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Revision 0

Engineering Evaluation Report for Single-Shell Tank Waste Management Area U 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

ch2m

P.O. Box 1600
Richland, Washington 99352

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By Janis D. Aardal at 10:24 am, Jul 23, 2018

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Statement of certification:

I am a licensed Professional Engineer in the State of Washington, No. 41198, with a degree in Environmental Engineering. I have over 26 years of professional experience, including 15 years with groundwater systems. I reviewed the attached engineering study referenced as "Engineering Evaluation Report for Single-Shell Tank Waste Management Area U Groundwater Monitoring, SGW-60578, 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).

March 26, 2018

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

Date

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Terms

amsl	above mean sea level
AEA	*Atomic Energy Act of 1954*
API	American Petroleum Institute
bgs	below ground surface
CAS	Chemical Abstracts Service
CCU	Cold Creek unit
CPGWM	Central Plateau Groundwater Model
DOE	U.S. Department of Energy
DWMU	dangerous waste management unit
DWS	drinking water standard
ECF	environmental calculation file
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FY	fiscal year
HEIS	Hanford Environmental Information System
K_d	distribution coefficient
MT3DMS	Modular Three-Dimensional Multi-Species Transport Model
OU	operable unit
P&T	pump and treat
PFP	Plutonium Finishing Plant
PUREX	Plutonium Uranium Extraction Facility
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	reduction-oxidation
SST	single-shell tank
SVOC	semivolatile organic compound
TDS	total dissolved solids
TOC	total organic carbon
TOX	total organic halides
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989)
TSD	treatment, storage, and disposal

UPR	unplanned release
VOC	volatile organic compound
WIDS	Waste Information Data System
WMA	waste management area

1 Introduction

This engineering evaluation report provides information to support the proposed final status groundwater monitoring for Waste Management Area (WMA) U based on evaluation of contaminants associated with WMA U, the expected migration behavior of contaminants in the WMA, and historical observations and measurements of groundwater contamination at WMA U. 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*). WMA U is an inactive single-shell tank (SST) farm 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 4. WMA U will be closed under WAC 173-303-665(6), "Dangerous Waste Regulations," "Landfills," "Closure and post-closure care," which is allowed by WAC 173-303-640(8)(b), "Tank systems," "Closure and post-closure care." 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.

WMA U is located in the 200 West Area of the Hanford Site in Washington State and overlies the 200-UP-1 Groundwater Operable Unit (OU) (Figure 1-1). WMA U includes 16 SSTs and ancillary equipment of the U Tank Farm that were initially used for interim storage of radioactive dangerous waste from the bismuth phosphate process at B and T Plants, and now contain wastes from other processes, particularly waste generated by the uranium recovery process at U Plant.

This report addresses the additional information for groundwater monitoring requested in Washington State Department of Ecology (Ecology) Letter 16-NWP-090, "Groundwater Monitoring Requirements for 200 West Area Single-Shell Tank (SST) Farms Final Status Groundwater Monitoring Plan." The letter requests that the U.S. Department of Energy (DOE) develop engineering reports in advance of the complete permit application for the SST WMAs, 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), "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.

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.

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 (G)(V) 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 (G)(V) 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 compliance monitoring program (WAC 173-303-645(10)) 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 compliance 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 WMA U 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), WAC 173-303-806(4)(a)(xx)(B) (hydrogeological information), and WAC 173-303-806(4)(a)(xx)(D) (plume maps).

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

Documented releases to the environment have occurred at WMA U. Details of the operational, regulatory, and groundwater monitoring history can be found in Chapter 2.

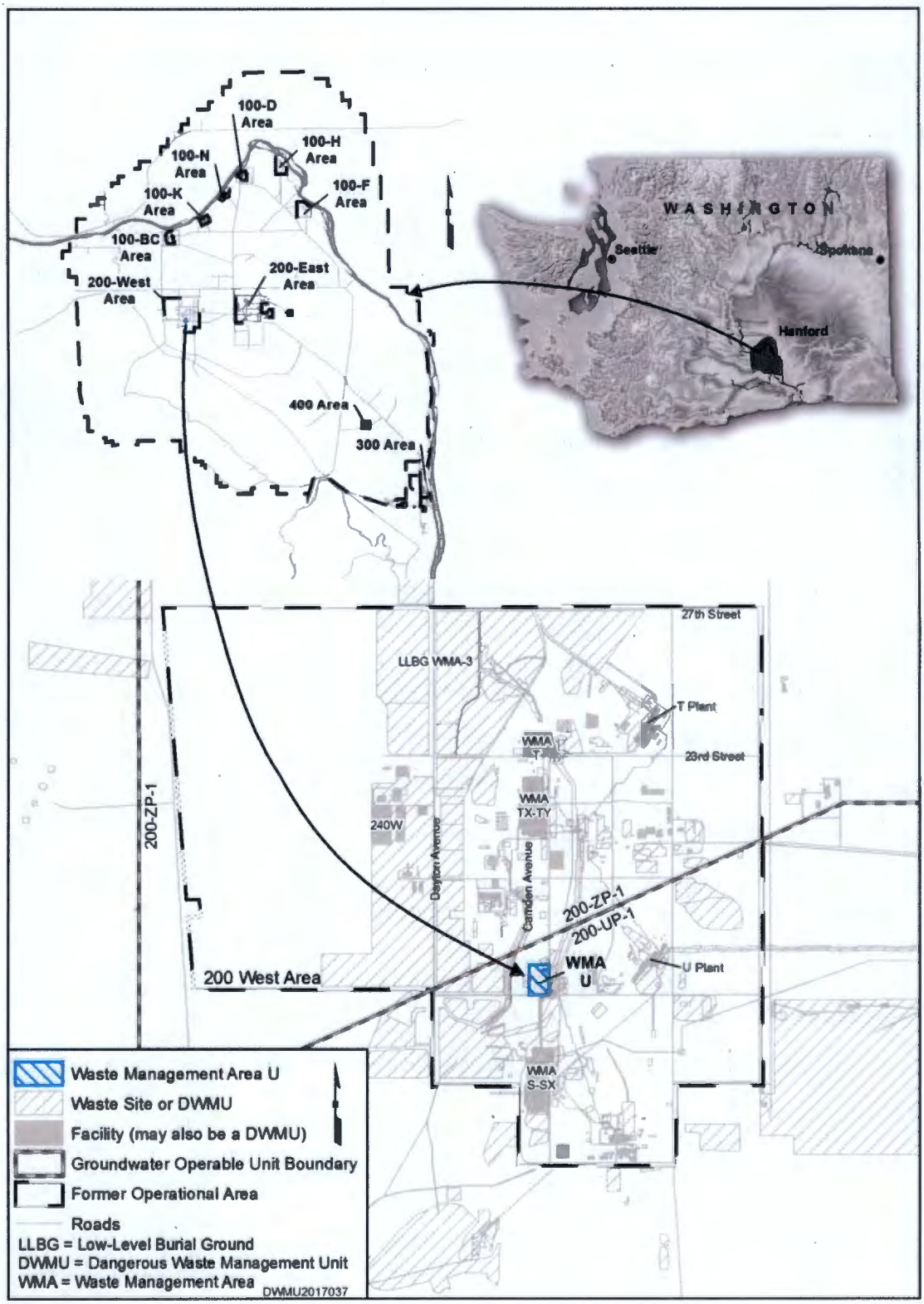


Figure 1-1. Location Map for WMA U

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 WMA U.
- 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 WMA U 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 evaluation environmental calculation file (ECF) (ECF-200UP1-17-0123, *Identification of Site-Specific Monitoring Constituents for Waste Management Area U*).
- Appendix C contains the topographic map.
- Appendix D contains regional plume maps in the vicinity of WMA U.
- 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 WMA U modeling ECF (ECF-200W-17-0074, *Groundwater Flow and Migration Calculations to Support Assessment of the WMA U Monitoring Network*).
- Appendix H contains the process for defining the groundwater monitoring statistical method.

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 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)(G) If the presence of dangerous constituents has been detected in the groundwater at the point of compliance at the time of permit application, the owner or operator must submit sufficient information, supporting data, and analyses to establish a compliance monitoring program which meets the requirements of WAC 173-303-645(10)... To demonstrate compliance with WAC 173-303-645(10), the owner or operator must address the following items: (I) A description of the wastes previously handled at the facility; (II) A characterization of the contaminated groundwater, including concentrations of dangerous constituents and parameters; (III) A list of constituents and parameters for which compliance monitoring will be undertaken in accordance with WAC 173-303-645 (8) and (10); (IV) Proposed concentration limits for each dangerous constituent and parameter, based on the criteria set forth in WAC 173-303-645 (5)(a), including a justification for establishing any alternate concentration limits…	Section 2.3 Chapter 8 Chapter 9 Appendix A Appendix B

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: (i) Whenever dangerous constituents under subsection (4) of this section, from a regulated unit are detected at the compliance point under subsection (6) of this section, the owner or operator must institute a compliance monitoring program under subsection (10) of this section. Detected is defined as statistically significant evidence of contamination as described in subsection (9)(f) of this section;…	Chapter 9
WAC 173-303-645(3) The owner or operator must comply with conditions specified in the facility permit that are designed to ensure that dangerous constituents under subsection (4) of this section, detected in the groundwater from a regulated unit do not exceed the concentration limits under subsection (5) of this section, in the uppermost aquifer underlying the waste management area beyond the point of compliance under subsection (6) of this section, during the compliance period under subsection (7) of this section…	Chapter 9
WAC 173-303-645(4)(a) The department will specify in the facility permit the dangerous constituents to which the groundwater protection standard of subsection (3) of this section, applies…	Section 9.4
WAC 173-303-645(5) (a) The department will specify in the facility permit concentration limits in the groundwater for dangerous constituents established under subsection (4) of this section... (b) The department will establish an alternate concentration limit for a dangerous constituent if it finds that the constituent will not pose a substantial present or potential hazard to human health or the environment as long as the alternate concentration limit is not exceeded...	Section 9.5
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(7) The department will specify in the facility permit the compliance period during which the groundwater protection standard of subsection (3) of this section applies…	Section 9.6

Table 1-1. Pertinent Requirements

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

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
WAC 173-303-645(10)(a) The owner or operator must monitor the groundwater to determine whether regulated units are in compliance with the groundwater protection standard under subsection (3) of this section. The department will specify the groundwater protection standard in the facility permit, including: (i) A list of the dangerous constituents and parameters identified under subsection (4) of this section; (ii) Concentration limits under subsection (5) of this section for each of those dangerous constituents and parameters (iii) The compliance point under subsection (6) of this section; and (iv) The compliance period under subsection (7) of this section.	Chapter 9
WAC 173-303-645(10)(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)*, and (c) of this section.	Chapter 9

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

2 Supporting Historical Information

2.1 Background

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

2.1.1 Facility Description

WMA U, which includes the SSTs and ancillary equipment of the U Tank Farm, is located in the south-central portion of the 200 West Area, near U Plant (Figure 2-1). SSTs in WMA U were used for interim storage of highly radioactive waste (called "metal" waste) generated by nuclear fuel reprocessing using the bismuth phosphate process at B and T Plants. Most of the metal waste was subsequently removed from the tanks and recycled through U Plant to remove uranium (Section 2.3.1.1.1 in DOE/RL-91-52, *U Plant Source Aggregate Area Management Study Report*). WMA U contains 16 underground SSTs constructed between 1943 and 1944. Twelve of the SSTs are 100-series tanks (241-U-101 through 241-U-112) that are 23 m (75 ft) in diameter and have capacities of 2,020,000 L (535,000 gal) (Section 1.2 in RPP-35485, *Field Investigation Report for Waste Management Area U*). Four of the SSTs are 200-series tanks (241-U-201 through 241-U-204) that are 6 m (20 ft) in diameter and have capacities of 210,000 L (55,000 gal). The bases of both the 100-series and 200-series tanks are approximately 11.3 m (37 ft) below ground surface (bgs). The 12 primary tanks were divided into 4 sets of 3 tanks each (e.g., tanks 241-U-101, 241-U-102, and 241-U-103) with cascade lines attaching each set so that waste would flow from east to west by gravity feed (Section 2.1.1 in RPP-15808, *Subsurface Conditions Description of the U Waste Management Area*). The cascade lines were about 7 m (21 ft) bgs. The WMA also contains ancillary equipment used to manage tank waste during operations, including six diversion boxes, the 271-UR control house, the 244-UR process vault, the 244-U double-contained receiver tank, waste transfer lines, pits, and junction boxes.

Multiple vadose zone wells, known as drywells, are located between and around each 100-series SST, generally installed to depths between 23 m (75 ft) and 46 m (150 ft) (Section 1.2.1 in RPP-35485). The drywells are open-bottom, 15 cm (6 in.) or 20 cm (8 in.) steel casings placed vertically around the tank perimeters. Beginning in the 1950s, the drywells were monitored with gross gamma and other radiation logging tools as a secondary means of leak detection (Section 2.1.1.2 in RPP-35485). Figure 2-2 depicts SST schematics from the WA7890008967, *Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion for the Treatment, Storage, and Disposal of Dangerous Waste*, Rev. 8c (hereinafter referred to as the Hanford Facility RCRA Permit) Part A Application for the SST System.

2.1.2 Operational History

The tanks in WMA U began operations in 1946 and were in continual use until 1980, at which time they were removed from service. From 1946 to 1980, the WMA U tanks first received nuclear fuel reprocessing waste, metal waste, from the bismuth phosphate process at B and T Plants. Most of the metal waste was subsequently removed from the tanks and recycled through U Plant to remove uranium. WMA U subsequently received fuel reprocessing waste from the Reduction Oxidation (REDOX) Plant and from other waste operations such as Plutonium Uranium Extraction Facility (PUREX). The tank farm was later interim stabilized (by removing pumpable liquids from the tanks) and isolation activities were performed (Section 2.3.2 in DOE/RL-91-52; Section 2.1 in PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*; and Section 2.1.2 in RPP-15808).

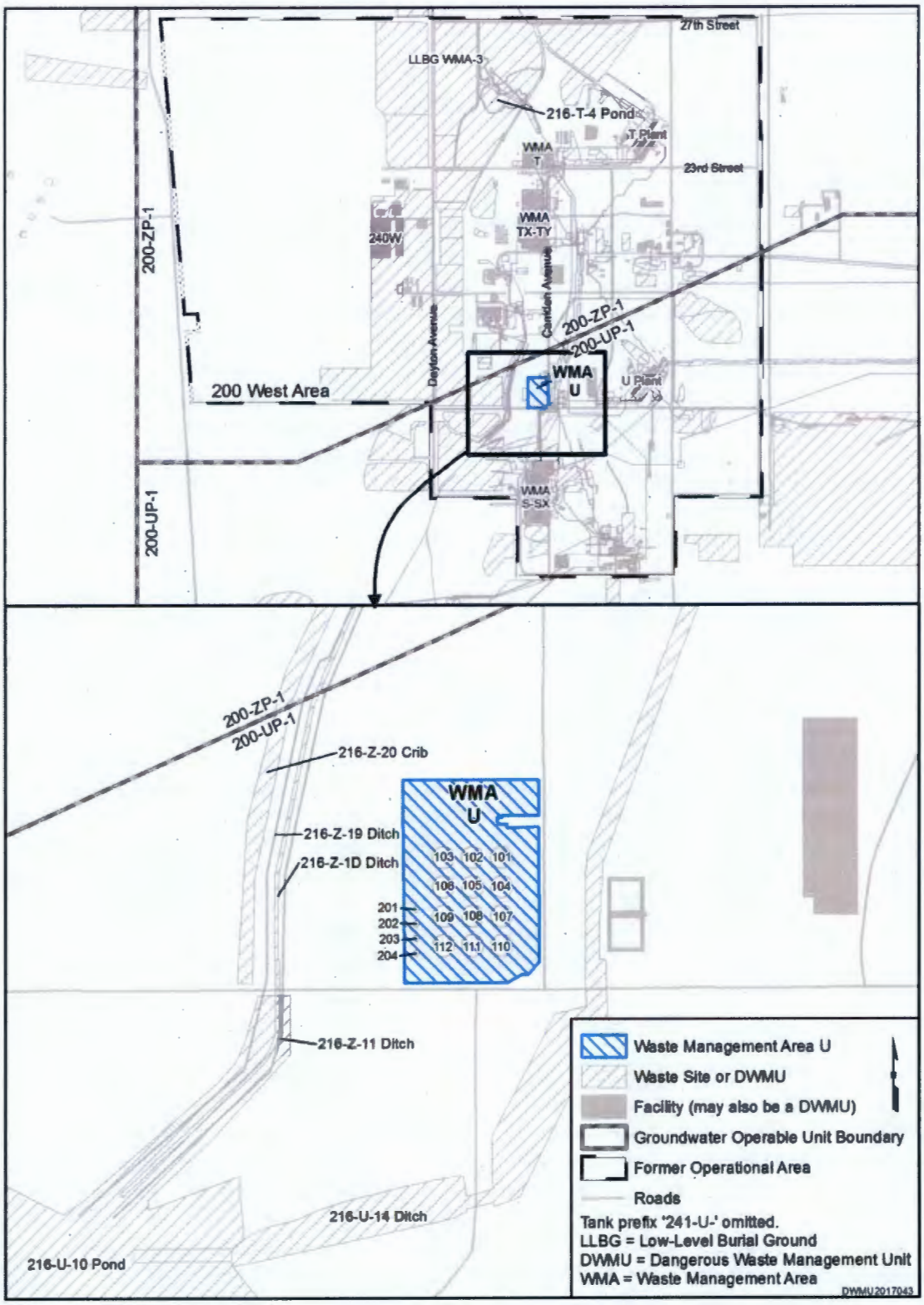
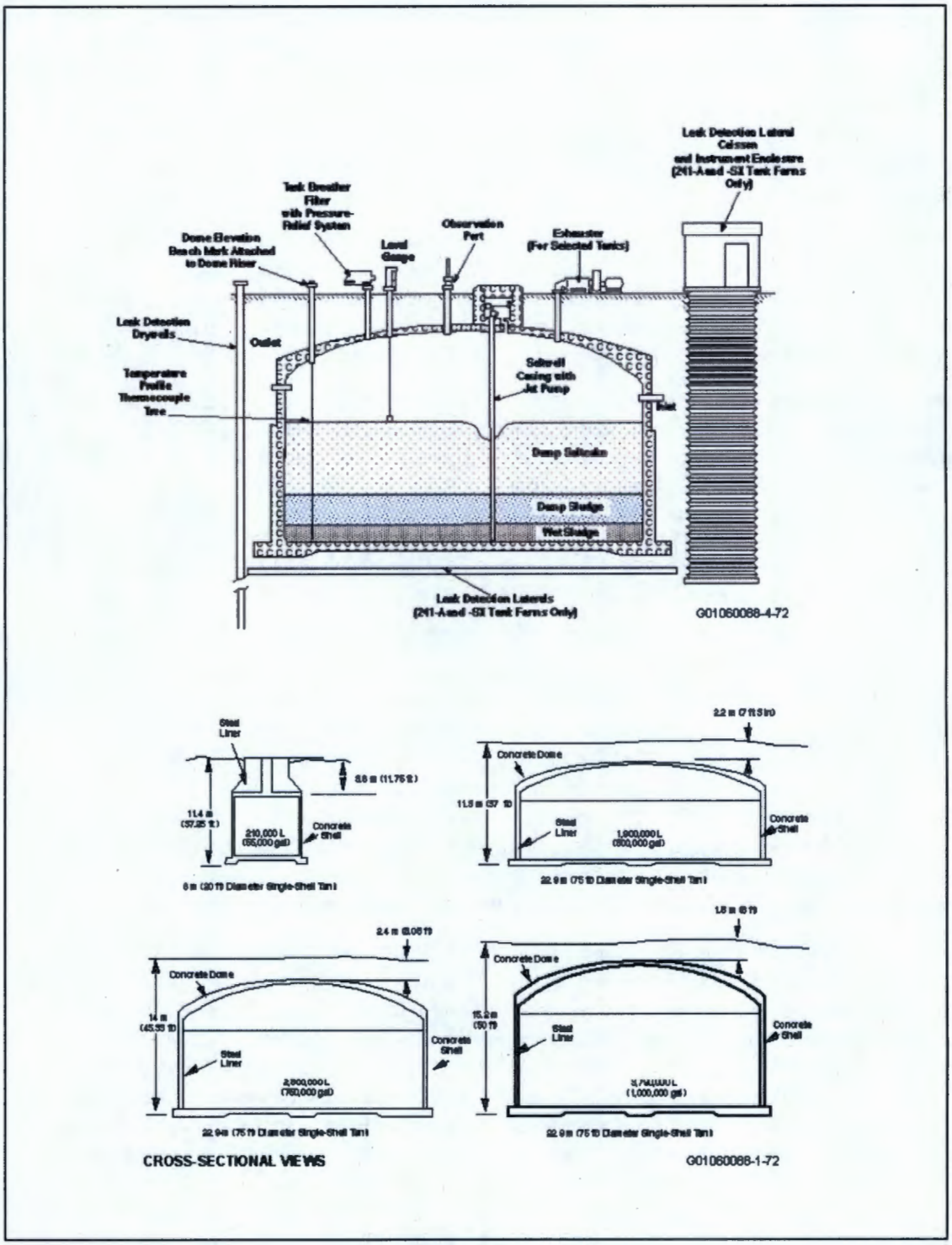


Figure 2-1. Location of WMA U Within the 200 West Area



Source: p. 10 in 11-NWP-054, "Approval of the Single-Shell Tank System Dangerous Waste Permit Application Part A Form, Revision 13."

Figure 2-2. SST Schematics from the Hanford Facility RCRA Permit Part A Application

Waste management operations created a complex intermingling of tank wastes. Waste was transferred between tanks and tank farms throughout the operational history, and, as a result, there is considerable uncertainty about the exact composition of waste in the tanks at any particular time (Section 2.1 in PNNL-13282). Nonradioactive chemicals were added to the tanks, and varying amounts of waste and heat-producing radionuclides were removed. In addition, natural processes caused settling, stratification, and segregation of waste components. As a result, it is difficult to estimate the composition of the waste remaining in the tanks through operational records.

Each of the SSTs at WMA U have been interim stabilized (HNF-EP-0182, *Waste Tank Summary Report for Month Ending May 31, 2017*) (Figure 2-3). This process involved pumping the supernatant and interstitial liquids from the SSTs to double-shell tanks until no more than 189,270 L (50,000 gal) of drainable interstitial liquid and less than 19,000 L (5,000 gal) of supernatant liquid remained in each tank (Appendix A in HNF-EP-0182).

Additional interim measures have been implemented to reduce infiltration and the subsequent migration of contaminants through the vadose zone to groundwater (Section 2.5.2 in DOE/RL-2009-74, Rev. 1, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*). Berms were constructed around WMA U in 2002 to stop run-on of natural precipitation, and known water lines have been cut, capped, or pressure tested to prevent leaks (Sections 5.1.1 and 5.1.3 in RPP-35485). Wells and drywells located in the WMA are potential preferential pathways for downward contaminant migration. Drywells in WMA U were capped in 1999 to prevent surface water infiltration (Section 5.1.2 in RPP-35485).

2.1.3 Single-Shell Tanks and Liquid Handling Structures within Waste Management Area U

Of the 16 tanks located within WMA U, 4 are classified "assumed or confirmed leakers": 241-U-101, 241-U-104, 241-U-110, and 241-U-112 (HNF-EP-0182) (Figures 2-2 and 2-3). Estimated leak volumes vary from 19,000 L (5,000 gal) in tank 241-U-110 to 208,000 L (55,000 gal) in tank 241-U-104. In addition to these, a riser leak at the 244-UR vault, a pipeline leak near tank 241-U-103, and contamination from operations activities have been reported as unplanned releases (UPRs) (Section 2.1.2 in RPP-15808). Each of the major listed leaks is discussed below to evaluate the severity of the contamination. The discussion refers to the radiation activity and radioactive constituents and components of released material; however, these constituents and components are not subject to dangerous waste regulation and are included here for the sole purpose of identifying releases from tanks.

Tank 241-U-101 was categorized as an assumed leaker in 1959 and has a total estimated leak volume of 113,600 L (30,000 gal) (Table 4-2 in HNF-EP-0182). Tank 241-U-101 first received metal waste from the bismuth phosphate process followed by receipt of uranium recovery waste. After tank 241-U-101 was no longer needed to support uranium recovery operations in 1956, it received 1,858,600 L (491,000 gal) of aged REDOX waste from tank SX-103 in 1958 to bring the total volume of waste in the tank to 2,044,000 L (540,000 gal) (Section 3.2.1 in RPP-15808). This volume remained constant for almost 2 years and then waste level drops were noted. Both the waste transfer records and waste tank summary report indicate a loss of 113,600 L (30,000 gal) from this tank in 1959 (UPR-200-W-154). However, this leak report is questionable as field data do not indicate evidence of a leak, much less a leak of such magnitude (Section 3.2.1 in RPP-15808). A loss of 113,600 L (30,000 gal) of REDOX high-level waste from tank 241-U-101 would have created a sizable cesium-137 plume in the vadose zone. None of the drywells around tank 241-U-101 display high cesium-137 content indicating evidence of a tank leak. While tank 241-U-101 remains an assumed leaker, without physical evidence for a cesium-137 plume associated with a waste loss event from tank 241-U-101, no substantive vadose zone contamination can be assumed.

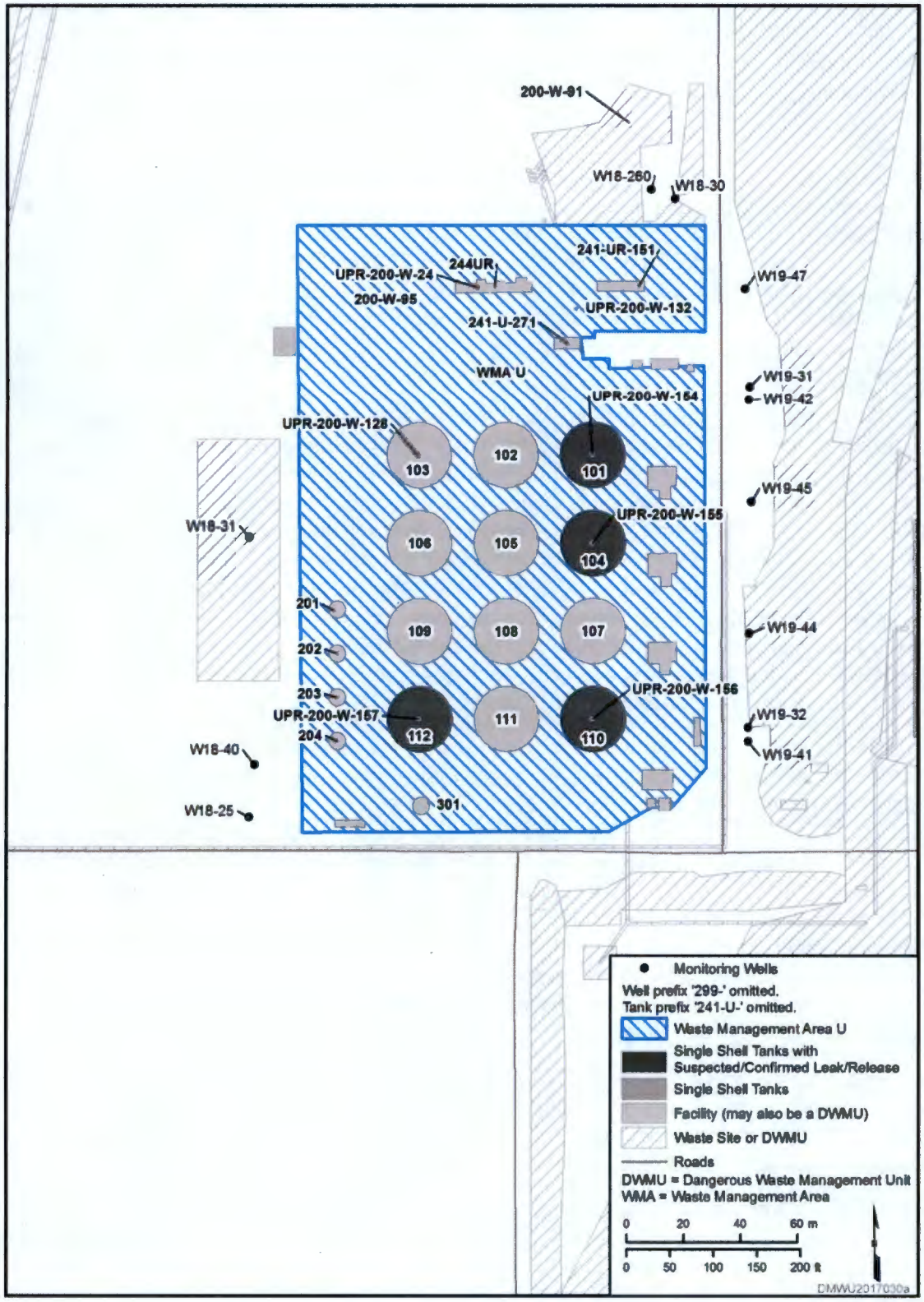


Figure 2-3. SSTs in WMA U

Tank 241-U-104 was categorized as an assumed leaker in 1961 and has a total estimated leak volume of 208,200 L (55,000 gal) (Table 4-2 in HNF-EP-0182). A tank bottom liner rupture, detected during a physical inspection of the tank in 1956, resulted in a significant leak from tank 241-U-104 in the early 1950s (Section 3.2.3 in RPP-15808). A 208,200 L (55,000 gal) leak volume has been estimated (UPR-200-W-155) (Table 4-2 in HNF-EP-0182). Operational records indicate uranium-rich metal waste as the primary waste stream in the tank at this time. Being the first in a three-tank cascade (tanks 241-U-104, 241-U-105, and 241-U-106), most of the uranium solids precipitated in this tank along with the heat-producing fission products, resulting in a tank bottom liner rupture from the resultant heat buildup (Section 3.2.3 in RPP-15808). Spectral gamma uranium activity data in 10 drywells around tank 241-U-104 and to the southwest also indicate the occurrence of a metal waste leak with tank 241-U-104 being the apparent source (Section 3.2.3 in RPP-15808). Uranium contamination is detected just below the tank bottom at 15 and 17 m (50 and 55 ft) bgs and extending up to 28 m (92 ft) bgs, and vertical uranium migration is indicated throughout the monitoring period between 1975 and 1994 (Section 3.2.3 in RPP-15808).

Tank 241-U-110 was categorized as an assumed leaker in 1975 and has a total estimated leak volume of 19,000 to 30,700 L (5,000 to 8,100 gal) (UPR-200-W-156) (Table 4-2 in HNF-EP-0182). The tank leak was originally reported on the basis of increased gamma activity in a neighboring drywell (with subsequent measurements indicating high cesium-137 concentrations) and a liquid level drop inside the tank (Section 3.2.3 in RPP-15808). Both spectral gamma data and the historical gross gamma record are consistent with a tank leak. Determination of the chemistry of the waste leaked from tank 241-U-110 is uncertain because of complex waste receipt and transfer history at tank 241-U-110 prior to the leak event in the early 1970s (Section 3.2.3 in RPP-15808). However, reviewing the waste history, the leaked tank fluid was likely a mixture of REDOX high-level supernatant mixed with various low-activity waste streams. Given the high cesium-137 concentration, REDOX waste was the largest contaminant contributor in the leaked tank fluid (Section 3.2.3 in RPP-15808).

Tank 241-U-112 was categorized as an assumed leaker in 1980 and has an estimated leak volume of 32,000 L (8,500 gal), although the volume is unconstrained and may be larger (UPR-200-W-157) (Table 4-2 in HNF-EP-0182 and Section 3.2.3 in RPP-15808). Tank 241-U-112 appears to have leaked in a similar fashion to tank 241-U-110. One drywell shows two distinct high cesium-137 concentration zones, possibly indicating more than one leak. One high-concentration zone was detected near the bottom of the tank at 15 and 21 m (50 and 68 ft) bgs and another at a deeper zone of 25 and 30 m (83 and 97 ft) bgs. The leak may have occurred between 1967 and 1969 when indications of a liquid level drop inside the tank were observed (Section 3.2.3 in RPP-15808). Historical gamma data do not indicate contaminant movement beginning in the early 1970s, suggesting that cesium-137 migration had already finished by that time (Section 3.2.3 in RPP-15808). Tank 241-U-112 stored similar waste to tank 241-U-110, suggesting that REDOX waste was a significant component in the leaked tank fluid.

Other liquid handling structures within WMA U, including six diversion boxes, the 271-UR control house and 244-UR vault, valve pits, and process pipelines, were used to transport or contain liquid waste associated with the tank farms. Information for the structures associated within WMA U that are identified as waste sites in the Waste Information Data System (WIDS) is provided below.

- There are six diversion box waste sites in WMA U. Diversion boxes are concrete structures containing transfer piping and were designed to contain leaks from transfers and drainage of effluent from operations within the unit. The diversion boxes drained to catch tanks or SSTs. In 1956, 1,900 L (500 gal) of metal waste overflowed from the 241-UR-151 diversion box at the northeast corner of the 241-U Tank Farm (UPR-200-W-132) (Section 2.1.2 in RPP-15808).

- There are four valve pits in WMA U. Valve pits are underground concrete structures designed to contain leaks from transfers and drainage operations and then drain to catch tanks. Valve pits were equipped with a leak detection system, which was designed to shut down operations if a leak in the pit were detected.

- There is one catch tank, one receiving vault, one double-contained receiver tank, and one septic tank in WMA U. The catch tank is an underground structure designed to receive valve pit or diversion box leaks during transfers and drainage operations. The catch tank is unlined and constructed of reinforced concrete. The receiving vault is a carbon steel plate tank with a capacity of 189,250 L (50,000 gal). The vault was covered with pumped concrete in 1992. The receiver tank consists of a reinforced concrete structure in a steel-lined vault containing a 79,500 L (21,000 gal) carbon steel tank. The tank was intended to receive saltwell waste from the 241-U Tank Farm but was not used for its intended purpose and no waste has been placed in the tank. The 2607-WUT septic tank is constructed of steel and includes a drain field. The system received sanitary effluent from the 241-U-271 control house. The water supply to the tank farm has since been isolated and drainage is no longer occurring.

- Pipeline structures in WMA U transferred effluent or condensate waste from the tank farm to surface liquid waste facilities. The pipelines were constructed of either carbon steel or stainless steel. Pipelines were either direct buried or encased in concrete. The pipelines delivered process fluids or condensate and were either gravity or pressurized lines.

These liquid handling structures within WMA U carried or contained waste effluent (e.g., mixed waste solutions and decontamination solutions) associated with the tanks. Therefore, impacts to groundwater from these structures will be assessed using the constituents identified from the tank waste.

2.1.4 Unplanned Releases

The following information about UPRs within WMA U is from Appendix D in RPP-35485, Section 2.1.2 in RPP-15808, and WIDS. In addition to the previously discussed documented leaks from SSTs (UPR-200-W-154, UPR-200-W-155, UPR-200-W-156, and UPR-200-W-157) and diversion boxes (UPR-200-W-132), there have been three other distinct UPRs associated with WMA U, as well as one consolidated UPR:

- 200-W-91 is a large area of contaminated soil discovered in 1983 and 1984 during routine radiological surveys of the tank farm perimeter. The area was documented as an Underground Radioactive Material Area in 1995 and covered with clean gravel.

- UPR-200-W-24 was caused by a violent chemical reaction in one of the blending tanks of the 244-UR Vault in 1953. The incident occurred when uranium metal waste supernate was being pumped from tank 241-U-109 to the blending tank. Acid in the tank caused a pressure buildup that released through a riser causing a geyser of liquid rising 9 m (30 ft) above the vault cover blocks for a duration of 30 seconds. The volume of waste released was unspecified but should not have exceeded the 56,800 L (15,000 gal) storage capacity of the vault (Section 2.1.2 in RPP-15808). Wind blew the contamination in a southeast direction and the ground surface was contaminated. The ground was covered with clean soil.

- UPR-200-W-128 occurred in 1971 and is associated with tank 241-U-103. The incident involved the contamination of personnel and the surrounding area when a waste line was cut. No details are provided to describe how the area around the 241-U-103 Tank Pit was affected or the dimensions of the affected area.

- 200-W-95 was created in an effort to consolidate the individually identified contamination areas within the 241-U Tank Farm. 200-W-95 includes UPR-200-W-24, UPR-200-W-128, UPR-200-W-132, UPR-200-W-154, UPR-200-W-155, UPR-200-W-156, and UPR-200-W-157 associated with WMA U, as well as 200-W-91, which is located just outside of the northeast boundary of WMA U. The site is identified as the contaminated soil surrounding the tanks and inside and adjacent to the perimeter fence for the tank farm. The horizontal and vertical extent of the soil contaminated by the previously listed UPRs is unknown.

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 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 WMA U. Under interim status, groundwater monitoring at WMA U has been conducted in accordance with WAC 173-303-400(3), "Dangerous Waste Regulations," "Interim Status Facility Standards" (and, by reference, 40 CFR 265, 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.

An interim status indicator parameter groundwater monitoring program (WHC-SD-EN-AP-012, *40 CFR 265 Interim-Status Ground-Water Monitoring Plan for the Single-Shell Tanks*, Rev. 0) was initiated in 1989 at WMA U. The indicator parameter monitoring program continued until 2000 when WMA U was placed into a groundwater quality assessment monitoring program in accordance with 40 CFR 265.93(d). The groundwater quality assessment was required because specific conductance results in downgradient well 299-W19-41 had exceeded the upgradient critical mean in August 1999 (Section 4.2 in PNNL-13185, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U at the Hanford Site*).

In 2000, a first determination report (PNNL-13282) reported elevated concentrations of chromium and nitrate (and technetium-99) had been historically present in downgradient wells and were increasing in well 299-W19-41 (Section 1.1 in PNNL-13282). The report concluded that elevated specific conductance in well 299-W19-41 was the result of nonhazardous constituents, principally bicarbonate, calcium, chloride, magnesium, sodium, and sulfate that had leached from the vadose by infiltrated surface water in the southern part of WMA U (Section 6.0 in PNNL-13282). While upgradient sources of nitrate were found, such as the cribs and trenches associated with the Plutonium Finishing Plant (PFP) (Section 4.2.3 in PNNL-13282), there was no evidence for upgradient sources of chromium (or technetium-99) (Section 6.0 in PNNL-13282). Therefore, interim status groundwater monitoring at WMA U has since continued under a groundwater quality assessment program. Assessment monitoring plan revisions were

issued to update the well network as wells went dry due to declining water levels and modify the monitoring constituents and sampling frequency. The most recent interim status monitoring plan revision was issued in 2012 (DOE/RL-2009-74, Rev. 1).

Under Revision 9 of the Hanford Facility Dangerous Waste Permit, the SST System treatment, storage, and disposal (TSD) unit, which includes WMA U, 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 (G)(V) to implement the compliance 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), WAC 173-303-806(4)(a)(xx)(B) (hydrogeological information), and WAC 173-303-806(4)(a)(xx)(D) (plume maps).

2.3 Waste Characteristics

WMA U received highly radioactive chemical waste generated by the major spent nuclear fuel reprocessing operations at the Hanford Site. These processes include bismuth phosphate fuel reprocessing, REDOX fuel reprocessing, PUREX fuel reprocessing, and tank farm interim stabilization and isolation activities (Section 2.1.2 in RPP-15808 and WHC-MR-0132, *A History of the 200 Area Tank Farms*).

The dangerous wastes identified on the SST System Permit Application Part A are presented in Table 2-1. Details of waste composition estimates at the suspected time of waste loss events are also provided in Section 3.2 in RPP-35485. Inventory estimates of the waste contents of tanks 241-U-101, 241-U-104, 241-U-110, and 241-U-112 at the time of their respective leaks are included in Table 2-2 (Section 3.2 in RPP-35485).

Table 2-1. Dangerous Wastes in the SST System Hanford Facility RCRA Permit Part A Application

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
D001	Ignitable waste	D034	Hexachloroethane
D002	Corrosive waste	D035	Methyl ethyl ketone
D003	Reactive waste	D036	Nitrobenzene
D004	Arsenic	D038	Pyridine
D005	Barium	D039	Tetrachloroethylene
D006	Cadmium	D040	Trichloroethylene
D007	Chromium	D041	2,4,5-Trichlorophenol
D008	Lead	D043	Vinyl chloride
D009	Mercury	F001	Spent halogenated solvents
D010	Selenium	F002	Spent halogenated solvents
D011	Silver	F003	Spent nonhalogenated solvents
D018	Benzene	F004	Spent nonhalogenated solvents
D019	Carbon tetrachloride	F005	Spent nonhalogenated solvents

Table 2-1. Dangerous Wastes in the SST System Hanford Facility RCRA Permit Part A Application

Dangerous Waste Code	Contaminant Description*	Dangerous Waste Code	Contaminant Description*
D022	Chloroform	WP01	Extremely hazardous waste/persistent dangerous waste
D028	1,2-Dichloroethane	WP02	Dangerous waste/persistent dangerous waste
D029	1,1-Dichloroethylene	WT01	Extremely hazardous waste/toxic dangerous waste
D030	2,4-Dinitrotoluene	WT02	Dangerous waste/toxic dangerous waste
D033	Hexachlorobutadiene	--	--

Source: 11-NWP-054. "Approval of the Single-Shell Tank System Dangerous Waste Permit Application Part A Form, Revision 13" (letter to Scott L. Samuelson, U.S. Department of Energy, Office of River Protection, and Charles G. Spencer, Washington River Protection Solutions, LLC, from Jane A. Hedges), Washington State Department of Ecology, Richland, Washington, June 3.

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

Table 2-2. Nonradiological Waste Profile for WMA U SSTs During Leaks

Analyte	241-U-101 during 1959 Leak (kg)	241-U-104 during 1956 Leak (kg)	241-U-110 during 1975 Leak (kg)	241-U-112 during 1967 Leak (kg)
Aluminum	3.97E+02	0.00E+00	1.71E+02	5.72E+02
Ammonia	2.82E+00	4.27E-01	5.24E+00	9.12E+00
Bismuth	0.00E+00	1.25E+01	1.59E-01	3.08E-01
Butanol	0.00E+00	0.00E+00	1.77E+00	0.00E+00
Calcium	2.62E+00	2.85E+01	9.05E-01	4.21E+00
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Carbonate	4.02E+00	7.09E+03	6.13E+01	3.53E+01
Chloride	5.88E+01	--	2.29E+01	--
Chlorine	--	2.42E+01	--	8.32E+01
Chromium	4.99E+01	3.49E+01	8.33E+00	6.77E+01
Ferrocyanide	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fluoride	2.15E-04	2.69E-03	6.43E+00	1.01E+01
Iron	1.82E+00	1.97E+01	4.96E-01	2.91E+00
Lanthanum	0.00E+00	0.00E+00	3.78E-11	0.00E+00
Lead	0.00E+00	0.00E+00	6.60E-01	1.81E-01
Manganese	5.29E-01	1.23E-04	8.28E-02	7.04E-01
Mercury	5.62E-03	5.76E-02	9.03E-04	7.48E-03
Nickel	1.86E+00	1.97E+01	4.76E-01	2.93E+00
Nitrate	2.42E+03	2.14E+03	6.92E+02	3.59E+03

Table 2-2. Nonradiological Waste Profile for WMA U SSTs During Leaks

Analyte	241-U-101 during 1959 Leak (kg)	241-U-104 during 1956 Leak (kg)	241-U-110 during 1975 Leak (kg)	241-U-112 during 1967 Leak (kg)
Nitrite	6.14E+02	1.96E+02	3.47E+02	9.06E+02
Normal paraffin hydrocarbons	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Phosphate	0.00E+00	1.26E+03	1.53E+01	2.33E+01
Potassium	1.81E+01	5.81E+00	7.04E+00	2.53E+01
Silicon	5.14E+00	2.36E+01	1.45E+00	8.09E+00
Silver	7.92E-04	5.05E-02	9.95E-05	2.05E-03
Sodium	2.22E+03	8.29E+03	8.19E+02	3.25E+03
Sulfate	3.21E+01	2.24E+03	3.25E+01	7.22E+01
Tributyl phosphate	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Uranium	5.38E-01	1.79E+02	1.53E-01	1.57E+00
Zirconium	0.00E+00	0.00E+00	3.95E-02	7.25E-02

Source: Adapted from RPP-35485, *Field Investigation Report for Waste Management Area U*, Table 3-12, Table 3-13, Table 3-17, and Table 3-18.

-- = not analyzed.

2.4 Interim Status Monitoring Network and Sampling History

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

Table 2-3. Interim Status Monitoring Plans

Document	Date Issued	Monitoring Program[a]
WHC-SD-EN-AP-012, Rev. 0, *40 CFR 265 Interim-Status Ground-Water Monitoring Plan for the Single-Shell Tanks*	1989	Indicator Evaluation Program
ECN 150201[b]	1991	
WHC-SD-EN-AP-012, Rev. 1, *40 CFR 265 Interim-Status Ground-Water Monitoring Plan for the Single-Shell Tanks*	1991	Indicator Evaluation Program
ECN 150144	1992	
ECN 172204	1993	
ECN 618171	1994	
PNNL-13185, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U at the Hanford Site*	2000	Groundwater Quality Assessment Program

Table 2-3. Interim Status Monitoring Plans

Document	Date Issued	Monitoring Program[a]
PNNL-13612, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U*	2001	Groundwater Quality Assessment Program
PNNL-13612-ICN-1	2003	
PNNL-13612-ICN-2	2006	
DOE/RL-2009-74, Rev. 0, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*	2011	Groundwater Quality Assessment Program
DOE/RL-2009-74, Rev. 1, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*	2012	Groundwater Quality Assessment Program

a. The Indicator Evaluation Program satisfies the requirements of 40 CFR 265.92(b)(2), (b)(3), (d)(1), (d)(2), and (e), "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Sampling and Analysis." The groundwater quality assessment program satisfies the requirements of 40 CFR 265.93(d)(3) through (e), "Preparation, Evaluation, and Response."

b. ECN 150201, *Engineering Change Notice to WHC-SD-EN-AP-012 Rev 000 Interim Status Groundwater Monitoring Plan for Single-Shell Tanks*, is associated with WHC-SD-EN-AP-012, Rev. 0 and identifies changes that were incorporated in the Rev. 1 plan. Although it references the Rev. 0 plan, ECN 150201 is also incorporated as part of the Rev. 1 plan.

ECN = engineering change notice

ICN = interim change notice

In 1989, the DOE, Richland Operations Office, initiated an interim status groundwater monitoring program at WMA U as described in WHC-SD-EN-AP-012, Rev. 0, based on the interim status indicator evaluation program requirements of 40 CFR 265, Subpart F, and WAC 173-303-400. The 1989 plan addressed interim status monitoring for each of the SST WMAs. For WMA U, the plan identified one upgradient well (299-W18-25) and two downgradient wells (299-W19-31 and 299-W19-32) (Table 3.9 in WHC-SD-EN-AP-012, Rev. 0). Existing well 299-W19-12 was included for information as it had a telescoping screen (two carbon steel casings and a screen [Chapter 3.0, p. 129 in WHC-SD-EN-AP-012, Rev. 0]). Monitoring constituents included the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b), "Sampling and Analysis." In addition, each well was to be sampled one time during the first year of monitoring for an expansive list of metals, anions, pesticides, herbicides, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polychlorinated biphenyls, cyanide, phenol, total dissolved solids (TDS), hydrazine, ammonium ion, dioxins, tritium, uranium, and gamma scan (p. 110, Table 3.1, and Appendix C in WHC-SD-EN-AP-012, Rev. 0).

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*). Sampling at WMA U began in July 1991 (Section 16.1.2 in DOE/RL-92-03).

