TRADEMARK DISCLAIMER
Reference herein to any specific commercial product, process, or service by tradename, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America
# Contents

1 Introduction .................................................................................................................................... 1-1

2 Background ..................................................................................................................................... 2-1
   2.1 Facility Description and Operational History ......................................................................... 2-1
   2.2 Regulatory Basis ..................................................................................................................... 2-4
   2.3 Waste Characteristics ............................................................................................................. 2-4

3 Geology and Hydrogeology ........................................................................................................... 3-1
   3.1 Geologic Setting ..................................................................................................................... 3-1
      3.1.1 Elephant Mountain Member ....................................................................................... 3-2
      3.1.2 Ringold Formation ...................................................................................................... 3-7
      3.1.3 Hanford Formation ...................................................................................................... 3-8
   3.2 Groundwater Hydrology ....................................................................................................... 3-16
   3.3 Well Placement ..................................................................................................................... 3-21
      3.3.1 Tests to Determine Placement of Additional Wells .................................................. 3-21

4 Groundwater Monitoring .............................................................................................................. 4-1
   4.1 Constituent List and Sampling Frequency to Establish Local Background Concentrations .. 4-1
   4.2 Constituent List and Sampling Frequency for Detection Monitoring .................................... 4-1
   4.3 Well Network ......................................................................................................................... 4-2
   4.4 Sampling and Analysis Protocol ............................................................................................ 4-2

5 Data Evaluation and Reporting .................................................................................................... 5-1
   5.1 Data Review ........................................................................................................................... 5-1
   5.2 Statistical Evaluation .............................................................................................................. 5-1
   5.3 Interpretation .......................................................................................................................... 5-2
   5.4 Evaluation of Monitoring Network ........................................................................................ 5-3
   5.5 Reporting and Notification ..................................................................................................... 5-3

6 References ....................................................................................................................................... 6-1

Appendix

A Quality Assurance Project Plan ................................................................................................. A-i
Figures

Figure 1-1. Modular Storage Units Location Map ................................................................. 1-2
Figure 2-1. 2011 Composite Map of the Modular Storage Units ...........................................2-1
Figure 2-2. Composite of Modular Storage Unit Construction with Standpipe Leak
Detection System .................................................................................................................. 2-2
Figure 2-3. Depiction of Gravity Drainage Operation from Purgewater Tanker Truck to Modular
Storage Unit ....................................................................................................................... 2-3
Figure 3-1. Regional Interpretation of Elephant Mountain Basalt Erosion from Past Ancestral
Columbia River and Cataclysmic Ice Age Floods ................................................................. 3-3
Figure 3-2. Interpretation of Fractured Flow Top Extent Beneath LERF
(Based on Red Dashed Line) ............................................................................................... 3-5
Figure 3-3. Interpreted Geologic Cross Section Northwest of the Modular Storage Units ......... 3-7
Figure 3-4. Interpretation of Basalt Surface and Groundwater Extent Beneath the Modular
Storage Units and Surrounding Area .................................................................................. 3-9
Figure 3-5. Seismic Reflection Survey Results along Profile 5 in Figure 3-2 ......................... 3-11
Figure 3-6. Interpretation of Ringold Formation to the Southeast and Southwest of the Modular
Storage Units .............................................................................................................................3-13
Figure 3-7. Conceptual Model of Buried Paleochannels Extending Through Gable Gap .......... 3-15
Figure 3-8. Historical Water Levels for Wells 299-E26-11, 699-47-46A, and 699-47-50 ........... 3-17
Figure 3-9. Water Table Map for the 200 Areas Measured in December 1987 ................. 3-18
Figure 3-10. Historical Water Levels for Wells 299-E26-11, 699-44-43B, and 699-45-42 ....... 3-18
Figure 3-11. Historical Water Levels for Wells 699-45-42, 699-50-42, and 699-51-36A .......... 3-19
Figure 3-12. March 2000 Water Table Map for the Confined and Unconfined Aquifers near
B Pond ................................................................................................................................. 3-20
Figure 3-13. Location of Downgradient Test Well and Additional Well Location Options Based on
Aquifer Conditions and Groundwater Flow as Described in Subsection 3.3.1 ............... 3-22
Figure 3-14. Regional Wells Identified for Estimating the Groundwater Flow Direction at the
Modular Storage Unit Facility ............................................................................................. 3-24

Tables

Table 2-1. 2010–2013 Maximum Groundwater Concentrations for Constituents Exceeding
Drinking Water Standards in 200-BP-5, 200-UP-1, 200-ZP-1, and the Perched
Water Horizon at WMA B/BX/BY .................................................................................. 2-5
Table 2-2. Maximum 2013 Modular Storage Unit Characterization Concentrations .............. 2-6
Table 4-1. First Year of Groundwater Monitoring at the Modular Storage Units to Establish
Initial Background Concentrations for a Detection Level Groundwater Monitoring
Program .............................................................................................................................. 4-2
Table 4-2. Groundwater Monitoring Schedule for Modular Storage Units ......................... 4-5
Table 5-1. Voluntary Notification and Reporting for Groundwater Monitoring .................... 5-4
# Terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>amsl</td>
<td>above mean sea level</td>
</tr>
<tr>
<td>ARAR</td>
<td>applicable or relevant and appropriate requirement</td>
</tr>
<tr>
<td>bgs</td>
<td>below ground surface</td>
</tr>
<tr>
<td>CAS</td>
<td>Chemical Abstracts Service</td>
</tr>
<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</td>
</tr>
<tr>
<td>DWS</td>
<td>drinking water standard</td>
</tr>
<tr>
<td>Ecology</td>
<td>Washington State Department of Ecology</td>
</tr>
<tr>
<td>EMB</td>
<td>Elephant Mountain Member</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>LERF</td>
<td>Liquid Effluent Retention Facility</td>
</tr>
<tr>
<td>LLWMA</td>
<td>low-level waste management area</td>
</tr>
<tr>
<td>IDW</td>
<td>investigation derived waste</td>
</tr>
<tr>
<td>NA</td>
<td>not applicable</td>
</tr>
<tr>
<td>OU</td>
<td>operable unit</td>
</tr>
<tr>
<td>QA</td>
<td>quality assurance</td>
</tr>
<tr>
<td>QAPjP</td>
<td>quality assurance project plan</td>
</tr>
<tr>
<td>Rwia</td>
<td>Ringold Wooded Island Basalt Gravel Unit A</td>
</tr>
<tr>
<td>SAP</td>
<td>sampling and analysis plan</td>
</tr>
<tr>
<td>TPA</td>
<td>Tri-Party Agreement</td>
</tr>
<tr>
<td>Tri-Party Agreement</td>
<td>Hanford Federal Facility Agreement and Consent Order</td>
</tr>
<tr>
<td>TSD</td>
<td>treatment, storage, and disposal</td>
</tr>
<tr>
<td>WAC</td>
<td>Washington Administrative Code</td>
</tr>
<tr>
<td>WMA</td>
<td>waste management area</td>
</tr>
<tr>
<td>XRF</td>
<td>X-ray fluorescence</td>
</tr>
</tbody>
</table>
1 Introduction

The Modular Storage Units are used to store and treat Hanford Site purgewater through evaporation and are located adjacent to the northeastern corner of the 200 East Area (Figure 1-1). Construction and operation of the Modular Storage Units were authorized by a U.S. Department of Energy (DOE) decision under its authority as the lead federal agency implementing the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) on the Hanford Site. Specifically, a CERCLA Section 104, “Response Authorities,” removal action decision was issued as an Action Memorandum in DOE/RL-2009-39, Investigation-Derived Waste Purgewater Management Action Memorandum.

Purgewater is one kind of the investigation derived wastes (IDWs) described in DOE/RL-2011-41, Hanford Site Strategy for Management of Investigation Derived Waste, hereinafter called the IDW Strategy, which is a joint decision of DOE, the U.S. Environmental Protection Agency (EPA) and the Washington Department of Ecology (Ecology), pursuant to the Hanford Federal Facility Agreement and Consent Order (Ecology et al., 1989), hereinafter called the Tri-Party Agreement (TPA), which defines purgewater as water extracted or otherwise derived from the ground in connection with well development, well remediation/reconstruction, well sampling, well decommissioning, well maintenance, aquifer testing, and decontamination water and with CERCLA remedial investigation and response actions. Because some of this groundwater is contaminated, it is not discharged to the ground. The Modular Storage Units, as of October 2013, consist of two units. Modular Storage Unit 2 is 3,785,400 L (1 million gal) and Modular Storage Unit 3 is 4,542,000 L (1.2 million gal).

DOE determined in DOE/RL-2009-80, Investigation Derived Waste Purgewater Management Work Plan, to install and operate a groundwater monitoring system after October 2014 if the Modular Storage Units are still in service at that time. Currently, the use of these Modular Storage Units for purgewater treatment is planned beyond 2014. Thus, this groundwater monitoring plan initiates the process of fulfilling this commitment in DOE/RL-2009-80. This plan proposes potential groundwater monitoring wells using existing interpretations of the geology and hydrogeology beneath the Modular Storage Units. Long-term groundwater monitoring was determined by DOE to be an applicable or relevant and appropriate requirement (ARAR) under CERCLA Section 121, “Cleanup Standards,” drawn from the substantive requirements of WAC 173-303-645, “Dangerous Waste Regulations,” “Releases from Regulated Units.”

It is unclear whether the Modular Storage Units are underlain by an unconfined aquifer or a confined aquifer; thus, this monitoring plan provides a phased approach for installation of the monitoring network. The proposed position of the initial test well is based on the most likely location to encounter unconfined aquifer conditions. Its location is also suitable as a downgradient well based on flow direction interpretations in PNNL-13404, Hanford Site Groundwater Monitoring for Fiscal Year 2000. Barometric response tests are outlined as part of the phased approach, if needed, to determine if aquifer conditions are unconfined or confined. If confined conditions are determined, an alternative groundwater monitoring program may be needed. Several other tests are also outlined in this monitoring plan to identify the most suitable downgradient and upgradient well locations. This plan is designed to provide direction through the establishment of the monitoring network and development of a statistical comparison for indicator parameters of dangerous waste constituents. After establishment of the indicator parameter comparison values, the plan should be updated; however, if resources are limited, the plan can continue to be used as a detection monitoring plan until resources are available.

This document provides a summary of the background events at the Modular Storage Units, the regulatory drivers for management of the site, and the 2013 waste characteristics of the collected purgewater from Modular Storage Units 2 and 3 in Chapter 2. Chapter 3 describes the current understanding of the regional geology and hydrogeology, well placement logic, and decision criteria for whether the findings require lead regulatory agreement or alternative monitoring requirements. Chapter 4
describes the criteria for developing a statistical groundwater detection monitoring program, including constituents to be analyzed, sampling frequency, and sampling protocols. Chapter 5 describes data evaluation and reporting requirements, and Chapter 6 contains references. The quality assurance project plan (QAP) is provided in Appendix A.

Figure 1-1. Modular Storage Units Location Map

LERF = Liquid Effluent Retention Facility
LLWMA = low-level waste management area
2 Background

This section presents the Modular Storage Units and operating history, the regulatory drivers for management of the site, and waste characteristics of the collected purgewater. The discussions in this section are summarized from DOE/RL-2009-39, DOE/RL-2011-41, and DOE/RL-2009-80.

Various internal work site documents and contractual documents were reviewed to complete the historical discussion in Section 2.1. Finally, telephone interviews were completed to determine leak detection monitoring results.

2.1 Facility Description and Operational History

The Modular Storage Units, located adjacent the northeastern corner of the 200 East Area (Figure 1-1), began service in 2011. The storage units are constructed as free-standing units installed on a planar surface at an elevation of approximately 179.5 m (~590 ft) (Figure 2-1). The storage units consist of a primary and secondary high-density polyethylene liner separated by a geotextile drainage media supported by metal walls. Each unit is capable of holding at least 3,785.41 kL (1,000,000 gal) of purgewater and measures 55.78 m by 55.78 m (183 ft by 183 ft). The drainage media interconnect with a leachate detection system consisting of a standpipe with measurable depth and sampling capability (Figure 2-2).
The Modular Storage Units were constructed by bolting the double-liner system, separated by the geotextile, to a sheet metal backing support with a neoprene batten strip. The metal backing is supported with a steel support frame bolted to a concrete slab. Seismic support is also provided by tension cables. The leak detection system consists of a 10.16 cm (4 in.) polyvinyl chloride capped standpipe connected to
the outer liner as shown in Figure 2-2. The standpipe is accessible for depth measurements and designed to facilitate sampling.

The Modular Storage Units are surrounded by a fence, berm, and graveled roadway and are supported by a compacted soil bottom; the walls are anchored to a concrete perimeter foundation. The site also has concrete sidewalks, an unloading ramp, and a splash pan. Staging space for vehicles used to transport the purgewater to the Modular Storage Units is also established.

The purgewater is transported from the well site to the facility via tanker truck. The purgewater is gravity drained into the units for containment and evaporation (Figure 2-3). As shown in Figure 2-1, the gravity drain ramp for unit 2 is located at the east corner and the gravity drain ramp for unit 3 is located at the west corner. Along with the purgewater, solids are deposited as sediments in the unit, and windblown silt and environmental media accumulated in the unit. A 10.3 cm (4 in.) raw water line was extended from the Effluent Treatment Facility to the Modular Storage Unit facility in 2011 providing a mechanism for management of sediments in each unit. The water line is activated, generally in the summer, when water levels in the units decrease through evaporation to levels approaching the height of the sediment in each unit. The addition of water ensures that sediments do not become exposed to the atmosphere.

These units are managed and operated as a CERCLA removal action under authority of the CERCLA decision document (DOE/RL-2009-39) and related sampling and analysis plans (SAPs), waste control plans, and the IDW Strategy (DOE/RL-2011-41).

Figure 2-3. Depiction of Gravity Drainage Operation from Purgewater Tanker Truck to Modular Storage Unit

Modular Storage Unit 2 was ready for service in 2010, and Modular Storage Unit 3 was installed in 2010 and 2011.

In April of 2012, an estimated 380 L (100 gal) wash-over event occurred at the Modular Storage Units as a result of high winds and wave migration over the side wall of one of the units. The spill area was defined, and soil remediation was completed by mid-May 2012. Confirmation sample results indicated that the remedial effort was successful.
As of October 2013, Modular Storage Unit 2 is approximately half full, and Modular Storage Unit 3 is three-quarters full. There has been no indication of release from the upper liner for either of these units based on e-tape measurements within the standpipe located between the two liners (Figure 2-2).

