U.S. Department of Energy
Hanford Site

NOV 1 2 2019

20-SGD-0017

Ms. Alexandra K. Smith, Program Manager
Nuclear Waste Program
Washington State Department of Ecology
3100 Port of Benton Boulevard
Richland, Washington 99354

Dear Ms. Smith:

ENGINEERING EVALUATION REPORT FOR SINGLE-SHELL TANK WASTE MANAGEMENT AREA A-AX GROUNDWATER MONITORING, SGW-60586, REVISION 0

This letter transmits the approved Engineering Evaluation Report for Single-Shell Tank Waste Management Area A-AX Groundwater Monitoring, SGW-60586, Revision 0 to the Washington State Department of Ecology (Ecology).

This report addresses the additional information for groundwater monitoring requested in Ecology's letter 16-NWP-086, Groundwater Monitoring Requirements for 200 East Area Single-Shell Tank Farms Final Status Groundwater Monitoring Plan.

If you have any questions, please contact me, or your staff may contact, Mike Cline, of my staff, on (509) 376-6070.

Sincerely,

William F. Hamel, Assistant Manager
for the River and Plateau
Richland Operations Office

SGD:RDH

Attachment

cc: See page 2

NOV 12 2019

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SGW-60586
Revision 0

Engineering Evaluation Report for Single-Shell Tank Waste Management Area A-AX Groundwater Monitoring

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

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

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

SGW-60586
Revision 0

Engineering Evaluation Report for Single-Shell Tank Waste Management Area A-AX Groundwater Monitoring

Date Published
May 2019

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U.S. Department of Energy (Owner/Operator) Certification

The following certification statement is provided for SGW-60586, Rev. 0, *Engineering Evaluation Report for Single-Shell Tank Waste Management Area A-AX Groundwater Monitoring*, which serves as permit reference material for the Single-Shell Tank System closure unit permit application, permit WA7890008967, Hanford Facility Dangerous Waste Permit (Site-Wide Permit), Revision 9, Part V, CUG-4, Groundwater Monitoring Addendum.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

10/21/19

B. T. Vance
U.S. Department of Energy
Richland Operations Office
Owner/Operator

Date

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CH2M HILL Plateau Remediation Company (Co-Operator) Certification

The following certification statement is provided for SGW-60586, Rev. 0, *Engineering Evaluation Report for Single-Shell Tank Waste Management Area A-AX Groundwater Monitoring*, which serves as permit reference material for the Single-Shell Tank System closure unit permit application, permit WA7890008967, Hanford Facility Dangerous Waste Permit (Site-Wide Permit), Revision 9, Part V, CUG-4, Groundwater Monitoring Addendum.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

L. T. Blackford
President
CH2M HILL Plateau Remediation Company
Co-Operator

5/29/19
Date

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Statement of certification:

I am a licensed Professional Engineer in the State of Washington, No. 41198, with a degree in Environmental Engineering. I have over 26 years of professional experience, including 15 years with groundwater systems. I reviewed the attached engineering study referenced as "Engineering Evaluation Report for Single-Shell Tank Waste Management Area A-AX Groundwater Monitoring, SGW-60586, 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).

April 30, 2019

Date

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

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Terms

AEA	*Atomic Energy Act of 1954*
API	American Petroleum Institute
BIX	ion exchange waste
bgs	below ground surface
CAS	Chemical Abstracts Service
CCU_g	Cold Creek unit unconsolidated coarse-grained gravel
CCU_z	Cold Creek unit silt
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CPGWM	Central Plateau Groundwater Model
DOE	U.S. Department of Energy
DWMU	dangerous waste management unit
DWS	drinking water standard
ECN	engineering change notice
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FY	fiscal year
ICP	inductively coupled plasma
ICN	interim change notice
HSU	hydrostratigraphic unit
K_d	distribution coefficient
OU	operable unit
P1	PUREX high-level waste supernate
P2R	Plateau to River (Model)
PUREX	Plutonium-Uranium Extraction
RCRA	*Resource Conservation and Recovery Act of 1976*
SST	single-shell tank
TDS	total dissolved solids

Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989)
TRIM	Tikhonov Regularized Inverse Method
TSD	treatment, storage, and disposal
UPR	unplanned release
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) A-AX based on evaluation of contaminants associated with WMA A-AX, the expected migration behavior of contaminants in the WMA, and historical observations and measurements of groundwater contamination at WMA A-AX. This evaluation includes results of groundwater flow and particle migration simulations that were performed based on water elevation mapping techniques. WMA A-AX 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 A-AX 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 A-AX is located in the 200 East Area of the Hanford Site in Washington State and overlies the 200-PO-1 Groundwater Operable Unit (OU) (Figure 1-1). WMA A-AX includes 10 SSTs and ancillary equipment of the 241-A and 241-AX Tank Farms that were used for storage of neutralized acidic aging wastes from the Plutonium-Uranium Extraction (PUREX) and B Plants.

This report addresses the additional information for groundwater monitoring requested in Washington State Department of Ecology (Ecology) Letter 16-NWP-086, "Groundwater Monitoring Requirements for 200 East 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.

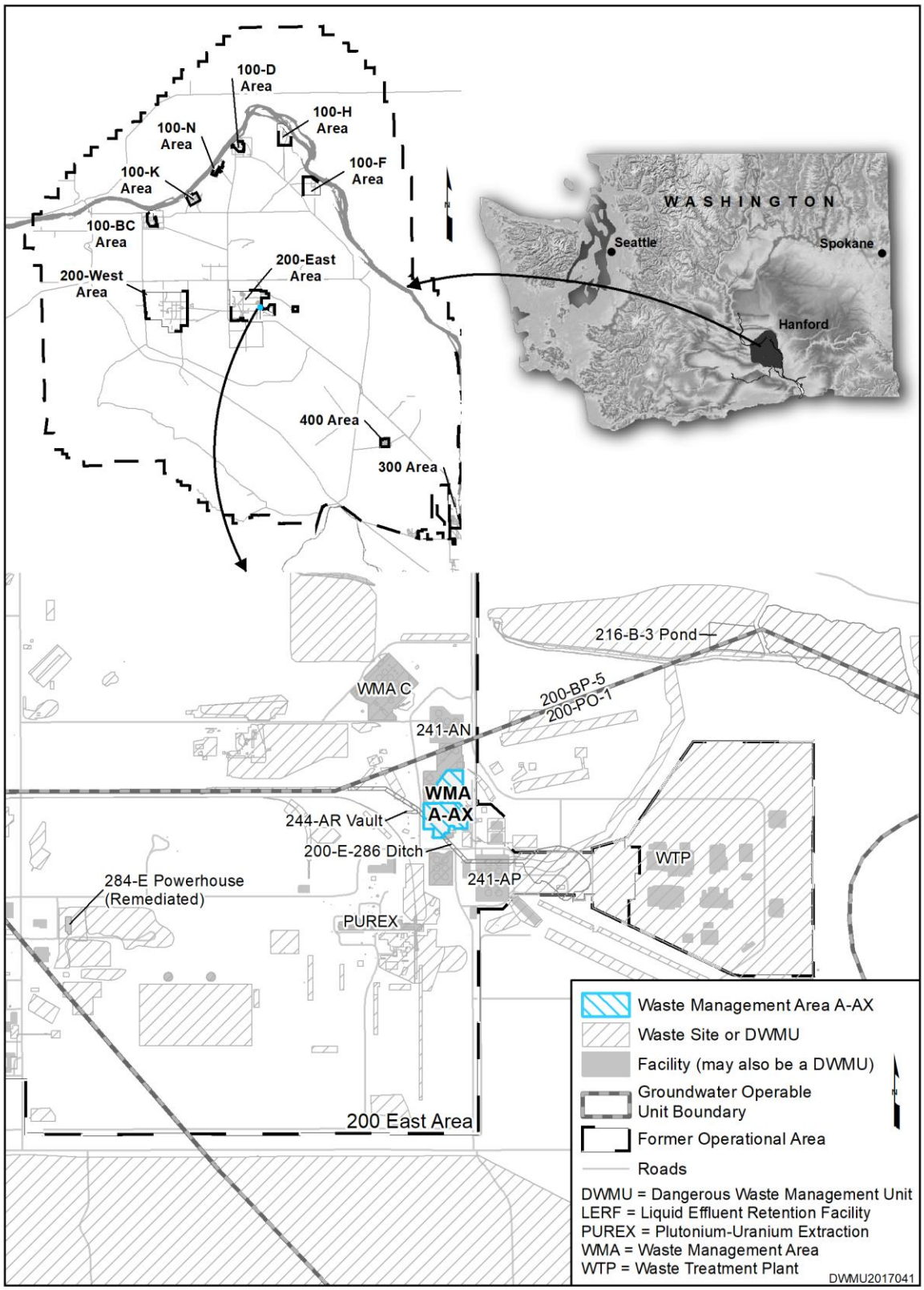


Figure 1-1. Location Map for WMA A-AX

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))[1] 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 A-AX 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.

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

[1] This report presents the information for the scenario where WMA A-AX enters the permit under a compliance monitoring program (WAC 173-303-645(10)). However, WMA A-AX is monitored under a groundwater quality assessment monitoring program (DOE/RL-2015-49) and a first determination report identifying any dangerous waste in the groundwater that is attributable to the WMA has not yet been issued. Depending on the outcome of the first determination report, the scenario where WMA A-AX enters the permit under a detection monitoring program (WAC 173-303-645(9)) is also possible.

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
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 B
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 C
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
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

Table 1-1. Pertinent Requirements

Pertinent Requirement	Section Where Requirement is Addressed
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 D
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 E
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 E

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 A-AX is one regulated unit. It is not being monitored as part of a group of regulated units.

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

This report is organized as follows:

- Chapter 2 includes historical information to support the final status groundwater monitoring program determination.
- Chapter 3 describes the geology and hydrogeology of WMA A-AX.
- Chapter 4 describes the contaminant migration conceptual model.
- Chapter 5 describes groundwater flow simulations for the 200 East Area.
- Chapter 6 describes calculations performed to evaluate wells for the proposed WMA A-AX 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 topographic map.
- Appendix C contains regional plume maps in the vicinity of WMA A-AX.
- Appendix D contains well as-built diagrams and proposed well locations.
- Appendix E contains the process for defining the groundwater monitoring statistical method.

2 Supporting Historical Information

2.1 Background

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

2.1.1 Facility Description

WMA A-AX, which includes the SSTs and ancillary equipment of the 241-A and 241-AX Tank Farms, is located in the east-central portion of the 200 East Area, near the PUREX Plant and directly south of the 241-AN Tank Farm (Figure 2-1). SSTs in WMA A-AX were used for storage of neutralized acidic aging wastes from the PUREX and B Plants (PUREX and Operating Practices Sections in WHC-MR-0132, *A History of the 200 Area Tank Farms*).

The 241-A Tank Farm consists of six SSTs constructed from 1954 to 1955. The 241-AX Tank Farm contains four SSTs constructed from 1963 to 1964. The 10 tanks within WMA A-AX had an operating capacity of 3,785,000 L (1,000,000 gal), with dimensions of 23 m (75 ft) in diameter and 13 m (44 ft) tall. The SSTs were installed below ground, with the tops of the tanks at least 1.8 m (6 ft) below grade to provide radiation shielding and protection for operating personnel.

The heat generated from the decay of radionuclides inside the tanks evaporated water that was in the wastes stored in these tanks (Section 3.1 in RPP-ENV-37956, *Hanford 241-A/AX Farm Leak Inventory Assessment Report*). The water vapor and other off-gases from the 241-A Tank Farm SSTs were drawn from each tank through an underground 51 cm (20 in.) diameter pipe that connects to an underground 61 cm (24 in.) diameter pipe (i.e., vapor header) (Section 3.1 in RPP-ENV-37956). When the 241-AX Tank Farm was constructed, a similar collection system and vapor header was installed that connects to the 241-AX-152 Diverter Station (Section 3.1 in RPP-ENV-37956). From the 241-AX-152 Diverter Station, the underground 61 cm (24 in.) diameter pipe from the 241-AX vapor header connects to the 241-A Tank Farm vapor header, which then connects to underground condensers and de-entrainment vessels that enter the 241-A-431 Tank Farm Ventilation Building (which housed ventilation and de-entrainment equipment) (Section 3.1 in RPP-ENV-37956). WMA A-AX also includes french drains that were used for liquid disposal and multiple liquid handling structures associated with the 241-A and 241-AX tank operations (including catch tanks, diversion boxes, process pipelines, valve pits, and the 244-AR Vault).

Multiple drywells historically used for leak detection by gross gamma logging are located between and around the WMA A-AX SSTs. The drywells are installed to depths between 23 m (75 ft) and 38 m (125 ft) (Section 3.2 in RPP-ENV-37956). In addition to drywells, the tanks within the 241-A Tank Farm have three horizontal lateral pipes that are approximately 3 m (10 ft) beneath each tank foundation that are connected to a vertical caisson that allows for probes to be inserted beneath the tank and monitor for gamma radiation that would indicate a leak (Section 3.2 in RPP-ENV-37956). Each tank within the 241-AX Tank Farm has an internal leak detection pit, consisting of a network of drain slots in the concrete base beneath the carbon steel liner that is connected to a 18 m (60 ft) deep leak detection well, that is then connected to the pump pit atop each tank (Section 3.2 in RPP-ENV-37956). 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.

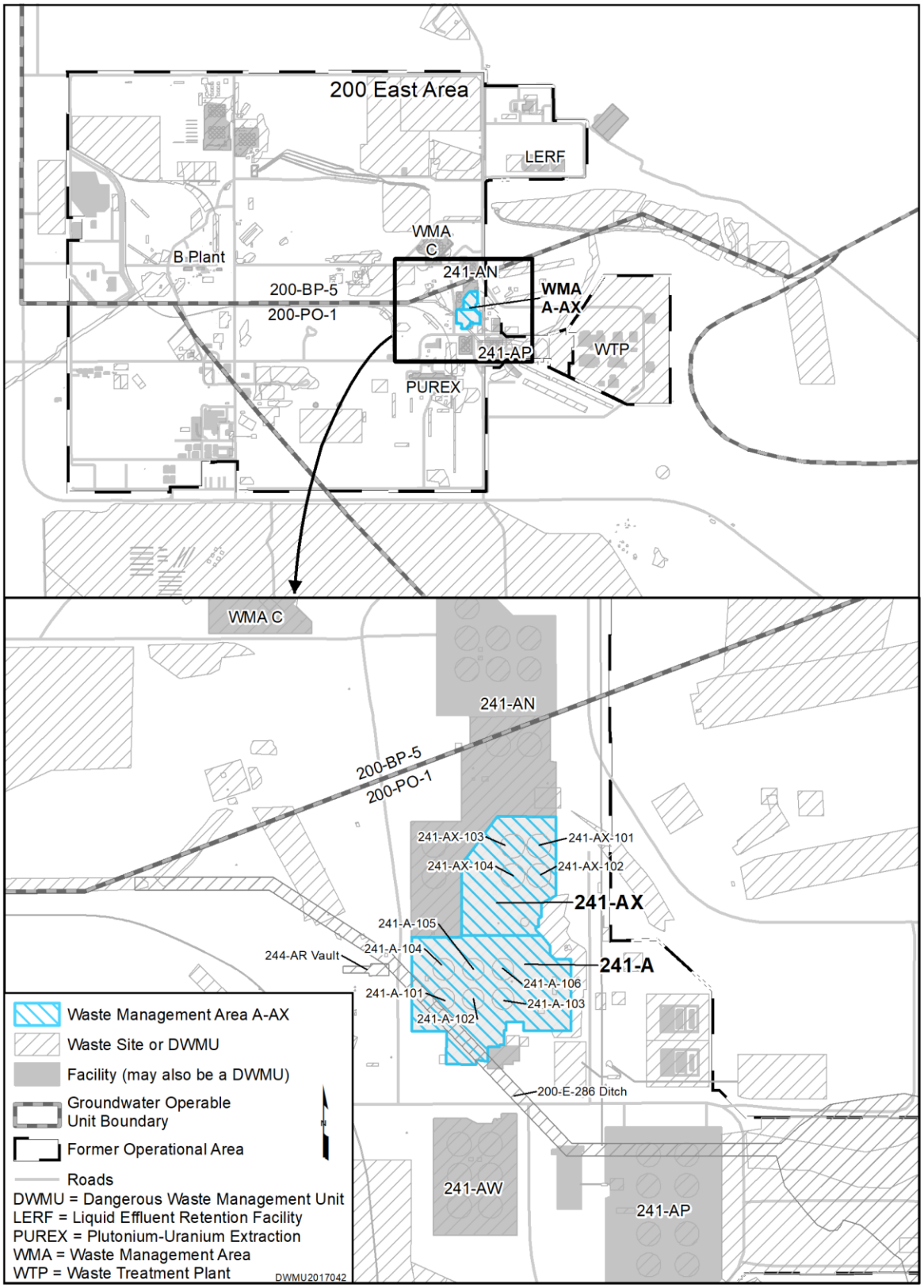
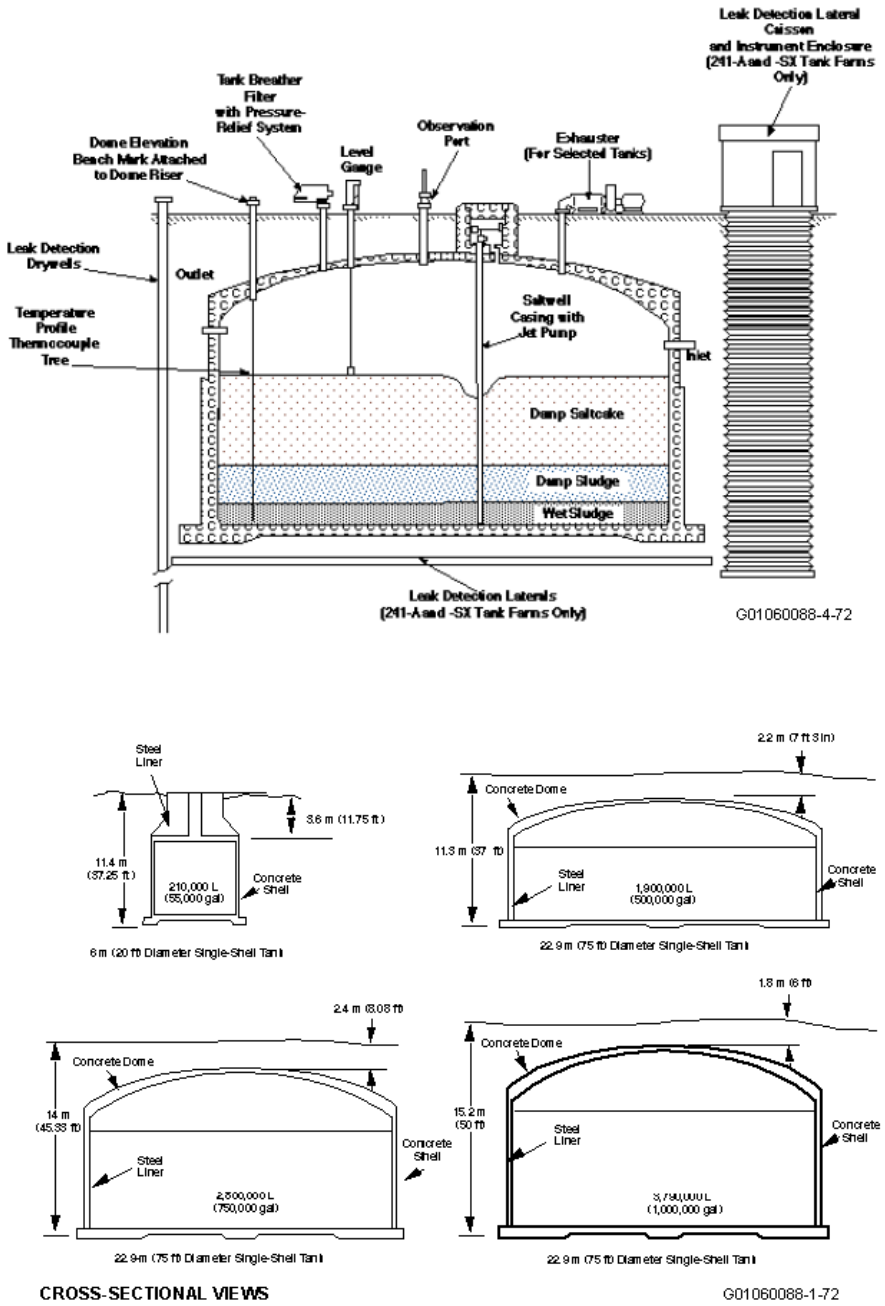


Figure 2-1. Location of WMA A-AX Within the 200 East Area



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

2.1.2 Operational History

Waste sent to the tanks in WMA A-AX came primarily from operations at the PUREX Plant and B Plant waste fractionation process. Starting in 1956 and continuing through 1972, the majority of the waste was neutralized acid waste from PUREX operations (pp. 35-69 and 83-97 in WHC-MR-0132). The PUREX waste streams were self-boiling. Vapors from the waste were collected in an underground header system and vented through stacks. Liquid drainage from the system was ultimately deposited to the 216-A-8 Crib, 216-A-16 french drain, 216-A-17 french drain, 216-A-23A french drain, and 216-A-23B french drain (Section 3.3.2 in RPP-7494, *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations*).

B Plant went into full operation in 1967 to isolate cesium through ion exchange and to purify strontium through solvent extraction from PUREX acid waste and PUREX supernatant waste. The operational processes and utilization of 241-A and 241-AX tanks described below is reported in Section 3.4 in RPP-7494. During B Plant operations, PUREX supernatant waste was first transferred from the 241-AX Tank Farm to the 241-C-105 tank, and subsequently sent to B Plant for fractionization. Between B Plant PUREX acid waste transfers, sludge was sluiced from WMA A-AX tanks for strontium recovery. Sluicing operations were performed at tanks 241-A-101 (beginning in 1968), 241-A-104 (beginning in 1969), 241-A-106 (beginning in 1970), 241-A-102 (beginning in 1973), 241-A-103 (beginning in 1974), 241-AX-101 (beginning in 1975), 241-AX-102 (beginning in 1976), 241-AX-103 (beginning in 1977), and 241-AX-104 (beginning in 1978). As the tanks were sluiced, the sound tanks 241-A-101, 241-A-102, 241-A-103, 241-AX-101, and 241-AX-102 were authorized for saltcake storage while leaking tanks were stabilized and isolated. As the tanks were sluiced, the sound tanks were refilled with a mixture of PUREX coating waste, organic wash waste, high-level B Plant waste, and other Hanford waste types. By the mid-1970s, every type of waste was co-mingled in the WMA A-AX tanks, primarily in tank 241-A-103 (Section 3.4 in RPP-7494).

The process of interim stabilization began in 1972 (Section 3.5 in RPP-7494). Interim stabilization involved pumping the supernate and interstitial liquids from the SSTs into 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, *Waste Tank Summary Report for Month Ending November 30, 2017*, Rev. 359). Each of the SSTs at WMA A-AX have been interim stabilized (Table 4-1 in HNF-EP-0182, Rev. 359).

As described in Section 3.5 in RPP-7494, the receiver tank for the interim stabilization process at WMA A-AX was 241-A-102. In 1977, saltwell waste from the 241-C Tank Farm was pumped via the 244-A Lift Station from 241-C-103 to tank 241-A-102, where the waste was then processed by the 242-A Evaporator. Condensate from the 242-A Evaporator was discharged to the 216-A-37-1 Ditch.

2.1.3 Single-Shell Tanks and Liquid Handling Structures Within WMA A-AX

Of the 10 tanks located within WMA A-AX (Figure 2-1), 2 are confirmed or assumed leakers: 241-A-104 and 241-A-105 (Table 4-1 in HNF-EP-0182, Rev. 359). Leaks from tanks 241-A-103, 241-A-104, 241-A-105, 241-AX-102, and 241-AX-104 were reassessed in the 2014 revision of RPP-ENV-37956. Although previously assumed to have leaked, based on tank integrity, tanks 241-A-103, 241-AX-102, and 241-AX-104 were classified as “sound” based on the incorporation of recommendations from the formal leak assessment reports identified in Table 2-1.

Table 2-1. Tanks Within WMA A-AX with Reclassification of Tank Integrity

Tank	Current Status	Leak Assessment Report	Waste Tank Summary Report Documenting Status Change
241-A-103	Sound	RPP-ASMT-42278, *Tank 241-A-103 Leak Assessment Report*	HNF-EP-0182, Rev. 306, *Waste Tank Summary Report for Month Ending September 30, 2013*
241-AX-102	Sound	RPP-ASMT-42628, *Tank 241-AX-102 Integrity Assessment Report*	HNF-EP-0182, Rev. 319, *Waste Tank Summary Report for Month Ending July 31, 2014*
241-AX-104	Sound	RPP-ASMT-57574, *Tank 241-AX-104 Integrity Assessment Report*	HNF-EP-0182, Rev. 321, *Waste Tank Summary Report for Month Ending September 30, 2014*

Leaks from tanks 241-A-104 and 241-A-105 were reassessed in Table ES-1 in RPP-ENV-37956; however, the revised leak volumes have not yet been formally adopted (as of November 2017) (Table 4-2 and Table 6-1 in HNF-EP-0182, Rev. 359). The leak volumes provided in the following paragraphs include estimates from both HNF-EP-0182, Rev. 359, and RPP-ENV-37956. Estimates of the nonradiological content of the SSTs at the time of the leak events are not available; therefore, the mean inventory of chemical constituents discharged from the tanks is presented in Table 2-2. Discussion in this section 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.

Table 2-2. Nonradiological Waste Discharge Profile for Leaking WMA A-AX SSTs

Analyte	241-A-104 (kg)	241-A-105 (kg)
Aluminum	4.60E+00	0.00E+00
Ammonia	2.27E+00	1.49E+00
Bismuth	3.27E-03	0.00E+00
Butanol	1.30E-02	4.75E-01
Calcium	1.14E+00	1.08E+01
Carbon tetrachloride	0.00E+00	0.00E+00
Carbonate	6.39E+01	8.27E+01
Chlorine	5.14E+00	4.06E+00
Chromium	6.71E+00	1.59E+00
Ferricyanide	0.00E+00	0.00E+00
Fluoride	9.65E-02	1.42E-01
Iron	7.91E-01	4.46E-01
Lanthanum	2.28E-10	0.00E+00
Lead	3.54E-01	4.09E-01
Manganese	7.38E-02	6.51E-03

Table 2-2. Nonradiological Waste Discharge Profile for Leaking WMA A-AX SSTs

Analyte	241-A-104 (kg)	241-A-105 (kg)
Mercury	2.44E-03	1.15E-03
Nickel	8.08E-01	4.04E-01
Nitrate	1.41E+02	3.35E+01
Nitrite	1.66E+02	8.57E+01
Normal-paraffinic hydrocarbon	0.00E+00	0.00E+00
Phosphate	1.60E+01	0.00E+00
Potassium	2.28E+00	1.49E+00
Silicon	2.23E+00	3.68E+00
Silver	1.69E-06	1.43E-04
Sodium	2.35E+02	9.16E+01
Sulfate	5.39E+01	4.61E+01
Tributyl phosphate	0.00E+00	0.00E+00
Uranium	2.34E-01	1.68E-01
Zirconium	3.55E-05	0.00E+00

Source: Table G-1 in DOE/RL-2009-85 ADD1, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit Addendum 1*.

Tank 241-A-104 was categorized as an assumed leaker in 1975 and has a total leak volume of 1,900 to 9,500 L (500 to 2,500 gal) (Table 4-2 in HNF-EP-0182, Rev. 359). During sluicing operations in 1975, increased radiation activity was detected in two laterals beneath the tank, although gross gamma scans of the drywells did not indicate activity above background levels (Section B2.5.3 in RPP-ENV-37956). Reassessment of the tank 241-A-104 leak in 2014 estimated the waste loss at approximately 7,600 L (2,000 gal) based on radioactivity in the laterals (Section 4.2.3 in RPP-ENV-37956). The waste type released from tank 241-A-104 was PUREX sludge supernate, containing approximately 0.56 Ci/gal of cesium-137 (activity as of May 2008) (Section 4.2.3.1 in RPP-ENV-37956). The cesium-137 inventory for the release is approximately 1,100 Ci (Section 4.2.3.3 in RPP-ENV-37956).

Tank 241-A-105 was categorized as an assumed leaker in 1963 and has a total leak volume of 38,000 to 1,022,000 L (10,000 to 270,000 gal) (Table 4-2 in HNF-EP-0182, Rev. 359). Tank 241-A-105 was categorized as a confirmed leaker in 1975 based on increased radioactivity detected in laterals and the information from a sudden steam release incident in 1965 (Section 4.3.1 in RPP-ENV-37956).
On January 28, 1965, tank 241-A-105 experienced a rapid pressurization event that resulted in the tank liner bulging upward (Section B3.1 in RPP-ENV-37956). In 1977, a topographical map produced of the tank bottom clearly showed that the bottom of the steel liner had ripped and separated from the sidewall along approximately three-fourths of the tank bottom (Section B3.2 in RPP-ENV-37956). Reassessment of tank 241-A-105 leaks in RPP-ENV-37956 concluded that the data obtained from the lateral from 1963 to 1986, showing elevated gamma activity and high temperatures below tank 241-A-105, clearly indicate the presence of a tank liner leak (Section 4.3.3 in RPP-ENV-37956). In-tank surface level changes and video observation of a bulge and ripped liner confirm that the tank leaked (Section 4.3.3 in RPP-ENV-37956).

The leak inventory estimate for tank 241-A-105 in RPP-ENV-37956 is based on the extent of the ripped liner, the dates when increased gamma activity was detected in the tank laterals, and the extent of contamination in the laterals. The estimated leak volume in RPP-ENV-37956 is 7,600 to 151,000 L (2,000 to 40,000 gal) depending on the waste type, based on an estimated 56,000 Ci of cesium-137 in the soil (Section 4.3.3 in RPP-ENV-37956). At least three leak events occurred at tank 241-A-105. PUREX high-level waste supernate (waste type P1) leaked from this tank in late 1963 and again in 1965 (Table ES-1 in RPP-ENV-37956). During sluicing operations from 1968 to 1970, 221-B Plant cesium ion-exchange waste (waste type BIX) also leaked from this tank (Table ES-1 in RPP-ENV-37956). In an effort to better quantify the inventory of waste leaked from tank 241-A-105, a new conceptual model was devised to describe the leak. Based on this conceptual model, the range of waste volume leaked from tank 241-A-105 was estimated to be between 7,600 L (2,000 gal) (if all P1waste) and 151,000 L (40,000 gal) (if all BIX waste) (Section 4.3.3 in RPP-ENV-37956).

WMA A-AX contains five french drains that were used for liquid waste disposal. The following information on the french drains was obtained from the Waste Information Data System (WIDS) (Figure 2-3).

- The 216-A-16 french drain is located in the southeast corner of the 241-A Tank Farm. It received approximately 60,000 L (15,850 gal) of floor drainage from the 241-A-431 Building and stack drainage from the 296-A-11 Stack. The 216-A-16 french drain also received overflow from the 216-A-17 french drain, and was taken out of service in March 1969.

- The 216-A-17 french drain, located in the southeast portion of the 241-A Tank Farm, received approximately 122,000 L (32,230 gal) of floor drainage from the 241-A-431 Building and stack drainage from the 296-A-11 Stack. The 216-A-17 french drain was taken out of service in 1969.

- The 216-A-23A and 216-A-23B french drains, located in the southeast corner of the 241-A Tank Farm, received approximately 6,000 L (1,585 gal) of tank condensate and the backflush from the 241-A-431 Building during operation of the french drains from 1957 through 1969. The total volume of this waste stream (6,000 L [1,585 gal]) was discharged to the 216-A-23A and 216-A-23B french drains. The french drains were connected to each other by an underground overflow pipe and were separated by 3 m (10 ft).

- The 241-A-702-WS-1 french drain is located in the southern portion of the 241-AX Tank Farm. Beginning in 1968, this french drain received steam condensate from the 241-A-702 Ventilation Building. Process steam was used in steam heaters to raise the temperature of vent gases from tanks 241-AY and 241-AZ to prevent wetting of the filters. The 241-A-702-WS-1 french drain was used in conjunction with a steam trap. The drain was permanently isolated in 1995.

Other liquid handling structures within WMA A-AX, including diversion boxes, valve pits, catch tanks, and process pipelines, were used to transport or contain liquid waste associated with the tank farms. Information for the structures associated within WMA A-AX that are identified as waste sites in WIDS is provided below.

- There are four diversion box waste sites in WMA A-AX. 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 double-shell tanks.

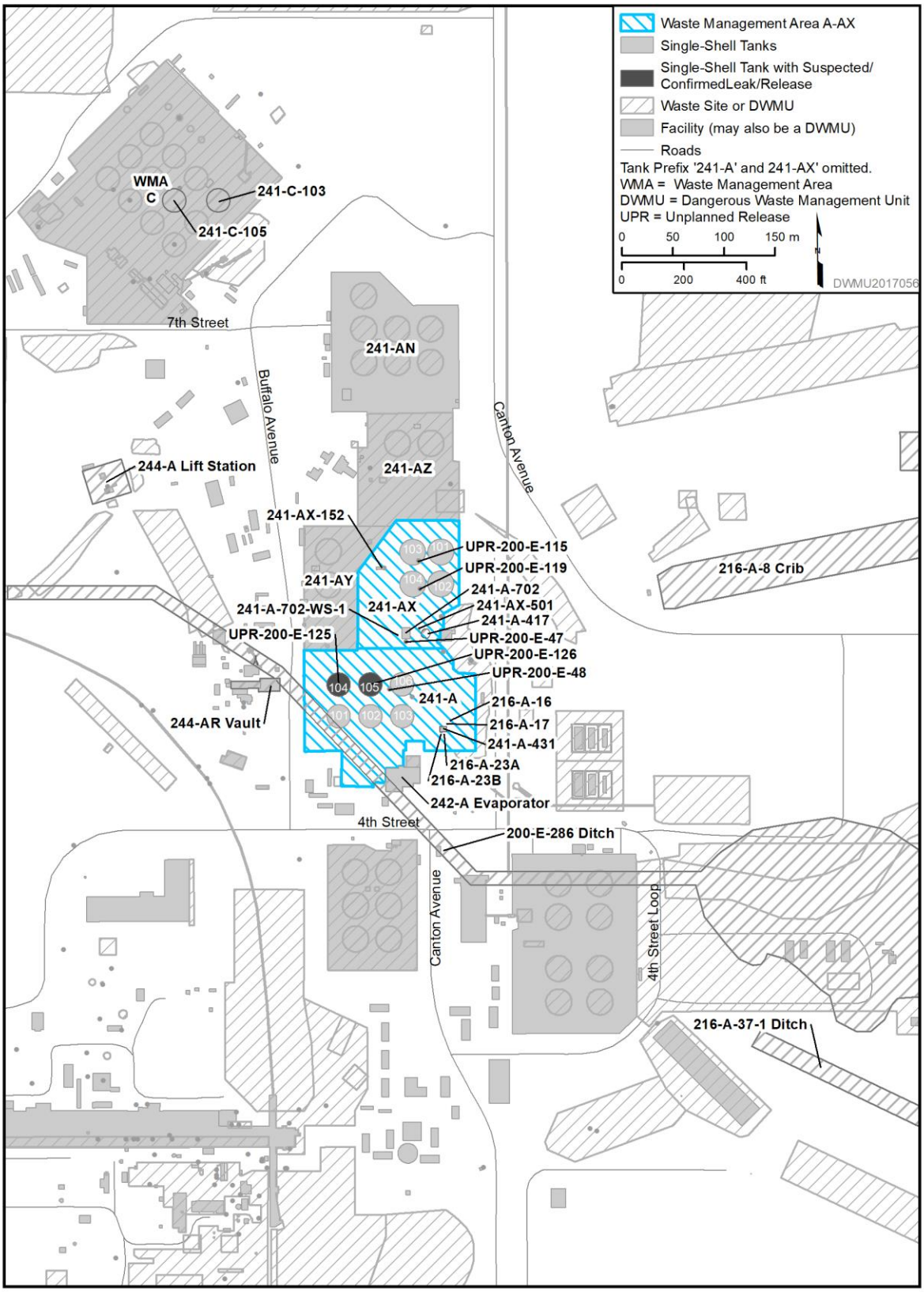


Figure 2-3. WMA A-AX and UPRs

- There are five valve pits in WMA A-AX. 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 was detected within the pit.
- There are three catch tanks in WMA A-AX. Catch tanks are underground structures designed to receive valve pit or diversion box leaks during transfers and drainage operations. Catch tanks are constructed of concrete and, in some cases, are lined with stainless steel. One catch tank (241-AX-152, shown in Figure 2-3) was declared leaking in March 2001. The 241-AX-152 Catch Tank liquid was removed and the tank isolated using administrative and engineering controls. The design capacity of the catch tank was 41,640 L (11,000 gal). In March 1980, a routine pressure test of the return pipeline from the 241-AX-501 Valve Pit to the 241-A-417 Catch Tank (Figure 2-3) indicated a leak at a flange connection. An excavation at the pipeline leak was performed; two barrels of contaminated soil, reading 10,000 cpm, were removed; and a new gasket was installed.
- Fourteen pipeline structures in WMA A-AX transferred process fluids or condensate waste from the tank farm to french drains and surface liquid waste facilities. The pipelines were constructed of carbon steel, stainless steel, vitrified clay, or fiberglass-reinforced epoxy. Pipelines were either direct buried or encased in concrete and were either gravity or pressurized lines. There are no releases or losses of transfer fluids documented in WIDS from pipelines in WMA A-AX.

These liquid handling structures within WMA A-AX 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 unplanned releases (UPRs) within WMA A-AX is from WIDS and Table 5-2 in RPP-ENV-37956. Locations of the UPRs associated with WMA A-AX are presented in Figure 2-3.

- UPR-200-E-47 occurred south of the 241-A-702 Building at the southern border of the 241-AX Tank Farm. This UPR was a 1974 surface contamination event consisting of white specks that covered a 30 by 76 m (98 by 250 ft) area near the building. The specks were assumed to have been windblown from the 702-A Vessel Ventilation Building stack. The parking area and vehicles were cleaned and returned to normal operation the same day.
- UPR-200-E-48 occurred adjacent to tank 241-A-106. This UPR was a small liquid release that occurred during installation of a new pump at the 241-A-106 tank pump pit in January 1974.
- UPR-200-E-115 occurred in February 1974, adjacent to tank 241-AX-103. This UPR consisted of a spray leak in the pump pit at the 241-AX-103 pump pit. According to WIDS, during bleeding of air from a line, air flowed up (instead of down) causing contaminated liquid to spray onto two employees and onto the ground adjacent to the 241-AX-103 pump pit.
- UPR-200-E-119 occurred in 1969, adjacent to tank 241-AX-104. This UPR occurred when an employee mistakenly pulled a contaminated electrode cable out of tank 241-AX-104 and set it on the ground. The contamination was limited to a small area near tank 241-AX-104.

- UPR-200-E-125 occurred in 1975 and is associated with a leak at 241-A-104 to underlying soil (this tank leak is described in Section 2.1.3). According to WIDS, approximately 9,463 L (2,500 gal), containing 18,000 Ci of cesium-137 were released from tank 241-A-104.
- UPR-200-E-126 is associated with a rapid pressurization event at tank 241-A-105 and occurred in the soil underneath the tank. A sudden steam release of severe intensity occurred in January 1965. Approximately 18,900 L (5,000 gal) of waste leaked from the deformed tank (this release amount does not include the cooling water added to the tank).

Each of the UPRs described above are within the 200-E-131 Contaminated Soil Associated with 241-A Tank Farm Complex waste site. The 200-E-131 waste site was created to consolidate and manage multiple, unrelated UPRs that had occurred in the 241-A, -AN, -AX, -AY, and -AZ Tank Farms complex and includes the entire area within the 241-A complex fence. Some of the releases, such as the preceding UPR waste sites, are identified in WIDS, but not all UPRs that have occurred at the 241-A Tank Farm are identified waste sites.

Another category of UPRs includes leaking or ruptured water lines, leaking fire hydrants, or broken valves. One such break in a water line occurred in February 1978 on the east side of the 241-A Tank Farm when 227,125 L (60,000 gal) of water was released to the soil column, resulting in a soil collapse in the center of the farm between tanks 241-A-102 and 241-A-105 (a known leaking tank) (Table 5-2 in RPP-ENV-37956).