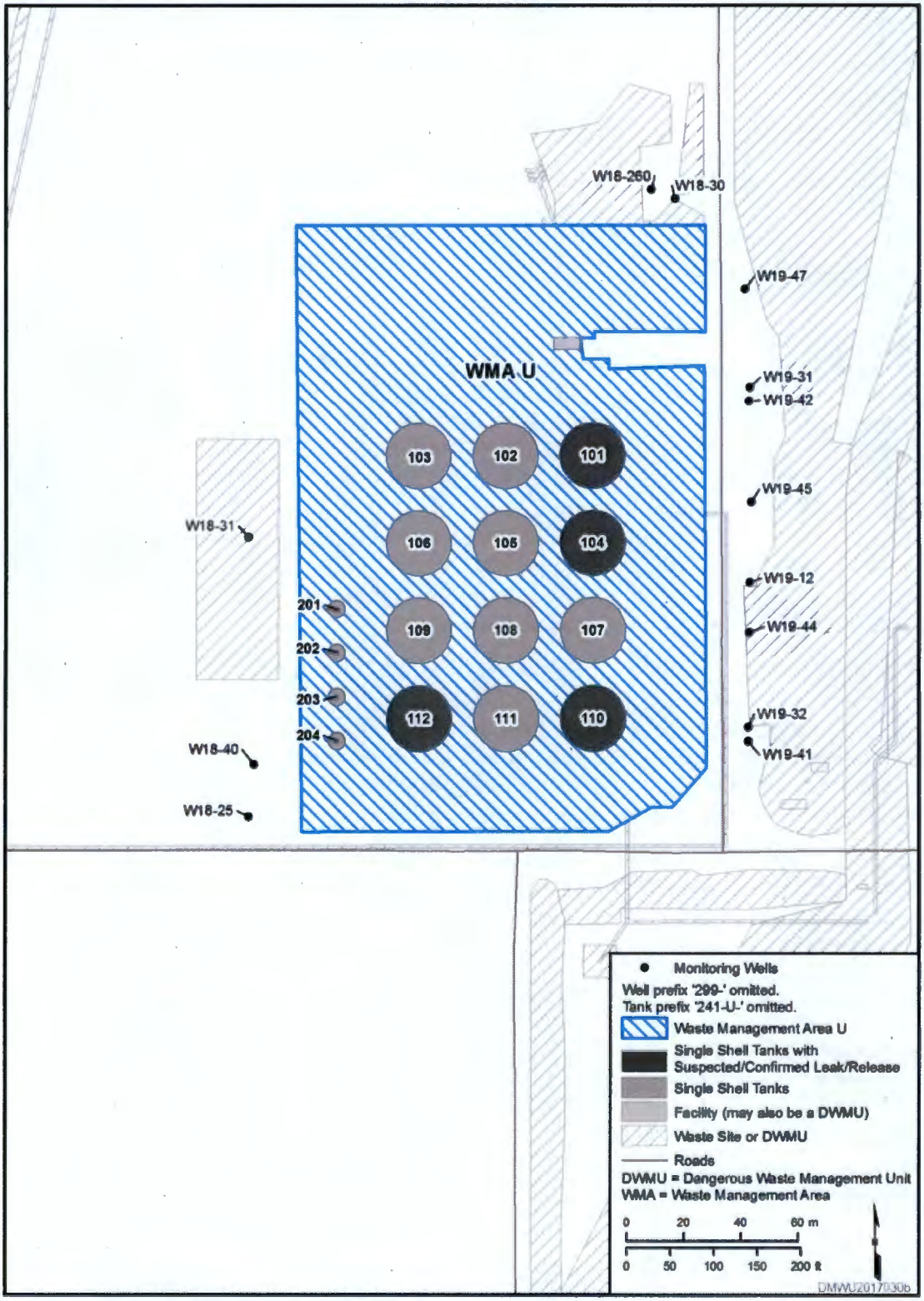


Figure 2-4. Wells Used During Interim Status Monitoring of WMA U

In 1991, WHC-SD-EN-AP-012 was revised (Rev. 1 and ECN 150201, *Engineering Change Notice to WHC-SD-EN-AP-012 Rev 000 Interim Status Groundwater Monitoring Plan for Single-Shell Tanks*) to modify the well network and constituent list. The compliance sampling network comprised one upgradient well (299-W18-25) and two downgradient wells (299-W19-31 and 299-W19-32) (Table 3-9 in WHC-SD-EN-AP-012, Rev. 1). Downgradient well 299-W19-12 was included for water-level measurements and limited nonradionuclide constituents (Table 3-9 in WHC-SD-EN-AP-012, Rev. 1). Crossgradient well 299-W19-1 was included for water-level measurements only (Table 3-9 in WHC-SD-EN-AP-012, Rev. 1). Two new wells (299-W18-30 and 299-W18-31) were planned for WMA U (Table 3-2 in WHC-SD-EN-AP-012, Rev. 1). The constituent list was revised to add site-specific parameters (cesium-137, strontium-90, total uranium, total plutonium, gamma scan, and tritium) (Section 3.4.1.12 and Table 3-11 in WHC-SD-EN-AP-012, Rev. 1).

The groundwater flow direction at WMA U was highly variable throughout the interim status monitoring period due to changing effluent discharge patterns within the 200 West Area and the slow decline of the groundwater mound from U Pond operations and the influence from nearby extraction wells. Groundwater flow was initially to the northeast in 1989 (Section 2.0 in WHC-SD-EN-AP-012, Rev. 0), then to the east/northeast in 1992 (Table 16-10 in DOE/RL-93-09, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1992*), to the northwest in 1994 (Table 4.11-11 in DOE/RL-94-136, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1994*), and then to the southeast in 1996 (Section 5.4.3.3 in PNNL-11470, *Hanford Site Groundwater Monitoring for Fiscal Year 1996*). As flow direction changes were observed, upgradient and downgradient well designations changed accordingly. The hydraulic gradient calculated from 1992 water-level data was 0.00085 (Section 16.4.1.2 in DOE/RL-93-09).

In 1992, ECN 150144, *Engineering Change Notice to WHC-SD-EN-AP-012 Rev 001 Interim Status Groundwater Monitoring Plan for Single-Shell Tanks* (Section 12), added new wells 299-W18-30 and 299-W18-31 as downgradient to WMA U. However, the groundwater flow direction change in 1992 resulted in changing the designation of well 299-W18-31 from downgradient to upgradient (Table 16-1 and Section 16.4.1.2 in DOE/RL-93-09). Well 299-W18-31 was reported as upgradient during the 1990s, except in 1994 and 1995 when it was reported as downgradient.

In 1993, ECN 172204, *Engineering Change Notice to WHC-SD-EN-AP-012 Rev 1 Interim Status Groundwater Monitoring Plan for Single-Shell Tanks*, groundwater monitoring constituents were revised adding total organics, cobalt-60, iodine-129, technetium-99, and TDS. In 1994, ECN 618171, *Engineering Change Notice to WHC-SD-EN-AP-012 Rev 1 Interim Status Groundwater Monitoring Plan for Single-Shell Tanks*, removed several radionuclides (cesium-137, strontium-90, total uranium, total plutonium, and gamma scan), mercury, and metals from the constituent list and added TDS and alkalinity.

When the flow direction changed to the northwest in 1994, the designation of wells was revised and the network comprised three upgradient wells (299-W19-12 [information only], 299-W19-31, and 299-W19-32) and three downgradient wells (299-W18-25, 299-W18-30, and 299-W18-31) (Table 4.11-1 and Section 4.11.1.2 in DOE/RL-94-136). In 1995, additional wells were included for the purpose of measuring water level only (299-W18-33, 299-W19-6, 299-W19-21, and 299-W19-27) (Table 4.11-1 in DOE/RL-96-01, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1995*).

By 1996, the groundwater flow direction changed to the southeast and the network comprised two upgradient wells (299-W18-25 and 299-W18-31) and three downgradient wells (299-W18-30, 299-W19-31, and 299-W19-32) (Table 6.1-14 and Section 5.4.3.3 in PNNL-11470). Upgradient well 299-W19-12 was not included in the network in 1996 and 1997 but was included again as a

downgradient well for information only beginning in 1998 to increase spatial coverage (Section 5.9.2.3 in PNNL-12086, *Hanford Site Groundwater Monitoring for Fiscal Year 1998*).

In 1997, water levels had declined to the point that well 299-W19-32 went dry, well 299-W18-30 was removed from the monitoring network as it was no longer upgradient nor downgradient, and wells 299-W18-25 and 299-W19-31 were expected to go dry by 1999 (Section 5.9.2.3 in PNNL-11793, *Hanford Site Groundwater Monitoring for Fiscal Year 1997*, and Table A.18 in PNNL-12086). In 1999, two new downgradient wells were constructed to replace two wells that were dry or drying (well 299-W19-41 was installed to replace well 299-W19-32, and well 299-W19-42 was installed to replace well 299-W19-31) (Section 2.8.3.7 in PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). The 1999 network comprised two upgradient wells (299-W18-25 and 299-W18-31) and five downgradient wells (299-W18-30, 299-W19-12 [information only], 299-W19-31, 299-W19-41, and 299-W19-42).

The changes in groundwater flow direction over time not only impacted the designations of wells in the network, but necessitated the recalculation of the critical means used for comparison to downgradient wells. Background values were initially established using quarterly monitoring data collected from April 1992 to March 1993 (Table 4.1 in PNNL-13185). Groundwater flow direction was initially to the northeast or north/northeast in 1989 through 1993 but changed to the north and north/northwest (1994 and 1995), and southeast (1996) before resuming an easterly direction in 1997. In 1996, critical means were exceeded for pH (299-W19-31) and total organic halides (TOX) (299-W18-30), but the meaning of the exceedances was uncertain given the flux in groundwater flow directions and resultant uncertainty in the upgradient or downgradient distinctions of the monitoring network wells (Section 6.9.3.3 in PNNL-11470). By 1997, the increase in TOX was determined to be the result of an upgradient carbon tetrachloride plume from PFP (Section 5.9.2.3 in PNNL-11793).

A recalculation of the critical mean for specific conductance in 1999 resulted in nearly a 50% decrease; from 533 µS/cm to 273 µS/cm (Section 4.2 in PNNL-13185). In August 1999, downgradient well 299-W19-41 exceeded the critical mean for specific conductance. Major contributors to the elevated specific conductance were nonhazardous constituents such as bicarbonate, calcium, chloride, magnesium, sodium, and sulfate (Section 1.1 in PNNL-13282). In 1999, it was observed that tank waste constituents chromium, nitrate, and technetium-99 that had historically been present in downgradient wells were increasing in well 299-W19-41 (Section 1.1 in PNNL-13282). Therefore, in 2000, WMA U entered a groundwater quality assessment monitoring program in accordance with 40 CFR 265.93(d) under PNNL-13185. The monitoring network reflected the changes documented in annual groundwater monitoring reports since the last WMA U network change to WHC-SD-EN-AP-012, Rev. 1 (ECN 150144 in 1992). The network comprised two upgradient wells (299-W18-25 and 299-W18-31) and six downgradient wells (299-W18-30, 299-W19-12 [information only], 299-W19-31 [dry], 299-W19-32 [dry], 299-W19-41, and 299-W19-42) (Table 5.1 in PNNL-13185). Wells 299-W19-31 and 299-W19-32 were included in the network even though they were sample dry and 299-W18-25 was expected to go dry in 2000 (Section 5.3.1 in PNNL-13185).

The groundwater quality assessment plan constituents included specific conductance, total organic carbon (TOC), pH, chloride, iron, manganese, sodium, sulfate, and carbon tetrachloride. Site-specific parameters chromium, nitrate, technetium-99, cobalt-60 (from gamma scan), iodine-129, and tritium were included because they were significant mobile constituents of tank waste (Table 5.2 in PNNL-13185). Technetium-99, cobalt-60, iodine-129, and tritium (radiological co-contaminants) were included for use as tracers (Table 5.2 in PNNL-13185). Encroachment of the PFP carbon tetrachloride plume resulted in a number of TOX exceedances that were unrelated to WMA U; therefore, TOX was not included (Section 5.3.2 in PNNL-13185). Additionally, the organic constituents in WMA U tank waste were

mostly complexants used during processing, and chlorinated hydrocarbons were insignificant (Section 5.3.2 in PNNL-13185). Phenols were not included because they were not a constituent of tank waste (Section 5.3.2 in PNNL-13185).

In 2000, the reported designation of well 299-W19-42 changed from downgradient to upgradient but switched back to downgradient in the 2001 report (Table A.12 in PNNL-13404, *Hanford Site Groundwater Monitoring for Fiscal Year 2000,* and Table A.40 in PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*). No discussion of the designation change was provided in either report.

In 2000, a first determination report was issued and concluded that the elevated specific conductance in 299-W19-41 was the result of nonhazardous constituents, principally bicarbonate, calcium, chloride, magnesium, sodium, and sulfate, that had leached from the vadose by infiltrated surface water in the southern part of WMA U (Section 6.0 in PNNL-13282). Upgradient sources of nitrate were found, but no evidence for upgradient sources of chromium or technetium-99 were determined, indicating a source for these constituents within WMA U (Section 6.0 in PNNL-13282). Therefore, an updated groundwater quality assessment plan was issued in 2001 to delineate the concentrations of groundwater contamination and the rate and extent of contaminant migration (Section 1.0 in PNNL-13612, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U*). The network was revised to remove dry wells 299-W18-25, 299-W19-31, and 299-W19-32. The network included one upgradient well (299-W18-31) and four downgradient wells (299-W18-30, 299-W19-12 [information only], 299-W19-41, and 299-W19-42) and proposed one new upgradient and four new downgradient wells (Section 5.2 in PNNL-13612). The constituent list was revised to include specific conductance, pH, temperature, alkalinity, anions (chloride, fluoride, nitrate, nitrite, and sulfate), metals, technetium-99, gross-alpha, iodine-129, tritium, low-level gamma scan, carbon tetrachloride, and chloroform (Section 5.3. in PNNL-13612).

Three of the five planned wells (upgradient well 299-W18-40 and downgradient wells 299-W19-44 and 299-W19-45) were installed in 2001 and added to the monitoring plan in 2003 (PNNL-13612-ICN-1, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U, Interim Change Notice 1,* to Table 5.2 in PNNL-13612). In addition, gross beta was added to the constituent list and iodine-129, carbon tetrachloride, and chloroform were removed (Table 5.2 in PNNL-13612-ICN-1). In 2006, downgradient well 299-W19-47 (installed in 2004) was added to the network and aluminum, gamma scan, tritium, and technetium-99 were removed as monitoring constituents (Table 5.2 in PNNL-13612-ICN-2, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U, Interim Change Notice 2*).

A new groundwater quality assessment monitoring plan was issued in 2011 (DOE/RL-2009-74, Rev. 0, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area U*) that revised the monitoring network and monitoring constituents. The assessment monitoring network included one upgradient well (299-W18-40) and seven downgradient wells (299-W18-30, 299-W19-12 [information only], 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47) (Table 3-2 in DOE/RL-2009-74, Rev. 0). Upgradient well 299-W18-31 was going dry and was included for water-level measurements only (Table 3-3 in DOE/RL-2009-74, Rev. 0).
The monitoring constituents included chromium, nitrate, alkalinity, anions (chloride, nitrate, sulfate), metals (calcium, magnesium, potassium, sodium), and field parameters (pH, specific conductance, temperature, turbidity, water level) (Table 3-2 and Section 3.1 in DOE/RL-2009-74, Rev. 0).
Additionally, the primary nonradiological constituents that were identified as potentially present in SST waste (RPP-23403, *Single-Shell Tank Component Closure Data Quality Objectives*) that were also included in 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, were included for one or more sample events (Tables 3-1 and 3-2 and Section 3.1 in DOE/RL-2009-74, Rev. 0).

Groundwater contaminants at WMA U included chromium, nitrate, and carbon tetrachloride (DOE/RL-2009-74, Rev. 0, Section 2.5.1). By 2009, chromium concentrations had decreased to near the analytical detection limit, with a maximum concentration of 18.9 µg/L at well 299-W19-42 in October 2009. Nitrate was most elevated in the southern portion of the unit, but concentrations were increasing in both downgradient and upgradient wells. During 2009, nitrate concentrations were above the drinking water standard (DWS) (45 mg/L) in at least one sample from downgradient wells 299-W19-12 (information only), 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47. The maximum nitrate concentration was 86 mg/L at well 299-W19-44 in January 2009. Because the downgradient concentrations were greater than upgradient, WMA U was considered a source of nitrate; however, upgradient nitrate sources also affected groundwater quality. Carbon tetrachloride was greater than the DWS of 5 µg/L, but the regional distribution of carbon tetrachloride indicated it originated from liquid waste disposal sites at PFP, located northwest of WMA U.

The 2012 revision to the monitoring plan altered the sampling frequency of network wells (Section 3.1 in DOE/RL-2009-74, Rev. 1). Prior to the revision, each well was sampled on a quarterly frequency. A reduced sampling frequency was shown to provide sufficient resolution to evaluate data trends, in part because of the relatively low groundwater flow velocity estimated at 29 m/yr (95 ft/yr) (Section 3.1 in DOE/RL-2009-74, Rev. 1). Thus, the monitoring approach was revised to sample the upgradient well on an annual basis and the downgradient monitoring wells on a semiannual frequency, in alternating quarters (Section 3.1 in DOE/RL-2009-74, Rev. 1).

The reduced sampling frequency was implemented in 2013 (Section 200-UP RCRA - WMA U in DOE/RL-2014-32, *Hanford Site Groundwater Monitoring Report for 2013*). Also in 2013, downgradient well 299-W18-30 went dry and was replaced by well 299-W18-260 (drilled in 2014 and sampled in 2015) (Section 11.13.2 in DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*).

In 2016, the network consisted of one upgradient well (299-W18-40) and seven downgradient wells (299-W19-12 [information only], 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, 299-W19-47, and 299-W18-260) (Table 3-20 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*). Groundwater flow beneath WMA U is affected by the 200 West pump and treat (P&T) system. While the flow direction in 2016 was similar to previous years (east), the flow direction is expected to turn toward the northeast over time in response to pumping in a nearby extraction well (Section 3.7 in DOE/RL-2016-66). The average 2016 flow rate (0.18 m/d [0.58 ft/d]) was consistent with the 2015 average rate of 0.19 m/d (0.62 ft/d) (Table 3-19 in DOE/RL-2016-12, *Hanford Site RCRA Groundwater Monitoring Report for 2015,* and Table 3-21 in DOE/RL-2016-66).

The dangerous waste constituent chromium is present in the groundwater at WMA U (Table 3-22 in DOE/RL-2016-66). During 2016, chromium was detected in several downgradient wells at concentrations from 4.49 to 34.2 µg/L while the concentration in upgradient well 299-W18-40 was 5.99 µg/L (Section 3.7 in DOE/RL-2016-66). Some chromium contamination may be a result of well screen corrosion as many of the network wells have elevated iron, manganese, and nickel, which indicate stainless steel corrosion (Section 3.7 in DOE/RL-2016-66). However, in wells 299-W19-45 and 299-W19-47 nickel is not routinely detected, while chromium is detected (ranging from 11.2 to 14.5 µg/L in 2016), indicating groundwater contamination (Section 3.7 in DOE/RL-2016-66). Concentrations of nitrate are above the DWS of 45 mg/L in each network well, including the upgradient well. Treated water injected into wells formerly used for the 200-ZP-1 interim action P&T system represents an upgradient

source of nitrate; however, WMA U is also a likely source of nitrate to groundwater given higher concentrations of nitrate downgradient compared to upgradient (Section 3.7 in DOE/RL-2016-66).

3 Geology and Hydrogeology

This chapter briefly describes the local geology and hydrogeology beneath the WMA U area. This information is summarized from Sections 2.4 and 2.5 in PNNL-13612 and Section 2.4 in DOE/RL-2009-74, Rev. 1, and is included to provide a brief overview of the current understanding of the site.

3.1 Stratigraphy

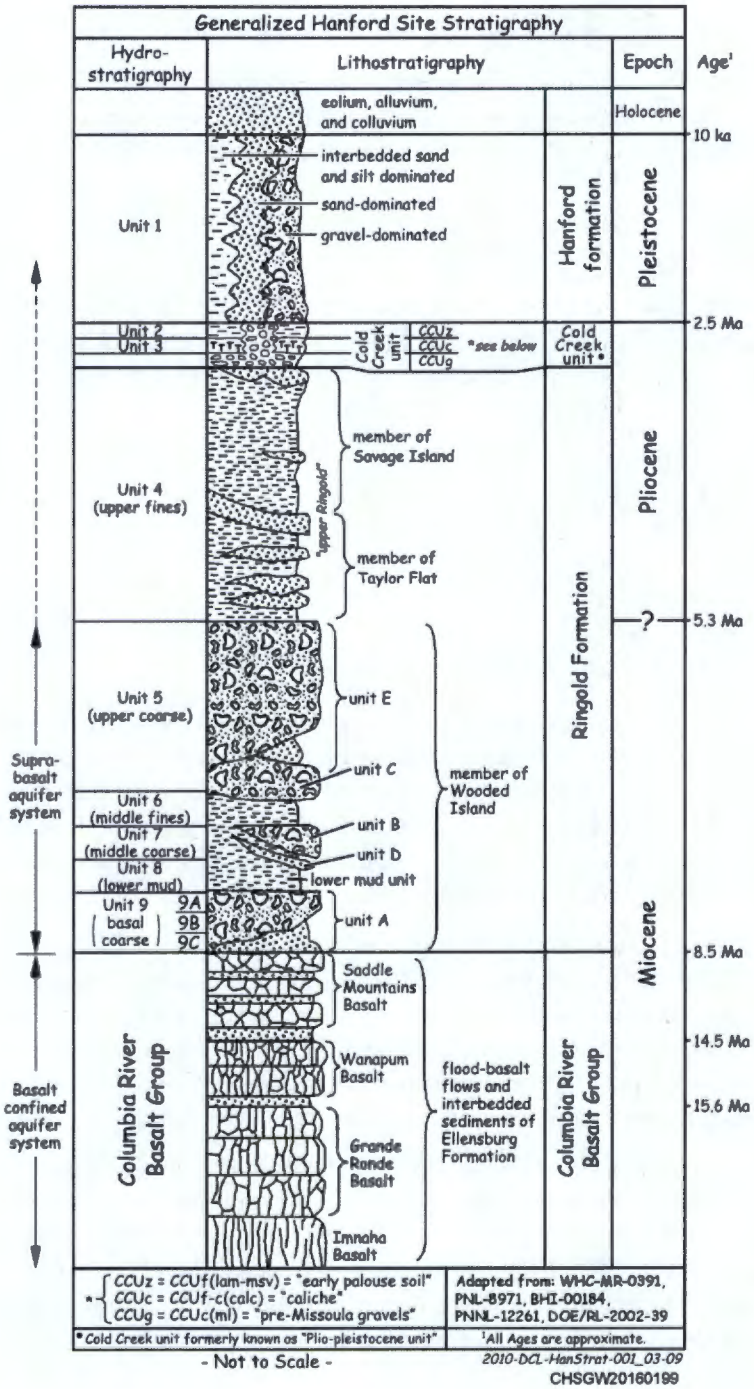
The generalized stratigraphy of the Hanford Site is shown in Figure 3-1. The local stratigraphy beneath WMA U consists of unconsolidated to semi-consolidated sediments overlying basalt bedrock of the Columbia River Basalt Group. Geologic cross sections are shown in Figures 3-2 and 3-3. The sedimentary 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 gravel of the Ringold Unit E
- Fine-grained Ringold lower mud unit
- Sand and gravel of Ringold Unit A (which overlies the basalt)

WMA U is underlain by approximately 150 m (490 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 uppermost unconfined aquifer unit is encountered within the Ringold Formation Unit E beneath WMA U.

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 WMA U the upper portion of the Hanford formation is gravel-dominated and the lower portion is sand and silt dominated. At WMA U, the upper, gravel dominated unit is approximately 16 m (53 ft) thick, and the Hanford formation has a total thickness of approximately 35 m (115 ft).

The CCU, which separates the Ringold Formation from the Hanford formation, is divided into two distinct sequences at WMA U. 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 WMA U.



Note: Complete reference citations are provided in Chapter 11.

Figure 3-1. General Stratigraphy at the Hanford Site

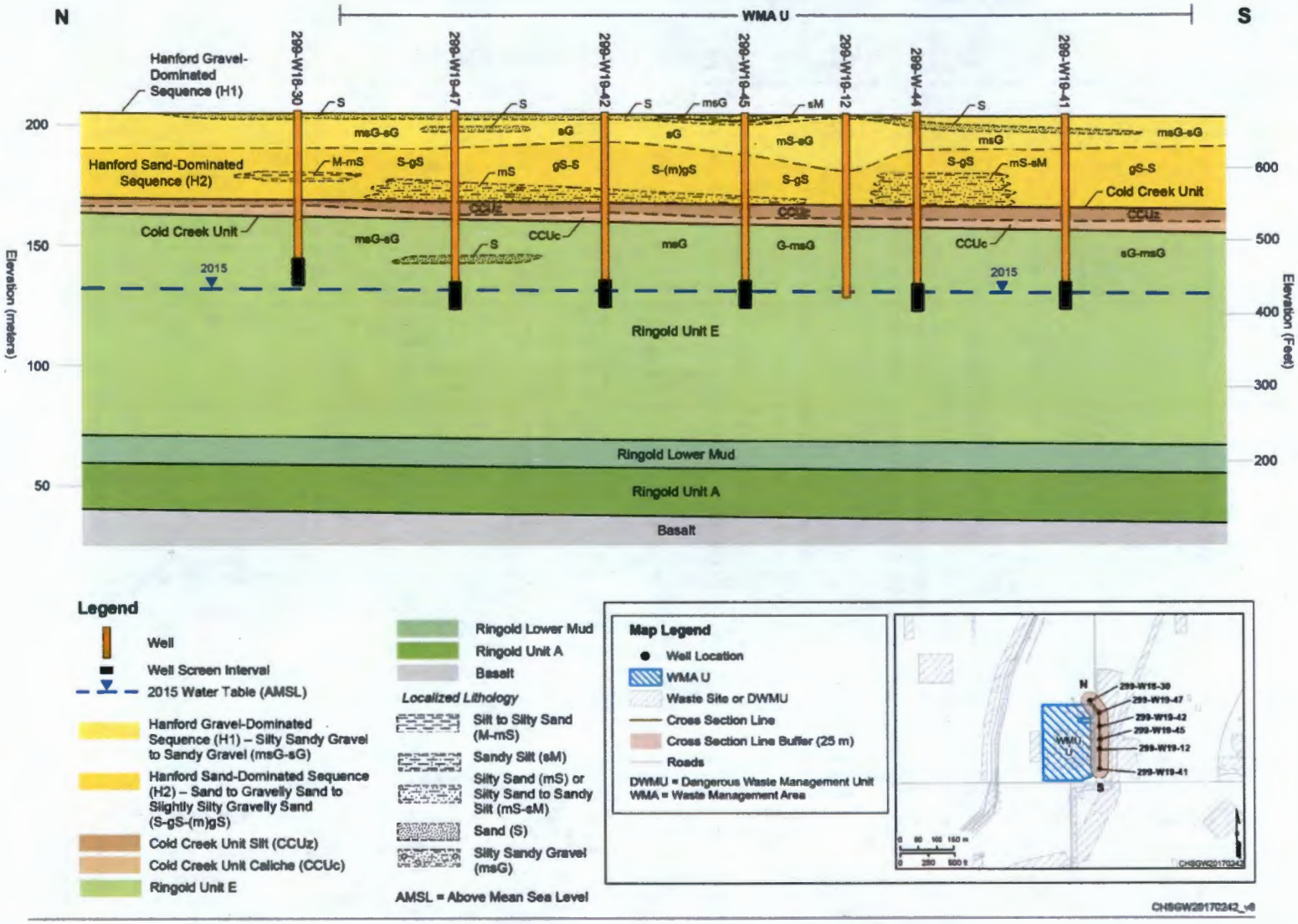


Figure 3-2. North to South Cross Section for WMA U

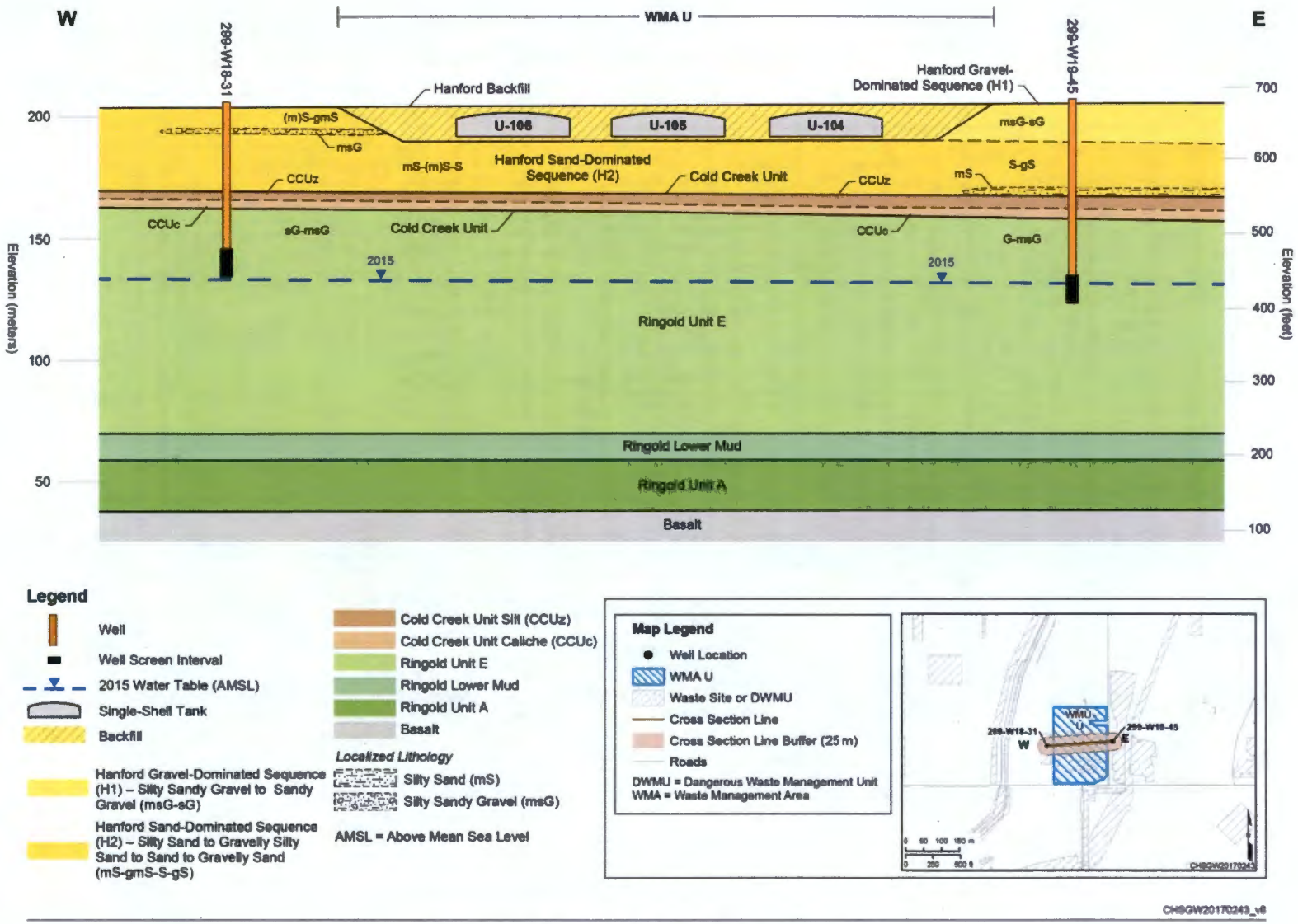


Figure 3-3. East to West Cross Section for WMA U

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, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*, 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 WMA U belongs entirely to the 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 WMA U 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 70.6 m (231 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*, Rev. 4) isolating the confined aquifers from potential releases from WMA U. The unconfined aquifer is approximately 70 m (230 ft) thick.

The saturated hydraulic conductivity of the Ringold E unit underlying WMA U is 5 m/d (16.4 ft/d) (Table 4-9 in CP-47631). Section 7.4 in PNNL-13378, *Results of Detailed Hydrogeologic Characterization Tests – Fiscal Year 1999*, gives a saturated hydraulic conductivity of 6.12 m/day (20.1 ft/day) 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 WMA U because of the units' very low hydraulic conductivities (Section 5.0 in PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*).

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 30 m (98.4 ft) bgs, would slow the downward movement of water and may divert it to the southwest, the direction the top of the unit is dipping beneath the WMA. 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.

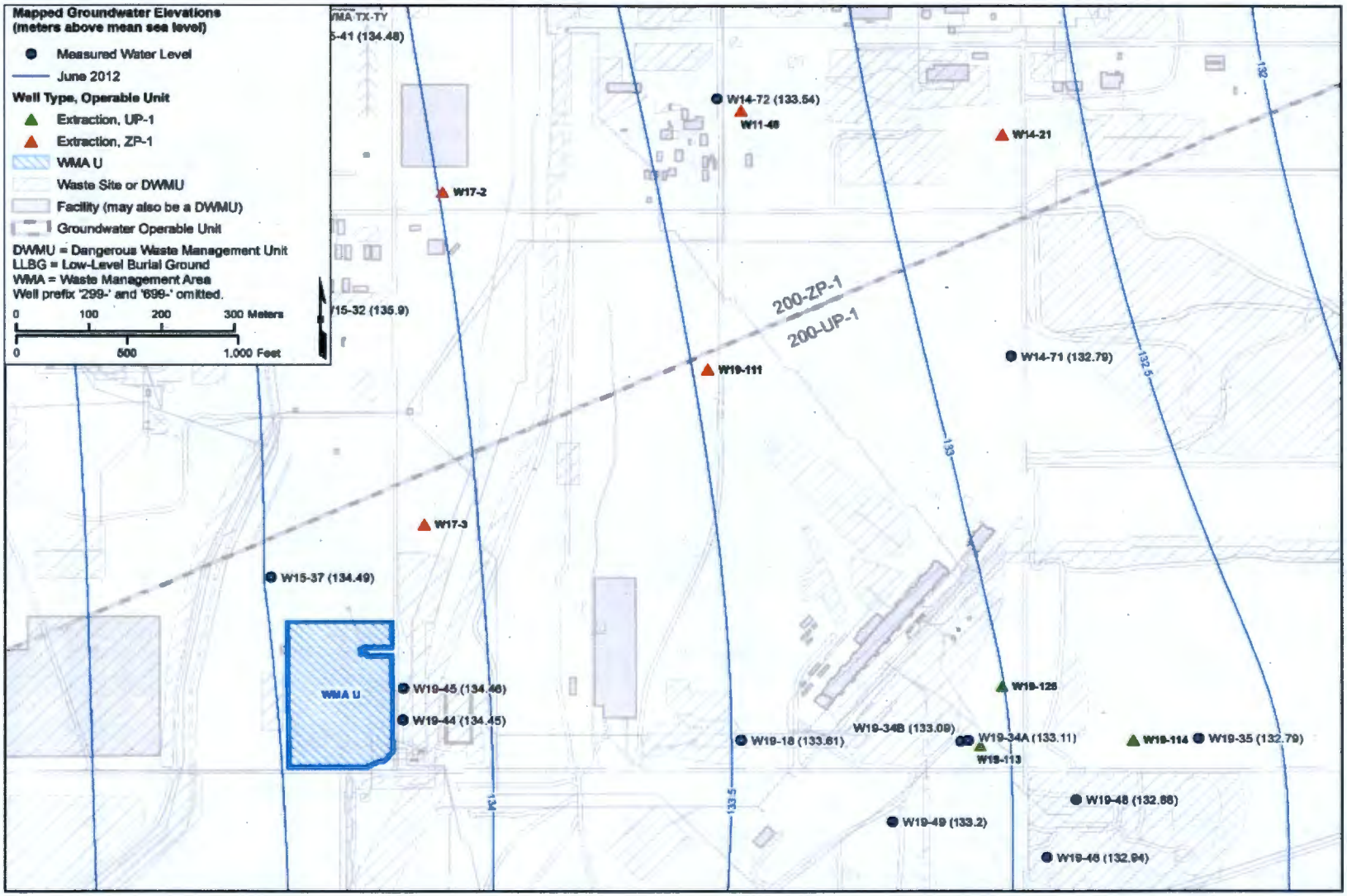
3.3 Groundwater Flow System

Elements of the groundwater flow system beneath WMA U 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 WMA U have varied greatly over the past several decades due to changing wastewater disposal in areas surrounding the WMA. Between 1950 and 1970, the groundwater flow direction beneath the WMA varied between southeast, east, and northeast, depending on effluent disposal volumes to the former 216-T-4 Pond to the north of the WMA and the former 216-U-10 Pond to the southwest (Sections 3 and 4 in PNNL-16069, *Development of Historical Water Table Maps of the 200 West Area of the Hanford Site (1950-1970)*). 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 to the west of the WMA and the 216-U-14 Ditch to the east (see Figure 2-1 for waste site locations). The effluent volume discharged to the 216-Z-20 Crib declined in 1992, and the flow direction beneath the WMA reversed to westerly because discharges to the 216-U-14 Ditch became dominant. Discharges to both sites had ceased by 1996, and the flow direction has been toward the east-northeast since that time.

Baseline groundwater levels were evaluated in two dimensions by interpolating water-level data obtained during June 2012, at which time no groundwater remedy was operating. Figure 3-4 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 2.5×10^{-3} m/m in 2012 with an average linear velocity of 0.089 m/d (0.292 ft/d) (Table 3-1 in SGW-55438, *Hanford Site Groundwater Monitoring for 2012: Supporting Information*).



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

Figure 3-4. Water Elevation Contours in June 2012 Prior to Startup of the 200 West P&T

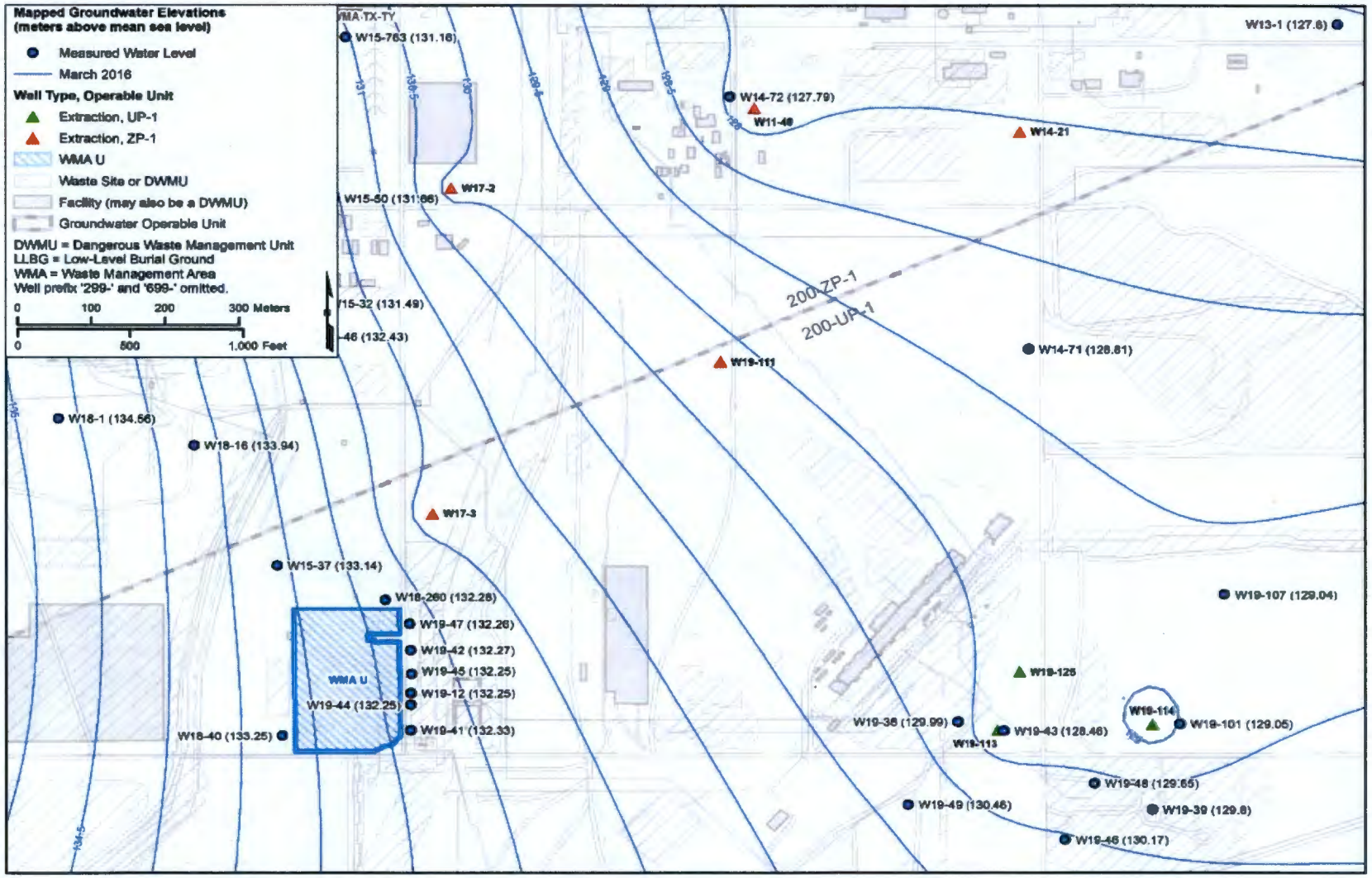
3.3.2 Hydrologic Conditions Due to Operation of the Pump and Treat Remedy

Water levels in the monitoring wells declined an average of 0.54 m/yr (1.79 ft/yr) from 2013 to 2015 (Section 11.13.2 in DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*). Water levels continued to decline in 2016 at an average rate of 0.37 m/yr (1.21 ft/yr) (Section 11.12.2 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 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-northeast beneath WMA U (Figure 3-5). Groundwater flow is affected by the 200 West P&T remedy, which began operating in 2012. The system extracts and treats contaminated groundwater. One extraction well (299-W17-3) is located near WMA U approximately 150 m (490 ft) north-northeast. Drawdown around this well accounts for the increased gradient at WMA U. The extraction well is shown on the March 2016 water table map (Figure 3-5). The hydraulic gradient beneath WMA U is estimated to be 5.0×10^{-3} m/m based on a trend surface analyses performed on four sets of water-level measurements at WMA U during 2016. The average groundwater flow rate during 2016 of 0.18 m/d (0.58 ft/d) was consistent with the 2015 average rate of 0.19 m/d (0.62 ft/d) (Section 11.12.2 in DOE/RL-2016-67). Groundwater flow rate and direction are further described in Section 4.3.



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

Figure 3-5. March 2016 Water Elevation Map for WMA U

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4 Contaminant Migration Conceptual Model

The following summary of a conceptual model of tank leak/release pathways to the groundwater is derived from information found in Section 5 in PNNL-13282, Section 3.2 in PNNL-13612, and Section 6.4 in RPP-35485.

4.1 Vadose Zone

The vadose zone at WMA U is approximately 70.6 m (236 ft) to 74.9 m (246 ft) thick and consists of (from top to bottom) the Hanford formation, the CCU, and the Ringold Formation. The lower hydraulic conductivity of the CCU (Table 3-1) is likely to slow downward movement of moisture and contaminants because of the finer textured sediment and associated calcium carbonate cementation that results in a small hydraulic conductivity of the CCU. Although the CCU is clearly a restriction to vertical migration of water (and associated dissolved contaminants) beneath WMA U, it is not impermeable and contaminated water can eventually reach the underlying groundwater. This is indicated by the apparent presence of contaminants from WMA U in groundwater at the site.

The unsaturated sediments above the water table affect how waste solutions move through the soil, how much is retained in the sediment column, and how much contamination eventually reaches the water table. The source of contamination for the WMA is liquid waste released to near-surface or subsurface sediments. These liquids would be expected to move through the sediment under both saturated and unsaturated conditions, depending on the volume of liquid released. In addition to expected lateral distribution in relatively homogeneous portions of the formation, lateral spreading may occur at changes in soil texture and hydraulic conductivity. Small volume leaks would tend to be retained in the vadose zone near the leak point. Larger releases would be expected to move deeper in the soil, spreading laterally as the wetting front moves downward.

4.2 Soil Moisture Factors

Tank leak/release events typically began with rapid discharge of some waste fluid volume into the subsurface from a point of release likely having a small spatial extent (on the order of inches to rarely feet). This discharge temporarily increases the moisture content of the unsaturated soil, particularly at the point of release. Typical release points may include poorly sealed openings in the tank structure, ruptured areas of steel tank liners nearby underlying concrete shell fractures, and breaks in waste transfer lines. Free liquids in soil move downward generally by gravity and move laterally typically by the forces of soil capillarity. The initial rate of liquid movement and the volume of soil that is eventually wetted by any particular release is a function of the volume of the leak, its duration, and the initial moisture content of the surrounding soil. The hydraulic conductivity of damp and/or wet soil is substantially higher than dry soil. Subsurface soil characterization at WMA U (Section 4.2.1 in PNNL-17163, *Characterization of Direct Push Vadose Zone Sediments from the 241-U Single-Shell Tank Farm*) indicated that much of the subsurface soil was relatively wet (i.e., wetter than the natural moisture content of soil in an arid environment).

Migration process at SST sites are anticipated to occur, for the most part, in partially saturated soils because leak/release volumes were not sufficient to fill the soil pore spaces for an appreciable length of time or very far from the point of entry. This condition is referred to as "unsaturated flow." In addition to vertical flow, lateral flow may occur under both saturated and unsaturated conditions due to the effects of capillary action and due to the effects of wetting front encountering zones of varying hydraulic conductivity. In formations such as those encountered in the Hanford Site, soil layers with different hydraulic properties tend to be layered more or less horizontally by sediment deposition processes. Consequently, flow in the lateral direction could occur at numerous depth intervals within the vadose zone.

External sources of water or other liquid may drive the contamination further downward. Infiltration of water from precipitation and unintentional, manmade releases such as leaking water lines may move residual waste remaining in the soil downward to the groundwater. Another potential source of water was discharges to nearby wastewater disposal sites: the 216-Z-20 Crib and Z Ditches to the west, and the 216-U-14 Ditch to the east (Section 3.3.3 in RPP-35485). These historical discharges likely created substantial areas of perched water atop the CCU; these perched units may have migrated laterally beneath WMA U, providing additional driving force for historical releases from the WMA. Historical observations of perched water during drilling wells in the vicinity of these waste sites, and others, indicates the possibility of historical perched water migration.

4.3 Hydrogeologic Considerations

Prior to startup of the 200 West P&T system in 2012, the groundwater flow direction under WMA U was east at a calculated rate (using the Darcy relationship) of 0.08 m/d (0.26 ft/d) (Section 3.3 in DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*). In 2015, the groundwater flow direction beneath the WMA was generally east to northeast as a result of groundwater extraction and injection for the 200 West P&T with a calculated groundwater velocity of 0.04 to 0.50 m/d (0.15 to 1.6 ft/d) (Section 11.13.2 in DOE/RL-2016-09).

Pump and treat 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 WMA U in the simulations described in Chapters 5 through 7 of this report.

4.4 Groundwater Chemistry

Under the current groundwater flow regime, contaminants reaching the groundwater from a release at WMA U would migrate as dissolved contamination plume(s) toward the east-northeast with the groundwater flow (Figure 3-5). The average groundwater flow rate for 2016 has been estimated at 0.18 m/d (0.59 ft/d) (Section 3.3.2). Section 6.4 in RPP-35485 discusses the conceptual models of tank leak/release pathways to the groundwater at WMA U in more detail.

- The following contaminants are present in the aquifer at WMA U:
  - Chromium
  - Carbon tetrachloride
  - Nitrate
  - Technetium-99

- WMA U is the apparent source of groundwater contamination limited to the downgradient (east) side of the tank farm (Chapter 6.0 in PNNL-13282). During 2016, chromium was detected in several downgradient wells at concentrations from 4.49 to 34.2 µg/L. The concentration in upgradient well 299-W18-40 was 5.99 µg/L. Conditions related to corrosion of stainless steel well components can also result in detectable chromium in groundwater samples. Corrosion-related chromium, however, is typically accompanied by iron, nickel, manganese, and occasionally other metals at definable concentrations relative to the proportion of the metals in the steel alloy. This condition has not been confirmed at WMA U.

- While dissolved chromium (generally present as the chromate hexavalent chromium ion) is highly mobile in the aquifer, it can migrate more slowly than the movement of moisture in the vadose zone beneath the tank farms, at least initially following release from a tank. This has been attributed to a reduction process where tank fluids dissolve divalent iron minerals in the sediment. The iron then reacts with the soluble hexavalent chromium, reducing it to trivalent chromium, which precipitates as an insoluble iron chromium hydroxide (Zachara et al., 2007, "Geochemical Processes Controlling Migration of Tank Wastes in Hanford's Vadose Zone"). This reaction may explain the current low concentrations of chromium in the groundwater. In the aquifer, dissolved chromium migrates to the east-northeast at the calculated groundwater flow rate of 0.18 m/d (0.59 ft/d).

- Concentrations of the nondangerous constituent nitrate are above 45 mg/L in all network wells, including the upgradient well. The upgradient nitrate source is treated water injected into wells formerly used for the 200-ZP-1 interim action P&T system. This injected water was treated for VOCs but still contained nitrate (Section 3.3.5 of DOE/RL-2011-118). The concentration in upgradient well 299-W18-40 was 79.7 mg/L, and the trend has been increasing since this well was drilled in 2001. Because nitrate in some downgradient wells are higher than the upgradient well, it is likely that WMA U is also a source of nitrate to the groundwater.

WMA U is a source of technetium-99 groundwater contamination (Section 4.2.4 in PNNL-13282). Although technetium-99 is not regulated under RCRA, it is mentioned in this discussion because the pattern of concentration changes of technetium-99 in wells down gradient of WMA U strongly parallels the behavior of nitrate in those wells. Concentrations in many downgradient wells are stable or slowly increasing, with the exception of well 299-W19-45 in which concentrations have increased substantially since 2011. During 2016, concentrations in this well increased to 8,730 pCi/L from the 2015 maximum of 6,950 pCi/L. During 2016, technetium-99 also exceeded the 900 pCi/L cleanup level for the 200-UP-1 OU in wells 299-W19-12 (information only), 299-W19-42, 299-W19-47, and 299-W18-260, with a maximum of 1,720 pCi/L in well 299-W18-260. The groundwater contamination at WMA U is believed to result from multiple sources in the WMA (Table 4-2 in HNF-EP-0182). The contamination is within the 200 West P&T capture zone.

4.5 Summary of Vertical Contaminant Distribution

Dangerous waste constituents specific to release from WMA U are not present in groundwater at depth based on historical monitoring. Evaluation of vertical distribution data is limited to the location of WMA U within the context of regional plumes present in 200-UP-1 OU including contaminant plumes originating from WMA U. Available vertical distribution data are limited to one well (299-W18-260) completed northeast of WMA U and samples collected during drilling. See Figure 4-1 for well location in relation to WMA U. This well was installed in September and October, 2014. The lack of observations and measurements introduces substantial uncertainty in interpreting correlation between individual well data and the WMA U operations.

Evaluated constituents were limited to available nonradiological vertical data associated with surrounding wells. Vertical profile samples were analyzed for carbon tetrachloride and nitrate, representing wide spread contaminants in 200-UP-1 OU, and present near WMA U.

During drilling of well 299-W18-260, groundwater samples were collected from the borehole at selected depths and analyzed by field and/or laboratory methods. Laboratory data were selected where both field and laboratory data were available for the vertical contaminant distribution plot. See Figure 4-2 for the observed vertical distribution of identified contaminants.