2.2 Regulatory Basis

Purgewater is defined as IDW under CERCLA and is subject to management in accordance with the terms of the TPA (Ecology et al., 1989) and the IDW Strategy (DOE/RL-2011-41). In accordance with the IDW Strategy (DOE/RL-2011-41), purgewater is defined as water extracted or otherwise derived from the ground in connection with water well activities at the Hanford Site. Wells that are included in this strategy are located outside the fence line of any treatment, storage, and disposal (TSD) identified in Appendix B of the TPA (Ecology et al., 1989) needing an operating permit. The Project Manager for the Lead Regulatory Agency may authorize exceptions to the requirements of this strategy on a case-by-case basis (within the Project Manager’s level of authority). For example, wells located within the fence line of a TSD that have been listed on a waste control plan or waste management plan for specific CERCLA operable units (OUs) may also be managed at the Modular Storage Units.

These Modular Storage Units are managed and operated as a CERCLA removal action under the authority of the decision document (DOE/RL-2009-39) and related SAPs, waste control plans, and the IDW Strategy (DOE/RL-2011-41). The Modular Storage Units were designed and are operated in accordance with the substantive requirements of WAC 173-303-680(2), “Dangerous Waste Regulations,” “Miscellaneous Units”) as an ARAR (DOE/RL-2009-39). Additional design and operational requirements for the Modular Storage Units were obtained from certain substantive requirements contained in WAC 173-303-650(2), (4), (5), and (6), “Dangerous Waste Regulations,” “Surface Impoundments” to the extent practicable.

As part of the purgewater management work plan (DOE/RL-2009-80), if the Modular Storage Units will be used after five years or if there is evidence of leakage from the Modular Storage Units to the environment, the U.S. Department of Energy, Richland Operations Office will implement groundwater monitoring. Operations of the Modular Storage Units will last beyond this five-year period; therefore, groundwater monitoring wells will be installed. The installation of four monitoring wells was included as part of the 200-BP-5 Groundwater OU baseline for after October 2014. Thus, this plan was created to locate the groundwater monitoring wells using existing interpretations of the geology and hydrogeology beneath the Modular Storage Units. Under CERCLA, ARARs for groundwater monitoring will implement the substantive requirements of WAC 173-303-645.

2.3 Waste Characteristics

Maximum groundwater concentrations for constituents exceeding the drinking water standard (DWS) primarily in 2012 and 2013 at wells located within the Central Plateau were compared to 2013 Modular Storage Unit characterization results in Tables 2-1 and 2-2, respectively. The 2013 Modular Storage Unit characterization included monitoring for nearly all Appendix IX constituents from 40 CFR 264, “Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.” The only constituents not analyzed from the Appendix IX (40 CFR 264) constituents were polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans; however, these constituents have never been of concern in Hanford Site groundwater because concentrations are generally nondetect or near the detection limit of $10^{-6}$ µg/L or lower. Anions, field monitoring parameters, and radionuclides were also analyzed.

As can be seen in Table 2-2, the detected Modular Storage Unit characterization constituents were anions, metals, and radionuclides. The modular storage unit characterization results were much lower than the
maximum results at the OUs provided in Table 2-1. This is consistent with the fact that several wells sampled are far field wells, significantly downgradient of source sites used to track the extent of contamination, which may be below DWSs in many cases. Most of the Modular Storage Unit characterization results were even below regional groundwater background levels (DOE/RL-96-61, Hanford Site Background: Part 3, Groundwater Background) (Table 2-2). Results that were greater than two orders of magnitude above the Hanford Site background levels were gross alpha, technetium-99, uranium-233/234, and uranium-238. Of the 20 other constituents above the Hanford Site background levels, 5 of the results appear to be elevated because they were unfiltered (aluminum, chromium, cobalt, iron, and manganese). Another constituent, copper, may be elevated because copper sulfide is added to reduce bacterial growth associated with perched water extraction. The copper sulfide is added regularly to the storage tank next to well 299-E33-344, located at the perched water remediation site near Waste Management Areas (WMAs) B/BX/BY in the 200 East Area.

The four constituents mentioned that exceeded the Hanford Site background levels by greater than two orders of magnitude appear to be good indicators of establishing groundwater quality associated with potential future releases from the Modular Storage Units. These constituents will be used as indicator parameters in addition to those defined in WAC 173-303-645.

Table 2-1. 2010–2013 Maximum Groundwater Concentrations for Constituents Exceeding Drinking Water Standards in 200-BP-5, 200-UP-1, 200-ZP-1, and the Perched Water Horizon at WMA B/BX/BY

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>200-ZP-1</th>
<th>200-UP-1</th>
<th>200-BP-5</th>
<th>Perched Water</th>
<th>Drinking Water Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Tetrachloride (µg/L)</td>
<td>2,500</td>
<td>790</td>
<td>&lt;1 (U)</td>
<td>&lt;1 (U)**</td>
<td>3.4 MTCA</td>
</tr>
<tr>
<td>Cesium-137 (pCi/L)</td>
<td>&lt;1.61 (U)*</td>
<td>&lt;10 (U)</td>
<td>&lt;5 (U)</td>
<td>&lt;32.5 (U)</td>
<td>4 mrem/yr</td>
</tr>
<tr>
<td>Chromium (µg/L)</td>
<td>761</td>
<td>1,150</td>
<td>80.3</td>
<td>199</td>
<td>100</td>
</tr>
<tr>
<td>Cobalt-60 (pCi/L)</td>
<td>&lt;2.0 (U)*</td>
<td>&lt;0.47 (U)</td>
<td>46</td>
<td>&lt;59.2 (U)</td>
<td>4 mrem/yr</td>
</tr>
<tr>
<td>Cyanide (µg/L)</td>
<td>146</td>
<td>&lt;4 (U)*</td>
<td>1,100</td>
<td>&lt;4 (U)</td>
<td>200</td>
</tr>
<tr>
<td>Gross Alpha (pCi/L)</td>
<td>&lt;3.4 (U)</td>
<td>2.87</td>
<td>2,300</td>
<td>55,000</td>
<td>NA</td>
</tr>
<tr>
<td>Gross Beta (pCi/L)</td>
<td>5,400</td>
<td>32.9</td>
<td>26,000</td>
<td>40,000</td>
<td>NA</td>
</tr>
<tr>
<td>Hexavalent Chromium (µg/L)</td>
<td>339</td>
<td>1,150</td>
<td>75.2</td>
<td>52.3</td>
<td>48</td>
</tr>
<tr>
<td>Iodine-129 (pCi/L)</td>
<td>16</td>
<td>13.3</td>
<td>4.76</td>
<td>&lt;7.98 (U)</td>
<td>1</td>
</tr>
<tr>
<td>Nitrate as NO3 (mg/L)</td>
<td>5,180</td>
<td>3,340</td>
<td>1,570</td>
<td>637</td>
<td>45***</td>
</tr>
<tr>
<td>Plutonium 239-240 (pCi/L)</td>
<td>0.091</td>
<td>--</td>
<td>&lt;0.0357 (U)*</td>
<td>&lt;0.0099 (U)**</td>
<td>15</td>
</tr>
<tr>
<td>Strontium-90 (pCi/L)</td>
<td>&lt;0.217 (U)*</td>
<td>--</td>
<td>2,400*</td>
<td>&lt;5.59 (U)*</td>
<td>8</td>
</tr>
<tr>
<td>Technetium-99 (pCi/L)</td>
<td>8,600</td>
<td>62,000</td>
<td>36,000</td>
<td>51,000</td>
<td>900</td>
</tr>
<tr>
<td>Trichloroethene (µg/L)</td>
<td>20</td>
<td>8.8</td>
<td>&lt;1 (U)</td>
<td>&lt;1 (U)**</td>
<td>5</td>
</tr>
<tr>
<td>Tritium (pCi/L)</td>
<td>200,000</td>
<td>350,000</td>
<td>35,000</td>
<td>34,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Uranium (µg/L)</td>
<td>12.9</td>
<td>229</td>
<td>4,470</td>
<td>51,500</td>
<td>30</td>
</tr>
</tbody>
</table>

* 2011 result
** 2010 result
*** Converted from 10 mg/L as N
NA = not applicable
U = nondetect value
<table>
<thead>
<tr>
<th>Date Collected</th>
<th>Constituent</th>
<th>Greatest Laboratory Value for 2013 Sampling Event at MODU Tanks</th>
<th>Regional Groundwater Background Level from DOE/RL-96-61</th>
<th>Orders of Magnitude over Regional Background Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/25/2013</td>
<td>Americium-241</td>
<td>1.1 pCi/L</td>
<td>0.08</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Gross alpha</td>
<td>200 pCi/L</td>
<td>0</td>
<td>&gt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Gross beta</td>
<td>350 pCi/L</td>
<td>4.15</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Technetium-99</td>
<td>280 pCi/L</td>
<td>0.98</td>
<td>&gt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Total beta radiostrontium</td>
<td>13 pCi/L</td>
<td>1.14</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Tritium</td>
<td>1700 pCi/L</td>
<td>142</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Uranium-233/234</td>
<td>140 pCi/L</td>
<td>0.88</td>
<td>&gt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Uranium-235</td>
<td>8.5 pCi/L</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Uranium-238</td>
<td>140 pCi/L</td>
<td>0</td>
<td>&gt;2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Radiological Detected Constituents</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Anionic Constituents Detects</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Alkalinity</td>
<td>140 mg/L</td>
<td>156.3</td>
<td>Below Background</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Bicarbonate</td>
<td>140 mg/L</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Chloride</td>
<td>93.9 mg/L</td>
<td>19.58</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Nitrogen in Nitrate</td>
<td>13.9 mg/L</td>
<td>9.41</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Sulfate</td>
<td>127 mg/L</td>
<td>55</td>
<td>&lt;2</td>
</tr>
<tr>
<td></td>
<td><strong>Metal Constituents Detected</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Aluminum</td>
<td>35.4 ug/L</td>
<td>11.7</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Arsenic</td>
<td>7.53 ug/L</td>
<td>11.8</td>
<td>Below Background</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Barium</td>
<td>89.8 ug/L</td>
<td>149</td>
<td>Below Background</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Calcium</td>
<td>42000 ug/L</td>
<td>58389</td>
<td>Below Background</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Chromium</td>
<td>23.7 ug/L</td>
<td>3.17</td>
<td>unfiltered</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Cobalt</td>
<td>57.9 ug/L</td>
<td>1.29</td>
<td>unfiltered</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Copper</td>
<td>135 ug/L</td>
<td>1.04</td>
<td>&gt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Iron</td>
<td>4220 ug/L</td>
<td>1104</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Lead</td>
<td>0.42 ug/L</td>
<td>1.3</td>
<td>Below Background</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Magnesium</td>
<td>27200 ug/L</td>
<td>31051</td>
<td>Below Background</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Manganese</td>
<td>184 ug/L</td>
<td>86.4</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Molybdenum</td>
<td>76.4 ug/L</td>
<td>4.67</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Nickel</td>
<td>14.1 ug/L</td>
<td>1.98</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Potassium</td>
<td>18400 ug/L</td>
<td>11089</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Selenium</td>
<td>2.19 ug/L</td>
<td>20.7</td>
<td>Below Background</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Sodium</td>
<td>56100 ug/L</td>
<td>32919</td>
<td>Questionable</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Vanadium</td>
<td>29.4 ug/L</td>
<td>19.3</td>
<td>&lt;2</td>
</tr>
<tr>
<td>3/25/2013</td>
<td>Zinc</td>
<td>23.1 ug/L</td>
<td>48.9</td>
<td>Below Background</td>
</tr>
</tbody>
</table>

Note: Regional groundwater background is defined by the 95th percentile from DOE/RL-96-61, Hanford Site Background: Part 3, Groundwater Background.

Table 2-2. Maximum 2013 Modular Storage Unit Characterization Concentrations
3 Geology and Hydrogeology

Detailed geology and hydrology data beneath the Modular Storage Units are sparse because no wells have been drilled in this area, and only peripheral geophysical investigations have been completed. Conceptual understandings of the underlying geology and hydrogeology were generated through cross sections using wells adjacent to the Modular Storage Units and discussions from the following reports reviewed for this area:

- BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*
- PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*
- PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*
- RHO-BWI-ST-14, *Subsurface Geology of the Cold Creek Syncline*
- SGW-39344, *Borehole Summary Report for the Installation of RCRA Wells 299-E26-77 (C6455), 299-E26-79 (C6826), 299-E25-236 (C6542) and 199-N-165 (C6693), FY 2008*
- SGW-51467, *Borehole Summary Report for the Installation of Two RCRA Groundwater Monitoring Wells in the 200 Areas, FY2011*
- SGW-52162, *Seismic Reflection Investigation at the Liquid Effluent Retention Facility, 200 East Area, Hanford Site Richland, Washington*
- SGW-52467, *Integrated Surface Geophysical Investigation Results at Liquid Effluent Retention Facility, 200 East Area, Hanford, Washington*
- WHC-MR-0235, *Borehole Completion Data Package for the Liquid Effluent Retention Facility*
- WHC-SD-EN-EV-024, *Site Characterization Report for the Liquid Effluent Retention Facility*

Four possible conclusions were identified for the underlying hydrogeology for this area:

1. There may be unconfined groundwater conditions in the suprabasalt sediments above the basalt.
2. Groundwater may be encountered within fractured basalt displaying unconfined conditions.
3. Groundwater may be encountered within fractured basalt displaying confined conditions.
4. Groundwater conditions may not be conducive for monitoring potential releases from the Modular Storage Units.

The following subsections describe the geographic setting, individual formations, groundwater hydrology, and logic for well locations for potential groundwater monitoring.

3.1 Geologic Setting

The Modular Storage Units reside in the Pasco Basin, between the axis of the Umtanum-Gable Mountain anticlinal ridge and the axis of the Cold Creek syncline. Additional third order en echelon folds also appear to be present to the north and west of the Modular Storage Units. The terrain surrounding the Modular Storage Units is flat to slightly sloping to the northeast. The elevation ranges between approximately 177 to 182 m (581 to 597 ft) above mean sea level (amsl).
The stratigraphy beneath the Modular Storage Units is interpreted mainly from review of geologic descriptions from borehole drilling records to the northwest, southwest, northeast, and east. Geophysical investigation to the north, south, and west were also used for interpreting the geology beneath the Modular Storage Units. Finally, past analytical and physical property tests associated with nearby boreholes were also considered. The three possible stratigraphic units present beneath the Modular Storage Units, in ascending order, are the Elephant Mountain Member of the Saddle Mountains Basalt (EMB), the Ringold Formation, and the Hanford formation; however, current interpretations consider the Ringold Formation absent because of erosion during cataclysmic ice age flooding. The thickness of the suprabasalt sediments near the Liquid Effluent Retention Facility (LERF) basins is estimated at 53 to 60 m (173 to 196 ft).