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 A-AX. Under interim status, groundwater monitoring at WMA A-AX has been conducted in accordance with WAC 173-303-400(3), “Dangerous Waste Regulations,” “Interim Status Facility Standards” (and, by reference, 40 CFR 265, “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” Subpart F, “Ground-Water Monitoring”), which requires monitoring to determine whether dangerous waste constituents from the DWMU have entered the groundwater in the uppermost aquifer underlying the unit.

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

An interim status indicator parameter groundwater monitoring program (WHC-SD-EN-AP-012, Rev. 0, *40 CFR 265 Interim-Status Ground-Water Monitoring Plan for the Single-Shell Tanks*) was initiated in 1989 at WMA A-AX in accordance with 40 CFR 265, Subpart F (as referenced by WAC 173-303-400(3)). The indicator parameter monitoring program continued until 2005, when WMA A-AX was placed into a groundwater quality assessment monitoring program in accordance with

40 CFR 265.93(d), "Preparation, Evaluation, and Response." The groundwater quality assessment was required because specific conductance results in downgradient well 299-E25-93 exceeded the upgradient critical mean in June 2005 (Section 1.1 in PNNL-15315, *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*).

In 2010, a first determination report (SGW-47538, *Groundwater Quality Assessment Report for Waste Management Area A-AX: First Determination*) was issued. The report found that elevated concentrations of nitrate and technetium-99 could have originated from WMA A-AX and that nickel, a dangerous waste constituent detected at elevated levels in downgradient wells 299-E25-40 and 299-E25-236, had originated from WMA A-AX (Section 4 in SGW-47538).

In 2016, a revised groundwater quality assessment plan (DOE/RL-2015-49, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*) was issued that updated the well network and monitoring constituents, and presented findings related to elevated nickel measured in groundwater samples (Sections 2.2, 2.5.1, and 2.5.2 in DOE/RL-2015-49). In 2012, a sharp, short-term increase in nickel concentrations in well 299-E25-236 was definitively associated with casing corrosion, as supported by a visual inspection of the interior of the well using a downhole video survey that showed significant corrosion. A video survey inside the casing of well 299-E25-40 was also performed in 2012, but did not show distinct corrosion characteristics (Sections 2.5.1 and 2.5.2 in DOE/RL-2015-49). Elevated metal concentrations in these wells were determined to be the result of stainless steel well casing corrosion and not a release from WMA A-AX (Section 2.2 in DOE/RL-2015-49). In 2017, a video survey of well 299-E25-41 identified a black residue in the bottom of the screen, just above the sump. Nickel concentrations in the well have been historically variable, but an overall increasing trend has been apparent since 2016.

Under Revision 9 of the Hanford Facility Dangerous Waste Permit, the SST System treatment, storage, and disposal (TSD) unit, which includes WMA A-AX, 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 A-AX received and transferred waste from PUREX fuel reprocessing and B Plant waste fractionation processes. The majority of the waste was neutralized acid waste from PUREX operations starting in 1956 and continuing through 1972 (pp. 35-69 and 83-97 in WHC-MR-0132).

The dangerous wastes identified on the SST System Part A Application are presented in Table 2-3. The nonradiological waste leak profiles for leaking SSTs 241-A-104 and 241-A-105 are presented in Table 2-2.

Table 2-3. Dangerous Wastes in the Single-Shell Tank 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
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."

*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."

2.4 Interim Status Monitoring Network and Sampling History

Table 2-4 identifies the interim status groundwater monitoring plans implemented at WMA A-AX. Figure 2-4 provides the locations of wells discussed in this section. A summary of the monitoring history for WMA A-AX is presented in Appendix A. Appendix A also contains the interim status groundwater monitoring data collected at WMA A-AX 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 2-4 is provided in Appendix A.

Table 2-4. 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, *Interim-Status Groundwater Monitoring Plan for the Single-Shell Tanks*	1991	Indicator Evaluation Program
ECN 150144	1992	
ECN 172204	1993	
ECN 618171	1994	
PNNL-13023, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*	2001	Indicator Evaluation Program
PNNL-13023-ICN-1	2002	
PNNL-13023-ICN-2	2004	
PNNL-13023-ICN-3	2004	
PNNL-15315, *RCRA Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*	2006	Groundwater Quality Assessment Program
DOE/RL-2015-49, Rev. 0, *Interim Status Groundwater Quality Assessment Plan for the Single-Shell Tank Waste Management Area A-AX*	2016	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 15021 is also incorporated as part of the Rev. 1 plan.

ECN = engineering change notice

ICN = interim change notice

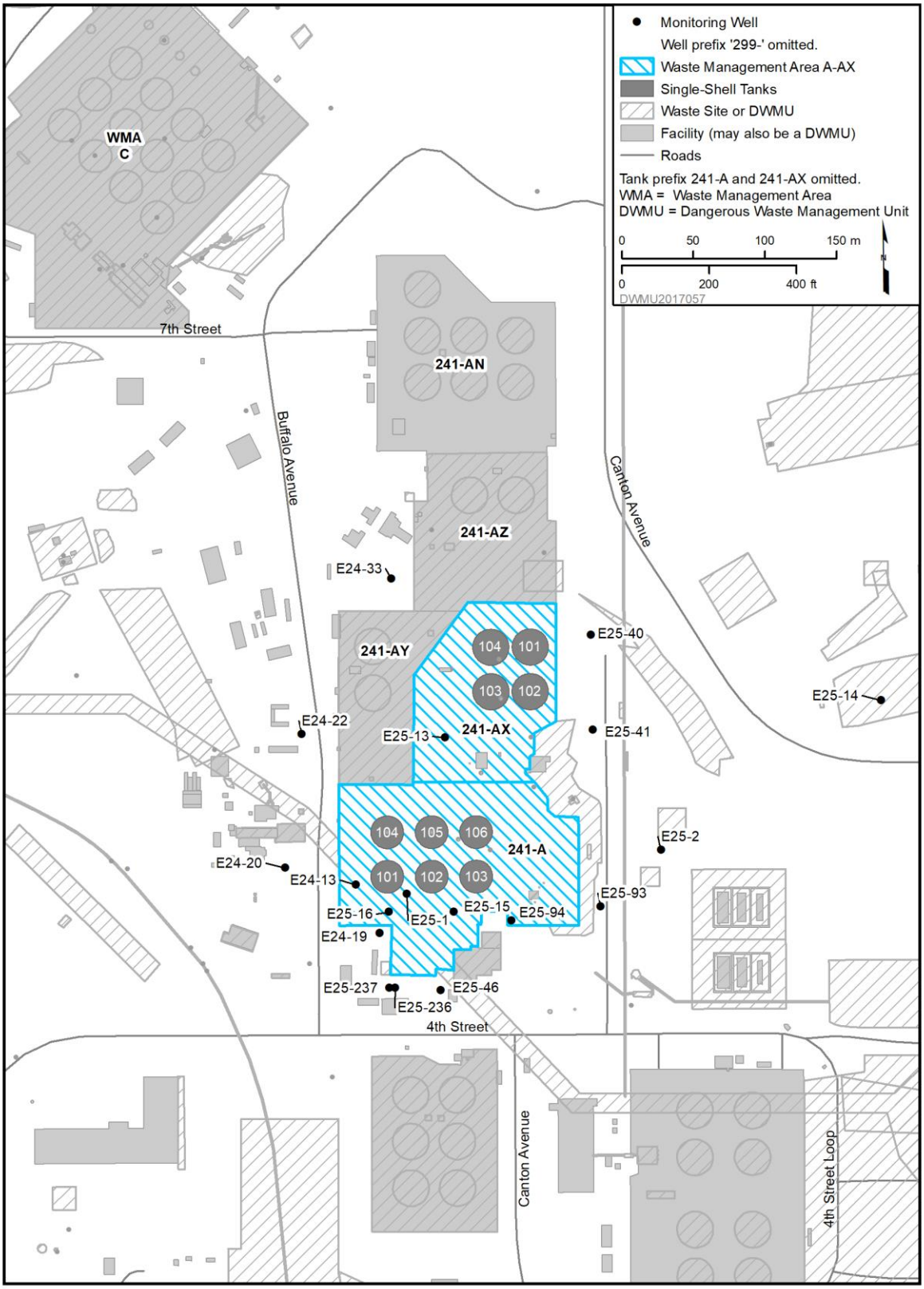


Figure 2-4. Wells Used During Interim Status Monitoring of WMA A-AX

In 1989, the DOE, Richland Operations Office, initiated an interim status groundwater monitoring program at WMA A-AX 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 A-AX, the plan identified three upgradient wells (299-E25-2, 299-E25-40, and 299-E25-41) and six downgradient wells (299-E24-13, 299-E24-19, 299-E25-1, 299-E25-13, 299-E25-15, and 299-E25-16) (Table 3.3 in WHC-SD-EN-AP-012). Wells 299-E24-13, 299-E-25-1, 299-E-25-2, 299-E25-13, 299-E25-15, and 299-E25-16 were existing wells installed between 1955 and 1969; the remaining wells were installed in 1989 (Chapter 3.0, p. 113 in WHC-SD-EN-AP-012). The groundwater flow direction at WMA A-AX was reported as southwest (Chapter 2.0, p. 88 in WHC-SD-EN-AP-012). 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, semivolatile organic compounds, 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 A-AX began in July 1991 (Section 16.1.2 in DOE/RL-92-03).

In 1991, WHC-SD-EN-AP-012 was revised (WHC-SD-EN-AP-012, *Interim Status Groundwater Monitoring Plan for the Single-Shell Tanks*, 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 WMA A-AX monitoring well network was unchanged by the revision (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).

Table 16.1 in DOE/RL-92-03 identified the 1991 WMA A-AX network as two upgradient wells (299-E25-40 and 299-E25-41) and two downgradient wells (299-E24-19 and 299-E24-20). Previously sampled wells 299-E24-13, 299-E25-1, 299-E25-2, 299-E25-15, and 299-E25-16 and one additional existing well (299-E25-14) were used for water-level measurements only (Table 16.1 in DOE/RL-92-03). In 1992, well 299-E25-46 was included in the monitoring well network as a downgradient well (Table 16-1 in DOE/RL-93-09, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1992*).

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 well 299-E25-46 as downgradient to WMA A-AX. 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. The WMA A-AX network reported for 1994 comprised two upgradient wells (299-E25-40 and 299-E25-41) and three downgradient wells (299-E24-19, 299-E24-20, and

299-E25-46), with one well (299-E25-2) used for water-level measurements only (Table 4.11-1 in DOE/RL-94-136, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1994*).

In 1999, the groundwater flow direction at WMA A-AX was revised from west/southwest to east due to a change in the vertical data used to determine water elevations (Section 2.9.2.8 in PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*). Due to the revised flow direction, the monitoring network required reevaluation as it had been designed for a southwest flow direction.

In 2001, a site-specific indicator evaluation monitoring plan was issued for WMA A-AX (PNNL-13023, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site*). The revised plan also reflected the inclusion of the 244-AR Vault and ancillary equipment as part of WMA A-AX, to align with the then-current Part A Application (these features were not included in the Part A Application when the preceding groundwater monitoring plan was issued).

The monitoring well network in PNNL-13023 was unchanged with two upgradient wells (299-E25-40 and 299-E25-41) and three downgradient wells (299-E24-19, 299-E24-20, and 299-E25-46), and well 299-E25-2 used for water-level measurements only (Table 4.1 in PNNL-13023). Due to the relatively flat nature of the water table in the 200 East Area, determination of the flow direction was difficult, and additional studies were needed to verify the newly determined direction (east) and potentially revise the network with new wells (Section 4.2.3 in PNNL-13023). Groundwater monitoring constituents included the contamination indicator parameters, groundwater quality parameters, and drinking water parameters required by 40 CFR 265.92(b), alkalinity, anions, low-level gamma scan, gross alpha, gross beta, inductively coupled plasma (ICP) metals, technetium-99, TDS, uranium and tritium to be sampled on a semi-annual basis with phenols, iodine-129, and strontium-90 being sampled on an annual basis (Table 4.3 in PNNL-13023).

In 2002, PNNL-13023-ICN-1, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site, Interim Change Notice*, was issued to revise the interpretation of the groundwater flow to southeast, update the monitoring well network designations due to the revised flow direction, update the critical means, and modify the monitoring constituents. As a result of the change in understanding of the groundwater flow direction beneath WMA A-AX, the monitoring well network was redesigned to include one upgradient well (299-E24-20), three downgradient wells (299-E25-2, 299-E25-41, and 299-E25-46), one marginally downgradient well (299-E25-40), and one crossgradient well (299-E24-19) (Table 4.1 in PNNL-13023-ICN-1). Groundwater monitoring constituents included the contamination indicator parameters and groundwater quality parameters, drinking water parameters required by 40 CFR 265.92(b), alkalinity, anions, low-level gamma scan, gross alpha, gross beta, ICP metals, iodine-129, strontium-90, technetium-99, uranium, and tritium (Tables 4.3 and 4.4 in PNNL-13023-ICN-1). The monitoring network reported for 2002 included upgradient well 299-E24-20 and downgradient wells 299-E24-19, 299-E25-41, and 299-E25-46, with 299-E25-40 identified for information only (Table A.31 in PNNL-14187, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*).

In 2003, the monitoring well network was revised to include two new downgradient wells drilled in 2003. The network consisted of one upgradient well (299-E24-20), three existing downgradient wells (299-E24-19, 299-E25-41, and 299-E25-46), and two new downgradient wells (299-E24-22 and 299-E25-93), with 299-E25-40 identified for information only (Table B.32 in PNNL-14548, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*).

In 2004, the monitoring well network was revised to include new well 299-E24-33, designated as downgradient. The network reported for 2004 included two upgradient wells (299-E24-20 and

299-E24-22) and five downgradient wells (299-E24-33, 299-E25-40, 299-E25-41, 299-E25-93, and 299-E25-94) (Table B.29 in PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*). Wells 299-E24-19 and 299-E25-46 had been decommissioned after borehole video surveys of each well confirmed extensive corrosion of the stainless steel casing in the vadose zone in proximity to a wet silt zone (84 to 86 m [276 to 282 ft] below the top of the casing) (Section 2.11.3.3 in PNNL-15070). Samples from both wells had elevated chromium, manganese, and nickel results due to the corrosion, with chromium concentrations above 6,000 µg/L at well 299-E25-46 in 2003.

In 2004, two interim change notices to PNNL-13023 were issued. PNNL-13023-ICN-2 (October 2004) updated the monitoring network, including a change in the designation of new well 299-E24-33 from downgradient to upgradient. The network in PNNL-13023-ICN-2 comprised one existing upgradient well (299-E24-20), two new upgradient wells (299-E24-22 and 299-E24-33), two existing downgradient wells (299-E25-2 and 299-E25-41), two new downgradient wells (299-E25-93 and 299-E25-94), and one existing marginally downgradient well (299-E25-40) (Table 4.1 in PNNL-13023-ICN-2, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site, Interim Change Notice*). PNNL-13023-ICN-3 (December 2004) updated the critical means used for statistical comparisons (p. 4.8 in PNNL-13023-ICN-3).

In 2005, PNNL-15141, *Investigation of Accelerated Casing Corrosion in Two Wells at Waste Management Area A-AX*, reported the cause of the corrosion, which resulted in the decommissioning of monitoring wells 299-E24-19 and 299-E25-46 (Executive Summary in PNNL-15141). In 2003, it was determined that two monitoring wells (299-E24-19 and 299-E25-46) in WMA A-AX failed due to rapid corrosion of the stainless steel casing between 84.3 and 84.6 m (276.6 and 277.7 ft) below ground surface (bgs) in well 299-E24-19, and from 83.6 to 84.9 m (274.4 to 278.6 ft) bgs in well 299-E25-46 (Executive Summary in PNNL-15141). The study found that the sidewall core samples from both wells generated acidic extract solutions, with pH values ranging from 1.8 to 2.5 (Section 4.3 in PNNL-15141). Sidewall core samples from well 299-E24-19 had elevated levels of water extractable sodium, and sidewall core samples from well 299-E25-46 had significantly elevated concentrations of extractable nitrate (Section 4.3 in PNNL-15141). These findings, coupled with groundwater monitoring data, clearly demonstrated that the vadose zone/groundwater chemistry in the vicinity of the two failed wells had been affected and compromised by a Hanford Site waste stream (Section 4.3 in PNNL-15141). The study concluded that the corrosion in the well casings was caused by high groundwater chlorinity related to the Wyoming bentonite used in the wells (Section 5.0 in PNNL-15141). The study recommended use of Portland cement as an annulus sealing agent in order to prevent well casing corrosion for wells located in zones with high moisture content or the potential to accumulate perched water (Section 5.0 in PNNL-15141).

In 2005, the designation of well 299-E24-33 changed from downgradient to upgradient, and downgradient well 299-E25-2 was again included in the well network (Table B.29 in PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*). In June 2005, downgradient well 299-E25-93 exceeded the critical mean for specific conductance, which was confirmed with subsequent sampling in July 2005 (Section 2.11.3.3 in PNNL-15670). Therefore, WMA A-AX entered a groundwater quality assessment monitoring program in accordance with 40 CFR 265.93(d) under PNNL-15315. PNNL-15315 included quarterly groundwater sampling for nitrate, sodium, sulfate, total organic carbon, chromium, lead, specific conductance, temperature, turbidity, alkalinity, anions, metals, and technetium-99 (Table A.2.2 in PNNL-15315). The monitoring well network consisted of three upgradient wells (299-E24-20, 299-E24-22, and 299-E24-33) and five downgradient wells (299-E25-2, 299-E25-40, 299-E25-41, 299-E25-93, and 299-E25-94) (Table A.2.2 and Figure A.2.1 in PNNL-15315).

In fiscal year (FY) 2008, one downgradient well (299-E25-236) was constructed and added to the monitoring network in order to replace wells that were damaged with corrosion (299-E24-19 and 299-E25-46) (Section 2.11.3.3 in DOE/RL-2008-66, *Hanford Site Groundwater Monitoring for Fiscal Year 2008*). Sampling at downgradient well 299-E25-236 began in FY 2009 (Table C-29 in DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009 Volumes 1 & 2*).

In 2012, a sharp, short-term increase in the nickel concentrations in well 299-E25-236 were measured that were later definitively associated with casing corrosion, as supported by a visual inspection of the interior of the well using a downhole video survey that showed significant corrosion (Sections 2.5.1 and 2.5.2 in DOE/RL-2015-49). A video survey inside the casing of well 299-E25-40 was also completed, but did not show distinct corrosion characteristics. Elevated metal concentrations in these wells were determined to be the result of stainless steel well casing corrosion and not a release from WMA A-AX (Section 2.2 in DOE/RL-2015-49).

In June 2013, downgradient well 299-E25-236 was decommissioned due to accelerated corrosion (Section 10.13.1in DOE/RL-2015-07, *Hanford Site Groundwater Monitoring Report for 2014*). In 2015, sampling began at the downgradient replacement well for 299-E25-236 (299-E25-237) (Section 3.1 in DOE/RL-2016-12, *Hanford Site RCRA Groundwater Monitoring Report for 2015*).

In 2016, a revised groundwater monitoring plan (i.e., DOE/RL-2015-49) was issued to update the well network with replacement well 299-E25-237 and revise the monitoring constituents. The monitoring well network consisted of three upgradient wells (299-E24-20, 299-E24-22, and 299-E24-33) and six downgradient wells (299-E25-2, 299-E25-40, 299-E25-41, 299-E25-93, 299-E25-94, and 299-E25-237) (Table 3-2 in DOE/RL-2015-49). The groundwater monitoring constituent list consisted of alkalinity, anions, filtered and unfiltered metals, pH, specific conductance, temperature, and turbidity (Table 3-2 in DOE/RL-2015-49). Additionally, the primary nonradiological constituents that were identified as potentially present in SST waste (Tables 4-1, 4-2, and 4-5 of 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-2015-49).

In 2016, groundwater flow beneath WMA A-AX was to the south-southeast with a flow rate of 0.091 m/d (0.3 ft/d) (Table 3-2 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*). Nitrate exceeded the drinking water standard (DWS) in two wells (upgradient well 299-E25-20 and downgradient well 299-E25-93) (Table 3-4 in DOE/RL-2016-66). Nitrate was detected in upgradient wells and in wells monitoring other sites that are upgradient, indicating that WMA A-AX is within a larger 200 East Area nitrate plume. As reported in Section 10.12.1 in DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*, an anomalous total iron result of 3,640 µg/L was measured in well 299-E25-40 in March 2016, exceeding the 300 µg/L secondary DWS. However, subsequent sampling in September and December showed concentrations of 38.6 and 96.8 µg/L. The elevated iron was likely caused by particles of aquifer sediment. Associated increases in manganese, nickel, and chromium, which would indicate well casing corrosion, were not observed in well 299-E25-40. Dissolved iron concentrations were below the detection limit (30 µg/L), consistent with the other network wells.

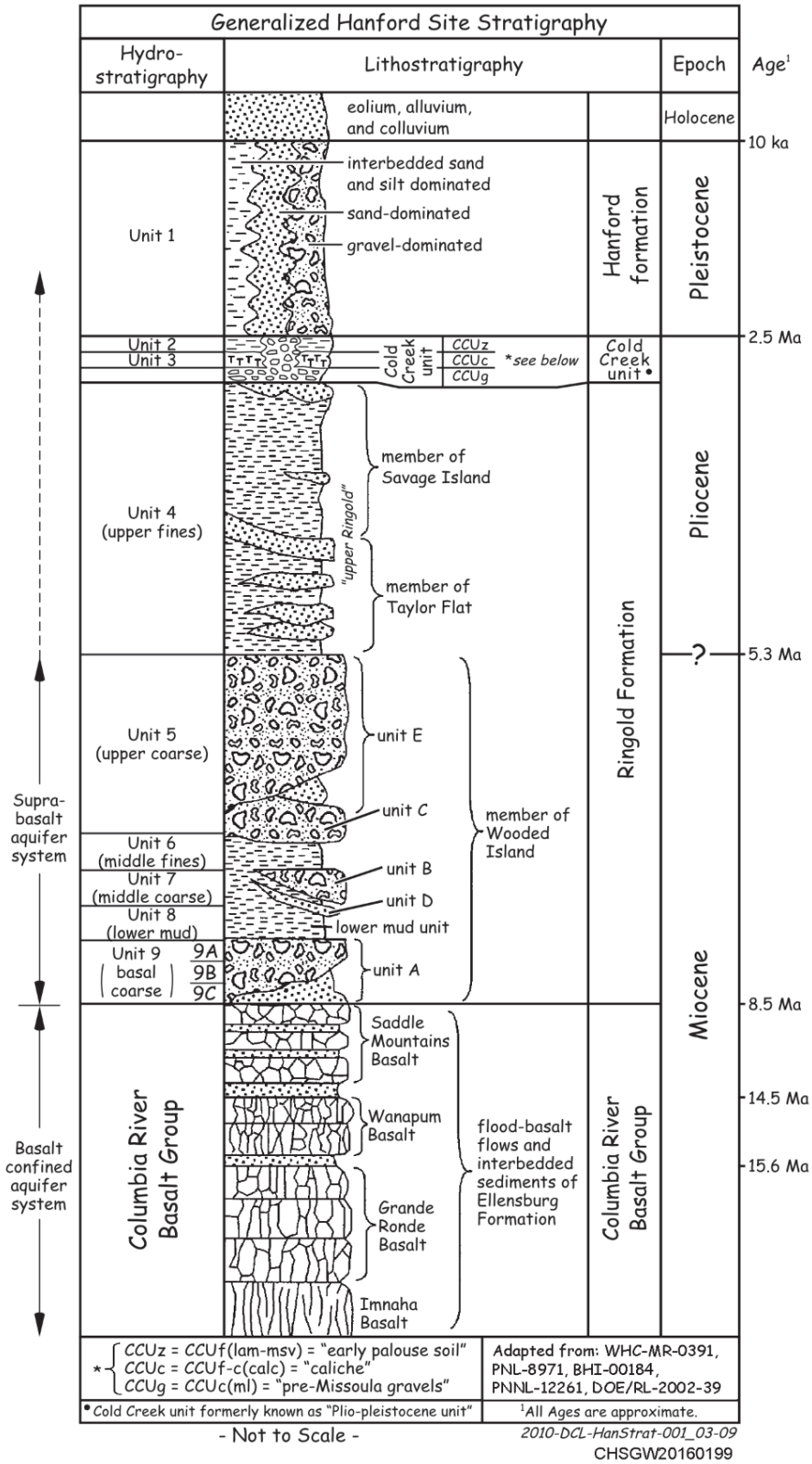
3 Geology and Hydrogeology

This chapter describes the local geology and hydrogeology beneath WMA A-AX and is included to provide a brief overview of the current understanding of the site. The information provided was obtained from several sources including Section 2.4 in DOE/RL-2015-49; Section 8.2.2 in RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*; Sections 2.2.2 through 2.2.7 and Section 2.3 in RPP-14430, *Subsurface Conditions Description of the C and A-AX Waste Management Area*; Section 5.4.1.1 in WHC-SD-EN-TI-019, *Hydrogeologic Model for the 200 East Groundwater Aggregate Area*; Section 2.4 in PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at Hanford Site*; and Section 3.1.3 in WHC-SD-EN-TI-012, *Geologic Setting of the 200 East Area: An Update*. Section 3.1 in PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*, and Sections 2 and 3 in WHC-SD-EN-TI-019 provide information on the hydrogeology of the 200 East Area and vicinity. The information provided in this chapter aligns with the current understanding of ECF-Hanford-13-0029, Rev. 5, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*, and CP-60925, *Model Package Report: Central Plateau Vadose Zone Geoframework Version 1.0*.

3.1 Stratigraphy

The generalized stratigraphy of the Hanford Site is presented in Figure 3-1. The stratigraphy beneath WMA A-AX consists of approximately 112 m (367 ft) of unconsolidated to semi-consolidated sediments overlying basalt bedrock of the Columbia River Basalt Group. The sedimentary units present (in descending sequence) below WMA A-AX are as follows:

- Sand and gravel backfill, and scattered amounts of eolian silty sand
- Sand and gravel of the Hanford formation
- Silt and gravel of the Cold Creek unit
- Sand and gravel of Ringold Formation member of Wooded Island unit A



Note: Complete reference citations are provided in Chapter 11.

Figure 3-1. General Stratigraphy of the Hanford Site

The Hanford formation is the informal name for the glaciofluvial deposits from cataclysmic Ice Age floodwaters sourced from glacial lakes, including Glacial Lake Missoula (Section 3.1.3.3 in WHC-SD-EN-TI-012). The last Ice Age floods occurred about 15,000 years ago; the earliest may have been 1 to 2 million years ago (Bjornstad, 2006, *On the Trail of the Ice Age Floods: A Geological Guide to the Mid-Columbia Basin*). The Hanford formation consists of mostly unconsolidated sediments that exhibit a wide range in grain size (from silt to boulders) (Section 3.1.3.3 in WHC-SD-EN-TI-012), and is further subdivided into three informal facies (H1, H2, and H3). Sand to gravelly sand (H2) predominates the vadose zone sedimentary sequence beneath and adjacent to WMA A-AX (Figure 3-2). The Hanford formation local to the WMA is approximately 76 m (250 ft) thick.

Hanford formation sand-dominated sequence (H2) overlies the Cold Creek unit silt (CCU_z) beneath the 241-A and 241-AX Tank Farms and ranges from slightly muddy sand to clay. The CCU_z is associated with fluvial overbank deposits, which can have variable thickness (Section 2.4.1 in DOE/RL-2015-49), but is estimated to be between 1 to 6 m (3 to 20 ft) thick and expected to be encountered at approximately 130 m (427 ft) above mean sea level. The CCU_z silt layer could be equivalent or partially equivalent to the early "Palouse" soil, a distinctive fine-grained unit beneath the 200 West Area (Section 2.5.3 in PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*).

The Cold Creek unit unconsolidated gravel (CCU_g), formerly referred to as the "pre-Missoula gravels," is an unconsolidated coarse-grained, moderately felsic gravel that varies from a sandy gravel with cobbles to a silty gravelly sand. The CCU_g underlies the CCU_z and overlies the Ringold Formation unit A (where it exists) or basalt. The CCU_g thickness is approximately 20 m (65 ft) and constitutes the majority of the unconfined aquifer saturated thickness.

The Ringold Formation consists of Miocene-Pliocene fluvial and lacustrine clastic sediment deposited by the ancestral Columbia River system and unconformably overlies the Miocene-age Columbia River Basalt Group. The Ringold Formation underlying the Cold Creek unit at WMA A-AX is the member of Wooded Island, which regionally consists of five gravel-dominated, fluvial depositional units, separated by widespread overbank, paleosol, and lacustrine deposits (Chapter 5 in BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site*). Of these five units, the silty sandy gravel deposits of the Ringold Formation member of Wooded Island, unit A (also referred to as the Ringold unit A or Rwia) are present at WMA A-AX and can range from 0 to 10 m (0 to 33 ft) in thickness. Intercalated lenticular sand and silt of the fluvial sand and overbank facies associations have been encountered locally in the middle part of the Ringold unit A (Section 4.2.1 in WCH-SD-EN-TI-012). Estimated depth to the top of the Ringold unit A is 100 m (330 ft) bgs.

Geologic cross sections that include selected wells in the southern portion of the 200 East Area present the approximate stratigraphy underlying and adjacent to WMA A-AX (Figure 3-2). Geologic contacts associated with the wells presented in the cross sections are based on the contacts defined in Table A-2 of Attachment A within ECF-Hanford-13-0029, Rev. 1, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*. Definition of the stratigraphic units and contacts shown in each cross section is consistent with the most current, integrated understanding of the subsurface geologic framework beneath the 200 East Area. In some cases, geologic contacts and stratigraphy from adjacent areas where data are available is projected to surrounding areas where data are less complete, utilizing the Leapfrog Hydro® geologic three-dimensional software (Chapter 3 in ECF-Hanford-13-0029, Rev. 1).

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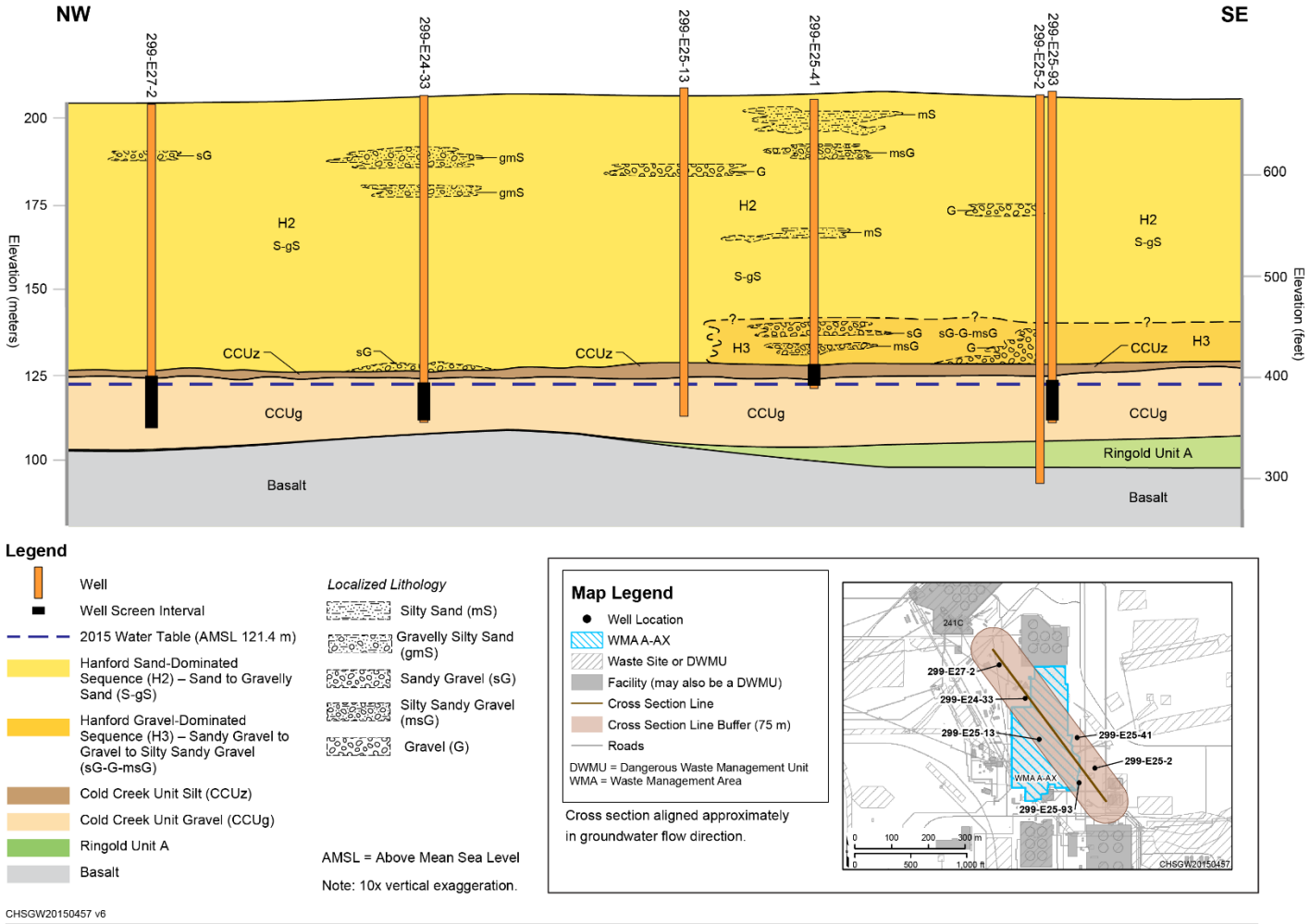

Figure 3-2. Northwest to Southeast Cross Section Beneath WMA A-AX

As indicated in each figure legend, geologic information associated with a well is projected to the cross section within a buffer zone extending 75 m (246 ft) from either side of the cross section line, resulting in approximate depths for stratigraphic contacts.

3.2 Hydrogeology

Groundwater beneath WMA A-AX occurs as an uppermost, unconfined aquifer in suprabasalt sediments and deeper confined aquifers within the Columbia River Basalt Group. The unconfined aquifer beneath WMA A-AX occurs at approximately 122 m (400 ft) above mean sea level (84 m [272 ft] bgs) within the CCU_g, and the Ringold Formation unit A where present. Near WMA A-AX, the unconfined aquifer is approximately 25 m (82 ft) thick, increasing in thickness toward the southwest. The top of the Elephant Mountain Member of the Saddle Mountains Basalt (Columbia River Basalt Group) defines the base of the unconfined aquifer. Confined zones in the basalt aquifers are present in sedimentary interbeds and/or interflow zones (i.e., networks of interconnecting vesicles and fractures) that occur between dense basalt flows (Section 2.3 in RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in B Pond-Gable Mountain Pond Area*) beneath the Central Plateau. There is no evidence of confined basalt and unconfined aquifer communication in the vicinity of WMA A-AX. Chapter 9 presents the well screen intervals across the aquifer beneath WMA A-AX.

Additional descriptions of the hydrogeology of WMA A-AX are provided in Section 8.2.2 in RPP-23748, Sections 2.2 and 2.4 in RPP-14430, and Sections 2 and 3 in WHC-SD-EN-TI-019. Section 3.1 in PNNL-12261 describes the hydrogeology of the entire 200 East Area and vicinity.

The CCU_z lies above the water table across the entire WMA A-AX, varies in thickness from 6 m (20 ft) beneath the 241-A Tank Farm, and pinches out to the northwest, west, and southwest (Figure 3-3). It is a potential partial obstruction for liquid infiltration through the vadose zone due to its relatively lower hydraulic conductivity than the underlying CCU_g and overlying Hanford formation (Table 4.1 in PNNL-19277). The increased content of silt and clay also causes the CCU_z to retain more moisture, thereby having higher moisture content than the coarser sediments above and immediately below. Throughout its extent in the 200 East Area, the CCU_z may cause perching of groundwater in places where the amount of vertically percolating fluids exceeds the unit's ability to transmit groundwater. The CCU_z could potentially act as an aquitard that could cause lateral spreading of liquid infiltration from higher in the vadose zone.

3.3 Groundwater Flow System

During the defense operational efforts at the Hanford Site (1943 to 1995), the groundwater elevation and flow direction throughout much of the 200 East Area were influenced by the persistent hydraulic mounding associated with planned discharges in the 200 West Area and with planned discharges within and near the 200 East Area. These include large-volume discharges to the 216-B-3 Pond (B Pond) system (located on the east side of the 200 East Area) and Gable Mountain Pond (i.e., 216-A-25 Pond, located to the north of the 200 East Area). This groundwater mounding is evident in hydrographs and water table maps up to, through, and in some locations beyond the 1990s. Along the east and east-central part of the 200 East Area, the mounding generated a local hydraulic gradient to the southwest (Chapter 4 in SGW-60338, *Historical Changes in Water Table Elevation and Groundwater Flow Direction at Hanford: 1944 to 2014*).

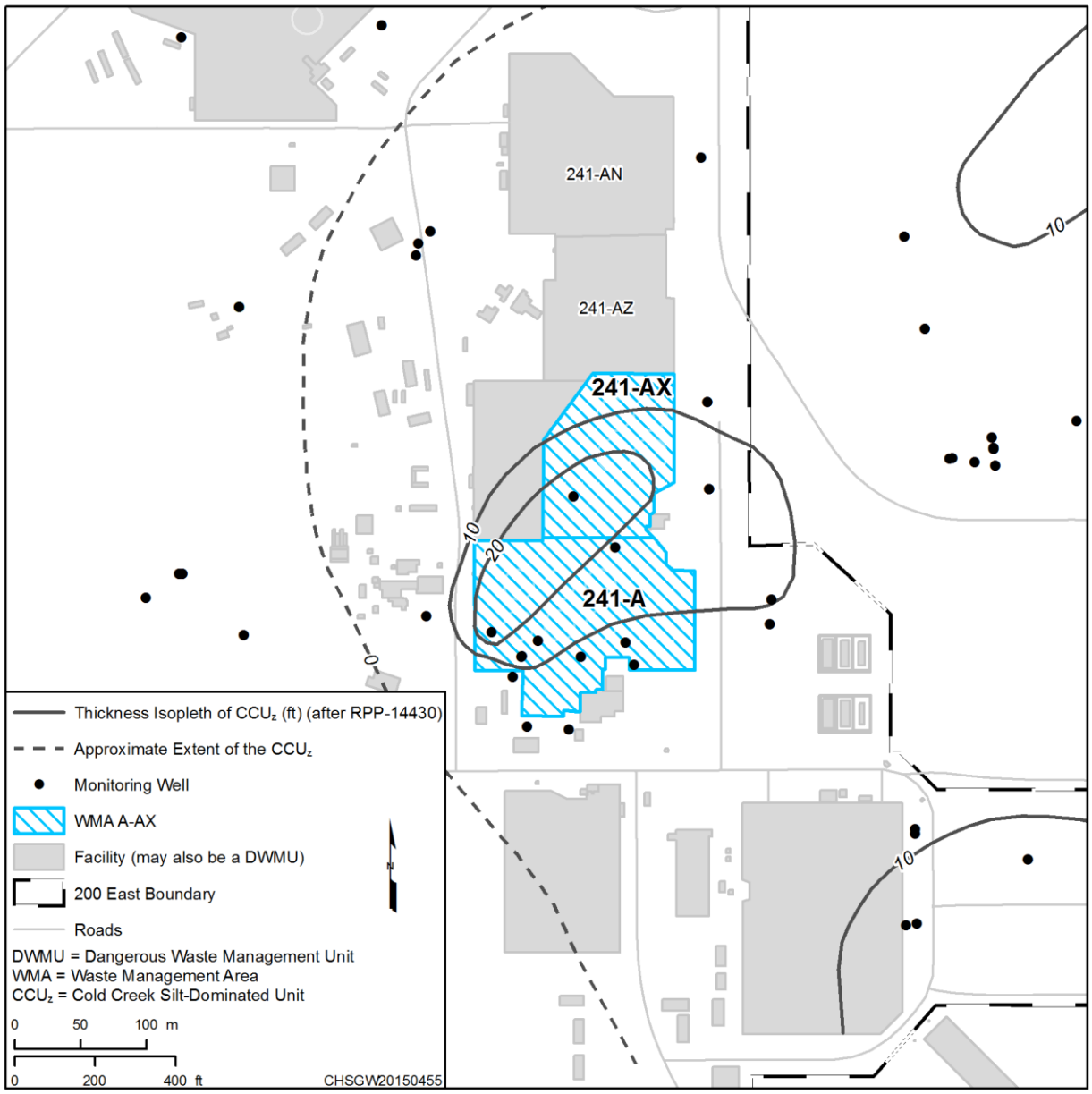

Figure 3-3. Isopach Map of the Cold Creek Unit Fine-Grained Facies (CCUz)

Water table elevations in the 200 East Area were at their highest during the Hanford Site's peak operating years (1960s through 1990s; Figure 2 in SGW-60338). The termination of discharges to the Gable Mountain Pond system in 1985, and subsequent termination of discharges to the B Pond system in 1993, resulted in the gradual dissipation of the 200 East Area groundwater mound. As groundwater elevations continued to decline, the water table became extremely flat throughout the 200 East Area. Because of the flat water table, it became difficult to estimate the direction of groundwater flow by measuring water levels and mapping the water table. Changes in groundwater elevations and associated hydraulic gradients and flow directions have become less discernible from year to year subsequent to the cessation of operational discharges. The changes in gradient magnitude have been accompanied by changes in groundwater flow direction, with most of the 200 East Area presently exhibiting a northwest-to-southeast flow direction. This flow direction suggests that the groundwater elevations and hydraulic gradients are approaching pre-operational conditions at the Hanford Site.

