54)	85.2 (279.54)	10.16 (4.00)	73.32 – 83.98 (240.54 – 275.54)	83.98 – 84.9 (275.54 – 278.54)

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 CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Sonic Assist	Sample Method:	Grab/Split Spoon	WELL NUMBER:	299-W15-30 B2410 TEMPORARY WELL NO: None
Drilling Fluid Used:	Air	Additives Used:	None	Coordinates: N	Not documented
Driller's Name:	B. Smith	WA State Lic Nr:	Not Available	Coordinates: E	Not documented
Drilling Company:	Water Development Corp.	Company Location:	Richland, WA	Start Card #:	Not Available
Date Started:	27Apr95	Date Completed:	05May95	Elevation Ground Surface:	

Depth to Water: **221.8 ft 03May95**
(Ground surface)

Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: **11.2 ft.**

Type of Surface Seal: **4x4 Concrete Pad**

GENERALIZED STRATIGRAPHY **Geologist's Log**

0 - 52 ft : Sand

52 - 68 ft : Sand - Hanford

68 - 89 ft : Gravelly Sand

89 - 135 ft : Gravel w/local sand and gravelly sand

135 - 137 ft : Sandy Silty Gravel

137 - 169 ft : Silty Gravelly Sand - highly calcareous

169 - 224 ft : Silty Sandy Gravels

224 - 234 ft : Silty Sandy Gravels

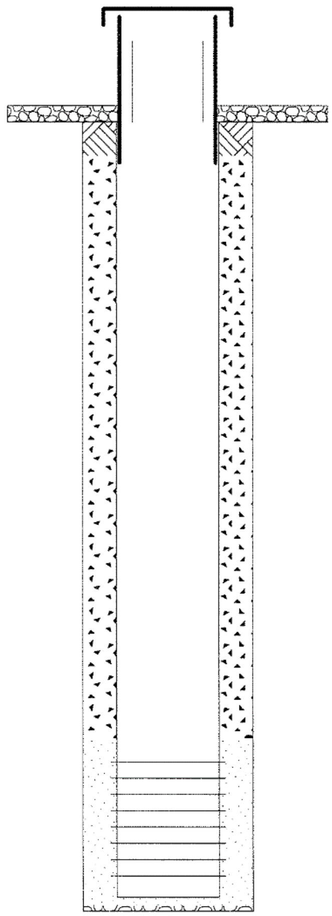
234 - 244 ft : Slightly Silty sandy Gravel

244 - 250 ft : Silty Sandy Gravels

250 - 257 ft : Slightly Silty sandy Gravel

257 - 267 ft : Silty Sandy Gravels

267 - 268.3 ft : Silty Sandy Gravels



268.3 ft : Borehole drilled depth

0 - 268.3 ft : 12.75-in. 11-3/4" Csg. w/12-3/4" shoe

Fill

0 - 11.2 ft : 12.75-inch hole

11.2 - 207.54 ft : 12.75-inch hole

207.54 - 210.54 ft : 12.75-inch hole

210.54 - 263.53 ft : 12.75-inch hole 10-20 Silica Sand

263.53 - 266.36 ft : 12.75-inch hole 10-20 Silica Sand

266.36 - 268.3 ft : 12.75-inch hole

Casing

0 - 218.08 ft : 8 inch 8-5/8" Carbon Steel Thd. Perm. Csg.

258 - 263 ft : 8 inch 8-5/8" SS Thd. Perm. Csg.

263 - 263.53 ft : 8 inch 8-5/8" SS Thd. End Cap

Screen

218.08 - 258 ft : 8 inch .020 Slot SS Wire Wrap (8" pipe size)

Drawing By: **JEA**
Reference: **Hanford Wells**
Revision: **1**
Revision Date: **10Jul01**
Print Date: **10Jul01**

Report Form: WELLS Project File: WELLS.GPJ

Figure E-1. Well 299-W15-30 Construction and Completion Summary

0535792

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W15-30

WELL DESIGNATION	:	**299-W15-30**
CERCLA UNIT	:	**ZP-1 Pump & Treat**
RCRA FACILITY	:	**Not Applicable**
DEPTH DRILLED (GS)	:	**268.3 ft**
MEASURED DEPTH (GS)	:	**268.3 ft. Btm. of hole - 263.53 ft. Btm. of well 03May95**
AVAILABLE LOGS	:	**Geologist**
DATE EVALUATED	:	**Not applicable**
EVAL RECOMMENDATION	:	**Not applicable**
LISTED USE	:	**Data not available**
CURRENT USER	:	**BHI 200 West (ZP-1) Pump & Treat**
PUMP TYPE	:	**Data not available**
MAINTENANCE	:	**Data not available**
COMMENTS	:	**Drill & Drive Sonic Assist 11-3/4" Carbon Steel Temp. Csg. Well was drilled with <2000 ft./min. bailing vel.**
TV SCAN COMMENTS	:	**Not Applicable**

Report Form: WELLS Project File: WELLS.GPJ

Drawing By:	**JEA**
Reference:	**Hanford Wells**
Revision:	**1**
Revision Date:	**10Jul01**
Print Date:	**10Jul01**

Figure E-1. Well 299-W15-30 Construction and Completion Summary (continued)

WELL SUMMARY SHEET

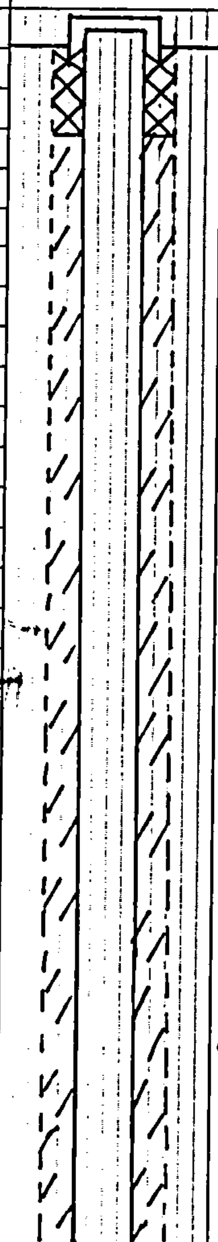
Start Date: 8/9/05	Page 1 of 2
Finish Date: 9/21/05	

Well ID: C4683		Well Name: 299-W15-83	
Location: NW of PFP		Project: CY 05 RCRA Monitoring Wells	
Prepared By: Bjorn Helgeson	Date: 8-17-05	Reviewed By: L.D. Walker	Date: 10/3/05
Signature: [signature]		Signature: [signature]	

CONSTRUCTION DATA

Description
6-IN DIAMETER PROTECTIVE S.S. CASING SET ABOVE THE 4-IN CASING
4-IN ID SCHEDULE 5, S.S. 304L WELL CASING 1.17' → 236.60'
4-IN ID ~~SCHEDULE~~ LOW 5, S.S. 304L WELL SCREEN 236.60 → 271.60' → 20 Slot (0.020")
4-IN ID SCHEDULE 5, S.S. 304L SUMP 271.60' → ~~273.00~~ 274.58
TEMPORARY CASING (9"x6" DUAL WALL) ALL REMOVED FROM BOREHOLE
PORTLAND CEMENT GROUT: 0' → 11'
GRANULAR BENTONITE: 11' → 219.6'
1/4" BENTONITE PELLETS: 219.6' → 226.5'
10-20 MESH COLORADO SILICA SAND: 226.5' → 277.3'
* ALL DEPTHS IN FEET BELOW GROUND SURFACE