Well 299-W18-260 exhibits few measurements of vertical characterization data, consisting of carbon tetrachloride and nitrate at five sample depths collected at elevations between 2.7 m (8.9 ft) and 26.3 m (86.3 ft) below the 2017 water table. Based on vertical characterization data, contaminants are present within the upper sections of the unconfined aquifer; consistent with the presence of multiple sources and extents of regional plumes. Well 299-W18-260 exhibits an increase in carbon tetrachloride and nitrate concentrations beginning about 2 m (6.6 ft) and 8 m (26.2 ft), extending to 20 m (65.6 ft) and 25 m (82.0 ft), respectively, below the 2017 water table.

In summary, the WMA U is located within the regional 200 West Area plumes and within the local-scale plumes. It is additionally impacted by the current, local 200-UP-1 P&T and 200 West P&T well network operations. Based on the limited data available, the vertical distribution of plume concentrations do not appear to penetrate the entire depth of the aquifer. Available data for the well are not sufficiently representative to evaluate vertical plume migration from a release from WMA U.

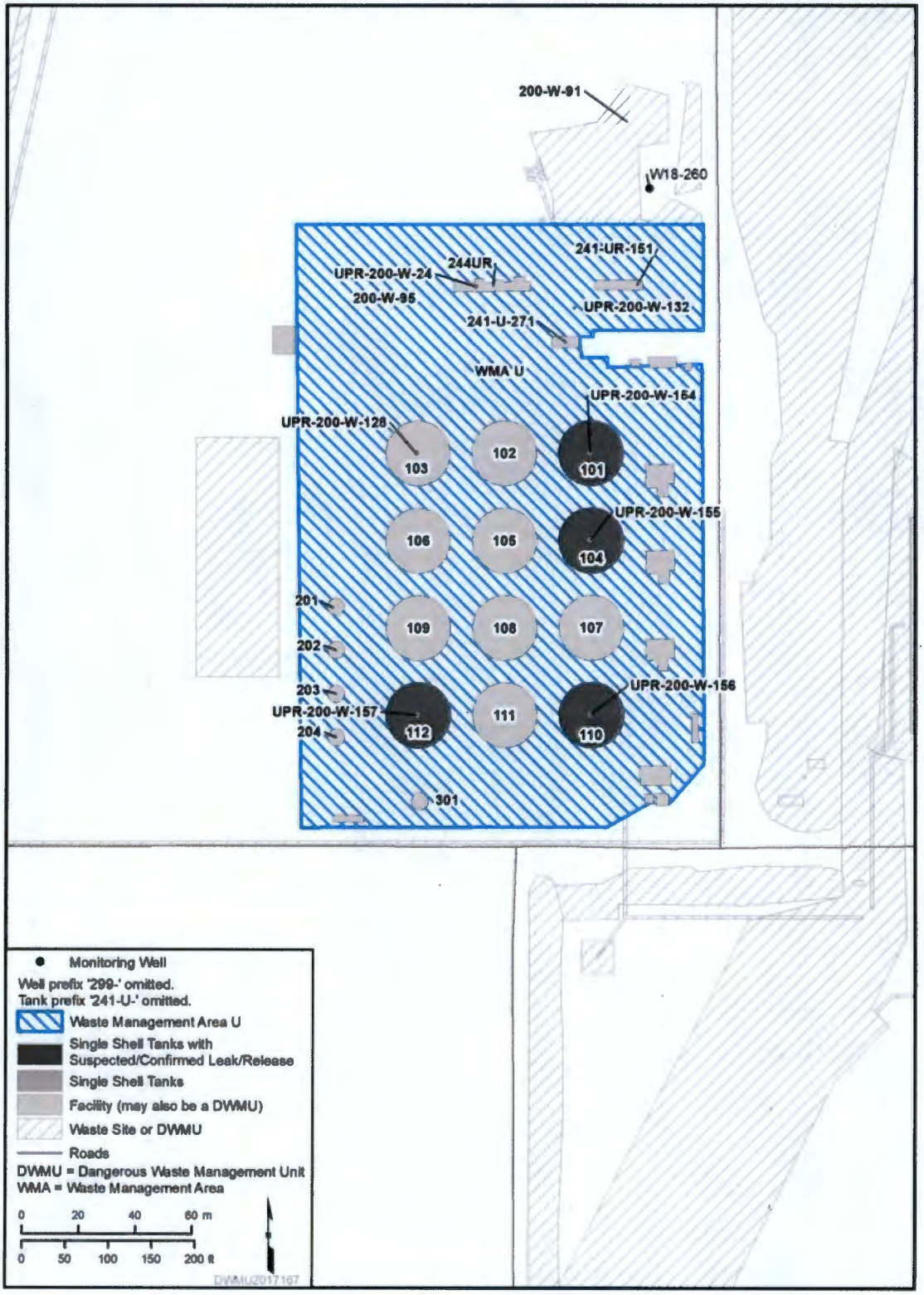


Figure 4-1. Wells Used During Interim Status Monitoring Including Vertical Contaminant Characterization Well Locations

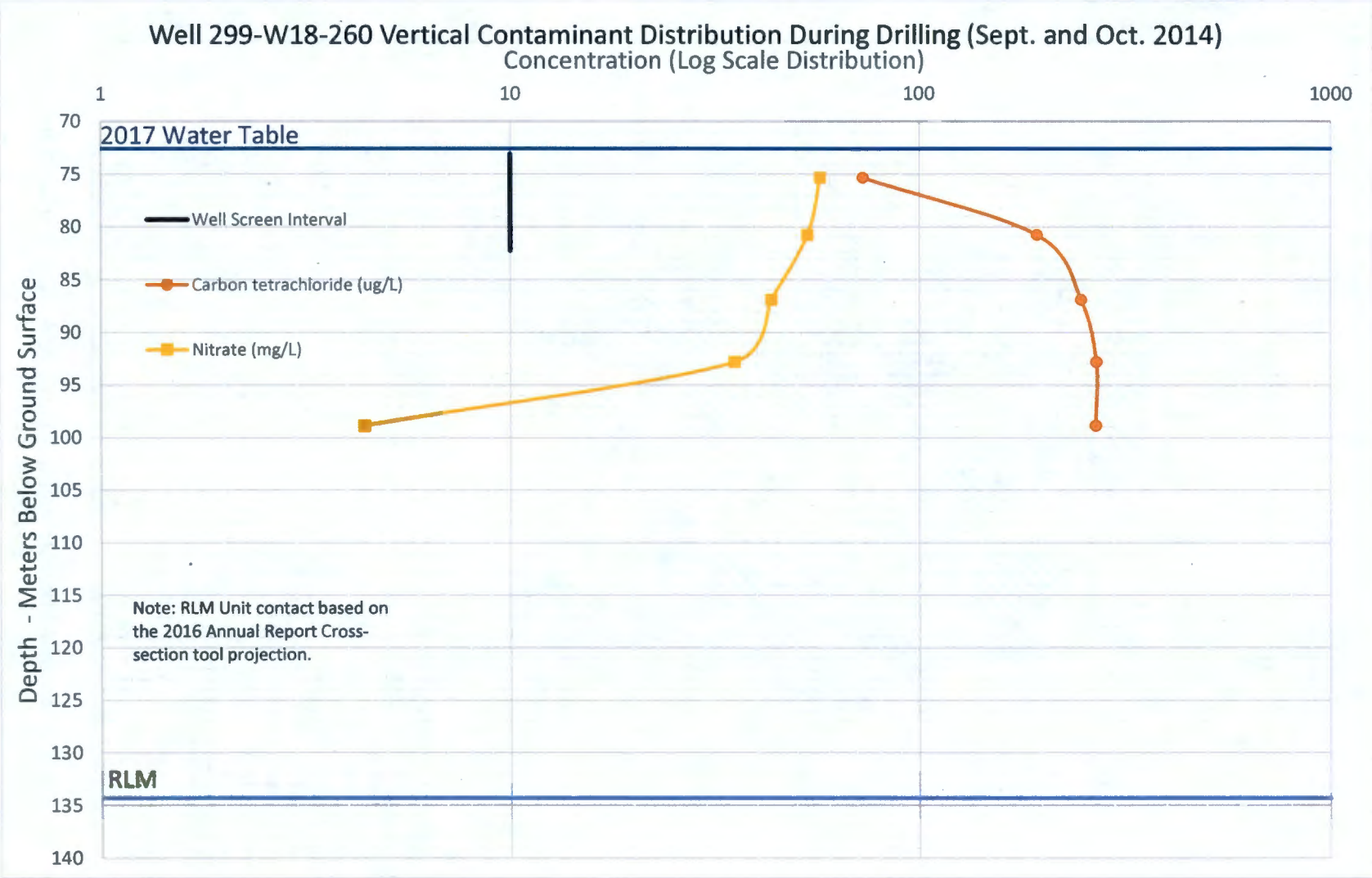


Figure 4-2. Vertical Contaminant Distribution Well 299-W18-260

5 Groundwater Flow Simulations

Groundwater flow simulations were conducted to evaluate the groundwater monitoring network for WMA U (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 (Figure 5-1) are documented in Table 3-20 in DOE/RL-2016-66. 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 WMA U.

5.1 Central Plateau Groundwater Model

The model package report describing the CPGWM 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.

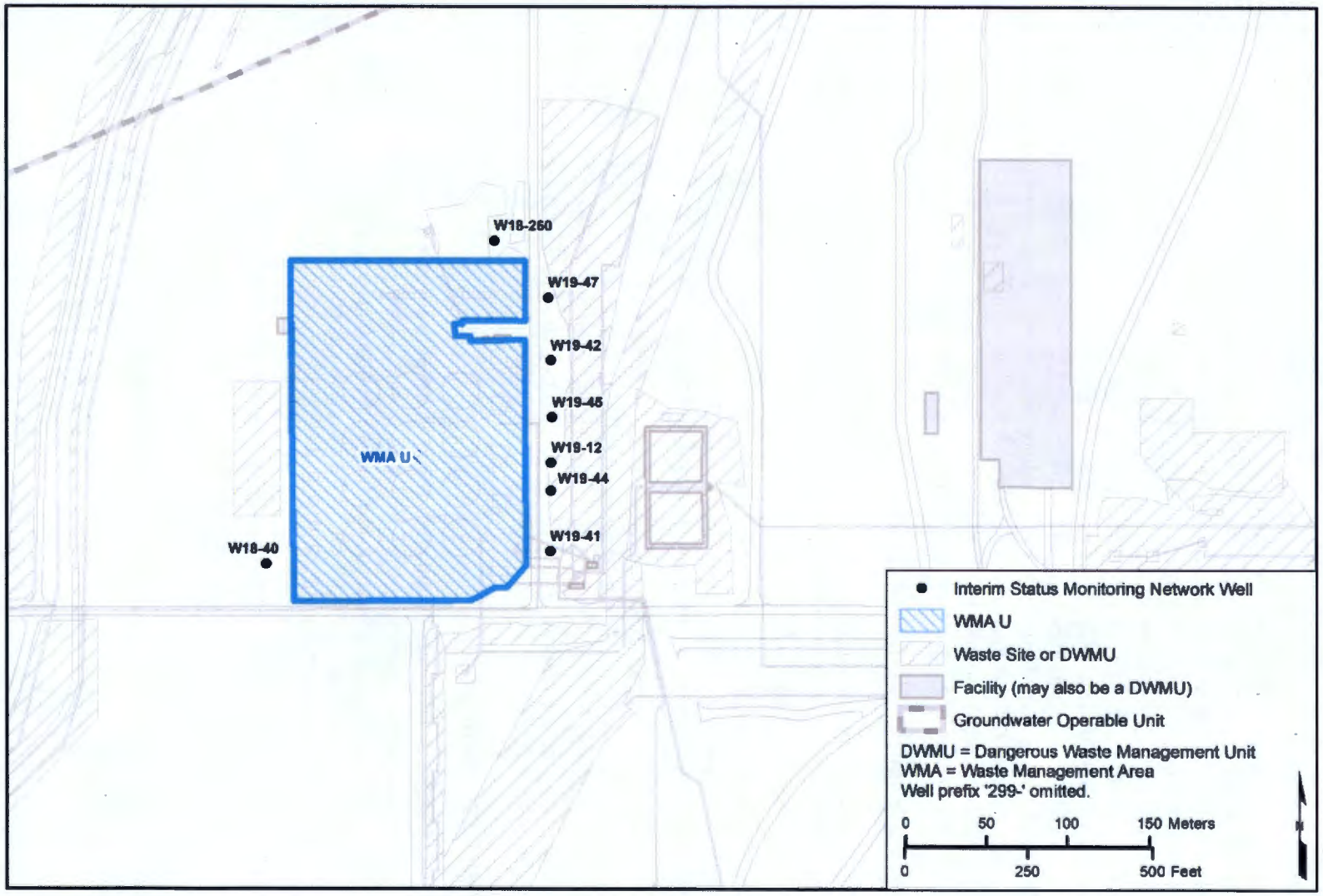
Contaminant transport is simulated using the Modular Three-Dimensional Multi-Species Transport Model (MT3DMS) code. MT3DMS was developed specifically for use with MODFLOW to simulate contaminant advection, dispersion, sources and sinks, and chemical reactions in groundwater systems.

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 upon 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 3-20 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*.

Figure 5-1. Interim Status Groundwater Monitoring Network

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

Table 5-1. Simulation Scenarios

Scenario	P&T System Capacity[a]	Sub-Scenario	Description	Scenario Weight (%)
1	2,305 gal/min (8,725 L/min)	A	Current conditions[b].	55
		B	Injection well 299-W10-35 operating at 50%.	5
		C	Injection well 299-W10-35 not operating.	3
		D	Injection well 299-W15-226 operating at 50%.	3
		E	Injection well 299-W15-226 not operating.	3
		F	Injection wells 299-W10-35 and 299-W15-226 not operating.	1
		G	Injection well 299-W10-36 not operating.	2
		H	Injection wells 299-W10-36, 299-W10-35, and 299-W15-226 not operating.	1
		I	Injection well 299-W6-14 not operating.	3
		J	Injection well 299-W6-16 not operating.	3
		K	Injection wells 299-W6-14 and 299-W6-16 operating at 50%.	3
		L	Injection wells 299-W6-14 and 299-W6-16 not operating.	1
		M	Injection wells 299-W18-41 and 299-W15-229 not operating.	2
		N	Injection wells 299-W15-29, 299-W18-36, 299-W18-38, and 299-W18-39 not operating.	3
		O	Injection wells 299-W15-228, 299-W15-229, 299-W15-29, 299-18-44, 299-W18-36, and 299-W15-29 operating at 50%.	5
		P	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 operating at 50%.	5
		Q	Injection wells 299-W15-229, 299-W15-29, 299-18-44, and 299-W18-36 not operating.	1
		R	Injection wells 299-W18-41, 299-W18-39, 299-W18-38, 299-18-42, and 299-18-43 not operating.	1
2		A	2,500 gal/min, injection rates rebalanced.	55

Table 5-1. Simulation Scenarios

Scenario	P&T System Capacity[a]	Sub-Scenario	Description	Scenario Weight (%)
	2,500 gal/min (9,464 L/min)	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
2 (cont.)	2,500 gal/min (9,464 L/min)	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 pathline 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 = 2,000 gal/min 200-ZP-1 + 305 gal/min 200-UP-1= 2,305 gal/min; Scenario 2 pumping rate = 2,180 gal/min 200-ZP-1 + 320 gal/min 200-UP-1 = 2,500 gal/min.

b. Current conditions as defined in Appendix G.

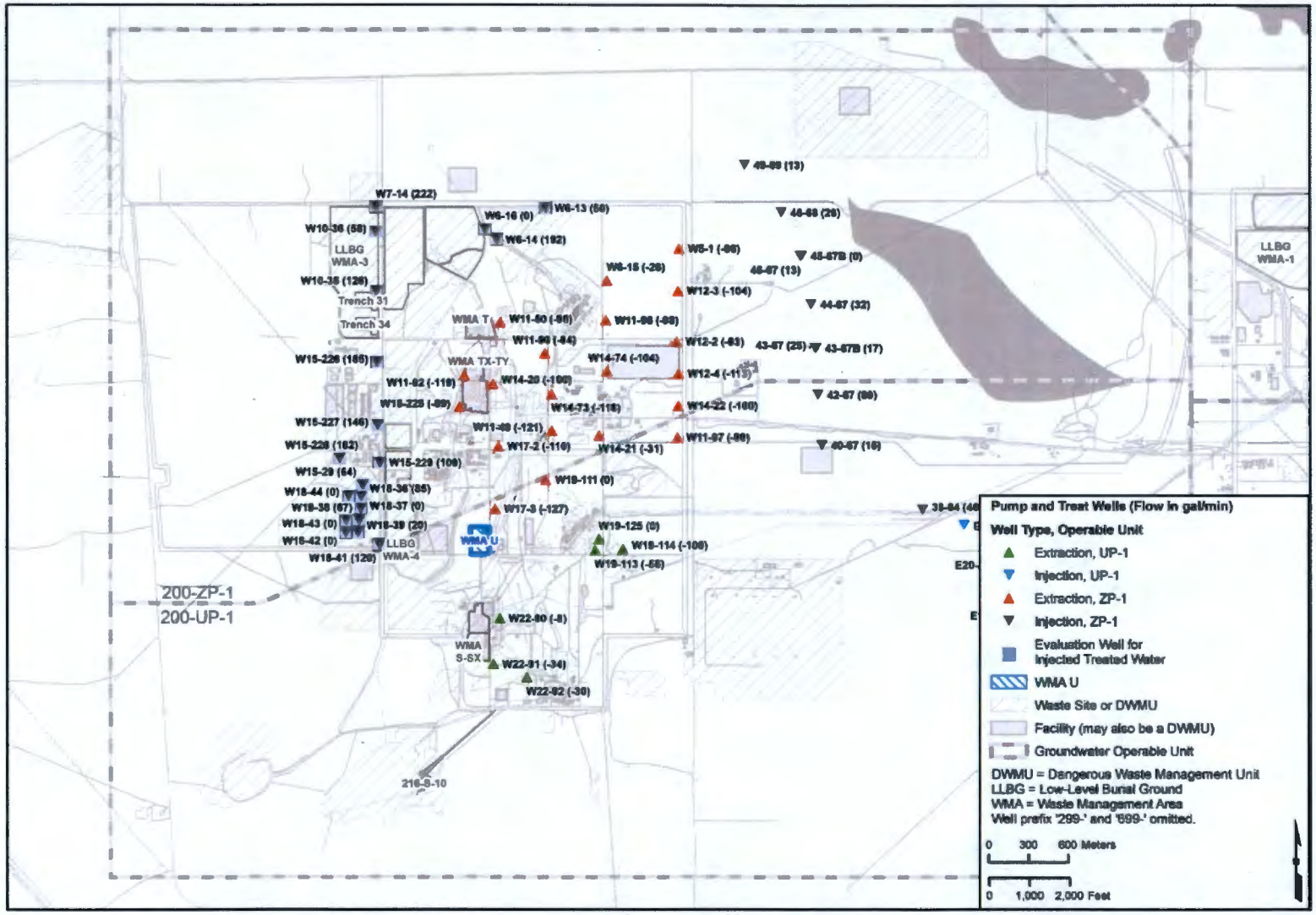


Figure 5-2. Locations and Average Pumping Rates (for December 2016) of 200 West P&T System Wells

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 and 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 WMA U 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 ECF-200W-17-0070 (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 elevations) (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 WMA U. The results of those simulations were used to evaluate the efficacy of the groundwater monitoring network to detect hypothetical releases from WMA U and to evaluate the efficacy of the monitoring network to determine whether increases in contamination from known releases are occurring.

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 or changes in concentration from a known release at WMA U. The simulations also account for the hydraulic influence of the 200 West P&T system extraction and injection wells. The simulations performed and output produced during the evaluation of the monitoring well network are described briefly in this chapter. Additional details about the modeling including software used, inputs, and assumptions are described in Appendix F and in Appendix G.

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

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 WMA U 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 WMA U 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 predominantly 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/day	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 WMA U, 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 perimeter of each of the 12 SSTs located in WMA U. The particle release locations are shown in Figure 6-1 in Appendix G. These "focused releases" reflect hypothetical leaks from the SSTs that reach the water table. This release scenario does not incorporate any aspects of transport through the overlying vadose zone. Once released to the water table, the particle movement is then predominantly horizontal, with minor components of vertical migration in response to very limited infiltration from groundwater recharge and the operation of nearby extraction and injection wells.

In all sub-scenarios for scenarios 1 and 2, particles were released annually and tracked through to the end of fiscal year (FY) 2037, which is when the 200-ZP-1 groundwater P&T remedy component is expected to cease operation in accordance with EPA et al., 2008, *Record of Decision Hanford 200 Area*

200-ZP-1 Superfund Site Benton County, Washington. For scenario 3, which evaluates conditions after cessation of the P&T system operations, the initial release to the water table is the end of FY 2037, after which 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 WMA U 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 WMA U 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 flow rates and directions all explicitly include the effects of injection. 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 to be produced.
- 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 WMA U 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.

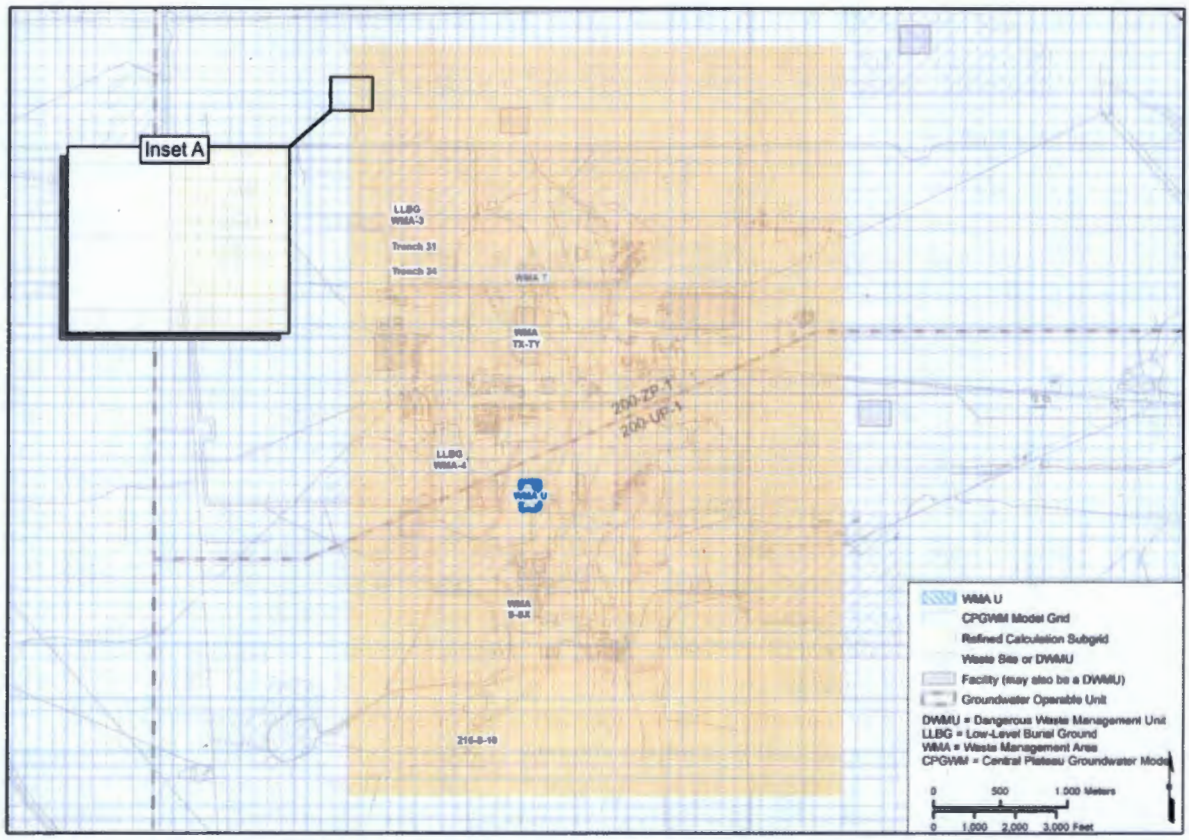


Figure 6-1. Location of Calculation Subgrid in Relation to 200 West Area Facilities Evaluated in Appendix F

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 WMA U 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 either 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 WMA U, unit concentrations representing the hypothetical contaminant release were released at the water table in four model grid cells representing WMA U (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 created 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 WMA U and to detect increases in contamination from known releases from the facility under varying 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 are derived from the calculations described in Chapter 6 that 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.

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

- Injected treated water dilution breakthrough curves – Time-series plots for each monitoring well of simulated treated water concentrations from treated water injected at 200 West P&T system injection wells.
- Release concentration breakthrough curves – Time-series plots for each monitoring well of simulated unit contaminant concentrations from the hypothetical release in the CPGWM model grid cell(s) beneath the facility'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 for a release from the facility. The relative detectability map is a combination of all the particle count maps within each scenario, which gives more 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 injected treated water dilution and release concentrations can be compared to evaluate which well locations will likely have higher dilutions from injected treated water and which will likely have more detectable concentrations from releases from the facility. The breakthrough curves for the existing monitoring wells are discussed in Section 7.1.

Differences between transport modeling and particle-tracking methods can result in variations in outputs. Those variations are apparent when comparing the release unit plume maps created using transport modeling and the particle-tracking maps created using particle-tracking. The maps show the results from 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 maps and

particle-tracking maps are included in the 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 WMA U would most likely migrate and be detectable. The relative detectability maps are discussed in Section 7.2. Section 7.3 presents an evaluation of the proposed monitoring well, and Section 7.4 presents the conclusions to the monitoring well network evaluation.

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.

For monitoring wells 299-W18-40, 299-W18-260, 299-W19-12, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47 (Figure 5-1), injected treated water dilution breakthrough curves and release concentration breakthrough curves 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 show the sub-scenario A, which is considered to represent the most likely future operating scenario. No release concentration breakthrough curve is included for upgradient well 299-W18-40.

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 that 200 West P&T system operating conditions of 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 injection treated water dilution up to 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-W18-260, 299-W19-12, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47, respectively, for scenario 1. Figure 7-8 shows the injected treated water dilution breakthrough curve for upgradient monitoring well 299-W18-40. 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 breakthrough curves at each monitoring well are generally consistent for the various sub-scenarios, suggesting that varying the injection well operations generally has minimal influence on the treated water observed at downgradient monitoring wells. This is likely due to the significant distance between the majority of the injection wells and the WMA U monitoring network wells. For all the evaluated monitoring well locations, the curves for sub-scenarios N and R, which represent extreme operational conditions in southernmost injection wells, were the primary outliers. These sub-scenarios have weights of 3% and 1%, respectively, indicating relatively low probability of occurrence. The results for scenario 2 (included in Appendix G) were similar to those for scenario 1.

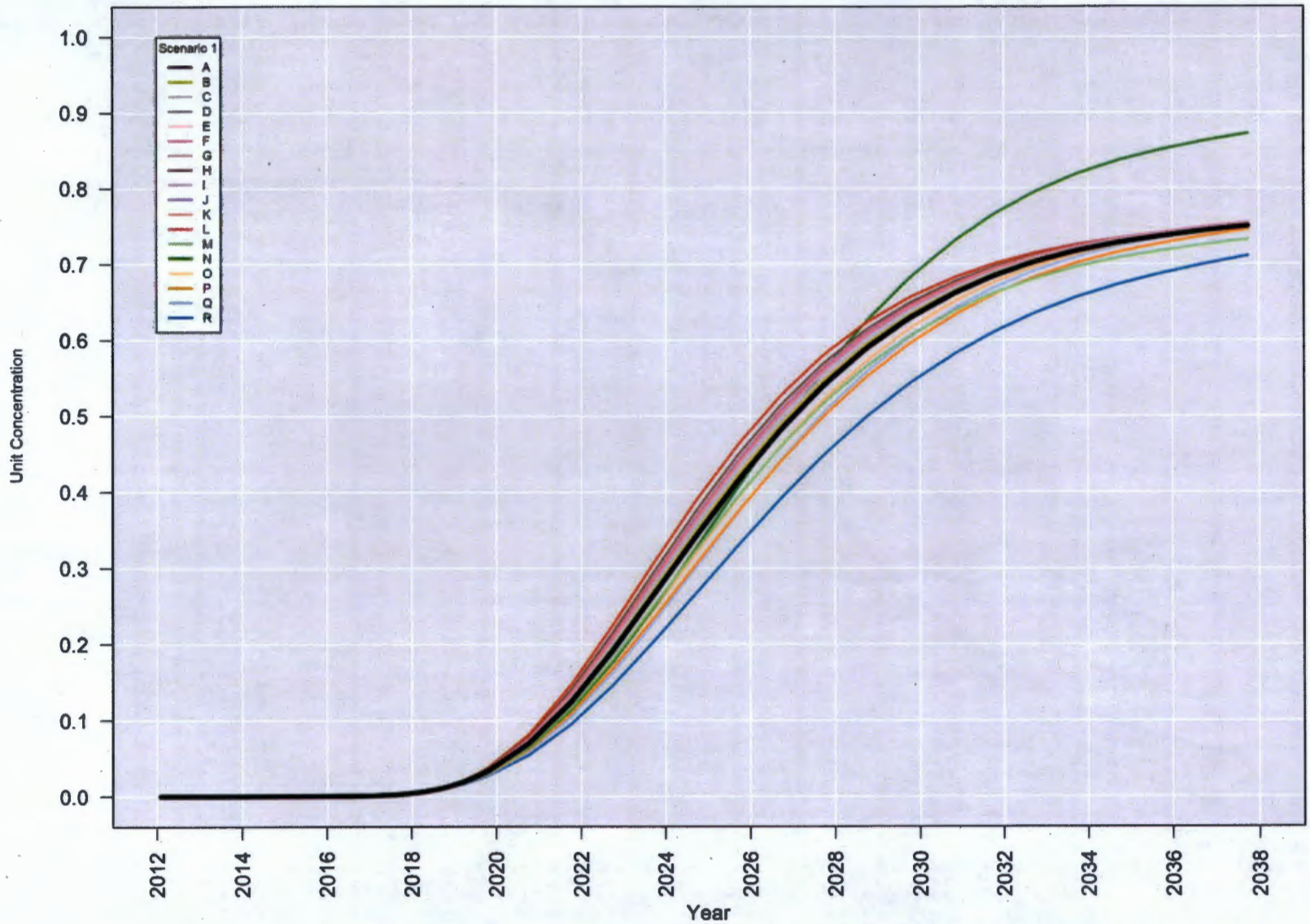


Figure 7-1. Injected Treated Water Dilution Breakthrough Curves at Monitoring Well 299-W18-260

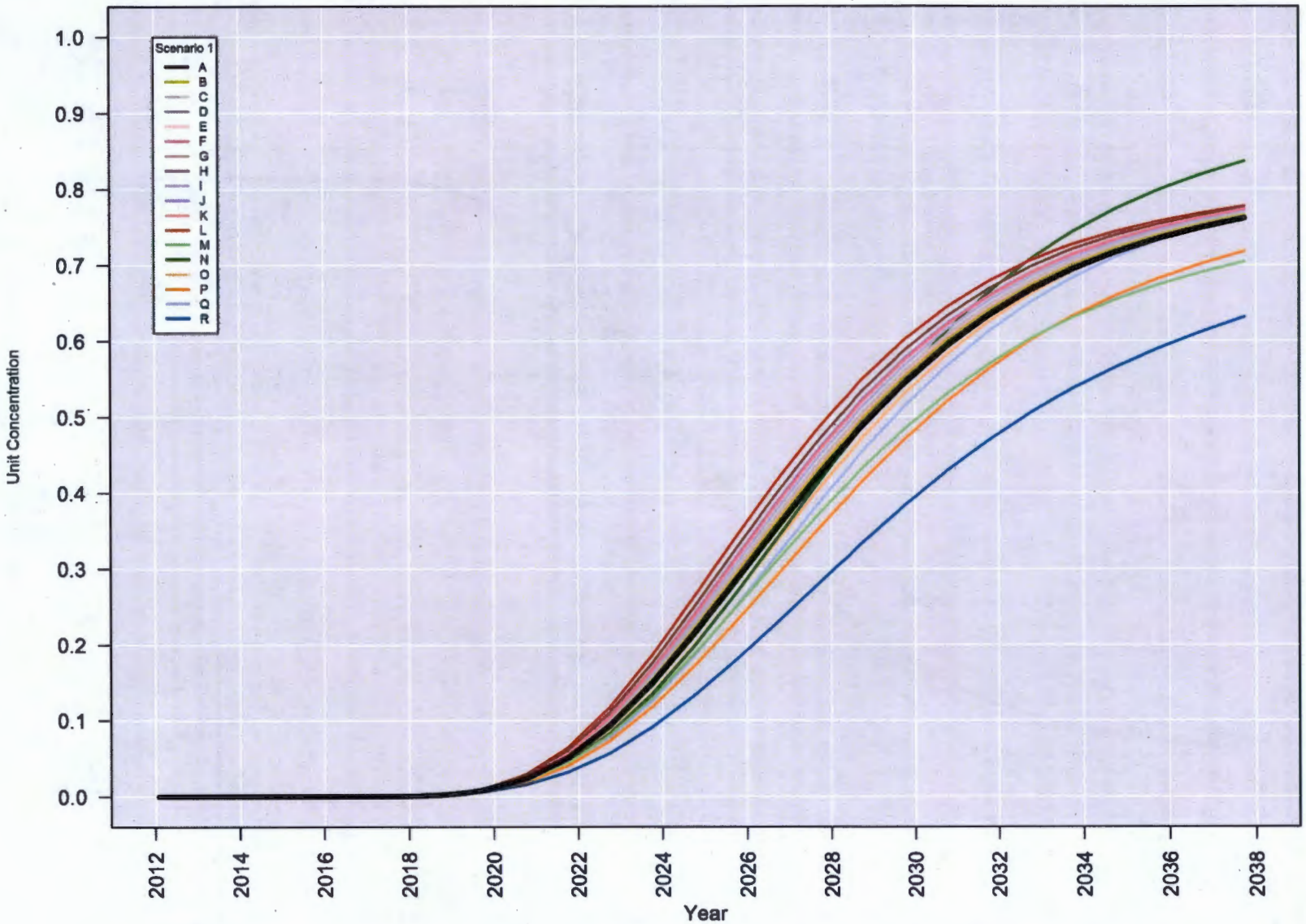


Figure 7-2. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, at Monitoring Well 299-W19-12

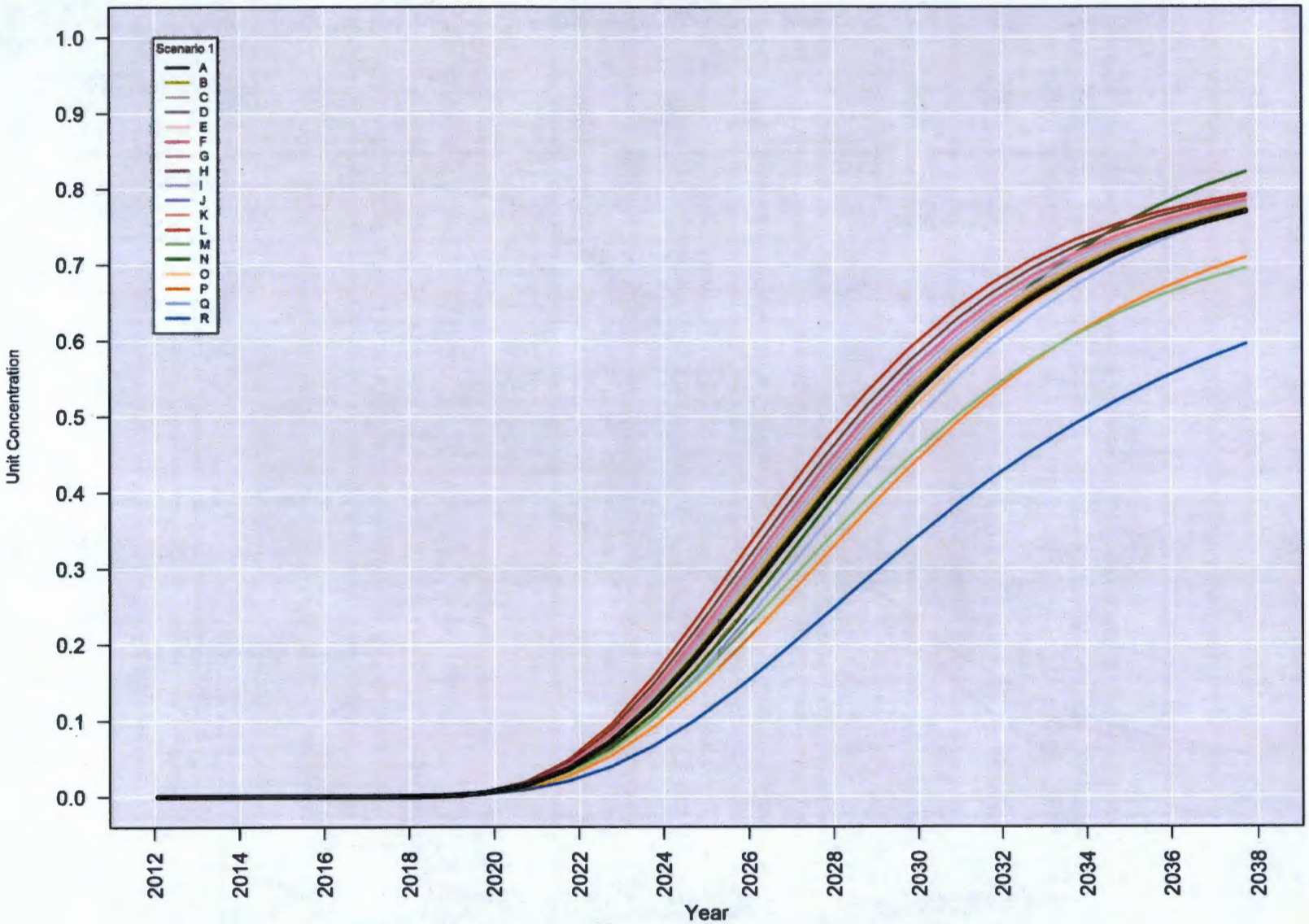


Figure 7-3. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, at Monitoring Well 299-W19-41

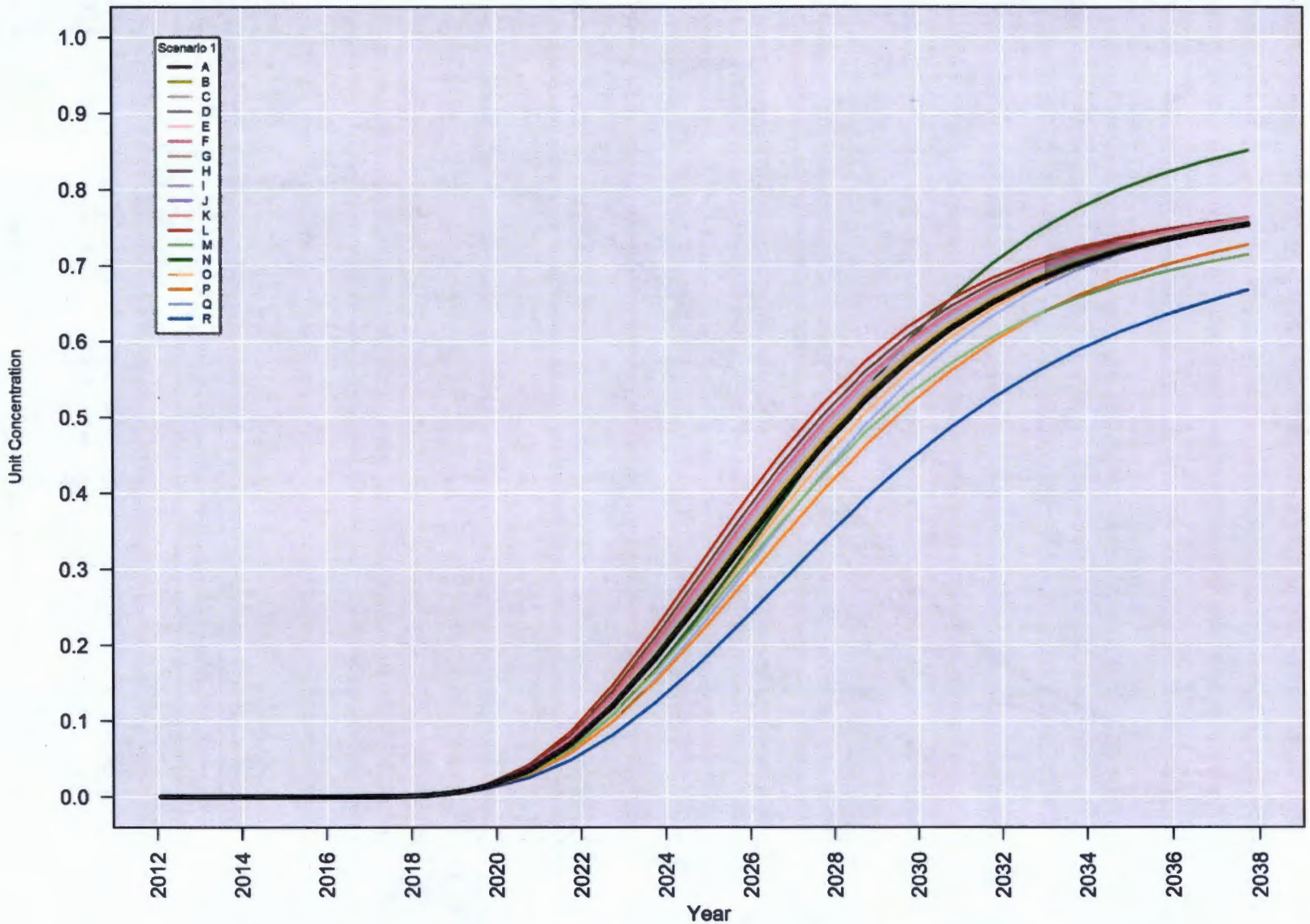


Figure 7-4. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, at Monitoring Well 299-W19-42

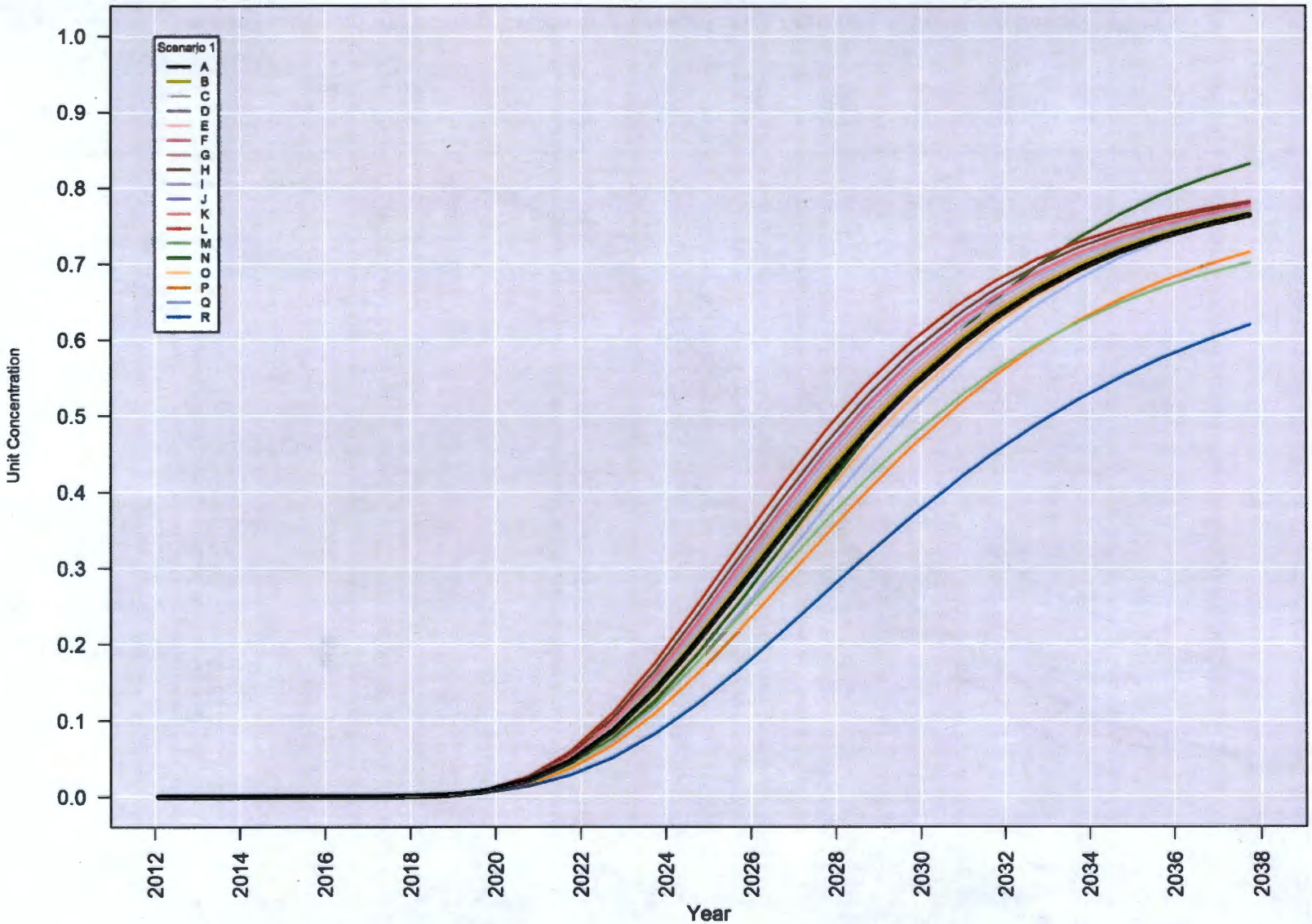


Figure 7-5. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, at Monitoring Well 299-W19-44

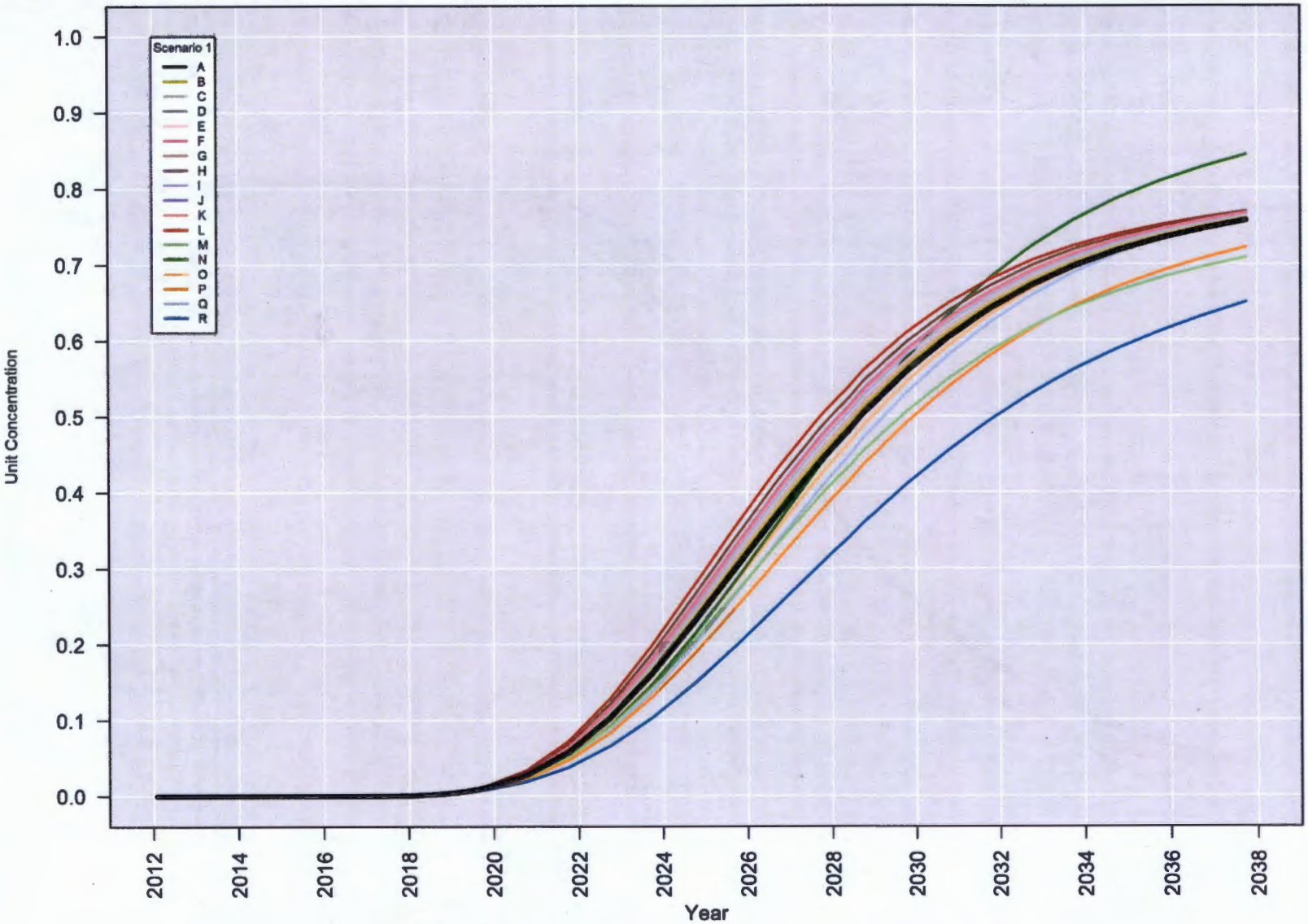


Figure 7-6. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, at Monitoring Well 299-W19-45