Efforts have been made to obtain more accurate well survey elevations and measurements of the deviation from vertical for 56 key monitoring wells in the 200 East Area. The 56 wells constitute what is termed the low-gradient monitoring network. The water-level measurements obtained from the low-gradient monitoring network were evaluated by generating digital grids of the mapped water table and performing trend surface analyses. In an effort to minimize error, data for each well were averaged over yearly periods. Results of those surface-mapping analyses, along with an estimate of the residual error in the water-level measurements, are described in Chapter 5 in SGW-54165, *Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site*. In 2016, groundwater near WMA A-AX was interpreted to flow to the south-southeast based on trend surface analysis (Section 3.1 in DOE/RL-2016-66). In ECF-200E-18-0066, *Groundwater Flow and Migration Calculations to Assess Monitoring Networks in the 200 East Area Dangerous Waste Management Units*, an analysis of groundwater flow was performed to evaluate the efficacy of the groundwater monitoring network for WMA A-AX. This analysis is described in Chapters 5 through 7.

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4 Contaminant Migration Conceptual Model

A tank waste contaminant migration model, summarized in the following sections, is discussed in Chapter 16 and Appendix A in DOE/ORP-2008-01, *RCRA Facility Investigation Report for Hanford Single-Shell Tank Waste Management Areas*. The following sections include additional content derived from Chapter 3 in PNNL-13023, Section 2.3 in PNNL-15315, and interpretation of more recently collected groundwater monitoring data at WMA A-AX.

4.1 Vadose Zone

The vadose zone beneath WMA A-AX is approximately 82 to 88 m (270 to 290 ft) thick and consists of the Hanford formation, the CCU_z, and the upper portion of the CCU_g (CP-60925). The lower hydraulic conductivity of the CCU_z may slow downward movement of liquids and associated contaminants between the overlying Hanford formation and underlying CCU_g because of the finer textured sediments that characterize this stratigraphic feature in the vadose zone.

The unsaturated sediments above the water table affect how liquids move through the soil, how much is retained in the sediment column, and how much liquid and associated contaminants eventually reach the water table. The source of contamination for WMA A-AX is aqueous liquid waste released from tanks and/or associated ancillary equipment to near-surface and/or subsurface sediments. These liquids generally move through the sediment under unsaturated conditions and, as a result, may tend to spread laterally. Small-volume leaks would tend to be retained in the vadose zone near the release point. Larger releases would be expected to move deeper into the soil, spreading laterally as the wetting front moves downward.

Downward migration of contaminated water through the vadose zone to groundwater may also have been aided by releases of additional volumes of water from leaking waste transfer piping systems, dust-suppression water, UPRs, spills, ruptured fresh water lines, and nearby cribs and ditches. Dissolved contaminants extracted from sediments collected from sidewall core samples (wells 299-E24-19 and 299-E25-46) suggest that waste water from Hanford Site waste streams containing nitrate have entered the vadose zone and migrated to depths nearly as deep as the water table at WMA A-AX (Section 3.3.2 in PNNL-15141). The detected groundwater contamination beneath WMA A-AX thus far includes the nondangerous waste constituent nitrate and well casing corrosion products such as nickel and chromium.

4.2 Soil Moisture Factors

Tank leak/release events began with rapid discharge of some waste fluid volume into the subsurface from a point of entry likely having a small spatial extent (on the order of a few square meters). This discharge temporarily increased the moisture content of the unsaturated soil, particularly at the point of entry. Points of entry included poorly sealed openings in the tank structure, ruptured areas of steel tank liners near underlying concrete shell fractures, and breaks in waste transfer lines.

The migration process occurred, for the most part, in partially saturated soils because leak/release volumes were insufficient 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 occurred because 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 and be enhanced by the unsaturated conditions. External sources of water or other liquid may have driven the contamination downward. Infiltration of fresh water (as well as precipitation and unintentional, manmade releases such as leaking water lines) may move residual waste remaining in the soil downward to the groundwater.

Additionally, the historical mounding groundwater conditions created by local discharge is a potential contributing factor to the soil moisture content of the CCU_z, as discussed in Section 3.2 of this report.

4.3 Hydrogeologic Considerations

Water levels in the uppermost unconfined aquifer have risen as much as 9 m (30 ft) beneath the 200 East Area because of artificial recharge from liquid waste disposal operations since the mid-1940s (Table 1 in SGW-60338). The largest volumes of discharge were to the B Pond system east of the 200 East Area, the 216-A-25 (Gable Mountain) Pond system north of the 200 East Area, and several of the PUREX Plant cribs to the east and south of WMA A-AX and WMA C. The Gable Mountain pond system is estimated to have received approximately 293 billion L (77.4 billion gal) of effluent and B Pond to have received about 256 billion L (67.6 billion gal) of effluent (Section 8.2.2.1 in RPP-23748). These large volumes disposed to the ponds (and lesser volumes to cribs and ditches) artificially recharged the unconfined aquifer creating large water table mounds. The increase in water table elevation was most rapid from 1954 to 1963.

The water table declined somewhat in the late 1960s and early 1970s, and then increased again in the early 1980s before a final decline throughout the 1990s when waste water discharges in the 200 East Area were reduced (Section 8.2.2.1 in RPP-23748). The average rate of water-level decline at WMA A-AX between March 1999 and March 2004 was calculated to be 0.10 m/yr (0.33 ft/yr) (Table 8-17 in RPP-23748). Based on the current monitoring network wells at WMA A-AX, from 2011 to 2016, the rate of water level decline has been approximately 0.04 m/yr (0.13 ft/yr).

Accompanying the historical changes in water level were changes in groundwater flow direction. Pre-Hanford Site groundwater flow direction was generally toward the east or southeast (Table 1 in SGW-60338). Since that time, the liquid disposal to B Pond, Gable Mountain pond, and other disposal facilities have impacted local flow directions in the 200 East Area several times during Hanford Site operations. Prior to 1990, there were no appropriately placed wells in the WMA A-AX area to provide historical groundwater flow directions (Section 8.2.2.1 in RPP-23748). The groundwater flow direction at WMA A-AX has been relatively consistent and toward the south-southeast from 1992 to 2003, which is consistent with the current determination of flow direction (southeast to south-southeast) and historical plume migration characteristics. The groundwater flow direction and gradient will be considered when evaluating the groundwater monitoring network. These factors are assessed in evaluating impact to groundwater beneath WMA A-AX in the simulations described in Chapters 5 through 7 of this report.

4.4 Subsurface Chemistry

The following sections discuss variations in vadose zone and groundwater chemistry at WMA A-AX.

4.4.1 Vadose Chemistry and Well Corrosion

The vadose zone chemistry at WMA A-AX appears to have been influenced by historical discharges from the 284-E Powerhouse (located in the south-central portion of the 200 East Area) that flowed through the 200-E-286 Ditch (Figure 4-1). This unlined ditch ran across the area that would become the southwestern end of the 241-A Tank Farm and conveyed steam condensate, cooling water, and boiler blowdown wastewater to A-Swamp (a predecessor to the B Pond system). Contaminants associated with the 200-E-286 Ditch include high ionic strength water softener regeneration solution that would have typically contained substantial chloride, calcium, and magnesium. Additional constituents may have included residues from other boiler water treatment chemicals. Waste water disposed to the ditch is expected to have percolated into the vadose along the ditch on its way to ultimate discharge in A-Swamp from 1945 to 1953 (Section 2.1.2.3 in DOE/RL-2015-49).

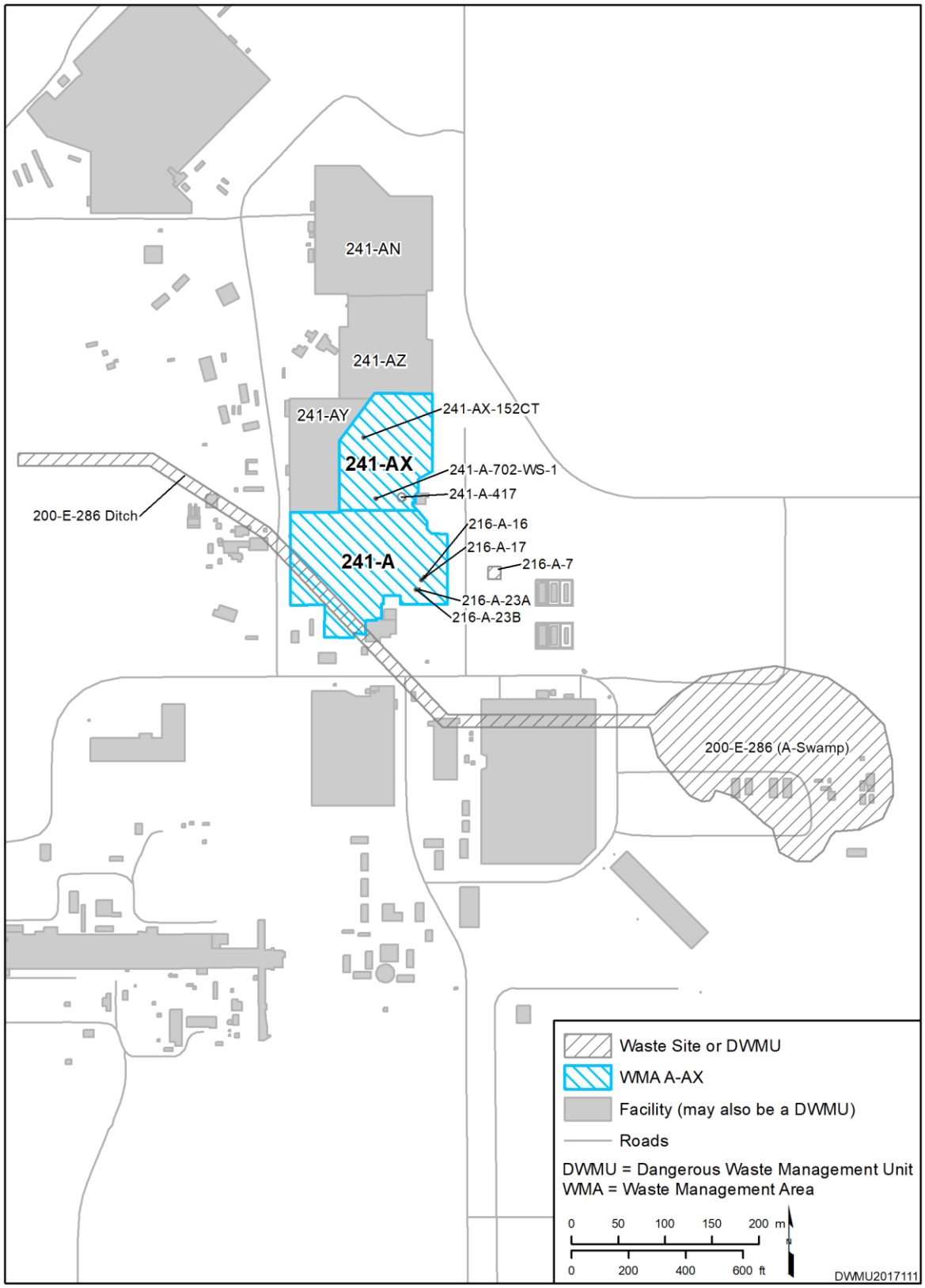

Figure 4-1. Location Map Showing Historic Location of the 200-E-286 Ditch and Swamp

Corrosion of the casings within the vadose zone of three wells at the WMA A-AX well network (299-E24-19, 299-E25-46, and 299-E25-236) has been documented. Metals indicative of presence of stainless steel corrosion (i.e., iron, nickel, chromium, and manganese in concentration ratios consistent with their distribution in stainless steel) were observed in wells that were subsequently confirmed by visual inspection to exhibit casing corrosion (Section 2.1.2 in DOE/RL-2015-49). The exact cause of soil conditions producing corrosion casing failures in this area has not been defined, although the potential for corrosion by chloride residues in vadose soil, at or just above the depth of the CCU_z, remains a likely candidate. The first two wells to show the effects of this corrosion, 299-E24-19 and 299-E25-46, were decommissioned in 2004 after corrosion was confirmed by a borehole video survey (Section 2.11.3.3 in PNNL-15070). Both these wells suffered extensive casing corrosion at the level of the CCU_z determined to have high moisture content. The groundwater at both well locations displayed high levels of dissolved stainless-steel corrosion constituents: chromium, nickel, and manganese (Section 2.11.3.3 in PNNL-15070).

In November 2012, a borehole video survey completed within well 299-E25-236 also revealed accelerated corrosion (Section 2.5.2 in DOE/RL-2015-49). The corrosion was identified between 80.2 and 81.4 m (263 and 267 ft) bgs, which corresponds to the depth of CCU_z. Black staining from the corroded casing extended downward approximately 8.5 to 9.8 m (28 to 32 ft) to groundwater at 89.9 m (295 ft) bgs. The surface of the groundwater inside the well was covered with various particles. Groundwater samples from 2011 and 2012 at well 299-E25-236 revealed elevated levels of chromium, iron, manganese, and nickel. Well 299-E25-236 was decommissioned in June 2013 due to confirmed casing corrosion, and replaced by well 299-E25-237 in January 2015.

Well 299-E25-41 exhibited a black residue in the bottom of the screen at about 83.8 m (275 ft) bgs on a video survey conducted in August 2017. The water level in the well at the time was at 823 m (270 ft) bgs. The perceived corrosion was not extensive, but its presence correlates with high nickel, sulfate, and chloride concentrations at its location. The water table at this location is within the CCU_z currently but was higher within the overlying Hanford formation in the past. The well was planned for replacement in 2018, but planned activities in the immediate vicinity of the well's location are prohibitive for placement of a drill rig over the site. Well cleaning has been scheduled for 299-E25-41 in an attempt to improve water quality in the well for monitoring until the well can be replaced.

4.4.2 Groundwater Chemistry

Elevated nitrate concentrations exceeding the 45 mg/L DWS occur in the groundwater near the southwest and southeast corners of WMA A-AX, as observed in wells 299-E24-20 and 299-E25-93 over the last decade (Figure 4-2). The nitrate observed in groundwater in the vicinity of WMA A-AX may derive from multiple sources; a broad plume of nitrate has been described extending from the vicinity of WMA B-BX-BY southeast to WMA A-AX and beyond (Figure 4-3). The time series of nitrate concentration observed in wells 299-E24-20 and 299-E24-93 suggest the possibility of groundwater impacts from releases local to WMA A-AX.

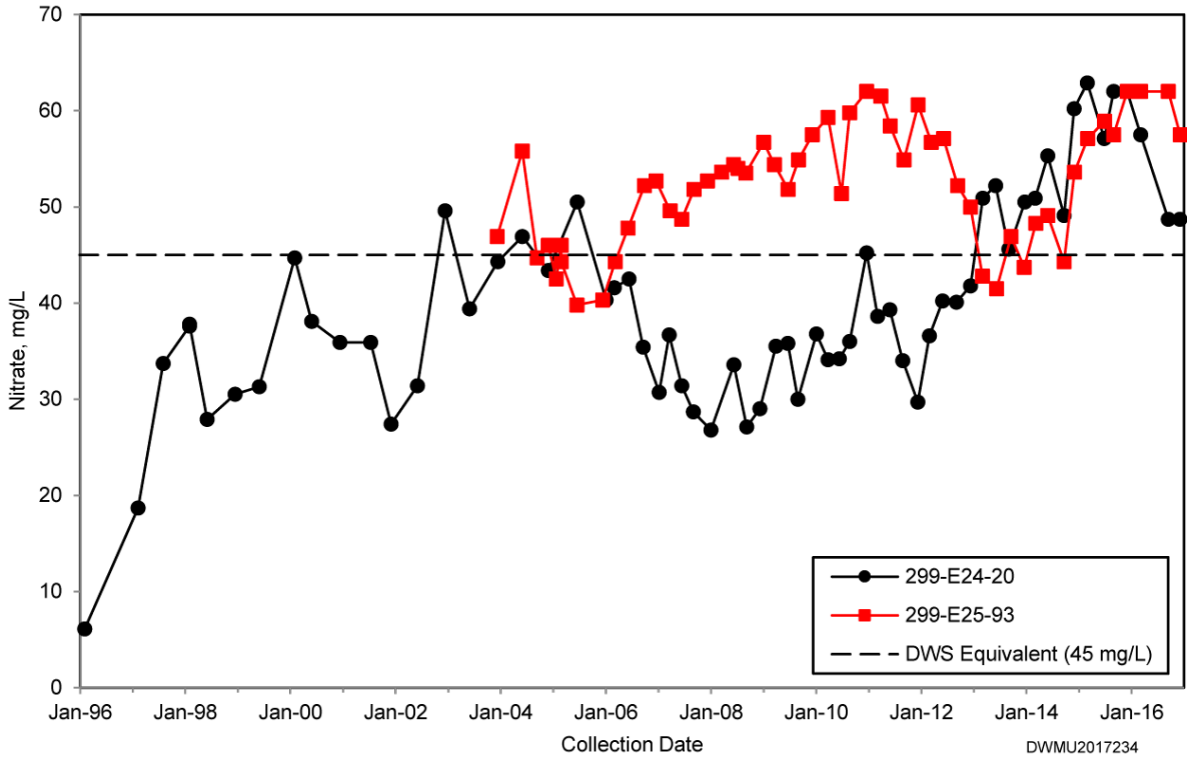

Figure 4-2. Concentration Trending Associated with Nitrate Plumes at WMA A-AX

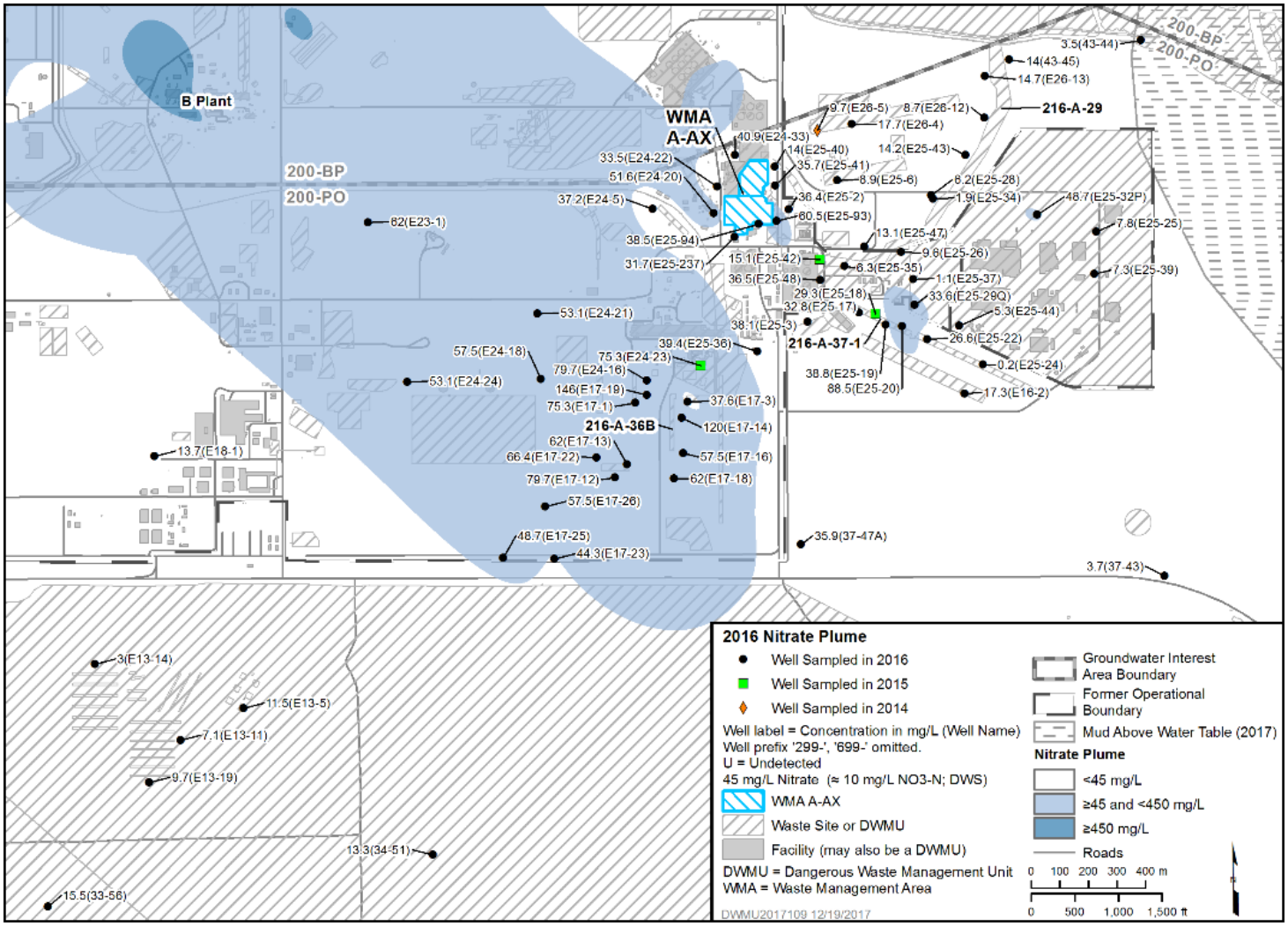

Figure 4-3. Nitrate Plumes at WMA A-AX and Surrounding Area in 2016

In 2015, a revised assessment plan (DOE/RL-2015-49) was drafted and implemented in 2016. The new plan is a continuation of the first determination process of the previous plan (PNNL-15315) and includes a comprehensive list of dangerous waste constituents for assessment. Completion of the first determination process will document whether any dangerous waste constituents related to a release(s) from WMA A-AX are impacting the groundwater chemistry.

Groundwater direction in the 200 East Area exhibited a reversal, from northwesterly flow to southeasterly flow in 2011; this change was first described by shifts in plume orientation observed in the 200-BP-5 OU in the vicinity of WM B-BX-BY (Section 3.4 in DOE/RL-2011-118, *Hanford Site Groundwater Monitoring for 2011*). The observed south-southeast flow direction into, and out of, the 200-PO-1 OU has remained consistent to date suggesting a probable return to prior flow conditions (Section 3.4 in DOE/RL-2011-118). The flow reversal carried additional contaminants from source areas in the 200-BP-5 OU to the monitoring areas in the southeast, including WMA A-AX. The arrival of this additional water mass at WMA A-AX is suggested by increasing trends in TDS in groundwater (as indicated by measurement of specific conductance) and selected ion concentrations (e.g., sulfate) observed in wells located on both up and downgradient sides of WMA A-AX.

As shown in Figures 4-4 and 4-5, concentration time series for groundwater specific conductance and sulfate (respectively) in upgradient well 299-E24-33 and downgradient wells 299-E25-41 and 299-E25-93 indicated increasing and parallel trends. These trends indicate that upgradient water is likely moving beneath WMA A-AX and the effects are being expressed as increases in specific conductance and sulfate.

Figure 4-6 illustrates the groundwater nitrate concentration time series for these same three wells. Nitrate has been consistently higher in downgradient well 299-E25-93, suggesting that the condition in that well may not be directly related to the regional plume migration indicated by the other two wells.

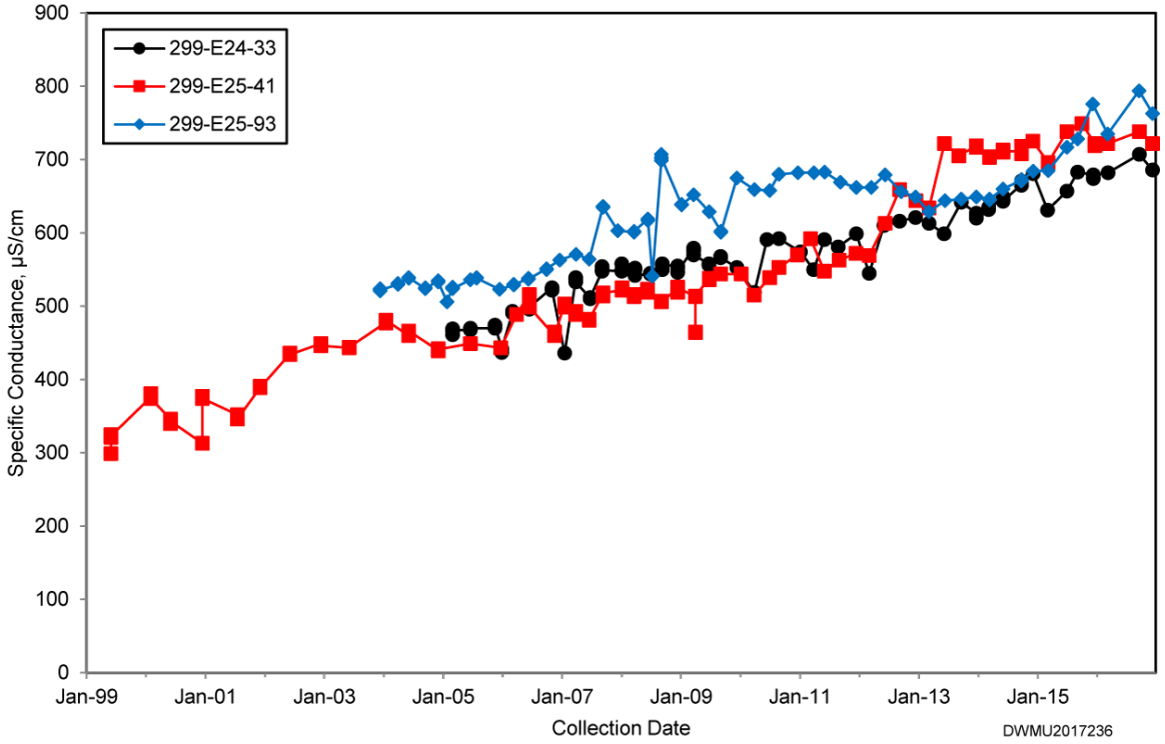

Figure 4-4. Time Series of Groundwater Specific Conductance in WMA A-AX Upgradient Well 299-E24-33 and Downgradient Wells 299-E25-41 and 299-E25-93

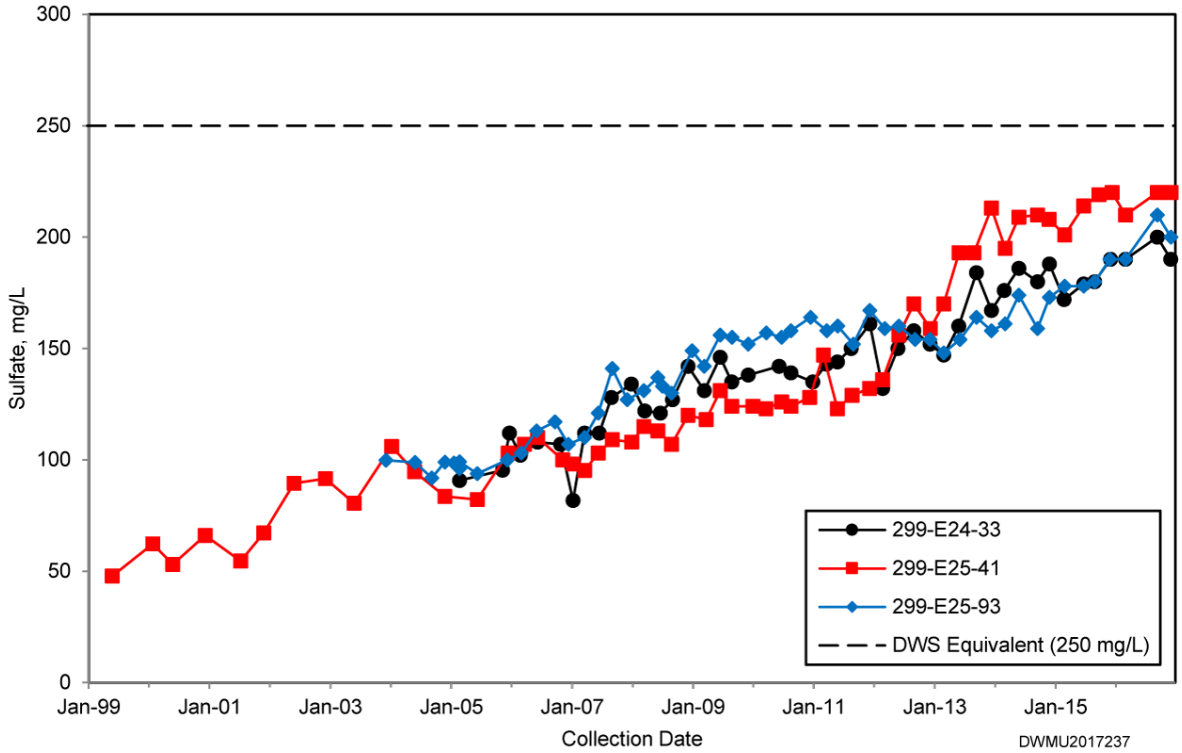

Figure 4-5. Time Series of Groundwater Sulfate Concentration in WMA A-AX Upgradient Well 299-E24-33 and Downgradient Wells 299-E25-41 and 299-E25-93

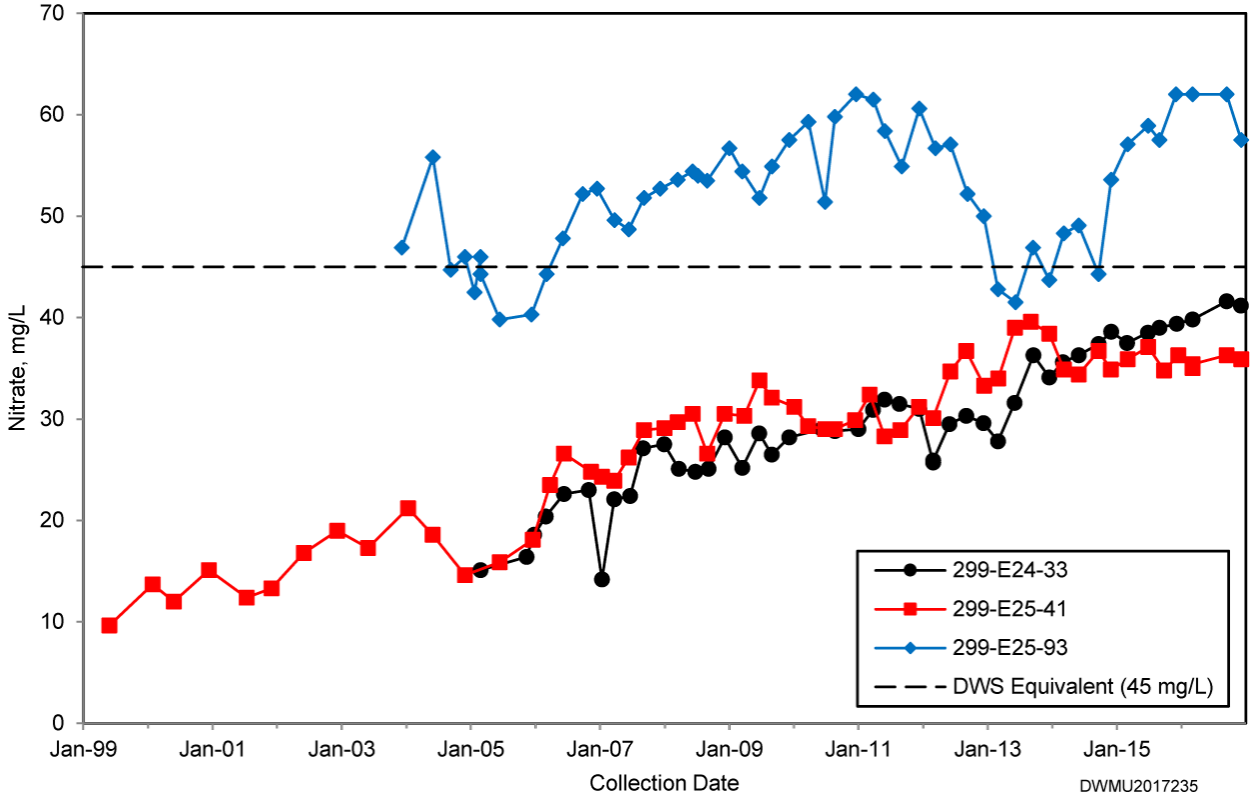

Figure 4-6. Time Series of Groundwater Nitrate Concentration in WMA A-AX Upgradient Well 299-E24-33 and Downgradient Wells 299-E25-41 and 299-E25-93

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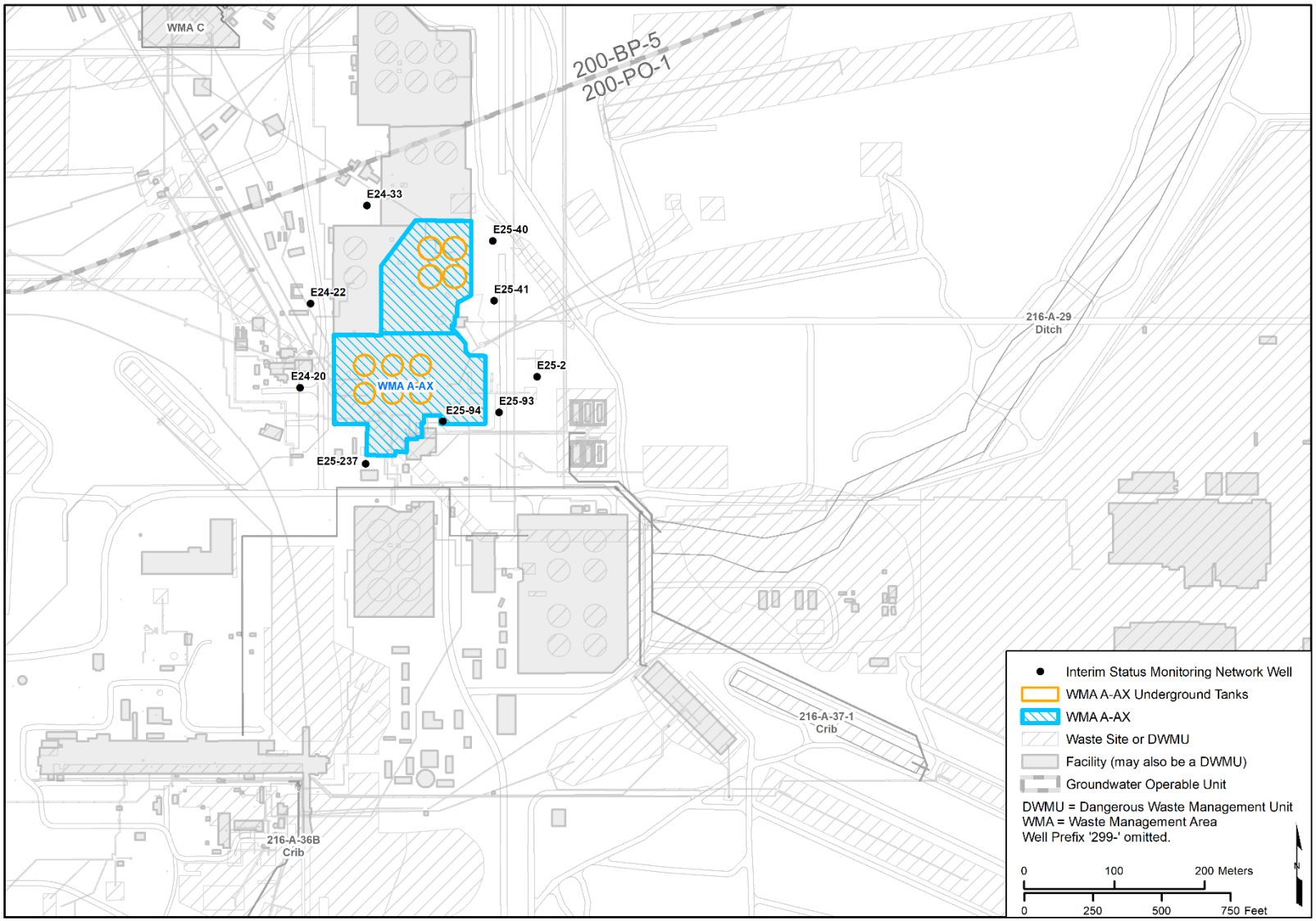
5 Calculation Methods

A systematic series of calculations was performed to evaluate whether the interim status groundwater monitoring wells for WMA A-AX (Figure 5-1) likely would detect increases in concentrations of contaminants in groundwater arising from potential releases from WMA A-AX that reach the underlying water table. The calculations were focused on evaluating potential future releases, rather than addressing the effects of pre-existing contamination. The calculations involve three major steps: groundwater elevation analysis based on discrete measured groundwater levels, estimation of horizontal contaminant migration potential using particle tracking, and estimation of vertical contaminant migration potential. The methods selected to accomplish these steps, and their merits relative to other considered methods, are discussed in this chapter.

The interim status monitoring network for WMA A-AX that was evaluated is described in Table 3-1 of DOE/RL-2016-66. The network (Figure 5-1) consists of three upgradient wells (299-E24-20, 299-E24-22, and 299-E24-33) and six downgradient wells (299-E25-2, 299-E25-40, 299-E25-41, 299-E25-93, 299-E25-94, and 299-E25-237).

5.1 Groundwater Elevation Evaluation Method Selection

To meet the objectives of this engineering evaluation, the method used to obtain groundwater elevation maps is a regularized inverse interpolation technique that is referred to as the Tikhonov Regularized Inverse Method (TRIM). TRIM is founded upon a formal mathematical method that seeks a trade-off between the complexity of the method or model that is used to interpret measured data versus the “fit” to those measured data that the chosen method or model attains. TRIM was implemented by combining the model calibration software PEST (Doherty, 2015, *Calibration and Uncertainty Analysis for Complex Environmental Models, PEST: complete theory and what it means for modelling the real world*) together with a simplified two-dimensional model of groundwater flow, constructed using MODFLOW-USG (Panday et al., 2013, *MODFLOW-USG Version 1: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation*). Prior to implementing this method, a review was conducted of potential alternative computational methods. This review is summarized below.



Source: Table 3-1 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*.

Figure 5-1. Interim Status Groundwater Monitoring Network

Two three-dimensional groundwater models were previously developed that together cover large areas of the Central Plateau, including either all or large parts of both the 200 West Area and the 200 East Area. These are the Central Plateau Groundwater Model (CPGWM) (CP-47631, *Model Package Report: Central Plateau Groundwater Model, Version 8.4.5*) and the Plateau to River (P2R) Model (CP-57037, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*). The CPGWM was developed primarily to support decisions made regarding groundwater remedies for the 200-ZP-1 and adjacent 200-UP-1 OUs located in the 200 West Area. The CPGWM is the principal computational tool used to design and evaluate the performance of those groundwater remedies. The P2R Model, which encompasses the entire 200 East Area and large parts of the 200 West Area, was developed primarily to support assessments of contaminant fate and transport and decisions made for the 200 East Area under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). Both the CPGWM and the P2R Model were considered for use in supporting the 200 East Area engineering studies and reports, in a manner analogous to that in which the CPGWM was used for the 200 West Area. Ultimately, neither the CPGWM nor the P2R Model was employed for purposes of this monitoring network evaluation in the 200 East Area. The primary shortcomings of these models for the purpose set forth in this assessment are as follows:

- The CPGWM was used in the analysis of the 200 West Area facilities because a predictive model was required to analyze how alternative potential operations of the 200 West Area regional pump and treat system would impact the rates and directions of groundwater flow and contaminant direction in that area. Unlike the 200 West Area, however, the 200 East Area has no region-wide pump and treat system or other groundwater remedy that will affect the rates and directions of groundwater flow and contaminant migration at such a scale.

- The P2R Model was developed at a scale and using a spatial discretization that is relevant to regional (i.e., far-field) rather than facility-specific (i.e., near-field) analyses. Facility-specific analyses that have previously been performed on the basis of the P2R Model were undertaken by developing local-scale models from the P2R Model based upon telescopic mesh refinement.