Diagram:



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 25, 50, 75, 100, 125 (150 crossed out)

Lithologic Description
0-5' no recovery
5'→8': sand
8'→24': sandy Gravel
24'→29' Gravelly sand
29'→38' silty sand
38'→63' Sand
63'→79' slightly silty sand
79'→84' Silty Sandy Gravel
84'→98' Sandy Gravel
98'→136' Gravel
136'→140' silty sandy gravel
140'→145' sand

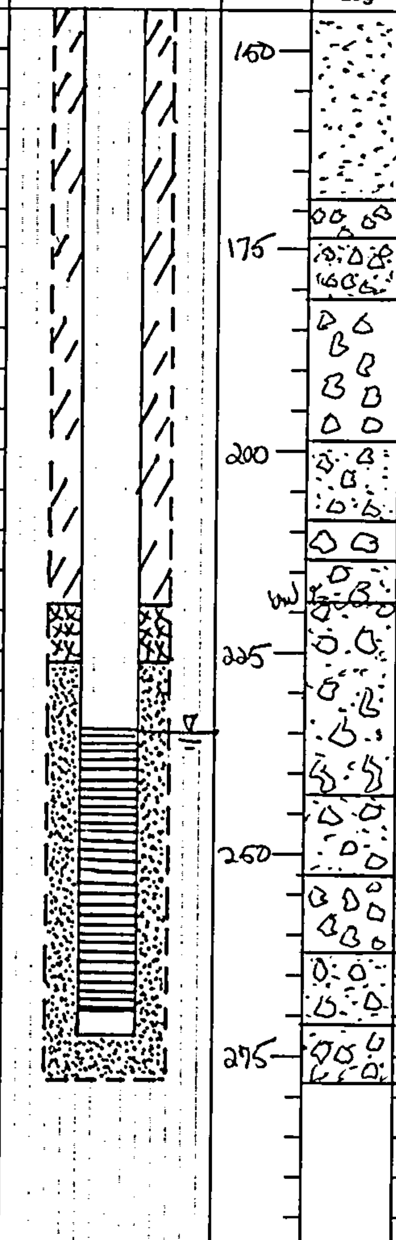
A-6003-643 (03/03)

Figure E-2. Well 299-W15-83 Construction and Completion Summary

WELL SUMMARY SHEET

Start Date: 8/9/05	Page 2 of 2
Finish Date: 9/21/05	
Well ID: C 4683	Well Name: 299-W15-83
Location: NW of PFP	Project: CY 05 RCRA Monitoring Wells
Prepared By: Brian Harrison, Date: 8-17-05	Reviewed By: L.D. Walker, Date: 10/3/05
Signature: B. Harrison	Signature: L.D. Walker

CONSTRUCTION DATA / **GEOLOGIC/HYDROLOGIC DATA**



Depth in Feet	Lithologic Description
160	145'→147' Gravel Layer
	147'→169' Sand
175	169'→174' Gravel
	174'→183' Gravelly Sand
	183'→199' Gravel
200	199'→209' Sandy Gravel
	209'→214' Gravel
WL	
225	214'→243' Sandy Gravel
	W.L. = 236.5' bgs (8/15/05)
250	243'→253' Sandy Gravel
	253'→263 Gravel
	263'→271' Sandy Gravel
275	271→278.4' Sandy Gravel
	TD = 278.4' bgs

A-6003-643 (03/03)

Figure E-2. Well 299-W15-83 Construction and Completion Summary (continued)

WELL SUMMARY SHEET

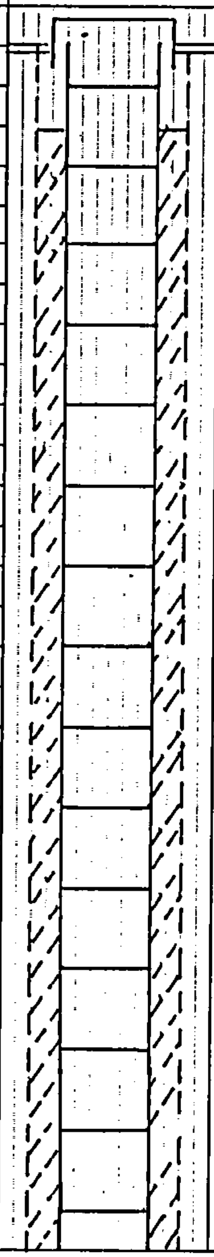
Start Date: 9/19/05	Page 1 of 2
Finish Date: 9/28/05	

Well ID: C4684	Well Name: 299-W15-94
Location: West of PFP	Project: FY05 PFP Groundwater monitoring Wells
Prepared By: Jeffrey Weiss — Date: 9/28/05	Reviewed By: L. D. Walker — Date: 10/4/05
Signature: Jeffy Wk	Signature: LD Walker

CONSTRUCTION DATA

Description
6" cement pad with 3.5" OD Post at corners
Portland Cement 0 → 10.8'
6" ID SS protective casing with 1" locking hasp 2.45' above pad
4" casing 1.03' below 6"
Bentonite Crumbles 10.8 → 221.6
4" ID SS 304 sch5 casing 2.0 → 236.1

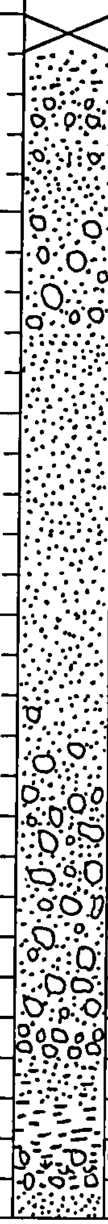
Diagram:



Depth in Feet: 0, 25, 50, 75, 100, 125

GEOLOGIC/HYDROLOGIC DATA

Graphic Log:



Lithologic Description
0-5' No recovery
5-10' SLIGHTLY SILTY SAND
10-15' SANDY GRAVEL
15-20' GRAVELY SAND
20-25' SAND
25-40' SANDY GRAVEL
40-85' SAND
85-95' GRAVELY SAND
95-125' SANDY GRAVEL
125-130' GRAVEL
130-135' SILTY SAND
135-142' SILT
142-146' SILTY GRAVEL
146-150' SAND

A-6003-643 (03/03)

Figure E-3. Well 299-W15-94 Construction and Completion Summary

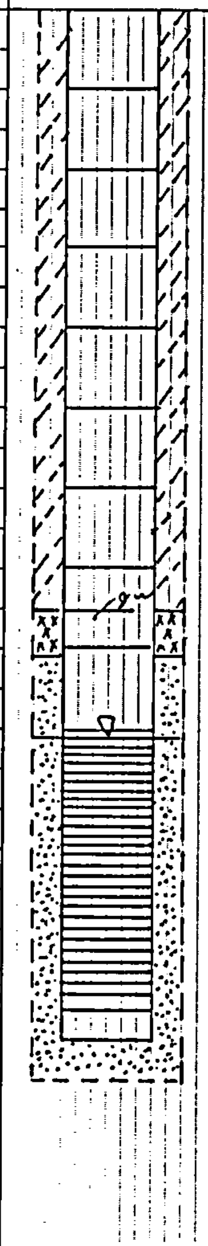
WELL SUMMARY SHEET

Start Date: 9/19/05	Finish Date: 9/28/05	Page 2 of 2
Well ID: C4684	Well Name: 299-W15-94	
Location: West of PFP	Project: FY05 PFP Groundwater Monitoring Wells	
Prepared By: Jeffrey Weiss, Date: 9/28/05	Reviewed By: L.D. Walker, Date: 10/4/05	
Signature: Jeffrey Weiss	Signature: LD Walker	