3.1.1 Elephant Mountain Member

Nature and extent of the EMB, one of the youngest members of the Saddle Mountains Basalt and the uppermost basalt beneath the Modular Storage Units, is based on geologic descriptions from nearby borehole drilling records, past geophysical investigations, and analytical and physical property tests associated with this stratigraphic unit. Analytical tests included X-ray fluorescence (XRF) analysis and physical property tests. Hydraulic tests were performed within the upper basalt flow top (e.g., fracture zone) at LERF wells to the west and southwest of the Modular Storage Units (Figure 1-1).

EMB has been characterized to the northeast, northwest, west, south, and southeast of the Modular Storage Units and is interpreted as consisting of only the oldest EMB flow (Elephant Mountain I Basalt) of the two EMB flows. The upper EMB was interpreted as being eroded by the ancestral Columbia River and cataclysmic Ice Age flood water (Figure 3-1). Further review of this interpretation indicates that some overlying younger Elephant Mountain II Basalt exists to the east and south of the Modular Storage Units. EMB I has been interpreted to thin progressively towards the Modular Storage Units as shown in Figure 3-1. Figure 3-1 also shows well names and interpreted basalt thickness, in meters, in the area depicted. The contours are isopleths of similar interpreted basalt thickness.

The EMB flow is considered continuous both beneath the Modular Storage Units and surrounding area, with a thickness ranging from approximately 12 m (39 ft), where significantly eroded (e.g., 699-48-48), to greater than 35 m (115 ft) north of the 200 East Area (e.g., near Gable Mountain Pond, 699-52-46) (Figure 3-1). Beneath the Modular Storage Units, EMB is estimated to range between approximately 20 to 25 m (65 to 80 ft) thick.

The EMB I flow (e.g., lower EMB flow) contains three intraflow structures: colonnade, entablature, and flow top. The colonnade makes up the bottom third of the flow (e.g., estimated at approximately 11.5 m [38 ft] based on the overall thickness near Gable Mountain Pond). The upper part of the colonnade grades from moderately to adequately developed columns into a platy cross-fractured colonnade and then into a hackly (e.g., fractured with jagged points) entablature. The entablature has numerous, irregular cross-fractures, vertical fractures, and small scattered vesicles near its top. The flow top is characterized by abundant vesicles and is brecciated and/or palagonitic (WHC-SD-EN-EV-024). Because of the erosion in this area associated with ancestral Columbia River flow paths and later cataclysmic Ice Age flooding, most to all basalt flow top may have been removed. RHO-ST-38, *Geohydrology of the Rattlesnake Ridge Interbed in the Gable Mountain Pond Area*, interpreted all basalt flow top as being removed north of the 200 East Area. Geophysical investigations at LERF indicated that the fractured flow top beneath LERF terminates prior to reaching the area beneath the Modular Storage Units (Figure 3-2). If the EMB I flow top is not present beneath the Modular Storage Units, then most likely the entablature, consisting of various fractures, defines the bedrock beneath the Modular Storage Units.
Structurally, EMB beneath the Modular Storage Units has been folded and possibly faulted. The Modular Storage Units reside south of a second-order anticlinal feature (the Gable Mountain structure) within the Pasco Basin (Figure 3-1). Most of the anticlines in the Pasco Basin are asymmetric and have second-order folds in their hinge zone (RHO-BWI-ST-14). Another structural feature to the northwest of the Modular Storage Units is the second-order Gable Butte fold. Two en echelon third-order folds extend to the southeast of the Gable Butte fold: the Pearl and Willa anticlines (Figure D-14 of RHO-BWI-ST-14). These structural features were assessed previously and were concluded to have begun over 14 million
years ago (e.g., early Miocene). Zones of weakness developed during the early Miocene, and deformation continued along the same trends and zones of weakness at a slow rate (<1 mm/yr) (RHO-BWI-ST-14). It is uncertain if these southeast-east plunging third-order anticlines have caused additional extensional fractures to the uppermost basalt surface beneath the Modular Storage Units. It should be noted that the south limb of the Willa anticline, located to the north/northwest of the Modular Storage Units, has been defined with a significant fold which may be associated with extensional fractures (Figure 3-3). For an aerial location view of the wells used to create the cross section in Figure 3-3, see Figure 3-1. Fractures associated with the Willa anticlinal fold may extend towards the Modular Storage Units. Figure 3-4 provides an interpretive view looking from above ground surface, at an angle facing to the northwest, into the subsurface to the top of basalt. The Hanford formation was removed from the figure in order to provide the current interpretation of the subsurface basalt topography. The figure emphasis is the top of the basalt surface, but other components that are provided include groundwater above the basalt surface, well locations, and well locations with respect to the Modular Storage Unit Facility. By comparison with Figure 3-2, the basalt surface rises in elevation to the west and north of the Modular Storage Unit Facility. Although the interpretation presented in these two figures implies no groundwater, these interpretations are based on little information and may not portray conditions accurately. Even if the interpretations are relatively correct, the basalt may be fractured allowing unconfined groundwater conditions within the basalt beneath the Modular Storage Unit Facility. However, if the basalt is not fractured, then unconfined groundwater conditions beneath the Modular Storage Unit Facility would only exist if the basalt is at an elevation below the current water table. The basalt elevation gain north of the Modular Storage Units in Figure 3-4 is based on the interpretation of seismic reflection survey data along Profile 5 as shown in Figure 3-2. The interpreted top of basalt along Profile 5 is presented in Figure 3-5.

Because of the proximity of the Willa anticlinal fold and directional trend, extensional fractures may add to the irregular cross-fractures, vertical fractures, and small scattered vesicles near the top of the entablature, if the flow top was eroded away.

Observations during drilling near the LERF basins, when initially encountering the EMB surface, were described as reddish weathered basalt with vesicles partially filled (WHC-MR-0235). The drilling rate was moderate through the upper EMB I to a depth of 2 to 3 m (6.5 to 9.8 ft) when drilling wells 299-E26-77 and 299-E26-79, respectively (Figure 1-1). Slug tests completed at these wells had greater hydraulic conductivity values than the overlying suprabasalt sediments, indicating a laterally transmissive horizon. SGW-41072, Liquid Effluent Retention Facility Characterization Report, concluded that hydraulic communication of the uppermost aquifer (e.g., unconfined suprabasalt sediments) extends into the fractured basalt surface because there was no impediment associated with the overlying sediments (e.g., low permeability mud is not present).

The thickness of the fractured basalt near LERF was interpreted to range from 2 m (6.5 ft) at well 299-E26-77 (west of the LERF) to 3.2 m (10.5 ft) at well 299-E26-79 (south of the LERF), and 1.5 m (5 ft) at well 299-E26-11 (east of LERF) (Figure 1-1). If this permeable basalt horizon extends to the northeast, under the Modular Storage Units, then potential releases from the Modular Storage Units could impact the groundwater quality of this potentially extensive groundwater transmissive zone. Even if the interpreted basalt flow top beneath LERF does not extend beneath the Modular Storage Units, vertical extension fractures along with fanning fractures associated with the hackly entablature may interconnect providing a possible extended permeable zone horizon. In order to investigate these possibilities, at least one test well will be drilled to the southwest of the Modular Storage Units to determine the nature of the basalt and whether groundwater may be present. During drilling, it will be important to note the depth to basalt and collect basalt samples to verify the nature of the basalt flow.
Figure 3-2. Interpretation of Fractured Flow Top Extent Beneath LERF (Based on Red Dashed Line)
This page intentionally left blank.
3.1.2 Ringold Formation

The Ringold Formation represents ancient fluvial and lacustrine deposits associated with the ancestral Columbia River and the formation exhibits consolidation and weathering. Where present, this Formation overlies the EMB (Figure 3-4). According to WHC-SD-EN-EV-024, remnant muds associated with the Ringold period exist to the east and northwest of the LERF site at wells 299-E26-11 and 299-E35-2, respectively. DOE/RL-92-19, 200 East Groundwater Aggregate Area Management Study Report, reported approximately 2.74 m (9 ft) of the Ringold Lower Mud Unit in well 299-E26-11 and mapped the Lower Mud Unit extending to this location from the east. BHI-00184 identified the Ringold muds east of the 200 East Area as paleosol overbank deposits. WHC-SD-EN-EV-024 concluded that the sediment layer was a paleosol based on XRF analysis. BHI-00184 states that pedogenically altered silt- and clay-rich overbank paleosol (facies association III) deposits of the Ringold Formation are easily distinguished from the basalt-rich sand and gravel of the Hanford formation. In 2000, PNNL-12261 defined the sediments near well 299-E26-11 as Ringold Wooded Island Basalt Gravel Unit A (Rwia) (PNNL-18819, Hanford Site Guidelines for Preparation and Presentation of Geologic Information), more specifically, the hydrogeologic unit 9C. Based on Plate 3 from PNNL-12261, the hydrogeologic unit 9C may extend to beneath the Modular Storage Units. Although the unit 9C is not normally considered a hydraulic confining unit, at well 299-E26-11 this unit does cause semiconfining conditions as defined by barometric response and greater groundwater table elevation (e.g., approximately 0.9 m (3 ft) higher than the unconfined wells to the west). Because of the comparable chemical nature of the groundwater at well 299-E26-11 with wells near the 216-B-3 Pond (B Pond), the lithology of the unit 9C and other noted mud layers appears to extend to well 299-E26-11. Figure 3-6 provides a possible interpretation of the hydrogeologic Ringold units extending from the southeast beneath B Pond to the Modular Storage Units and continuing to well 299-E26-11, located just east of LERF. Figure 3-6 indicates uncertainty associated with unit 9C, beneath the Modular Storage Units, in accordance with the current interpretation, presented in Figure 3-2.
The Ringold sediment at well 299-E26-11, as described in WHC-MR-0235, consists of a slightly gravelly sandy mud (5 percent gravel, 30 percent sand, and 65 percent mud). The color was reported as very dark grayish brown (10YR3/2). The gravel content was described as 90 percent mafic, and the sand content was 50 percent mafic. The sediments had no reaction to hydrochloric acid.

During drilling of the most recent LERF well, 299-E26-14 (Figure 1-1), low permeability sediments were encountered at 65.5 to 66.1 m (215.5 to 217 ft) below ground surface (bgs). The sediments were described as 95 percent silt and 5 percent gravel. Photographic review of this sediment layer, presented in SGW-51467, showed a distinct texture and color change from the overlying Hanford sandy gravels. The reddish brown hue and yellow tints associated with this layer correlate well with the distal overbank description provided in BHI-00184. Other characteristics associated with this layer included no reaction to hydrochloric acid, similar to Ringold sediments described at well 299-E26-11. An alternative explanation may be that the apparent Ringold sediments at 299-E26-14 are reworked, removed from one location and deposited at this location, or possibly associated with cataclysmic Ice Age floods.

Most of the area beneath LERF and the Modular Storage Units is currently considered devoid of Ringold sediments because of the high energy scouring associated glacial fluvial flooding in the Pleistocene and the lack of reflectors in the suprabasalt section during 2011 seismic data reviews. PNNL-19702 presents a conceptual model of various paleochannels originating to the northwest (Figure 3-7). An interpretive subsurface view of paleochannel E is shown in Figure 3-4, looking to the northwest. The Hanford sediments were removed from Figure 3-4 to portray the remnant basalt topography interpretation. Interpretive remnant Ringold sediments and groundwater above basalt are also portrayed in Figure 3-4. Finally, paleochannel F is depicted just north of the basalt ridge. Some of these paleochannels may have been formed during Ringold times, and isolated remnants of Ringold sediments are sometimes found within these older paleochannels as depicted in the interpretive Figure 3-4.

### 3.1.3 Hanford Formation

The Hanford formation beneath the Modular Storage Units is interpreted to range in thickness from approximately 53 to 60 m (173 to 196 ft) or more. The texture of the Hanford formation has locally been identified as loose to weakly cemented, sandy, pebble-cobble gravels to gravelly sand, with occasional layers of sand and/or muddy sand. Regionally, the Hanford formation is subdivided into an upper gravel sequence (H1), a sandy sequence (H2), and a lower gravel sequence (H3). The sandy sequence is present locally and, where it is missing, a single sequence of gravel-dominated facies exists, which is undifferentiated in cross-sections.

The Modular Storage Units are located along the eastern flank of a northwest/southeast trending cataclysmic flood channel (Figure 3-7). Because of multiple flood events and the turbulence and extremely high energy associated with these floods, it is difficult to correlate individual strata within flood sequences. In outcrops of the Hanford formation elsewhere in the Pasco Basin, for example, it is common to see changes from gravel-dominated sediments to sand and silt-dominated sediments over a distance of a few tens of meters.
Figure 3-4. Interpretation of Basalt Surface and Groundwater Extent Beneath the Modular Storage Units and Surrounding Area
This page intentionally left blank.
Note: The dashed magenta-yellow line portrays the interpretation of the basalt surface.

Figure 3-5. Seismic Reflection Survey Results along Profile 5 in Figure 3-2
Figure 3-6. Interpretation of Ringold Formation to the Southeast and Southwest of the Modular Storage Units
This page intentionally left blank.
Locally, beneath LERF, more silt or mud was found to the west and east than north or south based on geologic logs for the seven wells drilled within the LERF vicinity. However, high silt and clay content to the north and south of LERF was present near the contact with the EMB within the aquifer. These silt and clay layers ranged in thickness between 0.3 to 1.5 m (1 to 5 ft) and appear to be of Ringold age as discussed in Section 3.1.2. The basalt content in layers above the silt and clay indicates Hanford origin. Above these initial layers, the gravel content was generally about 60 percent, consisting of 40 to 70 percent mafics. Significantly more cobbles were described in the north and south boreholes than to the east and west throughout the borehole log descriptions. The grayish brown to very dark grayish brown color description of the sediments was consistent throughout the area. Calcium carbonate levels are low to within 21 m (70 ft) of ground surface, based on little to no reaction to hydrochloric acid. The upper zone with increased calcium carbonate levels correlates with low modeled velocities during refraction and resistivity modeling, as stated in SGW-52467, and may be a distinctive feature to differentiate H1 and H3 in this area if H2 is missing. Moisture observations ranged from dry to wet; however, the damp and wet descriptions in the vadose zone pertained to zones where water was added during drilling. In conclusion, based on the larger gravel content and size to the north and south of the LERF basins, the dominant flow during deposition appears to be from the northwest, aligning with the conceptual model in PNNL-19702 (Figure 3-7). There were no significant zones of silt or clay above the aquifer, indicating no perching horizons in the suprabasalt sediments beneath the LERF vicinity. If the main deposition was associated with the proposed paleochannel from the northwest, lower energy deposits may exist beneath the Modular Storage Units. If so, H2 should be present and the lower energy flow may explain why the basalt surface expression is higher beneath the Modular Storage Units.

Note: Paleochannel E is interpreted as extending beneath the LERF and MODU Tank Facilities.