- The analysis of monitoring networks in the 200 East Area focuses on the uncertainty that arises from the relatively low hydraulic gradients throughout the area. While the existing models function on a regional scale in the 200 East Area, on a facility-specific scale, in some parts of the 200 East Area, the CPGWM and P2R Model do not always reflect the near-field understanding of groundwater flow conditions based on multiple lines of evidence, including the low-gradient network and independent evaluations of existing contaminant extents and migration.

- Some 200 East Area facilities are in areas where the underlying “first water” (i.e., the water table) that a release would encounter either resides within basalt or is perched on mud units, which are conditions that the CPGWM and P2R Model were not developed to simulate.

TRIM provides a formalized method developed specifically for purposes of the monitoring network evaluation. TRIM was developed specifically to produce piece-wise continuous (gridded) depictions of groundwater elevations encompassing the 200 East Area facilities for the calendar years 2013, 2014, 2015, and 2016 (the four most comprehensive datasets available at the time the calculations were performed). Four years of data were evaluated because different datasets can produce differences in the interpretation of groundwater elevations and corresponding flow and potential migration directions. The groundwater elevation maps portray general patterns of hydraulic gradients and groundwater flow and in doing so depict likely directions of contaminant migration from a facility should a release reach the underlying water table.

5.2 Vertical Migration

Methods described by the American Petroleum Institute (API) (Nichols and Roth, 2006, "Downward Solute Plume Migration: Assessment, Significance, and Implications for Characterization and Monitoring of "Diving Plumes""), referred to as the "API calculator," were used to verify the appropriateness of the depths of the well screens for monitoring wells and ensure that vertical migration would not cause contaminant plumes to travel undetected beneath the downgradient monitoring well screens. The API calculator estimates the slope of the migration pathway along which dissolved constituents are anticipated to migrate based on the ratio of the specific discharge rate and the groundwater recharge rate.

5.3 Particle Tracking

The groundwater elevation maps depict general patterns of hydraulic gradients and groundwater flow, identifying likely directions of contaminant migration from a facility in case a release reaches the water table. Particle tracking provides a way to visualize the directions and potential paths of contaminant migration, enabling a more detailed assessment of a monitoring well network. Particle tracking was performed using the particle-tracking code mod-PATH3DU (Muffels et al., 2018, *User's Guide for mod-PATH3DU, A Groundwater Path and Travel-Time Simulator*).

For the regional-scale analysis, particle tracking was performed first considering only advective migration and subsequently considering both advective and dispersive migration mechanisms. The results of the regional particle-tracking analysis are presented in Chapter 7 of ECF-200E-18-0066.

For the facility-specific analysis presented in Appendix J of ECF-200E-18-0066, particle-tracking calculations assuming advective and dispersive migration were performed using a release of a large number of particles from WMA A-AX. Parameters used to calculate particle pathlines assume migration of a conservative (i.e., nonreactive) dissolved contaminant under representative conditions. The particle-tracking calculations produced outputs specific to WMA A-AX, including particle pathlines and particle count maps and time-series plots.

5.3.1 Particle Pathlines

Calculated particle pathlines illustrate how a hypothetical release to the water table from the facility would move and spread under conditions represented by each of the four mapped years (2013, 2014, 2015, and 2016). The facility-specific particle-tracking calculations and outputs are based upon the one-time, instantaneous release of a large number of particles at the water table. This approach produces many pathlines, each of which depicts the hypothetical path of a particle of dissolved contaminant that reaches the water table beneath the facility. Because vadose zone travel time is not explicitly considered, the year of the hypothetical particle release is also the year that contamination reaches the water table. The particle paths were post-processed to provide additional depictions and calculations, including particle counts at well locations and contour maps of particle density (particle count maps).

5.3.2 Particle Counts

Calculated particle counts serve as a surrogate for contaminant concentration to evaluate the relative efficacy of the interim status groundwater monitoring wells and the need for and suitability of any proposed new monitoring wells. Particle counts and relative arrival times at well locations were calculated by counting the number of particles that pass through the vicinity of an existing or potential monitoring well location and recording the time of arrival of each such particle. A radius of 10 m (33 ft) around each monitoring well location was used to count particles as they arrived. These calculations produce three outputs that can help evaluate the groundwater monitoring well network:

- A tabulation of particle density (counts) for each interim status groundwater monitoring well and each potential new monitoring well. This count is the total number of particles that pass through the vicinity of the well, regardless of time.
- For each well location, a time-series plot of the likely arrival, peak, and decline in the (relative) concentration of particles resulting from an instantaneous release from WMA A-AX. This plot is prepared by summing the particles within a small number of arrival-time bins in the manner used to construct a histogram.
- For each facility for each year, a particle count map that depict areas of relatively higher and lower potential impact from a release that reaches the water table. Contour maps of particle counts were generated by counting the number of particles that pass through a pre-defined uniform particle calculation grid. The particle calculation grid, which is specific to each facility, is oriented parallel to the predominant groundwater flow direction. The particle calculation grid for WMA A-AX is shown in Figure 5-2. (Note: The particle calculation grid is used only to process and summarize outputs from the particle tracking, not to undertake the particle tracking.)

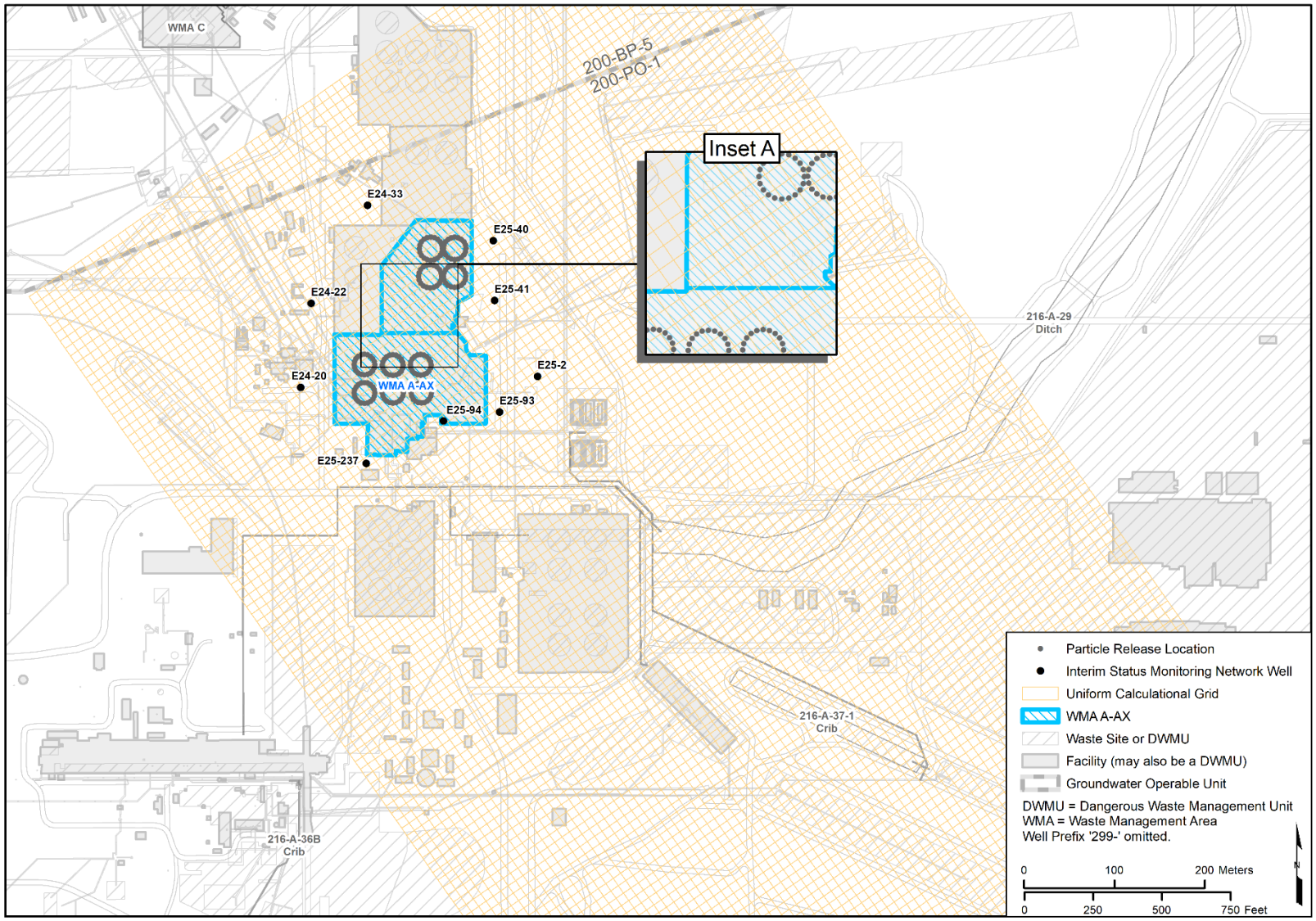


Figure 5-2. Particle Release Locations and Uniform Calculational Grid at WMA A-AX

6 Calculations

The assumptions, inputs, and calculation steps used to perform groundwater elevation mapping and particle tracking for WMA A-AX are discussed in this chapter. Additional details on the facility-specific calculations are included in Appendix J of ECF-200E-18-0066.

6.1 Assumptions and Inputs for Groundwater Elevation Analysis

The primary inputs required to generate the piece-wise continuous grids of groundwater elevations are the yearly average measured groundwater levels for calendar years 2013, 2014, 2015, and 2016. Measurements for wells within the low-gradient evaluation network were prioritized in this effort, supplemented with water-level measurements from wells outside the low-gradient monitoring network. Because of the difference in accuracy of the water-level measurements obtained from the monitoring wells, relative "weights" were assigned to each monitoring well, which influence how closely TRIM fits each well's measurements.

As described in ECF-200E-18-0066, groundwater elevation contour maps were constructed using the TRIM method, which combines the use of a simplified model of groundwater flow together with the use of Tikhonov regularization. The resulting groundwater elevation contour maps provide plausible interpretations of groundwater levels and hydraulic gradients between measured locations that match measured water levels and monitoring wells to a degree that is consistent with the trade-off between the fit with measured data and model complexity. The resulting interpretations achieve flow conservation through the use of the underlying groundwater model as the interpolation mechanism between measurement locations and achieve the fit to the measured groundwater elevations through the use of the Tikhonov regularization. The accuracy of the resulting contours is, however, influenced by several factors, including the following:

- The accuracy of the measured or recorded water levels
- The number, distribution, and location of monitoring wells
- The relationship between the vertical open interval(s) of the monitoring wells and those of any extraction or injection wells, where present

These potential sources of error mean that the maps only approximate actual conditions. The water-level and particle pathline maps are considered reasonable approximations that provide value and utility in the interpretation of likely directions and rates of groundwater movement. The maps also help identify areas downgradient of the 200 East Area facilities that likely would be impacted by a potential release that reaches the underlying water table. Considering multiple groundwater elevation events (i.e., in this case, multiple years) in the analysis helps to develop a reasonable estimate of potential migration pathways under the different conditions represented by those events.

Part of simplifying the model used in this analysis involved discretizing the hydraulic conductivity of the sediments within which the water table resides into three hydrostratigraphic unit (HSU) zones, representing the Hanford formation, Cold Creek unit, and Ringold Formation Unit E. Delineation of the HSU zones was prepared by intersecting the CPGWM water table grid with the three-dimensional geological model (ECF-Hanford-13-0029, Rev. 1). Within each of these delineated HSU zones, the hydraulic conductivity was defined as homogeneous for purposes of defining initial parameter values.

6.2 Particle-Tracking Assumptions and Input

The inputs to the particle-tracking calculations are composed of a shapefile with the starting locations of particles, the piece-wise continuous grids of water-level elevations obtained from the TRIM analysis, and the migration parameter values.

Particle-tracking calculations specific to WMA A-AX were performed to represent one-time releases to the water table that occur simultaneously from the 10 SSTs in WMA A-AX. The particle releases represent a hypothetical instantaneous release from WMA A-AX that reaches the water table. This release scenario does not incorporate any aspects of transport through the overlying vadose zone. After particles enter the groundwater, particle movement is predominantly horizontal, with minor components of vertical migration in response to limited infiltration from groundwater recharge and the operation of any nearby extraction wells (if present). The monitoring wells were assumed to be screened across the water table so that samples collected from them reflect the quality of water at or close to the water table. Because particle tracking relies on the outputs (mapped groundwater elevations) computed using TRIM, the assumptions and limitations that underlie the preparation of those maps using TRIM are implicit in any subsequent particle tracking.

6.2.1 Particle Starting Locations

The starting locations for particle-tracking calculations represent the area over which a potential release from a given facility likely would impact the underlying water table, assuming vertical transport through the vadose zone. Particle releases were located at plausible release sites within each facility. For the analysis performed for WMA A-AX, release locations were established from the circumference of the 10 SSTs in WMA A-AX (Figure 5-2). Twenty particles were released and tracked from each release location to provide the density of particles in space and time required for performing detailed facility-specific calculations, randomizing the seed values for the dispersion calculations. For WMA A-AX, 4,000 particles were released and tracked in the simulations performed for each of the four events (years).

6.2.2 Migration Parameters

Only a small number of parameters is required to perform the migration calculations using the groundwater elevation maps and particle-tracking methods developed here. The parameters used to represent dissolved contaminant migration are considered representative of local conditions for a conservative (i.e., nonreactive) solute dissolved within groundwater.

Particle tracking that considers advection and dispersion relies upon the assumption that the values of the dispersion coefficients in the two principal directions (longitudinal and transverse) are representative of physical processes that act to disperse dissolved constituents in groundwater at the scale of the calculations. The values of the dispersivity parameters used in this evaluation were those used for this area within the CPGWM (CP-47631). Those values, as described in ECF-200E-18-0066, were as follows:

- Longitudinal dispersivity: 3.5 m (11.5 ft)
- Transverse dispersivity: 0.7 m (2.3 ft)

The local-scale parameters of mobile (effective) porosity and hydraulic conductivity are defined specific to each 200 East Area facility. For WMA A-AX those parameters are as follows:

- Mobile porosity: As described in Appendix J of ECF-200E-18-0066, the value of 0.25 is used in this analysis.

- Hydraulic conductivity: As described in Appendix J of ECF-200E-18-0066, the CPGWM-calibrated value of 18,200 m/d (59,711 ft/d) is used in this analysis to determine the time for potential releases to reach the monitoring locations.

The primary purpose of the calculations was to estimate directions of potential contaminant migration in order to assess the efficacy of the geographical distribution of wells in the monitoring network. For the calculations performed for WMA A-AX, the values assigned to the hydraulic conductivity and mobile (effective) porosity do not directly affect the assessment of well locations. The values assigned to those parameters do, however, affect the calculations of relative arrival times at existing and potential monitoring well locations.

6.3 Calculation Steps

The following steps were taken to produce the results presented in this evaluation.

6.3.1 Groundwater Elevation Grids

To prepare the groundwater elevation grids, annual average values of the measured groundwater elevations obtained from the four most recent comprehensive monitoring datasets (obtained for 2013, 2014, 2015, and 2016) were obtained for each monitoring well. These water-level elevation data were used as the calibration targets for the analysis conducted using TRIM.

Values for the parameters of the simplified two-dimensional groundwater flow model underlying TRIM were iteratively updated using the Tikhonov regularization capabilities of the PEST (Doherty, 2015) program by obtaining successive improvements in the fit between the calculated and measured annual average groundwater levels for each year from 2013 through 2016, simultaneously. As described in Chapter 6 of ECF-200E-18-0066, this process occurred in two sub-steps:

1. First, an initial calibration was undertaken to produce a groundwater elevation map that approximated the measured groundwater levels but resulted in minimal deviation from the preferred system condition of homogeneity. This provided initial estimates for (a) the (relative) flow rates at each of the specified-flux boundaries, (b) the hydraulic head at the specified head boundary for each of the 4 years, and (c) the (relative) hydraulic conductivity in each of the three HSU zones.

2. Second, a series of iterations of Tikhonov regularized inversion was executed using PEST in regularization mode. During this step the effect that varying the model parameters to increase or decrease the fit to the measured data had on patterns of groundwater flow and hydraulic gradients was explored.

Next, the PEST program was executed using the Pareto mode incorporating the results obtained in Step 2. The purpose of this step of the analysis was to explore the trade-off between the measurement objective function (i.e., fit to the water-level data) and the regularization objective function (i.e., the correspondence with the preferred state of parameter smoothness) (Doherty, 2015). At the conclusion of the Pareto analysis, a global regularization weight parameter was selected that produced output that was considered representative of a reasonable correspondence between the calculated and measured groundwater elevations while also producing contours and hydraulic gradients that comport with the generally understood conditions at each of the 200 East Area facilities.

Using the output of the above model calibration, piece-wise continuous groundwater elevation grids for the entire 200 East Area were generated. Using these grids as the basis, the steps described below were implemented to perform the calculations and post-process the outputs to produce results specific to potential releases at WMA A-AX.

6.3.2 Particle Tracking

For the particle-tracking calculations, a file representing particle starting locations was prepared to use as input to the mod-PATH3DU program. Particles were released at the water table simultaneously from all particle starting locations to reflect a potential water table impact during each calendar year evaluated (2013, 2014, 2015, or 2016). Twenty particles were released and tracked from each particle starting location using a different random seed value for the dispersion calculations. The maximum tracking time was adjusted for each facility to allow enough time for the majority of the particles to pass by the locations of the monitoring wells.

Then mod-PATH3DU was executed to produce a pathline output file. A post-processing program was executed to convert the pathline output file into both shapefile and text file format, both of which list particle locations and times.

6.3.3 Particle Counts

Particle counts were calculated to create maps that illustrate the relative particle density downgradient of WMA A-AX from the simulated release at the facility and to produce time-series plots, or breakthrough curves.

To create particle count maps, a uniform particle calculational grid was defined having a 10 by 10 m (33 by 33 ft) cell size, large enough to envelop all pathlines generated during particle tracking (Figure 5-2). The grid is oriented parallel to the predominant direction of groundwater flow. Particles that pass through the grid are counted, enabling production of a contour map of particle counts for each grid cell. Using the particle calculational grid and the shapefile output from the particle tracking, for each of the four water-level mapping events, a count of unique pathlines intersecting each cell of the grid was determined to create a grid of pathline counts. Bilinear interpolation was used between cells of the pathline count grids to create particle count maps that depict the density of particles that passed through the mapped area.

In addition, breakthrough curves and particle count tables that show the relative arrival times of particles at each monitoring well location were generated. The particle pathlines were filtered to determine those that were first to pass within 10 m (33 ft) of each monitoring well. The corresponding tracking time for each particle was recorded. The total number of pathlines that passed within 10 m (33 ft) of a specific well within a stipulated time period was summed. The results were tabulated to produce the particle count tables and plotted as particle breakthrough curves.

7 Simulation Results and Conclusions

This chapter presents the results and conclusions from the facility-specific calculations. An analysis on a regional scale for the 200 East Area was first conducted to produce results that depict general patterns of hydraulic gradients, groundwater flow, and likely migration throughout the 200 East Area. The regional groundwater elevation maps produced using TRIM for calendar years 2013, 2014, 2015, and 2016 form the basis for the facility-specific calculations. The portions of those groundwater elevation maps in the vicinity of WMA A-AX are included in Section 7.1.

Based on the groundwater elevation maps, particle tracking was performed to simulate a hypothetical instantaneous release to the water table from all particle release locations within WMA A-AX. As described in Chapter 5, the outputs of particle-tracking calculations include the following:

- Maps of calculated particle pathlines for the flow conditions determined for each of the four simulated years (2013, 2014, 2015, and 2016)
- Time-series plots, referred to as particle breakthrough curves, of the relative arrival, peak, and decline in particle counts at each interim status groundwater monitoring well location and any proposed monitoring well location
- Tables of relative particle counts for each interim status groundwater monitoring well location and any proposed monitoring well location
- Maps of particle counts downgradient of WMA A-AX based on the flow conditions determined for each of the four years

The maps of particle pathlines are presented in Section 7.2; particle count maps and a summary of the particle count tables and breakthrough curves are provided in Section 7.3; and Section 7.4 presents the conclusions from this evaluation of the monitoring well network.

7.1 Groundwater Elevation Maps

Figures 7-1 through 7-4 show a portion of the 200 East Area regional groundwater elevation maps produced from the piece-wise continuous grids resulting from application of TRIM, focused on the area around WMA A-AX. These maps were produced using the outputs from TRIM for calendar years 2013 through 2016. The grids underlying these groundwater elevation maps were used as the basis for the subsequent particle-tracking calculations.

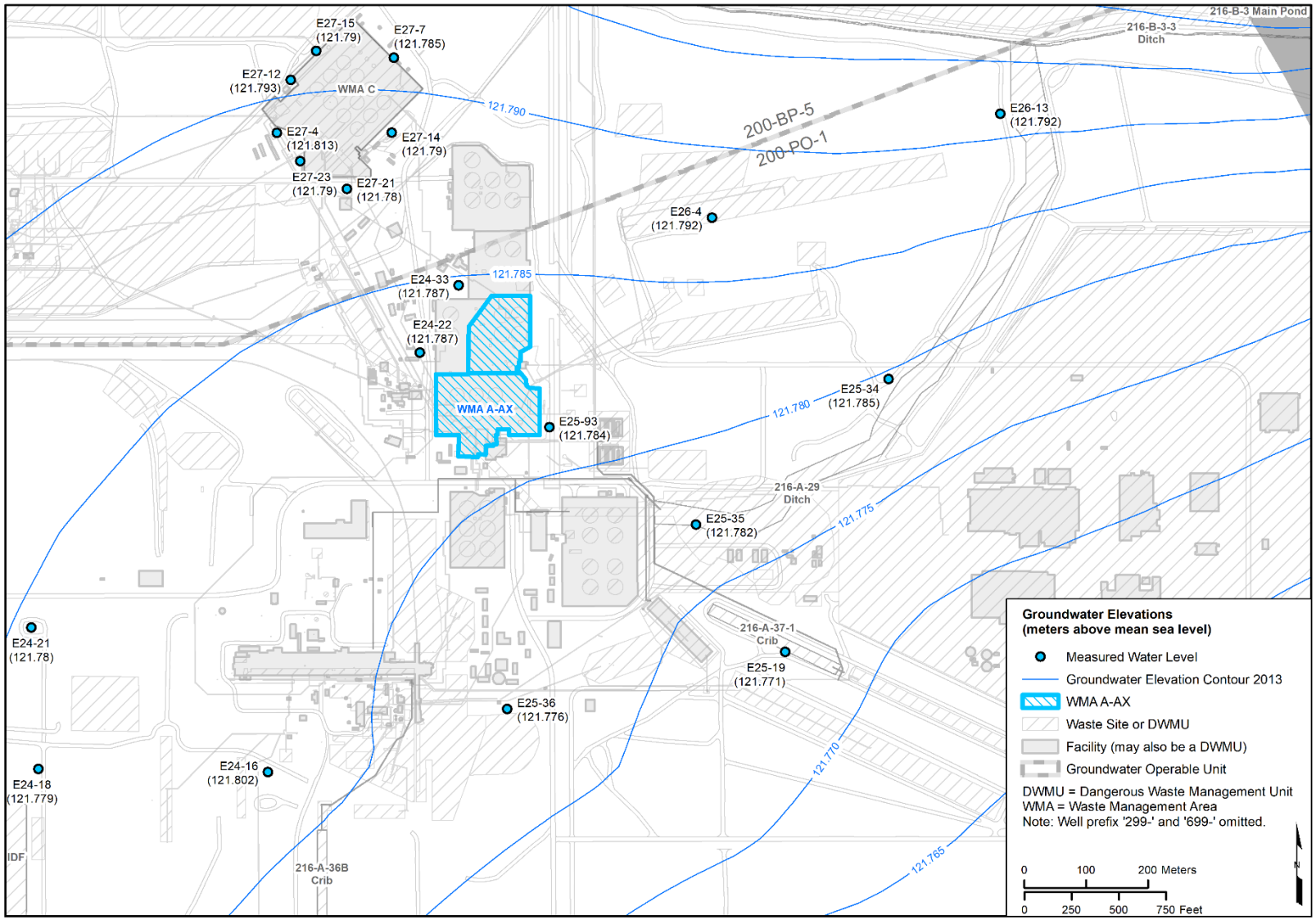


Figure 7-1. Groundwater Elevation Map for WMA A-AX, 2013

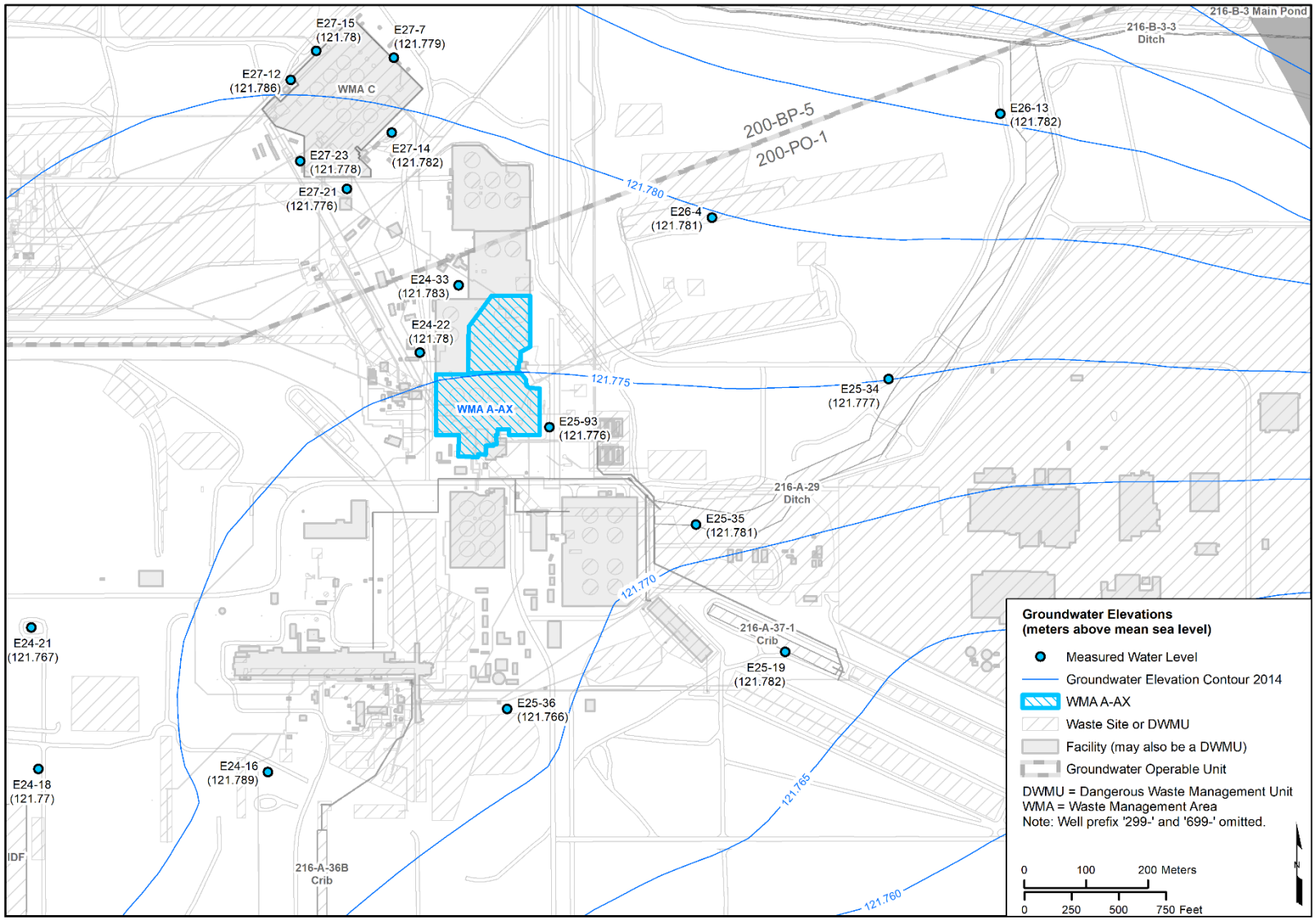


Figure 7-2. Groundwater Elevation Map for WMA A-AX, 2014

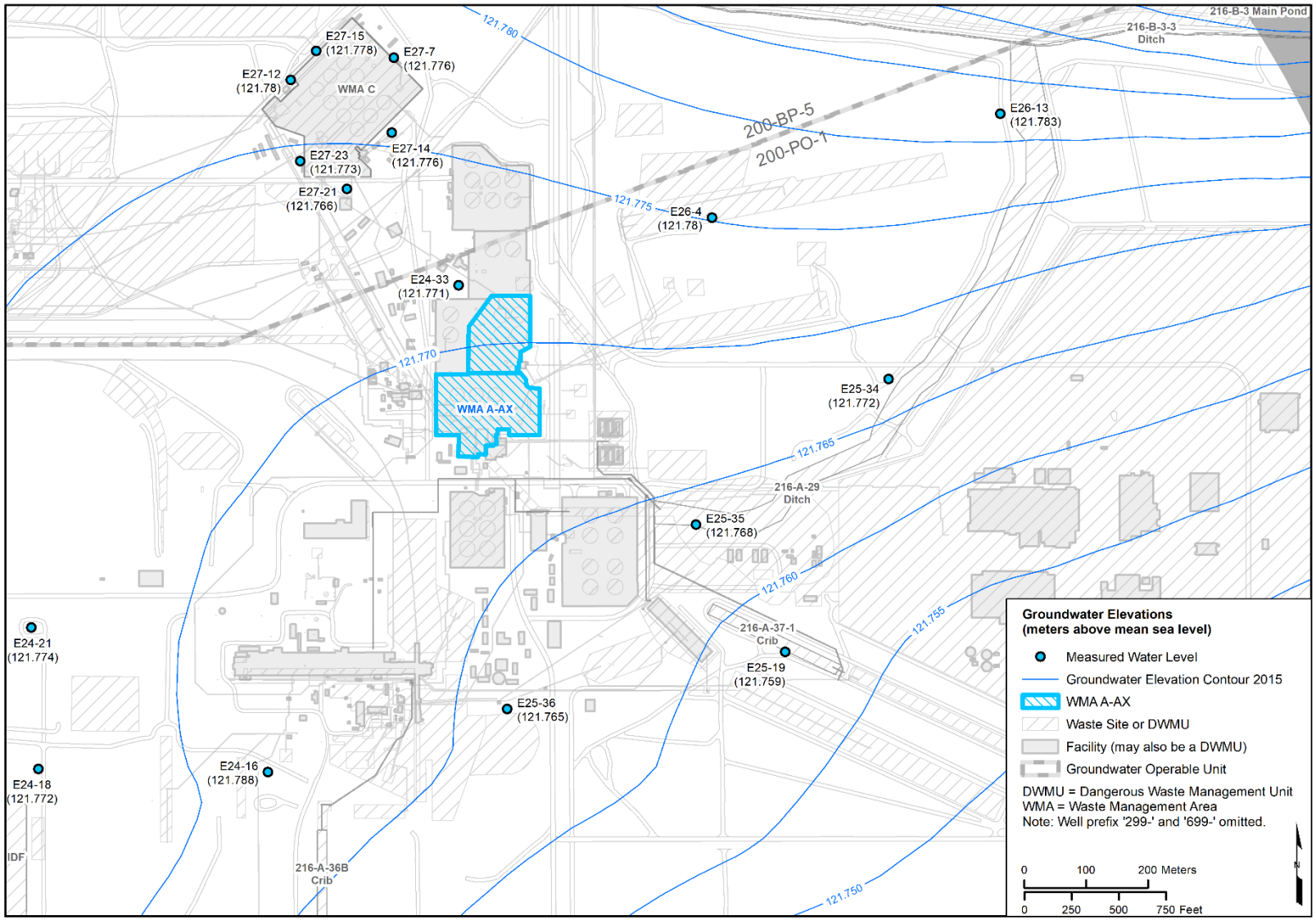


Figure 7-3. Groundwater Elevation Map for WMA A-AX, 2015

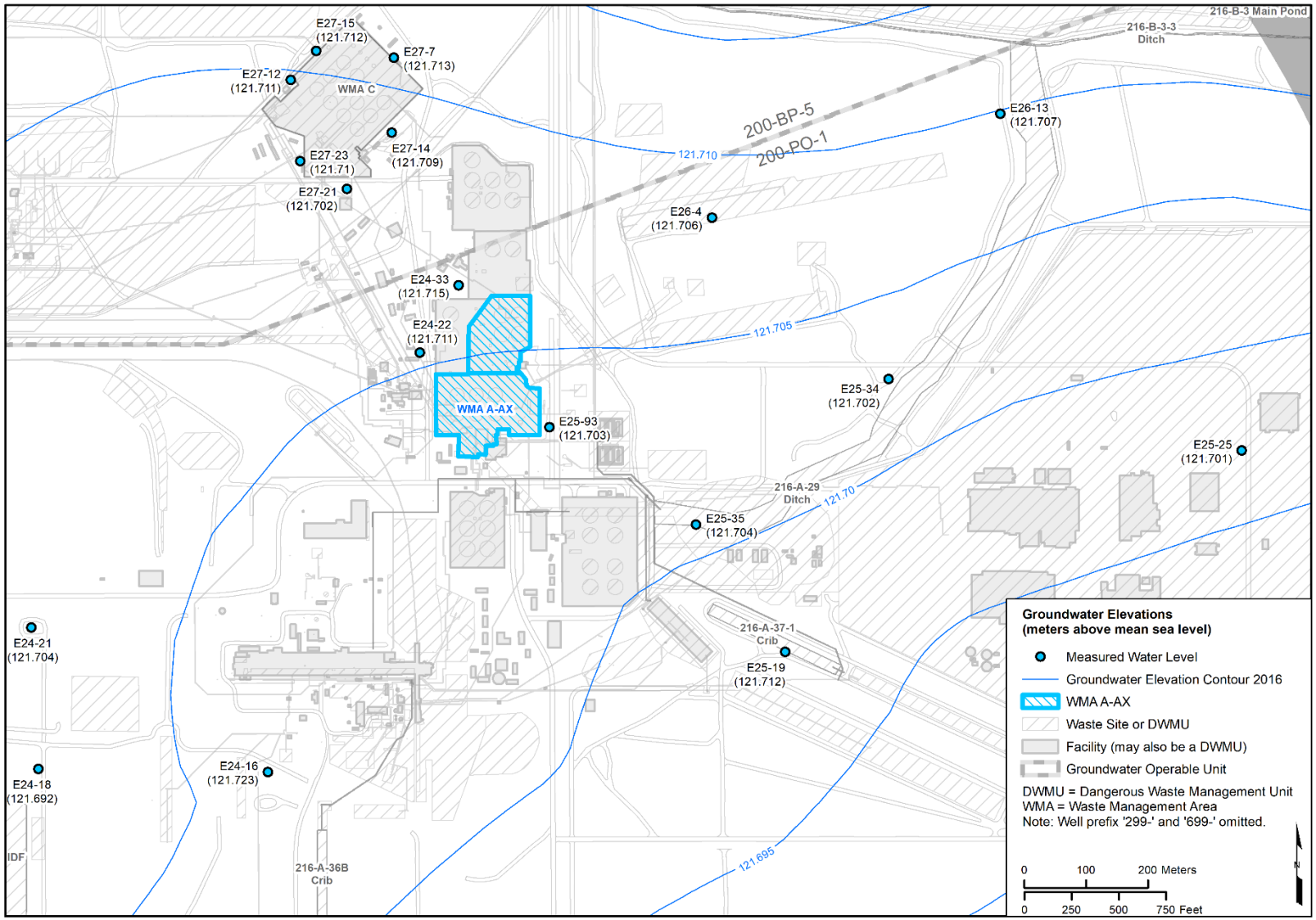


Figure 7-4. Groundwater Elevation Map for WMA A-AX, 2016

7.2 Particle Pathlines

Figures 7-5 through 7-8 depict the particle pathlines developed based on the groundwater elevation grids obtained from application of TRIM and given a release of a large number of particles at WMA A-AX. The calculations of particle pathlines accounted for both advection and dispersion, therefore depicting the patterns that the migration of contaminants might display for the groundwater conditions determined for calendar years 2013, 2014, 2015, and 2016. Figures 7-5 through 7-8 depict the particle paths calculated after 500 days of travel, by which time it was determined that all particles would have arrived at or passed by the interim status groundwater monitoring wells.

7.3 Particle Counts

The particle breakthrough curves and particle count tables prepared for downgradient monitoring wells are included in Appendix J of ECF-200E-18-0066. There are no tables or breakthrough curves for wells 299-E25-40 or 299-E25-2 in Appendix J because these wells do not intercept particles under the analyzed flow conditions. The total number of particles that passed within the vicinity of each well can be compared to evaluate which well locations received a higher particle density and therefore are more likely to detect concentrations of contaminants released from the facility given the full range of particle release locations. The relative time of arrival of particles at each well also can be compared.

After the total number of particles that passed each well location was calculated for each year (2013, 2014, 2015, and 2016), an average value was calculated for all 4 years:

- 299-E25-41 – Average = 27
- 299-E25-93 – Average = 183
- 299-E25-94 – Average = 1408
- 299-E25-237 – Average = 148

The average particle counts can be used to assess the relative potential for each well to detect a release from the facility. In this case, four of the six downgradient wells are located in areas of high potential for detecting releases from WMA A-AX and help provide coverage of the extent of particle pathlines.

Particle count maps identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable. Figures 7-9 through 7-12 depict the particle count maps developed based on releasing a large number of particles simultaneously from around the circumference of the 10 SSTs (release locations shown in Figure 5-2). Plausible release locations were placed around the circumference of the SSTs because the specific location where a release might occur cannot be predicted. Particle movement was analyzed considering both advection and dispersion for all the likely release locations, given the groundwater flow conditions estimated for calendar years 2013, 2014, 2015, and 2016. Figures 7-9 through 7-12 depict the particle density for the flow conditions estimated for the 4 years after 500 days of calculated travel, by which time it was determined that all particles would have arrived at or passed by the interim status groundwater monitoring wells.

The particle count maps show that the evaluated downgradient groundwater monitoring wells are well placed for detecting a release to the water table from WMA A-AX. Because the particle count maps show areas of high particle counts where there is no monitoring well, the addition of wells WMA_A-AX_PW-1 and WMA_A-AX_PW-2 is proposed.