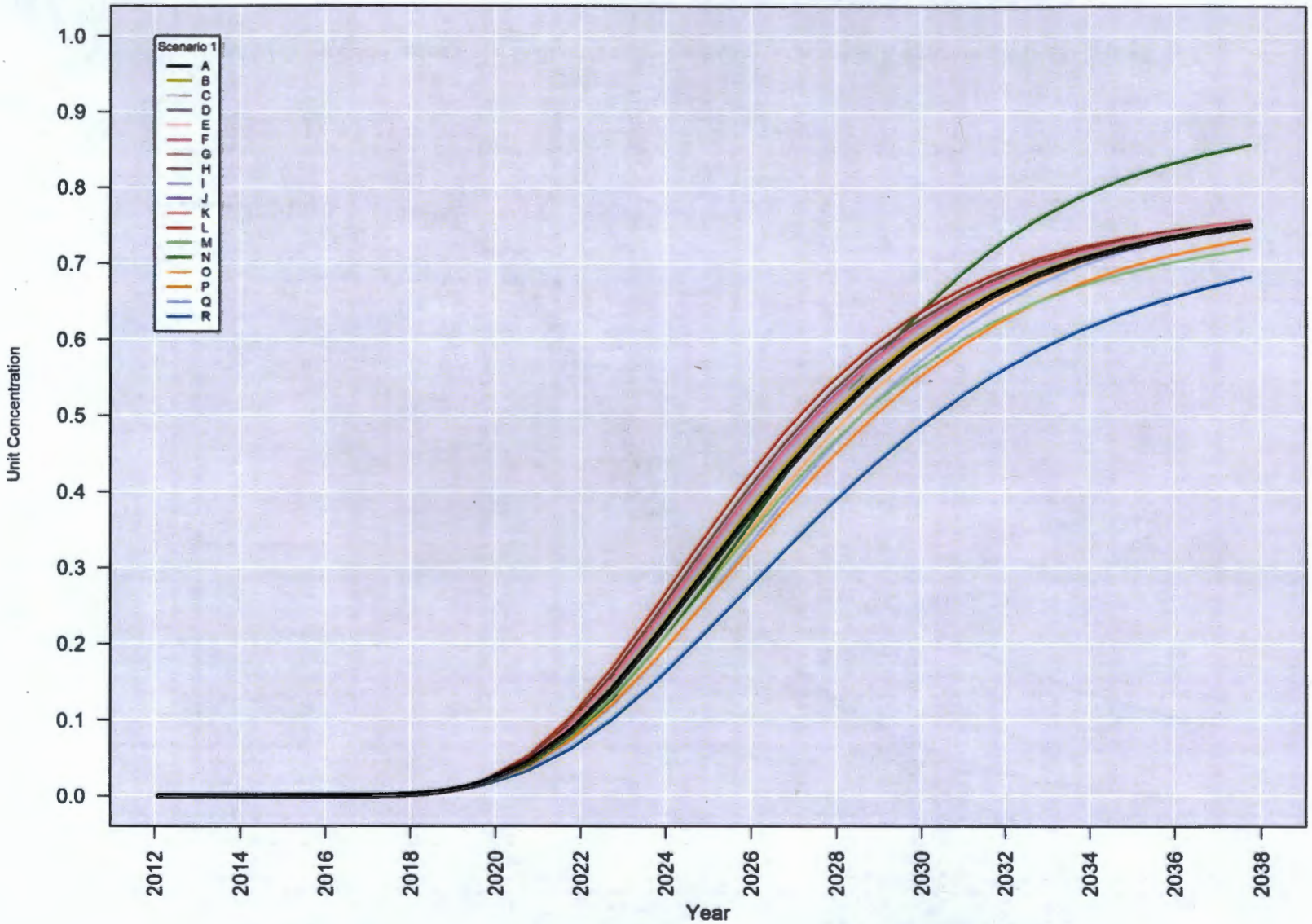


Figure 7-7. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, at Monitoring Well 299-W19-47

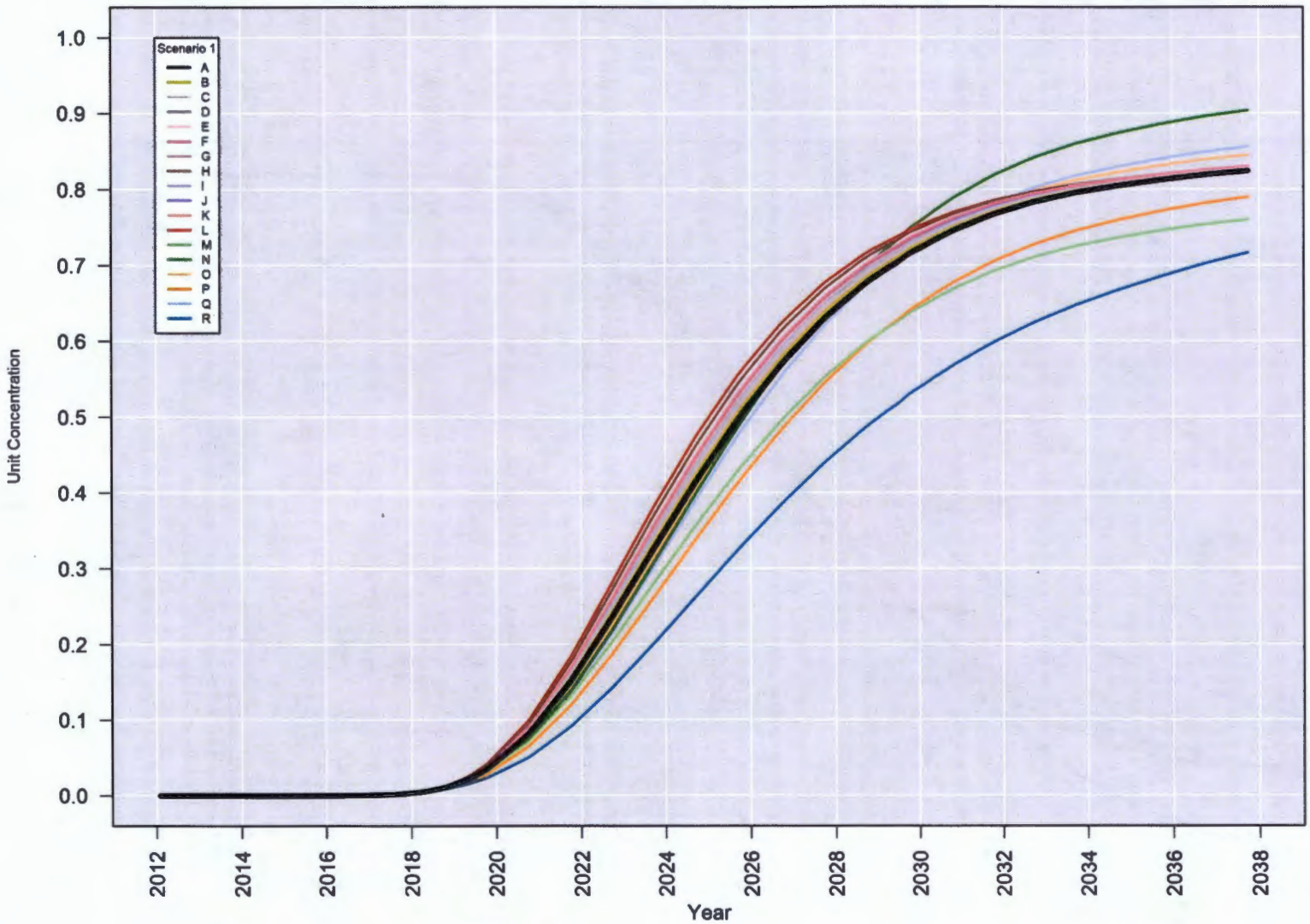


Figure 7-8. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Monitoring Well 299-W18-40

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-W18-260	1	0.711	0.873	0.754
	2	0.711	0.887	0.765
299-W18-40	1	0.717	0.904	0.825
	2	0.717	0.914	0.833
299-W19-12	1	0.632	0.837	0.762
	2	0.632	0.857	0.778
299-W19-41	1	0.595	0.822	0.768
	2	0.595	0.845	0.786
299-W19-42	1	0.668	0.851	0.756
	2	0.668	0.869	0.770
299-W19-44	1	0.620	0.832	0.764
	2	0.620	0.853	0.780
299-W19-45	1	0.650	0.844	0.759
	2	0.650	0.863	0.774
299-W19-47	1	0.684	0.858	0.753
	2	0.684	0.875	0.766

The release concentration breakthrough curves for monitoring wells 299-W18-260, 299-W19-12, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47 for all sub-scenarios in scenario 1 are shown in Figures 7-9 through 7-15, respectively. Figure 7-16 shows the release concentration breakthrough curve for upgradient monitoring well 299-W18-40.The release concentration breakthrough curves, which depict the simulated breakthrough of a unit-source release to the groundwater table from WMA U, 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 concentration 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, are indicative of well locations that are effective for monitoring releases from the facility. Wells for which breakthrough curves display high variation among different operating scenarios are indicative of wells that 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.

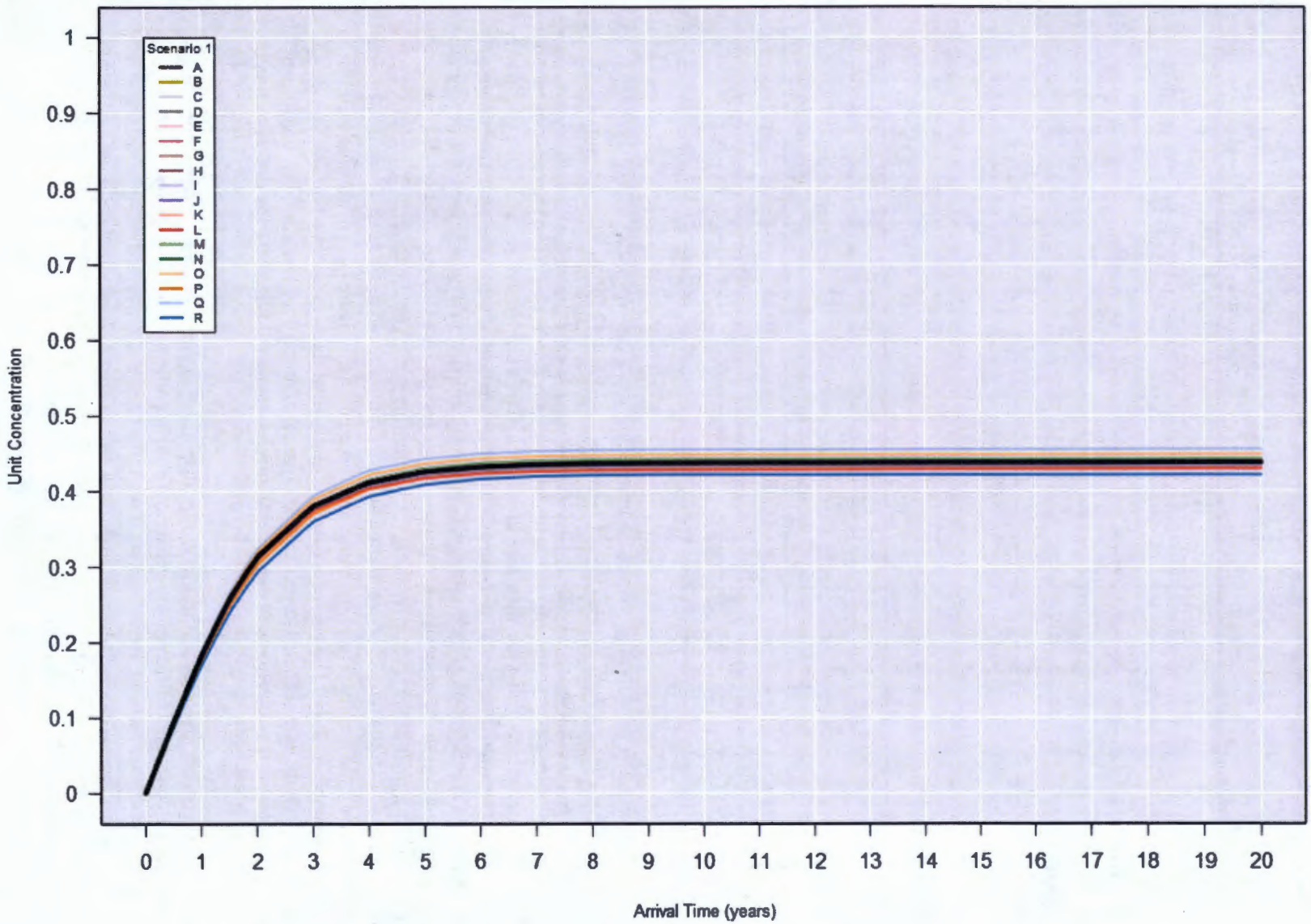


Figure 7-9. Release Concentration Breakthrough Curves at Monitoring Well 299-W18-260

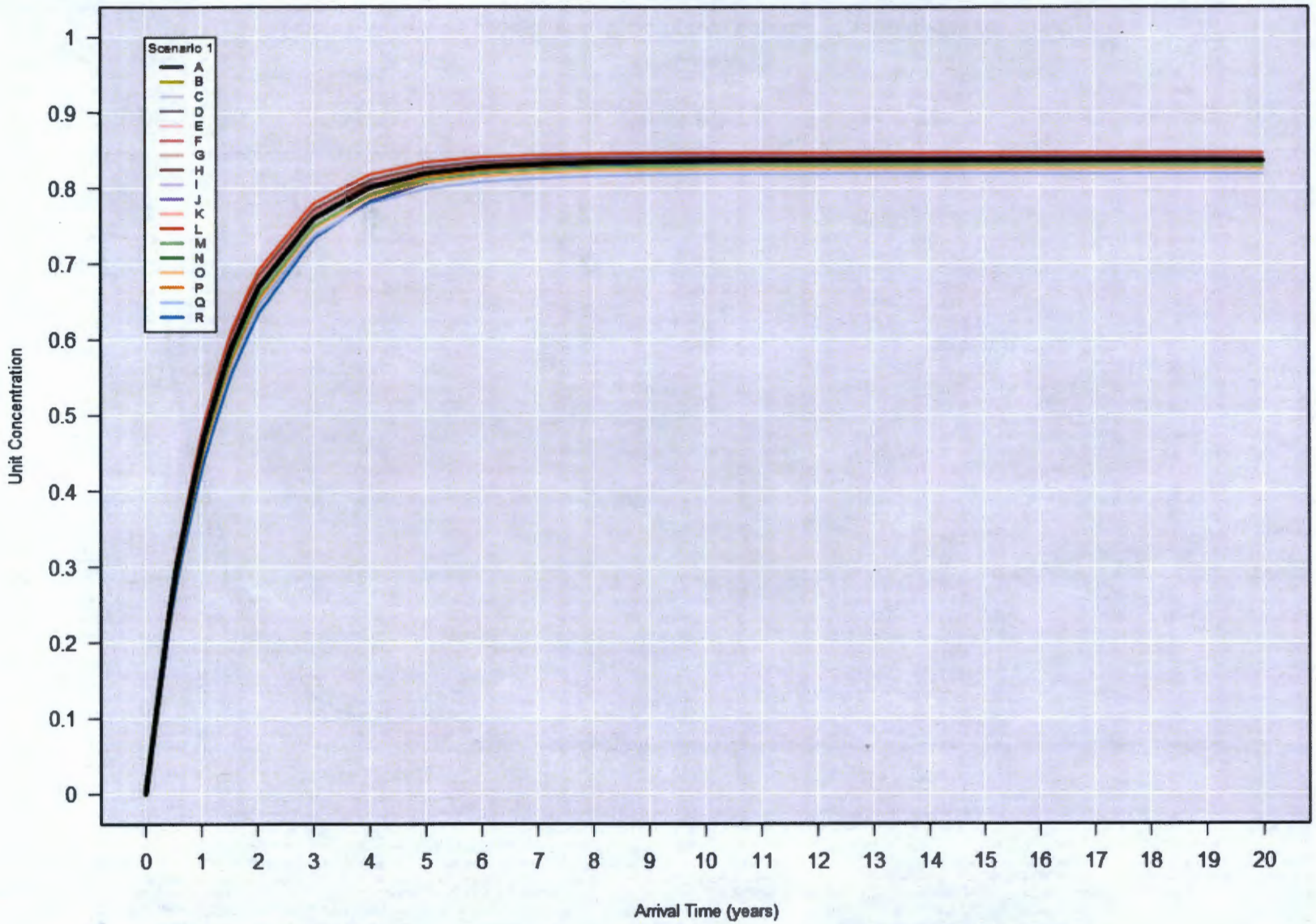


Figure 7-10. Release Concentration Breakthrough Curves at Monitoring Well 299-W19-12

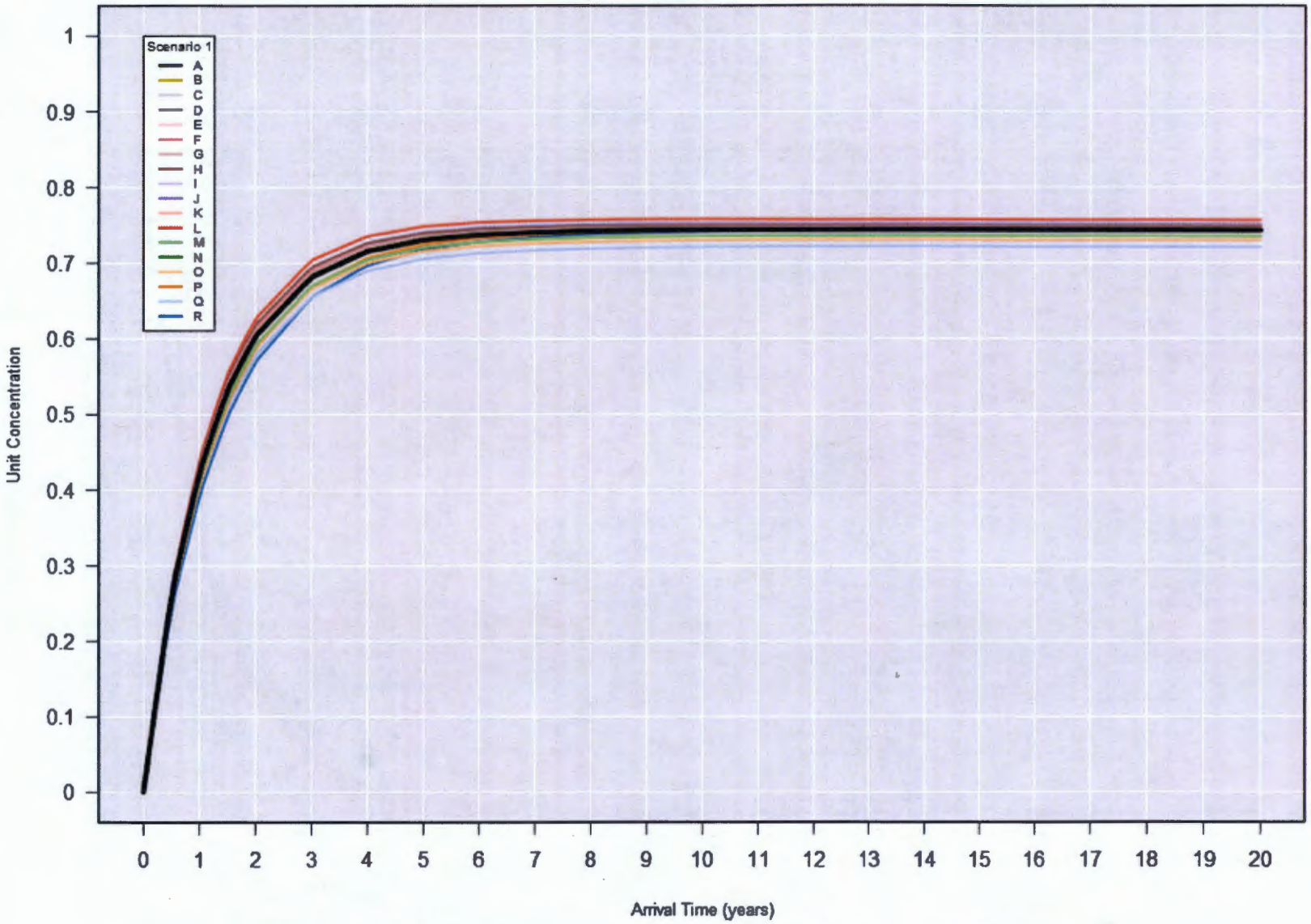


Figure 7-11. Release Concentration Breakthrough Curves at Monitoring Well 299-W19-41

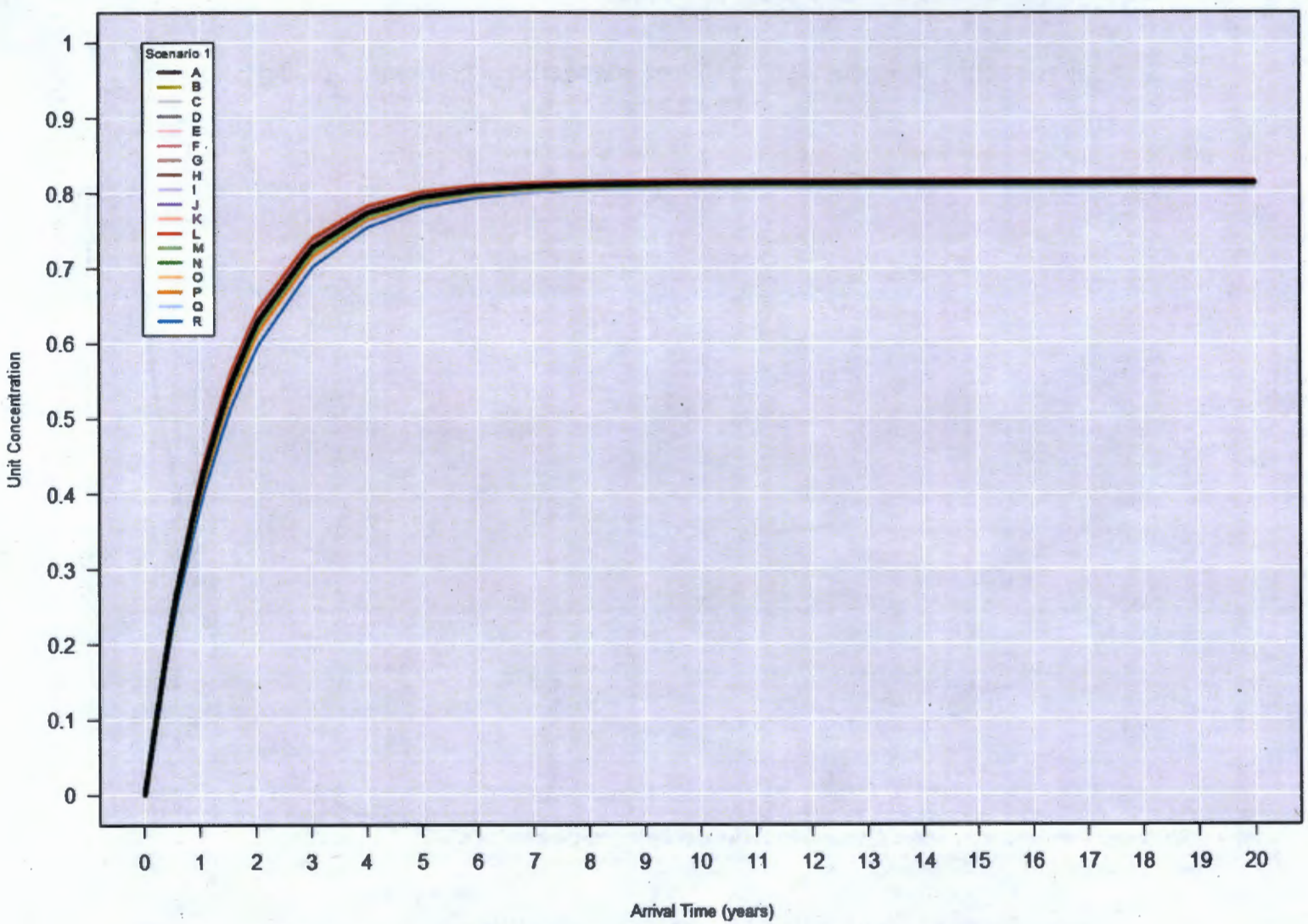


Figure 7-12. Release Concentration Breakthrough Curves at Monitoring Well 299-W19-42

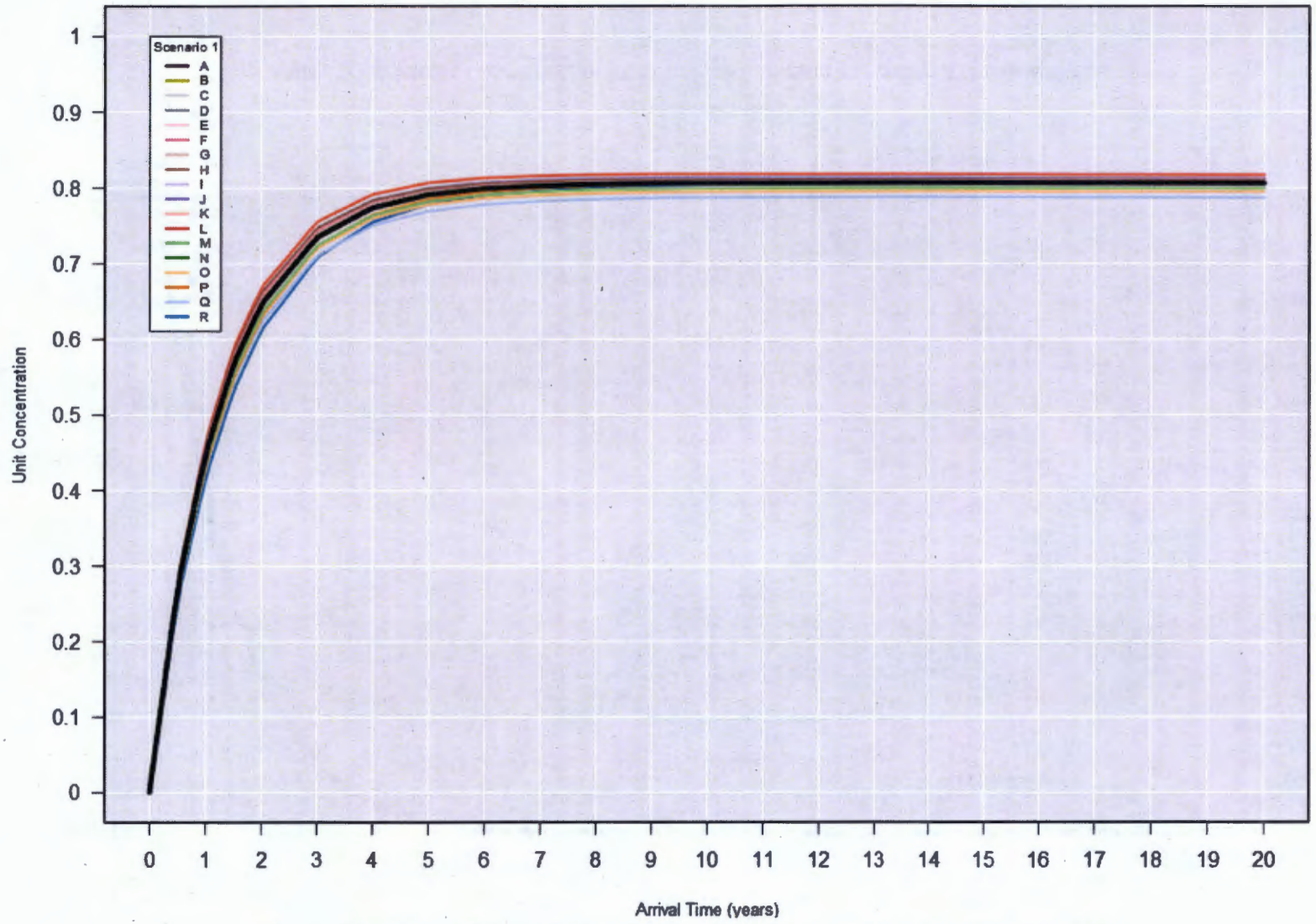


Figure 7-13. Release Concentration Breakthrough Curves at Monitoring Well 299-W19-44

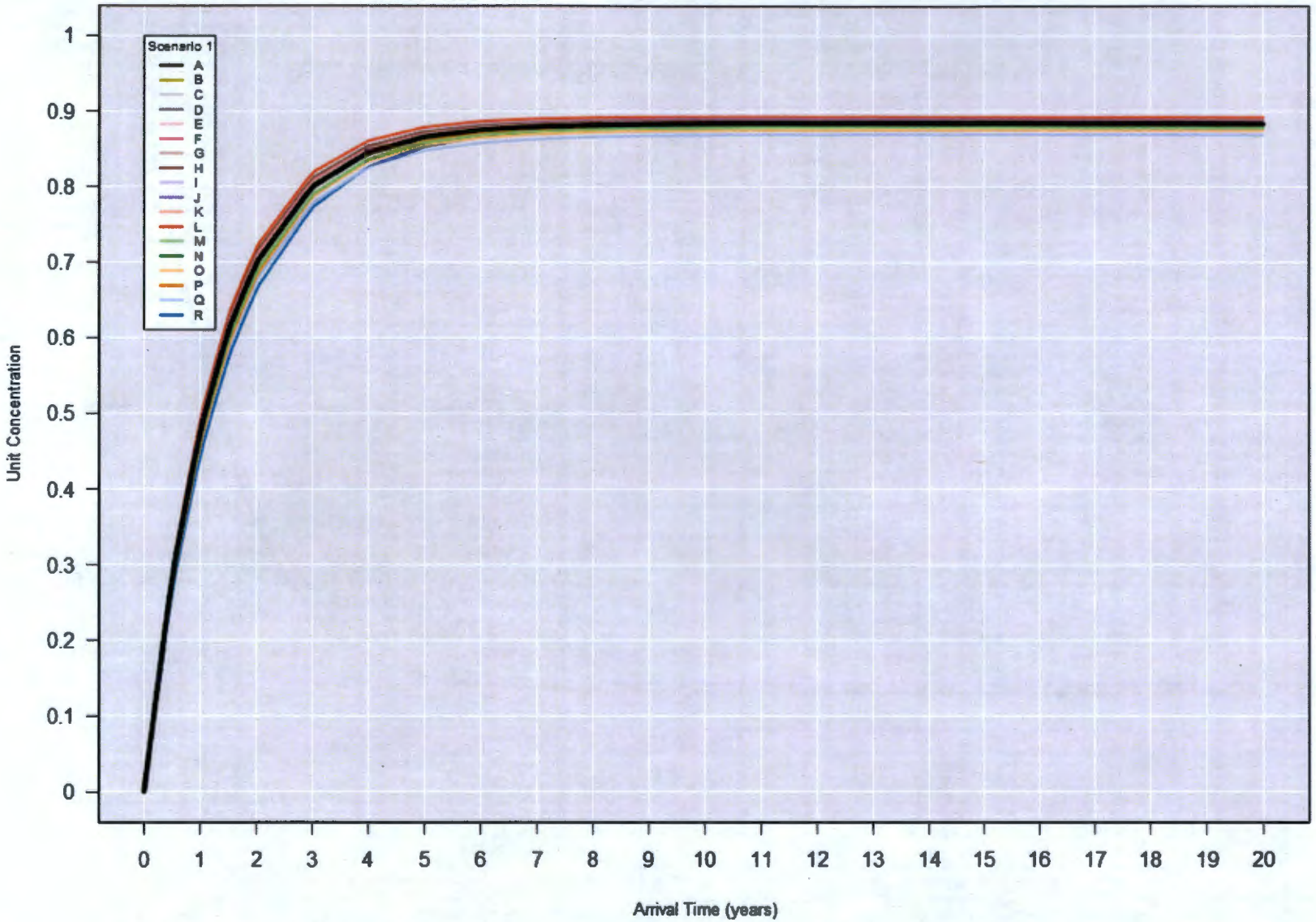


Figure 7-14. Release Concentration Breakthrough Curves at Monitoring Well 299-W19-45

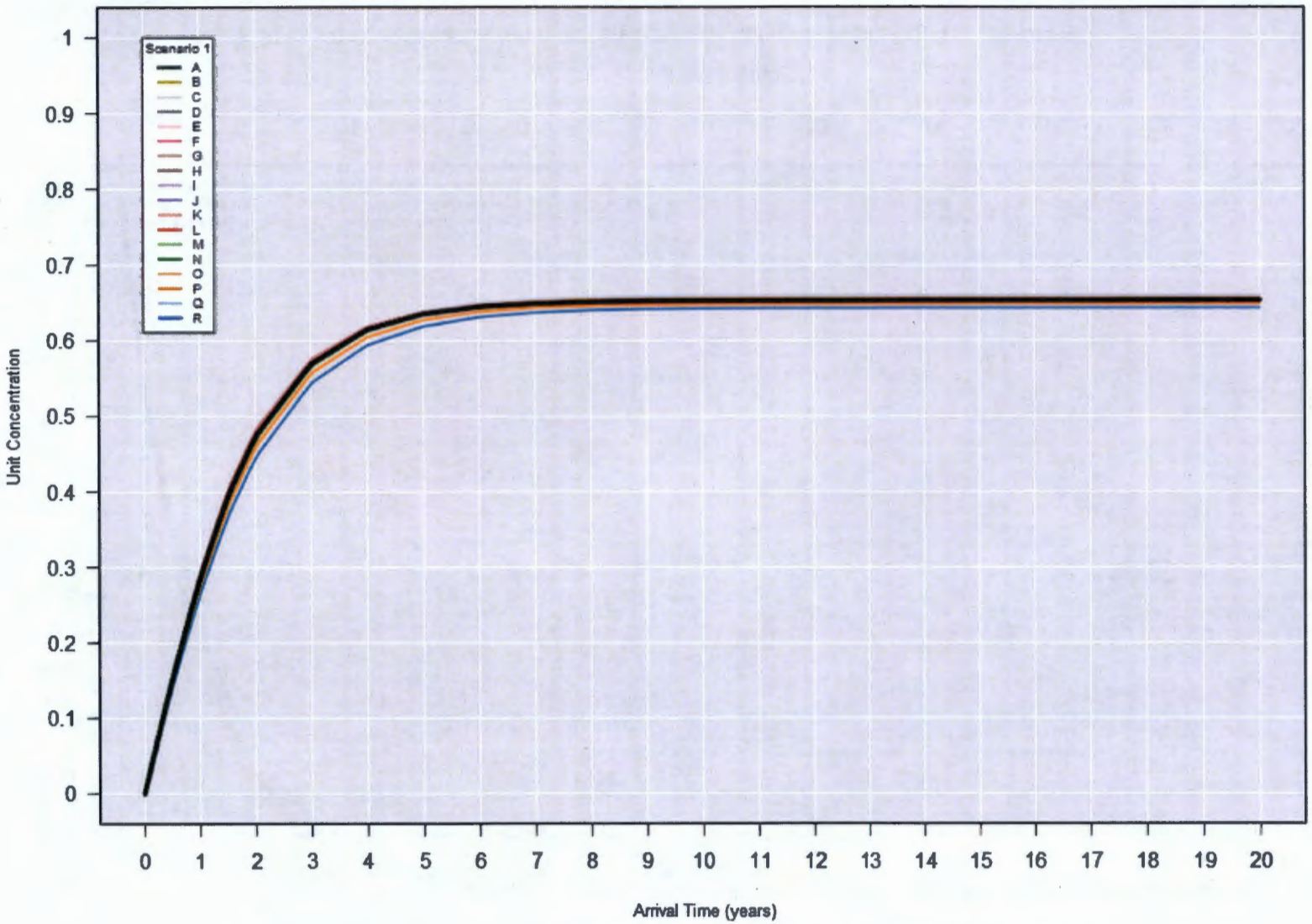


Figure 7-15. Release Concentration Breakthrough Curves at Monitoring Well 299-W19-47

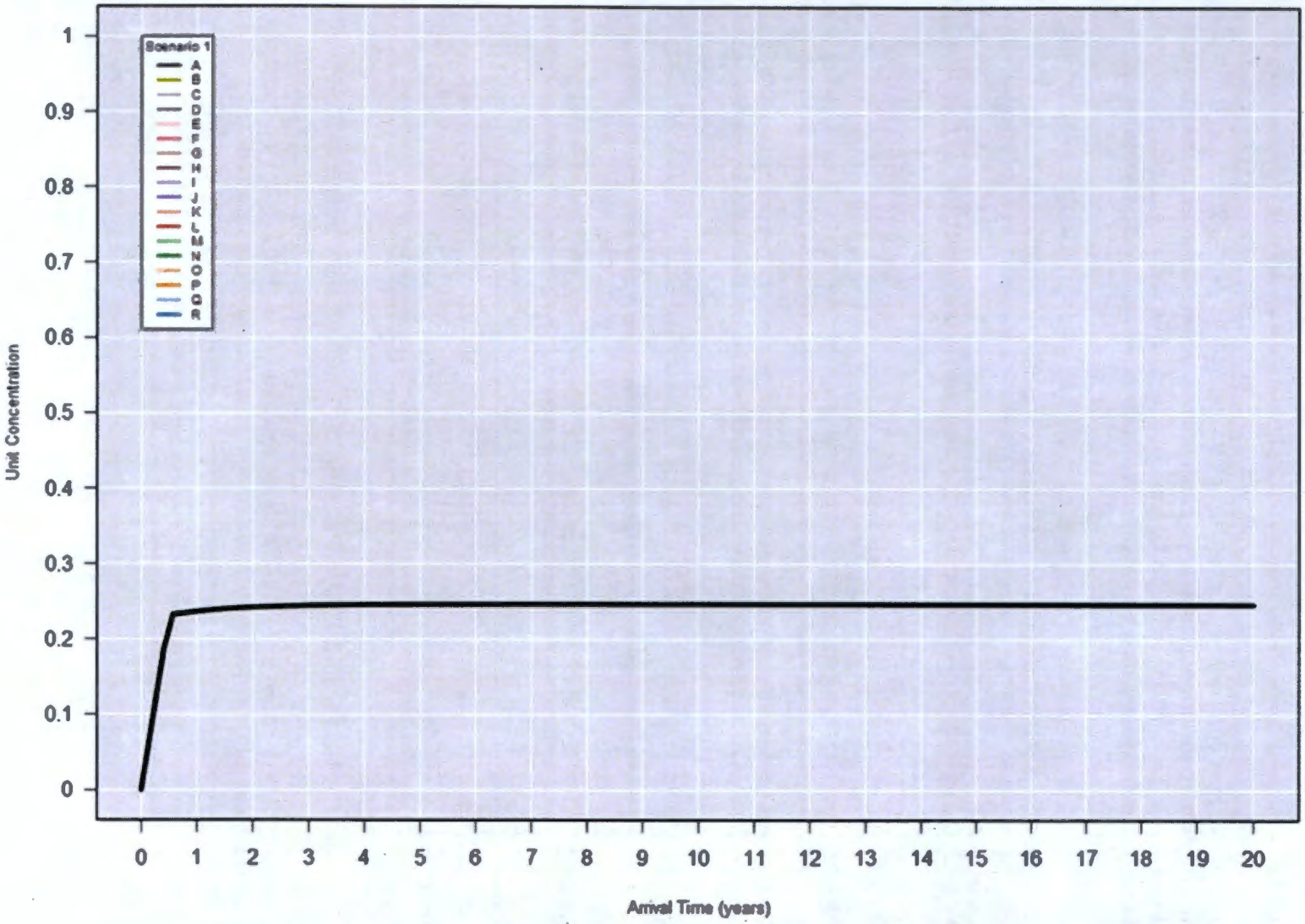


Figure 7-16. Release Concentration Breakthrough Curves at Monitoring Well 299-W18-40

Figures 7-9 through 7-16 show minimal variation in the breakthrough curves for the various 200 West P&T system operating scenarios, indicating that detection of releases at the well locations are not sensitive to changes in the 200 West P&T system operating conditions. Release concentration breakthrough curves for well 299-W18-260 indicate relatively more dilution (less of the original release concentration) and, therefore, less likely to detect releases for all the operating scenarios relative to the other monitoring well locations. However, the results indicate that well 299-W18-260 and the other wells in the monitoring network are located in areas having high potential for detecting releases from WMA U. 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-W18-260	1	0.422	0.456	0.438	0.156
	2	0.422	0.461	0.443	
299-W18-40	1	0.246	0.247	0.246	0.248
	2	0.246	0.247	0.246	
299-W19-12	1	0.818	0.846	0.835	0.905
	2	0.811	0.841	0.829	
299-W19-41	1	0.721	0.756	0.743	0.452
	2	0.712	0.749	0.735	
299-W19-42	1	0.806	0.817	0.813	0.397
	2	0.803	0.815	0.810	
299-W19-44	1	0.787	0.817	0.806	0.463
	2	0.779	0.811	0.799	
299-W19-45	1	0.868	0.892	0.883	0.920
	2	0.863	0.888	0.878	
299-W19-47	1	0.643	0.659	0.653	0.449
	2	0.643	0.661	0.655	

The release concentration breakthrough curves for scenario 3 (Figure 7-17) show lower release unit concentrations for monitoring well 299-W18-260 and significantly higher unit concentrations (greater than 0.9) for wells 299-W19-12 and 299-W19-45 after the cessation of 200 West P&T system operations. The release time for scenario 3 (represented on the figure as arrival time year 0) corresponds to October 1, 2037.

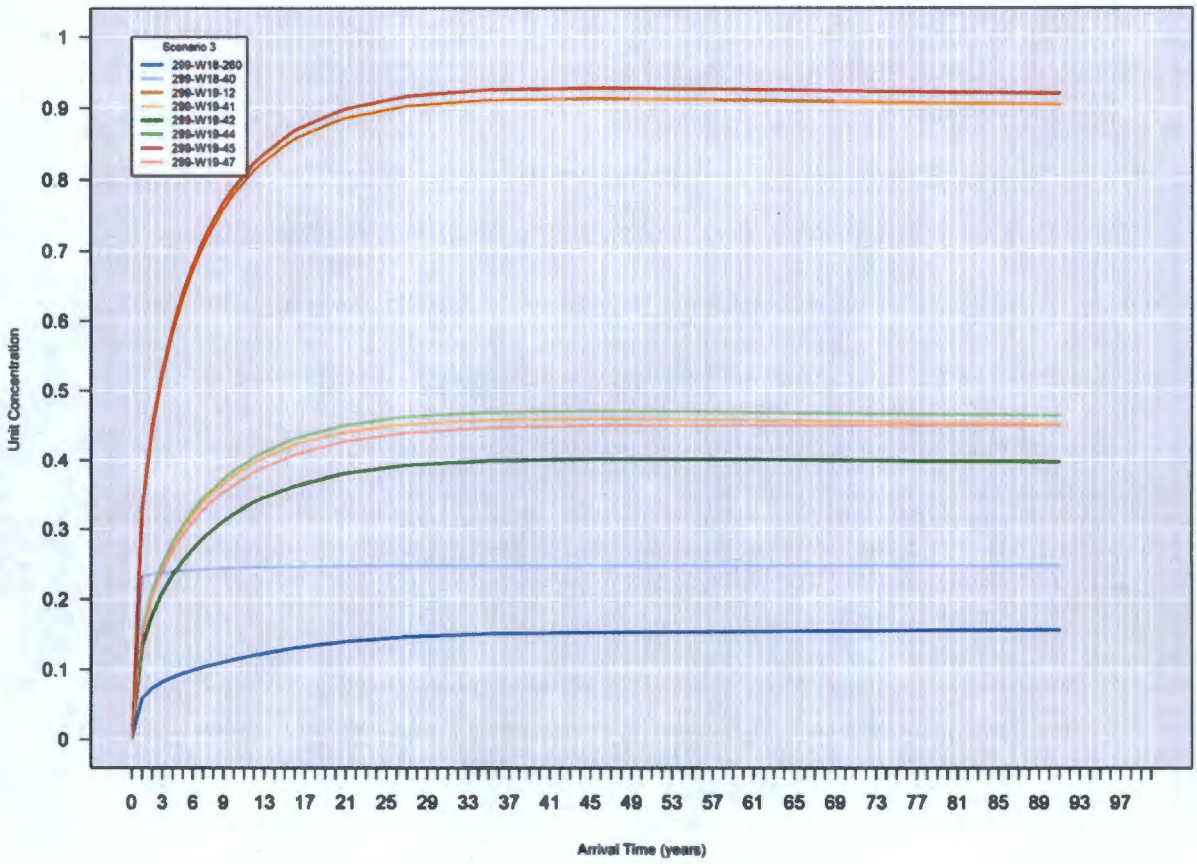


Figure 7-17. Release Concentration Breakthrough Curves at Monitoring Wells for Scenario 3

Figures 7-18 through 7-20 show plume maps of release unit concentration based on transport modeling representing 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. Figures 7-18 and 7-19 depict sub-scenario A for scenarios 1 and 2, which corresponds to the bold black lines on the breakthrough curves. Figures 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 predicted release dispersion from 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 calculated concentrations 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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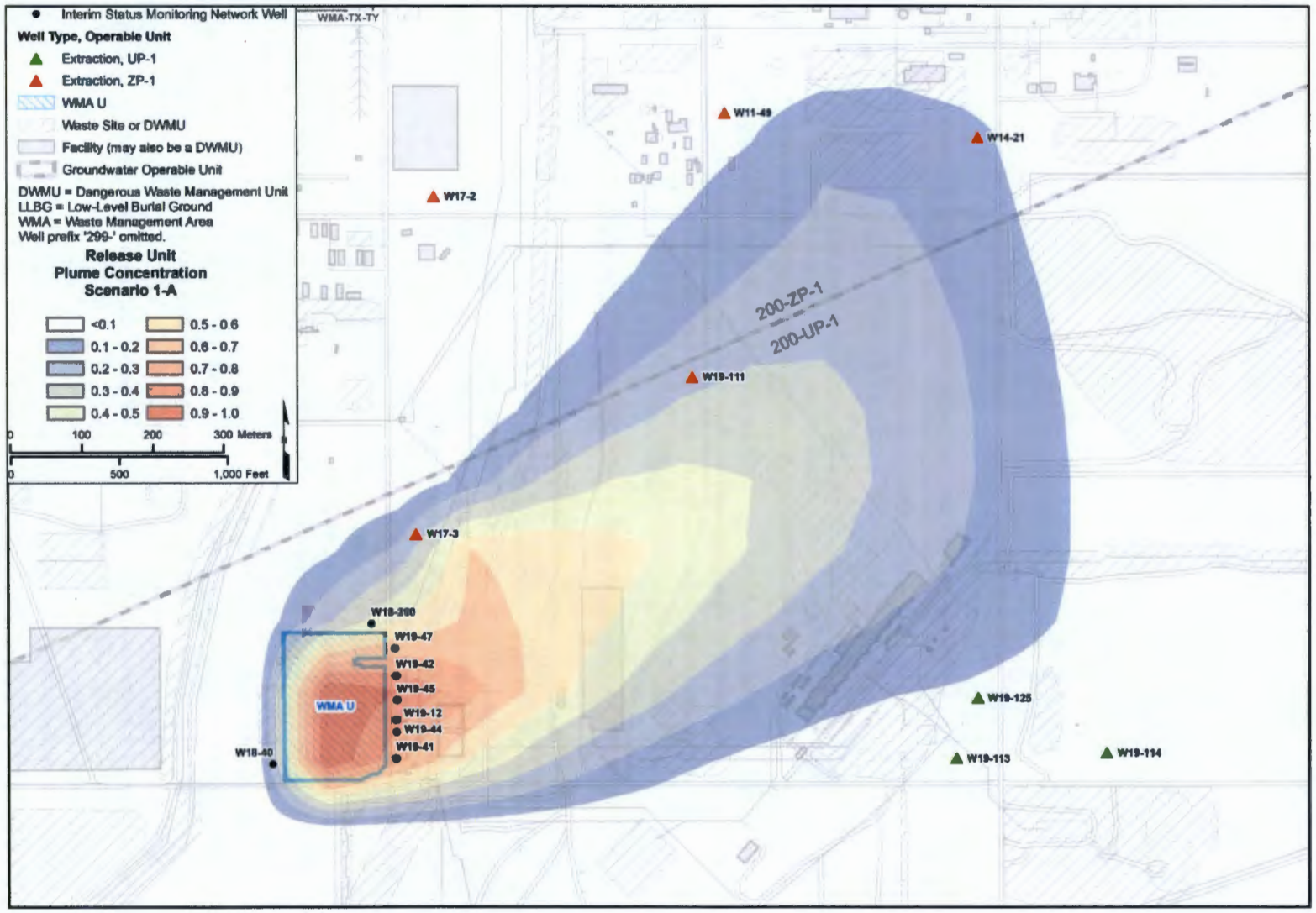

Figure 7-18. Release Unit Plume Map Scenario 1, Sub-Scenario A

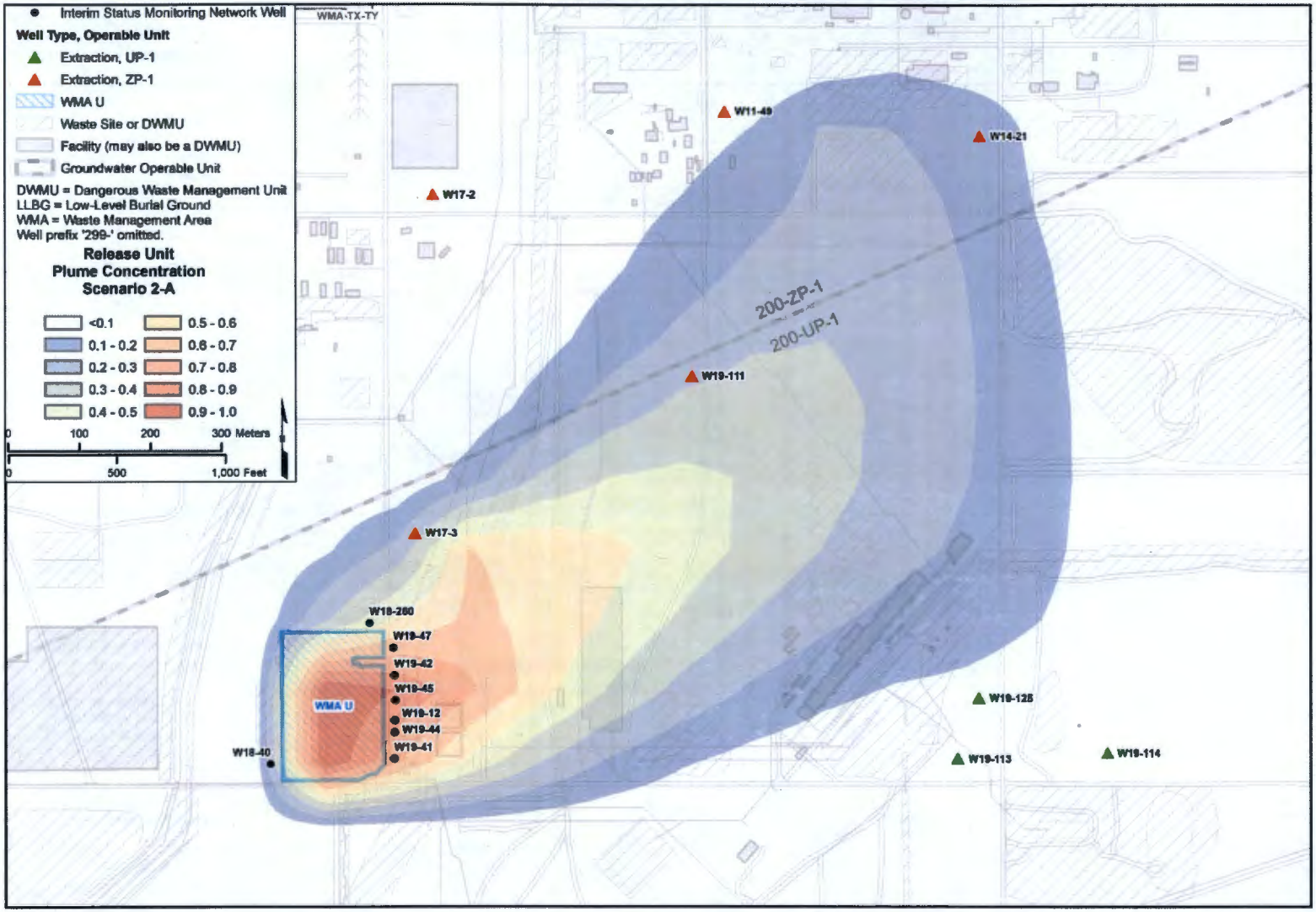

Figure 7-19. Release Unit Plume Map Scenario 2, Sub-Scenario A

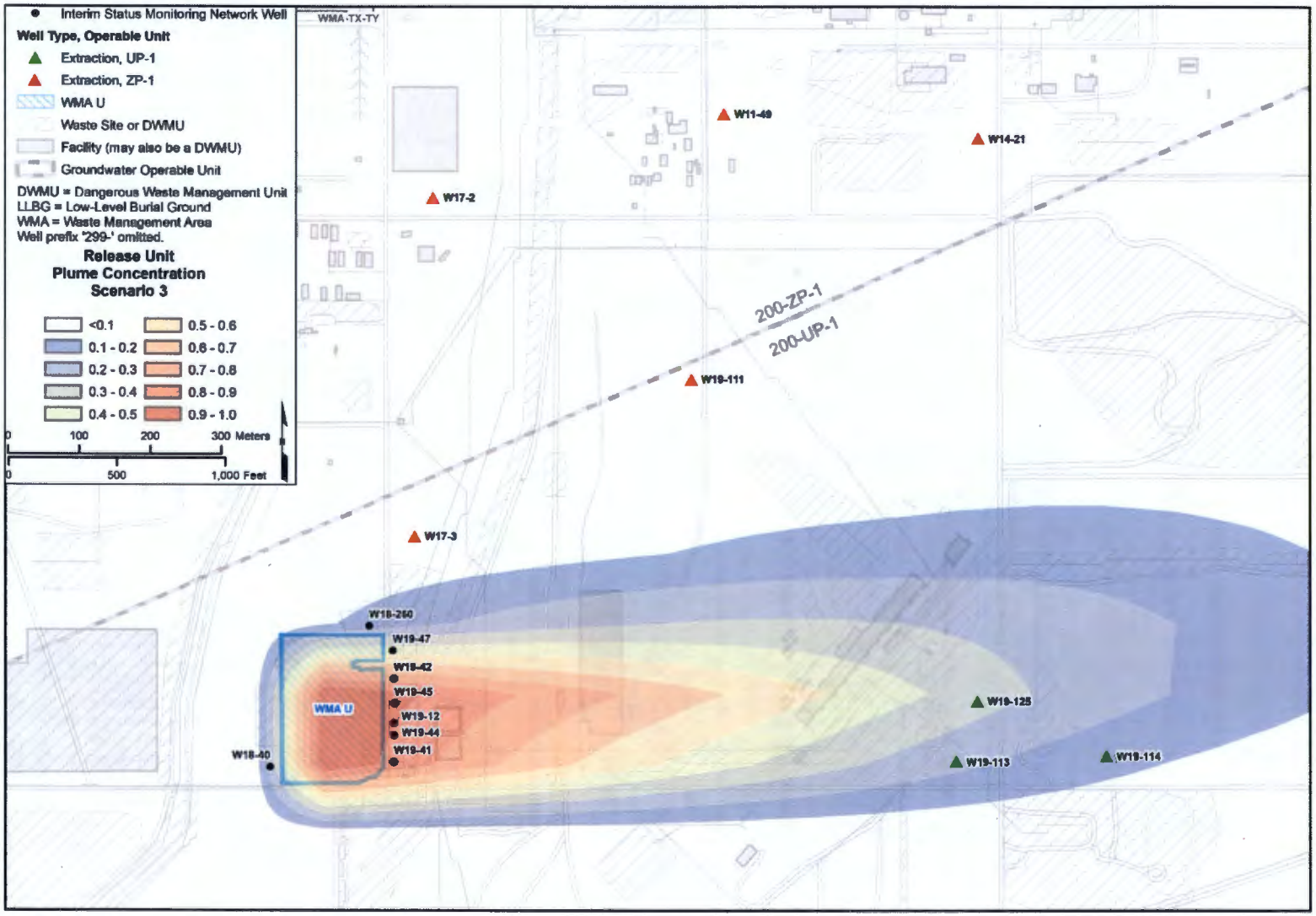

Figure 7-20. Release Unit Plume Map Scenario 3

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 from the interpolation between the nodes of the model cells, particle-tracking results are used in conjunction with the release unit plume maps for proper interpretation of the model results. For WMA U, upgradient well 299-W18-40 is shown in an area with release unit concentration greater than zero (Figures 7-18 through 7-20). The outer fringe of the release unit plume is a result of the spatial interpolation between the nodes (centers) of the grid cell representing the facility (in which the unit concentration of 1 was released) and the upgradient grid cell where well 299-W18-40 is located, which has a simulated unit concentration near zero. The particle-tracking results discussed in subsequent sections indicate this well 299-W18-40 remains upgradient of the potential release from WMA-U in the scenarios evaluated.