CONSTRUCTION DATA

Description
1/4" coated bentonite pellets 221.6 → 226.3
4" ID SS 304; 20 slot (0.02") screen 236.1 → 271.1
4" ID SS 304 sch 5 sump 271.1 → 274.1
10-20 mesh Colorado silica sand 226.3' → 278'
All depths are in feet below ground surface
All temporary casing removed from ground

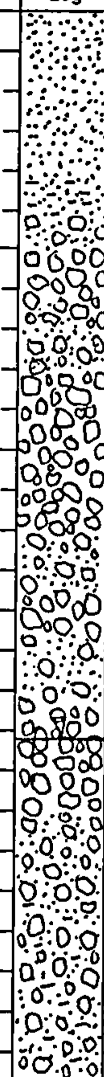
Diagram:



Depth in Feet: 150, 175, 200, 225, 250, 275

GEOLOGIC/HYDROLOGIC DATA

Graphic Log:



Lithologic Description
150'-165' SAND
160'-2" silt layer
165'-170' SILTY SAND
170'-175' GRAVELY SAND
175'-180' GRAVEL
180'-185' SANDY GRAVEL
185'-210' GRAVEL
210'-215' SANDY GRAVEL
215'-223' GRAVEL
223'-230' SANDY GRAVEL
230'-245' GRAVEL
Static water 237.75' (9/27/05)
245'-255' SANDY GRAVEL
255'-278' SILTY SANDY GRAVEL
278' Total depth drilled

A-6003-643 (03/03)

Figure E-3. Well 299-W15-94 Construction and Completion Summary (continued)

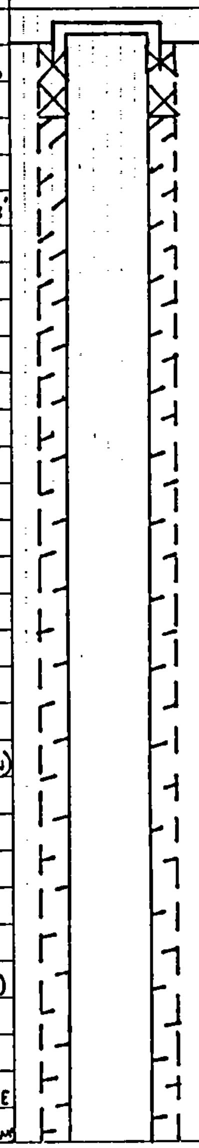
WELL SUMMARY SHEET	Start Date: 9-15-05 / Finish Date: 9-28-05	Page 1 of 3

Well ID: C4685		Well Name: 299-W15-152	
Location: West of PFP		Project: FY05 PFP Monitoring Well	
Prepared By: Bjorn Helgeson	Date: 9-28-05	Reviewed By: L. D. Walker	Date: 10/3/05
Signature: [signature]		Signature: [signature]	

CONSTRUCTION DATA

Description
6-in Diameter Protective SS Casing set 2.45' above ground
4-in ID Schedule 5, SS 304L Well Casing 1.51' → 236.03'
Screen (0.02" slot) 236.03' → 271.03'
Sump 271.03' → 274.00'
Temporary 9"x6" Oval Wall Casing 0' → 358.3'
Portland Cement Grout: 0' – 10.2'
Granular Bentonite: 10.2' – 227.1'
1/4" Coated Bentonite Pellets: 227.1' – 232.1'
Colorado Silica Sand (10-20 mesh) 232.1' – 279.8'
1/4" Coated Bentonite Pellets: 279.8' – 285.2'
Colorado Silica Sand (10-20 mesh) 285.2' – 358.3'
* All depths in ft below ground surface
All temporary casing removed from ground

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 25, 50, 75, 100, 125

Graphic Log

Lithologic Description
0-5': No Recovery
5-9': Sand
9'-15': Sandy Gravel
15'-20: Sandy Gravel
20'-30': Sandy Gravel
30-36': Sand
36-40': Sand
40-43': Gravelly Sand
43-69': Sand
69-72.5': Gravelly Sand
72.5-85': Sand
85-105': Sand
105-109': Slightly Silty Sand
110-119': Sand
119-127': Gravelly Sand
127-130': Silty Sandy Gravel
130-142': Silty Gravel
142-148': Gravelly Silty Sand
148'-170': Sand

A-6003-643 (03/03)

Figure E-4. Well 299-W15-152 Construction and Completion Summary

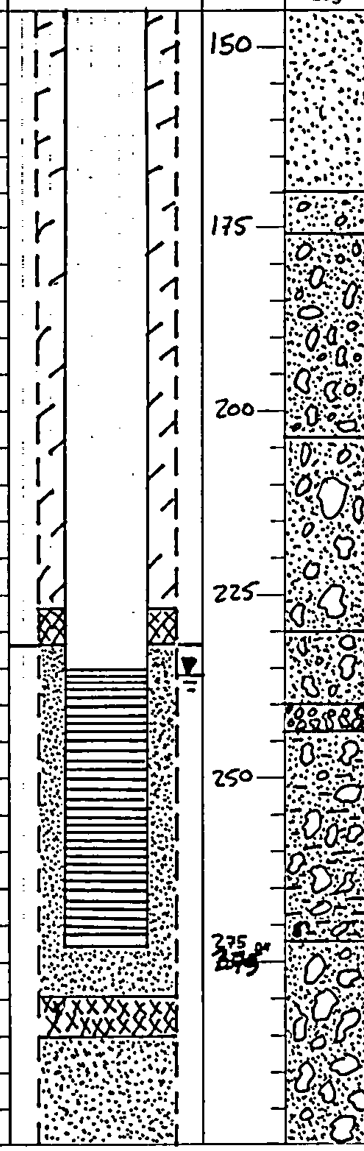
WELL SUMMARY SHEET

Start Date: 9-15-05	Page 2 of 3
Finish Date: 9-28-05	

Well ID: C4685	Well Name: 299-W15-152
Location: West of PFP	Project: FY05 PFP Monitoring Well
Prepared By: Bjorn Helgeson — Date: 9-28-05	Reviewed By: L. D. Walker — Date: 10-3-05
Signature: [signature]	Signature: [signature]

CONSTRUCTION DATA / **GEOLOGIC/HYDROLOGIC DATA**

Description	Diagram	Depth in Feet	Graphic Log	Lithologic Description



Lithologic Description:

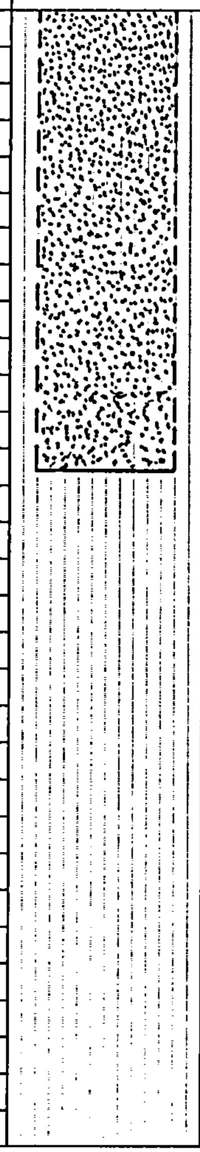
- 148-170': Sand
- 170-176': Gravelly Sand
- 176-204': Sandy Gravel
- 204-230': Sandy Gravel
- W.L. = 237.3' bgs
- 230-240': Sandy Gravel
- 240-244': Gravel
- 244-273': Silty Sandy Gravel
- 273-313': Sandy Gravel

A-6003-643 (03/03)

Figure E-4. Well 299-W15-152 Construction and Completion Summary (continued)

WELL SUMMARY SHEET		Start Date: 9-15-05 Finish Date: 9-28-05	Page 3 of 3
Well ID: C4685		Well Name: 299-W15-152	
Location: West of PFP		Project: FY05 PFP Monitoring Well	
Prepared By: Bjorn Helgeson	Date: 9-28-05	Reviewed By: L.D. Walker	Date: 10/3/05
Signature: Bjorn Helgeson		Signature: LD Walker	

CONSTRUCTION DATA — Description | Diagram



Depth in Feet: 300, 325, 350, 375

GEOLOGIC/HYDROLOGIC DATA — Graphic Log | Lithologic Description

Lithologic Description
273-313': Sandy Gravel
313-332': Gravelly Sand
332-347': Sandy Gravel
347-349': Sandy Gravel
349-353': Sand
353-358.3': Sandy Gravel
T.D. = 358.3' bgs

A-6003-643 (03/03)

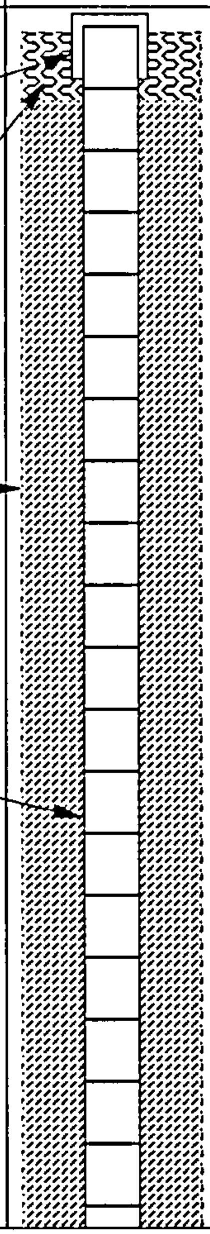
Figure E-4. Well 299-W15-152 Construction and Completion Summary (continued)

WELL SUMMARY SHEET		Start Date: 2/08/2006 Finish Date: 2/23/2006	Page 1 of 2
Well ID: C4986		Well Name: 299-W15-224	
Location: West of 200-ZP-1 Pump and Treat Facility		Project: CY06 LLBG Monitoring Wells	
Prepared By: Bjorn Helgeson	Date: 2/24/06	Reviewed By: L.D. Walker	Date: 4/6/06
Signature: [signature] for B. Helgeson		Signature: [signature]	

CONSTRUCTION DATA

Description
6-in, inner diameter stainless steel protective casing +2.9 ft
Portland Cement type I/II 0 - 10.2 ft
Bentonite Crumbles 10.2 - 220.5 ft
4-in, inner diameter stainless steel, type 304, schedule 5 casing +1.6 - 235.5 ft

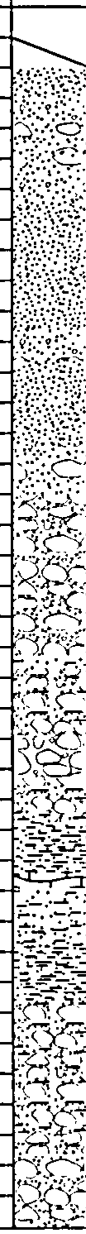
Diagram



Depth in Feet: 0, 25, 50, 75, 100, 125, 150, 175

GEOLOGIC/HYDROLOGIC DATA

Graphic Log



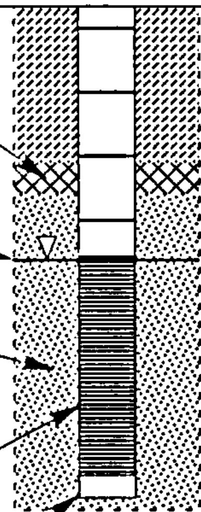
Lithologic Description (ft bgs)
0-5 No recovery
5-9 Sand, S
9-18 Sandy Gravel, sG
18-19 Silty Sand, mS
19-26 Sandy Gravel, sG
26-43 Sand, S
43-48 Sand, S
48-53 Gravelly Silty Sand, gmS
53-67 Sand, S
67-75 Gravelly Sand, gS
75-101 Sandy Gravel, sG
101-104 Silty Gravel, mG
104-119 Silty Sandy Gravel, msG
119-122 Gravel, G
122-129 Silty Sandy Gravel, msG
129-138 Silt, M
138-139.5 Silt, M (Cemented Caliche)
139.5-148 Sandy Silt, sM
148-158 Silty Sand, mS
158-184 Silty Sandy Gravel, msG
184-196.5 Sandy Gravel, sG

Figure E-5. Well 299-W15-224 Construction and Completion Summary

WELL SUMMARY SHEET		Start Date: 2/08/2006 Finish Date: 2/23/2006	Page 2 of 2
Well ID: C4986		Well Name: 299-W15-224	
Location: West of 200-ZP-1 Pump and Treat Facility		Project: CY06 LLBG Monitoring Wells	
Prepared By: Bjorn Helgeson	Date: 2/24/06	Reviewed By: L. D. Walker	Date: 4/6/06
Signature: LD Walker for B. Helgeson		Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
1/4-in coated bentonite pellets 220.5 - 225.6	
Static Water = 236.40	
10-20 mesh Colorado silica sand 225.6 - 274.1	
4-in, inner diameter stainless steel, type 304, 20 slot (0.02-in) screen 235.5 - 270.5	
4-in, inner diameter stainless steel, type 304, schedule 5 sump 270.5 - 273.5	
All temporary casing removed from the ground	
All depths are in feet below ground	



Depth in Feet: 200, 225, 250, 275, 300, 325, 350, 375

GEOLOGIC/HYDROLOGIC DATA

Graphic Log	Lithologic Description (ft bgs)
	196.5-211 Gravel, G
	211-247 Sandy Gravel, sG
	247-258 Silty Sand, mS
	258-263 Sandy Gravel, gS
	263-274.1 Gravel, G
	Total depth drilled = 274.1' bgs

Figure E-5. Well 299-W15-224 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/.

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-4 Monitoring Network – ECF-200W-17-0073

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The calculation ECF-200W-17-0073, *Groundwater Flow and Migration Calculations to Support Assessment of the LLBG WMA-4 Monitoring Network*, was performed to evaluate monitoring well locations for the Low-Level Burial Grounds Waste Management Area-4 groundwater monitoring network. The calculation is available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065097H.

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Appendix H

Statistical Method Determination

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Contents

Figures

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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.