Figure 3-7. Conceptual Model of Buried Paleochannels Extending Through Gable Gap
3.2 Groundwater Hydrology

The vadose zone beneath the Modular Storage Units is interpreted as consisting solely of Hanford suprabasalt sediments overlying the EMB. The only viable sources for potential perched water beneath the Modular Storage Units, other than the units and the new water line, are the unlined 216-B-3-1 Ditch and 216-B-3 Pond (Figure 1-1). The northern boundary of the 216-B-3-1 Ditch was located 350 m south of the Modular Storage Units. The northwest boundary of the 216-B-3 Pond is even farther, at 500 m southeast of the south boundary of the Modular Storage Units. Because perched water conditions were not seen at well 299-E26-11, which is closer to the 216-B-3-1 Ditch than the Modular Storage Units, perched water conditions are not likely to exist beneath the Modular Storage Units, unless they are associated with unknown releases from the new Modular Storage Units or newly installed water line. Historical review of the area indicates that there were no potable or raw water lines in the vicinity of the Modular Storage Units prior to 2011 based on review of site maps H-2-830460 (sheet 7) and H-2-830461 (sheet 7), respectively.

The water table directly beneath Modular Storage Units was approximately 3 m higher in elevation in 1988 than in October 2013, based on historic groundwater levels at well 699-47-46A (decommissioned in 2004) (Figure 3-8). If the interpreted top of basalt beneath the Modular Storage Units is correct (Figures 3-4 and 3-5), then some of the suprabasalt sediments under Modular Storage Units would have been previously saturated.

Historical groundwater level elevations were plotted to evaluate possible flow directions beneath the Modular Storage Units. Figure 3-8 shows the relationship between the historical groundwater elevation to the northwest (e.g., wells 699-47-50 and 699-47-46A) and southwest (e.g., well 299-E26-11) of the Modular Storage Units. The groundwater elevations in Figure 3-8 depict decreasing elevations to the northwest of well 299-E26-11. The decreasing groundwater elevations to the northwest indicate that groundwater flow was to the northwest in the past. The northwest groundwater flow direction interpretation is consistent with flow interpretations for low-level waste management area-2, located to the west of the Modular Storage Units, in the 1980s and early 1990s (Figure 3-9). The past groundwater flow direction was associated with liquid waste discharges to the 216-B-3 Pond (B Pond), which created a significant groundwater elevation (e.g., mound) in wells near B Pond as seen by the groundwater elevation isopleths in Figure 3-9.
As seen in Figure 3-10, groundwater levels in 1989 at 699-45-42, near B Pond, were 6 m greater than the current 2013 groundwater elevation at that well. Figure 3-10 also shows that wells 699-44-43B and 699-45-42 are still considerably greater in elevation than well 299-E26-11, indicating a current northwest to west groundwater flow direction beneath the Modular Storage Units. However, the groundwater elevation at well 699-50-42, located to the northeast of the Modular Storage Units, exceeded the groundwater elevation at well 699-45-42 in 2000 (Figure 3-11). Well 699-47-35B, located to the northeast of well 699-45-42, began to have a greater water level in 1998 than at well 699-45-42. These observations led to a southwest groundwater flow interpretation beneath the Modular Storage Units as discussed in PNNL-13404 (Figure 3-12). The primary work for this interpretation was completed in PNNL-12261. This interpretation was based on groundwater flow through more permeable Hanford formation sediments.
Figure 3-9. Water Table Map for the 200 Areas Measured in December 1987

Figure 3-10. Historical Water Levels for Wells 299-E26-11, 699-44-43B, and 699-45-42
Because well 299-E26-11, located to the southwest of the Modular Storage Units, still shows semiconfining conditions, it was interpreted that the Ringold sediments extend to this well from the east (Figure 3-4). Thus, groundwater is considered to flow approximately west to well 299-E26-11 from the east. However, if the current interpretation beneath the Modular Storage Units is correct and the basalt extends above the groundwater elevation, then groundwater, if present, is within a basalt fracture zone, as discussed in Section 3.1.1. If the fractures are horizontally connected with the fractured flow top near LERF, then groundwater flow may juxtapose (e.g., southeast) along the Ringold sediments, similar to what is shown in Figure 3-12. More specifically, it would appear to flow to the southwest if the interpretation is correct. However, because current interpretations beneath the Modular Storage Units are based on peripheral geophysics and geologic interpretations from wells adjacent this site, this monitoring plan will also consider the possibility of saturated suprabasalt sediment above the EMB. Both Hanford and Ringold saturated sediments are considered to be potentially beneath the Modular Storage Units.

If there are saturated Hanford sediments beneath the Modular Storage Units, then the top of basalt is lower in elevation than derived from the seismic reflection surveys. The conceptual groundwater flow direction for such a finding would also be considered to the southwest. The main reason for a southwest groundwater flow direction is because of the elevated groundwater elevation in the Ringold sediments interpreted to the south and southwest of the Modular Storage Units as shown in Figure 3-4.

If there are saturated Ringold sediments beneath the Modular Storage Units, then the top of basalt is again lower in elevation than derived from the seismic reflection surveys. The conceptual groundwater flow direction could be more westerly. The main reason would be because of a tongue-shaped saturated geometry of the Ringold sediments with greater groundwater elevations to the west, similar to the depiction east of the Modular Storage Units as depicted in Figure 3-12.

Figure 3-11. Historical Water Levels for Wells 699-45-42, 699-50-42, and 699-51-36A
Figure 3-12. March 2000 Water Table Map for the Confined and Unconfined Aquifers near B Pond

These interpretations of flow directions are based on past conditions. As a result, three point problems will be completed, using the initial test well at the Modular Storage Units and other wells in the area to
verify the actual flow direction for proper monitoring well placement. Finally, another possibility is that there is no hydraulic connection between groundwater beneath the Modular Storage Units and potential releases from the Modular Storage Units. In this case, there would be no need to install additional wells because groundwater monitoring would not serve a useful purpose for leak detection from the Modular Storage Units.

### 3.3 Well Placement

According to Figure 3-2, the sediments directly south of the Modular Storage Units are expected to have drained groundwater most recently based on the interpreted top of basalt elevation. Because this location is interpreted as the lowest elevation for the top of basalt below the Modular Storage Units, it appears to be the most logical location to drill a downgradient test well for the Modular Storage Units (Figure 3-13). This location is also southwest of the Modular Storage Units and would be a logical downgradient well should flow be southwest as described in Section 3.2.

#### 3.3.1 Tests to Determine Placement of Additional Wells

In order to provide an appropriate groundwater monitoring network for the Modular Storage Units, upgradient and downgradient monitoring well locations need to be determined based on current groundwater flow conditions. Unfortunately, monitoring wells near the Modular Storage Units are sparse, and the controlling hydrogeology is uncertain and may be complex.

The Modular Storage Units overlay an area of geology that has not been adequately characterized to determine the exact elevation of the top of basalt or differentiate the suprabasalt sediments present above the top of basalt. This statement is based on the description in SGW-52467, which described the top of basalt surface interpretation as tenuous. The reflector horizons for the suprabasalt sediments were described as extremely tenuous because no refraction or resistivity data can be used to help support the interpretation. As a result, the suprabasalt sediments are not adequately defined to determine what conditions may control the groundwater flow direction.

One example of hydrogeologic uncertainty is the extent of Ringold sediments which extend to well 299-E26-11, located to the southwest of the Modular Storage Units. Ringold sediments may potentially extend to beneath the Modular Storage Units, as discussed in Section 3.1.2. As a result, a greater groundwater elevation may be driven by semiconfining conditions as seen at well 299-E26-11. Such conditions may impose a westerly local groundwater flow beneath the Modular Storage Units as displayed in groundwater potentiometric surface elevations in Figure 3-12 (e.g., east of the Modular Storage Units). This possible condition is based on a conceptualization of a lateral connection with semiconfining Ringold sediments to the east and the greater water table levels to the east associated with past B Pond groundwater mounds.

Another conceptual model indicates that catastrophic glacial fluvial floods may have entirely eroded the Ringold Formation from beneath the Modular Storage Units as well as additional EMB. EMB may be lower than interpreted by past seismic resolution surveys because of the uncertainty discussed in SGW-52467. As a result, saturated Hanford sediments may be present below the Modular Storage Units. If saturated Hanford sediments overlay the top of basalt, the groundwater flow direction may be similar to the estimated southwest flow direction associated with past interpretations as shown in Figure 3-12.

A third possible groundwater flow condition may include south flow. This consideration is presented because of the changing geochemistry seen at well 299-E26-11. The geochemistry at well 299-E26-11 has recently changed from a calcium carbonate groundwater signature to a calcium sulfate signature. This change is similar to the groundwater changes to the west at wells 299-E26-10 and 299-E34-7 (location of wells presented in Figure 1-1). However, because the groundwater table at well 299-E26-11
is greater in elevation than wells to the west, the source of the change may be to the north. In addition to the changing geochemistry, tritium is still present at well 299-E26-11, which has not been reliably seen at wells to the west in nearly two decades. Thus, south flow similar to what is defined at LERF is a possible consideration.

A final consideration for this area is that no groundwater will be encountered. This consideration reflects the current top of basalt interpretation. Although basalt may be encountered above the expected groundwater elevation various precautionary actions will be taken before determining no groundwater is present. The precautionary actions are explained in the following paragraph.

In order to evaluate which of the four possibly expected hydrogeologic conditions exist beneath the Modular Storage Unit Facility, as provided above, a test well is being drilled. If groundwater is encountered during drilling, as discussed above for three of the four expected hydrogeologic conditions at the Modular Storage Unit Facility, then a variety of additional tests/investigations may be completed to confirm hydrogeologic conditions. The test/investigation sequence is dependent upon the conditions found and will progress as described in the following Drilling and Investigation Steps. If groundwater is not initially observed, three precautionary actions will be used to ensure well(s) are drilled deep enough and borehole(s) remain open long enough for potential low permeability sediments or basalt fractures to drain. These precautionary actions are as follows and are also integrated into the Drilling and Investigation Steps. First, drilling must advance deep enough to consider the various hydraulic possibilities and variables associated with drilling through Hanford sediments. Because Hanford sediments in this vicinity potentially contain cobble and boulder sized materials, the borehole may become deviated from vertical. Past gyroscopic surveys have found deviations from vertical requiring elevation corrections of up to a meter. Thus, deviations from vertical provide the appearance of advancing
to a greater depth than the actual true depth. Such a result is considered very possible at the Modular Storage Unit Facility test well. Therefore, one precautionary action will be to advance the drilling at least 1 m (3 ft) beyond the lowest estimate of the groundwater elevation. The lowest elevation in the unconfined aquifer in the area is 121.75 m (399.7 ft) amsl. As a result, drilling will extend to an elevation of 120.7 m (396 ft) amsl. Secondly, gyroscopic surveys will be completed once total depth has been reached to verify the true depth. The gyroscopic survey will allow additional time (e.g., day to days) for possible groundwater flow through low permeability or fractures to be evaluated. The third precautionary action will consist of an e-tape measurement each day, lowering the probe to the bottom of the well, to monitor for the presence of groundwater. After all of these precautionary actions have been completed and there is still no groundwater found, then the site will be determined to be absent of unconfined groundwater.

If groundwater is encountered at the test well then the **Drilling and Investigation Steps** will require the following measurement corrections at the test well after completion of drilling. Subsequent Modular Storage Unit wells drilled as a result of finding groundwater at the test well and also encountering groundwater will require the following measurement corrections after completion of drilling:

1. Precision surveys from existing bench marks used for other nearby wells
2. Gyroscopic surveys to account for any borehole deviation
3. Barometric response correction

These corrections will help reduce measurement error associated with groundwater flow calculations at the test well and later at the Modular Storage Unit monitoring network. Similarly, regional wells used for flow calculations will also be corrected. Reducing the error in groundwater water levels for the regional flow calculation should provide a representative local flow direction for the Modular Storage Unit Facility. The regional flow calculation will be used to locate the other three Modular Storage Unit Facility monitoring well locations. The other regional wells identified for estimating the groundwater flow direction at the Modular Storage Unit Facility that have had error reduction measurements include: wells 299-E26-14 and 299-E26-79 for unconfined conditions and well 299-E26-11 for confined conditions (Figure 3-14). If confining conditions are determined at the test well, then well 699-45-42 would also need to be corrected for groundwater measurement errors before used for calculating a confining flow direction.

Another **Drilling and Investigation Step** will include slug tests. Slug tests will define the hydraulic conditions. The slug tests will provide confirmation of the type of sediments the aquifer is contained in and the associated hydraulic conductivity. The hydraulic conductivity measurements will be used to derive the flow rate in the aquifer. Based on the study of hydraulic conductivity ranges for wells associated with the Liquid Effluent Retention Facility (LERF), values under 15 m/day have been associated with the Ringold Formation. For example, well 299-E26-11 ranged from 5.85 to 11.2 m/day for 10 different slug tests completed from 1990 to 2008. Wells with greater hydraulic conductivity at the LERF are either associated with the Hanford formation or fractured basalt. The hydraulic conductivity associated with the Hanford formation at LERF ranged from 24.4 to 42.8 m/day (DOE/RL-2013-46, *Groundwater Monitoring Plan for the Liquid Effluent Retention Facility*). Even greater hydraulic conductivity was associated with the fractured basalt. Thus, if slug test results at wells completed at the Modular Storage Unit Facility produce a calculated hydraulic conductivity of 15 m/day or less then the sediments will be considered Ringold Formation sediments. In this case wells 299-E26-11 and 699-45-42 would be used to derive the regional groundwater flow direction (Figure 3-14). However, if the hydraulic values are greater the sediments would be considered Hanford formation sediments and wells 299-E26-14 and 299-E26-79 would be used to derive the regional groundwater flow direction (Figure 3-14).
Below is the sequence of the test well drilling and investigation steps, including precautionary actions.

**Drilling and Investigation Step 1**

This step provides direction for two initial observations/determinations of possible hydrogeologic conditions found within sediments above the upper basalt surface or within the top 15 cm (6 inches) of the basalt at the Modular Storage Unit Facility. As the sequence of investigations continues hydrogeologic conditions are refined. As the hydrogeologic conditions are refined direction is provided for additional investigations of saturated low permeability hydrogeologic conditions within Step 1 or to another *Drilling and Investigation Step*. As the investigations for low permeability hydrogeologic conditions conclude, direction is provided for additional monitoring well drilling locations.

1. If groundwater is encountered above the basalt surface or with basalt fractures in the upper 15 cm (6 inches) of the basalt in the test well (or at additional monitoring wells) then go to investigation 1a. If no groundwater is initially encountered above basalt surface or within the top 15 cm (6 inches) of the basalt then go to investigation number 2.
   a. Deepen the well if necessary and construct well with screen across the groundwater bearing interval then go to 1b.
   b. Complete slug test. After obtaining slug test data go to investigation 1bi.
i. If slug test indicates low permeability saturated sediments in the test well or other associated monitoring wells, similar to well 299-E26-11, then complete a barometric response study, gyroscopic survey, and precision survey. The precision survey will be from the same bench mark used for well 299-E26-11. Go to investigation 3 if investigations are associated with the test well. If investigations are associated with an additional monitoring well then start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well location as previously determined. If slug test indicated high permeability saturated sediments, then go to **Drilling and Investigation Step 2**.