Figures 7-18 through 7-20 show that downgradient wells are generally well located for detecting releases. 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 the overall distribution, given advection and dispersion, of a hypothetical release to the water table below WMA U. For scenarios 1 and 2, the maps represent conditions in 2037; for scenario 3, the maps represent conditions in 2137.

In the calculations, particles released to the water table exhibited then 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 7-21 and 7-22 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 the 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 7-23) represents conditions after cessation of the 200 West P&T system operations and therefore does not have an injected treated water component.

The particle tracking indicates that the wells generally are well located for detecting releases from the facility. Well 299-W18-260 is on the edge of the release particle pathlines for scenarios 1 and 2 and is located beyond the extents of the particle tracking after cessation of the 200 West P&T system operations (scenario 3).

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

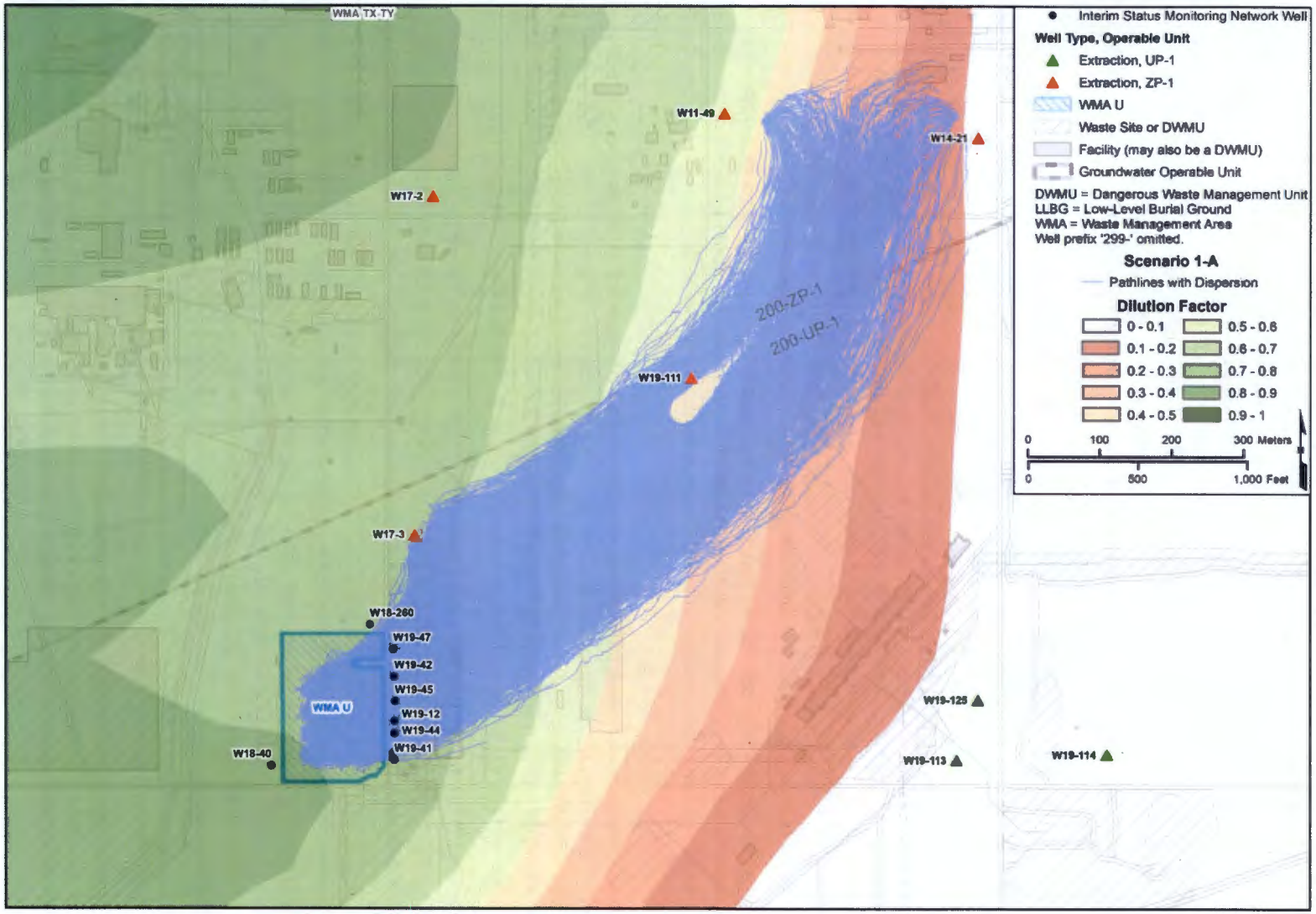

Figure 7-21. Particle Pathlines Superimposed on Injected Treated Water Unit Plumes Scenario 1, Sub-Scenario A

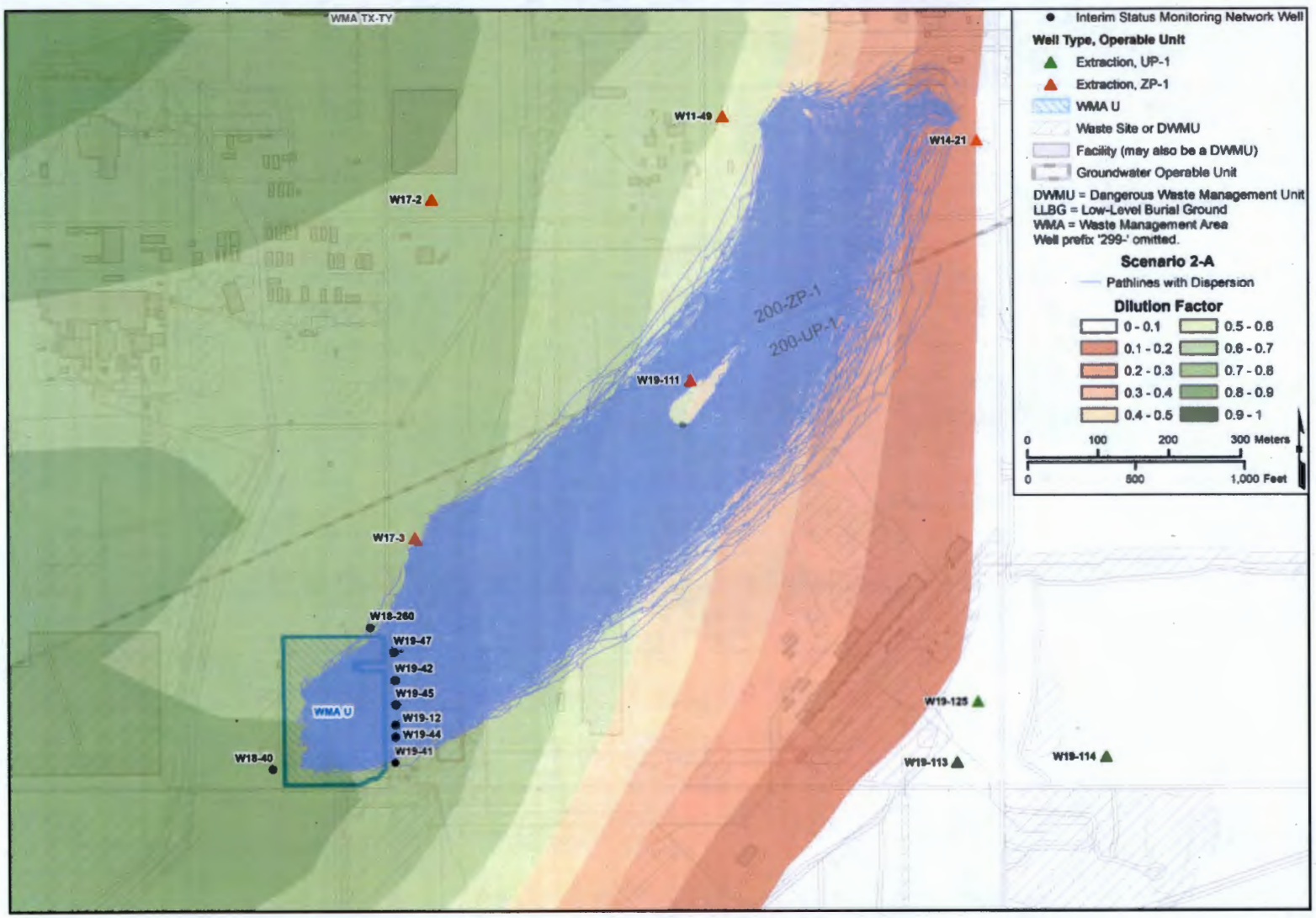

Figure 7-22. Particle Pathlines Superimposed on Injected Treated Water Unit Plumes Scenario 2, Sub-Scenario A

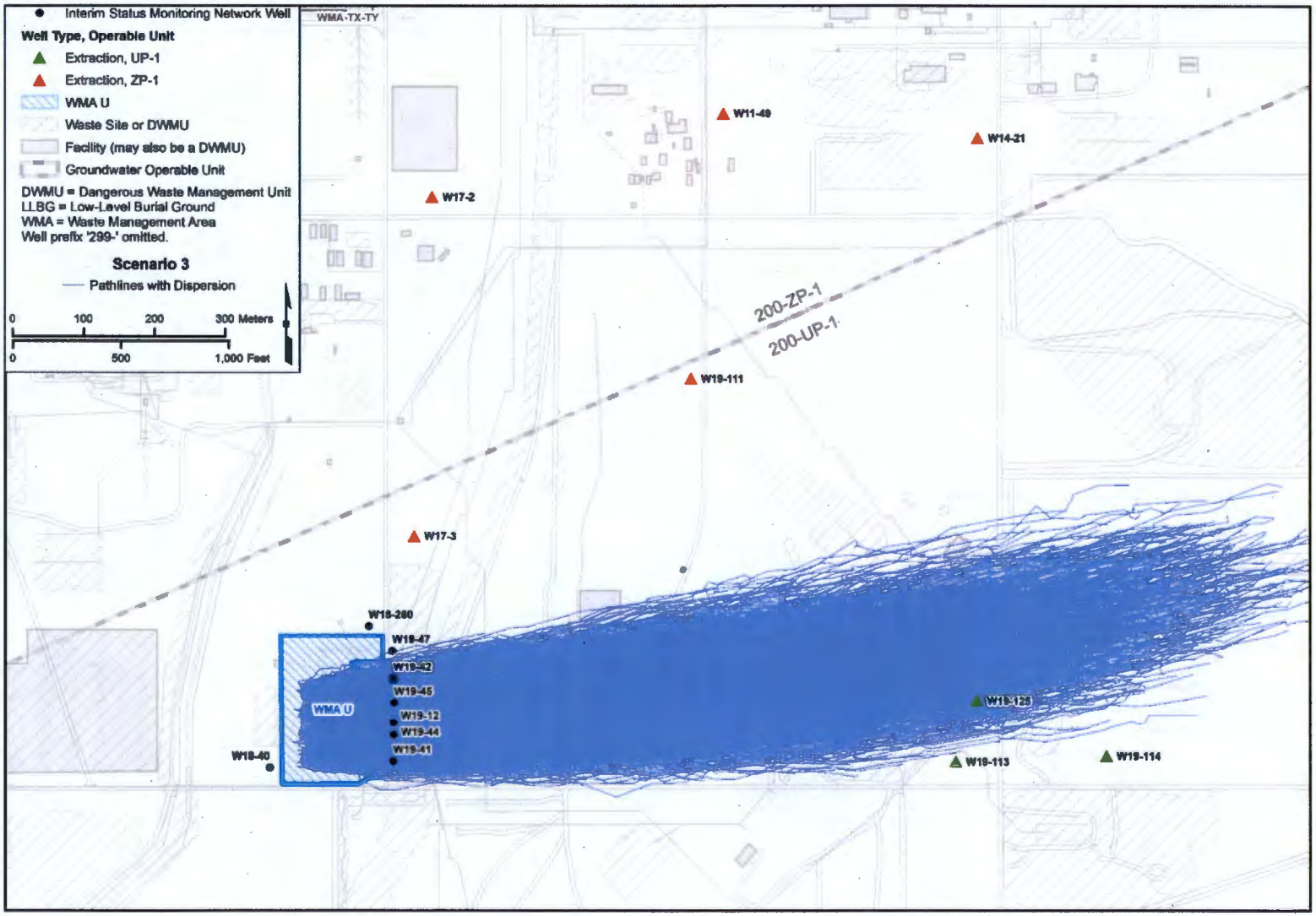

Figure 7-23. Particle Pathlines Scenario 3

Details of the calculations for these simulations are presented in Appendix G. In general, 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 for each sub-scenario were generated and are included as Appendix A in Appendix G. Using the particle counts, relative detectability 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 7-24 through 7-26 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 the downgradient groundwater monitoring wells generally are located in areas of high relative detectability for particle releases from WMA U except northern monitoring well 299-W18-260 and southern monitoring well 299-W19-41 are located at the extents of the relative detectability area. However, after the cessation of 200 West P&T system operations, the shift in the groundwater flow from a northeastern to an eastern direction results in well 299-W19-41 being in an area of higher detectability for scenario 3.

One new upgradient monitoring well, WMA-U_PW1 is proposed for the final status monitoring well network. The proposed location for the well is shown in Figures 7-24 through 7-26.

7.3 Breakthrough Curves for Proposed Wells

Using transport calculations, injected treated water dilution breakthrough curves were generated for each scenario and sub-scenario to evaluate the proposed upgradient well, WMA-U_PW1 (Figure 7-27). The proposed well is upgradient so release concentration breakthrough curves are not included herein.

The injected treated water breakthrough curves for the proposed wells indicate minimal sensitivity to most variations in 200 West P&T system injection operations. The exception is sub-scenario N, which has a higher unit concentration, approaching 90% injected treated water at the well location at the end of P&T system operations. Table 7-3 shows the range of the injected treated water dilution breakthrough curves for the proposed well for scenarios 1 and 2. The injected treated water dilution breakthrough curves for the proposed well for scenario 2 are included in Appendix G. Results for scenario 2 were similar to the results for scenario 1.

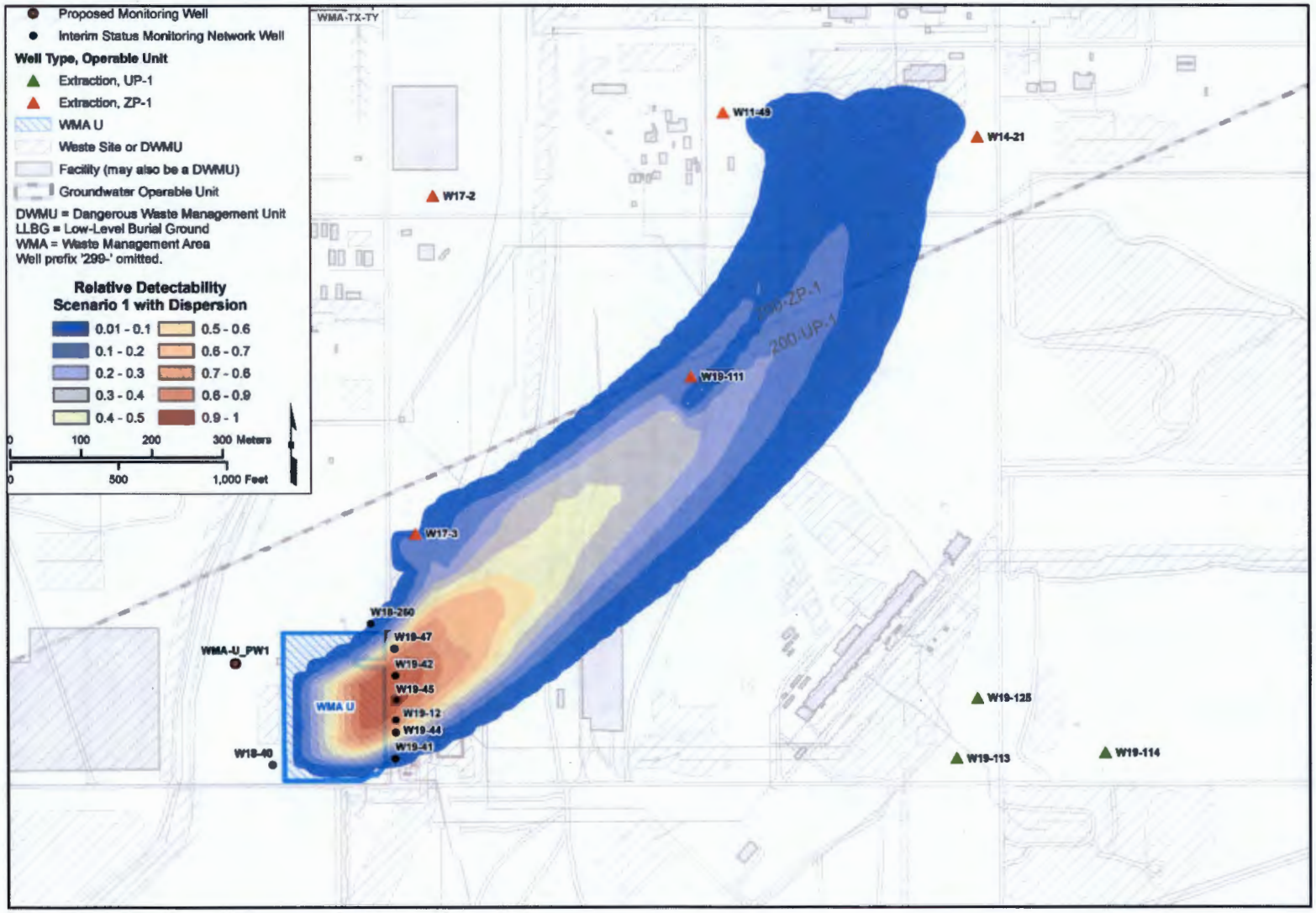

Figure 7-24. Relative Detectability of Release for Scenario 1

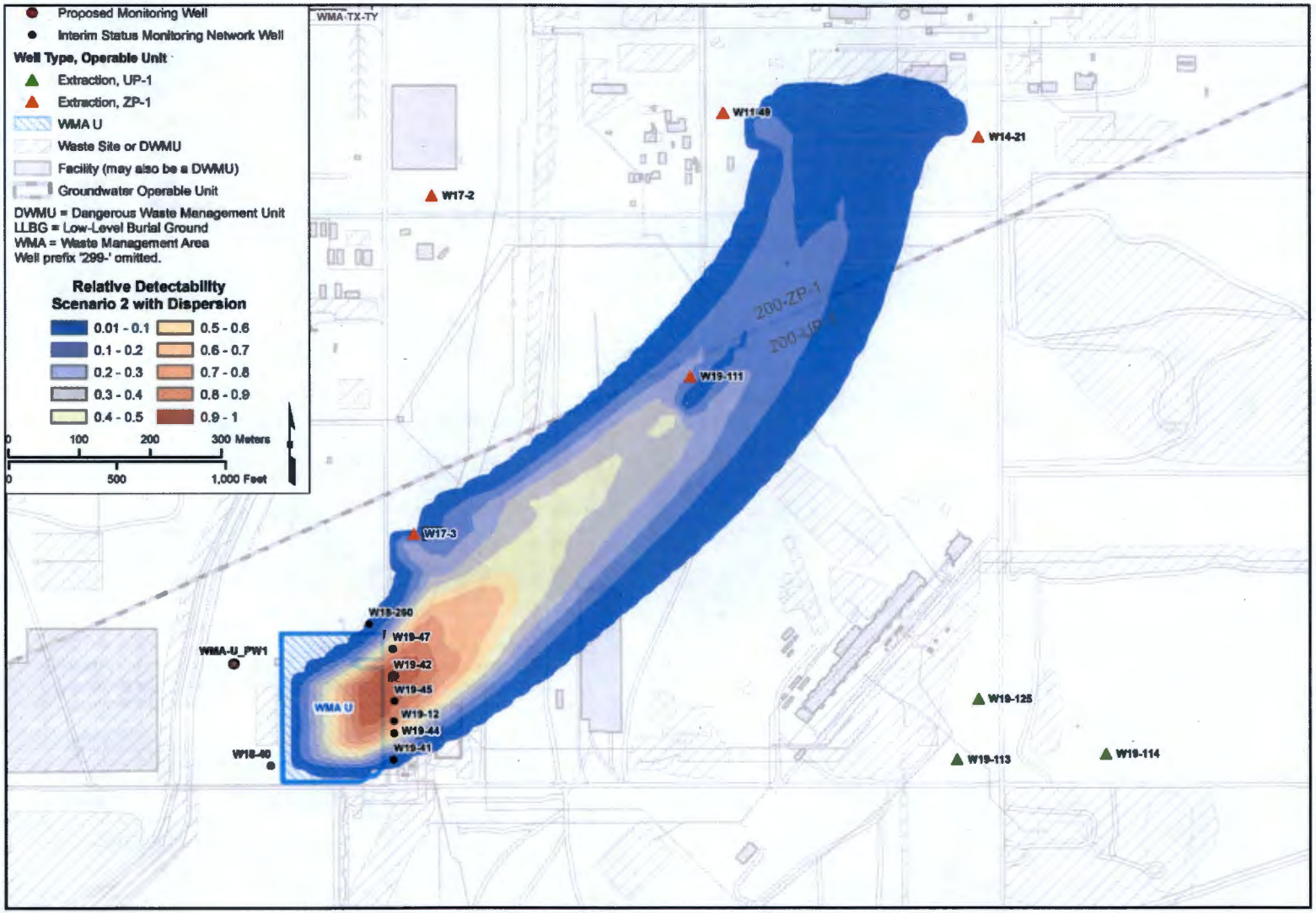

Figure 7-25. Relative Detectability of Release for Scenario 2

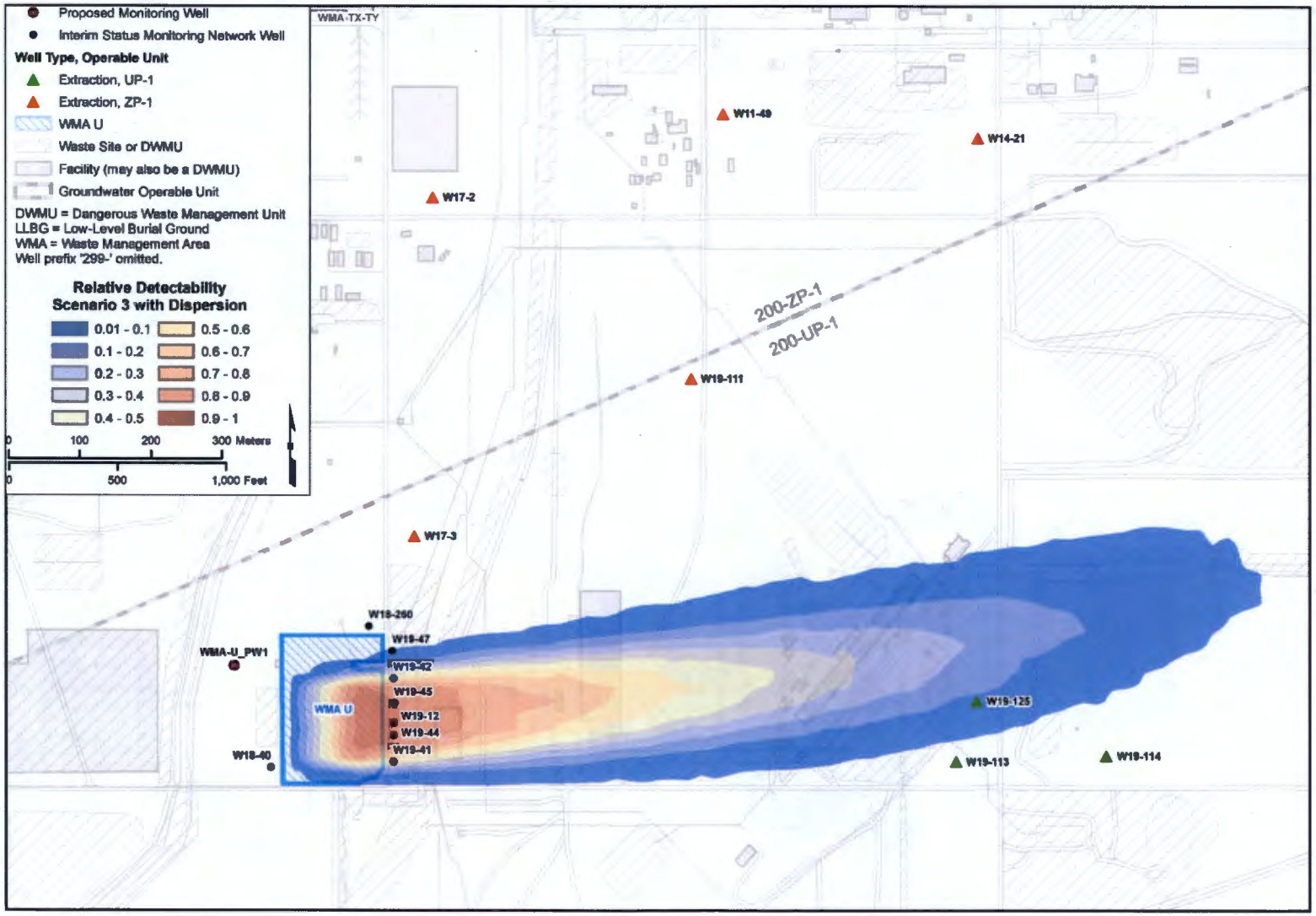

Figure 7-26. Relative Detectability of Release for Scenario 3

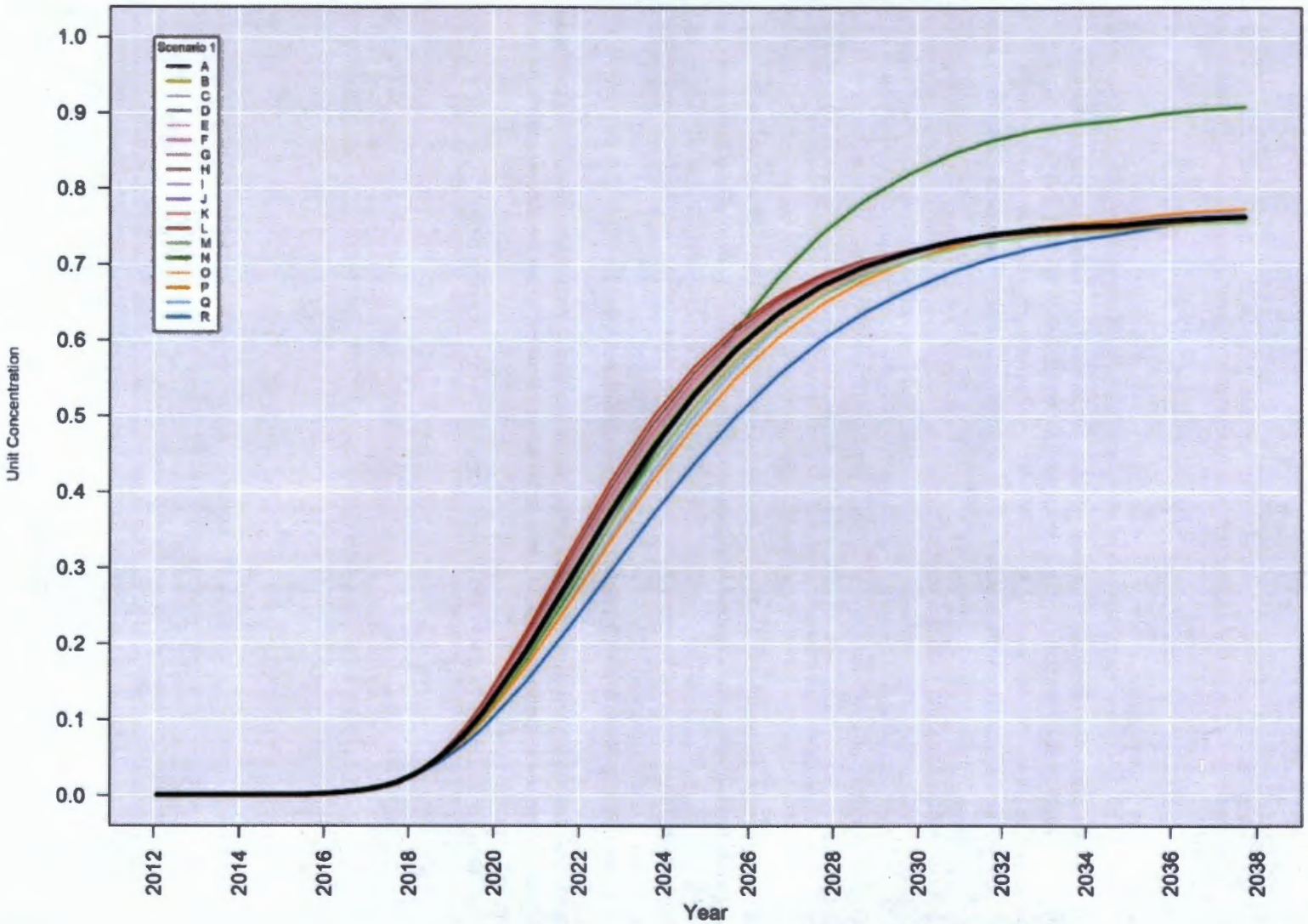

Figure 7-27. Injected Treated Water Dilution Breakthrough Curves, Scenario 1, Proposed Monitoring Well WMA-U_PW1

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-U_PW-1	1	0.757	0.909	0.768
	2	0.757	0.916	0.776

7.4 Modeling Conclusions

The proposed final status groundwater monitoring network for WMA U includes retaining existing upgradient well 299-W18-40; retaining existing downgradient wells 299-W18-260, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47; and eliminating existing downgradient well 299-W19-12. New upgradient well WMA_U_PW1 is 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.

Figure 7-28 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 simulations indicate that, under the scenarios evaluated the seven downgradient groundwater monitoring wells of the interim status groundwater monitoring network (299-W18-260, 299-W19-12, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47) are well placed for detecting increases in concentrations of contaminants due to a release to the water table from WMA U under the scenarios evaluated. However, well 299-W19-12 is not recommended for the final status monitoring network because it is not *Washington Administrative Code* compliant.

The release concentration breakthrough curves for the recommended downgradient monitoring network wells indicate a range of dilution of approximately 10%[1] to less than 60%[2] for the release unit concentrations. After completion of the 200 West P&T system operations (scenario 3), this dilution range becomes less than 10% to approximately 85%[3]. Additional discussion regarding each well is provided in Section 9.3.

[1] 10% dilution corresponds to a release unit concentration of approximately 0.9 for sub-scenario L of scenario 1 at monitoring well 299-W19-45 (Figure 7-14).

[2] 60% dilution corresponds to a release unit concentration of over 0.4 for sub-scenario R of scenario 1, at monitoring well 299-W18-260 (Figure 7-9).

[3] 10-85% dilution for scenario 3 corresponds to a release unit concentration of over 0.90 and approximately 0.15 for wells 299-W19-45 and 299-W18-260, respectively (Figure 7-17).

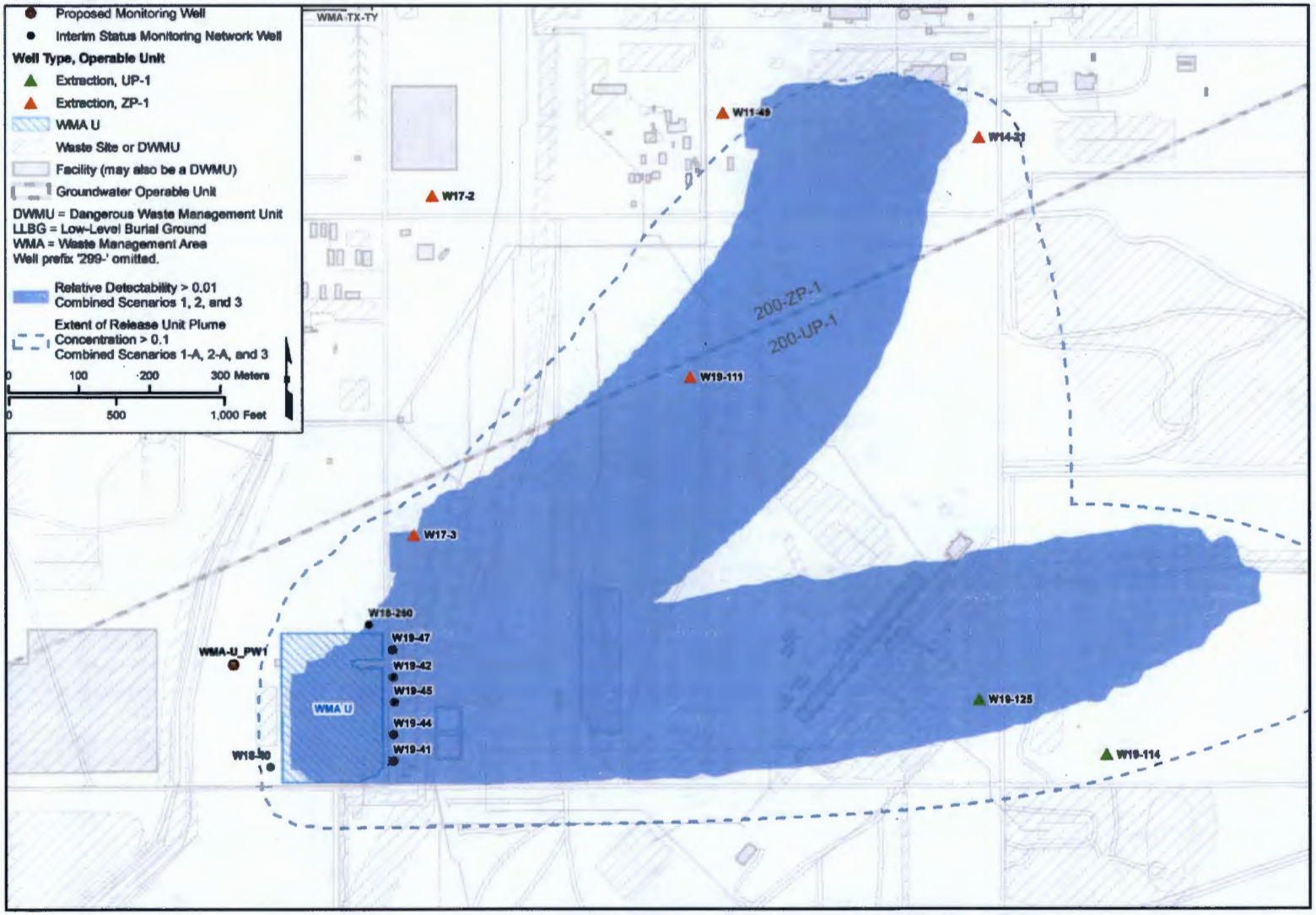

Figure 7-28. Proposed Final Status Groundwater Monitoring Network with Combined Relative Detectability and Release Unit Plume Results

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8 Identification of Site-Specific Monitoring Constituents

An evaluation of the waste constituents associated with WMA U, as identified in the RCRA Part A Application, and constituents that were detected in groundwater during interim status monitoring was performed to identify the proposed groundwater monitoring constituents to include in the final status groundwater monitoring program. The evaluation process and the resulting proposed constituents for monitoring are summarized in this chapter and detailed in Appendix B.

8.1 Selection Process for Monitoring Constituents

The data sets comprising the waste constituents associated with WMA U were evaluated and screened in accordance with the summary descriptions provided in Sections 8.1.1 through 8.1.3. Additional details of the methodology are provided in Chapter 3 of Appendix B with assumptions documented in Chapter 4 of Appendix B.

The dangerous wastes identified in the Hanford Facility RCRA Permit SST Part A Permit Application for the SST System and the groundwater sample results collected for WMA U during interim status monitoring comprise the data sets used to identify potential monitoring constituents. The use of the Part A Permit Application information and groundwater sample data are discussed in the following subsections.

8.1.1 Hanford Facility RCRA Permit Part A Form Dangerous Wastes

The Hanford Facility RCRA Permit Part A Form for the SST System identifies the dangerous wastes codes associated with the TSD unit, which includes the WMA U SSTs. A list of dangerous wastes and their corresponding Chemical Abstracts Service (CAS) numbers was compiled using the waste codes and represents the Part A Permit Application dangerous waste data set. The dangerous wastes identified in the SST Part A Permit Application are presented in Table 2-1.

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 (Appendix B, Tables 1 and 3). 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 Interim Status Groundwater Monitoring Results

Appendix A includes a summary of the interim status groundwater monitoring history at WMA U, including the changes to the wells network and monitoring constituents. In addition, groundwater sample results collected under interim status monitoring plans are presented for each well. The sample data were retrieved from the Hanford Environmental Information System (HEIS) database and presented in separate Microsoft® Excel® workbooks.

The nonradiological sample data for each well (excluding wells that were used for information purposes only) were evaluated to determine the maximum result for each detected chemical constituent. Sample data that were qualified with either "U" or an "R" qualifier[4] were excluded from the evaluation. Field parameters (e.g., dissolved oxygen, pH, specific conductance, temperature, turbidity, etc.), alkalinity

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[4] Data flagged with a "U" qualifier are analyzed for but not detected. Data flagged with an "R" qualifier are determined during formal data reviews as not valid for any use.

measurements, and nonanalyte-specific measures (e.g., TOC and TOX) were not considered in the evaluation. The maximum result for each detected constituent was compared to the Hanford Site 90th percentile groundwater background values, as appropriate (Table ES-1 in DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*) (Appendix B, Tables 2 and 4). Constituents that were detected above background values and non-naturally occurring constituents that do not have background values, were retained as potential monitoring constituents.

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 was performed to identify potential monitoring constituents to be included as proposed monitoring constituents to detect and monitor wastes from WMA U that impact groundwater. The initial step of this final evaluation identified those potential monitoring constituents that are also listed in Appendix 5 of Ecology Publication No. 97-407. As monitoring for the dangerous wastes in Appendix 5 of Ecology Publication No. 97-407 is already prescribed for WMA U (Section 9.4), these constituents were identified as proposed monitoring constituents.

The remaining potential monitoring constituents were evaluated in two groups:

- The first group comprised the potential monitoring constituents identified from the SST System Part A Permit Application (Section 8.1.1) that are not identified in Appendix 5 of Ecology Publication No. 97-407. Each of these constituents is a dangerous waste.
- The second group comprised the potential monitoring constituents identified from evaluation of the interim status groundwater results (Section 8.1.2) that were not listed in Appendix 5 of Ecology Publication No. 97-407 and were not identified from the Part A Permit Application.

The potential monitoring constituents in the first group (Part A Permit Application) were evaluated for availability of analysis. Any constituent that is not routinely analyzed by commercial laboratories was removed from consideration. The potential monitoring constituents in the first group that were not excluded due to unavailability of analysis were identified as proposed monitoring constituents.

The potential monitoring constituents in the second group (from interim status groundwater results) that were not already identified as proposed monitoring constituent through the preceding evaluation of the Part A constituents were evaluated as follows:

- Constituents were evaluated to determine if any are dangerous wastes. Any constituent identified as a dangerous waste was identified as a proposed monitoring constituent
- The remaining constituents were evaluated individually for one or more of the following:
  - Identifying related chemicals (e.g., parent compounds and isomers) that were already identified as proposed monitoring constituents (evaluated on a case-by-case basis).
  - Identifying any potential monitoring constituent that is not routinely analyzed by commercial laboratories. Any potential monitoring constituent that is not routinely analyzed by commercial laboratories was removed from consideration as a proposed monitoring constituent.
  - Comparing the maximum groundwater concentration of the potential monitoring constituent to the federal or state action level (evaluated on a case-by-case basis).

- Determining if a potential monitoring constituent was identified as present in the WMA U SSTs during leak events (Table 2-2) (evaluated on a case-by-case basis).

The results from the final monitoring constituent evaluation are detailed in Section 7.3 of Appendix B.

8.2 Results of Selection of Groundwater Monitoring Constituents

Based on the evaluation of the dangerous wastes identified from the SST System Part A Permit Application and groundwater data collected for WMA U under interim status monitoring plans, 61 waste constituents are identified as proposed monitoring constituents to detect and monitor any groundwater impacts from dangerous waste releases at WMA U (Table 8-1). Of the 61 waste constituents, 4 are nondangerous waste constituents that were quantified in groundwater above the applicable action level and were identified in the waste profile for the WMA U SSTs during leak events. Details of the constituent screening and selection process are provided in Chapter 7 of Appendix B of this document.

Table 8-1. Proposed Groundwater Monitoring Constituents for WMA U

Waste Constituent	CAS Number
Dangerous Waste Constituents	
1,1,1-Trichloroethane	71-55-6
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
1,1,2-Trichloroethane	79-00-5
1,1-Dichloroethylene	75-35-4
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1
1,2-Dichloroethane	107-06-2
1,4-Dichlorobenzene	106-46-7
1-Butanol (N-butyl alcohol)	71-36-3
2,4-Dinitrophenol	51-28-5
2,4-Dinitrotoluene	121-14-2
2-Hexanone (Methyl butyl ketone)	591-78-6
2-Methylphenol (o-Cresol)	95-48-7
2-Nitropropane	79-46-9
Acetone	67-64-1
Antimony	7440-36-0
Arsenic	7440-38-2
Benzene	71-43-2
Beryllium	7440-41-7
Bromodichloromethane	75-27-4
Cadmium	7440-43-9
Carbon disulfide	75-15-0

Table 8-1. Proposed Groundwater Monitoring Constituents for WMA U

Waste Constituent	CAS Number
Dangerous Waste Constituents	
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
Chromium	7440-47-3
Cobalt	7440-48-4
Copper	7440-50-8
Cresols	1319-77-3
Cyclohexanone	108-94-1
Diethyl phthalate	84-66-2
Endosulfan sulfate	1031-07-8
Ethyl acetate	141-78-6
Ethyl ether	60-29-7
Ethylbenzene	100-41-4
Isobutanol	78-83-1
Lead	7439-92-1
Mercury	7439-97-6
Methanol	67-56-1
Methyl ethyl ketone (2-Butanone)	78-93-3
Methyl isobutyl ketone	108-10-1
Methylene chloride	75-09-2
Nickel	7440-02-0
Nitrobenzene	98-95-3
Phenol	108-95-2
Pyridine	110-86-1
Selenium	7782-49-2
Silver	7440-22-4
Sulfide	18496-25-8
Tetrachloroethene	127-18-4
Tin	7440-31-5
Toluene	108-88-3
Trichloroethylene	79-01-6
Trichlorofluoromethane	75-69-4

Table 8-1. Proposed Groundwater Monitoring Constituents for WMA U

Waste Constituent	CAS Number
Dangerous Waste Constituents	
Vanadium	7440-62-2
Vinyl chloride	75-01-4
Xylene (total)	1330-20-7
Zinc	7440-66-6
Nondangerous Waste Constituents	
Aluminum	7429-90-5
Iron	7439-89-6
Manganese	7439-96-5
Nitrate	14797-55-8

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 (G)(V).