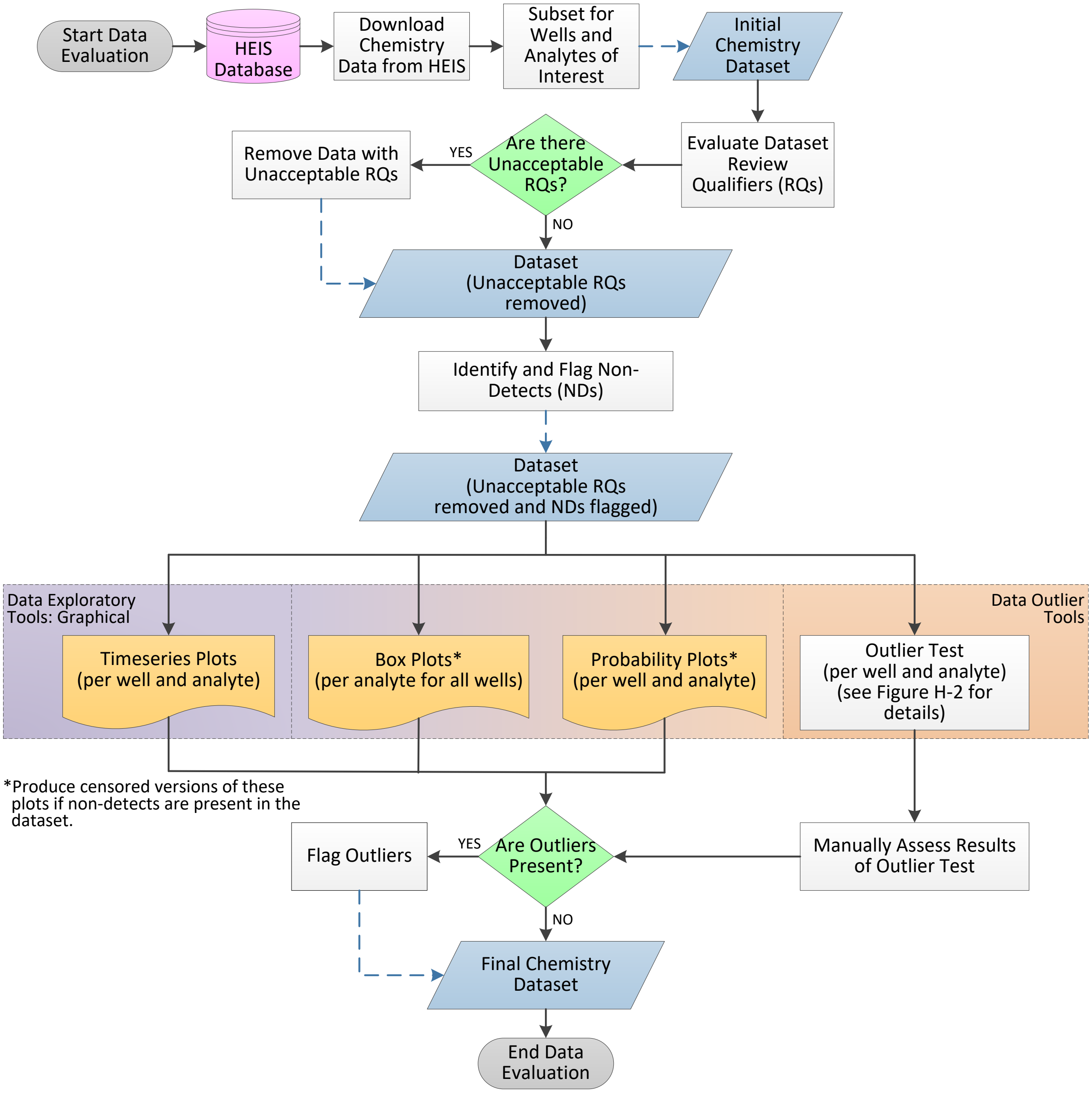

Figure H-1. Data Evaluation

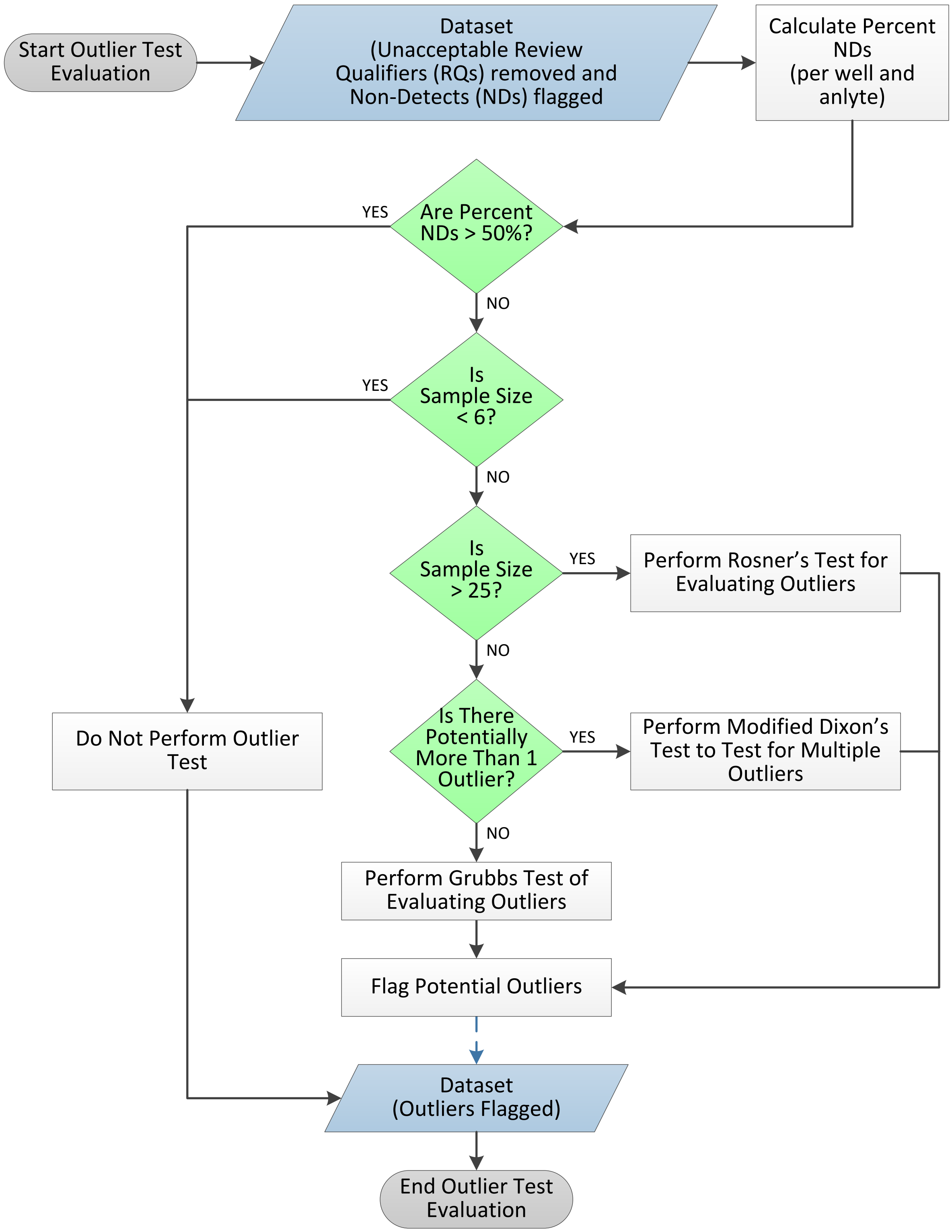

Figure H-2. Outlier Test Evaluation

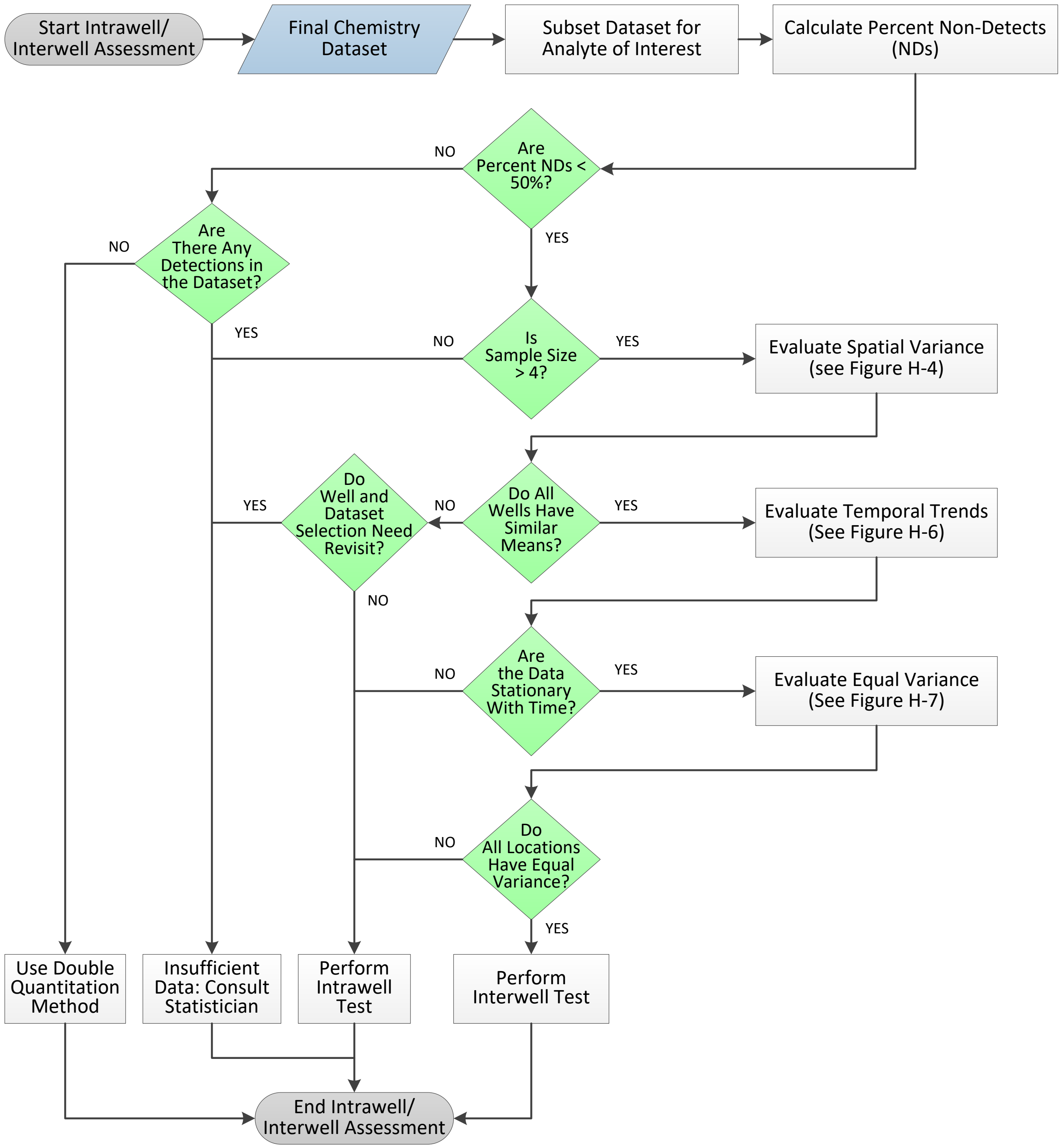