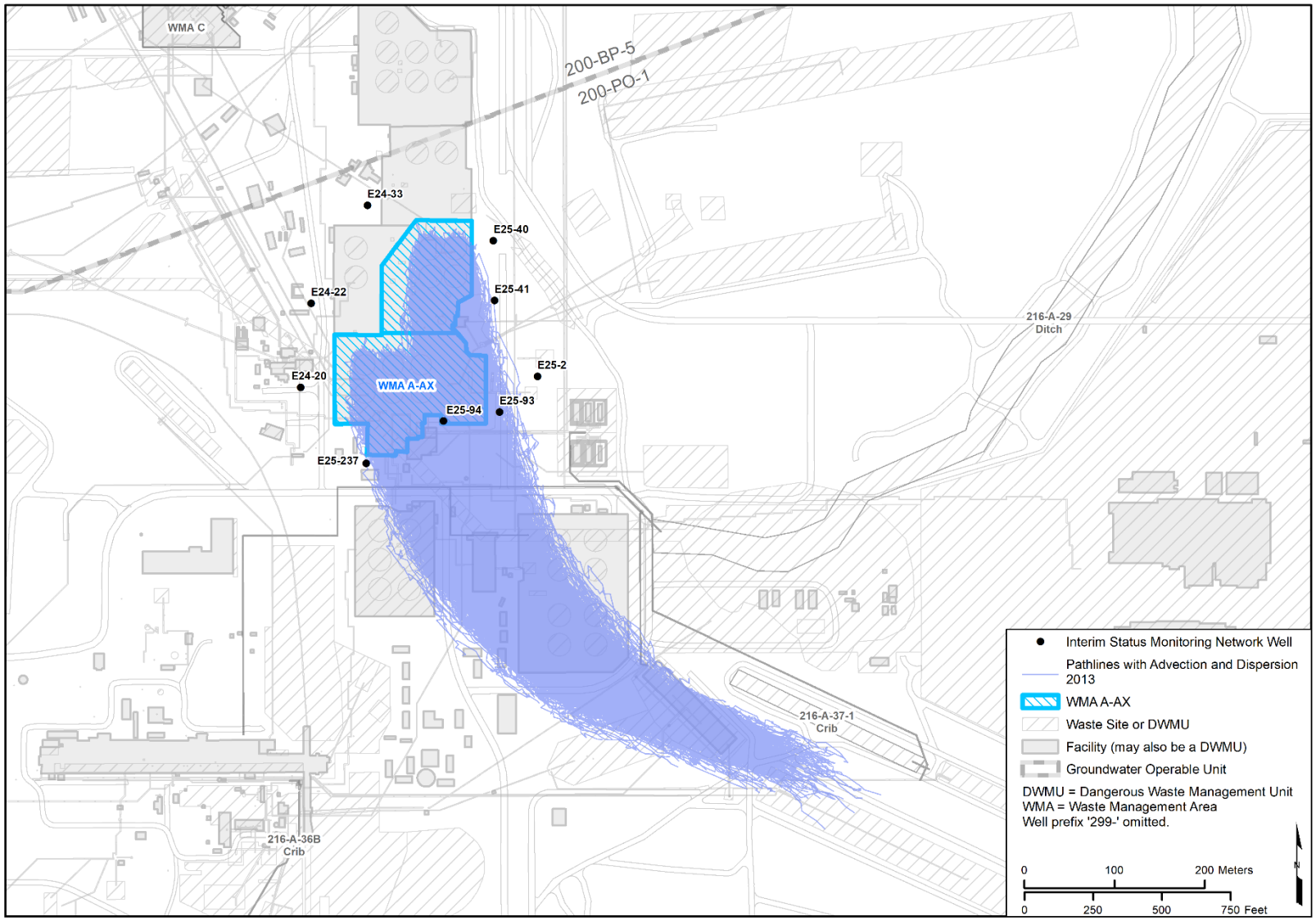


Figure 7-5. Local-Scale Particle Paths, Advection and Dispersion – WMA A-AX, 2013

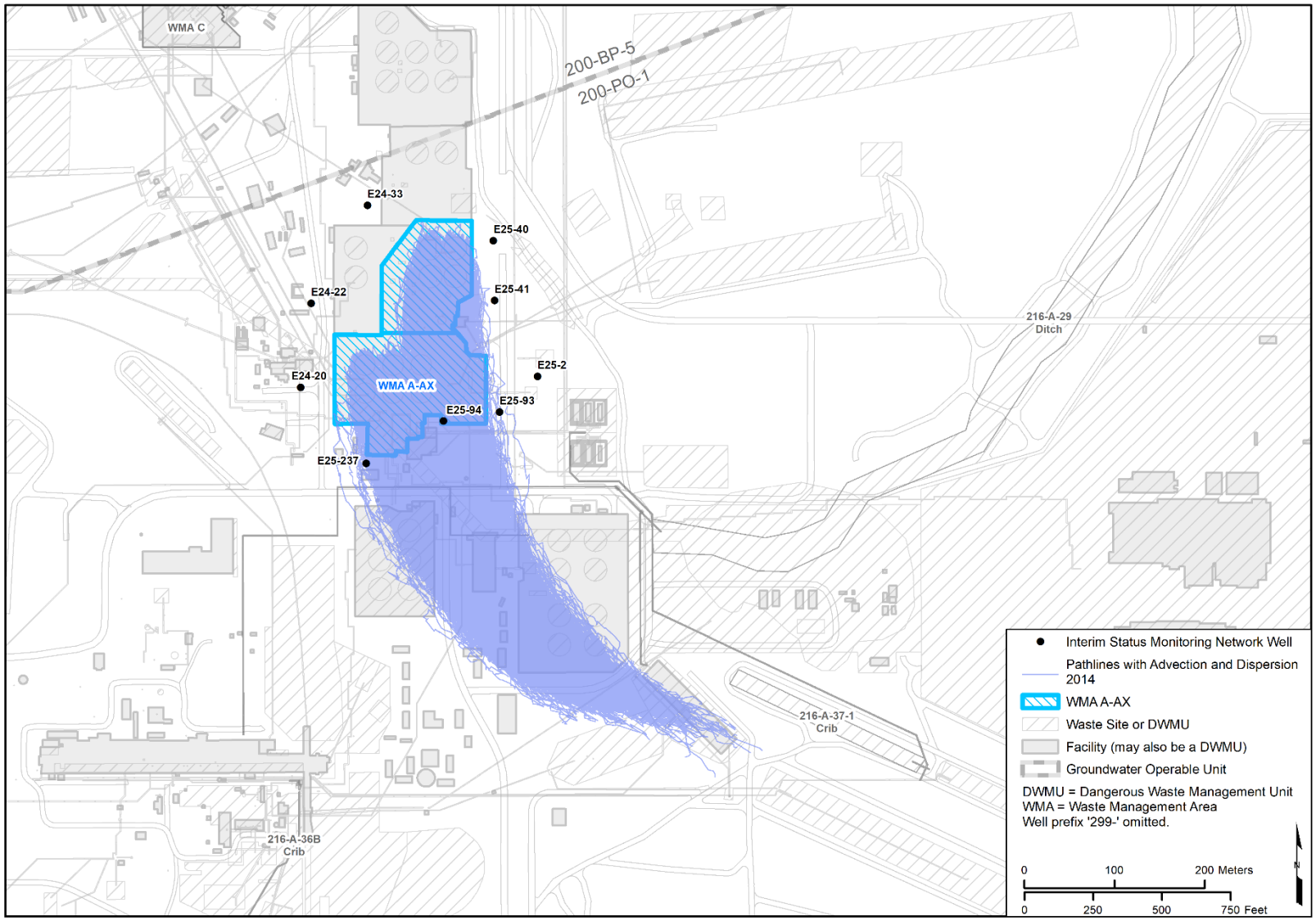


Figure 7-6. Local-Scale Particle Paths, Advection and Dispersion – WMA A-AX, 2014

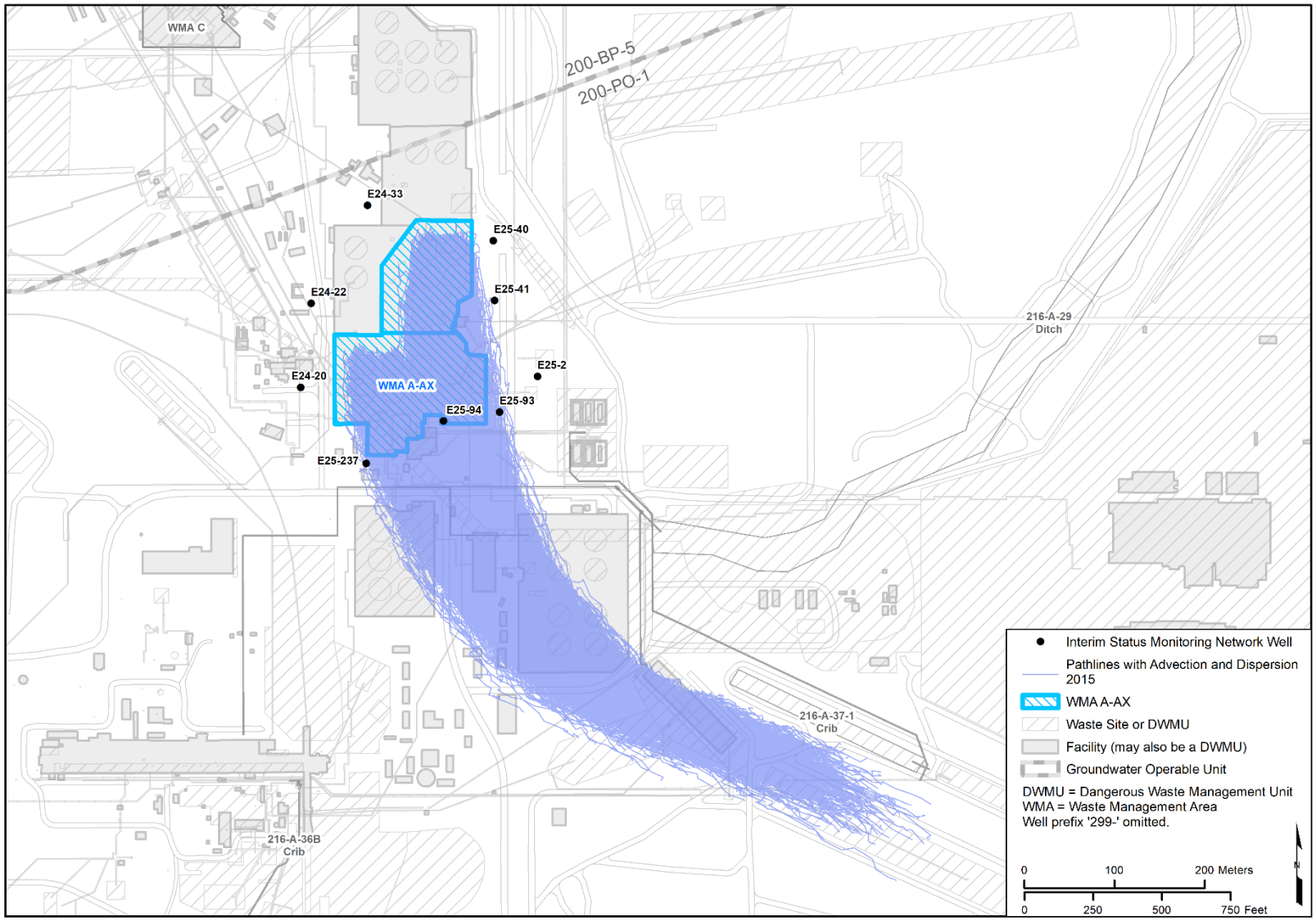


Figure 7-7. Local-Scale Particle Paths, Advection and Dispersion – WMA A-AX, 2015

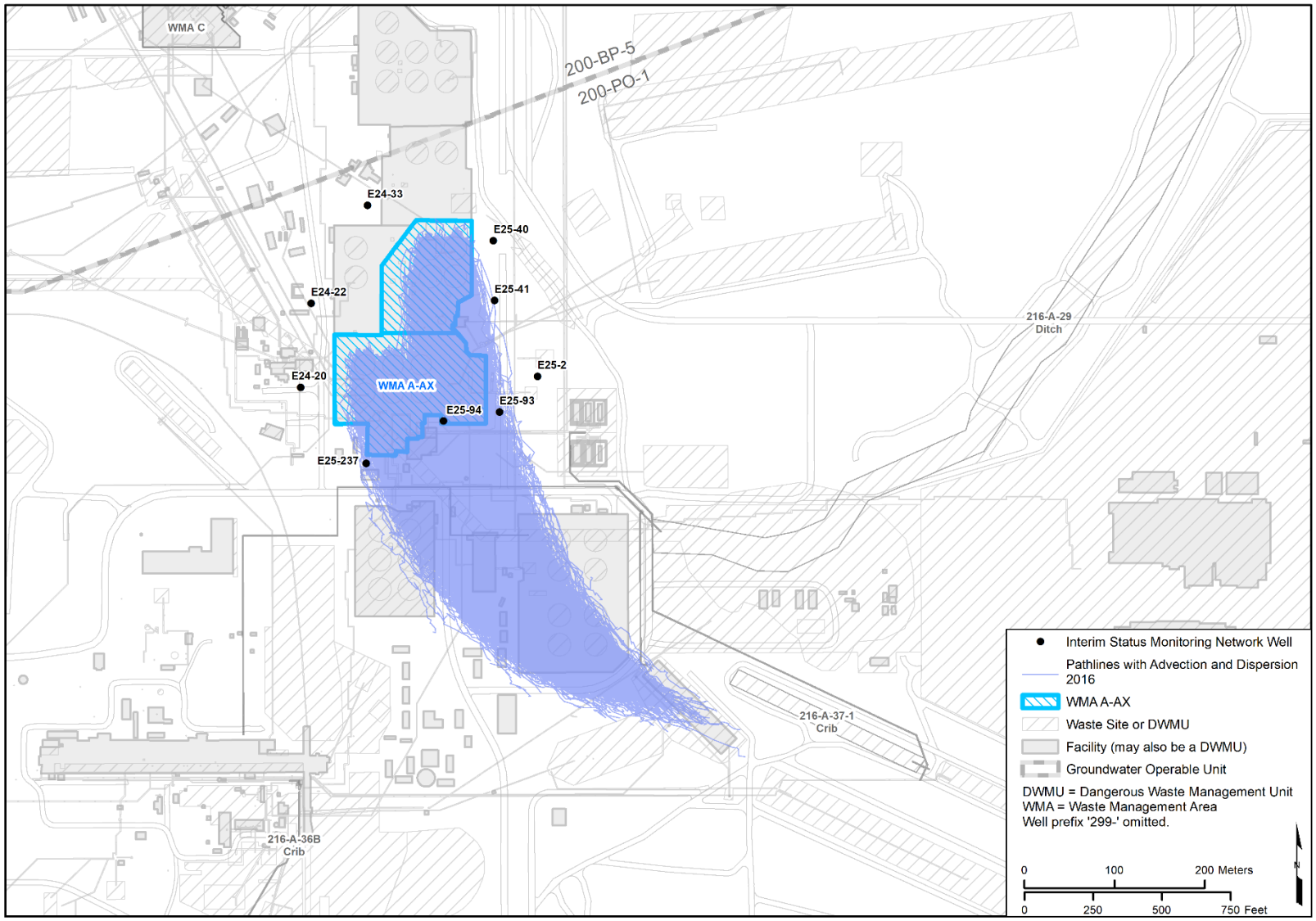


Figure 7-8. Local-Scale Particle Paths, Advection and Dispersion – WMA A-AX, 2016

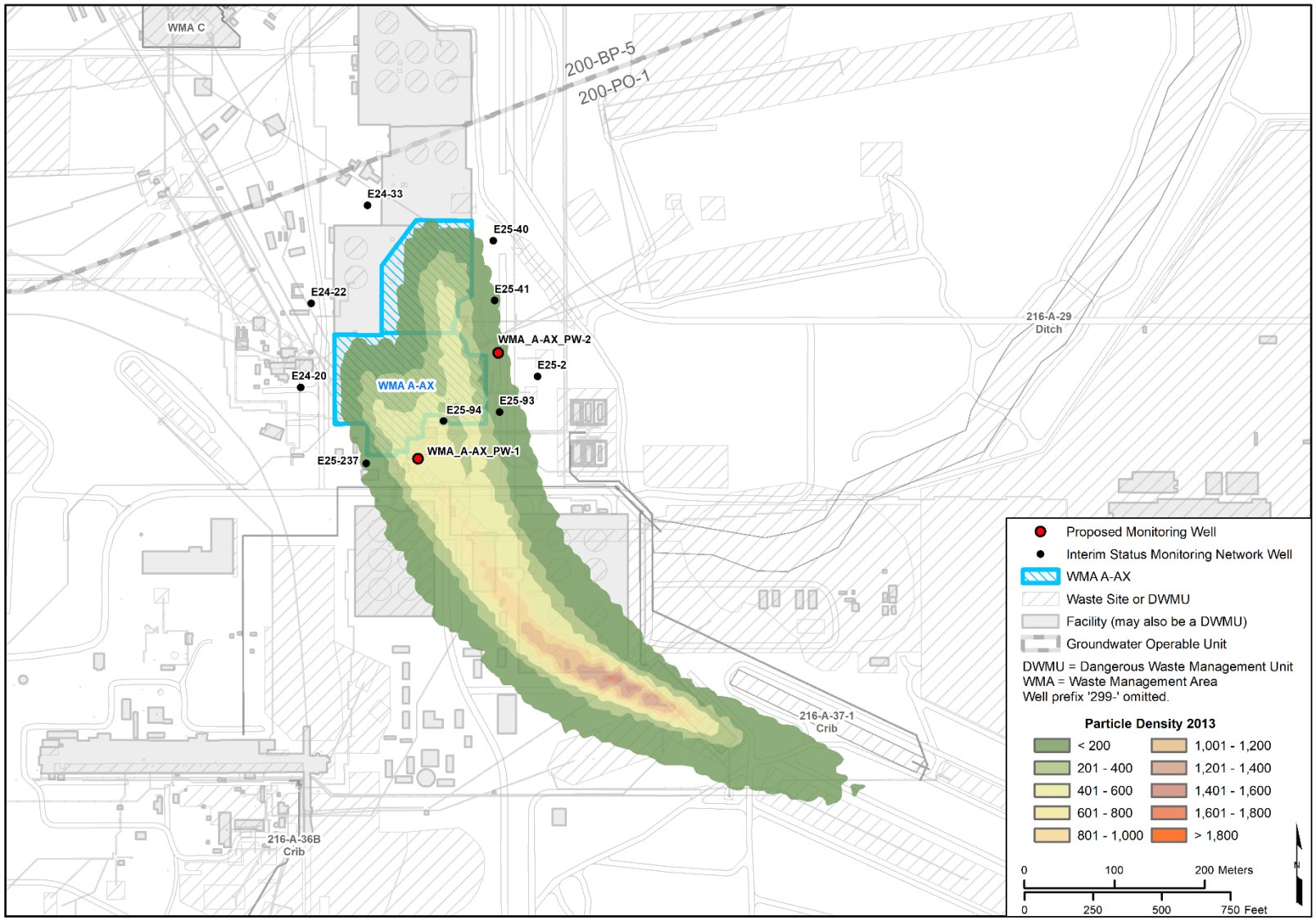


Figure 7-9. Particle Count Map – WMA A-AX, 2013

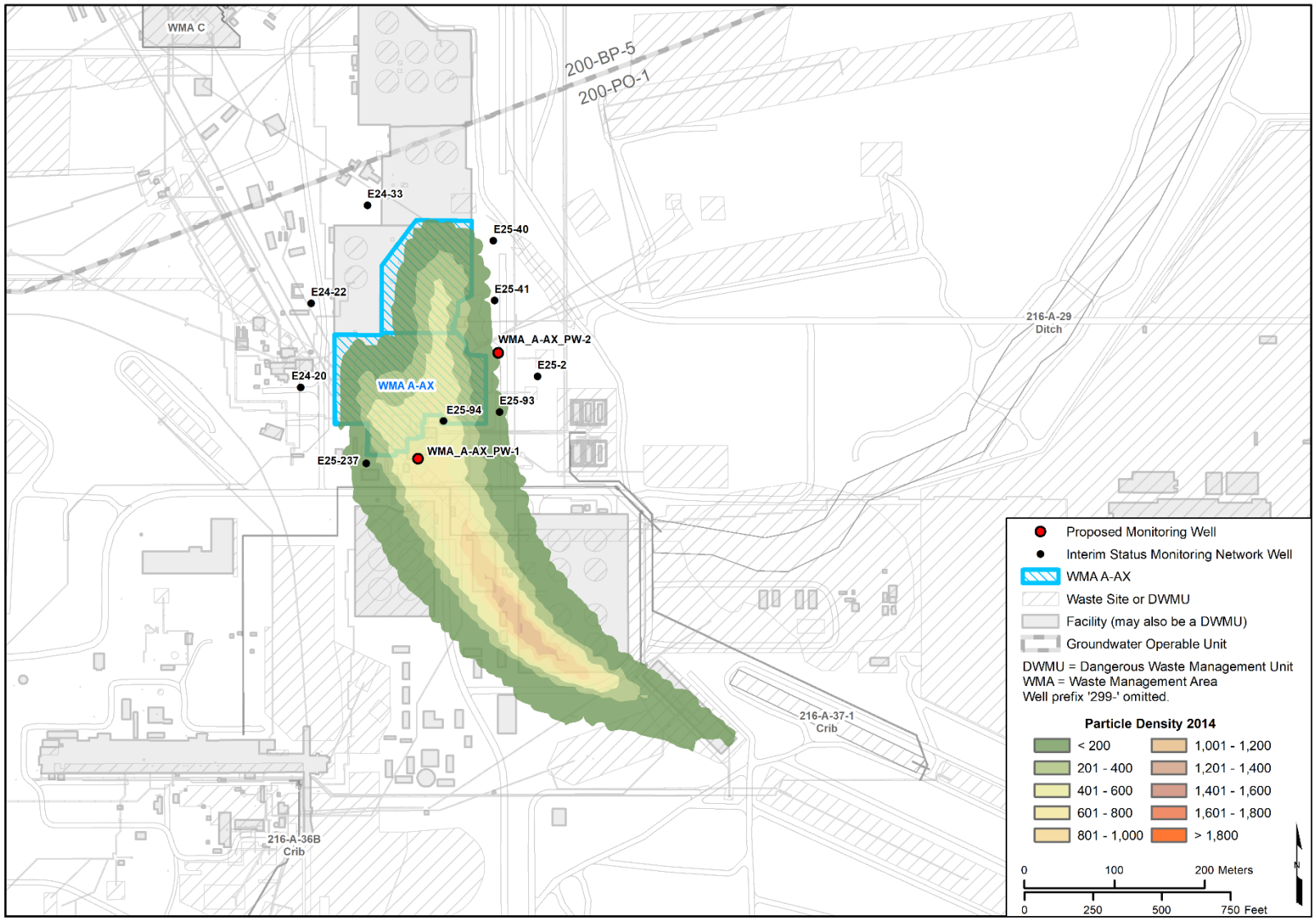


Figure 7-10. Particle Count Map – WMA A-AX, 2014

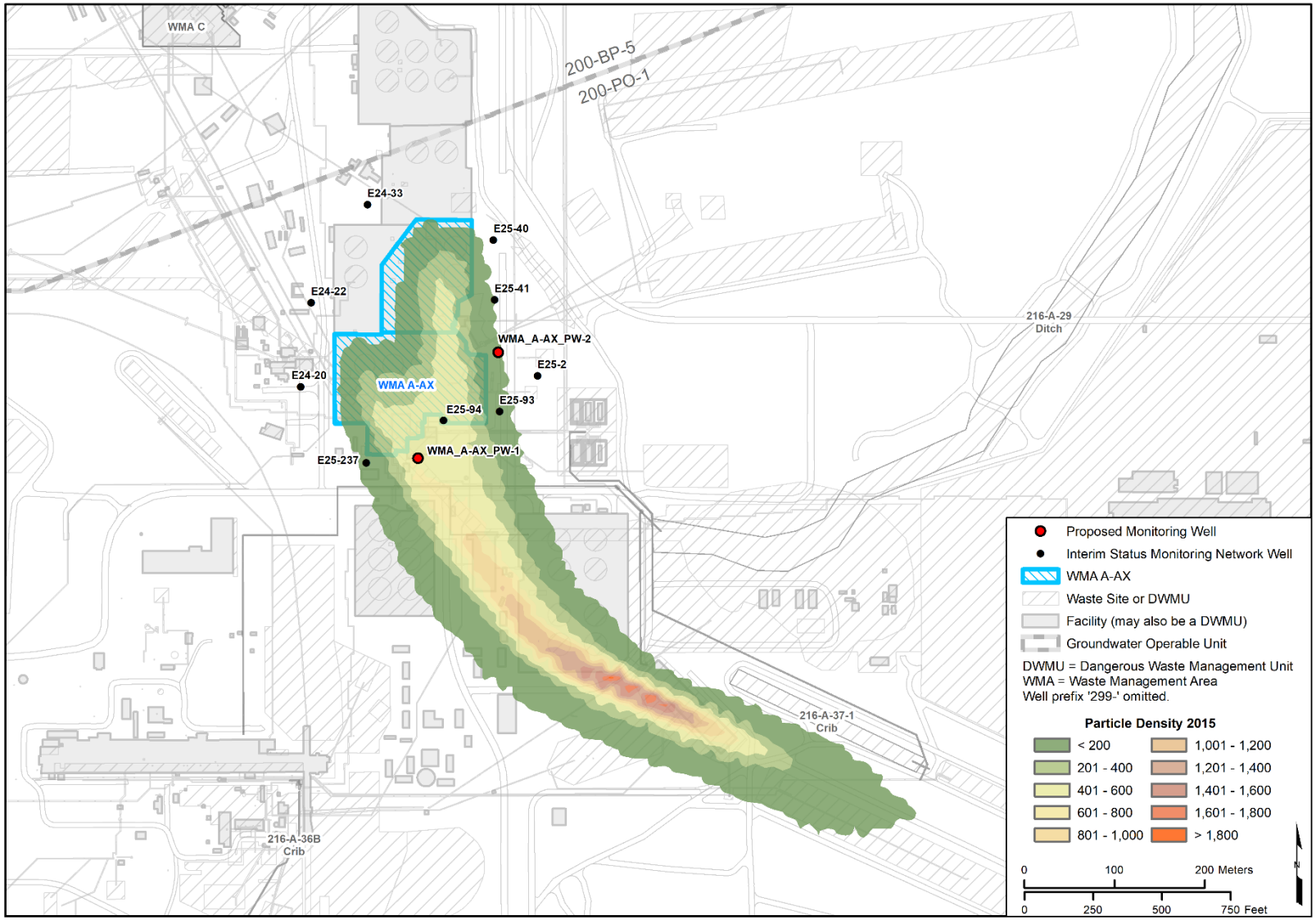


Figure 7-11. Particle Count Map – WMA A-AX, 2015

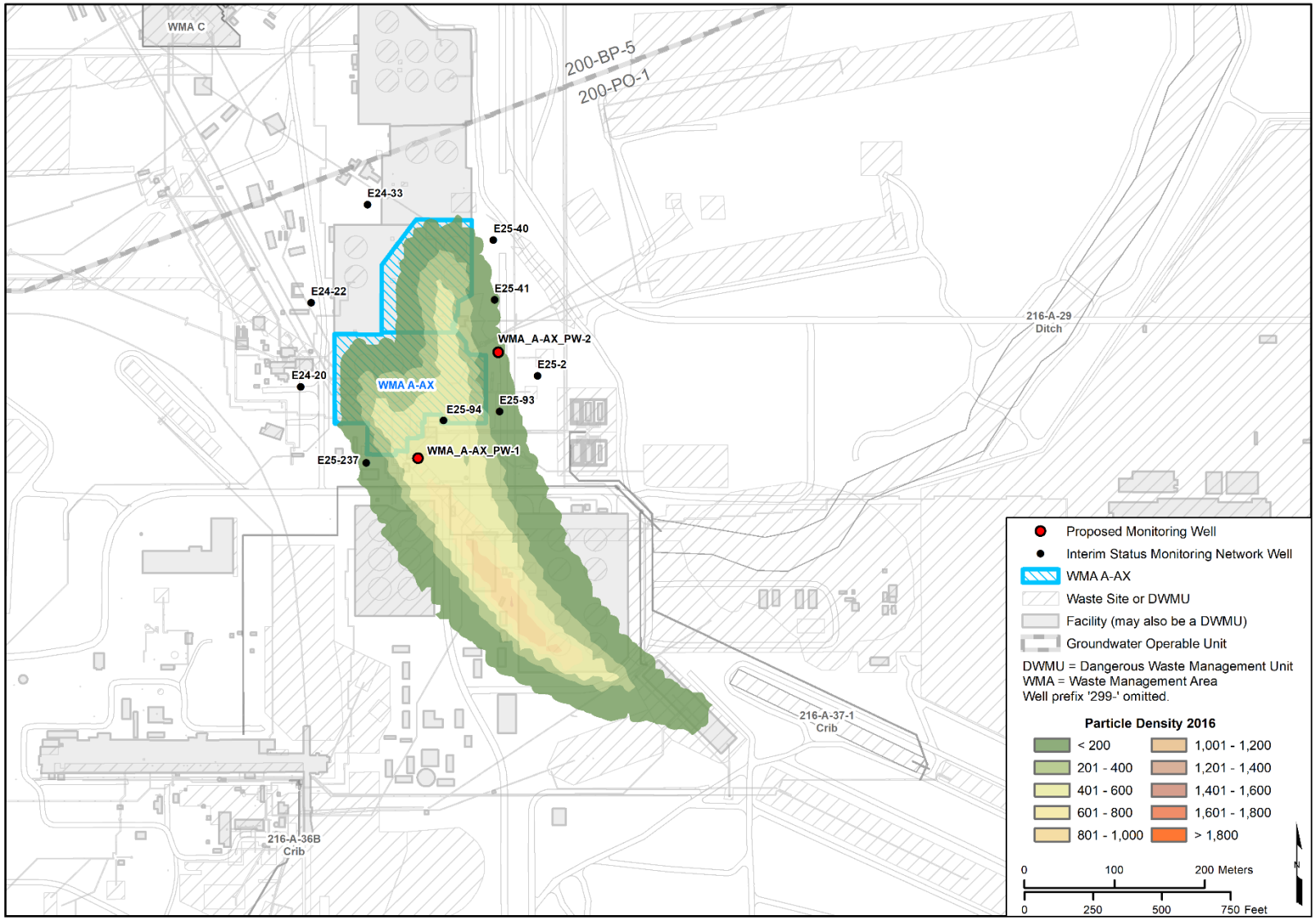


Figure 7-12. Particle Count Map – WMA A-AX, 2016

7.4 Monitoring Well Network Recommendations

The goal of well placement is for the well locations to span the range of particle pathline distribution as released from WMA A-AX. Based on the results of the calculations presented in Appendix J of ECF-200E-18-0066 and summarized herein, the proposed final status groundwater monitoring well network for detecting a potential release from WMA A-AX includes eight of the nine monitoring wells from the interim status groundwater monitoring well network and two proposed new wells. The existing wells proposed for use in the final status groundwater monitoring well network are downgradient wells 299-E25-40, 299-E25-41, 299-E25-93, 299-E25-94, and 299-E25-237, and upgradient wells 299-E24-20, 299-E24-22, and 299-E24-33. The proposed wells are WMA_A-AX_PW-1 and WMA_A-AX_PW-2. The calculations based on the four (2013 through 2016) groundwater elevation analyses indicate that the evaluated downgradient groundwater monitoring wells are well placed for detecting a release to the water table from WMA A-AX, and upgradient monitoring wells will remain upgradient under the conditions evaluated.

Well 299-E25-2 is not recommended for use in the final status groundwater monitoring well network because it is not constructed in accordance with WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells,” and it did not intercept any particles under the analyzed flow conditions. Proposed well WMA_A-AX_PW-2 replaces well 299-E25-2 and is located closer to the DWMU in an area better suited to detect releases.

The vertical migration evaluation for WMA A-AX is discussed in Section 3.6 in Appendix J of ECF-200E-18-0066. The outputs of the vertical migration calculations completed using the API calculator indicate that the depths of the well screens proposed for downgradient monitoring wells are appropriate, because vertical migration due to the accrual of recharge is not expected to result in contaminants traveling undetected beneath the downgradient monitoring well screens as long as local recharge conditions do not change substantially from the assumptions used in the calculations.

The final status monitoring well network proposed for WMA A-AX (upgradient wells 299-E24-20, 299-E24-22, and 299-E24-33 and downgradient wells 299-E25-40, 299-E25-41, 299-E25-93, 299-E25-94, 299-E25-237, WMA_A-AX_PW-1, and WMA_A-AX_PW-2) is discussed further in Section 9.3.

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8 Identification of Site-Specific Monitoring Constituents

An evaluation of the waste constituents associated with WMA A-AX, 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 ECF-200PO1-17-0223, *Identification of Site-Specific Monitoring Constituents for Waste Management Area A-AX*.

8.1 Selection Process for Monitoring Constituents

The datasets comprising the waste constituents associated with WMA A-AX 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 ECF-200PO1-17-0223, with assumptions documented in Section 4.1 of ECF-200PO1-17-0223.

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

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 waste codes associated with the TSD unit, which includes the WMA A-AX 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 dataset. The dangerous wastes identified in the SST Part A Permit Application are presented in Table 2-3.

The specified dangerous wastes were screened to identify mobile constituents by comparing literature reference values for constituent distribution coefficients (K_ds) 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 (ECF-200PO1-17-0223, 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 A-AX, including the changes to the well 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 database and presented in separate Microsoft® Excel® workbooks.

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The nonradiological sample data for each well (excluding wells used for information purposes only) were evaluated to determine the maximum measurement result for each detected chemical constituent. Sample data that were qualified with either "U" or an "R" qualifier[2] were not considered in the evaluation. Field parameters (e.g., dissolved oxygen, pH, specific conductance, temperature, turbidity), alkalinity measurements, and nonanalyte-specific measures (e.g., total organic carbon and total organic halides) were not considered in the evaluation. The maximum result for each detected chemical 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*) (Tables 2 and 4 in ECF-200PO1-17-0223). 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 identified potential monitoring constituents to be included as proposed monitoring constituents to detect and monitor wastes from WMA A-AX 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 A-AX (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).

[2] 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.

- 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 waste discharge profile for the WMA A-AX SSTs that have leaked (Table 2-2) (evaluated on a case-by-case basis).

The results from the final monitoring constituent evaluation are detailed in Section 7.3 in ECF-200PO1-17-0223.

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 A-AX under interim status monitoring plans, 90 waste constituents are identified as proposed monitoring constituents to detect and monitor any groundwater impacts from dangerous waste releases at WMA A-AX (Table 8-1). Of the 90 waste constituents, 5 are nondangerous waste constituents that were quantified in groundwater above the applicable action level and were identified in the waste discharge profile for the WMA A-AX SSTs that have leaked. Details of the constituent screening and selection process are provided in Chapter 7 of ECF-200PO1-17-0223.

Table 8-1. Proposed Groundwater Monitoring Constituents for WMA A-AX

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
1,2,3,4,6,7,8-Heptachlorodibenzodioxin	35822-46-9
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562-39-4
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673-89-7
1,2,3,4,7,8-Hexachlorodibenzofuran	70648-26-9
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227-28-6
1,2,3,6,7,8-Hexachlorodibenzofuran	57117-44-9
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653-85-7
1,2,3,7,8,9-Hexachlorodibenzofuran	72918-21-9
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408-74-3

Table 8-1. Proposed Groundwater Monitoring Constituents for WMA A-AX

Waste Constituent	CAS Number
1,2,3,7,8-Pentachlorodibenzofuran	57117-41-6
1,2,4-Trimethylbenzene	95-63-6
1,2-Dichloroethane	107-06-2
2,3,4,6,7,8-Hexachlorodibenzofuran	60851-34-5
2,3,4,6-Tetrachlorophenol	58-90-2
2,3,4,7,8-Pentachlorodibenzofuran	57117-31-4
2,3,7,8-Tetrachlorodibenzofuran	51207-31-9
2,4-D(2,4-Dichlorophenoxyacetic acid)	94-75-7
2,4-Dimethylphenol	105-67-9
2,4-Dinitrophenol	51-28-5
2,4-Dinitrotoluene	121-14-2
2-Nitropropane	79-46-9
2-Propanol	67-63-0
4,4'-DDT (Dichlorodiphenyltrichloroethane)	50-29-3
4,6-Dinitro-2-methylphenol	534-52-1
Acetone	67-64-1
Antimony	7440-36-0
Arsenic	7440-38-2
Benzene	71-43-2
Benzo(ghi)perylene	191-24-2
Benzoic acid	65-85-0
Cadmium	7440-43-9
Carbon disulfide	75-15-0
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

Table 8-1. Proposed Groundwater Monitoring Constituents for WMA A-AX

Waste Constituent	CAS Number
Cresols	1319-77-3
Cyclohexane	110-82-7
Cyclohexanone	108-94-1
Dibenz[a,h]anthracene	53-70-3
Ethyl acetate	141-78-6
Ethyl benzene	100-41-4
Ethyl ether	60-29-7
Heptachlorodibenzofurans	38998-75-3
Heptachlorodibenzo-p-dioxins	37871-00-4
Hexachlorodibenzofurans	55684-94-1
Hexachlorodibenzo-p-dioxin	34465-46-8
Hexavalent chromium	18540-29-9
Indeno(1,2,3-cd)pyrene	193-39-5
Isobutanol (Isobutyl alcohol)	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 (4-Methyl-2-pentanone)	108-10-1
Methylene chloride	75-09-2
n-Butyl alcohol (1-Butanol)	71-36-3
Nickel	7440-02-0
Nitrobenzene	98-95-3
Octachlorodibenzofuran	39001-02-0
Octachlorodibenzo-p-dioxin	3268-87-9
O-dichlorobenzene (1,2-Dichlorobenzene)	95-50-1
Pentachlorodibenzofurans	30402-15-4
Pentachlorodibenzo-p-dioxins	36088-22-9

Table 8-1. Proposed Groundwater Monitoring Constituents for WMA A-AX

Waste Constituent	CAS Number
Pyridine	110-86-1
Selenium	7782-49-2
Silver	7440-22-4
Sulfide	18496-25-8
Tetrachlorodibenzofurans	55722-27-5
Tetrachlorodibenzo-p-dioxins	41903-57-5
Tetrachloroethene	127-18-4
Tin	7440-31-5
Toluene	108-88-3
Trichloroethylene	79-01-6
Trichlorofluoromethane	75-69-4
Vanadium	7440-62-2
Vinyl chloride (Chloroethene)	75-01-4
Xylenes (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
Sulfate	14808-79-8

CAS = Chemical Abstracts Service

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."

While WMA A-AX continues to be monitored under a groundwater quality assessment program under interim status, a release to the environment (statistically significant evidence of contamination at the point of compliance) has not been documented under the most recent revision of the groundwater quality assessment plan (2016). However, due to previous releases from WMA A-AX, it is anticipated that WMA A-AX will be in compliance monitoring under WAC 173-303-645(10) when WMA A-AX 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 water-table mapping described in Chapter 7 indicate that the locations of the seven downgradient wells proposed for the monitoring well network (existing wells 299-E25-40, 299-E25-41, 299-E25-93, 299-E25-94, and 299-E25-237, and proposed wells WMA_A-AX_PW-1, and WMA_A-AX_PW-2) span the range of particle distribution as released from WMA A-AX. The well placement is suitable for detecting releases to the water table from WMA A-AX under the evaluated range of conditions. The proposed well locations comply with the intent of WAC 173-303-645(6), which is to detect waste constituents released and 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 as appropriate.

9.3 Proposed Groundwater Monitoring Network

The proposed groundwater monitoring network for WMA A-AX consists of three background (upgradient) and seven point of compliance (downgradient) wells to monitor for releases to the water table and detection of increases of contamination from WMA A-AX (Figure 9-1). The monitoring well locations were evaluated based on water elevation mapping and particle-tracking simulations that incorporate flow conditions for four years (2013 through 2016). Results of the simulations are presented in Chapter 7.

Well attributes are summarized in Table 9-1 and Appendix D. Each of the proposed network wells have been, or will be, constructed according to WAC 173-160. Each well is, or will be, screened in the upper unconfined aquifer in order to yield sufficient groundwater for representative sampling. Sections 9.3.1 through 9.3.10 provide details supporting the selection of each of the proposed locations. Based on the results of the API calculator (Section 3.6 in Appendix J of ECF-200E-18-0066), the depths of the monitoring wells, 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 A-AX is presented in Section 3.3. WAC 173-303-645(8)(a)(i) states that wells must be appropriately sited to, “Represent the quality of background groundwater that has not been affected by leakage from a regulated unit.” To meet the intent of WAC 173-303-645(8)(a)(i), three background (upgradient) wells have been selected that would be representative of ambient conditions. However, the wells do not represent groundwater that has not been 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 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 E. Selection of the statistical method for use in WMA A-AX is discussed in Section 9.7.

Based on current groundwater flow direction to the south-southeast (Table 3-2 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 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 (Section 3.6 in Appendix J of ECF-200E-18-0066) and determination of compliance with groundwater protections standards (WAC 173-303-645(10)(a)).