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 been observed at WMA U. Therefore, WMA U will be in compliance monitoring under WAC 173-303-645(10) when WMA U 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 six downgradient wells proposed for the monitoring well network (299-W18-260, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47) span the range of particle distribution as released from WMA U. The well placement is suitable for detecting releases to the water table from WMA U under the evaluated range of conditions. The proposed well locations comply with the intent of WAC 173-303-645(6), which is to detect increases of contamination from the facility that would pose a potential risk to ground and surface water. The downgradient wells are proposed as the point of compliance wells. Additional details regarding selection of these wells are presented in Chapter 7. In order to monitor the vertical contamination distribution at the point of compliance, data from available deep wells will be evaluated from other groundwater monitoring programs in the immediate area of the DWMU. These additional wells will be defined in the groundwater monitoring plan and added to the monitoring well network for the DWMU.

9.3 Proposed Groundwater Monitoring Network

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

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

> "In detection monitoring or where appropriate in compliance 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 WMA U is discussed in Section 9.7.

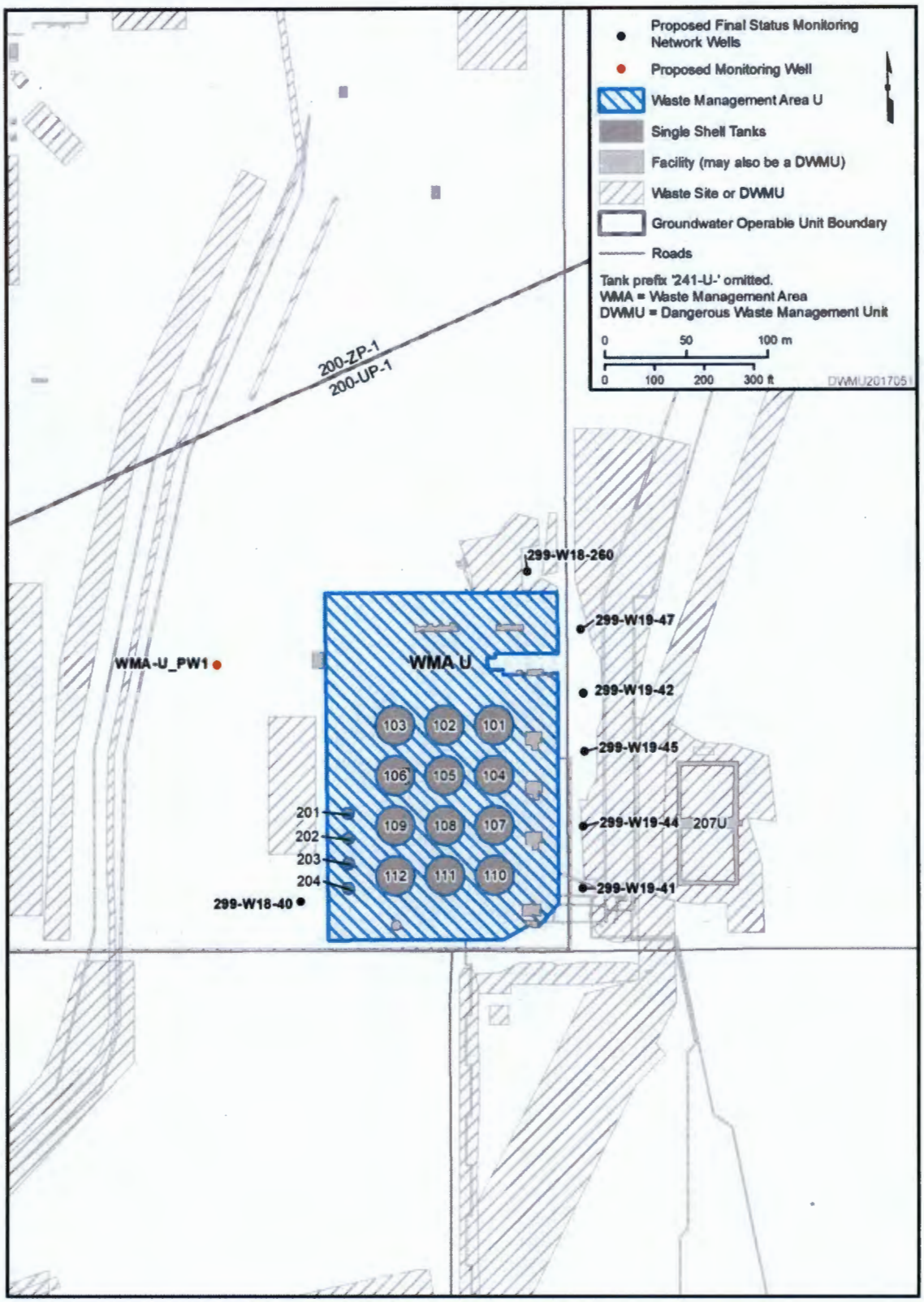

Figure 9-1. Proposed Final Status Groundwater Monitoring Network for WMA U

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

Well Name	Completion Date	Easting* (m)	Northing* (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-W18-40	9/28/2001	566723.29	134996.41	203.4 (667.4)	133.1 (436.6)	70.3 (230.7)	7.6 (24.9)	7/12/2017
299-W18-260	11/25/2014	566862.54	135196.89	205.7 (675.1)	132.1 (433.5)	73.7 (241.6)	9.3 (30.5)	6/23/2017
299-W19-41	9/23/1998	566896.53	135004.51	206.5 (677.6)	132.2 (433.6)	74.4 (244.0)	4.2 (13.8)	6/23/2017
299-W19-42	9/16/1998	566896.81	135122.90	206.2 (676.6)	132.1 (433.4)	74.1 (243.2)	4.4 (14.4)	6/23/2017
299-W19-44	9/13/2001	566896.95	135041.97	207.3 (680.1)	132.1 (433.2)	75.2 (246.8)	6.3 (20.7)	7/5/2017
299-W19-45	8/23/2001	566897.65	135087.65	206.4 (677.2)	132.1 (433.3)	74.4 (243.9)	5.4 (17.7)	7/5/2017
299-W19-47	8/25/2004	566895.31	135161.86	206.3 (676.8)	132.1 (433.4)	74.2 (243.4)	6.4 (21.0)	7/5/2017
WMA-U_PW1	TBD	566656.54	135140.85	205.04 (672.7)	133.4 (437.7) (est.)	71.0 (232.9) (est.)	10.7 (35.0)	TBD

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

amsl = above mean sea level

bgs = below ground surface

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

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

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

Based on current groundwater flow direction to the east and predictions of future groundwater flow direction toward the northeast over time (Section 3.7 in DOE/RL-2016-66), the selected point of compliance wells will provide representative samples of the quality of groundwater passing the point of compliance (WAC 173-303-645(8)(a)(ii)). These locations allow for the detection of contamination when dangerous waste or dangerous constituents have migrated from the WMA to the uppermost aquifer (WAC 173-303-645(8)(a)(iii)). The API calculator used 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 in Appendix G) and determination of compliance with groundwater protection standards (WAC 173-303-645(10)(a)).

9.3.1 Groundwater Monitoring Well 299-W18-40

Groundwater monitoring well 299-W18-40 is proposed as a background well. It was constructed in 2001 to the standards of WAC 173-160. This well is also used in the interim status groundwater monitoring network for WMA U. The well is upgradient and is screened from elevation 136.20 m (446.84 ft) to elevation 125.53 m (411.84 ft) (Appendix E). Well 299-W18-40 is screened across the upper 7.6 m (24.9 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Under 200 West P&T system operations in 2016, groundwater flow direction at well 299-W18-40 is predominantly to the east-northeast at this well (Figure 3-5); however, future groundwater flow direction may be impacted by ongoing 200 West P&T operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed (Appendix G and Chapter 7) 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. 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 7-21 through 7-23) and the results of transport calculations (Figures 7-18 through 7-20) indicate that this well will remain upgradient of WMA U under the scenarios evaluated. The modeling performed for the most likely future 200 West P&T system operating conditions for scenario 1 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 82% for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.82 shown on the injection injected treated water dilution breakthrough curve in Figure 7-8).

9.3.2 Groundwater Monitoring Well WMA_U_PW1

Groundwater monitoring well WMA_U_PW1 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 WMA U and conceptually, it will be constructed with 10.7 m (35 ft) of screen placed from the top of 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 at this location is predominantly to the east-northeast at this proposed location; however, future groundwater flow direction may be impacted by ongoing 200 West P&T operations (i.e., changes in operating conditions). Particle-tracking simulations and transport modeling were performed (Appendix G and Chapter 7) to evaluate the impacts of 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. 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 7-21 through 7-23) and the results of transport calculations (Figures 7-18 through 7-20) indicate that this well will remain upgradient of WMA U under the scenarios evaluated.

The modeling performed for the most likely future 200 West P&T system operating conditions for scenario 1 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 76% for the most likely future 200 West P&T system operating conditions for scenario 1 (corresponding to the value of about 0.76 shown on the injection injected treated water dilution breakthrough curve in Figure 7-27).

9.3.3 Groundwater Monitoring Well 299-W18-260

Groundwater monitoring well 299-W18-260 is proposed as a point of compliance well. It was constructed in 2014 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for WMA U. The well is downgradient of WMA U and is screened from elevation 131.96 m (432.94 ft) to elevation 122.82 m (402.94 ft) (Appendix E). Well 299-W18-260 is screened across the upper 9.3 m (30.5 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Under 200 West P&T system operations in 2016, groundwater flow direction is predominantly to the east-northeast at this well (Figure 3-5); 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 (Appendix G and Chapter 7) 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. 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 7-21 through 7-23) and the results of transport calculations (Figures 7-18 through 7-20) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-24 through 7-26) indicate that this well is located at the northern extent of the estimated area of detectability for scenarios 1 and 2 and to the north 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 7-9 and 7-17) indicate some dilution of the release concentration is expected at the well location, which is normal for a well at the outer extent of the detectable areas. The modeling performed for the most likely future 200 West P&T system operating conditions for scenario 1 calculates that a unit concentration released at the waste site would be reduced by approximately 56% (corresponding to a release unit concentration of approximately 0.44 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 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 7-1). 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 and of increases in contamination should there be a release from WMA U under the range of operating conditions evaluated.

9.3.4 Groundwater Monitoring Well 299-W19-41

Groundwater monitoring well 299-W19-41 is proposed as a point of compliance well. It was constructed in 1998 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for WMA U. The well is downgradient of WMA U is screened from elevation 138.69 m (455.03 ft) to elevation 128.03 m (420.03 ft) (Appendix E). Well 299-W19-41 is screened across the upper 4.2 m (13.8 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 3-5); 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 (Appendix G and Chapter 7) 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. Within each overall P&T system flow rate scenario, the simulations evaluated the impact on groundwater flow 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 7-21 through 7-23) and the results of transport calculations (Figures 7-18 through 7-20) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-24 through 7-26) indicate that this well is located in the southern portion of the estimated area of detectability for all the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-11 and 7-17) indicate very little 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 for scenario 1 calculates that a unit concentration released at the waste site would be reduced by approximately 25% (corresponding to a release unit concentration of approximately 0.75 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 77% 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 0.77 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 77%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from WMA U under the range of operating conditions evaluated.

9.3.5 Groundwater Monitoring Well 299-W19-42

Groundwater monitoring well 299-W19-42 is proposed as a point of compliance well. It was constructed in 1998 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for WMA U. The well is downgradient of WMA U and is screened from elevation

138.36 m (453.93 ft) to elevation 127.66 m (418.83 ft) (Appendix E). Well 299-W19-42 is screened across the upper 4.4 m (14.4 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 3-5); 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 (Appendix G and Chapter 7) 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. Within each overall P&T system flow rate scenario, the simulations evaluated the impact on groundwater flow 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 7-21 through 7-23) and the results of transport calculations (Figures-18 through 7-20) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-24 through 7-26) indicate that this well is located centrally in the estimated area of detectability for scenarios 1 and 2 and in the northern portion 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 7-12 and 7-17, indicate very little 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 for scenario 1 calculates that a unit concentration released at the waste site would be reduced by approximately 18% (corresponding to a release unit concentration of approximately 0.82 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 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 7-4). 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 and of increases in contamination should there be a release from WMA U under the range of operating conditions evaluated.

9.3.6 Groundwater Monitoring Well 299-W19-44

Groundwater monitoring well 299-W19-44 is proposed as a point of compliance well. It was constructed in 2001 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for WMA U. The well is downgradient of WMA U and is screened from elevation 136.45 m (447.66 ft) to elevation 125.78 m (412.66 ft) (Appendix E). Well 299-W19-44 is screened across the upper 6.3 m (20.7 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 3-5); 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 (Appendix G and Chapter 7) 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. Within each overall P&T system flow rate scenario, the simulations evaluated the impact on groundwater flow 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 7-21 through 7-23) and the results of transport calculations (Figures 7-18 through 7-20) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-24 through 7-26) indicate that this well is located centrally in the estimated area of detectability for all the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-13 and 7-17) indicate very little 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 for scenario 1 calculates that a unit concentration released at the waste site would be reduced by approximately 20% (corresponding to a release unit concentration of approximately 0.80 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 76% 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 0.76 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 76%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from WMA U under the range of operating conditions evaluated.

9.3.7 Groundwater Monitoring Well 299-W19-45

Groundwater monitoring well 299-W19-45 is proposed as a point of compliance well. It was constructed in 2001 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for WMA U. The well is downgradient of WMA U and is screened from elevation 137.36 m (450.64 ft) to elevation 126.72 m (415.74 ft) (Appendix E). Well 299-W19-45 is screened across the upper 5.4 m (17.7 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 3-5); 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 (Appendix G and Chapter 7) 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. Within each overall P&T system flow rate scenario, the simulations evaluated the impact on groundwater flow 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 7-21 through 7-23) and the results of transport calculations (Figures 7-18 through 7-20) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-24 through 7-26) indicate that this well is located centrally in the estimated area of detectability for all the scenarios evaluated. The release concentration breakthrough curves for this well (Figures 7-14 and 7-17) indicate very little 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 for scenario 1 calculates that a unit concentration released at the waste site would be reduced by approximately 11% (corresponding to a release unit concentration of approximately 0.89 shown in Figure 7-14) 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 76% 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 0.76 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 76%, because some amount of this injection dilution is already accounted for in the assumption of instantaneous mixing in both the release concentration dilution calculations and injected treated water dilution calculations. The actual amount of dilution of the release concentration that would result from the treated water injection would depend upon the relative locations of the release, of the injection well(s), and of the monitoring well, and other factors at the field-scale. Groundwater samples from this location are representative of groundwater quality at the point of compliance. Collectively with the other proposed monitoring network wells, this well would allow for the detection of contamination and of increases in contamination should there be a release from WMA U under the range of operating conditions evaluated.

9.3.8 Groundwater Monitoring Well 299-W19-47

Groundwater monitoring well 299-W19-47 is proposed as a point of compliance well. It was constructed in 2004 to the standards in WAC 173-160. This well is also used in the interim status groundwater monitoring network for WMA U. The well is downgradient of WMA U and is screened from elevation 136.33 m (447.28 ft) to elevation 125.69 m (412.38 ft) (Appendix E). Well 299-W19-47 is screened across the upper 6.4 m (21.0 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 3-5); 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 (Appendix G and Chapter 7) 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. Within each overall P&T system flow rate scenario, the simulations evaluated the impact on groundwater flow 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 7-21 through 7-23) and the results of transport calculations (Figures 7-18 through 7-20) indicate that the location of this well is suited for detecting releases from the facility. The results of the relative detectability evaluation (Figures 7-24 through 7-26) indicate that this well is located centrally in the estimated area of detectability for scenarios 1 and 2 and on the northern edge of the detectable area for scenario 3 (no flow from the 200 West P&T system). The release concentration breakthrough curves for this well (Figures 7-15 and 7-17) indicate very little 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 for scenario 1 calculates that a unit concentration released at the waste site would be reduced by approximately 35% (corresponding to a release unit concentration of approximately 0.65 shown in Figure 7-15) 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 7-7). 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 and of increases in contamination should there be a release from WMA U under the range of operating conditions evaluated.

9.4 Constituent List and Frequency

The proposed WMA U final status groundwater monitoring network detailed in this report consists of two upgradient wells (existing well 299-W18-40 and proposed well WMA-U_PW1) and six downgradient wells (299-W18-260, 299-W19-41, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47). These wells are part of the WMA U interim status groundwater monitoring network (Table 3-20 in DOE/RL-2016-66) and are shown in Figure 9-1.

For a compliance monitoring program, WAC 173-303-645(10)(a) requires,

> "The owner or operator monitor the groundwater to determine whether regulated units are in compliance with the groundwater protection standard under subsection (3) of this section. The department will specify the groundwater protection standard in the facility permit, including: (i) A list of the dangerous constituents and parameters identified under subsection (4) of this section; (ii) Concentration limits under subsection (5) of this section, for each of those dangerous constituents and parameters; (iii) The compliance point under subsection (6) of this section; and (iv) The compliance period under subsection (7) of this section."

Based on the analysis in Chapter 8, 61 waste constituents were selected to detect and monitor groundwater impacts from dangerous waste releases at WMA U.

Table 9-2 identifies the proposed monitoring network and sampling frequency for WMA U. The proposed site-specific monitoring constituents (Table 9-3) were identified in Chapter 8 (Table 8-1), with the addition of hexavalent chromium (added at the discretion of Ecology). The site-specific monitoring constituents 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, 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 WMA U.

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

Well Name	Purpose	WAC Compliant	Water Level	Site-Specific Constituents to Detect and Monitor Groundwater Impacts from Releases at Regulated Unit[a]								Dangerous Wastes[b]	Field Parameters[f]
				Sulfide	Metals[c]	Nitrate	Volatile Organic Compounds[d]	Semivolatile Organic Compounds[e]	Methanol	Endosulfan Sulfate	Hexavalent Chromium	Table 9-4	
299-W18-40	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
WMA-U_PW1	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-W18-260	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-W19-41	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-W19-42	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-W19-44	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-W19-45	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-W19-47	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	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-090 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. Sampling after this 2-year period will be performed annually, in accordance with WAC 173-303-645(10)(g).

c. Metals are provided in Table 9-3 and include aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, tin, vanadium, and zinc.

d. Volatile organic compounds are provided in Table 9-3 and include 1-butanol (n-butyl alcohol); 1,1-dichloroethylene; 1,1,1-trichloroethane; 1,1,2-trichloro-1,2,2-trifluoroethane; 1,1,2-trichloroethane; 1,2-dichloroethane; 1,4-dichlorobenzene; 2-butanone (methyl ethyl ketone); 2-hexanone (methyl butyl ketone); 2-nitropropane; acetone; benzene; bromodichloromethane; carbon disulfide; carbon tetrachloride; chlorobenzene; chloroform; cyclohexanone; ethyl acetate; ethyl

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

Well Name	Purpose	WAC Compliant	Water Level	Site-Specific Constituents to Detect and Monitor Groundwater Impacts from Releases at Regulated Unit[a]								Dangerous Wastes[b]	Field Parameters[f]
				Sulfide	Metals[c]	Nitrate	Volatile Organic Compounds[d]	Semivolatile Organic Compounds[e]	Methanol	Endosulfan Sulfate	Hexavalent Chromium	Table 9-4	

ether; ethylbenzene; isobutanol; methyl isobutyl ketone; methylene chloride; tetrachloroethene; toluene; trichloroethylene; trichlorofluoromethane; vinyl chloride; and xylene (total).

e. Semivolatile organic compounds are provided in Table 9-3 and include 1,2-dichlorobenzene (o-dichlorobenzene), 2,4-dinitrophenol; 2,4-dinitrotoluene; 2-methylphenol (o-cresol); cresols, diethyl phthalate; nitrobenzene; phenol; and pyridine.

f. Field parameters include pH, dissolved oxygen, 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
WAC = *Washington Administrative Code*
Q = quarterly
S = semiannually
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 WMA U

Waste Constituent	CAS Number
Inorganics	
Hexavalent chromium	18540-29-9
Sulfide	18496-25-8
Metals	
Antimony	7440-36-0
Arsenic	7440-38-2
Beryllium	7440-41-7
Cadmium	7440-43-9
Chromium	7440-47-3
Cobalt	7440-48-4
Copper	7440-50-8
Lead	7439-92-1
Mercury	7439-97-6
Nickel	7440-02-0
Selenium	7782-49-2
Silver	7440-22-4
Tin	7440-31-5
Vanadium	7440-62-2
Zinc	7440-66-6
Volatile Organic Compounds	
1-Butanol (N-butyl alcohol)	71-36-3
1,1-Dichloroethylene	75-35-4
1,1,1-Trichloroethane	71-55-6
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
1,1,2-Trichloroethane	79-00-5
1,2-Dichloroethane	107-06-2
1,4-Dichlorobenzene	106-46-7
2-Butanone (Methyl ethyl ketone)	78-93-3
2-Hexanone (Methyl butyl ketone)	591-78-6
2-Nitropropane	79-46-9

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

Waste Constituent	CAS Number
2-Propanone (Acetone)	67-64-1
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1
Benzene	71-43-2
Bromodichloromethane	75-27-4
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
Cyclohexanone	108-94-1
Ethyl acetate	141-78-6
Ethyl ether	60-29-7
Ethylbenzene	100-41-4
Isobutanol (Isobutyl alcohol)	78-83-1
Methylene chloride	75-09-2
Tetrachloroethene	127-18-4
Toluene	108-88-3
Trichloroethylene (TCE)	79-01-6
Trichlorofluoromethane	75-69-4
Vinyl chloride (Chloroethene)	75-01-4
Xylene (total)	1330-20-7
Semivolatile Organic Compounds	
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1
2,4-Dinitrophenol	51-28-5
2,4-Dinitrotoluene	121-14-2
2-Methylphenol (o-cresol)	95-48-7
Cresols	1319-77-3
Diethyl phthalate	84-66-2
Nitrobenzene	98-95-3
Phenol	108-95-2
Pyridine	110-86-1

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

Waste Constituent	CAS Number
Alcohols/Ketones	
Methanol	67-56-1
Pesticides	
Endosulfan sulfate	1031-07-8
Non-Dangerous Waste Constituents	
Anions	
Nitrate	14797-55-8
Metals	
Aluminum	7429-90-5
Iron	7439-89-6
Manganese	7439-96-5

CAS = Chemical Abstracts Service

In accordance with 16-NWP-090, performing 1 year of background monitoring for WAC 173-303-110(3)(c) and (7) constituents was established. 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. Section 9.7 provides details on the number of sample data required to determine a statistical method.

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

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

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

Constituent	CAS Number	Constituent	CAS Number
Inorganic Constituents			
Antimony	7440-36-0	Mercury	7439-97-6
Arsenic	7440-38-2	Nickel	7440-02-0
Barium	7440-39-3	Selenium	7782-49-2
Beryllium	7440-41-7	Silver	7440-22-4
Cadmium	7440-43-9	Sulfide	18496-25-8
Chromium	7440-47-3	Thallium	7440-28-0
Cobalt	7440-48-4	Tin	7440-31-5
Copper	7440-50-8	Vanadium	7440-62-2
Cyanide	57-12-5	Zinc	7440-66-6
Lead	7439-92-1		
Volatile Organic Compounds			
1,1-Dichloroethane	75-34-3	Carbon tetrachloride	56-23-5
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	Chlorobenzene	108-90-7
1,1,1-Trichloroethane	71-55-6	Chloroethane	75-00-3
1,1,1,2-Tetrachloroethane	630-20-6	Chloroform	67-66-3
1,1,2-Trichloroethane	79-00-5	Chloroprene	126-99-8
1,1,2,2-Tetrachloroethane	79-34-5	Dibromochloromethane	124-48-1
1,2-Dibromo-3-chloropropane	96-12-8	p-Dichlorobenzene (1,4-Dichlorobenzene)	106-46-7
1,2-Dibromoethane	106-93-4	Dichlorodifluoromethane	75-71-8
1,2-Dichloroethane	107-06-2	Ethylbenzene	100-41-4
1,2-Dichloropropane	78-87-5	Ethyl methacrylate	97-63-2
trans-1,2-Dichloroethylene	156-60-5	Isobutanol (Isobutyl alcohol)	78-83-1
1,2,3-Trichloropropane	96-18-4	Methacrylonitrile	126-98-7
cis-1,3-Dichloropropene	10061-01-5	Methyl bromide (Bromomethane)	74-83-9
trans-1,3-Dichloropropene	10061-02-6	Methyl chloride (Chloromethane)	74-87-3
trans-1,4-Dichloro-2-butene	110-57-6	Methyl iodide (Iodomethane)	74-88-4
2-Butanone (Methyl ethyl ketone; MEK)	78-93-3	Methyl methacrylate	80-62-6
2-Propanone (Acetone)	67-64-1	Methylene bromide (Dibromomethane)	74-95-3
2-Hexanone (Methyl butyl ketone)	591-78-6	Methylene chloride	75-09-2
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1	Propionitrile (Ethyl cyanide)	107-12-0

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

Constituent	CAS Number	Constituent	CAS Number
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
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

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

Constituent	CAS Number	Constituent	CAS Number
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
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

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

Constituent	CAS Number	Constituent	CAS Number
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
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 Concentration Limits

Under WAC 173-303-645(5), Ecology will specify in the facility permit the concentrations limits that are part of the groundwater protection standard of WAC 173-303-645(3). Concentration limits will be proposed in the final status groundwater monitoring plan.

9.6 Compliance Period

Under WAC 173-303-645(7)(a), Ecology will specify in the facility permit the compliance period during which the groundwater protection standard of WAC 173-303-645(3) applies. The compliance period is the number of years equal to the active life of the WMA (including any waste management activity prior to permitting, and the closure period). Per WAC 173-303-645(7)(b), the compliance period begins when the owner or operator initiates a compliance monitoring program meeting the requirements of WAC 173 303-645(10).

For WMA U, the compliance period will begin when the compliance monitoring program under WAC 173 303-645(10) begins. The compliance monitoring program will begin when WMA U is permitted as a final status unit in the future Hanford Facility Dangerous Waste Permit. Because WMA U has not yet been closed, the compliance period cannot yet be determined.

9.7 Statistical Method

Under the most recent (2012) interim status monitoring plan (DOE/RL-2009-74, Rev. 1), samples for site-specific constituents that are identified as proposed monitoring constituents (i.e., chromium and nitrate) were collected at WMA U wells (annually at the upgradient well and semiannually at downgradient wells). 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. While the minimum number of samples are available, these samples were collected over a 4-year or longer period. With the need to provide an adequate representation of current baseline conditions given the fluctuating groundwater beneath WMA U due to the 200 West P&T system (Section 3.3.2), an accelerated sampling program will be conducted.

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 sufficient time between samples so as to not cause a problem with autocorrelation of samples (i.e., resampling the same water). After 2 years of sampling is completed, the statistical test method can be determined using the decision matrix included in Appendix H. In addition to this methodology, hydrogeology of the area also will be considered. To date, there has not been an impact from injected water at WMA U, but an impact is anticipated to begin after 2020 (Figures 7-1 through 7-7). The impact of this event will be considered in the evaluation of the statistical method. 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, reevaluation of the monitoring network will be performed annually in conjunction with the WAC 173-303-645(10)(e) determination of groundwater flow direction and rate in the uppermost aquifer. If the analysis suggests a change in the flow regime (e.g., changes resulting from modifications to the 200 West P&T system operations) that indicates that the likely migration direction of any hypothetical release is outside of or on the margins of the monitoring network for a DWMU, then the model will be used to reevaluate the monitoring network for that DWMU.

Results of the reevaluation 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 reevaluated 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 B

Identification of Site-Specific Monitoring Constituents for Waste Management Area U – ECF-200UP1-17-0123

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The calculation ECF-200UP1-17-0123, *Identification of Site-Specific Monitoring Constituents for Waste Management Area U,* was performed to evaluate the waste constituents associated with Waste Management Area U and constituents detected during interim status groundwater monitoring to identify proposed groundwater monitoring constituents. The calculation is available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065260H.

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Appendix C

Topographic Map

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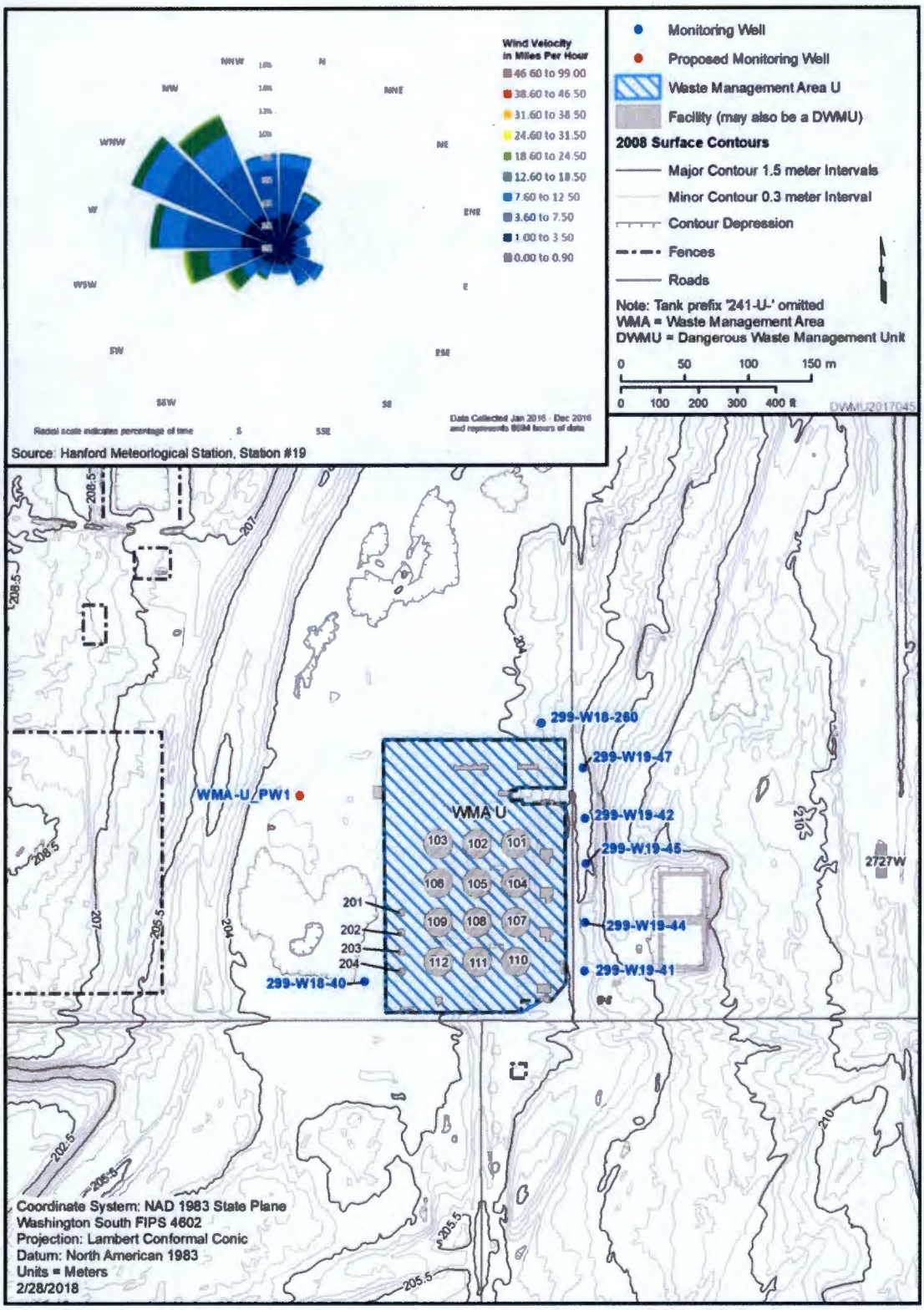

Figure C-1. Topographic Map

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Appendix D

Plume Maps

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D1 Introduction

This appendix presents regional plume maps in the vicinity of Waste Management Area (WMA) U (Figures D-1 and D-2). These plumes do not originate solely from WMA U but rather WMA U has likely contributed to the overall plumes.

In accordance with WAC 173-303-806(4)(a)(xx)(D), the maximum, detected result above background from each constituent sampled in 2016 from the WMA U monitoring well network (Table 3-20 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*) are presented (Figures D-3 through D-5). WAC 173-303-806(4)(a)(xx)(D)(II) defines the constituents to be those listed in Appendix "Ground-Water Monitoring List" in *Chemical Testing Methods for Designating Dangerous Waste*, which is incorporated at WAC 173-303-110(3)(c) and (7), and any other constituents not listed there which have caused a managed waste to be regulated. 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. Accordingly, the constituents identified in Appendix 5 of Ecology Publication No. 97-407 were evaluated for inclusion in these figures. Additionally, other chemical constituents that are not included in Appendix 5 of Ecology Publication No. 97-407, but were detected in 2016 samples from network wells, were evaluated for inclusion.

The maximum result for each detected constituent was compared to the Hanford Site 90th percentile groundwater background values, as appropriate (Table ES-1 in DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*). Dangerous waste constituents that were detected above background values, as well as those without background values, are presented in Figures D-3 and D-4. Figure D-5 presents chemical constituents that are nondangerous wastes and were detected above background values.

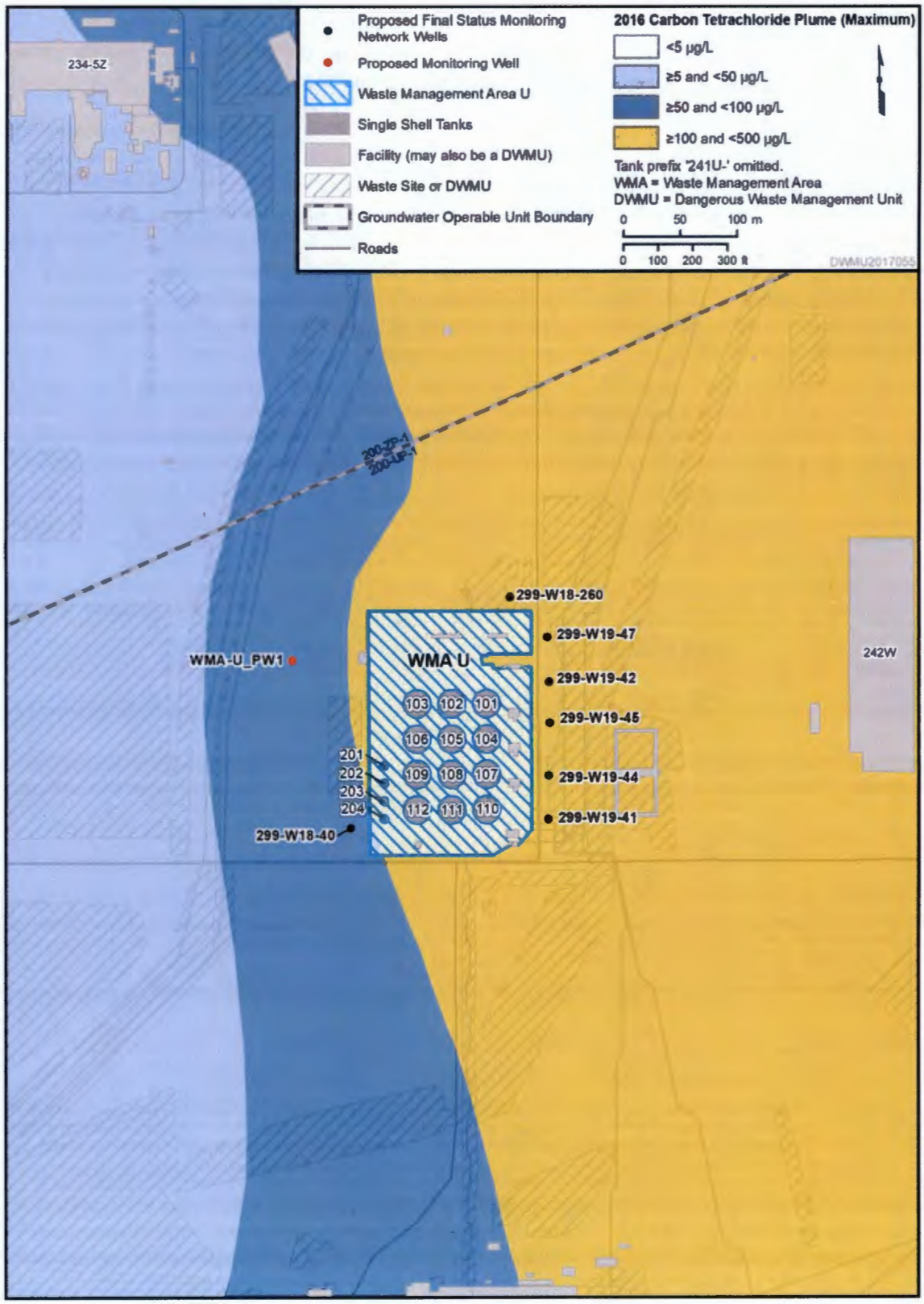


Figure D-1. Regional Carbon Tetrachloride Plume at WMA U

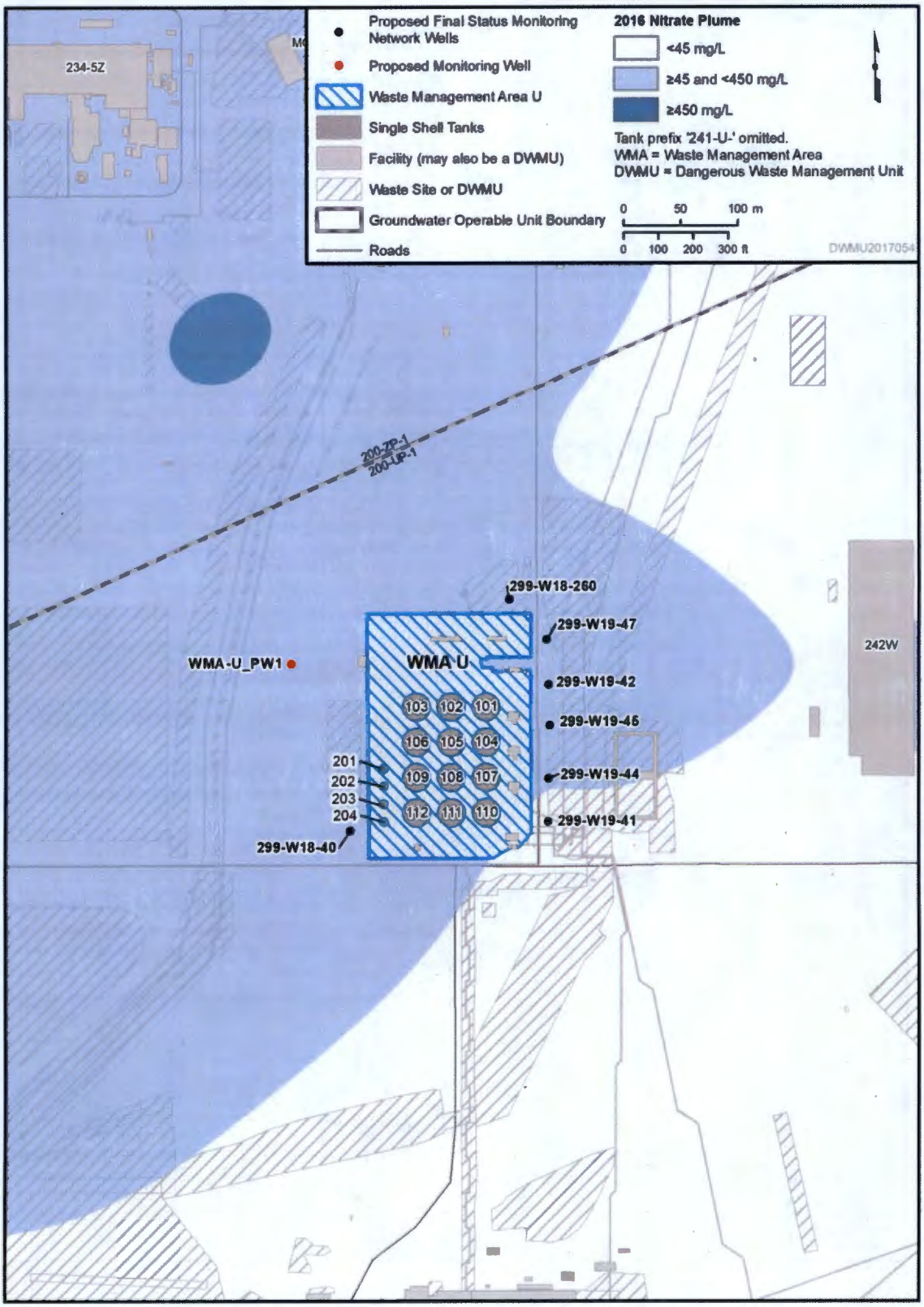


Figure D-2. Regional Nitrate Plume at WMA U

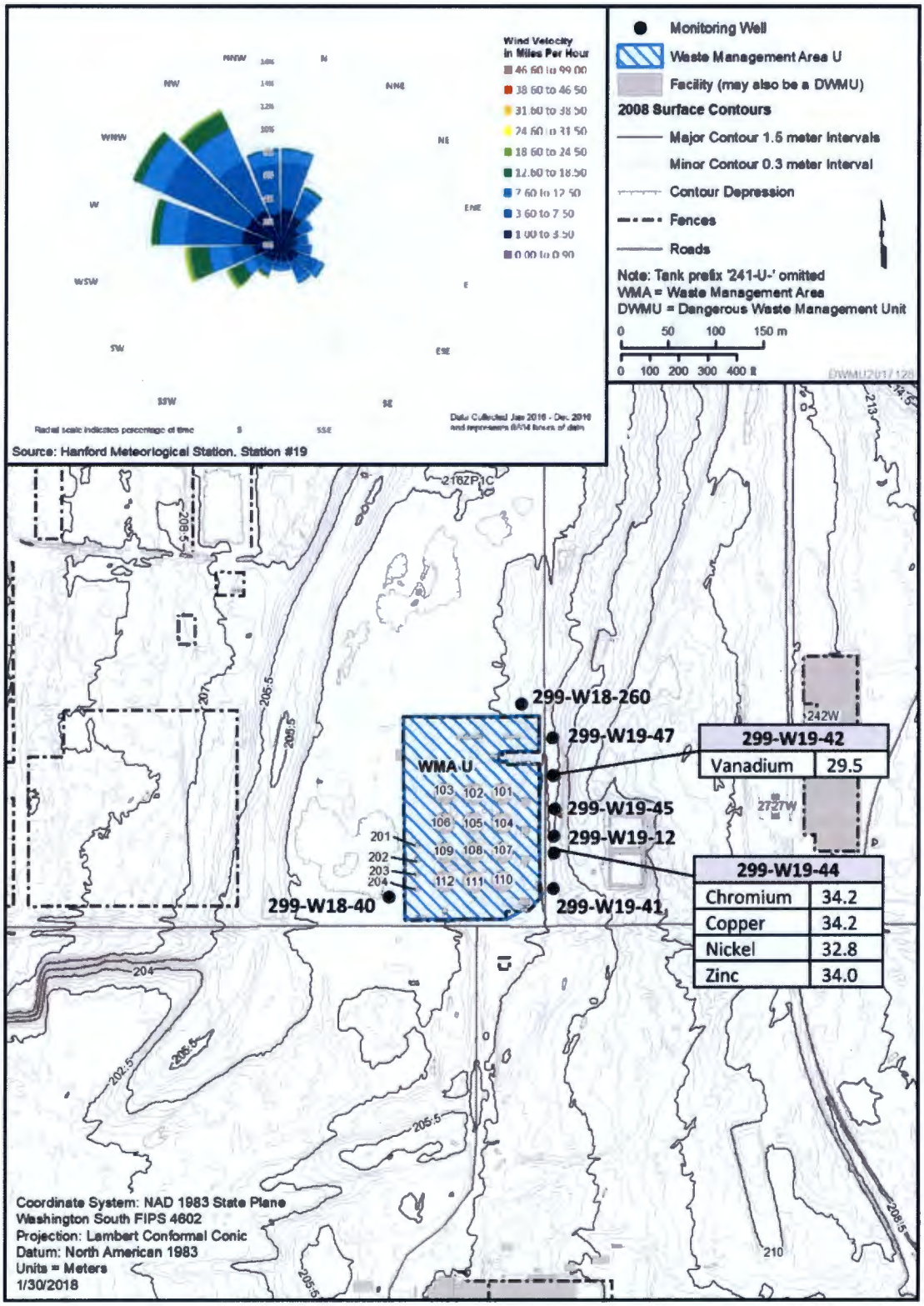
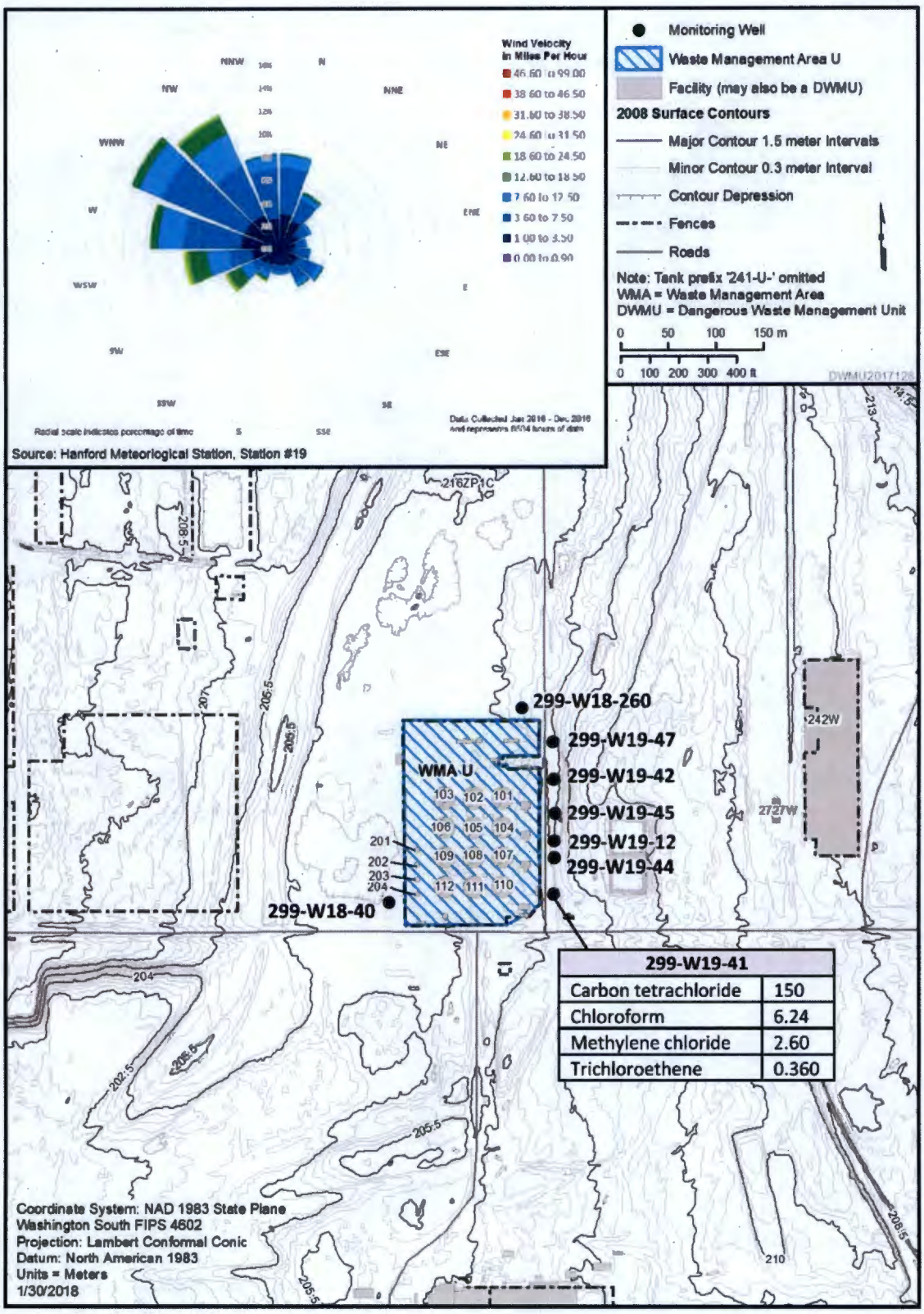


Figure D-3. 2016 Maximum Detected Groundwater Results of Metals and Inorganics in WMA U Network Wells (µg/L)



299-W19-41	
Carbon tetrachloride	150
Chloroform	6.24
Methylene chloride	2.60
Trichloroethene	0.360

Figure D-4. 2016 Maximum Detected Groundwater Results of Organics in WMA U Network Wells (µg/L)

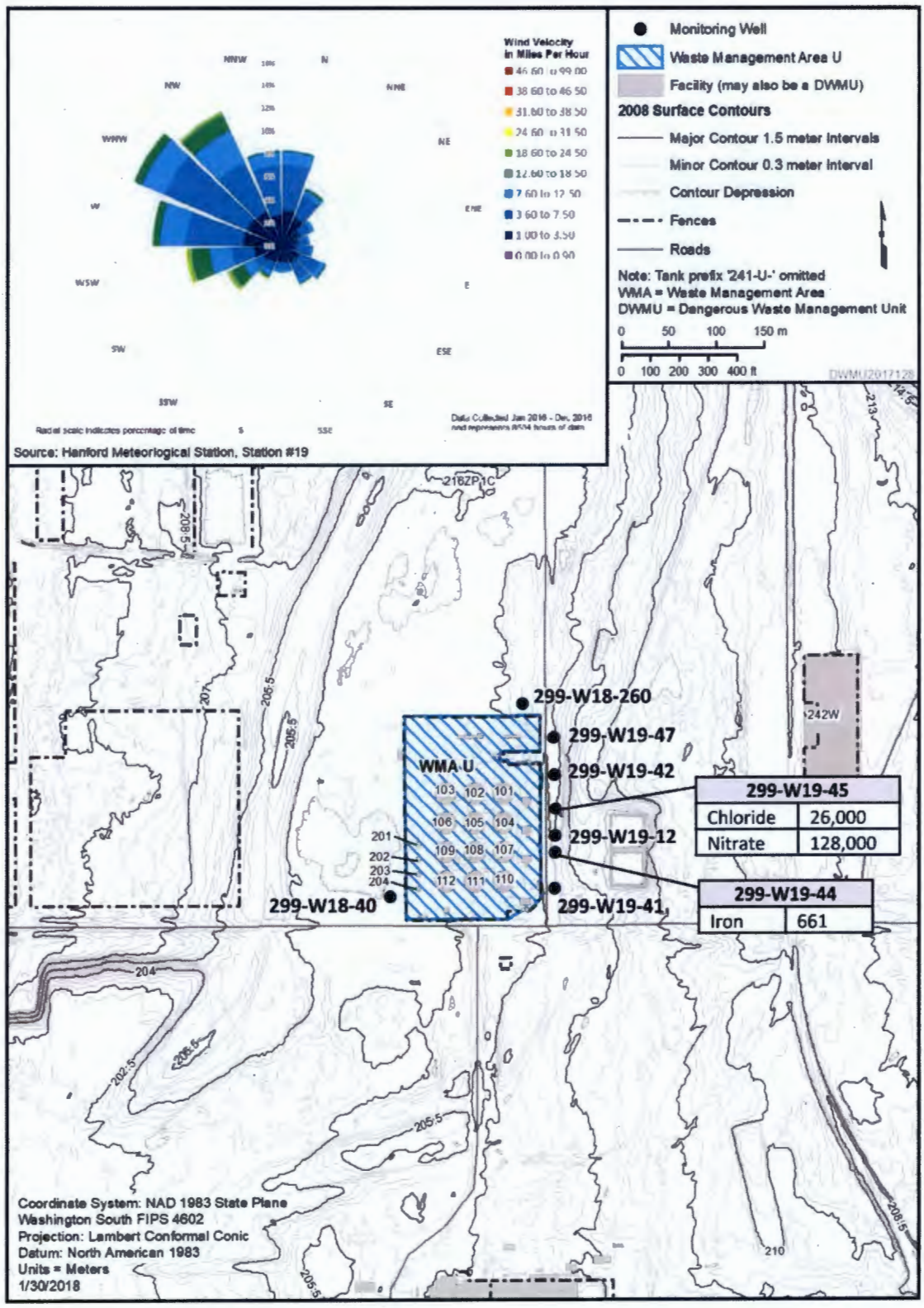


Figure D-5. 2016 Maximum Detected Groundwater Results of Nondangerous Constituents in WMA U Network Wells (µg/L)

D2 References

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Appendix E

Well As-Built Diagrams and Proposed Well Design Information

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E1 Introduction

This appendix provides the following information for the existing Waste Management Area (WMA) U 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-7 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 WMA U 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-W18-40	TU	136.2 (446.8)	125.53 (411.8)	10.7 (35.0)	Cable Tool
299-W18-260	TU	131.9 (432.9)	122.82 (402.9)	9.1 (29.9)*	Cable Tool
299-W19-41	TU	138.7 (455.0)	128.03 (420.0)	10.7 (34.9)*	Air Rotary
299-W19-42	TU	138.4 (453.9)	127.66 (418.8)	10.7 (35.1)*	Air Rotary
299-W19-44	TU	136.5 (447.7)	125.78 (412.7)	10.7 (35.0)	Cable Tool
299-W19-45	TU	137.4 (450.6)	126.72 (415.7)	10.6 (34.9)*	Cable Tool/Air Rotary
299-W19-47	TU	136.3 (447.3)	125.7 (412.4)	10.6 (34.9)*	Cable Tool

Table E-2. Sampling Interval Information for Wells within the WMA U 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

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

* Due to rounding and conversion of metric units, the computed open interval length based on the top and bottom elevations may differ slightly from the actual open interval length reported in the Summary Sheets below.