Figure H-3. Intrawell/Interwell Assessment

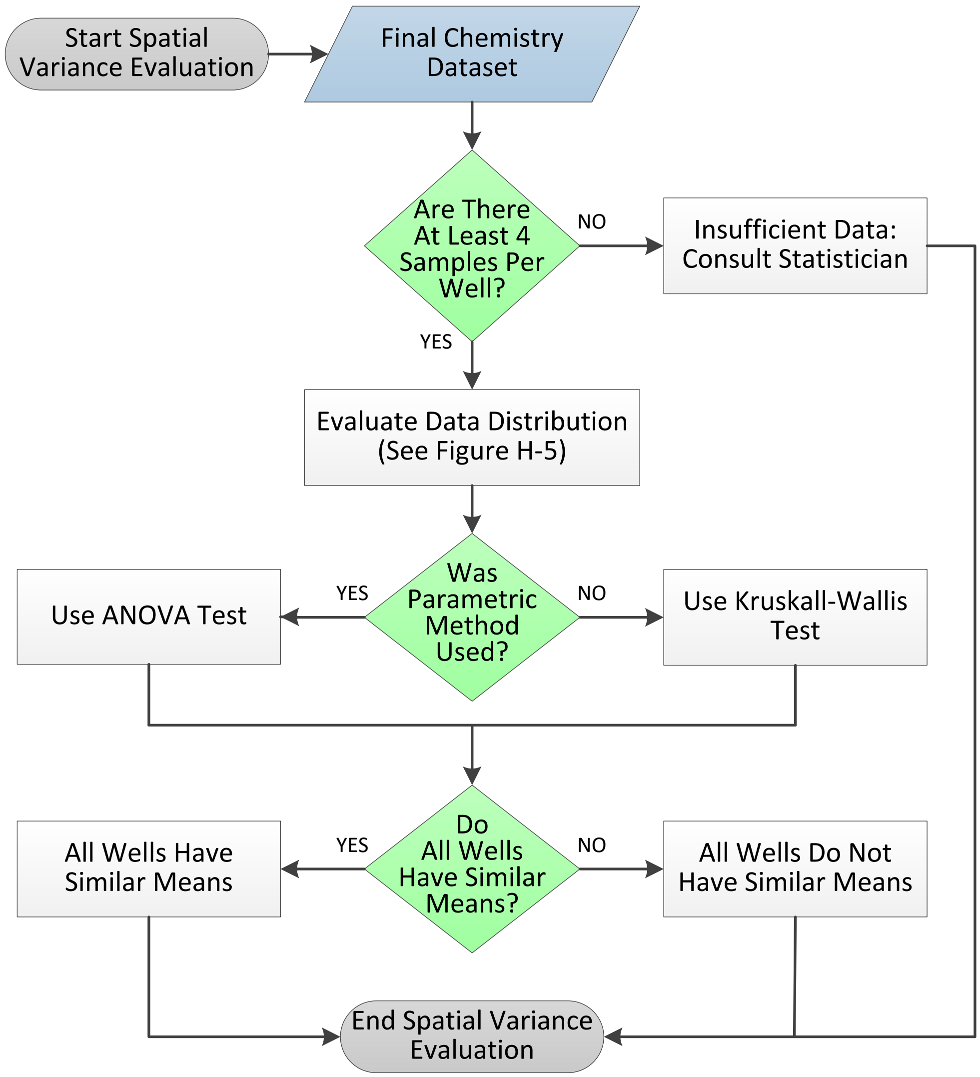

Figure H-4. Spatial Variance Evaluation

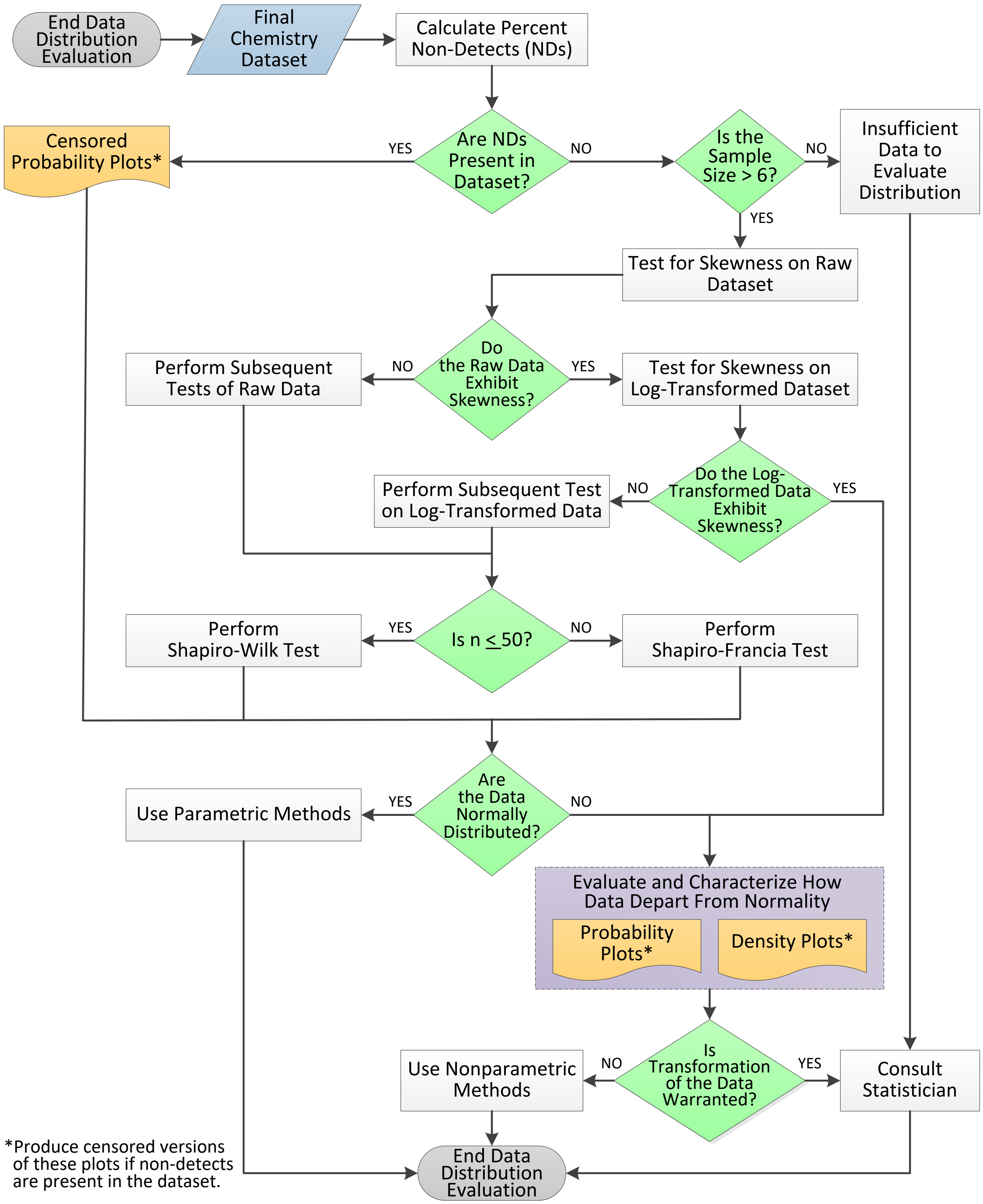