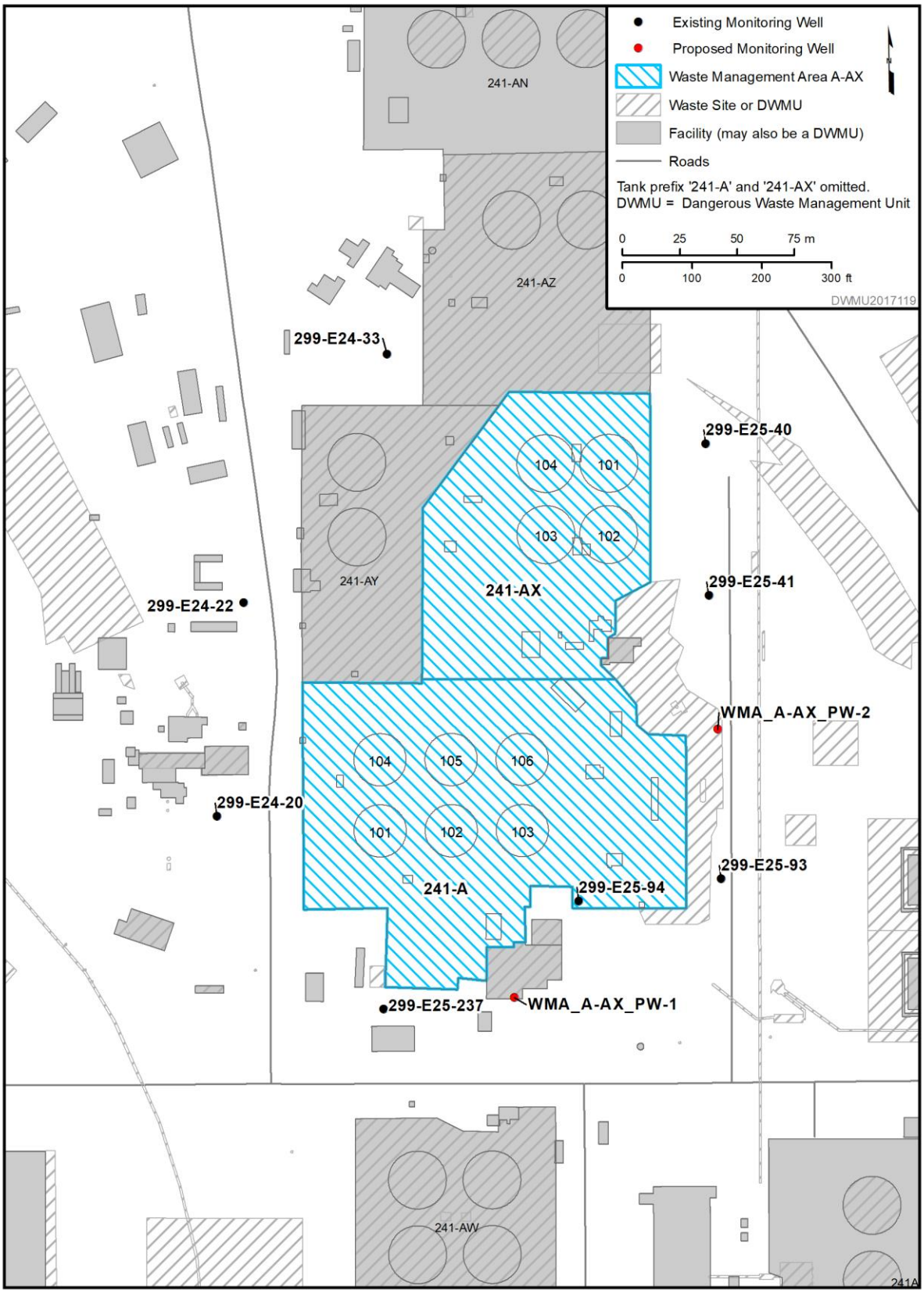

Figure 9-1. Proposed Final Status Groundwater Monitoring Network for WMA A-AX

Table 9-1. Attributes for Wells in the WMA A-AX 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-E24-20	3/14/1991	575251.10	136049.40	210.1 (689.4)	121.7 (399.4)	88.4 (289.9)	2.9 (9.4)	12/11/2017
299-E24-22	7/17/2003	575262.68	136142.82	209.6 (687.5)	121.7 (399.3)	87.8 (288.2)	10.1 (33.1)	12/11/2017
299-E24-33	8/27/2004	575325.40	136251.45	206.0 (676.0)	121.7 (399.3)	84.3 (276.6)	10.2 (33.5)	12/11/2017
299-E25-40	9/18/1989	575464.68	136212.32	203.1 (666.4)	121.7 (399.3)	81.4 (267.1)	1.8 (5.9)	12/15/2017
299-E25-41	9/22/1989	575466.06	136145.93	204.7 (671.7)	121.7 (399.4)	83.0 (272.3)	1.2 (4.0)	12/15/2017
299-E25-93	8/14/2003	575471.51	136022.09	207.3 (680.0)	121.7 (399.3)	85.6 (280.7)	9.9 (32.6)	12/12/2017
299-E25-94	9/27/2004	575409.17	136012.43	211.3 (693.3)	121.9 (400.0)	89.4 (293.3)	11.2 (36.8)	12/12/2017
299-E25-237	1/19/2015	575323.84	135965.27	211.9 (695.1)	121.8 (399.5)	90.1 (295.6)	9.3 (30.4)	12/11/2017
WMA_A-AX_PW-1	TBD	575381.11	135970.28	TBD	121.7 (399.3)	90.5 (296.9)	TBD	TBD
WMA_A-AX_PW-2	TBD	575469.93	136087.54	TBD	121.7 (399.3)	87.1 (285.8)	TBD	TBD

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

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

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

amsl = above mean sea level

bgs = below ground surface

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

9.3.1 Groundwater Monitoring Well 299-E24-20

Groundwater monitoring well 299-E24-20 is proposed as a background well. It was constructed in 1991 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is upgradient of WMA A-AX and is screened from elevation 125.01 m (410.15 ft) to elevation 118.86 m (389.95 ft) (Appendix D). Based on 2017 water elevation data, well 299-E24-20 is screened across the upper 2.9 m (9.4 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this proposed well location for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, this well will remain upgradient of WMA A-AX under expected groundwater flow conditions.

9.3.2 Groundwater Monitoring Well 299-E24-22

Groundwater monitoring well 299-E24-22 is proposed as a background well. It was constructed in 2003 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is upgradient of WMA A-AX and is screened from elevation 122.32 m (401.32 ft) to elevation 111.62 m (366.22 ft) (Appendix D). Based on 2017 water elevation data, well 299-E24-22 is screened across the upper 10.1 m (33.1 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this proposed well location for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, this well will remain upgradient of WMA A-AX under expected groundwater flow conditions.

9.3.3 Groundwater Monitoring Well 299-E24-33

Groundwater monitoring well 299-E24-33 is proposed as a background well. It was constructed in 2004 to the standards of WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is upgradient of WMA A-AX and is screened from elevation 121.27 m (397.86 ft) to elevation 111.51 m (365.86 ft) (Appendix D). Based on 2017 water elevation data, well 299-E24-33 is screened across the upper 10.2 m (33.5 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this proposed well location for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, this well will remain upgradient of WMA A-AX under expected groundwater flow conditions.

9.3.4 Groundwater Monitoring Well 299-E25-40

Groundwater monitoring well 299-E25-40 is proposed as a point of compliance well. It was constructed in 1989 to the standards in WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is downgradient of WMA A-AX and is screened from elevation 126.30 m (414.37 ft) to elevation 119.90 m (393.37 ft) (Appendix D). Based on 2017 water elevation data, well 299-E25-40 is screened across the upper 1.8 m (5.9 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this well for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, well 299-E25-40 is located north of the likely migration area, outside the area of high relative particle density.

9.3.5 Groundwater Monitoring Well 299-E25-41

Groundwater monitoring well 299-E25-41 is proposed as a point of compliance well. It was constructed in 1989 to the standards in WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is downgradient of WMA A-AX and is screened from elevation 126.91 m (416.38 ft) to elevation 120.51 m (395.38 ft) (Appendix D). Based on 2017 water elevation data, well 299-E25-41 is screened across the upper 1.2 m (4.0 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this well for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, well 299-E25-41 is located on the northern margin of the area of moderate relative particle density.

9.3.6 Groundwater Monitoring Well 299-E25-93

Groundwater monitoring well 299-E25-93 is proposed as a point of compliance well. It was constructed in 2003 to the standards in WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is downgradient of WMA A-AX and is screened from elevation 122.47 m (401.81 ft) to elevation 111.77 m (366.71 ft) (Appendix D). Based on 2017 water elevation data, well 299-E25-93 is screened across the upper 9.9 m (32.6 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this well for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, well 299-E25-93 is located centrally in the likely migration area, in an area of moderate relative particle density.

9.3.7 Groundwater Monitoring Well 299-E25-94

Groundwater monitoring well 299-E25-94 is proposed as a point of compliance well. It was constructed in 2004 to the standards in WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is downgradient of WMA A-AX and is screened from elevation 121.36 m (398.17 ft) to elevation 110.69 m (363.17 ft) (Appendix D). Based on 2017 water elevation data, well 299-E25-94 is screened across the upper 11.2 m (36.8 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this well for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, well 299-E25-94 is located centrally in the likely migration area, in an area of high relative particle density.

9.3.8 Groundwater Monitoring Well 299-E25-237

Groundwater monitoring well 299-E25-237 is proposed as a point of compliance well. It was constructed in 2015 to the standards in WAC 173-160. This well is used in the interim status groundwater monitoring network for WMA A-AX. The well is downgradient of WMA A-AX and is screened from elevation 123.18 m (404.12 ft) to elevation 112.51 m (369.12 ft) (Appendix D). Based on 2017 water elevation data, well 299-E25-237 is screened across the upper 9.3 m (30.4 ft) of the uppermost unconfined aquifer (Table 9-1) and yields sufficient groundwater for representative sampling.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at this well for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, well 299-E25-237 is located on the southwestern margin of the area of moderate relative particle density.

9.3.9 Groundwater Monitoring Well WMA_A-AX_PW-1

Groundwater monitoring well WMA_A-AX_PW-1 is a proposed point of compliance well. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of WMA A-AX. The screened interval of the well will be designed to yield sufficient groundwater for representative sampling when constructed.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at the location of the proposed well for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, proposed well WMA_A-AX_PW-1 is located centrally in the likely migration area, in an area of high relative particle density.

9.3.10 Groundwater Monitoring Well WMA_A-AX_PW-2

Groundwater monitoring well WMA_A-AX_PW-2 is a proposed point of compliance well that would replace the non-WAC 173-160 compliant well 299-E25-2. If the well location is approved, it will be constructed according to WAC 173-160. The proposed location for the well is downgradient of WMA A-AX. The screened interval of the well will be designed to yield sufficient groundwater for representative sampling when constructed.

Water table maps were produced using TRIM, and particle-tracking simulations were performed to evaluate the movement of groundwater and identify areas of the aquifer where a hypothetical release that impacts the water table beneath WMA A-AX would be most likely to migrate and be detectable (described in Chapters 5 through 7 and ECF-200E-18-0066). Figures 7-1 through 7-8 indicate that the direction of groundwater flow is predominantly to the southeast at the location of the proposed well for the flow conditions evaluated. Figures 7-9 through 7-12 indicate that for the years mapped, proposed well WMA_A-AX_PW-2 is located on the northern margin of the area of moderate relative particle density.

9.4 Constituent List and Frequency

The proposed WMA A-AX final status groundwater monitoring network detailed in this report consists of three upgradient wells (299-E24-20, 299-E24-22, and 299-E24-33) and seven downgradient wells (299-E25-40, 299-E25-41, 299-E25-93, 299-E25-94, 299-E25-237, WMA_A-AX_PW-1, and WMA_A-AX_PW-2). Each of the existing wells are part of the WMA A-AX interim status groundwater monitoring network (Table 3-4 in DOE/RL-2015-49) 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, 90 waste constituents were selected to detect and monitor groundwater impacts from dangerous waste releases at WMA A-AX.

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

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

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[g]
				Hexavalent Chromium	Methanol	Sulfide	Metals[c]	Anions[d]	Volatile Organic Compounds[e]	Semivolatile Organic Compounds[f]	Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans[g]	Herbicides and Pesticides[h]	Table 9-4	
299-E24-20	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-E24-22	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-E24-33	Upgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-E25-40	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-E25-41	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-E25-93	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-E25-94	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
299-E25-237	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
WMA_A-AX_PW-1	Downgradient	Y	E	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/S	Q/A	Q/S
WMA_A-AX_PW-2	Downgradient	Y	E	Q/S	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-086 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).

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

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[g]
				Hexavalent Chromium	Methanol	Sulfide	Metals[c]	Anions[d]	Volatile Organic Compounds[e]	Semivolatile Organic Compounds[f]	Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans[g]	Herbicides and Pesticides[h]	Table 9-4	

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

d. Anions are provided in Table 9-3 and include nitrate and sulfate.

e. 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; 1,2,4-trimethylbenzene; 2-butanone (methyl ethyl ketone); 2-nitropropane; 2-propanol; 2-propanone (acetone); 4-methyl-2-pentanone (methyl isobutyl ketone); benzene; carbon disulfide; carbon tetrachloride; chlorobenzene; chloroform; cyclohexane; cyclohexanone; ethyl acetate; ethyl ether; ethylbenzene; isobutanol (isobutyl alcohol); methylene chloride; tetrachloroethene; toluene; trichloroethylene (TCE); trichlorofluoromethane; vinyl chloride (chloroethene); and xylene (total).

f. Semivolatile organic compounds are provided in Table 9-3 and include 1,2-dichlorobenzene (o-dichlorobenzene); 2,3,4,6-tetrachlorophenol; 2,4-dimethylphenol; 2,4-dinitrophenol; 2,4-dinitrotoluene; 4,6-dinitro-2-methyl phenol; benzo(ghi)perylene; benzoic acid; cresols; dibenz[a,h]anthracene; indeno(1,2,3-cd)pyrene; nitrobenzene; and pyridine.

g. Polychlorinated dibenzodioxins and polychlorinated dibenzofurans are provided in Table 9-3 and include 1,2,3,4,6,7,8-heptachlorodibenzodioxin; 1,2,3,4,6,7,8-heptachlorodibenzofuran; 1,2,3,4,7,8,9-heptachlorodibenzofuran; 1,2,3,4,7,8-hexachlorodibenzofuran; 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin; 1,2,3,6,7,8-hexachlorodibenzofuran; 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin; 1,2,3,7,8,9-hexachlorodibenzofuran; 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin; 1,2,3,7,8-pentachlorodibenzofuran; 2,3,4,6,7,8-hexachlorodibenzofuran; 2,3,4,7,8-pentachlorodibenzofuran; 2,3,7,8-tetrachlorodibenzofuran; heptachlorodibenzofurans; heptachlorodibenzo-p-dioxins; hexachlorodibenzofurans; hexachlorodibenzo-p-dioxin; octachlorodibenzofuran; octachlorodibenzo-p-dioxin; pentachlorodibenzofurans; pentachlorodibenzo-p-dioxins; tetrachlorodibenzofurans; and tetrachlorodibenzo-p-dioxins.

h. Herbicides and pesticides are provided in Table 9-3 and include 2,4-D (2,4-dichlorophenoxyacetic acid) and 4,4'-DDT (dichlorodiphenyltrichloroethane).

g. Field parameters include pH, 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
N = well is not constructed as a resource protection well (WAC 173-160, “Minimum Standard for Construction and Maintenance of Wells”)
Q = quarterly
S = semiannually
WAC = *Washington Administrative Code*
Y = well is, or will be, constructed as a resource protection well (WAC 173-160)

Table 9-3. Proposed Groundwater Monitoring Constituents for WMA A-AX

Waste Constituent	CAS Number
Inorganics	
Hexavalent chromium	18540-29-9
Sulfide	18496-25-8
Metals	
Antimony	7440-36-0
Arsenic	7440-38-2
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
1,2,4-Trimethylbenzene	95-63-6
2-Butanone (Methyl ethyl ketone)	78-93-3
2-Nitropropane	79-46-9
2-Propanol	67-63-0
2-Propanone (Acetone)	67-64-1
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1

Table 9-3. Proposed Groundwater Monitoring Constituents for WMA A-AX

Waste Constituent	CAS Number
Benzene	71-43-2
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
Cyclohexane	110-82-7
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
2,3,4,6-Tetrachlorophenol	58-90-2
2,4-Dimethylphenol	105-67-9
2,4-Dinitrophenol	51-28-5
2,4-Dinitrotoluene	121-14-2
4,6-Dinitro-2-methylphenol	534-52-1
Benzo(ghi)perylene	191-24-2
Benzoic acid	65-85-0
Cresols	1319-77-3
Dibenz[a,h]anthracene	53-70-3
Indeno(1,2,3-cd)pyrene	193-39-5
Nitrobenzene	98-95-3

Table 9-3. Proposed Groundwater Monitoring Constituents for WMA A-AX

Waste Constituent	CAS Number
Pyridine	110-86-1
Alcohols/Ketones	
Methanol	67-56-1
Herbicides	
2,4-D(2,4-Dichlorophenoxyacetic acid)	94-75-7
Pesticides	
4,4'-DDT (Dichlorodiphenyltrichloroethane)	50-29-3
Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans	
1,2,3,4,6,7,8-Heptachlorodibenzodioxin	35822-46-9
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562-39-4
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673-89-7
1,2,3,4,7,8-Hexachlorodibenzofuran	70648-26-9
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227-28-6
1,2,3,6,7,8-Hexachlorodibenzofuran	57117-44-9
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653-85-7
1,2,3,7,8,9-Hexachlorodibenzofuran	72918-21-9
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408-74-3
1,2,3,7,8-Pentachlorodibenzofuran	57117-41-6
2,3,4,6,7,8-Hexachlorodibenzofuran	60851-34-5
2,3,4,7,8-Pentachlorodibenzofuran	57117-31-4
2,3,7,8-Tetrachlorodibenzofuran	51207-31-9
Heptachlorodibenzofurans	38998-75-3
Heptachlorodibenzo-p-dioxins	37871-00-4
Hexachlorodibenzofurans	55684-94-1
Hexachlorodibenzo-p-dioxin	34465-46-8
Octachlorodibenzofuran	39001-02-0
Octachlorodibenzo-p-dioxin	3268-87-9
Pentachlorodibenzofurans	30402-15-4
Pentachlorodibenzo-p-dioxins	36088-22-9
Tetrachlorodibenzofurans	55722-27-5
Tetrachlorodibenzo-p-dioxins	41903-57-5

Table 9-3. Proposed Groundwater Monitoring Constituents for WMA A-AX

Waste Constituent	CAS Number
Nondangerous Waste Constituents	
Anions	
Nitrate	14797-55-8
Sulfate	14808-79-8
Metals	
Aluminum	7429-90-5
Iron	7439-89-6
Manganese	7439-96-5

CAS = Chemical Abstracts Service

In accordance with 16-NWP-086, 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, after which sampling to establish background concentrations will be discontinued. Section 9.7 provides details on the number of sample data required to determine a statistical method.

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

Constituent	CAS Number	Constituent	CAS Number
Inorganic Constituents			
Antimony	7440-36-0	Mercury	7439-97-6
Arsenic	7440-38-2	Nickel	7440-02-0
Barium	7440-39-3	Selenium	7782-49-2
Beryllium	7440-41-7	Silver	7440-22-4
Cadmium	7440-43-9	Sulfide	18496-25-8
Chromium	7440-47-3	Thallium	7440-28-0
Cobalt	7440-48-4	Tin	7440-31-5
Copper	7440-50-8	Vanadium	7440-62-2
Cyanide	57-12-5	Zinc	7440-66-6
Lead	7439-92-1	--	--

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

Constituent	CAS Number	Constituent	CAS Number
Volatile Organic Compounds			
1,1-Dichloroethane	75-34-3	Carbon tetrachloride	56-23-5
1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	Chlorobenzene	108-90-7
1,1,1-Trichloroethane	71-55-6	Chloroethane	75-00-3
1,1,1,2-Tetrachloroethane	630-20-6	Chloroform	67-66-3
1,1,2-Trichloroethane	79-00-5	Chloroprene	126-99-8
1,1,2,2-Tetrachloroethane	79-34-5	Dibromochloromethane	124-48-1
1,2-Dibromo-3-chloropropane	96-12-8	p-Dichlorobenzene (1,4-Dichlorobenzene)	106-46-7
1,2-Dibromoethane	106-93-4	Dichlorodifluoromethane	75-71-8
1,2-Dichloroethane	107-06-2	Ethylbenzene	100-41-4
1,2-Dichloropropane	78-87-5	Ethyl methacrylate	97-63-2
trans-1,2-Dichloroethylene	156-60-5	Isobutanol (Isobutyl alcohol)	78-83-1
1,2,3-Trichloropropane	96-18-4	Methacrylonitrile	126-98-7
cis-1,3-Dichloropropene	10061-01-5	Methyl bromide (Bromomethane)	74-83-9
trans-1,3-Dichloropropene	10061-02-6	Methyl chloride (Chloromethane)	74-87-3
trans-1,4-Dichloro-2-butene	110-57-6	Methyl iodide (Iodomethane)	74-88-4
2-Butanone (Methyl ethyl ketone; MEK)	78-93-3	Methyl methacrylate	80-62-6
2-Propanone (Acetone)	67-64-1	Methylene bromide (Dibromomethane)	74-95-3
2-Hexanone (Methyl butyl ketone)	591-78-6	Methylene chloride	75-09-2
4-Methyl-2-pentanone (Methyl isobutyl ketone)	108-10-1	Propionitrile (Ethyl cyanide)	107-12-0
Acetonitrile (Methyl cyanide)	75-05-8	Styrene	100-42-5
Acrolein	107-02-8	Tetrachloroethene	127-18-4
Acrylonitrile	107-13-1	Toluene	108-88-3
Allyl chloride	107-05-1	Trichloroethene (TCE)	79-01-6
Benzene	71-43-2	Trichlorofluoromethane	75-69-4
Bromodichloromethane	75-27-4	Vinyl acetate	108-05-4
Bromoform	75-25-2	Vinyl chloride (Chloroethene)	75-01-4
Carbon disulfide	75-15-0	Xylenes (total)	1330-20-7
Semivolatile Organic Compounds			
1-Naphthylamine	134-32-7	Dimethyl phthalate	131-11-3

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

Constituent	CAS Number	Constituent	CAS Number
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	Di-n-butyl phthalate	84-74-2
1,2,4-Trichlorobenzene	120-82-1	m-Dinitrobenzene	99-65-0
1,2,4,5-Tetrachlorobenzene	95-94-3	Di-n-octylphthalate	117-84-0
1,4-Dioxane	123-91-1	Dinoseb (2-sec-Butyl-4,6-dinitrophenol)	88-85-7
1,4-Naphthoquinone	130-15-4	Diphenylamine	122-39-4
2-Acetylaminofluorene	53-96-3	Disulfoton	298-04-4
2-Chloronaphthalene	91-58-7	Ethyl methanesulfonate	62-50-0
2-Chlorophenol	95-57-8	Famphur	52-85-7
2-Methylphenol (o-cresol)	95-48-7	Fluoranthene	206-44-0
2-Methylnaphthalene	91-57-6	9H-Fluorene (Fluorene)	86-73-7
2-Naphthylamine	91-59-8	Hexachlorobenzene	118-74-1
2-Nitrophenol (o-Nitrophenol)	88-75-5	Hexachlorobutadiene	87-68-3
2-Picoline	109-06-8	Hexachlorocyclopentadiene	77-47-4
2,3,4,6-Tetrachlorophenol	58-90-2	Hexachloroethane	67-72-1
2,4-Dichlorophenol	120-83-2	Hexachlorophene	70-30-4
2,4-Dimethylphenol	105-67-9	Hexachloropropene	1888-71-7
2,4-Dinitrophenol	51-28-5	Indeno(1,2,3-cd)pyrene	193-39-5
2,4-Dinitrotoluene	121-14-2	Isodrin	465-73-6
2,4,5-Trichlorophenol	95-95-4	Isophorone	78-59-1
2,4,6-Trichlorophenol	88-06-2	Isosafrole	120-58-1
2,6-Dichlorophenol	87-65-0	Kepone	143-50-0
2,6-Dinitrotoluene	606-20-2	Methapyrilene	91-80-5
3-Methylcholanthrene	56-49-5	Methyl methanesulfonate	66-27-3
3-Methylphenol (m-Cresol)	108-39-4	Methyl parathion	298-00-0
4-Methylphenol (p-cresol)	106-44-5	Naphthalene	91-20-3
3,3′-Dichlorobenzidine	91-94-1	Nitrobenzene	98-95-3
3,3′-Dimethylbenzidine	119-93-7	o-Nitroaniline (2-Nitroaniline)	88-74-4
4-Aminobiphenyl	92-67-1	m-Nitroaniline (3-Nitroaniline)	99-09-2
4-Bromophenyl phenyl ether	101-55-3	p-Nitroaniline (4-Nitroaniline)	100-01-6
4-Chloro-3-methylphenol (p-Chloro-m-cresol)	59-50-7	p-Nitrophenol (4-Nitrophenol)	100-02-7
4-Chlorophenyl phenyl ether	7005-72-3	N-Nitrosodi-n-butylamine	924-16-3

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

Constituent	CAS Number	Constituent	CAS Number
4-Nitroquinoline 1-oxide	56-57-5	N-Nitrosodiethylamine	55-18-5
4,6-Dinitro-o-cresol (4,6-Dinitro-2-methyl phenol)	534-52-1	N-Nitrosodimethylamine	62-75-9
5-Nitro-o-toluidine	99-55-8	N-Nitrosodiphenylamine	86-30-6
7,12-Dimethylbenz[a]anthracene	57-97-6	n-Nitroso-di-n-dipropylamine (N-Nitrosodipropylamine; Di-n-propylnitrosamine)	621-64-7
Acenaphthene	83-32-9	N-Nitrosomethylethalamine	10595-95-6
Acenaphthylene	208-96-8	n-Nitrosomorpholine	59-89-2
Acetophenone	98-86-2	N-Nitrosopiperidine	100-75-4
Aniline	62-53-3	N-Nitrosopyrrolidine	930-55-2
Anthracene	120-12-7	Parathion	56-38-2
Aramite	140-57-8	Pentachlorobenzene	608-93-5
Benz[a]anthracene (Benzo[a]anthracene)	56-55-3	Pentachloroethane	76-01-7
Benz[e]acephenanthrylene (Benzo[b]fluoranthene)	205-99-2	Pentachloronitrobenzene	82-68-8
Benzo[k]fluoranthene	207-08-9	Pentachlorophenol	87-86-5
Benzo[ghi]perylene	191-24-2	Phenacetin	62-44-2
Benzo[a]pyrene	50-32-8	Phenanthrene	85-01-8
Benzyl alcohol	100-51-6	Phenol	108-95-2
Bis(2-chloroethoxy)methane	111-91-1	p-Phenylenediamine	106-50-3
Bis(2-chloroethyl)ether	111-44-4	Phorate	298-02-2
Bis(2-chloro-1-methylethyl) ether (2,2'-Oxybis(1-chloropropane))	108-60-1	Pronamide	23950-58-5
Bis(2-ethylhexyl) phthalate	117-81-7	Pyrene	129-00-0
Butylbenzylphthalate	85-68-7	Pyridine	110-86-1
p-Chloroaniline (4-Chloroaniline)	106-47-8	Safrole	94-59-7
Chlorobenzilate	510-15-6	Tetraethyl dithiopyrophosphate	3689-24-5
Chrysene	218-01-9	o-Toluidine	95-53-4
Diallate	2303-16-4	O,O,O-Triethyl phosphorothioate	126-68-1
Dibenz[a,h]anthracene	53-70-3	sym-Trinitrobenzene	99-35-4
Dibenzofuran	132-64-9	Aroclor 1016	12674-11-2
m-Dichlorobenzene (1,3-Dichlorobenzene)	541-73-1	Aroclor 1221	11104-28-2

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

Constituent	CAS Number	Constituent	CAS Number
Diethyl phthalate	84-66-2	Aroclor 1232	11141-16-5
O,O-Diethyl O-2-pyrazinyl phosphorothioate	297-97-2	Aroclor 1242	53469-21-9
Dimethoate	60-51-5	Aroclor 1248	12672-29-6
p-(Dimethylamino)azobenzene	60-11-7	Aroclor 1254	11097-69-1
alpha, alpha-Dimethylphenethylamine	122-09-8	Aroclor 1260	11096-82-5
Pesticides			
4,4′-DDD	72-54-8	Endosulfan I	959-98-8
4,4′-DDE	72-55-9	Endosulfan II	33213-65-9
4,4′-DDT	50-29-3	Endosulfan sulfate	1031-07-8
Aldrin	309-00-2	Endrin	72-20-8
alpha-BHC	319-84-6	Endrin aldehyde	7421-93-4
beta-BHC	319-85-7	Heptachlor	76-44-8
delta-BHC	319-86-8	Heptachlor epoxide	1024-57-3
gamma-BHC (Lindane)	58-89-9	Methoxychlor	72-43-5
Chlordane	57-74-9	Toxaphene	8001-35-2
Dieldrin	60-57-1	-	-
Herbicides			
2,4-D; 2,4-Dichlorophenoxyacetic acid	94-75-7	Silvex; 2,4,5-TP	93-72-1
2,4,5-T; 2,4,5-Trichlorophenoxyacetic acid	93-76-5	-	-
Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans			
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	Polychlorinated dibenzofurans	N/A
Polychlorinated dibenzo-p-dioxins	N/A	-	-

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

CAS = Chemical Abstracts Service

N/A = not applicable

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 A-AX 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.

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 A-AX, 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 A-AX is permitted as a final status unit in the future Hanford Facility Dangerous Waste Permit. Because WMA A-AX has not yet been closed, the compliance period cannot yet be determined.

9.7 Statistical Method

Under the most recent (2016) interim status monitoring plan (DOE/RL-2015-49), the dangerous wastes identified in Appendix 5 of Ecology Publication 97-407, as well as supporting constituents (chloride, nitrate, and sulfate), were included for quarterly sampling. As of February 2018, seven samples have been collected under the 2016 plan. 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 number of samples collected under DOE/RL-2015-49 is approaching the minimum required for statistical evaluation for existing wells proposed for final status monitoring, the network includes an additional new proposed well. With the need to provide an adequate representation of baseline conditions at WMA A-AX, 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 of the constituents in Table 9-2 at a quarterly frequency for 2 years. Quarterly monitoring will allow for sufficiently long enough time between samples so as to not cause a problem with autocorrelation of samples (i.e., resampling the same water). After 2 years of sampling is completed, the statistical test method can be determined using the decision matrix included as Appendix E. In addition to this methodology, hydrogeology of the area also will be considered. Following this initial 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. Throughout the year, water-level measurements are also taken as part of routine sampling, and annually for water-level mapping. Analysis of groundwater elevation will be used to interpret changes in the groundwater flow regime. Evaluation of the continued suitability of the monitoring network will be performed annually in conjunction with the WAC 173-303-645(9)(e) determination of groundwater flow direction and rate in the uppermost aquifer. If the analysis suggests a change in the flow regime (e.g., changes resulting from a CERCLA remedy) 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 particle tracking using the new groundwater flow conditions will be performed to re-evaluate the monitoring network for that DWMU.

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

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11 References

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Appendix A

Interim Status Data Summary

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A1 Introduction

Section 2.4 of the main document summarizes the groundwater monitoring history at Waste Management Area (WMA) A-AX. An interim status indicator parameter groundwater monitoring program under 40 CFR 265, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," was initiated in 1989. The indicator parameter monitoring program continued until 2006 when WMA A-AX was placed into a groundwater quality assessment monitoring program in accordance with 40 CFR 265.93(d), "Preparation, Evaluation, and Response." WMA A-AX has been monitored under a groundwater quality assessment program since 2006.

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

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Appendix B

Topographic Map

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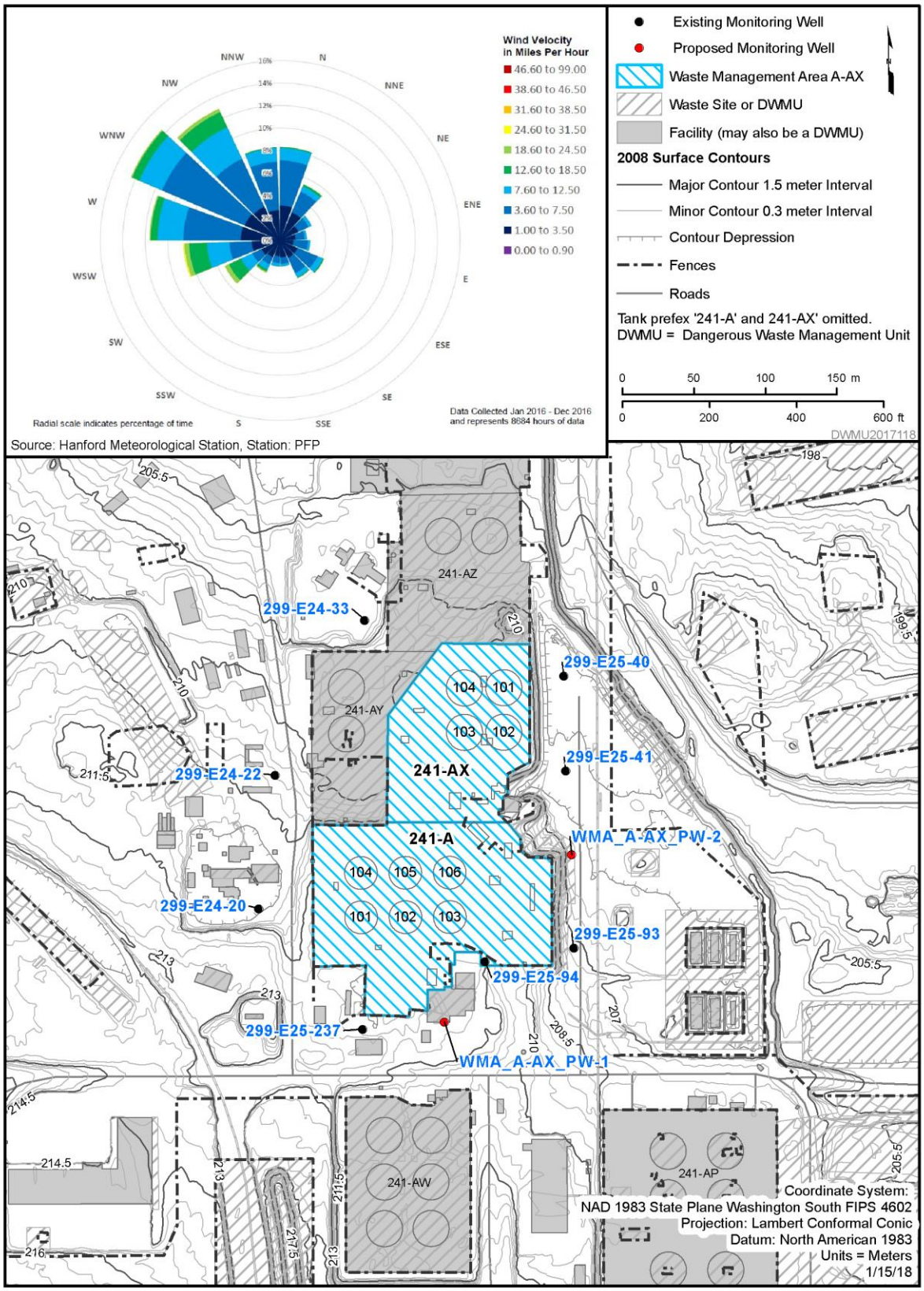

Figure B-1. Topographic Map

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Appendix C

Plume Maps

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C1 Plume Maps

This appendix presents regional plume maps in the vicinity of Waste Management Area (WMA) A-AX (Figures C-1 and C-2). This plume does not originate solely from WMA A-AX, but rather WMA A-AX has likely contributed to the overall plume.

In accordance with WAC 173-303-806(4)(a)(xx)(D), “Dangerous Waste Regulations,” “Final Facility Permits,” the maximum, detected result above background from each constituent sampled in 2016 from the WMA A-AX monitoring well network (Table 3-1 in DOE/RL-2016-66, *Hanford Site RCRA Groundwater Monitoring Report for 2016*) are presented (Figures C-3 through C-6).
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), “Sampling, Testing, Methods and Analytes,” and any other constituents not listed there that 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 C-3 through C-5. Figure C-6 presents chemical constituents that are nondangerous wastes and were detected above background values.