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

Table E-3. Planned Location, Depth, and Screen Interval for Proposed Well within the WMA U 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-U_PW1	135140.85	566656.54	204.4 (670.6)	133.4 (437.7)	71.0 (232.9)	134.1 (439.9)	10.16 (4)	71.0 (232.9) – 81.7 (267.9)	81.7 (267.9) – 82.6 (270.9)

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

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

bgs = below ground surface

WELL SUMMARY SHEET 0540421

Page 1 of 2

Date: 08/17/01

Well ID: C3395	Well Name: 299-W18-40
Location: SW corner of 241-U Tank Farm	Project: CY01 RCRA Drilling
Prepared By: C. Martinez / L.D. Walker Date: 09/19/01	Reviewed By: DC Weekes Date: 10/10/01
Signature: C. Martinez / LD Walker	Signature: DC Weekes

CONSTRUCTION DATA

Description:

Portland cement Grout 0'-11.6'

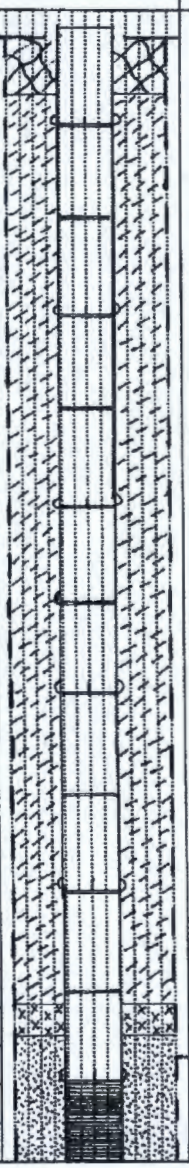
Casing: 4" sched 5
SS 304L ~~+1.9' → 218.27'~~
+1.9' → 218.27'

Granular Bentonite:
11.6' → 202.0'

Bentonite Pellets:
202.0' → 207.8'

Wellscreen: SS 304L
0.020-in slot cont. wire-wrap
218.27' → 253.28'

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 40, 80, 120, 160, 200

Graphic Log

Lithologic Description:

0'-10' Fill material
10'-17' Silty Sandy Gravel (mSG)
17'-19' Gravelly Sand (GS)
19'-23' Sandy Gravel (SG)
23'-27' Slightly Silty Sandy Gravel
27'-30' Silty Sand (mS)
30'-47.5' Sand (S)
47'-53' Silty Sandy GRAVEL (mSG)
53'-56' Gravelly SAND (gS)
56'-69.5' Silty sandy GRAVEL (mSG)
69.6'-114' SAND (S)
114-132.6' Sandy SILT (sM)
(81' silt layer)
132.5'-138.0' Silty Sandy Gravel w/ caliche
138'-144' Silty sandy Gravel (mSG)
144'-180' Sandy GRAVEL (SG)
180'-220.5' Silty sandy GRAVEL (mSG)
220.5'-222.5' Cemented silty sandy gravel
222.5'-250.0' Silty sandy GRAVEL (mSG)

BHI-EE-189 (12/97)

Figure E-1. Well 299-W18-40 Construction and Completion Summary

WELL SUMMARY SHEET

Page 2 of 2

Date: 09/19/01

Well ID: C 3395	Well Name: 299-W18-40
Location: SW Corner of 241-U Tank Farm	Project: CY01 RCRA Drilling
Prepared By: C. Martinez / LD Walker — Date: 09/19/01	Reviewed By: DC Weekes — Date: 10/10/01
Signature: C. Martinez / DC Weekes for LD Walker	Signature: DC Weekes

CONSTRUCTION DATA

Description	Diagram
Sandpack: 10-20 mesh silica 207.8' → 257.8'	
Tailpipe with welded endcap: 253.28' → 255.28'	
(WHATS FROM 257.8 TO 260 SLOUGH?)	
All temporary casing removed from ground	
All depths are in feet below ground surface	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
240		250.0'-252.5' cemented silty sandy gravel
		252.5'-260' silty sandy gravel (nsc)
280		TD = 260' bgs
		WL = 214.6' 9/27/01
300		

BHI-EE-189 (12/97)

Figure E-1. Well 299-W18-40 Construction and Completion Summary (continued)

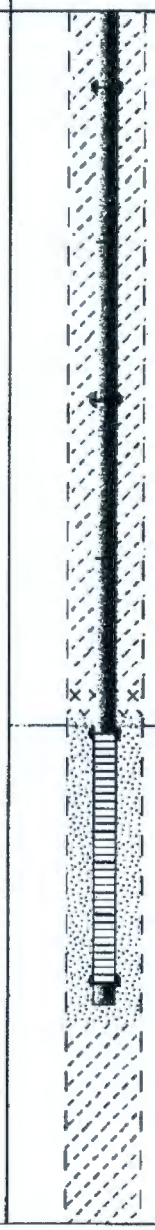
WELL SUMMARY SHEET		Start Date: 8-20-2014 Finish Date:11-25-14	Page 1 of 3
Well ID: C8925		Well Name: 299-W18-260	
Location: N of WMA U Tank Farm		Project: TPA M-24 Monitoring Wells	
Prepared by: Abby Wicks	Date: 10-23-2014	Reviewed by: D. MEHRER	Date: 1-21-15
Signature: Abby A. Wicks		Signature:	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
Temporary Casing Materials		0		
10 3/4" Carbon Steel				0'-4' Drill Pad, Sandy Gravel [sG]
(9 3/4" OD, 10 3/4" ID)				4'-15' Sand [S]
0.0 ft -129.87' ft bgs				
8" Carbon Steel				15'-19' Sandy Gravel [sG]
(8 11/16" OD, 8 3/4" ID)				19'-28' Gravel [G]
129.87 ft bgs-232.12		25		28'-33' Sandy Gravel [sG]
Permanent Casing Materials				33'-45' Sandy Gravel [sG]
4" Type 304 L sch 10s Riser				
2.00 ft ags-239.77 ft bgs				
4" Type 304 L sch 10s Continuous wire wrap screen				45'-48' Sandy Gravel [sG]
20 Slot		50		48'-58' Sand [S]
239.77 ft bgs-269.77 ft bgs				58'-60' Silty Sand [mS]
4" Type 304 L sch 10s Sump				60'-78' Sand [S]
269.77 ft bgs-272.77 ft bgs				
Construction Materials				
Concrete		75		78'-80' Sandy Silt [sM]
0 ft bgs-2.5 ft bgs				80'-85' Slightly Silty Sand [(m)S]
Type I-II Portland Cement Grout				85'-90' Sand [S]
2.5 ft bgs-14.10 ft bgs				90'-95' Silty Sand [mS]
Granular Bentonite Crumbles				95'-100' Sand [S]
14.10 ft bgs-233.4 ft bgs		100		100'-103' Sandy Silt [sM]
3/8" Bentonite Pellets				103'-105' Sand [S]
233.4 ft bgs-235.8 ft bgs				105'-110' Silty Sand [mS]
16-30 Mesh Colorado Silica Sand				110'-115' Sandy Silt [sM]
235.8 ft bgs- 274.4 ft bgs				115'-117' Sand [S]
3/4" Bentonite Hole Plug		125		117'-131.4' Silt [M]
274.4 ft bgs- 322.2 ft bgs				131.4'-136' Caliche Silt [M]
Natural Fill				136'-145' Gravelly Silt [gM]
322.2 ft bgs-326.3 ft bgs				
Note: All temporary casing has been removed from the ground. All depths are reported in feet below ground surface (ft bgs) unless otherwise noted.				

A-6003-643 (03/03)

Figure E-2. Well 299-W18-260 Construction and Completion Summary

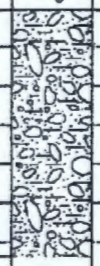
WELL SUMMARY SHEET		Start Date: 8-20-2014 Finish Date: 11-25-14	Page 2 of 3
Well ID: C8925		Well Name: 299-W18-260	
Location: N WMA U Tank Farm		Project: TPA M-24 Monitoring Wells	
Prepared by: Abby Wicks	Date: 10-23-2014	Reviewed by: J.D. MEHRER	Date: 1-21-15
Signature: Abby A. Wicks		Signature:	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
		150		145'-155' Sandy Gravel [sG]
				155'-185' Gravel [G]
		175		
				185'-190' Sandy Gravel [sG]
		200		190'-326.3' Sandy Gravel [sG]
		225		
				Depth to water 236.6 ft bgs. 9/18/14
		250		
		275		

A-6003-643 (03/03)

Figure E-2. Well 299-W18-260 Construction and Completion Summary (continued)

WELL SUMMARY SHEET		Start Date: 8-20-2014 Finish Date: 11-25-14	Page 3 of 3
Well ID: C8925		Well Name: 299-W18-260	
Location: N WMA U Tank Farm		Project: TPA M-24 Monitoring Wells	
Prepared by: Abby Wicks	Date: 10-23-2014	Reviewed by: J.D. MEHRER	Date: 1-21-15
Signature: Abby A. Wicks		Signature:	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
		300 325		190'-326.3' Silty Sandy Gravel [msG] TD @ 326.3' bgs DTW 237.4' bgs 11/25/14

A-6003-643 (03/03)

Figure E-2. Well 299-W18-260 Construction and Completion Summary (continued)

0502374

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Air Rotary - TUBEX	Sample Method:	Grab/Split Spoon	WELL NUMBER:	299-W19-41 B8551
Drilling Fluid Used:	Reverse Air	Additives Used:	None	TEMPORARY WELL NO:	Not Allowed
Driller's Name:	Willie Franklin	WA State Lic Nr:	Not Available	Coordinates: N	Not documented
Drilling Company:	Layne Christensen	Company Location:	Salt Lake City, Ut	Coordinates: E	Not documented
Date Started:	17Sep98	Date Completed:	23Sep98	Start Card #:	Not Available
				Elevation Ground Surface:	Brass Marker

Depth to Water: 220.35 ft 23Sep98
(Ground surface)

GENERALIZED STRATIGRAPHY — Geologist's Log & Geophysical Logs

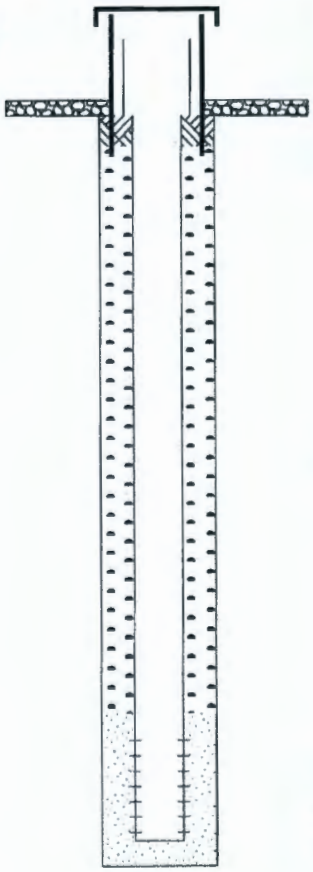
Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 10.5 ft

Type of Surface Seal: 4x4 Concrete Pad

0 - 0.1 ft : Asphalt
0.1 - 14 ft : Silty sandy gravel
14 - 22 ft : Sand
22 - 39 ft : Sandy gravel
39 - 43 ft : Gravelly sand
43 - 47 ft : Sandy gravel
47 - 54 ft : Gravelly sand
54 - 81 ft : Sand
81 - 84 ft : Sand (Fn)
84 - 88 ft : Sand (Cse)
88 - 91 ft : Sand (Fu)
91 - 127 ft : Sand
127 - 136 ft : Silty sand
136 - 144 ft : Sandy silt - calcareous
144 - 168 ft : Silty sandy gravel
168 - 188 ft : Sandy gravel
188 - 249 ft : Silty sandy gravel
(Water Level = 220.35')
249 - 253 ft : Silty sandy gravel - Fe staining
253 - 264.5 ft : Silty sandy gravel



Fill	*Casing*	*Screen*
0 - 10.5 ft : 9.125-inch hole Cement Seal	0 - 220.05 ft : 4 inch 4" Sch.5 SS Csg.	
10.5 - 210.4 ft : 9.125-inch hole Bentonite Chips		
210.4 - 255.47 ft : 9.125-inch hole 20/40 Silica Sand		220.05 - 255.14 ft : 4 inch 4" Wire Wrap SS Screen .010 Slot
255.47 - 264.5 ft : 9.125-inch hole 20/40 Silica Sand	255.14 - 255.47 ft : 4 inch 4" SS End Cap	

264.5 ft : Borehole drilled depth

0 - 264.5 ft : 9.125-in. 8-5/8" CS Temp. Csg. set with TUBEX reverse air rotary

Drawing By:	TGB
Reference:	Hanford Wells
Revision:	0
Revision Date:	25Sep98
Print Date:	28Dec98

Report Form: WELLS Project File: WELLS.GPJ

Figure E-3. Well 299-W19-41 Construction and Completion Summary

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W19-41

WELL DESIGNATION	:	299-W19-41
CERCLA UNIT	:	
RCRA FACILITY	:	
DEPTH DRILLED (GS)	:	264.5 ft
MEASURED DEPTH (GS)	:	255.47
AVAILABLE LOGS	:	Geologist & Geophysical Logs
DATE EVALUATED	:	Data not available
EVAL RECOMMENDATION	:	Data not available
LISTED USE	:	Data not available
CURRENT USER	:	RCRA & Operations
PUMP TYPE	:	Data not available
MAINTENANCE	:	Data not available
COMMENTS	:	8-5/8" TUBEX Sys. 4-1/2" Reverse Cir. Drl. Pipe with Interchange
TV SCAN COMMENTS	:	

Report Form: WELL8 Project File: WELLS.GPJ

Drawing By: TGB
Reference: Hanford Wells
Revision: 0
Revision Date: 25Sep98
Print Date: 28Dec98

Figure E-3. Well 299-W19-41 Construction and Completion Summary (continued)

0502376

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Air Rotary - TUBEX	Sample Method:	Grab/Split Spoon	WELL NUMBER:	299-W19-42 B8553
Drilling Fluid Used:	Reverse Air	Additives Used:	None	TEMPORARY WELL NO:	Not Allowed
Driller's Name:	Willie Franklin	WA State Lic Nr:	Not Available	Coordinates: N	Not documented
Drilling Company:	Layne Christensen	Company Location:	Salt Lake City, Ut	Coordinates: E	Not documented
Date Started:	31Aug98	Date Completed:	16Sep98	Start Card #:	Not Available
				Elevation Ground Surface:	Brass Marker

Depth to Water: 219.56 ft 16Sep98
(Ground surface)

GENERALIZED STRATIGRAPHY — Geologist's Log & Geophysical Logs

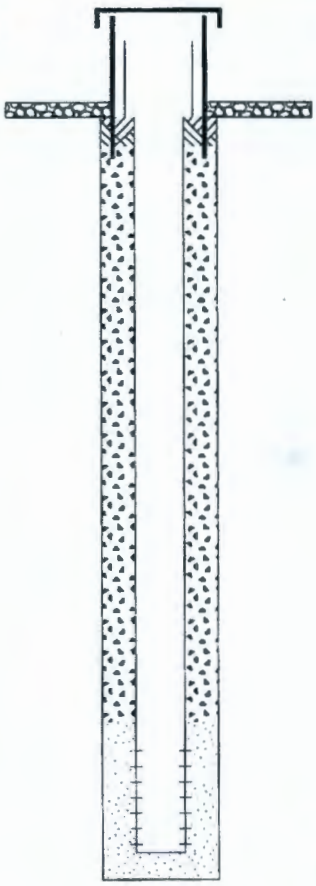
Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 10.2 ft

Type of Surface Seal: 4x4 Concrete Pad

0 - 0.7 ft : Backfill (gm 5)
0.7 - 7 ft : Sand
7 - 15 ft : Sandy gravel
15 - 119.5 ft : Silty sand
15 - 16 ft : Sand
16 - 32.5 ft : Sandy gravel
32.5 - 39 ft : Sandy gravel
39 - 43.5 ft : Sandy gravel
43.5 - 52 ft : Slightly silty gravelly sand
52 - 53 ft : Sandy gravel
53 - 71 ft : Sand
71 - 79 ft : Sand
79 - 84 ft : Slightly silty sand
84 - 89 ft : Sand
89 - 105 ft : Slightly silty sand
119.5 - 138.5 ft : Silt
138.5 - 141 ft : Caliche
141 - 170 ft : Silty sandy gravel
170 - 189 ft : Silty sandy gravel
189 - 196 ft : Gravelly sand
196 - 222 ft : Sandy gravel
222 - 265.2 ft : Silty sandy gravel



Fill	Casing	Screen
0 - 10.2 ft : 9.125-inch hole Cement Seal	0 - 220.28 ft : 4 inch 4" Sch 5 SS Csg.	
10.2 - 210.2 ft : 9.125-inch hole Bentonite Chips		
210.2 - 255.7 ft : 9.125-inch hole 20-40 Silica Sand		220.28 - 255.37 ft : 4 inch 4" Wire Wrap SS Screen .010 Slot
255.7 - 265.2 ft : 9.125-inch hole 20-40 Silica Sand	255.37 - 255.7 ft : 4 inch 4" SS End Cap	

265.2 ft : Borehole drilled depth

0 - 265.2 ft : 9.125-in. 8-5/8" CS Temp. Csg.

Drawing By: TGB
Reference: Hanford Wells
Revision: 0
Revision Date: 21Sep98
Print Date: 28Dec98

Report Form: WELL8 Project File: WELL5.GPJ

Figure E-4. Well 299-W19-42 Construction and Completion Summary

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W19-42

WELL DESIGNATION	:	299-W19-42
CERCLA UNIT	:	
RCRA FACILITY	:	
DEPTH DRILLED (GS)	:	265.2 ft
MEASURED DEPTH (GS)	:	
AVAILABLE LOGS	:	Data not available
DATE EVALUATED	:	Data not available
EVAL RECOMMENDATION	:	Data not available
LISTED USE	:	Data not available
CURRENT USER	:	RCRA & Operations
PUMP TYPE	:	Data not available
MAINTENANCE	:	Data not available
COMMENTS	:	8-5/8" TUBEX Sys. 4-1/2" Reverse Cir. Drl. Pipe with Interchange
TV SCAN COMMENTS	:	

Drawing By: TGB
Reference: Hanford Wells
Revision: 0
Revision Date: 21Sep98
Print Date: 28Dec98

Report Form: WELLS Project File: WELLS.GPJ

Figure E-4. Well 299-W19-42 Construction and Completion Summary (continued)

0540340

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Cable Tool	Sample Method:	Grab/Split Spoon	WELL NUMBER:	299-W19-44 C3393
Drilling Fluid Used:	None	Additives Used:	raw water	TEMPORARY WELL NO:	Not Allowed
Driller's Name:	K. Olson	WA State Lic Nr:	Data not available	Coordinates: N	Not documented
Drilling Company:	RSI	Company Location:	Woodland, Ca.	Coordinates: E	Not documented
Date Started:	06Sep01	Date Completed:	13Sep01	Start Card #:	R
				Elevation Ground Surface:	

Depth to Water: 230.9 ft 05Sep01
(Ground surface)

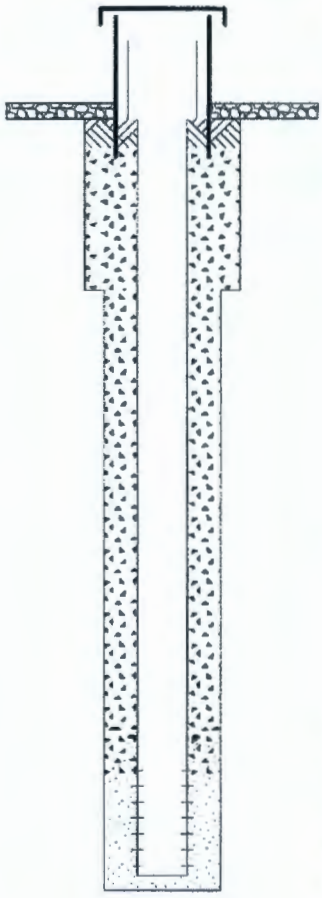
GENERALIZED STRATIGRAPHY Geologist's Log

0 - 2.5 ft : Sandy Gravel (Sg)
2.5 - 7 ft : gravelly Sand (gS)
7 - 11 ft : sandy Gravel (sG)
11 - 19 ft : gravelly Sand (gS)
19 - 31 ft : silty sandy Gravel (MSG)
31 - 38.5 ft : sandy Gravel (sG)
38.5 - 44 ft : gravelly Sand (gS)
44 - 45.5 ft : sandy Gravel (sG)
45.5 - 50 ft : cemented silty Gravel
50 - 52 ft : gravelly Sand (gS)
52 - 58 ft : Sand (S)
58 - 59.2 ft : Silt (m)
59.2 - 67 ft : Sand (S)
67 - 67.5 ft : sandy Silt (sm)
67.5 - 68 ft : Silt (m)
68 - 69 ft : Sand (S)
69 - 70.5 ft : Silt (m)
70.5 - 81.5 ft : Sand (S)
81.5 - 88 ft : sandy Silt (sm)
88 - 97.5 ft : silty Sand (mS)
97.5 - 103 ft : Sand (S)
103 - 131.8 ft : silty Sand (mS)
131.8 - 144.5 ft : Silt (m)

144.5 - 150.5 ft : Caliche
150.5 - 155 ft : slightly silty gravelly sand
155 - 233 ft : silty sandy Gravel

233 - 234.45 ft : cemented silty sandy gravel
234.5 - 267.5 ft : silty sandy Gravel (msG)

267.5 - 269.5 ft : cemented silty sandy gravel
269.5 - 272 ft : silty sandy Gravel (msG)



Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 10.3 ft

Type of Surface Seal: 4x4 Concrete Pad

Fill	*Casing*	*Screen*
0 - 10.3 ft : 12-inch hole Cement Surface Seal	0 - 229.9 ft : 4 inch 304L SS sch 5 csg	
10.3 - 61 ft : 12-inch hole Bentonite crumbles		
61 - 231.3 ft : 9-inch hole Bentonite crumbles		
213.3 - 218.9 ft : 9-inch hole 1/4" Bentonite Pellets		229.9 - 264.9 ft : 4 inch 304L SS Wire Wrap .020 slot scm
218.9 - 266.9 ft : 9-inch hole 10/20 Silica Sand		
266.9 - 272 ft : 9-inch hole 10/20 Silica Sand	264.9 - 266.9 ft : 4 inch 304L SS Sump	

272 ft : Borehole drilled depth

0 - 61 ft : 12-in. Cable Tool 11-3/4" CS Temp csg
61 - 272 ft : 9-in. Cable Tool 8-5/8" CS Temp csg

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 18Oct01
Print Date: 24Oct01

Report Form: WELLS Project File: WELLS.GPJ

Figure E-5. Well 299-W19-44 Construction and Completion Summary

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W19-44

WELL DESIGNATION	:	299-W19-44
CERCLA UNIT	:	
RCRA FACILITY	:	
DEPTH DRILLED (GS)	:	272.0 ft
MEASURED DEPTH (GS)	:	266.9 13Sep01
AVAILABLE LOGS	:	Geologist & Geophysical
DATE EVALUATED	:	Data not available
EVAL RECOMMENDATION	:	Data not available
LISTED USE	:	RCRA Monitoring
CURRENT USER	:	RCRA & Operations
PUMP TYPE	:	Not Documented
MAINTENANCE	:	Data not available
COMMENTS	:	Cable Tool 11-3/4" Temp CS csg to 61 ft, 8-5/8" temp Cs csg to 272 ft
TV SCAN COMMENTS	:	

Report Form: WELLS Project File: WELLS.GPJ

Drawing By:	JEA
Reference:	Hanford Wells
Revision:	0
Revision Date:	18Oct01
Print Date:	24Oct01

Figure E-5. Well 299-W19-44 Construction and Completion Summary (continued)

WELL SUMMARY SHEET

0540420

Page 1 of 2

Date: 08/15/01

Well ID: C3394	Well Name: 299-W19-45
Location: East side of 241-U	Project: CY01 RCRA Drilling
Prepared By: Charlene Martinez — Date: 08/21/01	Reviewed By: DC Weekes — Date: 9/20/01
Signature: Charlene Martinez	Signature: DC Weekes

CONSTRUCTION DATA

Description

6"-dia. protective casing set 1.0' above 4" stainless casing

4" ID SS304L casing: +2.11' → 224.12'

Portland Cement Grout: 0' → 9.5'

Bentonite Crumbles: 9.5' → 207.3'

3/8" Bentonite Pellets: 207.3' → 213.4'

4" ID SS304L 0.020-in. slot cont. wire-wrap wellscreen: 224.12' → 259.03'

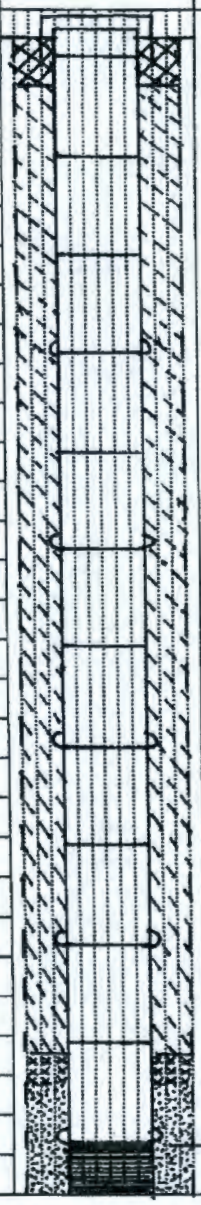
10-20 mesh silica sand: 213.4' → 216.61'

4" ID SS304L Tailpipe (Sump): 259.03' → 261.13'

All temporary casing removed.

All depths are in feet below ground surface.

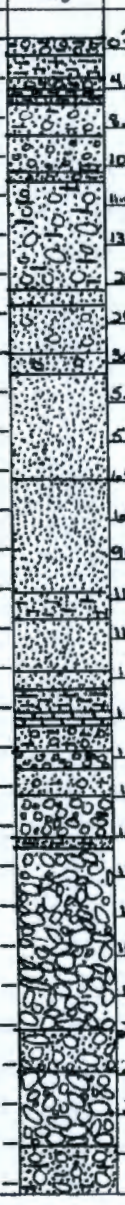
Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 40, 80, 120, 160, 200

Graphic Log



Lithologic Description

0'-4.5' Silty Sandy Gravel (msG)
4.5'-8.0' Sandy Silt (sm)
8.0'-10.5' Silty Sandy Gravel (msG)
10.5'-11.0' Silt (m)
11.0'-13.0' Silty Sand (ms)
13.0'-20.0' Silty Sandy Gravel (msG)
20.0'-28.5' Sandy Gravel (sG)
28.5'-30.0' Slightly Silty Sandy Gravel
30.0'-52.0' Silty Sandy Gravel (msG)
52.0'-55.0' Sand (s)
55.0'-64.0' Gravelly Sand (GS)
64.0'-69.0' Sand (s) to gravel
69.0'-90.0' Sand (s)
90.0'-113' Sand (s)
113.0'-118.0' Silty Sand (ms)
118.0'-129.0' Sand (s)
129.0'-133' Sand (s)
133.0'-137.0' Sandy Silt (sm)
137.0'-139.0' Calcrete
139.0'-145.0' Silty Sandy Gravel (msG)
145.0'-148.0' Gravel (G)
148.0'-154.0' Gravelly Silty Sand (gms)
154.0'-163.0' Gravel (g)
163.0'-166.0' Silty Sand (ms)
166.0'-202.0' Gravel (g) to silt/sand
202.0'-210.0' Sandy Gravel (sg)
210.0'-226.0' Gravel (g)
226.0'-246.0' Silty Sandy Gravel (msg)

BHI-EE-189 (12/97)

Figure E-6. Well 299-W19-45 Construction and Completion Summary

WELL SUMMARY SHEET

Page 2 of 2

Date: 08/15/01

Well ID: C3394		Well Name: 299-W19-45	
Location: East of 241-U Tank Farm		Project: C401 RCRA Drilling	
Prepared By: Charlene Martinez	Date: 08/21/01	Reviewed By: DCWeekes	Date: 9/20/01
Signature: Charlene Martinez		Signature: DCWeekes	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
		240		
				CMW 10/23/01
				~~287.0' – 259.0 Silty sandy gravel~~
				~~(mag) slightly cemented~~ CMW 10/23/01
				(part of previous description)
		280		285' – 266.0'
		300		
				TD = 266.1' bgs
				Static water level = 224.4'
				on 8/24/01
All temporary casing removed.				
All depths are in feet below ground surface.				

BHI-EE-189 (12/97)

Figure E-6. Well 299-W19-45 Construction and Completion Summary (continued)

WELL SUMMARY SHEET

Start Date 04/23/04
Finish Date. 08/09/04
Page 1 of 2

Well ID: C4258	Well Name 299-W19-47
Location East side of WMA-4/200 West	Project. RCRA/CERCLA drilling, FY 2004
Prepared By Charlene Martinez Date: 08/11/04	Reviewed By L.D. Walker Date. 8-24-04
Signature Charlene Martinez	Signature. LD Walker

CONSTRUCTION DATA

Description:

11 7/8" / 10 7/8" temporary casing used.

6" ID SS304 protective casing set + 1.0' above permanent.

4" ID SS304, sch.5 riser: + 2.0' → 227.05'

Portland Cement: 0' → 10.7'

Granular Bentonite: 10.7' → 215.8'

* Formation slough 62.3' → 66.3'

3/8" Bentonite Pellets: 215.8' → 220.7'

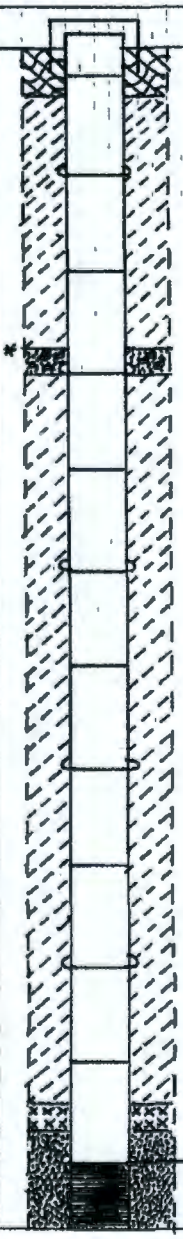
10-20 mesh Colorado Silica Sand: 220.7' → 269'

4" ID SS304, sch.5, 0.020-inch cont. wire-wrap wellscreen: 227.05' → 262.04'

All depths in feet below ground surface.

All temporary casing removed from ground.

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 40, 80, 120, 160, 200

Graphic Log

Lithologic Description

0'-1' Backfill material
1'-8' SAND(S) Hanford fmtn
8'-15' sandy GRAVEL(SG)
15'-16.5' SAND(S)
16.5'-17.5' sandy GRAVEL(SG)
17.5'-23' SAND(S)
23'-27' sandy GRAVEL(SG)
27'-36' silty sandy GRAVEL(mSG)
36'-47' sandy GRAVEL(SG)
47'-53' gravelly SAND(gS)
53'-90' SAND(S)
90'-124' silty SAND(mS)
124'-138' SILT(m) (Cold Creek unit)
138'-145' CALICHE. Silty Sandy Gravel (mSG)
145'-162' Silty Sandy GRAVEL (mSG)
162'-165' Sandy GRAVEL(SG)
165'-185.5' Silty Sandy GRAVEL (mSG)
185.5'-192' Sand (S)
192'-198.5' silty sandy gravel (mSG)
198.5'-201' sand (S)
201'-204' sandy gravel (SG)
204'-227' silty sandy gravel (mSG)
227'-229' sandy GRAVEL(SG)

A-6003-643 (03/03)

Figure E-7. Well 299-W19-47 Construction and Completion Summary

WELL SUMMARY SHEET		Start Date 04/23/04	Page 2 of 2
		Finish Date 08/09/04	
Well ID: C4258		Well Name 299-W19-47	
Location East side of WMA-U/200 West		Project: RCRA/CERCLA drilling FY 2004	
Prepared By: Charlene Martinez	Date 08/11/04	Reviewed By: L.D. Walker	Date 8-24-04
Signature: Charlene Martinez		Signature: D Walker	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
4" ID SS304, sch. 5 sump: 262.04' → 265.02'		240		229'-238' silty sandy GRAVEL (msG)
				238'-244' sandy GRAVEL (sG)
				244'-260' silty sandy GRAVEL (msG)
				260'-266' sandy GRAVEL (sG)
				266'-269' silty sandy GRAVEL (msG)
	TD=>269' bgs	280		
				TD @ 269' bgs
				Static water => 226.84' bgs (08/09/04)
NCR-04-GRP-015 issued on the formation slough condition at 62.3' → 66.3'				
All depths in feet below ground surface:				
All temporary casing removed from ground.				

A-6003-643 (03/03)

Figure E-7. Well 299-W19-47 Construction and Completion Summary (continued)

E2 Reference

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

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Appendix F

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

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

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Appendix G

Groundwater Flow and Migration Calculations to Support Assessment of the WMA U Monitoring Network – ECF-200W-17-0074

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The calculation ECF-200W-17-0074, *Groundwater Flow and Migration Calculations to Support Assessment of the WMA U Monitoring Network,* was performed to evaluate monitoring well locations for the Waste Management Area U groundwater monitoring network. The calculation is available at: https://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0065258H.

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Appendix H

Statistical Method Determination

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H2 Reference **H-10**

Figures

Figure H-1. Data Evaluation H-2
Figure H-2. Outlier Test Evaluation H-3
Figure H-3. Intrawell/Interwell Assessment H-4
Figure H-4. Spatial Variance Evaluation H-5
Figure H-5. Data Distribution Evaluation H-6
Figure H-6. Temporal Trend Analysis H-7
Figure H-7. Equal Variance Evaluation H-8
Figure H-8. Chart Legend H-9