Figure H-5. Data Distribution Evaluation

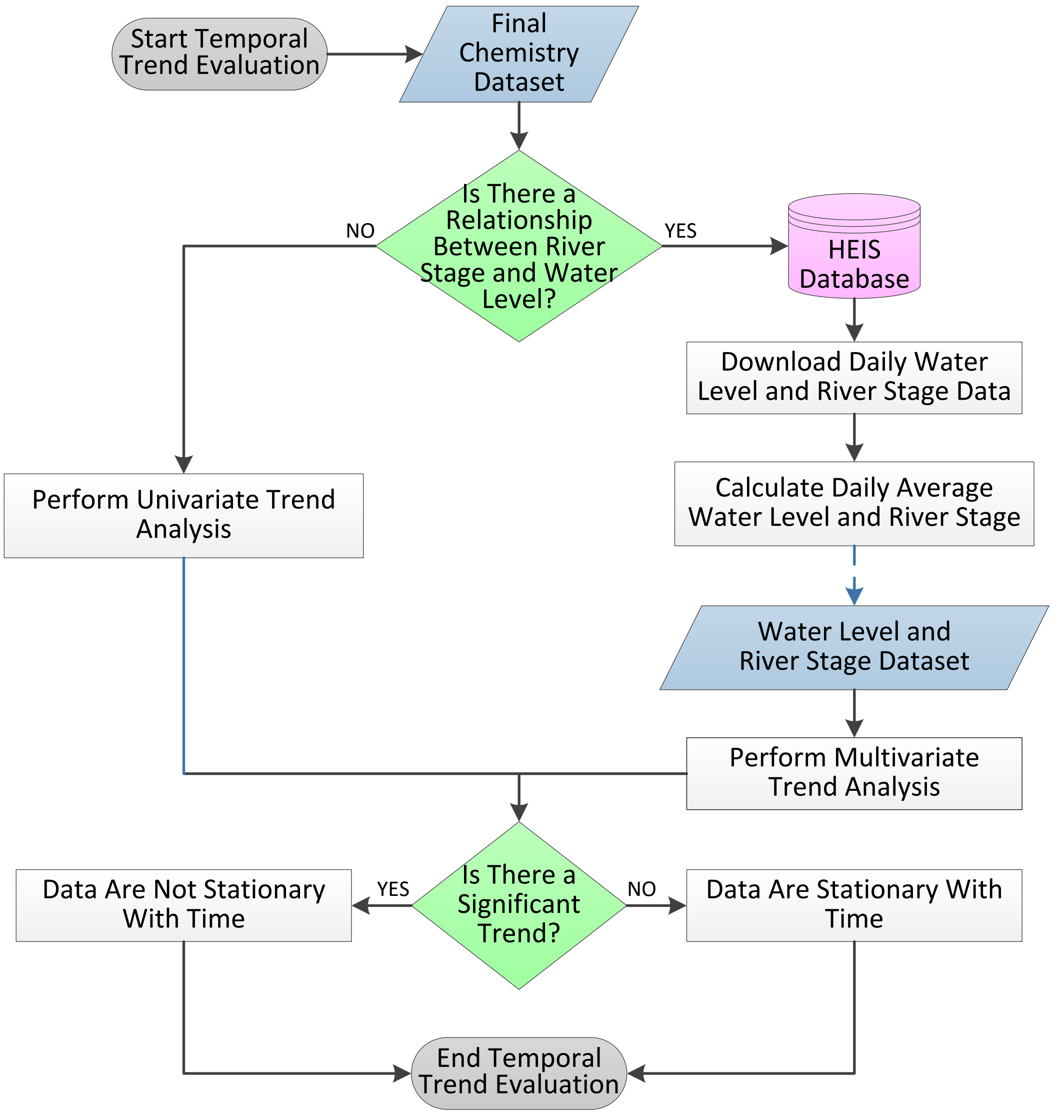

Figure H-6. Temporal Trend Analysis

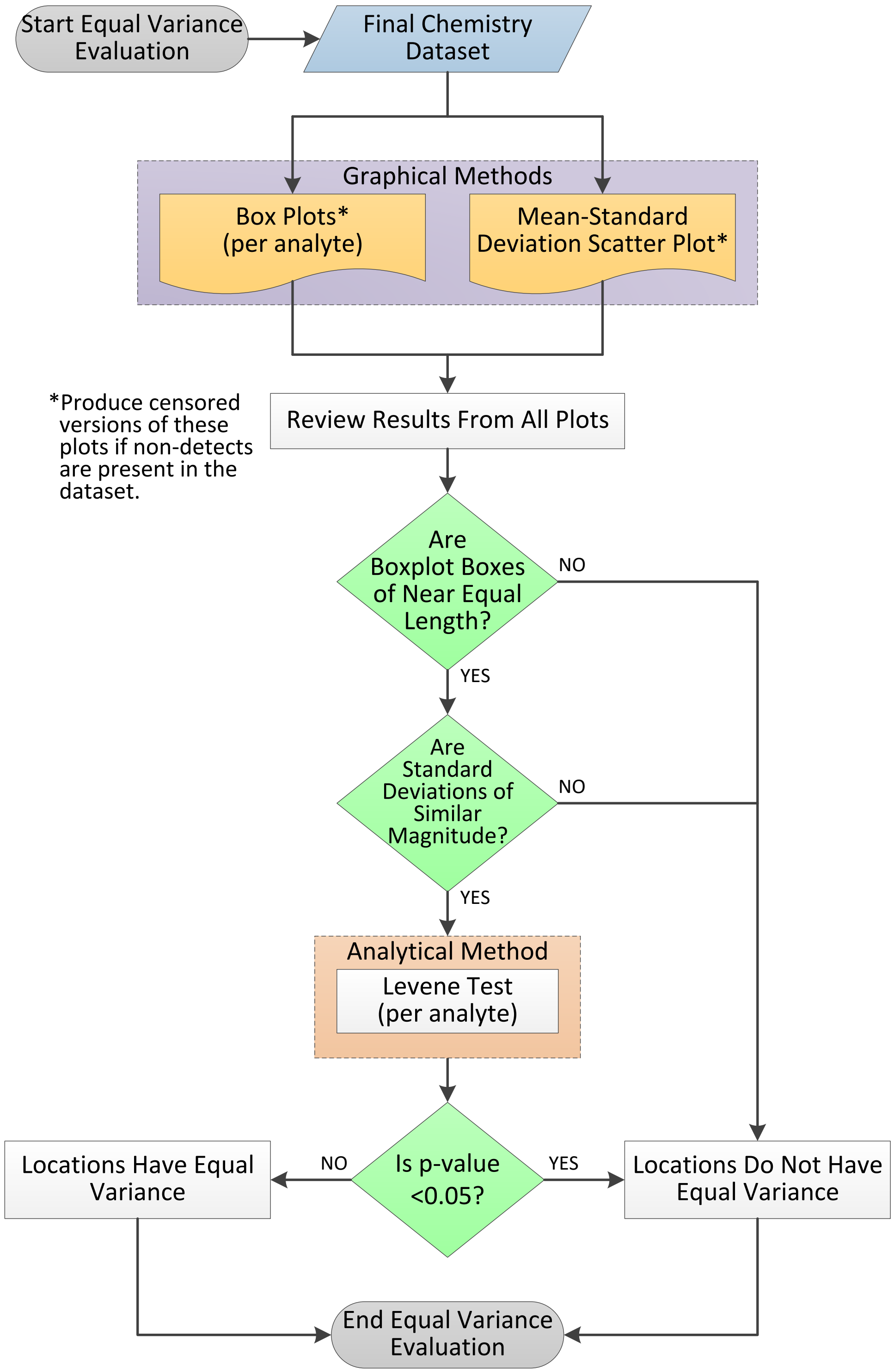