2. If no groundwater is encountered above the basalt or within the top 15 cm (6 inches) of basalt, allow at least two hours for groundwater to drain into the borehole before any additional drilling. If groundwater is encountered go to investigation 1a, above. If no groundwater is encountered, then go to **Drilling and Investigation Step 3**.


4. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a westerly groundwater flow direction then go to investigation 4a, otherwise go to investigation 5.

   a. Drill two additional downgradient wells to the west of Modular Storage Units 2 and 3 as shown in Figure 3-13 (A and B). Drill an upgradient well at C, to the east, as displayed in Figure 3-13. Start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well.

5. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a southwest groundwater flow direction then go to investigation 5a, otherwise go to investigation 6.

   a. Drill two additional downgradient wells to the southwest of Modular Storage Units 2 and 3 as shown in Figure 3-13 (D and E). Based on the regional southwesterly flow derivation, the upgradient well would be located at F, to the northeast, as displayed in Figure 3-13. Additional well drilling will start with the downgradient wells. If well D appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well.

6. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a south groundwater flow direction then go to investigation 6a, otherwise meet with DOE and regulators to devise appropriate well locations.

   a. Drill two additional downgradient wells to the south of Modular Storage Units 2 and 3 as shown in Figure 3-13 (E and G). Based on the regional south flow derivation, the upgradient well would be located at H, to the north, as displayed in Figure 3-13. Again, if H appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well.
Drilling and Investigation Step 2

This step provides direction for additional investigations associated with well completion in a high permeability hydrogeologic condition. As the sequence of investigations continues direction is provided for additional investigations for high permeability sediments or fractured basalt within Step 2. The investigations for high permeability hydrogeologic conditions conclude providing direction for additional drilling locations and starting the test well drilling and investigation steps over at Step 1.

1. Complete a barometric response study, gyroscopic survey, and precision survey. The precision survey will be from the same bench mark used for wells 299-E26-14 and 299-E26-79. Go to investigation 2 if investigations are associated with the test well. If investigations are associated with an additional monitoring well then start at Drilling and Investigation Step 1 for the next downgradient or upgradient well location as previously determined.

2. If the regional groundwater flow direction using the test well and wells 299-E26-14 and 299-E26-79 in a 3 point problem derives a westerly groundwater flow direction then go to investigation 2a, otherwise go to investigation 3.
   a. Drill two additional downgradient wells to the west of Modular Storage Units 2 and 3 as shown in Figure 3-13 (A and B). Drill an upgradient well at C, to the east, as displayed in Figure 3-13. Start at Drilling and Investigation Step 1 for the next downgradient or upgradient well.

3. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a southwest groundwater flow direction then go to investigation 3a, otherwise go to investigation 4.
   a. Drill two additional downgradient wells to the southwest of Modular Storage Units 2 and 3 as shown in Figure 3-13 (D and E). Based on the regional southwesterly flow derivation, the upgradient well would be located at F, to the northeast, as displayed in Figure 3-13. Additional well drilling will start with the downgradient wells. If well D appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at Drilling and Investigation Step 1 for the next downgradient or upgradient well.

4. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a south groundwater flow direction then go to investigation 4a, otherwise meet with DOE and regulators to devise appropriate well locations.
   a. Drill two additional downgradient wells to the south of Modular Storage Units 2 and 3 as shown in Figure 3-13 (E and G). Based on the regional south flow derivation, the upgradient well would be located at H, to the north, as displayed in Figure 3-13. Additional well drilling will start with the downgradient wells. If well H appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at Drilling and Investigation Step 1 for the next downgradient or upgradient well.

Drilling and Investigation Step 3

This step provides direction for additional investigations associated with no groundwater found above the basalt surface or within the top 15 cm (6 inches) of the basalt. As the sequence of investigations continues direction is provided for additional drilling and investigations for groundwater. If groundwater is found
then a sequence of investigations continues to define the hydrogeologic conditions. As the hydraulic conditions are defined then direction is provided for the proper sequence of additional investigations and well installations. If no groundwater is encountered then it is assumed there is no continuing unconfined hydraulic horizon beneath the Modular Storage Units and each organization (Department of Energy Richland Operations Office, Washington State Department of Ecology, and CH2M Hill) is to meet with Environmental Protection Agency to determine alternative monitoring requirements.

1. If no groundwater is encountered above the top of basalt or within the 15 cm (top 6 inches) of basalt, allow at least two hours for groundwater to drain into the borehole before any additional drilling. If no groundwater is found after two hours for the test well or potential subsequent wells, then drilling should continue to an elevation of 121.3 m (398 ft) or an estimated depth of 59 m (194 ft) bgs for the test well or equivalent depth for additional wells. Basalt chip samples will be collected every 15 cm (6 in) to assess the nature of the basalt. Upon arrival at the 121.3 m (398 ft) elevation, allow at least two hours to determine if groundwater is present at this elevation. If groundwater is encountered then go to investigation 1a. If no groundwater then go to investigation 2.

   a. Deepen the well if necessary and construct well with screen across the groundwater bearing interval then go to 1b.

   b. Complete slug test. After obtaining slug test data go to investigation 1bi if low permeability conditions are found. Go to 1bii if high permeability conditions are found.

      i. Complete a barometric response study, gyroscopic survey, and precision survey. The precision survey will be from the same bench mark used for well 299-E26-11. Go to investigation 3 if investigations are associated with the test well. If investigations are associated with an additional monitoring well then start at Drilling and Investigation Step 1 for the next downgradient or upgradient well location as previously determined.

      ii. Complete a barometric response study, gyroscopic survey, and precision survey. The precision survey will be from the same bench mark used for wells 299-E26-14 and 299-E26-79. Go to investigation 7 if investigations are associated with the test well. If investigations are associated with an additional monitoring well then start at Drilling and Investigation Step 1 for the next downgradient or upgradient well location as previously determined.

2. If no groundwater is encountered at the elevation of 121.3 m (398 ft) for the test well or equivalent depth for potential subsequent wells, then continue to an elevation of 120.7 m (396 ft) or 60 m (196 ft) bgs for the test well or equivalent depth for potential subsequent wells. Basalt chip samples will continue to be collected every 15 cm (6 in.) to assess the nature of the basalt. Upon arrival at the 120.7 m (396 ft) elevation, allow at least two hours to determine if groundwater is present at this elevation. If there is no groundwater, then assume that there is no continuing hydraulic horizon beneath the Modular Storage Units. Meet with EPA to determine alternative monitoring requirements. If groundwater is encountered then go to investigation 2a.

   a. Deepen the well if necessary and construct well with screen across the groundwater bearing interval then go to 2b.

   b. Complete slug test. After obtaining slug test data go to investigation 2bi if low permeability conditions are found. Go to 2bii if high permeability conditions are found.

      i. Complete a barometric response study, gyroscopic survey, and precision survey. The precision survey will be from the same bench mark used for well 299-E26-11. Go to
investigation 3 if investigations are associated with the test well. If investigations are associated with an additional monitoring well then start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well location as previously determined.

ii. Complete a barometric response study, gyroscopic survey, and precision survey. The precision survey will be from the same bench mark used for wells 299-E26-14 and 299-E26-79. Go to investigation 7 if investigations are associated with the test well. If investigations are associated with an additional monitoring well then start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well location as previously determined.


4. If the regional groundwater flow direction using the test well and wells 299-E26-11 and 699-45-42 in a 3 point problem derives a westerly groundwater flow direction then go to investigation 4a, otherwise go to investigation 5.

   a. Drill two additional downgradient wells to the west of Modular Storage Units 2 and 3 as shown in Figure 3-13 (A and B). Drill an upgradient well at C, to the east, as displayed in Figure 3-13. Start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well.

5. If the regional groundwater flow direction using the test well and wells 299-E26-11 and 699-45-42 in a 3 point problem derives a southwest groundwater flow direction then go to investigation 5a, otherwise go to investigation 6.

   a. Drill two additional downgradient wells to the southwest of Modular Storage Units 2 and 3 as shown in Figure 3-13 (D and E). Based on the regional southwesterly flow derivation, the upgradient well would be located at F, to the northeast, as displayed in Figure 3-13. Additional well drilling will start with the downgradient wells. If well D appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well.

6. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a south groundwater flow direction then go to investigation 6a, otherwise meet with DOE and regulators to devise appropriate well locations.

   a. Drill two additional downgradient wells to the south of Modular Storage Units 2 and 3 as shown in Figure 3-13 (E and G). Based on the regional south flow derivation, the upgradient well would be located at H, to the north, as displayed in Figure 3-13. Additional well drilling will start with the downgradient wells. If well H appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at **Drilling and Investigation Step 1** for the next downgradient or upgradient well.

7. If the regional groundwater flow direction using the test well and wells 299-E26-14 and 299-E26-79 in a 3 point problem derives a westerly groundwater flow direction then go to investigation 7a, otherwise go to investigation 8.
a. Drill two additional downgradient wells to the west of Modular Storage Units 2 and 3 as shown in Figure 3-13 (A and B). Drill an upgradient well at C, to the east, as displayed in Figure 3-13. Start at Drilling and Investigation Step 1 for the next downgradient or upgradient well.

8. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a southwest groundwater flow direction then go to investigation 8a, otherwise go to investigation 9.

   a. Drill two additional downgradient wells to the southwest of Modular Storage Units 2 and 3 as shown in Figure 3-13 (D and E). Based on the regional southwesterly flow derivation, the upgradient well would be located at Option F, to the northeast, as displayed in Figure 3-13. Additional well drilling will start with the downgradient wells. If well D appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at Drilling and Investigation Step 1 for the next downgradient or upgradient well.

9. If the regional groundwater flow direction using wells 299-E26-11 and 699-45-42 in a 3 point problem derives a south groundwater flow direction then go to investigation 9a, otherwise meet with DOE and regulators to devise appropriate well locations.

   a. Drill two additional downgradient wells to the south of Modular Storage Units 2 and 3 as shown in Figure 3-13 (E and G). Based on the regional south flow derivation, the upgradient well would be located at H, to the north, as displayed in Figure 3-13. Additional well drilling will start with the downgradient wells. If well H appears to have limited groundwater available, then the upgradient well may require an alternative location, such as C, per substantive requirements WAC 173-303-645(8)(a)(i)(A). Start at Drilling and Investigation Step 1 for the next downgradient or upgradient well.
This page intentionally left blank.
4 Groundwater Monitoring

This section lists the wells to be monitored, constituents to analyze, and sampling frequency for initiating and establishing a groundwater detection monitoring network at the Modular Storage Units. This section is also predicated on suitable groundwater conditions being found beneath the Modular Storage Units in order to establish a groundwater detection monitoring network. The following discussion anticipates a southwest groundwater flow direction. Upon completion of the one year background quality groundwater evaluation period, this plan should be updated. However, if resources are not immediately available, this plan can be used during the transition to monitoring for the detection monitoring program at the Modular Storage Units. Quality assurance (QA) and quality control requirements are provided in the QAPjP in Appendix A.

4.1 Constituent List and Sampling Frequency to Establish Local Background Concentrations

Table 4-1 lists the constituents to be analyzed for establishing initial background concentrations for a detection level groundwater monitoring program at the Modular Storage Units. The table reflects the substantive monitoring requirements as specified in WAC 173-303-645(9)(a) including indicator parameters, waste constituents, and heavy metals. The waste constituents identified in Table 4-1 reflect the characterization analyses that exceeded regional background groundwater concentrations by greater than two orders of magnitude (Section 2.3). The indicator parameters and heavy metals are further defined by substantive constituents that may exceed the maximum contaminant levels as defined in 40 CFR 265.94(a)(2)(i), “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” “Recordkeeping and Reporting.”

The four anticipated wells (e.g., test well and D, E, and F) and the constituents to be sampled quarterly for the first year are listed in Table 4-1. Quarterly sampling will commence within three months of all the Modular Storage Units wells being installed and accepted through the QA program.

Because of potential limiting hydrogeologic conditions, fewer than three downgradient wells may be sufficient to monitor conditions in the aquifer. For example, the test well or the test well and one other downgradient well may be the only wells determined to be representative downgradient wells. Possible reasons may include finding no groundwater at a certain well location or finding confining conditions at one potential downgradient location and unconfined conditions at the other downgradient well locations. Alternative upgradient locations may be necessary because of limiting local hydrogeologic conditions (i.e., no groundwater encountered).

Maintenance problems and sampling logistics can delay scheduled sampling events. If sampling of a well is delayed more than two months, that sampling event will be cancelled because it is nearly time for the next scheduled sampling event. If a sampling event is missed, then additional events will be necessary to establish statistical upgradient background concentrations for comparison with downgradient concentrations. In that case, the background period would be extended beyond the first year, until four sampling events are complete.

4.2 Constituent List and Sampling Frequency for Detection Monitoring

Table 4-2 lists the constituents to be analyzed for the detection level groundwater monitoring program at the Modular Storage Units. The wells and constituents for this program are to be sampled in accordance with this table. The table assumes that the wells installed were determined to be sufficient for detection monitoring, and four quarters of background sampling has been collected at each well. After four quarterly background quality sampling events, critical mean values will be established using a student
t-test. Maintenance problems and sampling logistics can delay scheduled sampling events. If sampling of a well is delayed more than four months, that sampling event will be cancelled because it is nearly time for the next scheduled sampling event.

4.3 Well Network

Figure 3-13 and Section 3.3.1 show and discuss three potential groundwater monitoring well networks for the Modular Storage Units. The most anticipated network, based on past interpretations, is a southeast flow network utilizing the test well and wells D and E as downgradient wells and well F as the upgradient well. Local groundwater flow directions during the first year of background monitoring will be used to compare with the initial regional flow directions, derived by wells and conditions described in Section 3.3.1. If the local groundwater flow direction is significantly different from the regional conditions used to establish the network, recommendations will be provided in the updated monitoring plan to establish a sufficient monitoring network. CERCLA wells in the Modular Storage Units network also support the regional 200-BP-5 OU. Sampling for the Modular Storage Units and the 200-BP-5 OU will be coordinated to eliminate duplicate analyses and well trips.

In the updated monitoring plan, a table will be provided that summarizes the well attribute information, including the depth to water in each well. All of the wells in the Modular Storage Units will be constructed to meet the substantive requirements of WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells.” These wells will have stainless-steel casing and screen, sand pack in the screened interval, and full annular seal above. Given the current rate of water table decline (0.05 m/yr [0.164 ft/yr]), the wells will be extended 3 m (10 ft) below the contact with groundwater. Based on historical groundwater levels prior to Hanford operations, this should be sufficient for continued use regardless of continued groundwater elevation declines.