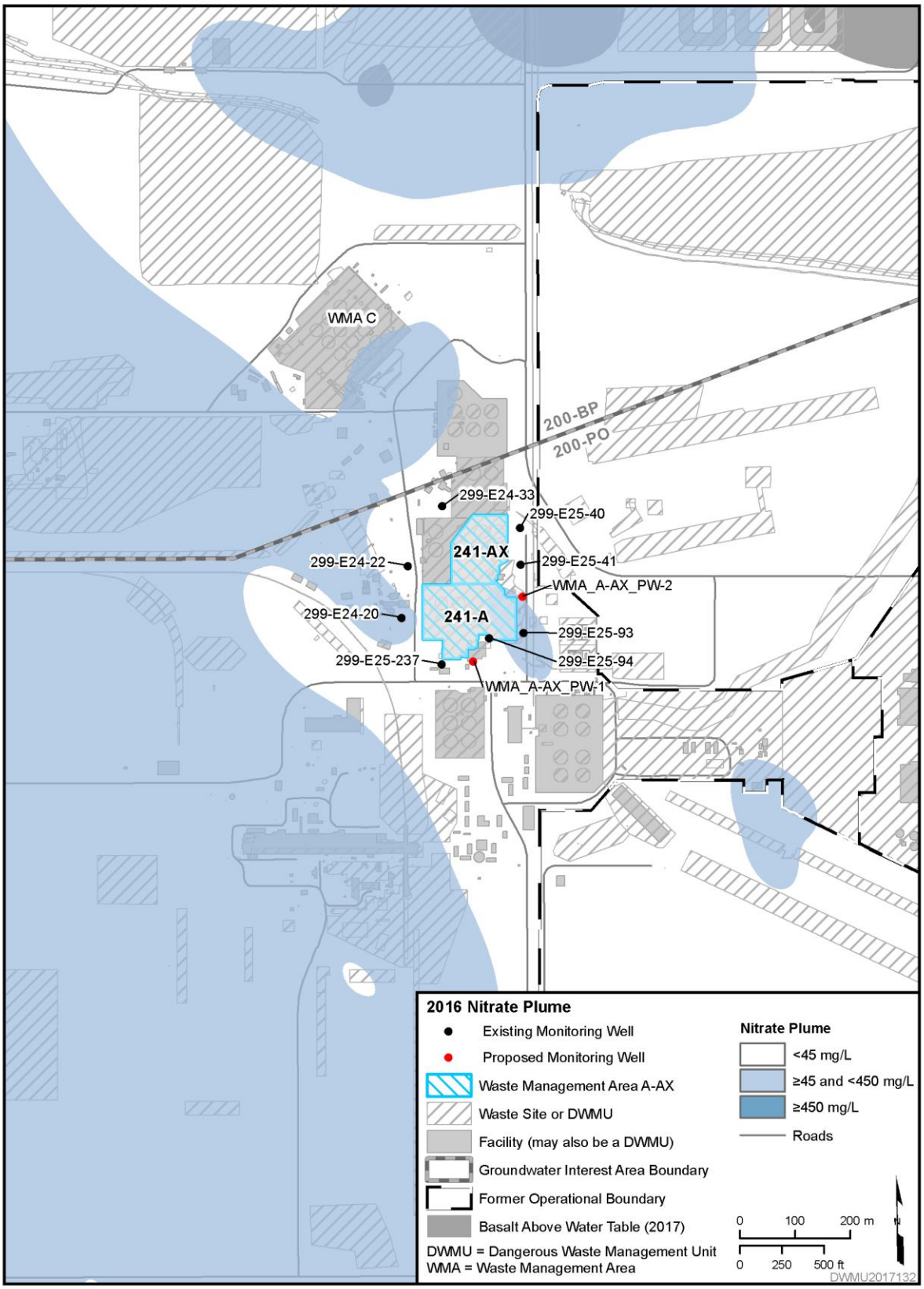

Figure C-1. Regional Nitrate Plume at WMA A-AX

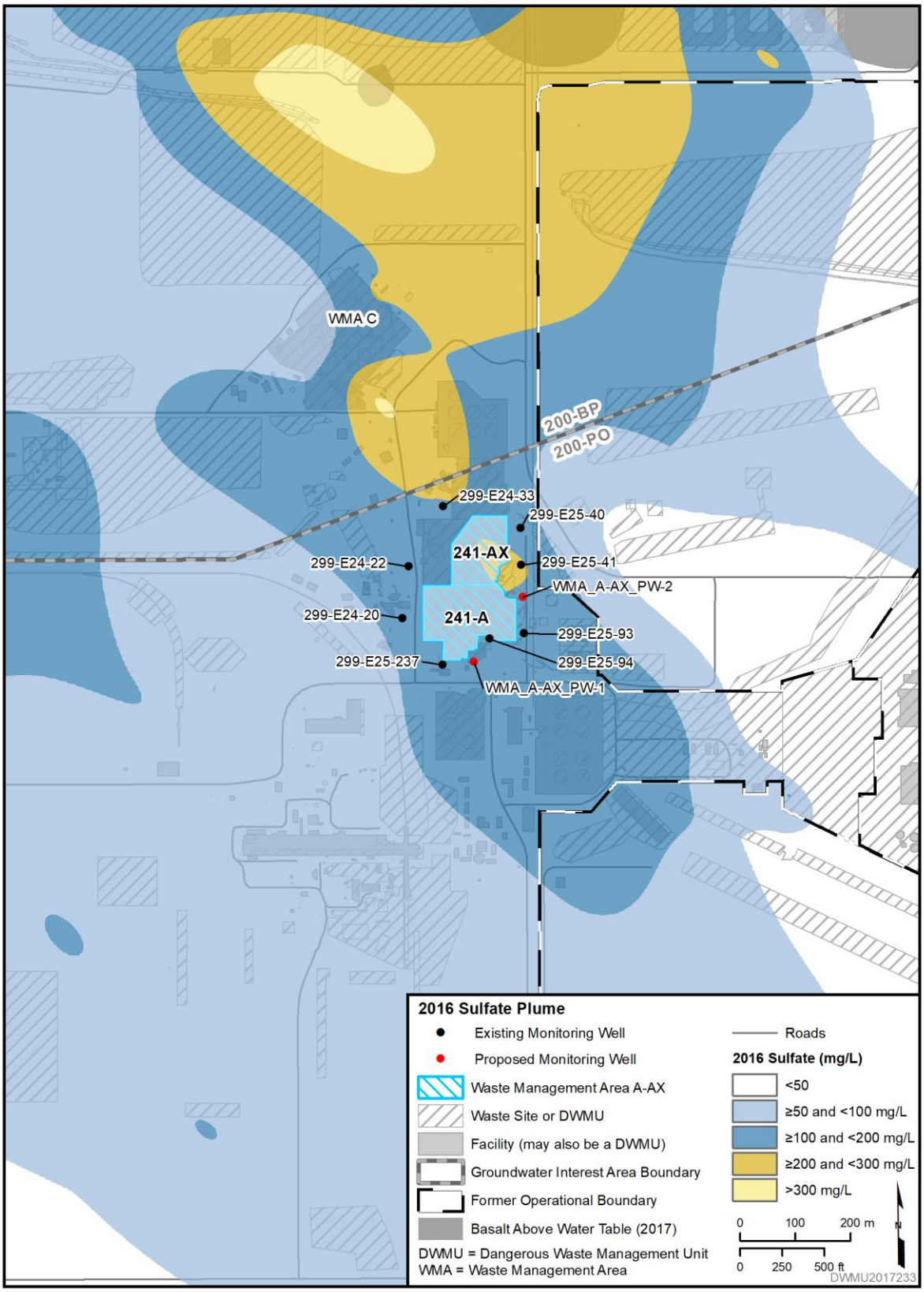

Figure C-2. Regional Sulfate Plume at WMA A-AX

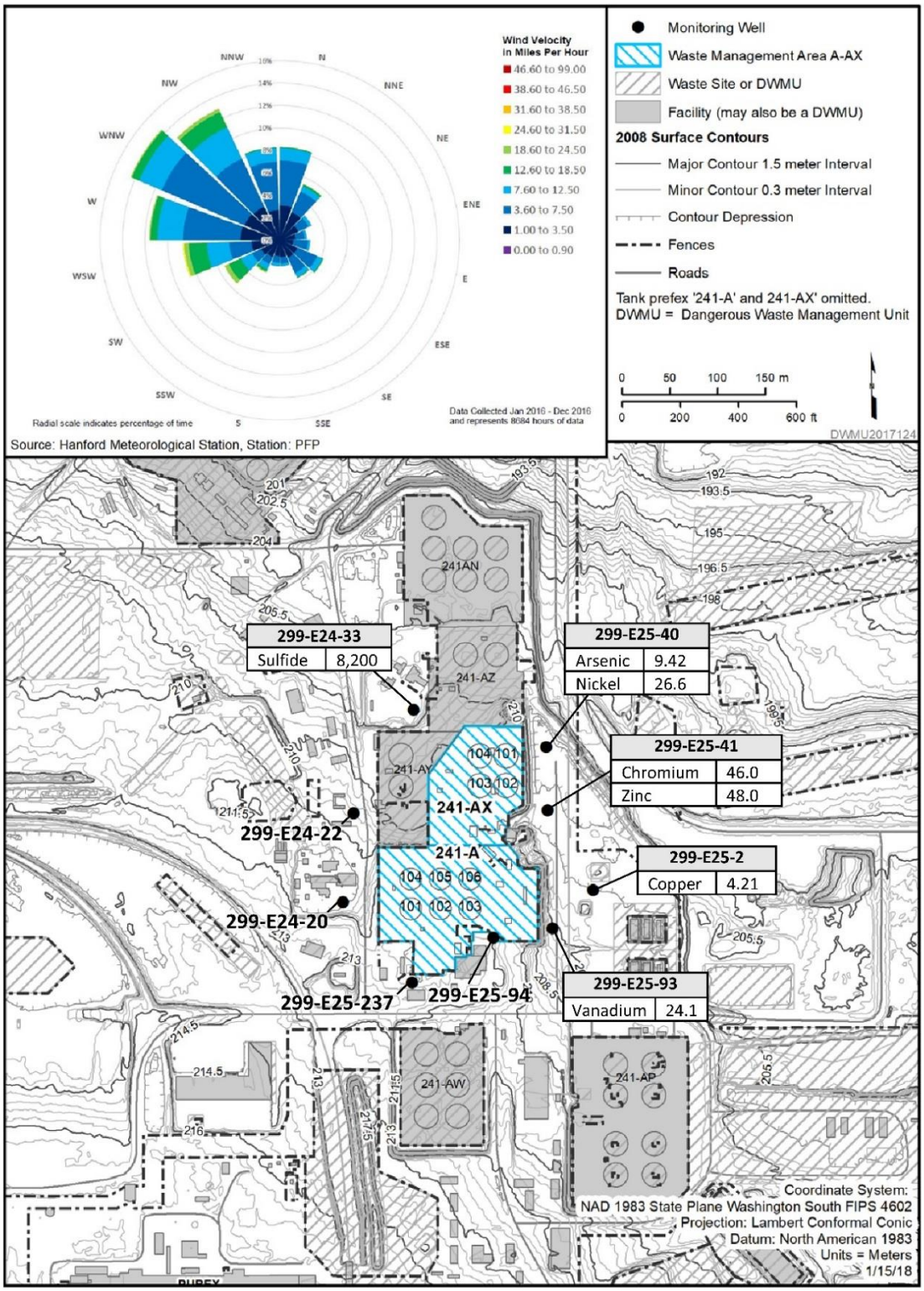

Figure C-3. 2016 Maximum Detected Groundwater Results of Metals and Inorganics in WMA A-AX Network Wells (µg/L)

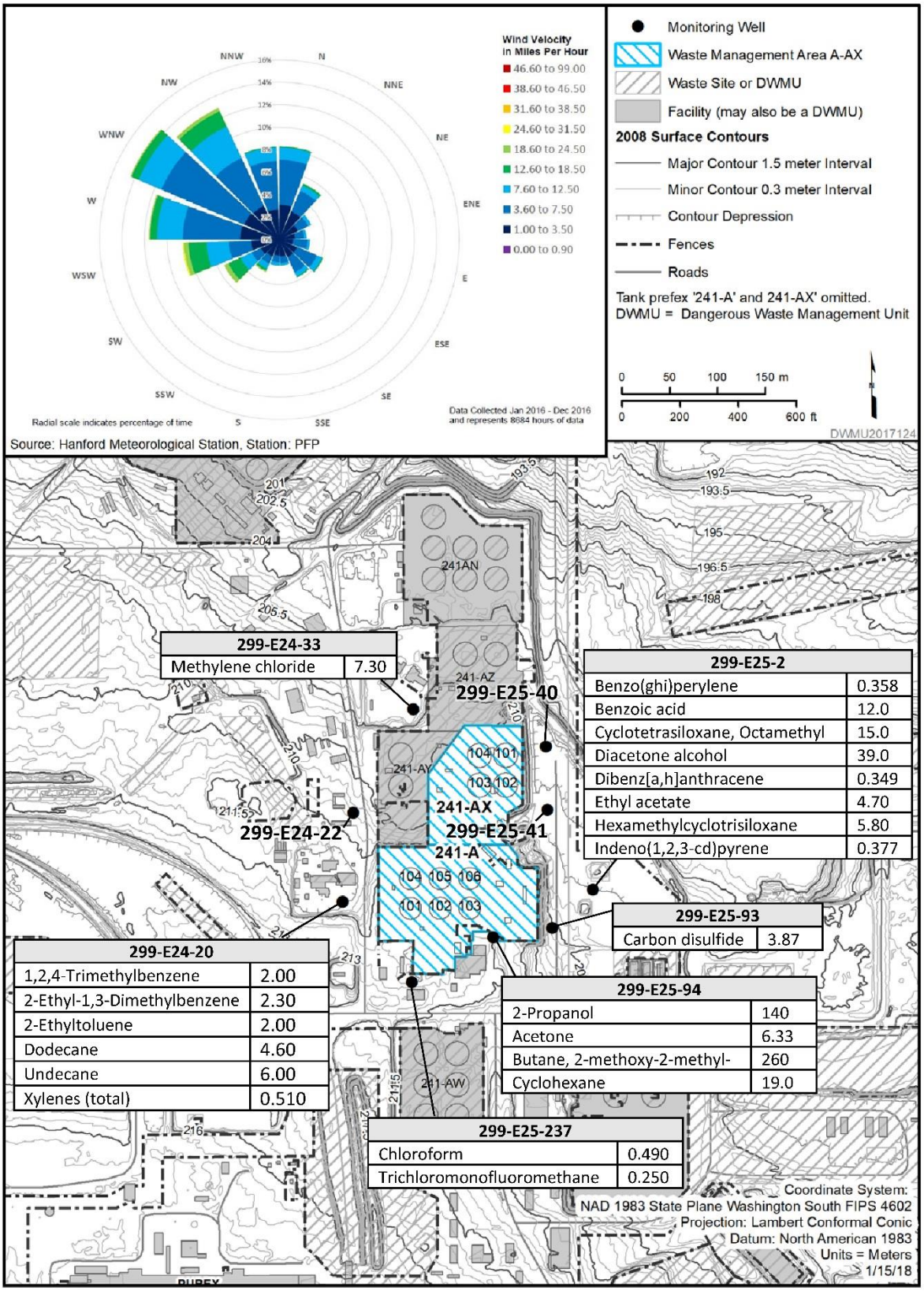

Figure C-4. 2016 Maximum Detected Groundwater Results of Organics in WMA A-AX Network Wells (µg/L)

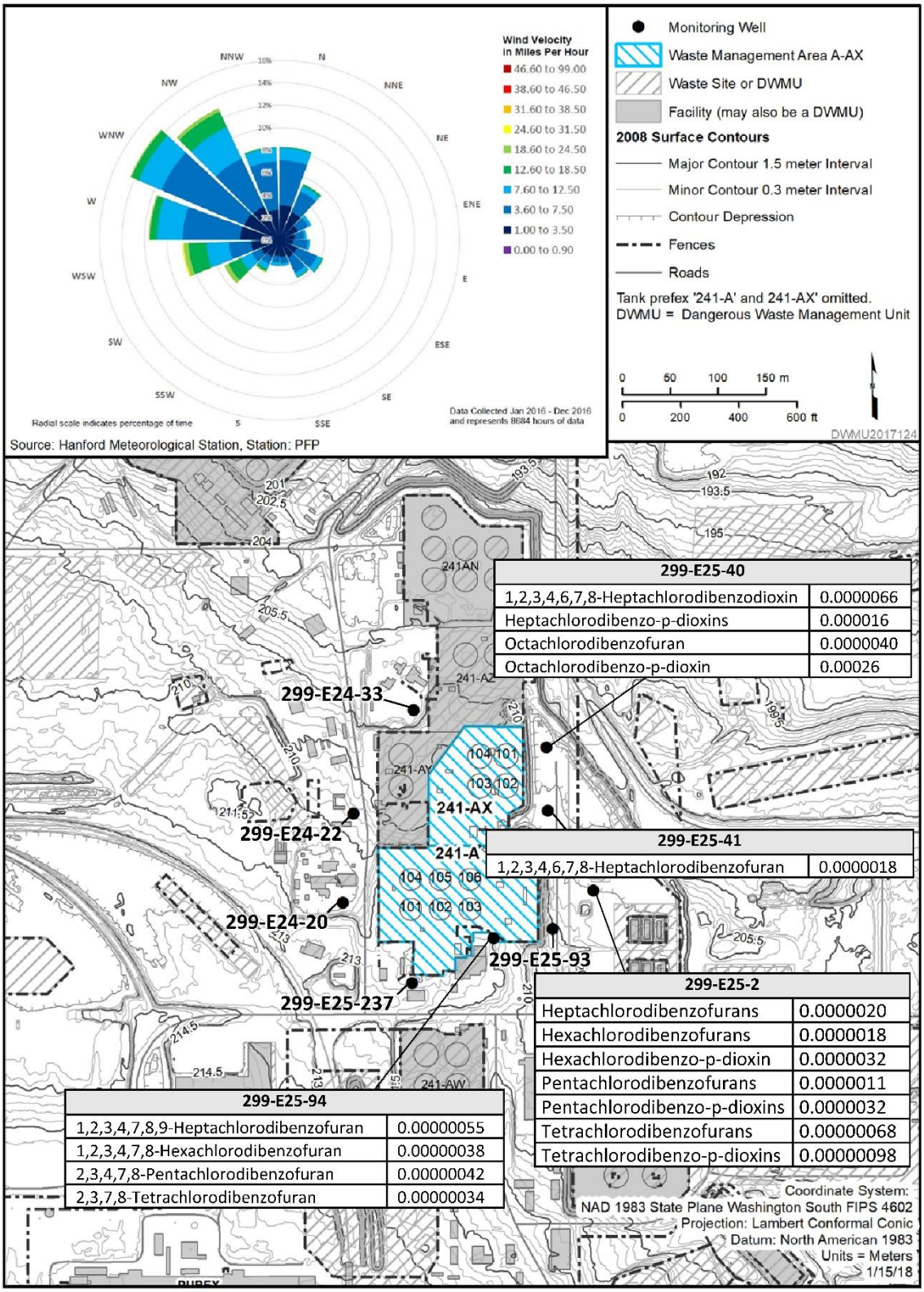

Figure C-5. 2016 Maximum Detected Groundwater Results of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans in WMA A-AX Network Wells (µg/L)

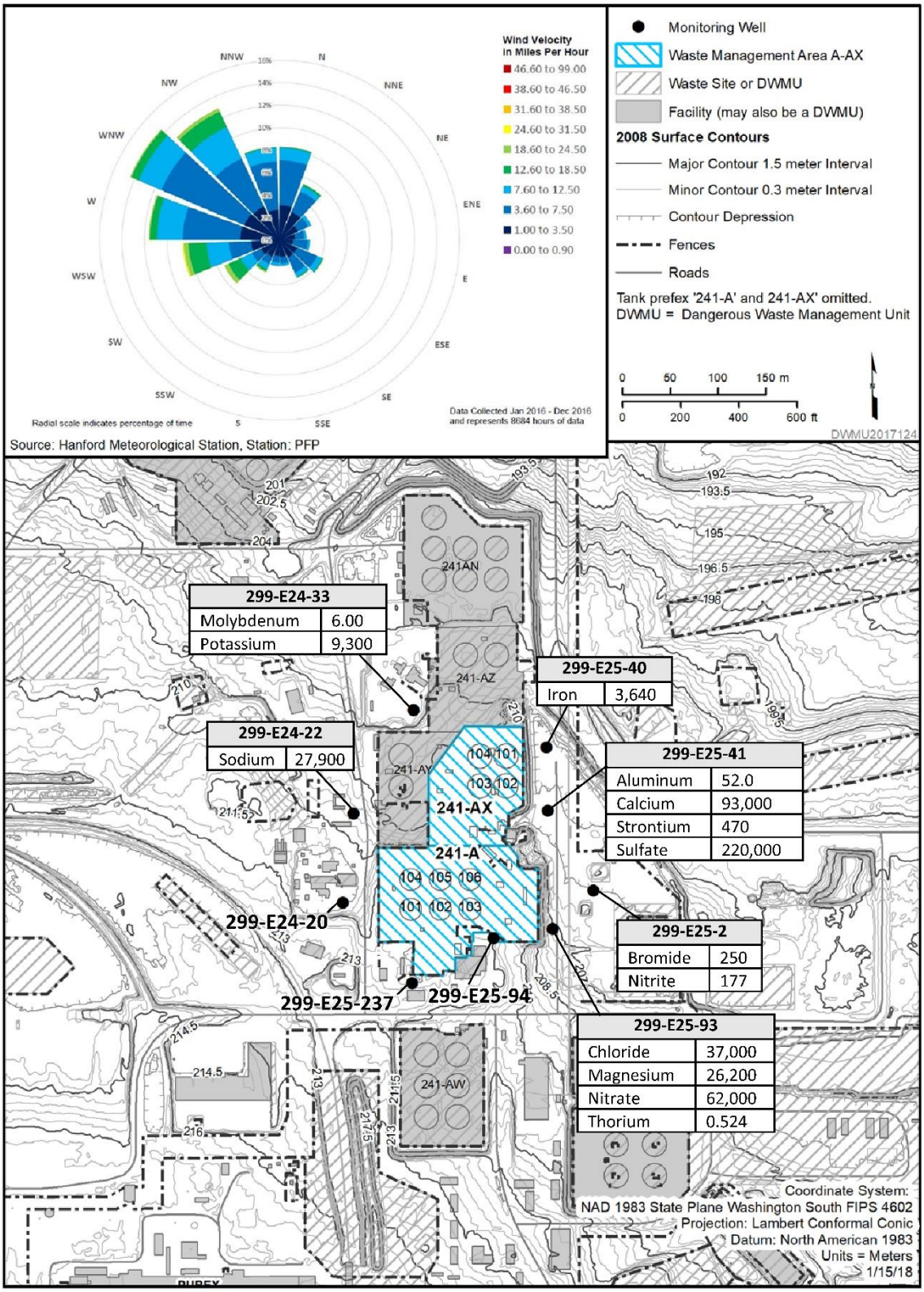

Figure C-6. 2016 Maximum Detected Groundwater Results of Nondangerous Constituents in WMA A-AX Network Wells (µg/L)

C2 References

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Appendix D

Well As-Built Diagrams and Proposed Well Locations

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D1 Introduction

This appendix provides the following information for the existing Waste Management Area (WMA) A-AX groundwater monitoring wells:

- Well name
- Hydrogeologic unit monitored (the aquifer portion at the well screen perforation) (Table D-1)
- The following sampling interval information, as provided in Table D-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 information is provided in Table D-3:

- Well location
- Surface elevation
- Estimated water elevation
- Estimated water depth

Figures D-1 through D-8 provide construction and completion summaries for the existing network wells.

Table D-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 D-2. Sampling Interval Information for Wells Within the WMA A-AX 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-E24-20	TU	125.01 (410.1)	118.87 (390.0)	6.1 (20.1)	Cable tool
299-E24-22	TU	122.32 (401.13)	111.64 (366.3)	10.7 (35.1)	Becker hammer
299-E24-33	TU	122.18 (400.9)	111.51 (365.79)	10.7 (35.0)	Cable tool
299- E25-40	TU	126.230 (414.4)	119.90 (393.4)	6.4 (21.0)	Cable tool
299- E25-41	TU	126.91(416.4)	120.51 (395.4)	6.4 (21.0)	Cable tool
299- E25-93	TU	122.46 (401.8)	111.79 (366.7)	10.7 (35.0)	Becker hammer
299- E25-94	TU	121.36 (398.2)	110.70 (363.2)	10.7 (35.0)	Cable tool
299-E25-237	TU	123.18 (404.1)	112.51 (369.1)	10.7 (35.0)	Cable tool

Table D-2. Sampling Interval Information for Wells Within the WMA A-AX 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 Figures D-1 through D-8.

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

Table D-3. Planned Locations, Surface Elevations, and Estimated Water Elevations and Depths for Proposed Wells Within the WMA A-AX 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_A-AX_PW-1	135970.28	575381.11	212.2 (696.2)	121.7 (399.3)	90.5 (296.9)	TBD	TBD	TBD	TBD
WMA_A-AX_PW-2	136087.54	575469.93	208.8 (685.0)	121.7 (399.3)	87.1 (285.8)	TBD	TBD	TBD	TBD

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

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

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

bgs = below ground surface

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

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WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Cable Tool	Sample Method:	Grab/Split Spoon	WELL NUMBER:	299-E24-20 A4756
Drilling Fluid Used:	NA	Additives Used:	None	TEMPORARY WELL NO:	None
Driller's Name:	K. Olson	WA State Lic Nr:	Not Available	Coordinates: N	Not documented
Drilling Company:	KEH Constr. Forces	Company Location:	Hanford	Coordinates: E	Not documented
Date Started:	31Jan91	Date Completed:	14Mar91	Start Card #:	Not Available
				Elevation Ground Surface:	

Depth to Water: 281.6 ft 13Mar91
(Ground surface) 285.64 ft 02May91

GENERALIZED STRATIGRAPHY Geologist's Log

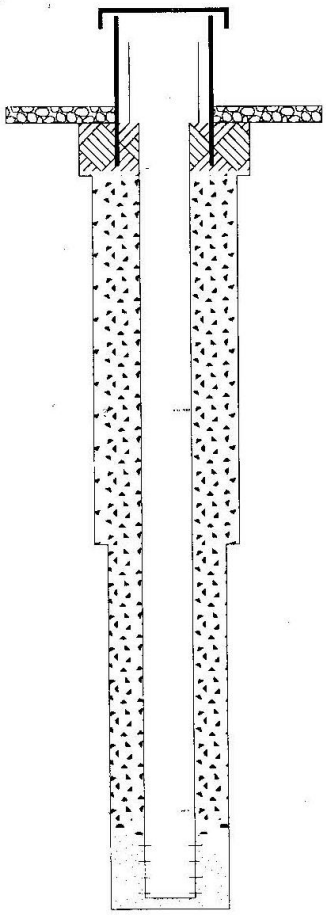
Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 18.3 ft.

Type of Surface Seal: 4x4 Concrete Pad

0 - 15 ft : Slightly Silty Gravelly Sand
15 - 20 ft : Gravelly Sand
20 - 25 ft : Slightly Silty Gravelly Sand
25 - 27 ft : Gravelly Silt
27 - 35 ft : Gravelly Sand
35 - 90 ft : Sandy Gravel
90 - 95 ft : Gravelly Sand
95 - 100 ft : Slightly Gravelly Sand
100 - 105 ft : Sand
105 - 115 ft : Sandy Gravel
115 - 125 ft : Gravelly Sand
125 - 130 ft : Sandy Gravel
130 - 135 ft : Gravelly Sand
135 - 140 ft : Sand
140 - 160 ft : Gravelly Sand
160 - 185 ft : Sand
185 - 200 ft : Slightly Gravelly Sand
200 - 210 ft : Sand
210 - 215 ft : Gravelly Sand
215 - 220 ft : Sand
220 - 225 ft : Slightly Gravelly Sand
225 - 230 ft : Sand
230 - 240 ft : Slightly Gravelly Sand
240 - 250 ft : Gravelly Sand
250 - 255 ft : Slightly Gravelly Sand
255 - 265 ft : Gravelly Sand
265 - 275 ft : Sand
275 - 280 ft : Gravelly Sandy Silt
280 - 290 ft : Gravelly Sand
290 - 295 ft : Sandy Gravel
295 - 300 ft : Sand
300 - 304.02 ft : Sandy Gravel



Fill	*Casing*	*Screen*
0 - 18.3 ft : 13-inch hole Cement	0 - 20.33 ft : 13 inch 12-3/4" CS Temp. Casing	
18.3 - 20.33 ft : 13-inch hole 8-20 Mesh Bentonite Crumbles	0 - 279.23 ft : 4 inch 4" Perm. Casing	
20.33 - 163.1 ft : 11-inch hole 8-20 Mesh Bentonite Crumbles	20.33 - 163.1 ft : 11 inch 10-3/4" CS Temp. Casing	
163.1 - 269.3 ft : 9-inch hole 8-20 Mesh Bentonite Crumbles	163.1 - 304.02 ft : 9 inch 8-5/8" CS Temp. Casing	
269.3 - 274.7 ft : 9-inch hole 1/4" - 3/8" Bentonite Pellets		279.23 - 299.35 ft : 4 inch 4" .010 SS Wire Wrap Pipe Size
274.7 - 299.65 ft : 9-inch hole 8-12 Silica Sand	299.35 - 299.65 ft : 4 inch End Cap	
299.65 - 304.02 ft : 9-inch hole 8-12 Silica Sand		

304.02 ft : Borehole drilled depth

0 - 20.33 ft : 13-in. 12-3/4" CS Temp. Casing
20.33 - 163.1 ft : 11-in. 10-3/4" CS Temp. Casing
163.1 - 304.02 ft : 9-in. 8-5/8" CS Temp. Casing

Drawing By: DLF
Reference: Hanford Wells
Revision: 0
Revision Date: 07Jan98
Print Date: 07Jan98

Figure D-1. Well 299-E24-20 Construction and Completion Summary

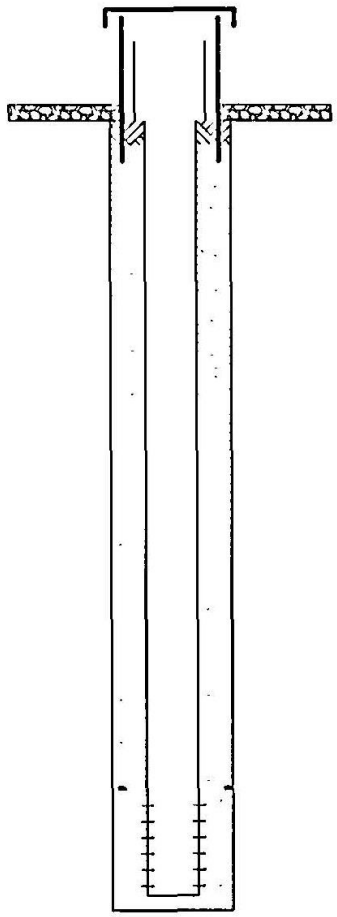
AS-BUILT WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Becker Hammer	Sample Method:	Grab/Split Spoon	WELL NUMBER:	299-E24-22 C4123
Drilling Fluid Used:	Air	Additives Used:	None	TEMPORARY WELL NO:	Not Allowed
Driller's Name:	Paul Lodder	WA State Lic Nr:	1628	Coordinates: N	Not documented
Drilling Company:	Layne Christensen	Company Location:	Salt Lake City, Ut	Coordinates: E	Not documented
Date Started:	10Jul03	Date Completed:	17Jul03	Start Card #:	R05132
				Elevation Ground Surface:	

Depth to Water: 286.02 ft 17Jul03
(Ground surface)

GENERALIZED STRATIGRAPHY Geologist's Log

0 - 2 ft : Backfill
2 - 15 ft : Sand (s)
15 - 25 ft : gravelly Sand (gS)
25 - 175 ft : Sand (S)
175 - 180 ft : gravelly Sand (gS)
180 - 220 ft : Sand (S)
220 - 225 ft : gravelly Sand (gS)
225 - 270 ft : Sand (S)
270 - 272 ft : silty/clay (m)
272 - 281 ft : Sand (S)
281 - 285 ft : gravelly Sand (gS)
285 - 290 ft : Sand (S)
290 - 300 ft : gravelly Sand (gS)
300 - 310 ft : sandy Gravel (sG)
310 - 330 ft : silty sandy Gravel (msG)



Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 10 ft

Type of Surface Seal: 4x4 Concrete Pad

Fill	Casing	Screen
0 - 10 ft : 9-inch hole Cement surface seal	0 - 286.21 ft : 4 inch 304 SS sch 5 csg	
10 - 276.5 ft : 9-inch hole Granular bentonite		
276.5 - 281.1 ft : 9-inch hole 1/4" bentonite pellets		286.21 - 321.26 ft : 4 inch 304 SS wire wrap .020 slot scrn
281.1 - 323.68 ft : 9-inch hole 10/20 Silica sand	321.26 - 323.68 ft : 4 inch SS sump/end cap	
323.68 - 330 ft : 9-inch hole 10/20 Silica sand		

330 ft : Borehole drilled depth

0 - 330 ft : 9-in. Becker Hammer 9"X6" dual wall temp drive pipe

Drawing By:	JEA
Reference:	Hanford Wells
Revision:	0
Revision Date:	06Oct03
Print Date:	07Oct03

Figure D-2. Well 299-E24-22 Construction and Completion Summary

WELL SUMMARY SHEET	Start Date: 04/16/04 Finish Date: 06/02/04	Page 1 of 2

Well ID: C4259	Well Name: 299-E24-33
Location: n. west of AX Tank Farm/200 East	Project: RCRA / CERCLA drilling, FY 2004
Prepared By: Charlene Martinez — Date: 06/04/04	Reviewed By: L.D. Walker — Date: 6/10/04
Signature: Charlene Martinez	Signature: LD Walker

CONSTRUCTION DATA		GEOLOGIC/HYDROLOGIC DATA		
Description	Diagram	Depth in Feet	Graphic Log	Lithologic Description
10 5/8" OD temporary casing set to 265' bgs		0		0-0.3' crushed gravel (drill pad)
				0.3'-23' SAND(S)
6" ID SS protective casing set +1.08' above permanent				23'-26' gravelly SAND(gS)
				26'-40' SAND(S)
4" ID SS304 riser (schedule 5): +2.05' → 275.1'		40		40'-58' slightly silt gravelly sand(mgS)
				58'-78' SAND(S)
				68'-silt lens (<0.3' thick)
Portland Cement Grout: 11' → 0'		80		78'-90' slightly silt gravelly sand (mgS)
				90'-115' gravelly SAND(gS)
Granular Bentonite: 11' → 245.6'				115'-252' SAND(S)
		120		
		160		
All depths in feet below ground surface:				
All temporary casing removed from ground.		200		

Figure D-3. Well 299-E24-33 Construction and Completion Summary (1 of 2)

WELL SUMMARY SHEET

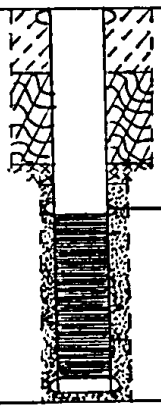
Start Date: 04/16/04
Finish Date: 06/02/04
Page 2 of 2

Well ID: C4257	Well Name: 299-E24-33
Location: 1 west of AX Tank Farm/200 East	Project: RCRA/CERCLA drilling: FY2004
Prepared By: Charlene Martinez Date: 06/04/04	Reviewed By: L.D. Walker Date: 6/10/04
Signature: Charlene Martinez	Signature: LD Walker

CONSTRUCTION DATA

Description
8 5/8" OD carbon steel casing set from 265'–315'
Portland Cement Grout: 246.6' → 264.7'
3/8" Bentonite Pellets: 264.7' → 269.4'
10-20 mesh Colorado Silica sand 269.4' → 315.4'
4" ID SS 304, sched. 5, 0.020-inch slot well screen: 275.1' → 310.1'
4" ID SS 304, sched. 5 sump: 310.1' → 313.1'
All depths in feet below ground surface.
All temporary casing removed from ground.

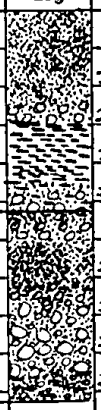
Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 240, 280, 320, 360, 400

Graphic Log



Lithologic Description
252'–255.5' sandy GRAVEL (SG)
255.5'–267.5' SILT (m)
267.5'–268.5' sandy SILT (sm)
268.5'–274' silty sandy GRAVEL (msG)
274'–275' SAND (S)
275'–280' sandy GRAVEL (SG)
280'–290' SAND (S)
290'–292' silty sandy GRAVEL (msG)
292'–313' sandy GRAVEL (SG)
313'–315.4' silty sandy GRAVEL (msG)
TD = 315.4' bgs
Static water @ 274.35' bgs (06/02/04)

A-6003-643 (03/03)

Figure D-3. Well 299-E24-33 Construction and Completion Summary (2 of 2)

A 4789

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number 299-E25-40 Geologist M D Lobrecht GOODWIN Page 1 of 3

Reviewed by V. T. McGhan Date 12-4-89

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description
143.7' of 10" CARBON STEEL CASING		5		SAND (Tr Cobbles)
		10		SAND
CEMENT GROUT		15		SAND
		20		SAND (Tr. Cobbles)
273.1' of 8" CARBON STEEL CASING		25		"
		30		"
		35		"
		40		SANDY GRAVEL
		45		SAND
FACTORY INSTALLED CENTRALIZERS		50		"
		55		"
253.25' of 4" DIA. STAINLESS STEEL CASING		60		"
		65		SLIGHTLY GRAVELLY SAND
		70		Sl. Gravelly SAND
		75		Sandy GRAVEL
		80		Gravelly SAND
		85		Gravelly SAND
8-20 BENTONITE		90		Gravelly SAND
		95		Gravelly SAND
		100		SAND
		105		SAND
		110		SAND
		115		SAND
		120		SAND
		125		SAND
		130		SAND

A-1800-186 (3/87)

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Figure D-4. Well 299-E25-40 Construction and Completion Summary (1 of 3)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number 299-E25-40 Geologist M.O Lubrecht, Goodwin Page 2 of 3

Reviewed by V.L. McElhan Date 12-4-89

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description
10" DIA CARBON STEEL		135		SAND
CASING 0'- 143.7'		140		SAND
		145		SAND
		150		SAND
8" DIA. CARBON STEEL		155		"
CASING 0'- 273.1'		160		"
		165		slightly gravelly SAND
		170		" " "
		175		SAND
		180		"
		185		"
		190		"
		195		Sandy GRAVEL
		200		" "
		205		" "
		210		SLIGHTLY GRAVELLY SAND
		215		" " "
		220		SAND
		225		"
8-20 BENTONITE		230		"
		235		"
		240		"
3/8" VOLCLAY TABLETS		245		"
		250		SLIGHTLY MUDDY SAND
16-30 COL. SILICA SAND		255		MUD
		260	8-24-89	SLIGHTLY GRAVELLY SAND

A-1800-186 (3/87)

Figure D-4. Well 299-E25-40 Construction and Completion Summary (2 of 3)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number 299-E25-40 Geologist LUBRECHT, GOODWIN Page 3 of 3

Reviewed by [illegible] Date 12-4-89

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description
10-SLOT, STAINLESS STEEL CHANNEL PACK SCREEN -21.0'		265		SANDY GRAVEL
		270		" "
		275	T.D. 274'	

A-1800-186 (3/8

Figure D-4. Well 299-E25-40 Construction and Completion Summary (3 of 3)

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Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number 299-E25-41 Geologist M Lubrecht Page 1 of 3

Reviewed by [illegible] Date 12-7-89

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description
10" CARBON STEEL CASING		5		SAND
0-138'-7 1/2" (TEMPORARY)		10		SAND
		15		Sl. Muddy SAND
		20		Sandy GRAVEL
290'-3" of 8" CARBON		25		Sandy GRAVEL
STEEL CASING		30		SAND
		35		SAND
		40		Muddy Sandy GRAVEL
257.[illegible] 4" STAINLESS		45		Sl. Gravelly SAND
STEEL CASING		50		SAND
		55		SAND
		60		Sl. Gravelly SAND
		65		Sl. Gravelly SAND
		70		Gravelly SAND
		75		Gravelly SAND
		80		Sl. Gravelly SAND
		85		Gravelly SAND
		90		Gravelly SAND
		95		Gravelly SAND
		100		SAND
		105		SAND
		110		SAND
		115		SAND
		120		Interbedded SAND & muddy f. SAND
		125		Interbedded SAND & muddy f. SAND
		130		SAND

A-1800-186 (3/87)

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Figure D-5. Well 299-E25-41 Construction and Completion Summary (1 of 3)

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Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number 299 - E25 - 41 Geologist M. LUBRECHT Page 2 of 3

Reviewed by [illegible] Date 12-7-89

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description
139' 7 1/2" OF 10" CARBON STEEL CASING		135		SAND
		140		"
		145		"
280' 3" OF 5" CARBON STEEL CASING		150		"
		155		"
		160		"
		165		"
257.42' OF 4" STAINLESS STEEL CASING		170		"
		175		"
		180		slightly gravelly SAND
		185		" " "
		190		SAND
		195		"
		200		sandy GRAVEL
		205		sandy GRAVEL
		210		gravelly SAND
		215		" "
		220		MUDDY SANDY GRAVEL
		225		" " "
		230		GRAVELLY SAND
		235		" "
		240		" "
		245		" "
		250		" "
		255		SANDY MUD
		260		" "

A-1800-186 (3-87)

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Figure D-5. Well 299-E25-41 Construction and Completion Summary (2 of 3)

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AS-BUILT DIAGRAM

Well Number 299-E25-41 Geologist M. LUBRECHT Page 3 of 3

Reviewed by [illegible] Date 12-7-89

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description D/W @ 262.24 9-22-89
280' 3" of 6" CARBON STEEL CASING		265		SANDY MUD
		270		MUDDY SANDY GRAVEL
		275		SANDY GRAVEL
21.01' of 4" CHANNEL PACK SCREEN (10 SLOT)				

COMPLETION SYMBOLS:

- CEMENT GROUT
- BENTONITE CRUMBLES
- BENTONITE PELLETS
- SILICA SAND
- CASING JOINT
- CASING CENTRALIZER

A-1800-186 (3/8)

Figure D-5. Well 299-E25-41 Construction and Completion Summary (3 of 3)

WELL SUMMARY SHEET	Start Date: 07/01/03 Finish Date: 07/09/03	Page 1 of 2
Well ID: C4122	Well Name: 299-E25-93	
Location: East of 241-A Tank Farm	Project: CY03 RCRA Drilling	
Prepared By: Charlene Martinez — Date: 07/15/03	Reviewed By: L.D. Walker — Date: 8/11/03	
Signature: Charlene Martinez	Signature: L.D. Walker	

CONSTRUCTION DATA

Description	Diagram
Dual-wall temporary casing used. 9" OD: Inner casing 7 1/6"	
Protective casing set (6" ID) + 1.11' above permanent casing	
4" ID SS 304 sched 10 casing: +2.00' → 278.23'	
Portland Cement Grout: 0' → 10.5'	
Granular Bentonite: 10.5' → 268.5'	
1/4" Bentonite Pellets: 268.5' → 273.1'	
All temporary casing removed from ground!	
All depths are in feet below ground surface.	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
0		0'-2' Backfill material
		2'-11' SAND(S)
		Hanford Formation @ 11' bgs.
		11'-20' SAND(S)
		20'-25' Gravelly SAND(gS)
40		25'-35' SAND(S)
		35'-45' Gravelly SAND(gS)
		45'-106' SAND(S)
80		
		106'-115' Gravelly SAND(gS)
		115'-215' SAND(S)
120		
160		
200		
		215'-220' gravelly SAND(gS)
		220'-266' SAND(S)

A-6003-643 (03/03)

Figure D-6. Well 299-E25-93 Construction and Completion Summary (1 of 2)

WELL SUMMARY SHEET

Start Date: 07/01/03
Finish Date: 07/09/03
Page 2 of 2

Well ID: C4122	Well Name: 299-E25-93
Location: East of 241-A Tank Farm	Project: C403 RCRA drilling
Prepared By: Charlene Martinez — Date: 07/15/03	Reviewed By: L.D. Walker — Date: 8/11/03
Signature: Charlene Martinez	Signature: LD Walker

CONSTRUCTION DATA

Description:

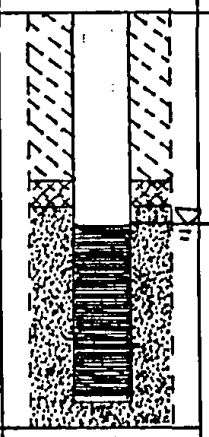
10-20 mesh silica sand:
273.1' → 320.0'
4" ID SS 304 schedule 10
well screen: .020 SLOT
278.23' → 313.26'

4" ID SS 304 schedule 10
sump endcap
313.26' → 315.26'

All temporary casing removed from ground.

All depths are in feet below ground surface.