Figure H-7. Equal Variance Evaluation

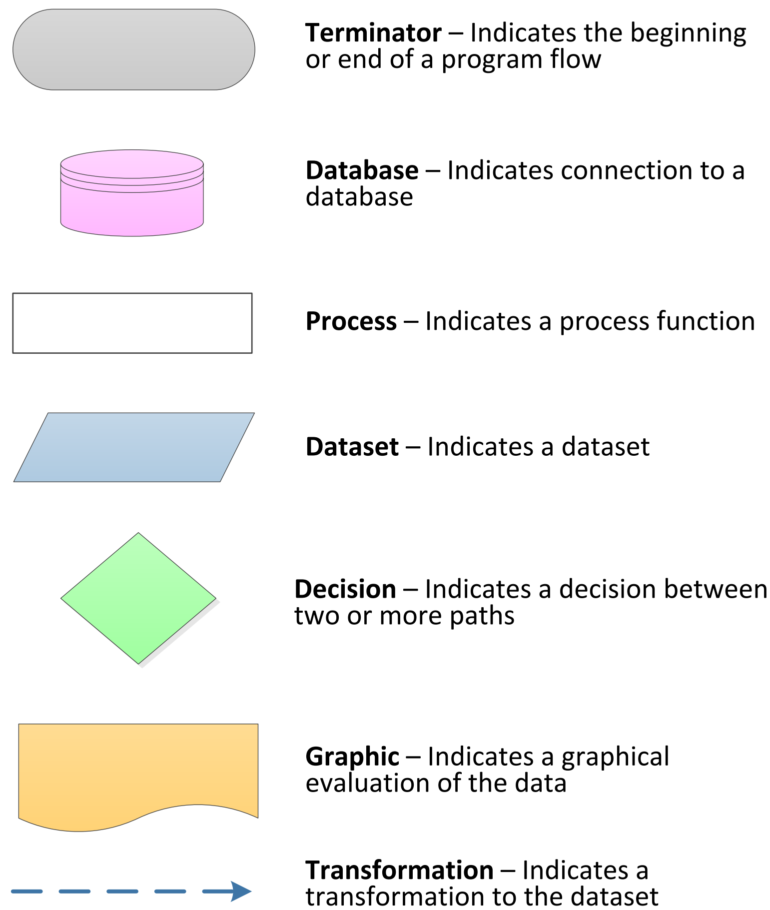

Figure H-8. Chart Legend

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.