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H1 Introduction

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

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

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

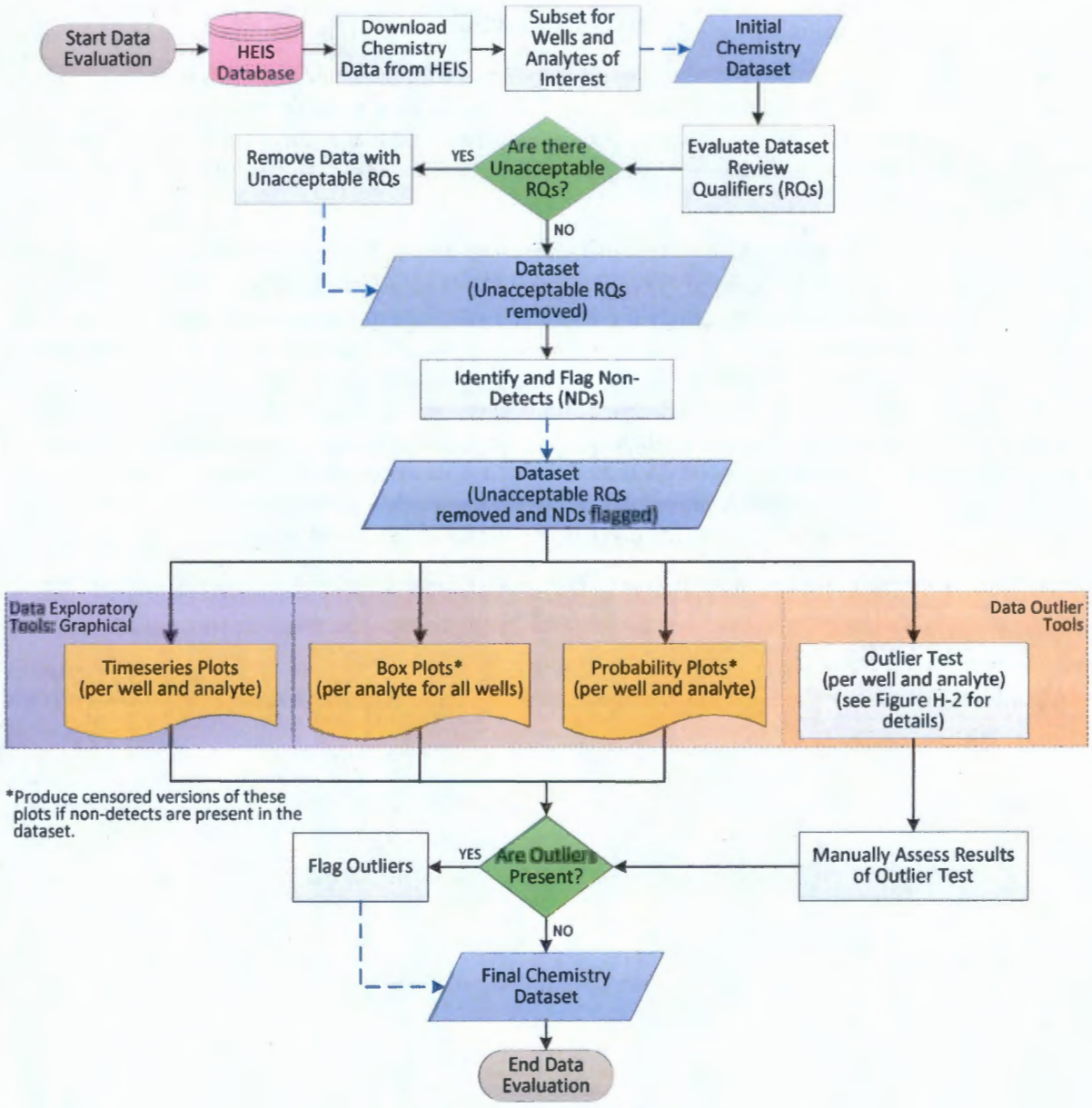

Figure H-1. Data Evaluation

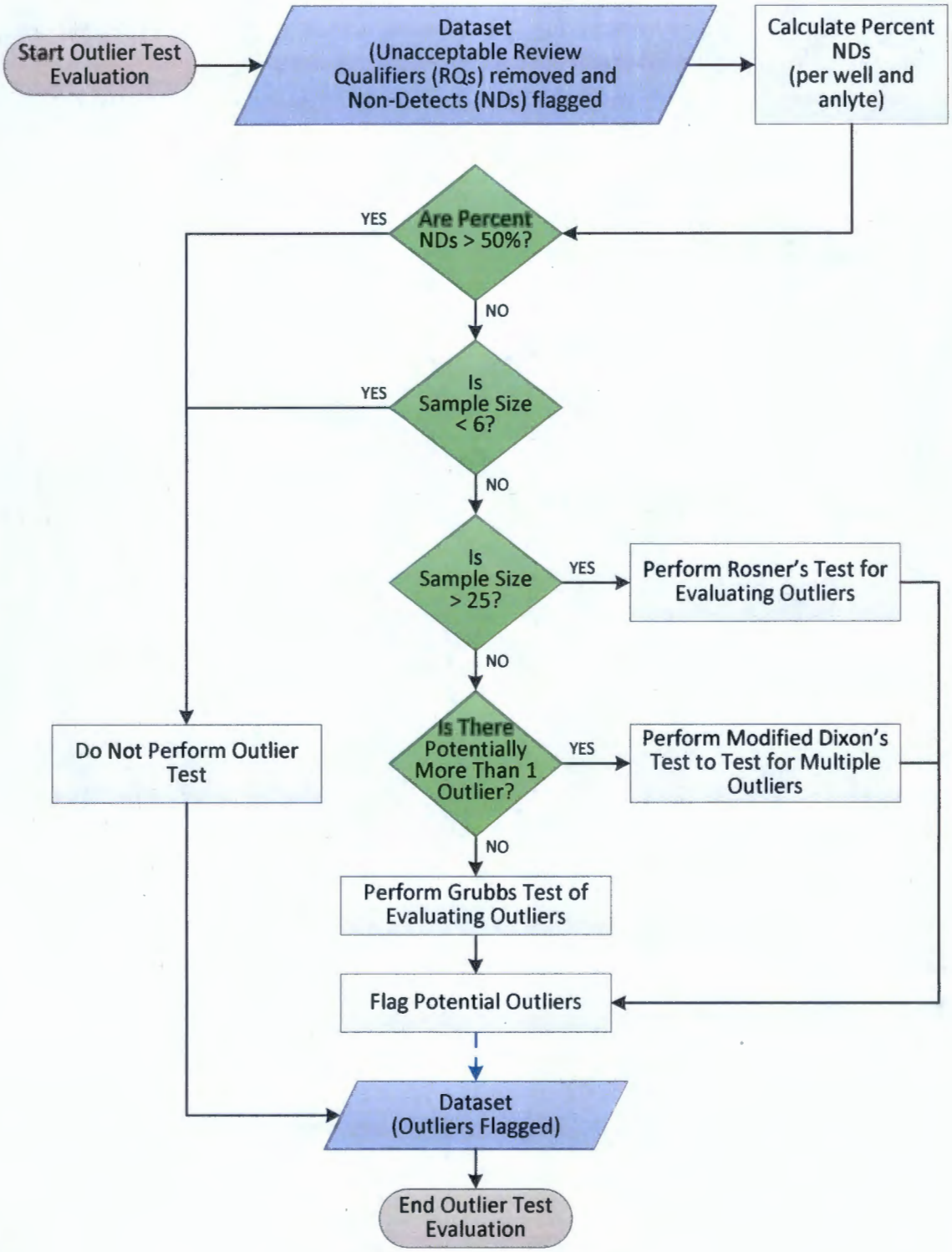

Figure H-2. Outlier Test Evaluation

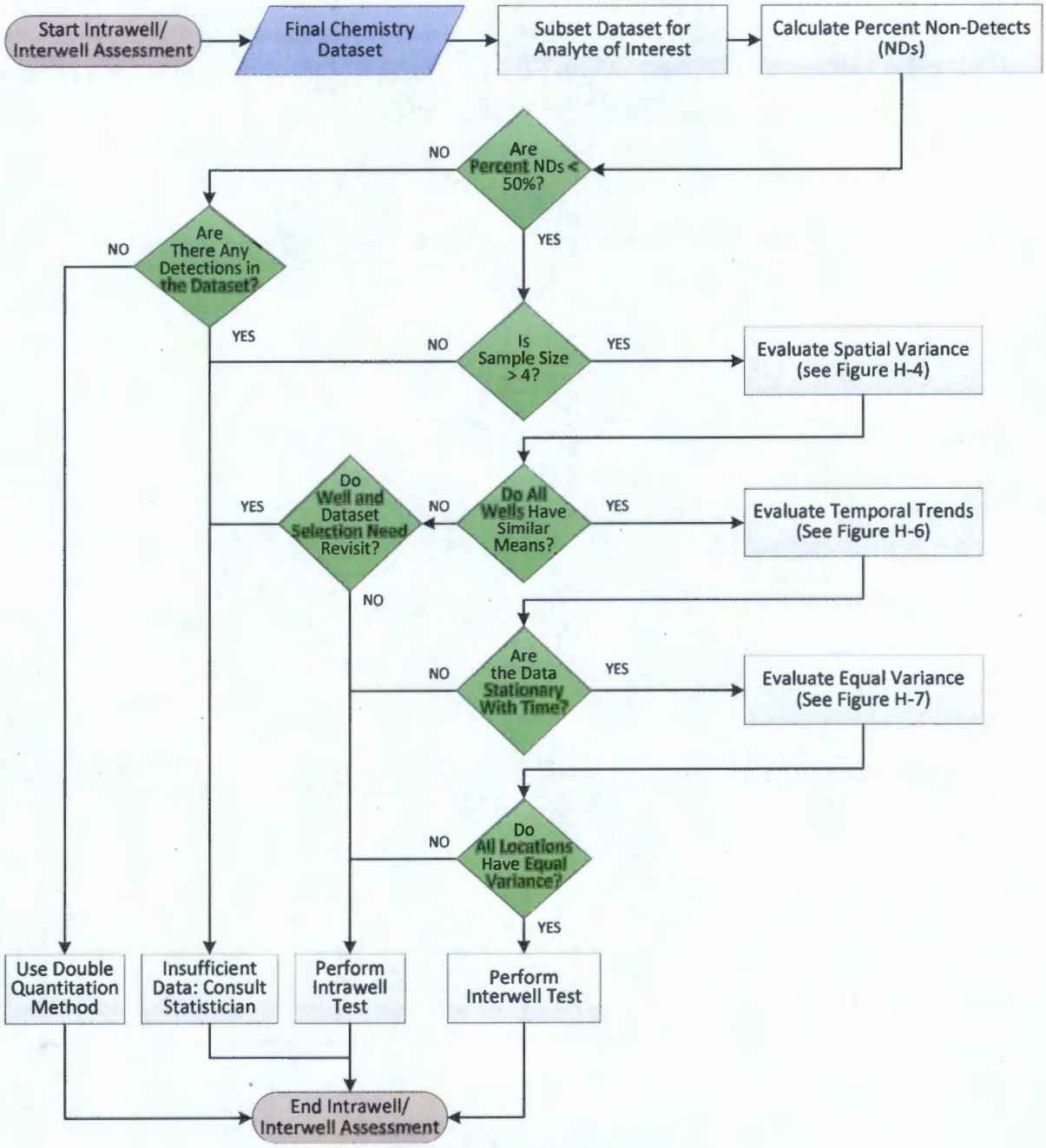

Figure H-3. Intrawell/Interwell Assessment

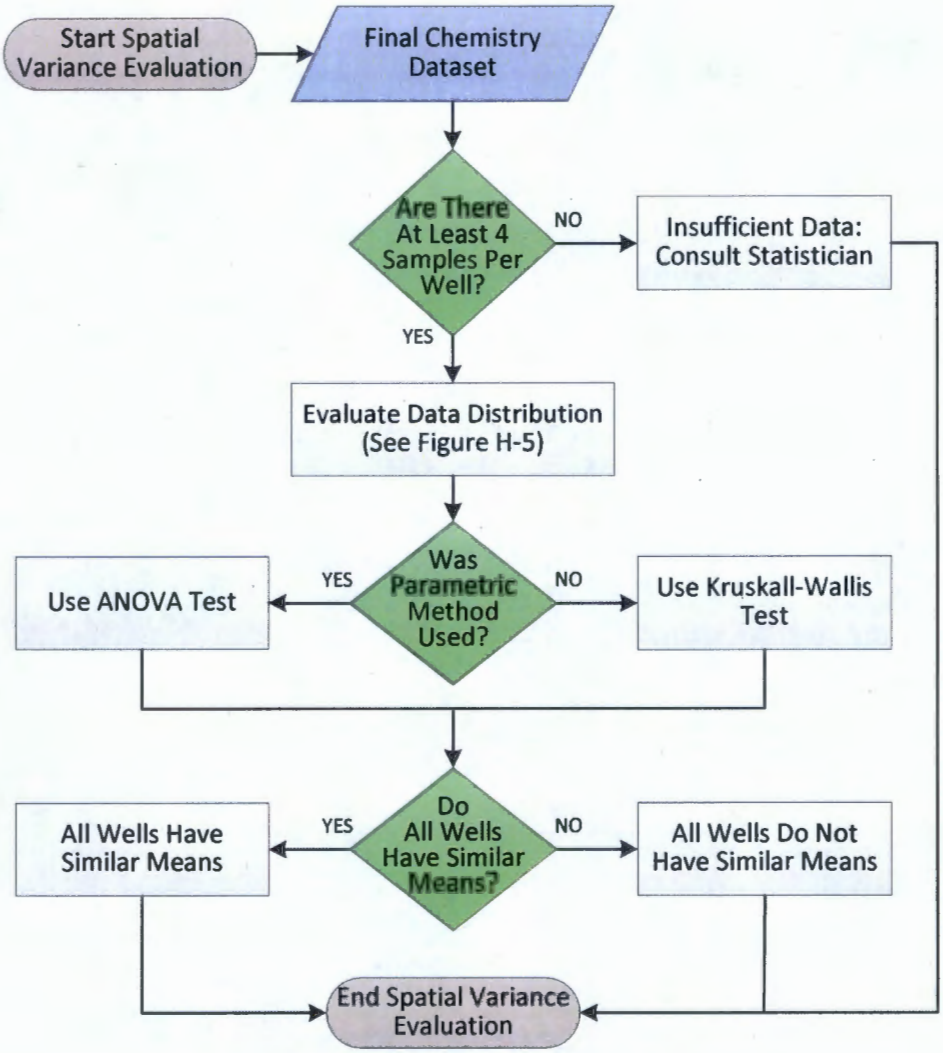

Figure H-4. Spatial Variance Evaluation

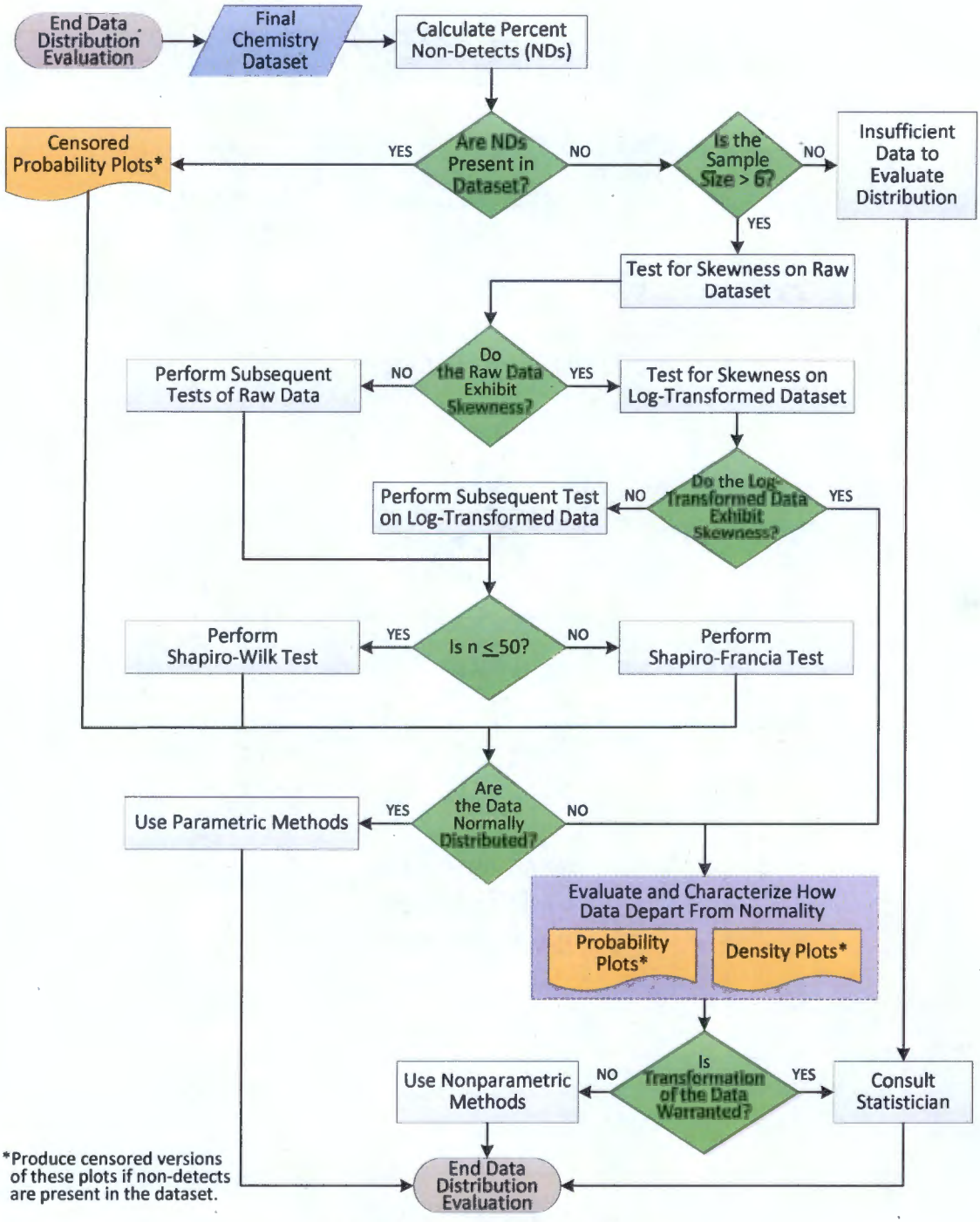

Figure H-5. Data Distribution Evaluation

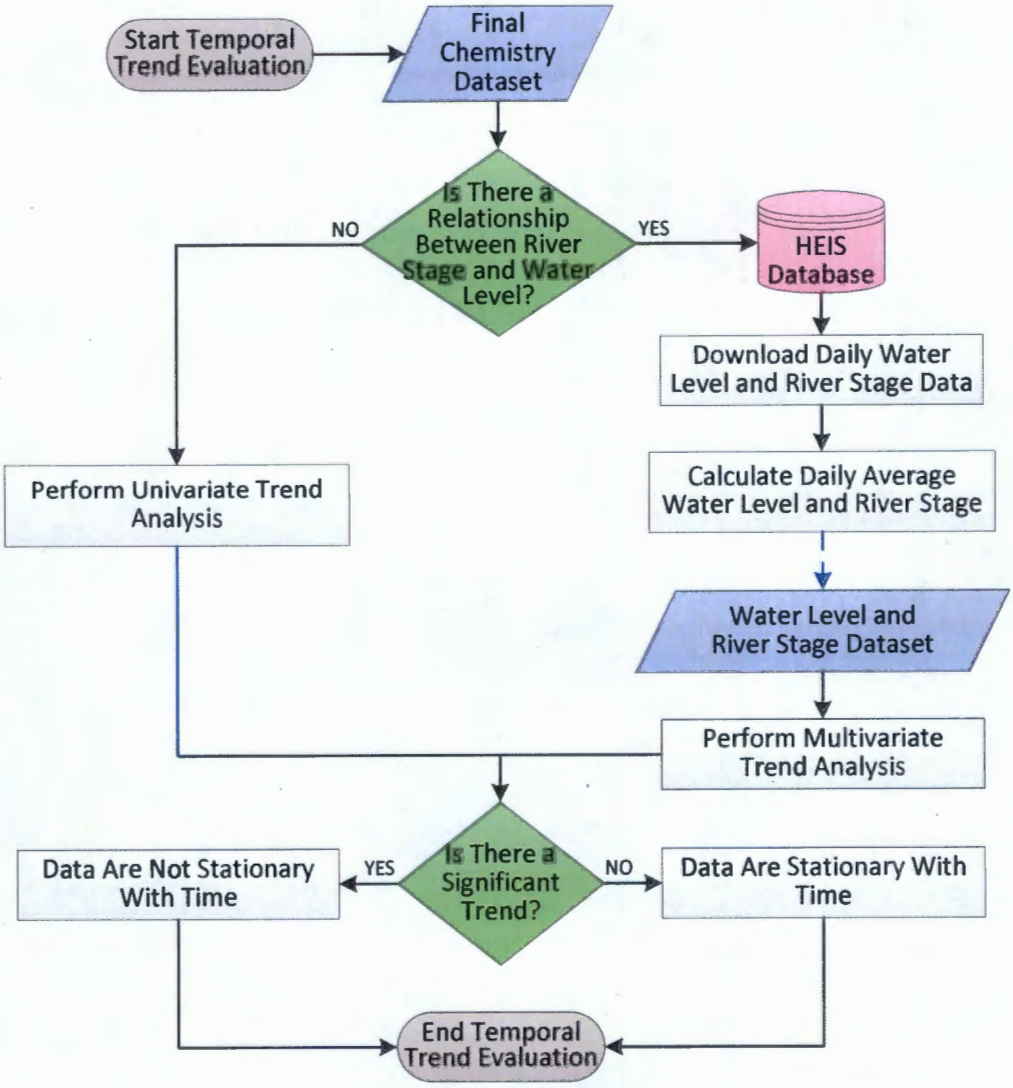

Figure H-6. Temporal Trend Analysis

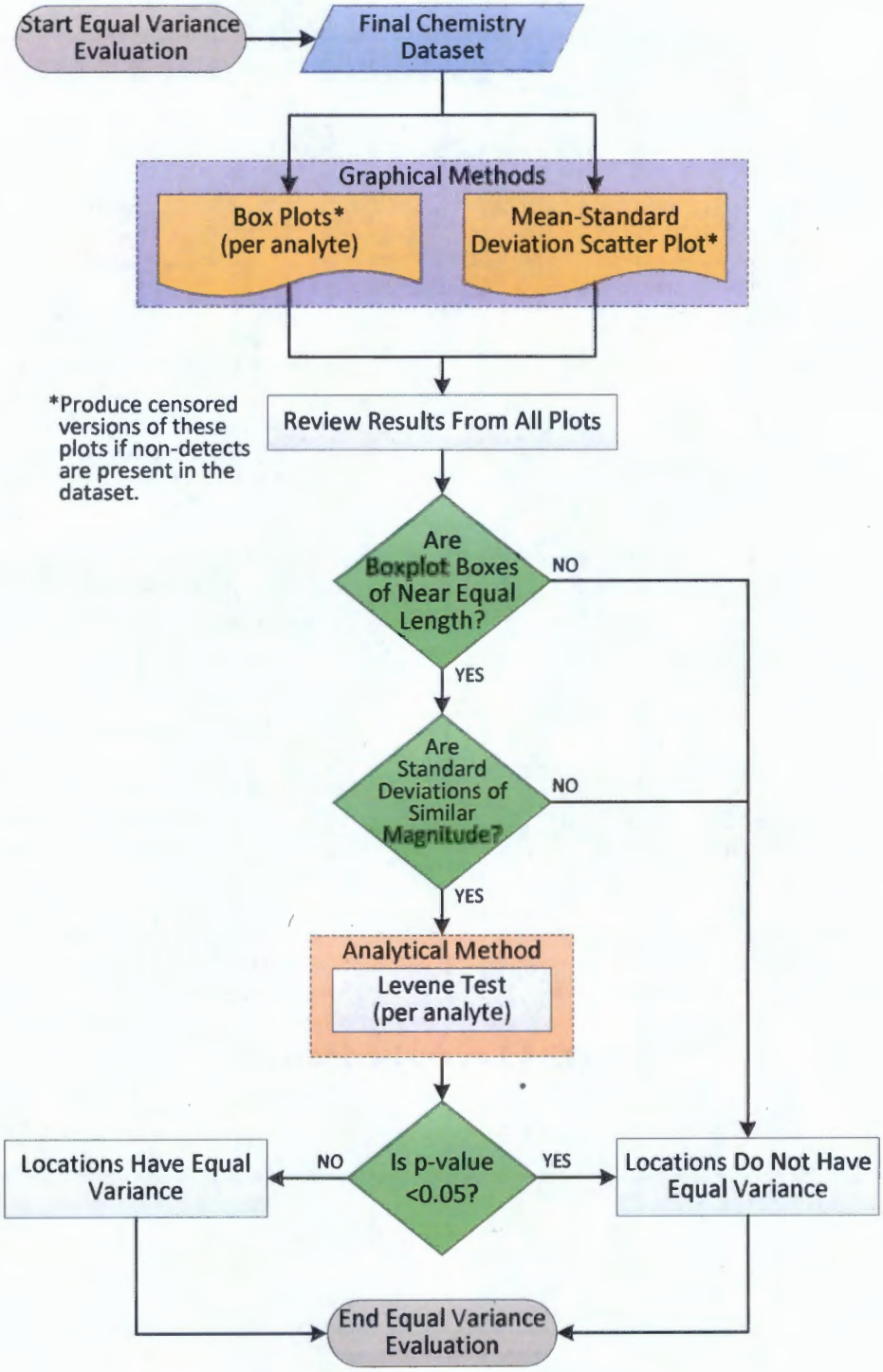

Figure H-7. Equal Variance Evaluation

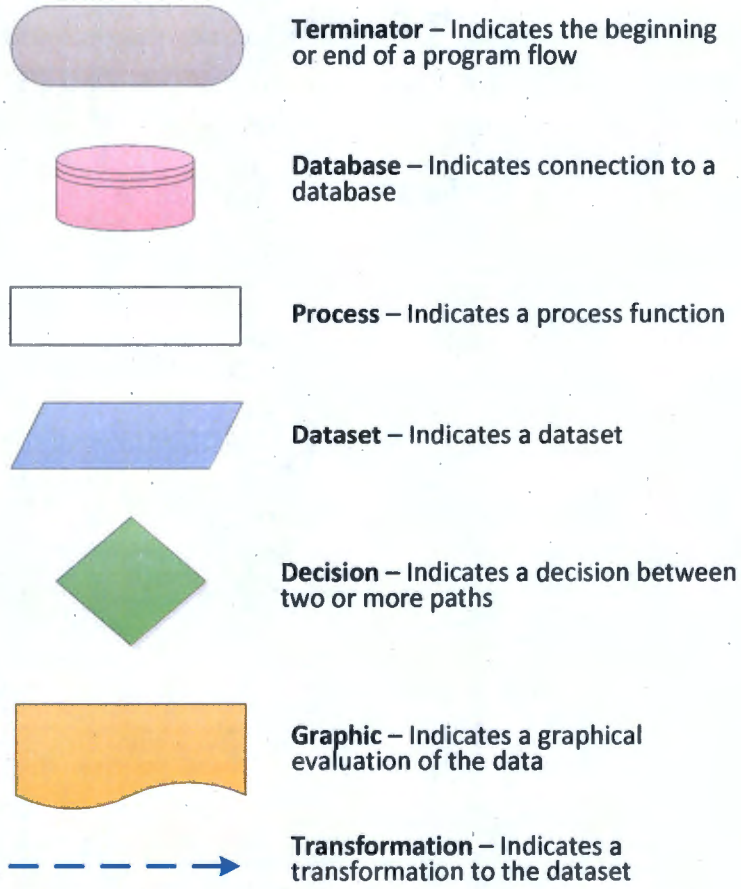

Figure H-8. Chart Legend

H2 Reference

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

Review Comment Record	Washington State Department of Ecology Nuclear Waste Program Cleanup Section/ER Project	Received: November 20, 2017, Dispositions: January 25/26, 2018 RCR Closed: March 8, 2018 Page 1 of 15

Document Title(s)/Number(s): Engineering Evaluation Report for Single Shell Tank Waste Management Area U Groundwater Monitoring/SGW-60578

Document Lead/Phone #/email: Dwayne Crumpler 372-7925 dwayne.crumpler@ecy.wa.gov | **Project Manager/Phone #/email:** Jeff Lyon 372-7914 jeff.lyon@ecy,wa,gov

Item # Page # Section # Line #s	Comment and Basis/Justification	Modification Needed	DOE Response	Ecology Response	O/C	Reviewer (Initials)
General 1	Comment: Provide in the first or second paragraph whether the information in this report meets the regulatory requirements based on this engineering evaluation.		No change to the text. This information is provided in the first paragraph of page 1-2, further details provided in Table 1-1.	Ensure that statistical analysis is included in the GWMP.	C 1/25/2018 No change.	DG
General 2	Comment: **Dilution:** The issue of dilution is not addressed in particle tracking (Chapter 6.2) while it is somewhat addressed in transport calculation (Chapter 6.3).	Address how the dilution will impact the actual concentration values for the dangerous waste constituents as it relates to the Method Detection Limit.	No change to the text. The purpose of the modeling is to determine the location of wells. The modeling is not chemical specific, and is not tied to the MDL for each constituent. This was not the purpose of the modeling. To do this would require an estimate of the volume of the release, which would introduce uncertainty and not change the conclusion.	Agree with DOE response and discussion at 1/25/2018 meeting.	C 1/25/2018 No change.	DG
Item 1 P: 1-1	Comment: *Information requested as per our letter:* 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.* Comment: with the above sentence, include a sentence reflecting "the purpose of the engineering is to meet regulatory requirements (cite all the relevant regulations ....) to detect any leak coming from the Tank Farm." 2. *Information supporting design of the groundwater monitoring program that is capable of detecting **significant increases** in*	Provide a paragraph at the bottom of this list that states how you meet each of these requirements.	No change to the text. 1. Information requested is provided in Chapter 1 and Table 1-1. 2. Text modified. 3. Discussed with Ecology. Given this text is a quote from a letter received by RL from Ecology, and will be left in the document as written with no reference to M-24. Affects all TF EERs		C 1/25/2018 Redline reviewed.	DG

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	groundwater contamination at the earliest practicable time. Comment: Above is a good statement but the language **"significant increase"** is not the right word we used earlier. The letter actually reads, "significant statistical increases". Please change to include "statistical". 3. *Uncertainty in groundwater flow direction so that the appropriate number of wells can be located and drilled. This includes 1 year of background monitoring for constituents listed in WAC 173-3110(3) (c), "Sampling, Testing, Methods and Analytes," unless previously performed to Ecology's satisfaction. Given the 3-year schedule for drilling and installing new wells, there should be at least 2 years minimum of groundwater monitoring for any new wells or revised groundwater monitoring networks.* Comment: The 3 year schedule should not be mentioned here. That schedule is a prioritization process followed under TPA milestone M-24. It is not supported through RCRA. Our detection monitoring is always prioritized as no. 1 and is installed accordingly. Permit will not allow the above concept 3 year schedule.					
Item 2 P: 1-7, First row	This states that the requirements of WAC 173-303-645(8)(a) regarding the monitoring system are addressed in Section 9.3. Section 9.3 does not address the requirement that wells be installed at appropriate locations and **depths**…"	Provide information in the report on the need (or not) to address potential vertical contamination, and the basis.	<u>Accept.</u> There is existing contamination that includes a vertical component being addressed under CERCLA. Focus of this analysis on recent or future release. A technical memo has been drafted addressing the vertical component of contaminant movement in the aquifer for the particle tracking. Text from technical memo regarding vertical movement to be added as a section to the 200 West Regional ECF. The following text has been added to Section 6.1 "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		C 1/25/2018 Redline reviewed.	SL

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			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 3 times the saturated thickness from extraction wells are predominantly horizontal. The facility-specific results of the API calculator are presented in Section 7.5 of Appendix G. The following text has been added to Section 9.3, "Based on the API calculator (discussed in Appendix F), the depths of the monitoring wells, screened across the top of the water table, are appropriate." Would affect all EERs.			
Item 3 P: 2-3 L: 13-15	Comment: Change 12,000 gallons to 5,000 gallons as this is the maximum supernatant liquid for interim stabilization of tanks according to HNF-EP-0182. Basis/Justification: Glossary of Terms in HNF-EP-0182.	See comment for modification needed.	Accept. Revision to statement that is repeated in subsequent tank farm EERs. Existing text used the 1989 tank farm GWMP as the source for defining "interim stabilization." Text change: "This process involved pumping the supernatant and interstitial liquids from the SSTs to double-shell tanks until no more than 189,270 L (50,000 gal) of drainable interstitial liquid and less than ~~45,424 L (12,000 gal)~~ 19,000 L (5,000 gal) of supernatant liquid remained in each tank (Appendix A in HNF-EP-0182, *Waste Tank Summary Report for Month Ending May 31, 2017*). ~~(Section 2.0 in WHC-SD-EN-AP-012, Rev. 0, *40 CFR 265 Interim Status Ground-Water Monitoring Plan for the Single-Shell Tanks*).~~" Would affect all tank farm EERs.		C 1/25/2018 Redline reviewed.	DC
Item 4 P: 2-13 Figure 2-4	Comment: Provide which wells are "dry". Basis/Justification: Wells that provide representative groundwater monitoring samples cannot be taken in "dry wells".	See comment for modification needed.	Accept with modification. No change to the figure. The purpose/context of the figure being referred to is to show wells discussed, not to provide all information available.		C 1/25/2018 Redline reviewed.	DC

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			Each EER has a version of this standard figure in Section 2.4 that provides the location for each well discussed in this historical summary section. Text added. An additional sentence is provided at the end of the first paragraph: "The status of the monitoring wells through the plans indicated in Table 2-4 is provided in Appendix A." Would affect all EERs.			
Item 5 P: 3-5 Table 3-1	Comment: Provide the hydraulic conductivities associated with WMA U for this document. Basis/Justification: These hydraulic conductivities are too high for the 200 West Area WAC 173-303-645(8).	Provide hydraulic conductivities for WMA U or 200 West Area.	Accept. Text changed to read: "The saturated hydraulic conductivity of the Ringold E unit underlying WMA U is 5 m/d (16.4 ft/d) (Table 4-9 in CP-47631). Section 7.4 in PNNL-13378, *Results of Detailed Hydrogeologic Characterization Tests – Fiscal Year 1999*, gives a saturated hydraulic conductivity of 6.12 m/day (20.1 ft/day) based on field measurements." Would affect all EERs.		C 1/25/2018 Redline reviewed.	DC
Item 6 P: 3-7 S: 3.3.2 L: 6-7	Comment: This states: "The decline is due to the substantial reduction of wastewater discharges to the soil column in the mid- 1990s and operation of the 200 West P&T system." This does not provide the specific effects of the P&T system, which is the key aspect of evaluating current and future monitoring system requirements.	Provide information on the specific effects of the 200 West Pump and Treat System.	Accept. Changed text to read: "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 in 2012. Water level changes associated with the start-up (GW-50907 and ECF-200ZP1-12-0074)" Would affect all EERs.		C 1/25/2018 Redline reviewed.	SL
Item 7 P: 3-7 S: 3.3.2	Comment: Provide the rate of decline in the water table for the year 2016. Basis/Justification: WAC 173-303-645(8).	Rate of water level decline.	Accept. The following text was added to the document: "Water levels continued to decline in 2016 at an average rate of 0.37 m/yr (1.21 ft/yr) (Section 11.12.2 in DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*)."		C 1/25/2018 Redline reviewed.	DC

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			Would affect all EERS.			
Item 8 P: 3-7, S: 3.3.2	Comment: This discussion does not describe the effects of the P&T system. When did the changes in the hydrologic flow system occur, and what are the quantifiable effects (i.e. gradient magnitude, direction)? Information in Section 4.3, first paragraph, also provides effects of the pump and treat system, and would be useful in Section 3.3.2.	Provide more specific information regarding the changes in the flow system as a result of the P&T system.	Accept. The following sentence was added to the last paragraph of Section 3.3.2: "Groundwater flow rate and direction are further described in Section 4.3." Would affect all EERs.		C 1/25/2018 Redline reviewed.	SL
Item 9 P: 4-3 S: 4.4 L: 4-5	Comment: Provide if chromium is a source contaminant at WMA U. The sentence "Chromium may be present in wells at WMA U as a groundwater contaminant." means the source is WMA U, or is the source corrosion in wells? Basis/Justification: Unclear statement.	Provide all the sources of contamination coming from WMA U.	Accept. This chapter is intended to outline the contaminant migration conceptual model, not a discrete discussion of contamination. Empirical data is incorporated into the discussion and indicates chromium is detected in the vicinity of this farm. Deleted sentence "Chromium may be present in the wells at WMA U as a groundwater contaminant." See response to comment 38.	Add hexavalent chromium per Ecology direction in Chapter 9.	C 1/25/2018 Redline reviewed.	DC
Item 10 P: 4-3 S: 4.4 L: 19-25	Comment: Provide how the groundwater flow relates to concentration levels upgradient vs. source component from WMA U. Basis/Justification: Unclear contribution of nitrate to the aquifer.	Provide component of contamination of nitrate from WMA U vs. upgradient.	No change to text. As presented in Appendix D, there is a large CERCLA past-practice nitrate plume. In the early to mid-2000 timeframe, data show that there was nitrate in wells downgradient of WMA U. Later the entire area was overcome with CERCLA past-practice releases. See plume extents from interactive Annual Groundwater Report tool. Between 2009 and 2010 an upgradient plume encroached on the upgradient side of the farm. By 2011 the plume had extended over and through the farm. Would affect all EERs.		C 1/25/2018 No change.	DC
Item 11 P: 4-3 S: 4.4 L: 36	Comment: Provide if nitrate and technetium-99 are being treated at the 200 West Pump and Treat. Basis/Justification:	Provide what contaminants are treated at 200 West Pump and Treat.	No change to text. Both Tc-99 and nitrate are treated at 200 West P&T. Would affect all EERs.		C 1/25/2018 No change.	DC
Item 12 P: 5-5, L: 1-7	The text states: "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." It appears only injection rates in the	Explain the basis for the sub-scenario conditions for the UP-1 wells. Discuss why extraction well rates and injection well rates are not varied.	No change to text. ZP-1 was designed and being operated as a concentric system with extraction in the middle and injection around the outside. The injection was initially to demonstrate capture. The aquifer can be pumped	Discussion answered questions.	C 1/25/2018 No change.	SL

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	ZP-1 wells are varied for the sub-scenarios, and extraction rates in UP-1 are not varied at all. The report does not clearly state that injection and extraction rates are not varied in UP-1 wells, or the reason why.		aggressively; however, injection is variable due to capacity and where we want to steer contamination and get rid of the water. We don't typically vary extraction rates.			
Item 13 P: 5-5 L: 17-20	The approach here is not well explained. "The CPGWM represents the "as-built" extraction and injection well screened intervals (i.e., top and bottom elevations) 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 focused on the quality of water at or close to the water table." Does this imply the model is constructed with several layers and these wells are somehow represented within these layers? Are vertical effects somehow addressed by this approach?	Provide a more complete description how the model actually is constructed to address the injection and monitoring well screen intervals. Discuss how vertical effects of contaminant movement is addressed.	Accept. Citation to MNW2 package added to the text. https://pubs.usgs.gov/tm/tm6a30/ The flow model is discretized. The reason we went with the particle tracking as the preferred method for determining well locations is that it is quasi-independent/semi-analytical in an X-Y-Z location. The flow model and transport model all utilize a block average. At every step of the particle path it re-calculates where it is in three dimensional space that is nearly grid independent. The respective screen lengths of wells are represented by a line sink only partially penetrating a layer, if that is how the well is constructed (MNW2 Package, https://pubs.usgs.gov/tm/tm6a30/) Would affect all EERs.	Accept.	C 1/25/2018 Redline reviewed.	SL
Item 14 Chapter 7	Comment: Summarize the results and conclusions NOT what is included in the analysis.	Provide the results and conclusions in this Chapter	No change to the text. The requested information is in Section 7.3. Sentence added to the end of the first paragraph "Conclusions can be found in Section 7.3." Would affect all EERs.		C 1/25/2018 No change.	DG
Item 15 P: 7-1 onward Chapter 7	Comment: Provide the range for the "breakthrough curves" that would aid the reader in understanding the impacts (dilution and release concentrations) for all the "breakthrough curves". Basis/Justification: No results are provided in this chapter, yet the title is "Results and Conclusions".	Provide the results of the graphs in text form so the reader understands the average, and range of values along with anticipated value (Sub scenario A) for Scenarios 1, 2 and 3. Provide the endpoint sub scenarios for all the curves.	Accept. Added Tables 7-1 and 7-2 showing min and max values for the breakthrough curves. Would affect all EERs in 200 West.		C 1/25/2018 Redline reviewed.	DC
Item 16 P: 7-18 S: 7.1 Figure 7-15	Comment: Provide more discussion about the results. It is unclear why the curves are so widespread for Scenario 3 compared to Scenario 1 and 2. Basis/Justification:	Provide an interpretation of the results. Do not let the reader make their own interpretation.	No change to the text. This figure is looking at individual wells—it's a different breakdown, than an individual well with each sub-scenario associated with it.		C 1/25/2018 No change.	DC
Item 17 P: 7-22	Comment: What is the vertical discretization of the particle tracking simulations?	Discuss how the vertical aspects of contaminant migration are addressed.	No change needed.		C 1/25/2018	SL

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L: 23-25		Is a given contaminant concentration assumed to be evenly distributed throughout the entire aquifer thickness or only at the top of the aquifer?	Discussed and text added to 6.1 and 9.3. Refer to Item 2. Would affect all EERs.		No change.	
Item 18 S: Figures 7-18, 7-21 and 7-24, 7-25	Comment: Move the legend so it does not block the streamlines or image of flow for these three figures. Basis/Justification: Cannot see the diagram for the legend.	Move legend on the page.	Accept. Figures will be modified.		~~C 1/25/2018 Pending change to figure~~ C 3/8/2018 Redline reviewed	DC
Item 19 P: 7-29 S: 7.2 L: 1-11	Comment: This paragraph is a repeat from Chapter 6. Delete the paragraph. Basis/Justification: Redundant.	Delete.	No change needed.	Agree not to delete.	C 1/25/2018 No change.	DC
Item 20 P: 7-29 L: 30-32	Comment: The combined extents of the relative detectability and unit plume on the referenced figure are not clearly indicated in this paragraph. It would be helpful to state here that the combined extents are shown for a relative detectability greater than 0.01, and that the unit plume extent is greater than 0.1.	Clarify in this paragraph that results of both the relative detectability extent from particle tracking and the unit plume extent from transport modeling are shown.	Accept. Text changed to read: "Figure 7-25 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."	Accept.	C 1/25/2018 Redline reviewed.	SL
Item 21 P: 8-1 S: 8.1.1	Comment: Provide how the BBI differs from the Part A for constituents. EDTA is a known constituent and other constituents are present in the tanks that breakdown to form other constituents that may be dangerous. Basis/Justification: Completeness and accuracy.	Provide the difference between the BBI and the Part A for the WMA U.	No change to the text. The BBI was not used for any part of the tank farm EERs.		C 1/25/2018 No change.	DC
Item 22 P: 8-1 S: 8.1.2 L: 37	Comment: Provide why the maximum result is used instead of the lowest detectable level. Basis/Justification: Unclear and incomplete discussion.	Provide rationale for using maximum detected result.	No change needed. Detectability is not a component in these evaluations because actual groundwater data is used (as opposed to the waste stream analysis results used for LERF and the calculated leachate values used in the previous version of 31/34).		C 1/25/2018 No change.	DC

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			Rationale is provided: As described on p. 8-2, line 2, maximum detected results are used in comparison to the Hanford Site 90th percentile groundwater background values. Constituents with maximum results above background are retained as potential monitoring constituents. Later, in Section 8.1.3 (p. 8-2, lines 37-38) the maximum groundwater results are used in one of the final evaluation steps. The max result for nondangerous constituents that are not previously dispositioned is compared to an action level to determine whether or not to include it as a potential monitoring constituent. <u>Would affect all tank farm EERs.</u>			
Item 23 P: 8-2 S: 8.1.3	Comment: These two paragraphs are very confusing and need to be rewritten. Words are missing in the first sentence of this section. This section does not provide a clear step by step of the analysis to reach the "Final Monitoring Constituent Evaluation". My recommendation is to combine paragraph 1 and 2 as redundancy exists. 2nd paragraph repeats again in the bullets. Provide the basis for why "Appendix 5 constituents are already prescribed for WMA U." Basis/Justification: Unclear, redundant, no explanation for basis of evaluation.	Rewrite to read, "The constituents retained as potential monitoring constituents based on criteria in Sections 8.1.1 and 8.1.2 were compiled." A final evaluation was performed to identify potential monitoring constituents to be included as proposed monitoring constituents to detect and monitor wastes from WMA U that impact groundwater. The initial step of this final evaluation identified those potential monitoring constituents that are also listed in Appendix 5 of Ecology Publication No. 97-407. As monitoring for the dangerous wastes in Appendix 5 of Ecology Publication No. 97-407 is already prescribed for WMA U (Section 9.4) because it is in groundwater assessment monitoring under interim status, these constituents were identified as proposed monitoring constituents.	The changes in proposed rewrite relative to original text are in red font. "The constituents retained as potential monitoring constituents in Sections 8.1.1 and 8.1.2 were compiled <u>for the final evaluation described in this section</u>. Second revision requested was not made, stating that Appendix 5 monitoring is a result of the site being in groundwater quality assessment monitoring under interim status. Monitoring for Appendix 5 constituents has been required by Ecology per letter for each of the Rev 9 final status units, not just those in assessment monitoring. <u>Would affect all tank farm EERs.</u>		C 1/25/2018 Redline reviewed.	DC

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		The remaining potential monitoring constituents were evaluated in two groups.				
Item 24 P: 8-2 S: 8.1.3 L: 22-40	Comment: Provide which constituents were eliminated through each step of the process. Clearly some number of constituents began and through the process it was reduced to 61 constituents – where did each constituent get eliminated based on the process? Basis/Justification: No justification is provided for when a constituent is required in either Appendix 5, Part A permit application, or groundwater monitoring results.	Provide which constituent(s) got eliminated in the process.	No change to text. We have detailed the process in Appendix B.		C 1/25/2018 No change.	DC
Item 25 P: 8-2 S: 8.1.3 L: 37-38	Comment: Provide why this evaluation step is important. As written, no basis for why it is being evaluated. Basis/Justification: Provide the basis/justification for this step related to the regulations.	Provide basis for this step in the regulations. DO NOT DELETE IT.	No change to text. There is no basis for this step in the regulations—we do not set a GWPS in this calculation. This step used to reduce the non-dangerous potential monitoring constituent list based on data.		C 1/25/2018 No change.	DC
Item 26 P: 8-3 S: 8.2 L: 8	Comment: Change "WMA T" to "WMA U". Basis/Justification: Wrong WMA identified.	See comment.	Accept.		C 1/25/2018 Redline reviewed.	DC
Item 27 Chapter 9	Comment: Based on the current engineering evaluation, summarize if the current network is regulatory compliant. If not, what else is needed?	See comment.	No change to text. See introductory paragraph to Chapter 9 and second paragraph of Section 9.2. This is standard EER text. Would affect all EERs.		C 1/25/2018 No change.	DG
Item 28 P: 9-1 S: 9.3 L: 42	Comment: Add the phrase, "located at the point of compliance" between "(downgradient) wells" and "to monitor for releases…" Basis/Justification: Clarity, meets WAC 173-303-646(6).	See comment.	No change to text. Would affect all the EERs.		C 1/25/2018 No change.	DC
Item 29 P: 9-2 L: 7-9	Comment: This paragraph states, "Each well is screened in the upper unconfined aquifer in order to yield sufficient groundwater for representative sampling." The report does not address potential vertical contamination. These wells are screened in the uppermost part of the aquifer and I do not see that any	Address the vertical aspects of the flow system, contaminant migration, and monitoring.	No change needed. See Item 2. Changes were made to Section 6.1 and 9.3. Would affect all EERs.	Changes incorporated elsewhere address this comment.	C 1/25/2018 No change.	SL

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	wells have been drilled to or characterization completed in the deeper part of the aquifer.					
Item 30 P: 9-2 S: 9.3 L: 19	Comment: Provide what "sufficient samples have been collected" means. Provide how this relates to the regulations. Basis/Justification: Clarity, completeness, regulation connection.	See comment.	Accept. The context of this comes later in Section 9.4 where we give the frequency of sampling. The sampling frequency will not be added in Section 9.3. Additional text was added to the end of the sentence, "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." Would affect all EERs.		C 1/25/2018 Redline reviewed.	DC
Item 5a P: 9-2 L: 28-30	Comment: This makes the statement that "the determination of background will be completed on an intra-well basis." However, Section 9.7 states that the statistical method will be decided after 2 years of baseline data is collected and evaluated.	Remove the sentence.	Accept. Deleted, "… the determination of background will be completed on an intra-well basis. Use of intra-well statistical methods eliminates the need for data from a background (upgradient) well not impacted by Hanford Site operations to assess the conditions at the DWMU."		C 1/25/2018 Redline reviewed.	SL
Item 31 P: 9-2 L: 33-40	Comment: This paragraph generally discusses the justification for wells that are appropriately located, and makes a key point that "…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)) and allow for the detection of contamination…" The end of this paragraph states, "…since they are immediately downgradient of the facility and are screened in the uppermost unconfined aquifer." This implies that the wells will provide representative samples solely because they are screened in the uppermost unconfined aquifer. The uppermost aquifer is 200 ft thick, so it is not necessarily true that wells screened in the uppermost aquifer will meet the stated requirements.	Provide additional description that the wells meet the requirements because they will provide samples from the upper portion of the unconfined aquifer (if this is true), and that contamination migrating from the unit will be detected.	Accept. Text modified to read: "Based on current groundwater flow direction to the east and predictions of future groundwater flow direction toward the northeast over time (DOE/RL-2016-66, Section 3.7), 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 waste management area to the uppermost aquifer (WAC 173-303-645(8)(a)(iii)). Assessment of the vertical component of contaminant migration shows that wells screened in the top of the uppermost unconfined aquifer are suitable for monitoring based on the API calculator (discussed in Appendix F) and determination of compliance with groundwater protections standards (WAC 173-303-645(10)(a))." This would affect all EERs.		C 1/25/2018 Redline reviewed.	SL

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Item 32 P: 9-2 L: 38-39	Comment: The text cites compliance with groundwater protection standards (WAC 173-303-645(10)(a)). I believe the citation should be (WAC 173-303-645(10)(b)), which addresses locations of groundwater monitoring wells. It states, "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), and (c) of this section."	Review and correct the citation.	No text change needed.	Discussed and determined no change needed.	C 1/25/2018 No change.	SL
Item 33 P: 9-3 Figure 9-1	Comment: Provide why only one upgradient well is sufficient. It would appear another upgradient well is needed in the west side in the northern part of the WMA. Basis/Justification: Upgradient contamination entering the farm is not monitored in the northern portion.	See comment.	Accept. Another well will be proposed in the northwest corner of WMA U.		~~C 1/26/2018 Pending addition of the well to figures and text~~ C 3/8/2018 Redline reviewed.	DC
Item 34 P: 9-4, Table	Comment: This table is lacking some important parameters regarding the well screen placement.	Suggest that information on depth to top of screen, and depth to bottom of screen be provided in the table rather than in the text.	No change to text. This table is not intended to be comprehensive. Also this information is provided elsewhere in the document, in both the text and in Appendix E. Would affect all EERs.	Disregard comment.	C 1/25/2018 No change.	SL
Item 35 P: 9-5 S: 9.3.1, 9.3.2, L: 9-16; 28-35	Comment: Delete the lines starting with "however" and ending with "release". This information has already been provided in Chapters 6 and 7, is redundant and provides no valuable information. Basis/Justification: Redundant.	Delete these redundant lines that are discussed in Chapters 6 and 7.	No change to text. Would affect all EERs.	Discussed, agreed to leave.	C 1/26/2018 No change.	DC
Item 36 P: 9-6/9-7 S: 9.3.3, 9.3.4, 9.3.5, 9.3.6, 9.3.7	Comment: Delete the lines starting with the word "however" and ending with the word "release". This information has already been provided in Chapters 6 and 7, and is redundant and provides no valuable information. Basis/Justification: Redundant.	Delete these redundant lines that are discussed in Chapters 6 and 7.	No change to text. Would affect all EERs.	Discussed, agreed to leave.	C 1/26/2018 No change.	DC

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Item 37 P: 9-9 S: 9.4 L: 22-25	Comment: Move this paragraph to Section 9.3 or delete it. It is not located in the right section. Monitoring well network is discussed in Section 9.3. Basis/Justification:		No change to text. Would affect all EERs.	Discussed, agreed to leave.	C 1/26/2018 No change.	DC
Item 38 P: 9-10 Table 9-2	Comment: Add hexavalent chromium and its associated EPA method to the list of constituents. Analyzing for the appropriate chromium will aid in determining what chromium is present in the groundwater at WMA U. Basis/Justification: Basis for whether hexavalent chromium or trivalent chromium is present in the groundwater.		Accept. This change would be a note "at the discretion of Ecology". If accepted, this change would add new entries in Table 9-2 and Table 9-3 (use same format as analogous WMA T tables), and change text. EPA methods not presented in EER. Suggested text, Section 9.4, paragraph 3: "Table 9-2 identifies the proposed monitoring network and sampling frequency for WMA U. The proposed site-specific monitoring constituents (Table 9-3) were identified in Chapter 8 (Table 8-1), with the addition of hexavalent chromium (added at the discretion of Ecology). The site-specific monitoring constituents will be sampled quarterly for the first 2 years of monitoring. After background concentrations…"		C 1/25/2018 Redline reviewed.	DC
Item 39 P: 9-19 S: 9.6	Comment: Provide the date of 1999 for the beginning of the compliance period. When groundwater assessment under the interim status standards began is when the compliance period began based on the interim status regulations and now the final status regulations. Basis/Justification: 40 CFR 265 and WAC 173-303-640(7).	See comment.	No change to text. See section 2.2 for discussion of when WMA U entered groundwater quality assessment monitoring. Specific dates for the compliance period would be in the GWMP.		C 1/26/2018 No change.	DC
Item 40 P: 9-19 L: 26-27	Comment: This refers to Appendix H to determine the statistical test method. Appendix H provides a method to evaluate based on statistical information only. The evaluation must also consider the site hydrogeology.	Include here and in Appendix H that the evaluation and determination of the statistical method will also include an evaluation of the hydrogeologic conditions.	Accept. See also, Items 27, 5a and 33. Additional sentence added "In addition to this methodology, hydrogeology of the area also will be considered." Would affect all EERs.	Text addition accepted.	C 1/25/2018 Redline reviewed.	SL

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Item 41 Chapter 10	Comment: Rev 9 will have a separate appendix on well maintenance plan and procedures (a modified version of current "Hanford Well Maintenance and Inspection Plan", HNF-56398, rev 20 published in Sept, 2016 in Rev. 8C. Modify this section to incorporate that the wells will be maintained to meet the attachment in Rev. 9.	Include a reference to the Rev. 9 Attachment in the permit.	Accept with modification. Chapter 10 is not intended to address well maintenance. It is intended to address how we maintain a compliant network. Changed title of Chapter 10 to "Routine Evaluation of the Monitoring Network." Would affect all EERs.		C 1/26/2018 Redline reviewed.	DG
Item 42 P: 10-1 S: 10 L: 24	Comment: Add a sentence that explains what will be done if a change in the groundwater monitoring network is required. Basis/Justification: WAC 173-303-645(2).	Add "If a change in the groundwater monitoring network is determined, a permit modification to the groundwater monitoring plan would occur in accordance with WAC 173-303-815."	Accept. Added text, "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." Would affect all EERs.		C 1/26/2018 Redline reviewed.	DC
Item 43 Appendix B	Comment: Appendix B needs to provide more details on the constituents that were eliminated. All the constituents should be listed in this appendix and clearly demonstrated why each of the constituents were eliminated or carried forward in the process. As is, this information cannot be traced to that type of process. How did you start with 72 instead of some huge number of constituents and eliminate down to 61? Basis/Justification: Clarity, transparency, completeness.	Update calculation to show how each constituent remained or was eliminated.	No change to text. The number of constituents handled at each step of the evaluation are provided in Appendix B, Chapter 7 subsection discussions, followed by a table identifying specific constituents applicable to the discussion.	Discussed and resolved.	C 1/26/2018 No change.	DC
Item 44 P: B-7 S: 3.1	Comment: This section should include only discussion of the Part A dangerous wastes and the specific set of constituents that are included based on that. The discussion of mobility should be in a separate sub-section.	Suggest that the discussion of mobility be provided in a separate subsection.	No change to text. Discussed the suggested change and concluded this subsection was appropriately written as-is.	Discussed and determined that mobility was the screening tool.	C 1/26/2018 No change.	SL
Item 45 Appendix D	Comment: Provide the plume maps of all detected constituents in groundwater. Each detected constituent needs to have a plume map. Basis/Justification: WAC 173-303-806(4)(a)(xx)(D).	Plumes in WMA U that are detected.	Accept. PRC is preparing additional figures for Appendix D that will provide the maximum detected result in the 2016 data set for each constituent detected above background. Would affect all EERs.	Reviewed and accepted format and content of draft figures.	~~C~~ ~~1/26/2018~~ ~~Pending the addition of additional figures~~ C 3/8/2018 Redline reviewed.	DC
Item 46 P: F-32	Comment: The statement in the text and on the figure title are misleading. The values on the figure only	Correct the text and figure title.	Accept.		~~C~~ ~~1/25/2018~~	SL

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L: 31-32 and P: F-33, Figure 4-1	represent the rates for December 2016. This seems to be the case for all the values on Figure 4-1 in Appendix F.				~~pending editorial change~~ C 3/8/2018 Redline reviewed.	
Item 47 P: F-48 and F-86	Comment: Figures 7-3 and 7-39 showing sub-scenario C injected water plumes with injected water flow pathlines. These indicate flow pathlines radiating from the location of injection well 299-W10-35; however, this injection well is not operating in scenario C. This brings into question the graphical depictions of all the simulations.	Review and correct, or provide an explanation.	Accept. Text added to the end of the first paragraph in 7.1.1. This figure is intended to show a qualitative comparison of the extent and migration of injected water. As such, particles are released around all injection wells regardless of their operating rate. Would affect all EERs.	Satisfied with the discussion. Text added to 7.1.1 of Appendix F.	~~C 1/25/2018 Redline reviewed~~ C 3/8/2018 Redline reviewed.	SL
Item 48 P: F-50 and F-88	Comment: Figures 7-5 and 7-41 showing sub-scenario E injected water plumes with injected water flow pathlines. These indicate flow pathlines radiating from the location of injection well 299-W15-226; however, this injection well is not operating in scenario E. (It appears that the flow pathlines are superimposed on several figures in the same manner).	Review and correct, or provide an explanation.	Accept. Text added to the end of the first paragraph in 7.1.1. This figure is intended to show a qualitative comparison of the extent and migration of injected water. As such, particles are released around all injection wells regardless of their operating rate. Would affect all EERs.	Satisfied with the discussion. Text added to 7.1.1 of Appendix F.	C 1/25/2018 Redline reviewed.	SL
Item 49 P: F-137, Table A-3	Comment: The historical monthly extraction rates for well 299-W17-3 provided in Appendix F, Table A-3 range from 8 to 127 gpm. This would suggest that the predicted extraction rate (in App. F, Table A-4) of 132 gpm may not be achievable.	Discuss the likelihood that the predicted extraction rate of 132 gpm in well 299-W17-3 can be maintained.	No text change. Table A-3 shows actual extraction rates for 2016—the predicted extraction rate of 132 gpm is achievable, however; the limiting factor is the ability to inject the water due to current operational restrictions. Would affect all EERs.	Discussion clarified concerns.	C 1/25/2018 No change.	SL
Item 50 P: F-137, Table A-3	Comment: The historical monthly extraction rates for well 299-W17-3 provided in Appendix F, Table A-3 range from 8 to 127 gpm. This would suggest that the predicted extraction rate (in App. F, Table A-4) of 132 gpm may not be achievable.	Discuss the likelihood that the predicted extraction rate of 132 gpm in well 299-W17-3 can be maintained.	**Duplicate of previous comment. (Item 49)**	Duplicate of previous comment.	C 1/25/2018 No change.	SL
Item 51 P: G-26 S: 4.2.1	Comment: As pointed out above, the Figure 4-1 does not depict average pumping rates, but just the rate for December 2016.	Review and correct.	Accept. This is a typographical error. Figure callouts should only refer to December 2016. "January through" will be deleted throughout Appendix G. Would affect all EERs.		~~C 1/25/2018 Pending adjustment of figure captions.~~	SL

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					C 3/8/2018 Redline reviewed.	
Item 52 P: G-31 S: 6.1 L: 19-23	Comment: Item 1 indicates pumping rates from CY2015 and 2016 were calculated on an average monthly basis, and assumed future pumping rates were developed. The assumed future rates are not comparable to historical averages.	Provide a discussion on this.	No change to text. Table A-4 shows predicted future extraction rates—the limiting factor in the historical averages has been the ability to inject the water due to operational restrictions. Would affect all EERs.	Discussion clarified concerns.	C 1/25/2018 No change.	SL
Item 53 P: H-1 App. H	Comment: Provide what statistical method is planned for WMA U in the text. Basis/Justification:	Provide statistical method that will be used for WMA U.	No change to text. See also, Items 27, 5a, 33, and 40. Need one codified answer, considering all the details. Would suggest that we are still unable to determine a statistical method and defer to 2 years out in the GW Addendum. Would affect all EERs.		C 1/25/2018 No change needed.	DC

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