4.4 Sampling and Analysis Protocol

Groundwater monitoring at the Modular Storage Units will follow the QAPjP described in Appendix A.

<table>
<thead>
<tr>
<th>Hazardous Waste Constituent Name</th>
<th>CAS Number</th>
<th>Analytical Method*</th>
<th>Wells and Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test Well</td>
</tr>
<tr>
<td>Arsenic</td>
<td>7440-38-2</td>
<td>EPA-600/4-84-017 Method 200.8</td>
<td>Q</td>
</tr>
<tr>
<td>Barium</td>
<td>7440-39-3</td>
<td>SW-846 Method 6010B/C</td>
<td>Q</td>
</tr>
<tr>
<td>Cadmium</td>
<td>7440-43-9</td>
<td>SW-846 Method 6010B/C</td>
<td>Q</td>
</tr>
<tr>
<td>Chromium</td>
<td>7440-47-3</td>
<td>SW-846 Method 6010B/C</td>
<td>Q</td>
</tr>
<tr>
<td>Fluoride</td>
<td>16984-48-8</td>
<td>EPA/600 Method 300</td>
<td>Q</td>
</tr>
<tr>
<td>Lead</td>
<td>7439-92-1</td>
<td>EPA-600/4-84-017 Method 200.8</td>
<td>Q</td>
</tr>
</tbody>
</table>
Table 4-1. First Year of Groundwater Monitoring at the Modular Storage Units to Establish Initial Background Concentrations for a Detection Level Groundwater Monitoring Program

<table>
<thead>
<tr>
<th>Hazardous Waste Constituent Name</th>
<th>CAS Number</th>
<th>Analytical Method*</th>
<th>Wells and Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test Well</td>
</tr>
<tr>
<td>Mercury</td>
<td>7439-97-6</td>
<td>SW-846 Method 7470A</td>
<td>Q</td>
</tr>
<tr>
<td>Nitrate as N</td>
<td>14797-55-8</td>
<td>EPA/600 Method 300</td>
<td>Q</td>
</tr>
<tr>
<td>Selenium</td>
<td>7782-49-2</td>
<td>EPA-600/4-84-017 Method 200.8</td>
<td>Q</td>
</tr>
<tr>
<td>Silver</td>
<td>7440-22-4</td>
<td>SW-846 Method 6010B/C</td>
<td>Q</td>
</tr>
<tr>
<td>Endrin</td>
<td>72-20-8</td>
<td>SW-846 Method 8081B</td>
<td>Q</td>
</tr>
<tr>
<td>Lindane</td>
<td>58-89-9</td>
<td>SW-846 Method 8081B</td>
<td>Q</td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>72-43-5</td>
<td>SW-846 Method 8081B</td>
<td>Q</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>8001-35-2</td>
<td>SW-846 Method 8081B</td>
<td>Q</td>
</tr>
<tr>
<td>2,4-D</td>
<td>94-75-7</td>
<td>SW-846 Method 8151A</td>
<td>Q</td>
</tr>
<tr>
<td>2,4,5-TP Silvex</td>
<td>93-72-1</td>
<td>SW-846 Method 8151A</td>
<td>Q</td>
</tr>
<tr>
<td>Radium</td>
<td>7440-14-4</td>
<td>Alpha Energy Analysis/Gamma Energy Analysis</td>
<td>Q</td>
</tr>
<tr>
<td>Gross Alpha</td>
<td>127-18-4</td>
<td>EPA Method 900</td>
<td>Q</td>
</tr>
<tr>
<td>Gross Beta</td>
<td>12587-47-2</td>
<td>EPA Method 900</td>
<td>Q</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NA</td>
<td>Instrument/meter</td>
<td>Q</td>
</tr>
<tr>
<td>Coliform Bacteria</td>
<td>NA</td>
<td>SW-846 Method 9223</td>
<td>Q</td>
</tr>
</tbody>
</table>

Parameters Establishing Groundwater Quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CAS Number</th>
<th>Analytical Method*</th>
<th>Wells and Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Test Well</td>
</tr>
<tr>
<td>Chloride</td>
<td>108-90-7</td>
<td>EPA/600 Method 300</td>
<td>Q</td>
</tr>
<tr>
<td>Iron</td>
<td>75-01-4</td>
<td>SW-846 Method 6010B/C</td>
<td>Q</td>
</tr>
<tr>
<td>Manganese</td>
<td>67-66-3</td>
<td>SW-846 Method 6010B/C</td>
<td>Q</td>
</tr>
<tr>
<td>Phenols</td>
<td>74-87-3</td>
<td>SW-846 Method 8041A or SW-846 Method 8270</td>
<td>Q</td>
</tr>
<tr>
<td>Sodium</td>
<td>10061-01-5</td>
<td>SW-846 Method 6010B/C</td>
<td>Q</td>
</tr>
<tr>
<td>Sulfate</td>
<td>75-71-8</td>
<td>EPA/600 Method 300</td>
<td>Q</td>
</tr>
</tbody>
</table>

Parameters Used as Indicators of Groundwater Contamination

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CAS Number</th>
<th>Analytical Method*</th>
<th>Wells and Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>100-41-4</td>
<td>Instrument/meter</td>
<td>Q</td>
</tr>
</tbody>
</table>
Table 4-1. First Year of Groundwater Monitoring at the Modular Storage Units to Establish Initial Background Concentrations for a Detection Level Groundwater Monitoring Program

<table>
<thead>
<tr>
<th>Hazardous Waste Constituent Name</th>
<th>CAS Number</th>
<th>Analytical Method*</th>
<th>Wells and Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Conductance</td>
<td>107-12-0</td>
<td>Instrument/Meter</td>
<td>Q Q Q Q Q Q</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>126-98-7</td>
<td>SW-846 Method 9060</td>
<td>Q Q Q Q Q Q</td>
</tr>
<tr>
<td>Total Organic Halides</td>
<td>100-42-5</td>
<td>SW-846 Method 9020</td>
<td>Q Q Q Q Q Q</td>
</tr>
</tbody>
</table>

Parameters Detected in Modu-Tank Effluent at Greater Than 2 Orders of Magnitude above Background

<table>
<thead>
<tr>
<th>Constituent Name</th>
<th>CAS Number</th>
<th>Analytical Method</th>
<th>Wells and Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Alpha</td>
<td>127-18-4</td>
<td>EPA Method 900</td>
<td>Q Q Q Q Q Q</td>
</tr>
<tr>
<td>Technetium-99</td>
<td>108-88-3</td>
<td>Tc-99 – liquid scintillation</td>
<td>Q Q Q Q Q Q</td>
</tr>
<tr>
<td>Uranium-233/234</td>
<td>10061-02-6</td>
<td>Alpha Energy Analysis</td>
<td>Q Q Q Q Q Q</td>
</tr>
<tr>
<td>Uranium-238</td>
<td>79-01-06</td>
<td>Alpha Energy Analysis</td>
<td>Q Q Q Q Q Q</td>
</tr>
</tbody>
</table>

* For EPA Method 200.8, see EPA-600/R-94/111, Methods for the Determination of Metals in Environmental Samples, Supplement 1. For EPA Methods 300, see EPA-600/4-79-020, Methods for Chemical Analysis of Water and Wastes. EPA Method 900 is “Gross Alpha and Gross Beta Radioactivity in Drinking Water Method 900.” For 4-digit EPA methods, see SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Third Edition; Final Update IV-B.

CAS = Chemical Abstracts Service
EPA = U.S. Environmental Protection Agency
NA = not applicable
Q = quarterly sampling frequency
Table 4-2. Groundwater Monitoring Schedule for Modular Storage Units

<table>
<thead>
<tr>
<th>Well Namea</th>
<th>Purpose</th>
<th>WAC Compliant</th>
<th>Water Level</th>
<th>pHd</th>
<th>Specific Conductance</th>
<th>Technetium-99</th>
<th>Total Organic Carbon</th>
<th>Total Organic Halides</th>
<th>Nitrate</th>
<th>Sulfate</th>
<th>Gross Alpha/Beta</th>
<th>Isotopic Uranium</th>
<th>Manganese</th>
<th>Sodium</th>
<th>Alkalinity</th>
<th>Dissolved Oxygend</th>
<th>Temperatured</th>
<th>Turbidityd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Well</td>
<td>Downgradient</td>
<td>Y</td>
<td>S</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>A</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Option D</td>
<td>Downgradient</td>
<td>Y</td>
<td>S</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>A</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Option E</td>
<td>Downgradient</td>
<td>Y</td>
<td>S</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>A</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Option F</td>
<td>Upgradient</td>
<td>Y</td>
<td>S</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S4</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>A</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

a. Well names to be determined upon completion of drilling and hydraulic tests.
c. Constituents not required by substantive ARARs but needed to support interpretation.
d. Field measurement.
e. For anions, analytes include chloride, fluoride, nitrate, nitrite, and sulfate. For metals, analytes include (but are not limited to) calcium, chromium, iron, manganese, potassium, and sodium.

4 = quadruplicate samples
A = to be sampled annually
ARAR = applicable or relevant and appropriate requirement
S = to be sampled semiannually
Y = well will be constructed to WAC 173-160, “Minimum Standards for Construction and Maintenance of Wells”
WAC = Washington Administrative Code
This page intentionally left blank.
Data Evaluation and Reporting

This chapter discusses data evaluation and reporting for the Modular Storage Units.

5.1 Data Review

Data review, validation, and verification are discussed in the QAPJTP in Appendix A.

5.2 Statistical Evaluation

The goal of detection monitoring is to determine if the Modular Storage Units have affected groundwater quality beneath the site, which is determined based on the results of specified statistical tests.

The sampling procedures and statistical evaluation methods are based on substantive requirements of WAC 173-303-645(8)(h). This plan requires the use of a statistical method that compares mean concentrations of the five contamination indicator parameters (e.g., pH, specific conductance, technetium-99, total organic carbon, and total organic halides) in the downgradient wells to the background levels obtained from upgradient well.

The chosen statistical method for comparing baseline (background) groundwater quality with compliance point groundwater quality is the Welch’s \( t \)-test, an adaptation of the Student’s \( t \)-test. The Welch’s \( t \)-test meets the substantive statistical requirements outlined in WAC 173-303-645(8)(h) and is recommended for detection monitoring when population variances might differ between two groups, as stated in EPA 530/R-09-007, Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance. Applying this parametric \( t \)-test provides a reasonably robust statistical procedure and assurance when background data are at a minimum and the underlying populations may not meet normality. However, normality can usually be met by log transforming the data.

The Welch’s \( t \)-test procedure can be implemented as follows:

I. Compute the sample mean \( \bar{x} \), standard deviation \( s \), and variance \( s^2 \), in each of the background and compliance well data sets.

II. Compute Welch’s \( t \)-statistic using the following equation

\[
 t = (\bar{X}_{BG} - \bar{X}_{c}) / \sqrt{\frac{s_{BG}^2}{n_{BG}} + \frac{s_c^2}{n_c}}
\]

III. Compute the approximate degrees of freedom using the following equation

\[
 df = \left[ \frac{s_{BG}^2}{n_{BG}} + \frac{s_c^2}{n_c} \right] / \left[ \frac{(s_{BG}^2/n_{BG})^2}{n_{BG} - 1} + \frac{(s_c^2/n_c)^2}{n_c - 1} \right]
\]

IV. Use Table 16-1 of Appendix D in EPA 530/R-09-007 to assign the upper 95 percent critical mean based on the degrees of freedom.

V. Compare the \( t \)-statistic against the critical point, \( t_{cp} \). When the condition \( t \leq t_{cp} \), conclude that there is no statistically significant difference between the background and compliance point population means. If, however, \( t > t_{cp} \), conclude that the compliance point population mean is significantly greater than the background mean at the \( \alpha \) level of significance.

As monitoring continues and the process is shown to be in control (i.e., there is no statistically significant evidence of facility impact to groundwater), the baseline mean and standard deviation should be updated periodically (e.g., every 1 or 2 years) to incorporate the new data (EPA 530/R-09-007). This reduces uncertainty in the background and helps adjust for groundwater influences from outside sources. This updating process should continue for the lifetime of the monitoring program.
If an exceedance occurs, resampling within one month of receipt of the result will be undertaken to verify or refute the original exceedance. The analytical result from the resample is substituted into the previous formulas in place of the original value obtained, and the Welch’s $t$-test statistic is updated. If resampling does not confirm the exceedance, and “if the exceedance can be shown to be a measurement in error or a confirmed outlier, it should be excluded from the revised background. Otherwise, any disconfirmed exceedances (including any resamples that exceed the background limit but are disconfirmed by other resamples) should probably be included when updating the background. The reason is that background limits designed to incorporate retesting are computed as low as possible to ensure adequate statistical power” (EPA 530/R-09-007).

If resampling confirms statistically significant evidence of contamination, the following will be performed in accordance with WAC 173-303-645(9)(g):

- Notify lead agency in writing within seven days of the finding, indicating which chemical parameters have shown statistically significant evidence of contamination.

- Sample the groundwater in all monitoring wells and determine if constituents included any dangerous waste constituents listed in 40 CFR 264, Appendix IX and, if so, in what concentration. Also, continue to monitor for groundwater quality parameters and indicator parameters. For any of these compounds detected, the owner or operator may resample quarterly for those compounds detected. If the constituents are detected in consecutive analysis and not associated with upgradient sources or laboratory issues, they will form the basis for compliance monitoring.

- If dangerous constituent(s) are detected, establish a compliance monitoring program and submit to the lead agency within 90 days.

- If dangerous constituents are not detected, continue to monitor in accordance with the detection monitoring program.

### 5.3 Interpretation

After the data are validated and verified, the acceptable data are used to interpret groundwater conditions at the Modular Storage Units. Interpretive techniques include the following:

- **Hydrographs**: Graph water levels versus time to determine decreases, increases, seasonal, or man-made fluctuations in groundwater levels.

- **Water table maps**: Use water table elevations from multiple wells to construct contour maps and to estimate flow directions. Groundwater flow is assumed to be perpendicular to lines of equal potential on the maps.

- **Trend plots**: Graph concentrations of constituents versus time to determine increases, decreases, and fluctuations. May be used in tandem with hydrographs and/or water table maps to determine if concentrations relate to changes in water level or in groundwater flow directions.

- **Plume maps**: Mapped distributions of chemical constituent concentrations in the aquifer to determine extent of contamination. Changes in plume distribution over time aid in determining movement of plumes and direction of groundwater flow.