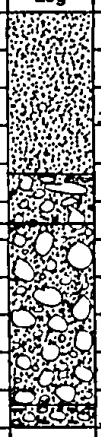
Diagram:



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 240, 280, 320

Graphic Log:



Lithologic Description:

240.6' - 317' sandy GRAVEL (SG)

Ringold formation @ 317' bgs

317' - 320' silty sandy GRAVEL (msG)

TD @ 320' bgs.

static water => 278.04' bgs (07/15/03)

A-6003-643 (03/03)

Figure D-6. Well 299-E25-93 Construction and Completion Summary (2 of 2)

WELL SUMMARY SHEET

Start Date: 09-13-04
Finish Date: 9-27-04
Page 1 of 2

Well ID: C4665	Well Name: 299-E25-94
Location: NE Corner of 242-A Evap. Parking Lot	Project: RCRA CY04 Monitoring Wells
Prepared By: Jess Hocking — Date: 9/27/04	Reviewed By: L.D. Walker — Date: 10-13-04
Signature: Jess Hocking	Signature: LD Walker

CONSTRUCTION DATA

Description	Diagram
4" sch. 5s TP-304/304L Riser 0.5' → 295.1'	
4" sch. 5s TP-304/304L CONT. WIRE-WRAP 0.020-SLOT SCREEN 295.1' → 330.1'	
4" sch. 5s TP-304/304L Sump 330.1' → 331.1'	
10-20 mesh Colorado Silica Sand 333' → 288'	
5/8" Wyoming Bentonite Pellets 288' → 282'	
Portland Cement 282' → 267'	
Pure Wyoming Bentonite Crumbles 267' → 13'	
Portland Cement 13' → 3'	
10" diameter temporary drill casing driven to 332' bgs	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
0		0-4' DRILL PAD / MISC. FILL MATERIAL
		4-44' Sand (S)
		44-45' Silt (M)
		45-70' Sand (S)
40		
		70-77' Slightly silty sand ((m)S)
		77-85' Slightly silty gravelly sand ((m)gS)
80		85-120' Slightly silty sand ((m)S)
120		120-140' Sand (S)
		140-145' Slightly silty sand ((m)S)
		145-150' Sand (S)
		150-160' Silty Sand (mS)
160		160-175' Slightly silty sand ((m)S)
		175-185' Sand (S)
		185-195' Slightly silty sand ((m)S)
		195-230' Sand (S)
200		
		230-235' Slightly silty sand ((m)S)
		235-268' Sand (S)

A-6003-643 (03/03)

Figure D-7. Well 299-E25-94 Construction and Completion Summary (1 of 2)

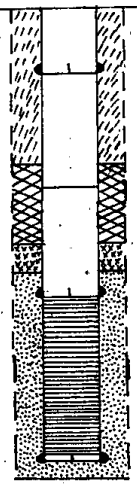
WELL SUMMARY SHEET

Start Date: 09-13-04
Finish Date: 9-27-04
Page 2 of 2

Well ID: C4665
Well Name: 299-E25-94
Location: NE Corner of 242-A Evap. Parking Lot.
Project: RCRA CY04 Monitoring Wells
Prepared By: Jess Hocking
Date: 9/27/04
Reviewed By: L.D. Walker
Date: 10/13/04
Signature: Jess Hocking
Signature: L.D. Walker

CONSTRUCTION DATA

Description	Diagram
NOTE: ALL TEMPORARY CASING HAS BEEN REMOVED FROM THE GROUND.	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
240		
		268-268.5' Gravelly Sand (gS)
		268.5-270' Gravelly silty sand (gmS)
		270-271.7' Silty sand (mS)
280		271.7'-280' Silt (M)
		280-285.5' Gravelly sand (gS)
		285.5-288' Sandy gravel (sG)
		288-296' Silty sandy gravel (msG)
		296-325' Sandy gravel (sG)
320		325-330' Slightly silty gravelly sand (~)gS)
		330-333' Gravelly sand (gS)
TD		333=TD Silty Sandy gravel (msG)
360		
		TD = 333' bgs (9/23/04)
		DTW = 295.6' bgs (9/21/04)

A-6003-643 (03/03)

Figure D-7. Well 299-E25-94 Construction and Completion Summary (2 of 2)

WELL SUMMARY SHEET	Start Date: 11-10-2014 Finish Date: 1-19-2015	Page 1 of 3
Well ID: C8922	Well Name: 299-E25-237	
Location: S. of WMA A-AX	Project: M24 Drilling	
Prepared by: Julie Johanson	Date: 12-17-14	Reviewed by: J.D. MEHRER	Date: 1/21/15
Signature: Julie Johanson	Signature:	

CONSTRUCTION DATA

Surface Completion:

4'x4'x6" Concrete Pad with brass survey marker and 6 9/16" protective monument (3.00' ags)

Well Completion material:

High Strength Concrete
0.0' bgs - 2.8' bgs

Type I/II Portland Cement
2.8' bgs - 10.42' bgs

Granular Bentonite (Medium Chips, 8-20 Crumbles, 3/4" Chunks)
10.42' bgs - 285.43' bgs

3/8" Bentonite Pellets
285.43' bgs - 287.27' bgs

10-20 Colorado Silica Sand
287.27' bgs - 332.3' bgs

3/8" Bentonite Pellets
332.3' bgs - 334.1' bgs

3/4" Bentonite Chunks
334.1' bgs - 372.04' bgs

Natural Fill
372.04' bgs - 374.78' bgs

Permanent Well:

4" ID PVC Blank
1.98' ags - 291.00' bgs

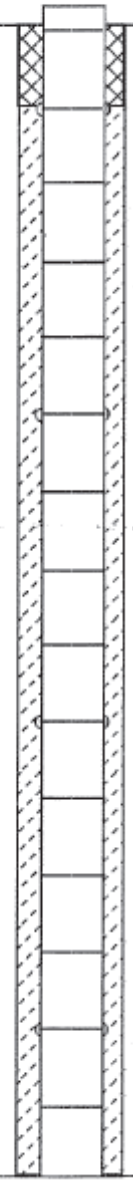
4" ID Stainless Steel 0.020 Slot Screen
291.00' bgs - 326.00' bgs

4" ID Stainless Steel Sump
326.00' bgs - 329.02' bgs

All temporary casing completely removed from ground on 1/15/2015

ags = above ground surface
bgs = below ground surface

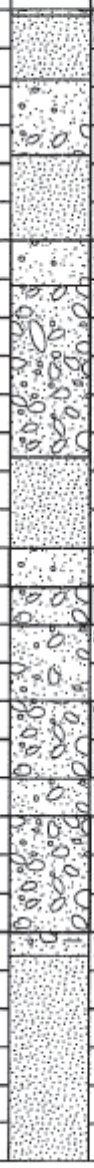
Diagram



GEOLOGIC/HYDROLOGIC DATA

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

Graphic Log



Lithologic Description

0-0.5: Gravelly Sand (gS) Drill Pad.
0.5-9: Sand (S)
9-18: Gravelly Sand (gS)
18-30: Sand (S)
30-36: Gravelly Sand (gS)
36-58: Sandy Gravel (sG)
58-70: Sand (S)
70-75: Gravelly Sand (gS)
75-80: Sandy Gravel (sG)
80-90: Gravelly Sand (gS)
90-100: Sandy Gravel (sG)
100-105: Gravelly Sand (gS)
105-120: Sandy Gravel (sG)
120-123: Slightly Silty Gravelly Sand((m)gS)
123-167: Sand (S)

A-6003-843 (03/03)

Figure D-8. Well 299-E25-237 Construction and Completion Summary (1 of 3)

WELL SUMMARY SHEET	Start Date: 11-10-2014 Finish Date: 1-19-2015	Page 2 of 3
Well ID: C8922	Well Name: 299-E25-237	
Location: S. of WMA A-AX	Project: M24 Drilling	
Prepared by: Julie Johanson	Date: 12-17-14	Reviewed by: J.D. MEHRER	Date: 1/21/15
Signature: Julie Johanson	Signature:	

CONSTRUCTION DATA

Well Completion material:

High Strength Concrete
0.0' bgs - 2.8' bgs

Type I/II Portland Cement
2.8' bgs - 10.42' bgs

Granular Bentonite (Medium Chips, 8-20 Crumbles, 3/4" Chunks)
10.42' bgs - 285.43' bgs

3/8" Bentonite Pellets
285.43' bgs - 287.27' bgs

10-20 Colorado Silica Sand
287.27' bgs - 332.3' bgs

3/8" Bentonite Pellets
332.3' bgs - 334.1' bgs

3/4" Bentonite Chunks
334.1' bgs - 372.04' bgs

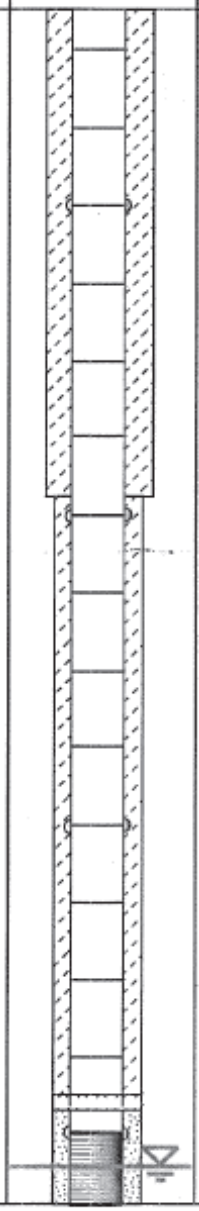
Natural Fill
372.04' bgs - 374.78' bgs

Permanent Well:

4" ID PVC Blank
1.98' ags - 291.00' bgs

4" ID Stainless Steel 0.020 Slot Screen
291.00' bgs - 326.00' bgs

4" ID Stainless Steel Sump
326.00' bgs - 329.02' bgs



GEOLOGIC/HYDROLOGIC DATA

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

Lithologic Description:

123-167: Sand (S)
167-170: Gravelly Sand (gS)
170-220: Sand (S)
220-230: Slightly Silty Sand ((m)S)
230-235: Sand (S)
235-243: Slightly Silty Sand ((m)S)
243-248: Slightly Silty Gravelly Sand((m)gS)
248-278: Sand (S)
278-280.7: Sandy Silt (sM)
280.7-290: Gravelly Silty Sand (gmS)
290-305: Silty Sandy Gravel (msG)
DTW: 295.36' bgs

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Figure D-8. Well 299-E25-237 Construction and Completion Summary (2 of 3)

WELL SUMMARY SHEET	Start Date: 11-10-2014 Finish Date: 1-19-2015	Page 3 of 3
Well ID: C8922	Well Name: 299-E25-237	
Location: S. of WMA A-AX	Project: M24 Drilling	
Prepared by: Julie Johanson	Date: 12-17-14	Reviewed by: J.D. MEHRER	Date: 1-21-15
Signature: Julie Johanson	Signature: J.D. Mehrer	

CONSTRUCTION DATA

Well Completion:

High Strength Concrete
0.0' bgs - 2.8' bgs

Type I/II Portland Cement
2.8' bgs - 10.42' bgs

Granular Bentonite (Medium Chips, 8-20 Crumbles, 3/4" Chunks)
10.42' bgs - 285.43' bgs

3/8" Bentonite Pellets
285.43' bgs - 287.27' bgs

10-20 Colorado Silica Sand
287.27' bgs - 332.3' bgs

3/8" Bentonite Pellets
332.3' bgs - 334.1' bgs

3/4" Bentonite Chunks
334.1' bgs - 372.04' bgs

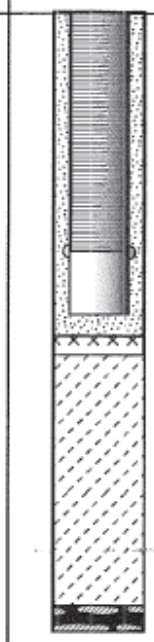
Natural Fill
372.04' bgs - 374.78' bgs

Permanent Well:

4" ID PVC Blank
1.98' ags - 291.00' bgs

4" ID Stainless Steel 0.020 Slot Screen
291.00' bgs - 326.00' bgs

4" ID Stainless Steel Sump
326.00' bgs - 329.02' bgs



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 300, 325, 350, 375

Graphic Log

Lithologic Description

290-305: Silty Sandy Gravel (msG)

305-306: Sand (S)
306-345.78: Silty Sandy Gravel (msG)

345.78-366.19: Silty Sandy Gravel (msG) (Hard tool Slurry)

366.19-374.5: Silty Sandy Gravel (msG)

374.5-375: Basalt

TD: 374.78' bgs

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Figure D-8. Well 299-E25-237 Construction and Completion Summary (3 of 3)

D2 References

NAD83, 1991, *North American Datum of 1983*, as revised, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: http://www.ngs.noaa.gov/.

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 E

Statistical Method Determination

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E1 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, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*) of the main text at a quarterly frequency for 2 years. After 2 years of sampling is completed, the statistical test method can be determined using the flowcharts presented in this appendix.

The flowcharts (Figures E-1 through E-7) 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 flowcharts 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 analysis of variance (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 flowcharts do not proclaim to provide every detail of every process but are to be used as a guide.

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

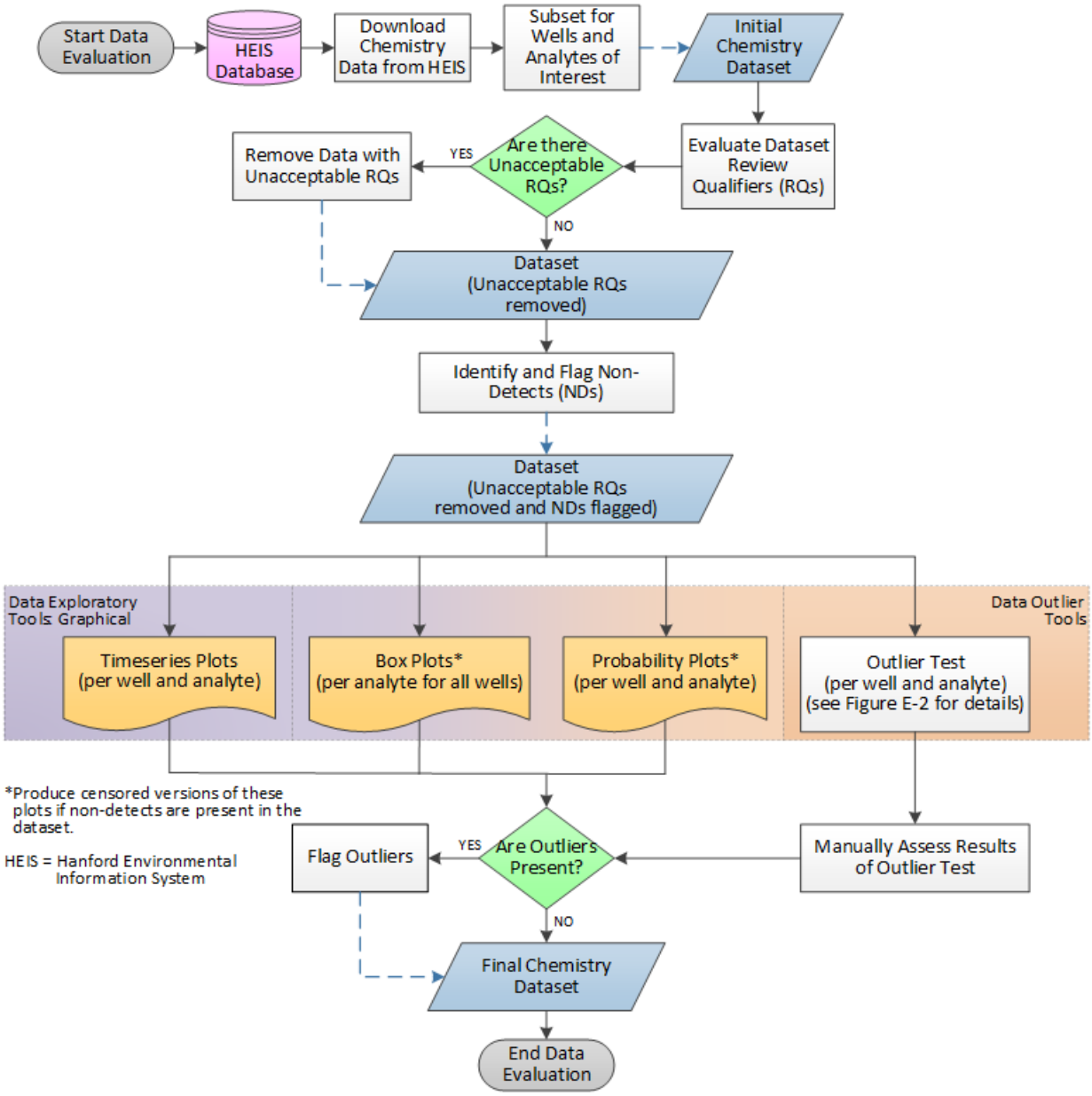


Figure E-1. Data Evaluation

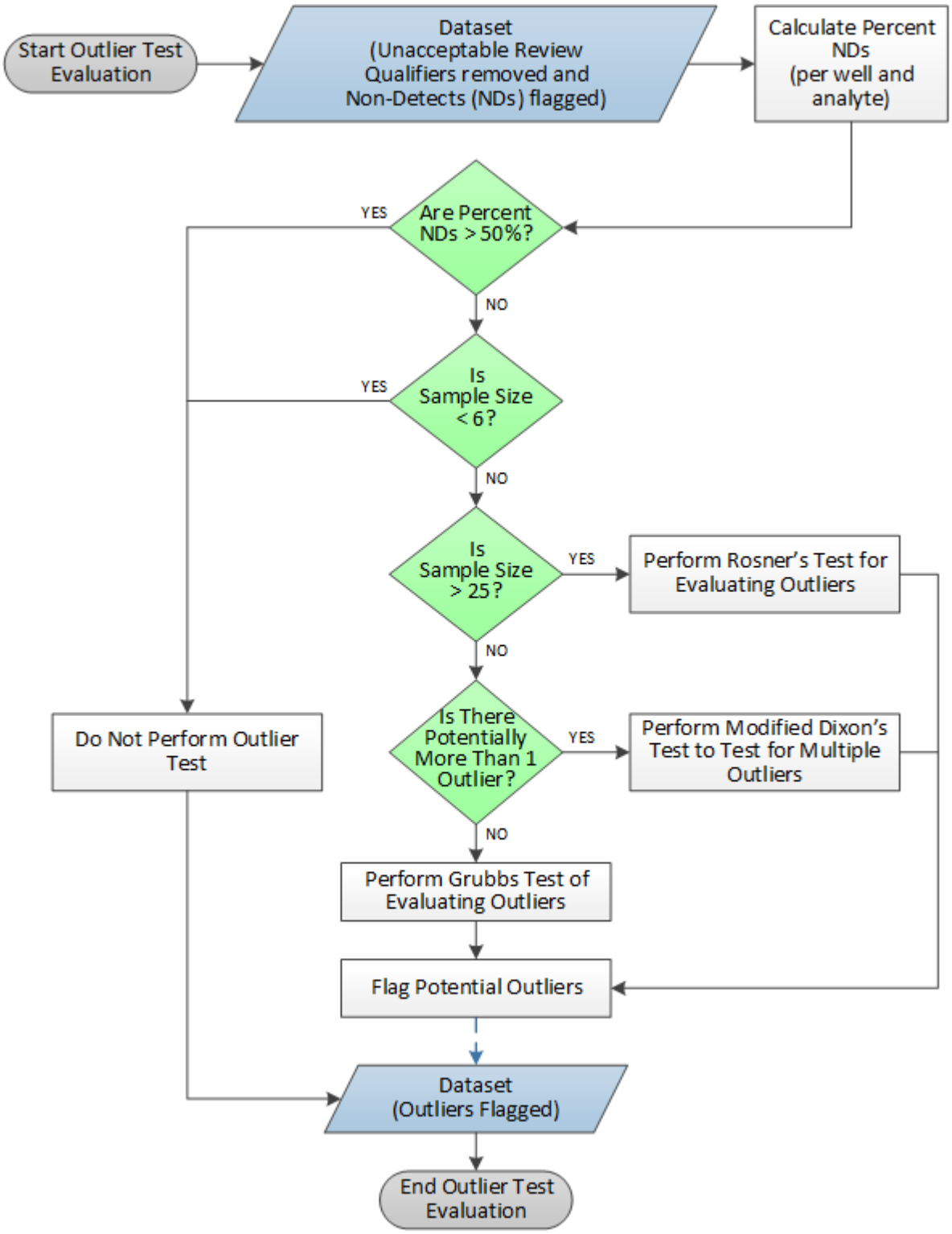


Figure E-2. Outlier Test Evaluation

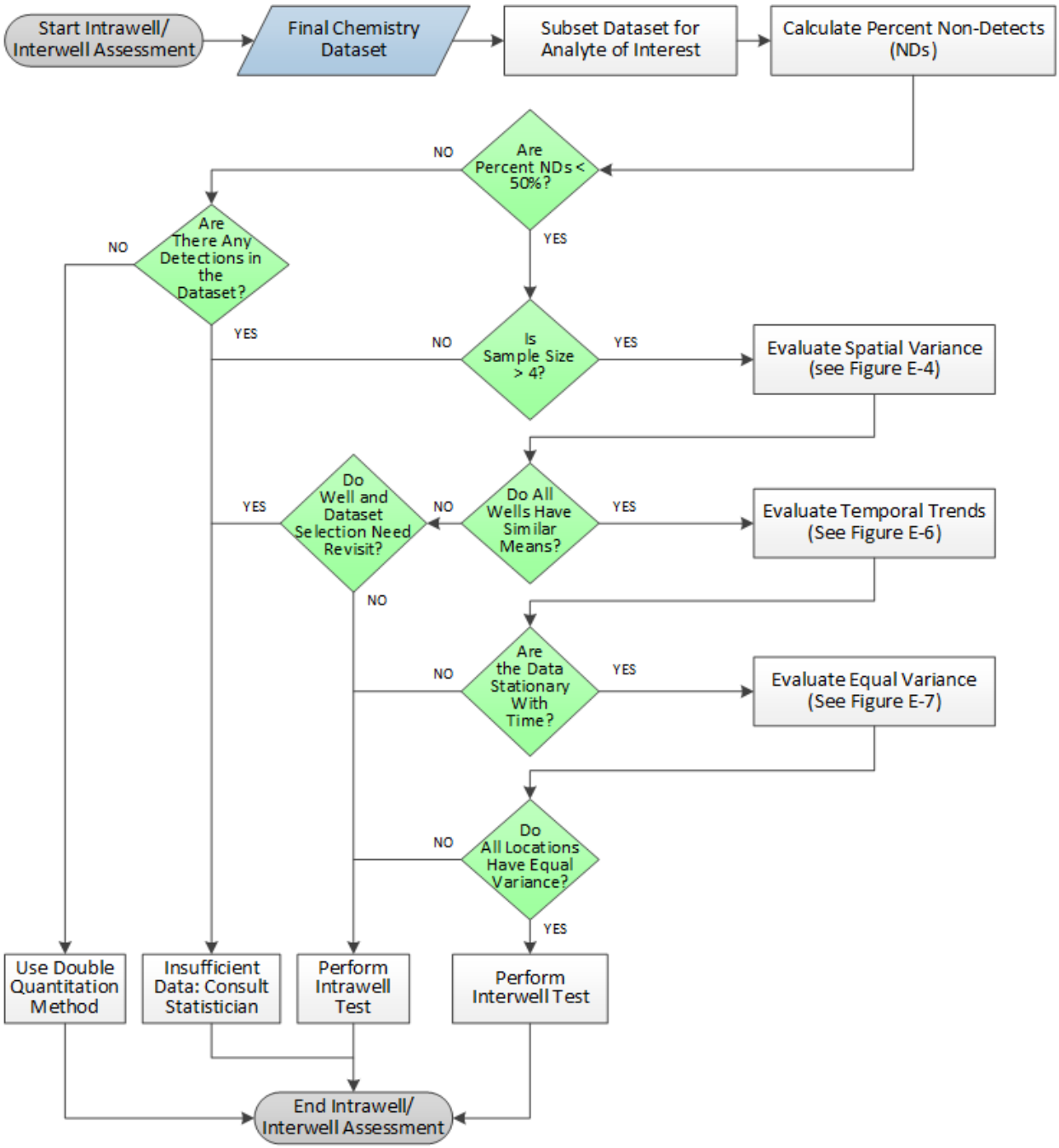


Figure E-3. Intrawell/Interwell Assessment

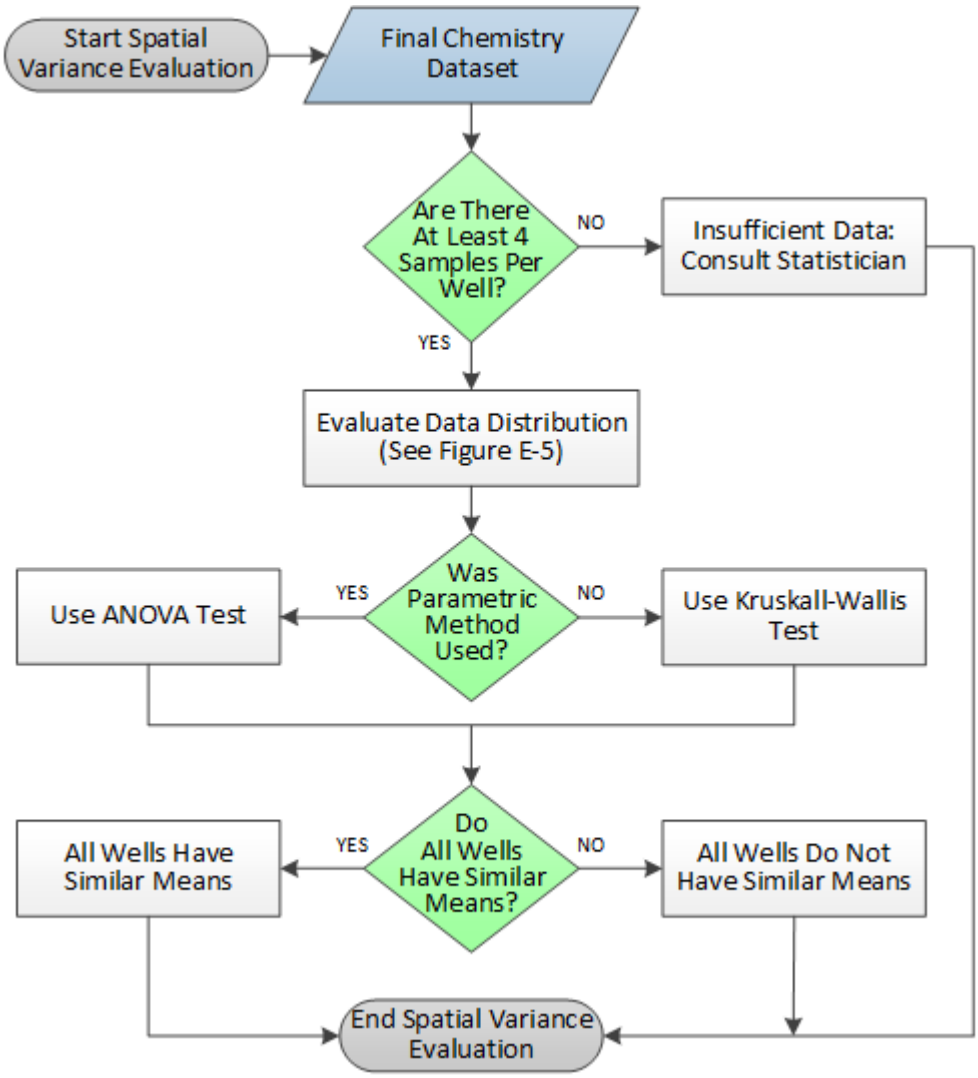


Figure E-4. Spatial Variance Evaluation

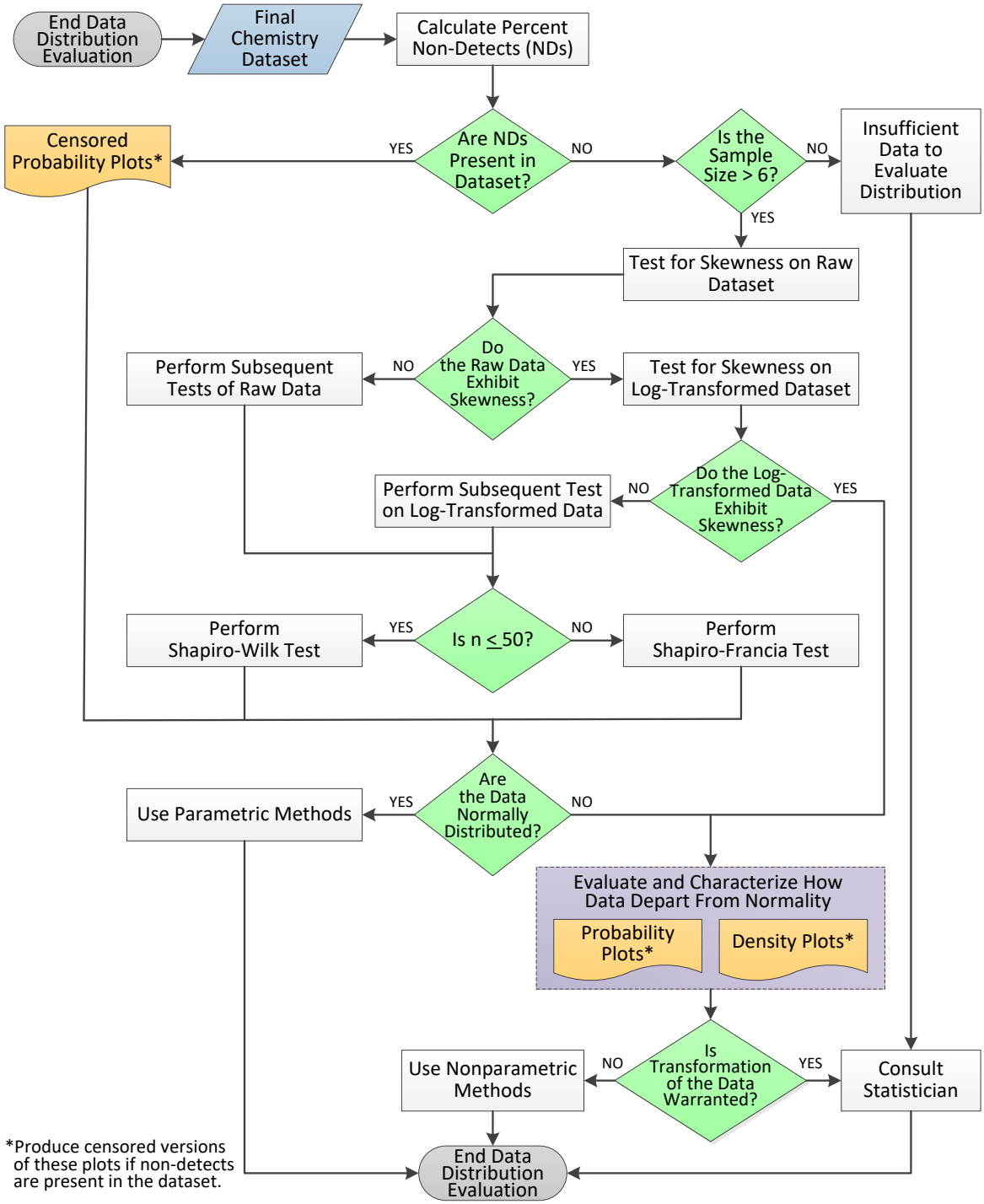
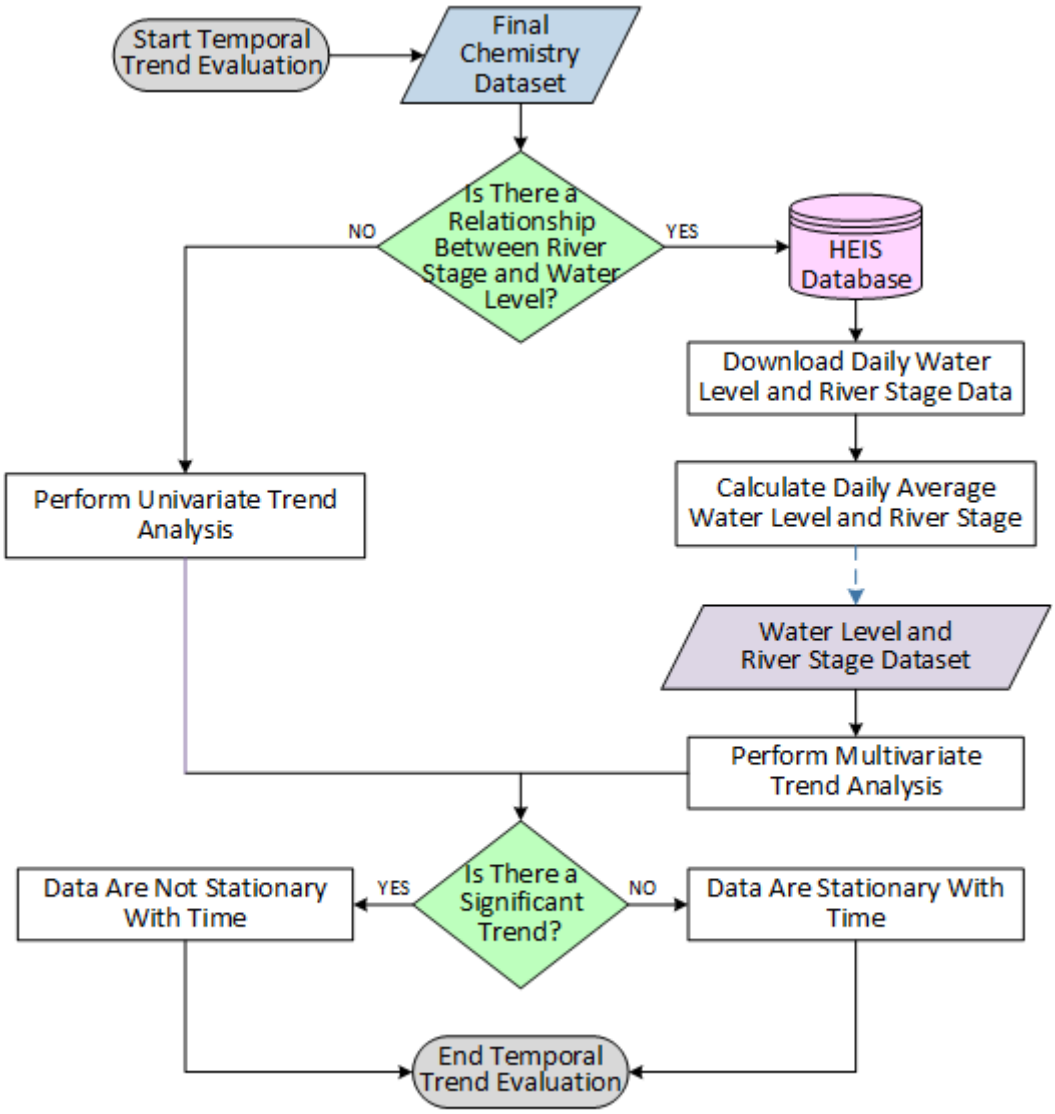


Figure E-5. Data Distribution Evaluation



HEIS = Hanford Environmental Information System

Figure E-6. Temporal Trend Analysis

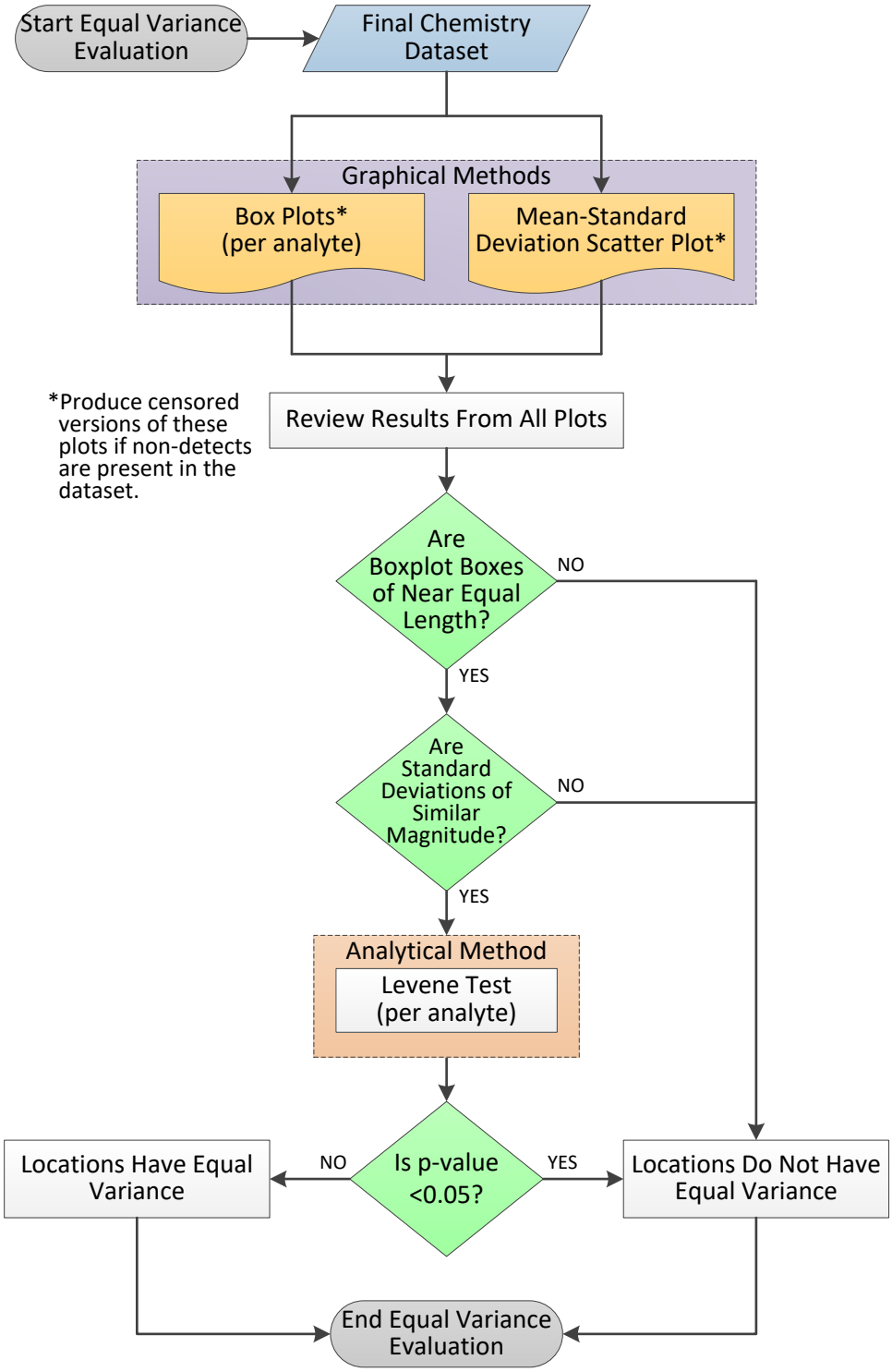


Figure E-7. Equal Variance Evaluation

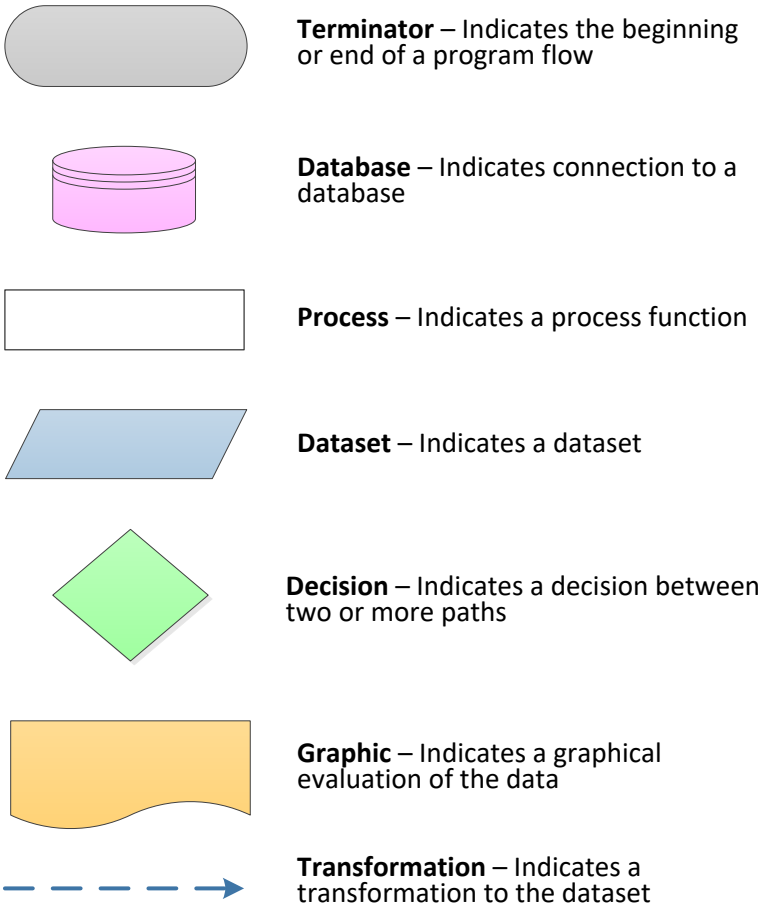


Figure E-8. Chart Legend

E2 References

Ecology Publication No. 97-407, 2014, *Chemical Test Methods For Designating Dangerous Waste WAC 173-303-090 & -100*, Hazardous Waste and Toxics Reduction Program, Washington State Department of Ecology, Olympia, Washington. Available at: https://fortress.wa.gov/ecy/publications/documents/97407.pdf.

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://www.itrcweb.org/gsmc-1/Content/Resources/Unified_Guidance_2009.pdf.