- **Contaminant ratios**: Can sometimes be used to distinguish among different sources of contamination.
5.4 Evaluation of Monitoring Network

Per substantive requirement 40 CFR 265.93(f), “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” “Preparation, Evaluation, and Response,” and WAC 173-303-645(9)(e), an annual evaluation of the groundwater monitoring network to determine if it remains adequate to monitor the Modular Storage Units including groundwater flow rate and direction is required. The network must include upgradient and downgradient wells in the uppermost aquifer. The groundwater flow direction beneath the Modular Storage Units has been interpreted as southwest since 2000 based on regional water levels. Investigative techniques defined in Section 3.3.1 will be used to locate the appropriate upgradient and downgradient wells at the depths to yield representative groundwater samples from the uppermost aquifer. Every year, corrected water level measurements will be evaluated to verify if the monitoring network remains sufficient or if modifications are required. The findings of the evaluation will be reported annually per substantive requirements 40 CFR 265.94.

Water level measurements will be collected before each sampling event. A more comprehensive set of water level measurements will be made for the Modular Storage Units, including measurements that are corrected for borehole deviation from vertical and precision surveyed. Each well will be evaluated for barometric response, if needed.

Any new wells needed at the Modular Storage Units will be negotiated and prioritized under TPA (Ecology et al., 1989) Milestone M-24-00.

5.5 Reporting and Notification

Notification and reporting is being completed voluntarily for the Modular Storage Units. Results of detection monitoring will be reported annually in the Hanford Site groundwater monitoring reports (e.g., DOE/RL-2013-22, Hanford Site Groundwater Monitoring Report for 2012). Notifications and change of monitoring will follow the information in Table 5-1.
<table>
<thead>
<tr>
<th>Submittal</th>
<th>Submittal Period</th>
<th>Reporting Vehicle</th>
<th>Voluntary Accepted Equivalent Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>First year of sampling: concentrations of interim primary drinking water constituents, identifying those that exceed limits</td>
<td>Quarterly</td>
<td>Quarterly Modular Storage Units report&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40 CFR 265.94(a)(2)(i)</td>
</tr>
<tr>
<td>Concentration and statistical analyses of groundwater contamination indicator parameters</td>
<td>Annually, after 4 quarters of analytical results</td>
<td>Hanford groundwater monitoring report&lt;sup&gt;b&lt;/sup&gt;</td>
<td>40 CFR 265.94(a)(2)(ii)</td>
</tr>
<tr>
<td>Results of groundwater surface elevation evaluation and description of response, if appropriate</td>
<td>Annually</td>
<td>Hanford groundwater monitoring report&lt;sup&gt;b&lt;/sup&gt;</td>
<td>40 CFR 265.94(a)(2)(iii)</td>
</tr>
<tr>
<td>Notification of statistical exceedance</td>
<td>Within 7 days of verification</td>
<td>Letter to EPA &lt;sup&gt;c&lt;/sup&gt;</td>
<td>WAC 173-303-645(g)(i)</td>
</tr>
<tr>
<td>Submittal of Draft Investigation Monitoring Report&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Within 90 days of verification results</td>
<td>U.S. Department of Energy, Richland Operations Office document</td>
<td>WAC 173-303-645(g)(iv)</td>
</tr>
</tbody>
</table>


<sup>a</sup> Quarterly reports of the data are generated including indicator parameters, waste constituents, and heavy metals. Indicator parameters and heavy metals are further defined by substantive constituents that may exceed the maximum contaminant levels as defined in substantive requirement 40 CFR 265.94(a)(2)(i).

<sup>b</sup> Annual report is provided in the Hanford Site Groundwater Monitoring Report.

<sup>c</sup> Required if an indicator parameter is verified with a statistical increase.

EPA = U.S. Environmental Protection Agency
6 References


Section 104, “Response Authorities.”

Section 121, “Cleanup Standards.”


Appendix A

Quality Assurance Project Plan
This page intentionally left blank.
A Quality Assurance Project Plan

A1 Project Management

A1.1 Project/Task Organization
A1.2 Regulatory Project Manager
A1.3 U.S. Department of Energy, Richland Operations Office Project Manager
A1.5 Contractor Groundwater Remediation Department Manager
A1.6 Project Manager
A1.7 CERCLA Monitoring and Reporting
A1.8 Groundwater Sampling Operations
A1.9 Quality Assurance
A1.10 Environmental Compliance Officer
A1.11 Health and Safety
A1.12 Radiological Engineering
A1.13 Sample Management and Reporting Organization
A1.14 Contract Laboratories
A1.15 Waste Management
A1.16 Problem Definition/Background
A1.17 Project/Task Description
A1.18 Quality Objectives and Criteria
A1.19 Special Training/Certification
A1.20 Documents and Records

A2 Data Generation and Acquisition

A2.1 Sampling Process Design (Experimental Design)
A2.2 Regulatory Requirements
A2.3 Judgmental Sampling
A2.4 Sampling Methods
A2.5 Sample Handling and Custody
A2.6 Analytical Methods
A2.7 Quality Control
A2.8 Field Quality Control Samples
A2.9 Laboratory Quality Control Samples
A2.10 Quality Control Requirements
A2.11 Instrument/Equipment Testing, Inspection, and Maintenance
A2.12 Instrument/Equipment Calibration and Frequency
A2.13 Inspection/Acceptance of Supplies and Consumables
A2.14 Nondirect Measurements ........................................................................... A-15
A2.15 Data Management ............................................................................... A-15

A3 Assessment and Oversight .................................................................................. A-15
A3.1 Assessments and Response Actions ............................................................... A-15
A3.2 Reports to Management ............................................................................ A-15

A4 Data Validation and Usability .......................................................................... A-16
A4.1 Data Review, Verification, and Validation .................................................... A-16
A4.2 Verification and Validation Methods ............................................................ A-16
A4.3 Reconciliation with User Requirements ....................................................... A-16

A5 References ..................................................................................................... A-17

Figure

Figure A-1. Project Organization ............................................................................ A-2

Tables

Table A-2. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits for Modular Storage Units Constituents ............................................. A-7
Table A-3. Quality Control Samples ..................................................................... A-10
Table A-4. Field and Laboratory Quality Control Elements and Acceptance Criteria .......... A-11
Terms

ALARA as low as reasonably achievable
ARAR applicable or relevant and appropriate requirement
CERCLA Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CRDL contract-required detection limit
DOE U.S. Department of Energy
DQA data quality assessment
DQO data quality objective
DUP laboratory matrix duplicate
EB equipment blank
Ecology Washington State Department of Ecology
EPA U.S. Environmental Protection Agency
FTB full trip blank
FWS field work supervisor
FXR field transfer blank
HEIS Hanford Environmental Information System
ICP inductively coupled plasma
ICP/MS inductively coupled plasma/mass spectrometry
LCS laboratory control sample
MB method blank
MDL method detection limit
MS matrix spike
MSD matrix spike duplicate
NTU nephelometric turbidity unit
QA quality assurance
QC quality control
RPD relative percent difference
RL DOE Richland Operations Office
SAP sampling and analysis plan
SMR Sample Management and Reporting
TPA Tri-Party Agreement
Tri-Party Agreement Hanford Federal Facility Agreement and Consent Order
TSD treatment, storage, and disposal
This page intentionally left blank.
A Quality Assurance Project Plan

The contractor’s quality assurance (QA) program describes the contractor’s QA structure, requirements, implementation methods, and responsibilities. The contractor’s environmental QA program plan provides the requirements for collecting and assessing environmental data in accordance with the following documents:

- DOE O 414.1D, *Quality Assurance*
- EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5)
- DOE/RL-96-68, *Hanford Analytical Services Quality Assurance Requirements Documents* (HASQARD)

This quality assurance project plan (QAPjP) establishes the quality requirements for environmental data collection, including planning, implementing, and assessing the sampling, field measurements, and laboratory analysis. Sections 6.5 and 7.8 of the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a), hereinafter called the Tri-Party Agreement (TPA), Attachment 2, “Action Plan,” require that the QA and quality control (QC) and sampling and analysis activities specify the QA requirements for treatment, storage, and disposal (TSD) units. HASQARD requirements (DOE/RL-96-68) also apply to this work.

The content of this QAPjP is patterned after the QA elements of EPA/240/B-01/003. The QAPjP demonstrates conformance to the Part B requirements of *Quality Systems for Environmental Data and Technology Programs: Requirements with Guidance for Use* (ANSI/ASQ E4-2004). This QAPjP is divided into four sections (designated in EPA/240/B-01/003), which describe the quality requirements and controls applicable to this investigation. This QAPjP is intended to supplement the contractor’s environmental QA program plan (CHPRC-00189, *CH2M HILL Plateau Remediation Company Environmental Quality Assurance Program Plan*).

A1 Project Management

This section addresses the basic aspects of project management and will ensure that the project has defined goals, participants understand the goals and approaches used, and planned outputs are appropriately documented.

A1.1 Project/Task Organization

The project organization in regard to planning, sampling, analysis, and data assessment is described in the subsections that follow and is shown in Figure A-1. The project manager maintains a list of the individuals or organizations that are the points of contact for each functional element shown in the figure. For each functional primary contractor role, there is a corresponding oversight role within the U.S. Department of Energy (DOE).

A1.2 Regulatory Project Manager

The U.S. Environmental Protection Agency (EPA) project manager is responsible for the oversight of the Modular Storage Units monitoring network. EPA can request this plan during a regulatory compliance inspection for review. EPA will work with the DOE Richland Operations Office (RL) to resolve concerns regarding the work as described in this QAPjP.
A1.3 U.S. Department of Energy, Richland Operations Office Project Manager


The RL technical lead is responsible for day-to-day oversight of the contractor’s performance of the work scope, working with the contractor and the regulatory agencies to identify and work through issues, and providing technical input to the RL project manager.

A1.5 Contractor Groundwater Remediation Department Manager

The contractor groundwater remediation department manager provides oversight for all activities and coordinates with DOE, the regulators, and primary contractor management in support of groundwater sampling and reporting activities. The remediation department manager also provides support to the project manager to ensure that work is performed safely and cost effectively.
A1.6 Project Manager

The Modular Storage Units project manager is responsible for direct management of activities performed under this QAPjP and for ensuring that the project file is properly maintained for activities directly affecting the Modular Storage Units and the 200-BP-5 Groundwater Operable Unit. The project manager works with QA, Health and Safety, and the field work supervisor (FWS) to plan and implement the work scope. The project manager is responsible for version control of the sampling and analysis plan (SAP) to ensure that personnel are working to the most current job requirements. The project manager also coordinates with and reports to DOE and the primary contractor management.

A1.7 CERCLA Monitoring and Reporting

The CERCLA groundwater monitoring and reporting manager is responsible for direct management of activities performed to be met at the Modular Storage Units for groundwater monitoring, as described further in Chapters 4 and 5. The CERCLA monitoring and reporting manager coordinates with and reports to DOE and the primary contractor management regarding the Modular Storage Units monitoring requirements. The CERCLA monitoring and reporting manager assigns scientists to provide technical expertise.

A1.8 Groundwater Sampling Operations

Groundwater sampling operations is responsible for planning and coordinating field sampling resources and providing the FWS for routine groundwater sampling operations. The FWS directs the samplers, who collect groundwater samples in accordance with the SAP and corresponding standard procedures and work packages. The samplers also complete the field logbook and chain-of-custody forms, as well as any shipping paperwork, and ensure delivery of the samples to the analytical laboratory.

A1.9 Quality Assurance

The QA point of contact is matrixed to the project manager and is responsible for QA issues on the project. Responsibilities include overseeing implementation of the project QA requirements; reviewing project documents, including data quality objective (DQO) summary reports, SAPs, and the QAPjP; and participating in QA assessments on sample collection and analysis activities, as appropriate. The QA point of contact must be independent of the unit generating the data.

A1.10 Environmental Compliance Officer

The environmental compliance officer provides technical oversight, direction, and acceptance of project and subcontracted environmental work, and develops appropriate mitigation measures with the goal of minimizing adverse environmental impacts.

A1.11 Health and Safety

The Health and Safety organization is responsible for coordinating industrial safety and health support within the project as carried out through health and safety plans, job hazard analyses, and other pertinent safety documents required by federal regulations or by internal primary contractor work requirements.

A1.12 Radiological Engineering

The Radiological Engineering lead is responsible for the radiological/health physics support within the project. Specific responsibilities include conducting as low as reasonably achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization for all work planning.
The Radiological Engineer lead identifies radiological hazards and implements appropriate controls to maintain worker exposures ALARA (e.g., requiring personal protective equipment).

A1.13 Sample Management and Reporting Organization

The Sample Management and Reporting (SMR) organization coordinates laboratory analytical work to ensure that the laboratories conform to Hanford Site internal laboratory QA requirements (or their equivalent), as approved by DOE, EPA, and the Washington State Department of Ecology. SMR receives analytical data from the laboratories, performs data entry into the Hanford Environmental Information System (HEIS) database, and arranges for data validation. SMR is responsible for informing the project manager of any issues reported by the analytical laboratory.

A1.14 Contract Laboratories

The contract laboratories analyze samples in accordance with established procedures and provide necessary sample reports and explanations of results to support data validation. The laboratories must meet site-specified QA requirements and must have an approved QA plan in place.

A1.15 Waste Management

Waste Management communicates policies and procedures and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost effective manner.

A1.16 Problem Definition/Background

The problem definitions, as adopted through ARARs, 40 CFR 265.90(b) (“Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities”), are provided in Chapters 3, 4, and 5 of this monitoring plan. The site background is provided in Chapters 2 and 3.

A1.17 Project/Task Description

The project description is provided in Chapters 3, 4, and 5 of this monitoring plan and includes the selection of appropriate dangerous waste or dangerous waste constituents, collection and analyses of groundwater from the monitoring network, interpretation of analytical results, evaluation of monitoring network, and reporting.

The target analytes, along with the monitoring wells and frequency of sampling, are provided in Section 4.

A1.18 Quality Objectives and Criteria

The groundwater monitoring quality objectives and criteria are defined in Tables A-2, A-3, A-4, and A-5 of this QAP/IP in order to meet the evaluation requirements in Chapter 4 of the monitoring plan.

A1.19 Special Training/Certification

Workers receive a level of training that is commensurate with their responsibilities and that complies with applicable DOE orders and government regulations including ARARs, such as working with the Dangerous Waste Training Plan maintained for TSD units to meet the requirements of WAC 173-303-330, “Dangerous Waste Regulations,” “Personnel Training.” The FWS, in coordination with line management, will ensure that all field personnel meet all special training requirements.
A1.20 Documents and Records

The project scientist is responsible for ensuring that the current version of the groundwater monitoring plan is being used and providing any updates to field personnel. Version control is maintained by the administrative document control process. Significant changes to the plan that affect DQOs will be reviewed and approved by DOE and the regulatory agency prior to implementation. Table A-1 defines the types of changes that may be made to the sampling design and the documentation requirements.

<table>
<thead>
<tr>
<th>Type of Change</th>
<th>Action</th>
<th>Documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary addition of wells or constituents, or increasing sampling frequency</td>
<td>Project management approval; notify regulator agency if appropriate</td>
<td>Project’s schedule tracking system</td>
</tr>
<tr>
<td>Unintentional impacts to groundwater monitoring plan including one-time missed well sampling due to operational constraints, delayed sample collection, broken pump, lost bottle set, missed sampling of indicator parameters, loss of samples in transit, etc.</td>
<td>Electronic notification</td>
<td>Annual report</td>
</tr>
<tr>
<td>Planned change to groundwater monitoring activities including addition or deletion of constituents or wells and changing sampling frequency</td>
<td>Revise monitoring plan</td>
<td>Revised groundwater monitoring plan</td>
</tr>
<tr>
<td>Anticipated unavoidable changes (e.g., dry wells)</td>
<td>Electronic notify; revise monitoring plan</td>
<td>Annual report and revised groundwater monitoring plan</td>
</tr>
</tbody>
</table>


Logbooks are required for field activities. The logbook must be identified with a unique project name and number. Individuals responsible for the logbooks will be identified in the front of the logbook, and only authorized persons may make entries into the logbooks. Logbooks will be controlled in accordance with internal work requirements and processes.

The HEIS database will be identified as a repository of data for the Hanford Facility Operating Record, unit file. Records may be stored in either electronic or hardcopy format. Documentation and records, regardless of medium or format, are controlled in accordance with internal work requirements and processes that ensure accuracy and irretrievability of stored records. Records required by the TPA (Ecology et al., 1989a) will be managed in accordance with the requirements therein.

Groundwater monitoring results will be reported annually in accordance with the ARARs of 40 CFR 265.94(b), “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,” “Recordkeeping and Reporting.” The reports will be part of the annual Hanford Site groundwater monitoring report.
A2 Data Generation and Acquisition

This section addresses data generation and acquisition to ensure that the project methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are appropriate and documented.

A2.1 Sampling Process Design (Experimental Design)

The sampling design is based on regulatory requirements and judgmental sampling.

A2.2 Regulatory Requirements


A2.3 Judgmental Sampling

Judgmental sampling is limited to the selection of sample locations and supplemental sample collection and analytical analyses. The sample locations are based on past groundwater flow interpretations and three point problems using appropriate regional wells as defined in Section 3.3. The supplemental indicator parameter and groundwater quality parameter sample collection and analytical analyses are based on knowledge of past characterization results associated with the Modular Storage Units as discussed in Section 2.3.

A2.4 Sampling Methods

Sampling described in CHPRC-00189 includes the following items:

- Field sampling methods
- Sample preservation, containers, and holding times
- Corrective actions for sampling activities
- Decontamination of sampling equipment

The groundwater sampling operations supervisor must ensure that situations which may impair the usability of samples and/or data are documented in field logbook or on nonconformance report forms in accordance with internal corrective action procedures, as appropriate. The groundwater sampling operations supervisor will note any deviations from the standard procedures for sample collection, contaminants of potential concern, sample transport, or monitoring that occur. The groundwater sampling operations supervisor is also responsible for coordinating all activities relating to the use of field monitoring equipment (e.g., dosimeters and industrial hygiene equipment). Field personnel will document in the logbook all noncompliant measurements taken during field sampling. Ultimately, the groundwater sampling operations supervisor will be responsible for developing, implementing, and communicating corrective action procedures, documenting all deviations from procedure, and ensuring that immediate corrective actions are applied to field activities. Problems with sample collection, custody, or data acquisition that adversely impact the quality of data, or that impair the ability to acquire data or failure to follow procedure, will be documented in accordance with internal corrective action procedures, as appropriate.
A2.5 Sample Handling and Custody

A sampling and data tracking database is used to track samples from the point of collection through the laboratory analysis process. Laboratory analytical results are entered and maintained in the HEIS database. Each sample is identified and labeled with a unique HEIS sample number. The contractor’s environmental QA program plan specifies the following sample handling information:

- Container requirements
- Container labeling and tracking process
- Sample custody requirements
- Shipping and transportation

Sample custody during laboratory analysis is addressed in the applicable laboratory standard operating procedures. Laboratory custody procedures will ensure that sample integrity and identification are maintained throughout the analytical process. Storage of samples at the laboratory will be consistent with laboratory instructions prepared by the SMR organization.

A2.6 Analytical Methods

Information on analytical methods is provided in Table A-2. These analytical methods are controlled in accordance with the laboratory’s QA plan and the requirements of this QAPjP. The primary contractor participates in oversight of offsite analytical laboratories to qualify the laboratories for performing Hanford Site analytical work.

Table A-2. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits for Modular Storage Units Constituents

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Collection and Preservation</th>
<th>Analysis Methods</th>
<th>Method Quantitation Limit (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity, Field</td>
<td>Field measurement</td>
<td>Instrument/ meter</td>
<td>1 µS/cm</td>
</tr>
<tr>
<td>pH, Field Measurement</td>
<td>Field measurement</td>
<td>Instrument/ meter</td>
<td>0.1</td>
</tr>
<tr>
<td>Total Organic Carbon</td>
<td>G, HCL to pH&lt;2, cool to ~4°C</td>
<td>SW-846° Method 9060</td>
<td>1,000</td>
</tr>
<tr>
<td>Total Organic Halides</td>
<td>G, H₂SO₄ to pH&lt;2, no head space, cool to ~4°C</td>
<td>SW-846° Method 9020</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Collection and Preservation</th>
<th>Analysis Methods</th>
<th>Method Quantitation Limit (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>P, HNO₃ to pH&lt;2</td>
<td>SW-846° Method 6010B/C, SW-846 Method 7470A (mercury only) EPA/600 Method 200.8</td>
<td>10</td>
</tr>
<tr>
<td>Barium</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Cadmium</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Chromium</td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>
Table A-2. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits for Modular Storage Units Constituents

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Collection and Preservation&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>Analysis Methods&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Method Quantitation Limit (µg/L)&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Selenium</td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Manganese</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
<td></td>
<td>4,000</td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td></td>
<td>750</td>
</tr>
</tbody>
</table>

**Anions**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Collection and Preservation</th>
<th>Analysis Methods</th>
<th>Method Quantitation Limit (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate</td>
<td>P, none, cool to ~4°C</td>
<td>EPA/600 Method 300.0</td>
<td>250</td>
</tr>
<tr>
<td>Sulfate</td>
<td></td>
<td></td>
<td>550</td>
</tr>
<tr>
<td>Chloride</td>
<td></td>
<td>EPA/600 Method 300.0</td>
<td>400</td>
</tr>
<tr>
<td>Fluoride</td>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>Nitrite</td>
<td></td>
<td></td>
<td>250</td>
</tr>
</tbody>
</table>

**Herbicides/Pesticides**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Collection and Preservation</th>
<th>Analysis Methods</th>
<th>Method Quantitation Limit (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endrin</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>Lindane</td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>AG, none, cool to ~4°C</td>
<td>SW-846 Method 8081B, SW-846 Method 8151A</td>
<td>0.5</td>
</tr>
<tr>
<td>Toxaphene</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>2,4-D</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>2,4,5-TP Silvex</td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Radionuclides**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Collection and Preservation</th>
<th>Analysis Methods</th>
<th>Method Quantitation Limit (pCi/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Alpha</td>
<td></td>
<td>EPA Method 900</td>
<td>3 (pCi/L)</td>
</tr>
<tr>
<td>Gross Beta</td>
<td></td>
<td></td>
<td>4 (pCi/L)</td>
</tr>
<tr>
<td>Radium</td>
<td>P, nitric acid pH&lt;2</td>
<td>Alpha Energy Analysis, Gamma Energy Analysis</td>
<td>20 (pCi/L)</td>
</tr>
<tr>
<td>Technetium-99</td>
<td></td>
<td>Tc-99 – Liquid Scintillation</td>
<td>15 (pCi/L)</td>
</tr>
<tr>
<td>Isotopic Uranium</td>
<td></td>
<td>Alpha Energy Analysis</td>
<td>1 (pCi/L)</td>
</tr>
</tbody>
</table>
Table A-2. Preservation Techniques, Analytical Methods Used, and Current Method Quantitation Limits for Modular Storage Units Constituents

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Collection and Preservation&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>Analysis Methods&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Method Quantitation Limit (µg/L)&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Field measurement</td>
<td>Instrument/meter</td>
<td>NA</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Field measurement</td>
<td>Instrument/meter</td>
<td>0.1 NTU</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>G/P, cool to ~4ºC</td>
<td>EPA Standard Method 2320</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPA/600 Method 310.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EPA/600 Method 310.2</td>
<td></td>
</tr>
<tr>
<td>Coliform Bacteria</td>
<td>P, NaSO₃ to pH&lt;2, cool to ~4ºC</td>
<td>SW-846 Method 9223</td>
<td>10 Col/100 ml</td>
</tr>
<tr>
<td>Phenols</td>
<td>G, Residual Chlorine Na₂S₂O₃, cool to ~4ºC</td>
<td>SW-846 Method 8041A</td>
<td>5</td>
</tr>
</tbody>
</table>

<sup>a</sup> P = plastic; G = glass; AG = amber glass.
<sup>b</sup> All samples will be cooled to 4ºC upon collection.
<sup>c</sup> Constituents grouped together are analyzed by the same method, unless otherwise indicated. For EPA Method 200.8, see EPA/600/R-94/111, Methods for the Determination of Metals in Environmental Samples, Supplement 1. For EPA Method 300, see EPA/600/4-79/020, Methods of Chemical Analysis of Water and Wastes. For EPA Method 900, see EPA-900, Gross Alpha and Gross Beta Radioactivity in Drinking Water Method 900. For 4-digit EPA methods, see SW-846, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. Third Edition; Final Update IV-B.
<sup>d</sup> Detection limit units, except where indicated.

EPA = U.S. Environmental Protection Agency
NTU = nephelometric turbidity unit

Laboratories providing analytical services in support of this QAP/P will report issues to the CH2M HILL Plateau Remediation Company SMR project coordinator, who will then initiate an issue resolution record. The issue reporting process is intended to document analytical issues and the resolution of those issues with the project scientist. The corrective action program addresses the following items:

- Evaluation of impacts of laboratory QC failures on data quality
- Root cause analysis of QC failures
- Evaluation of recurring conditions that are adverse to quality
- Trend analysis of quality-affecting problems
- Implementation of a quality improvement process
- Control of nonconforming materials that may affect quality

### A2.7 Quality Control

The QC procedures must be followed in the field and laboratory to ensure that reliable data are obtained. Field QC samples will be collected to evaluate the potential for cross-contamination and to provide information pertinent to field variability. Field QC for sampling will require the collection of field
replicates (duplicates), trip or field blanks, and equipment blanks. Laboratory QC samples estimate the precision and bias of the analytical data. Field and laboratory QC samples are summarized in Table A-3.

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Primary Characteristics Evaluated</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Field Quality Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full trip blank (FTB)</td>
<td>Contamination from containers or transportation</td>
<td>1 per 20 well trips</td>
</tr>
<tr>
<td>Field transfer blank (FXR)</td>
<td>Contamination from sampling site</td>
<td>1 each day; volatile organic compounds sampled</td>
</tr>
<tr>
<td>Equipment blank (EB)</td>
<td>Contamination from non-dedicated equipment</td>
<td>As needed(^a)</td>
</tr>
<tr>
<td>Replicate/duplicate samples</td>
<td>Reproducibility</td>
<td>1 per 20 well trips</td>
</tr>
<tr>
<td><strong>Laboratory Quality Control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method blanks</td>
<td>Laboratory contamination</td>
<td>1 per batch</td>
</tr>
<tr>
<td>Laboratory duplicates</td>
<td>Laboratory reproducibility</td>
<td>(^b)</td>
</tr>
<tr>
<td>Matrix spikes</td>
<td>Matrix effect and laboratory accuracy</td>
<td>(^b)</td>
</tr>
<tr>
<td>Matrix spike duplicates</td>
<td>Laboratory reproducibility/accuracy</td>
<td>(^b)</td>
</tr>
<tr>
<td>Surrogates</td>
<td>Recovery/yield</td>
<td>(^b)</td>
</tr>
<tr>
<td>Laboratory control samples</td>
<td>Method accuracy</td>
<td>1 per batch</td>
</tr>
</tbody>
</table>

\(^a\) For portable Grundfos\(^\circ\) (registered trademark of Grundfos Pumps Corporation, Colorado Springs, Colorado) pumps, equipment blanks are collected 1 per 10 well trips. Whenever a new type of nondedicated equipment is used, an equipment blank will be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the decontamination procedure for the nondedicated equipment.

\(^b\) As defined in the laboratory contract or quality assurance plan and/or analysis procedures.

QC = quality control

### A2.8 Field Quality Control Samples

Field QC samples will be collected to evaluate the potential for cross-contamination and laboratory performance. QC samples and the required frequency for collection are described in this section.

Full trip blanks (FTBs) are prepared by the sampling team prior to traveling to the sampling site. The FTB is filled with high-purity reagent water. The bottles are sealed and transported, unopened, to the field in the same storage containers used for samples collected that day. Collected FTBs are analyzed for the same constituents as the samples. FTBs are used to evaluate potential contamination of the samples due to the sample bottles, preservative, handling, storage, or transportation.
<table>
<thead>
<tr>
<th>Method(^a)</th>
<th>QC Element</th>
<th>Acceptance Criteria</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Chemical Parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkalinity</td>
<td>MB(^b)</td>
<td>&lt;MDL</td>
<td>Flagged with “C”</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td>LCS</td>
<td>80-120% recovery(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td>Conductivity</td>
<td>DUP</td>
<td>≤20% RPD(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td>pH</td>
<td>MS(^e)</td>
<td>75-125% recovery(^c)</td>
<td>Flagged with “N”</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>EB, FTB</td>
<td>&lt;2 times MDL</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td>Total organic halides</td>
<td>Field duplicate</td>
<td>≤20% RPD(^f)</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td><strong>Ammonia and Anions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anions by IC</td>
<td>MB</td>
<td>&lt;MDL</td>
<td>Flagged with “C”</td>
</tr>
<tr>
<td></td>
<td>LCS</td>
<td>80-120% recovery(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td></td>
<td>DUP</td>
<td>≤20% RPD(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>75-125% recovery(^c)</td>
<td>Flagged with “N”</td>
</tr>
<tr>
<td></td>
<td>EB, FTB</td>
<td>&lt;2 times MDL</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td></td>
<td>Field duplicate</td>
<td>≤20% RPD(^f)</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICP metals</td>
<td>MB</td>
<td>&lt;CRDL</td>
<td>Flagged with “C”</td>
</tr>
<tr>
<td></td>
<td>LCS</td>
<td>80-120% recovery(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>75-125% recovery(^c)</td>
<td>Flagged with “N”</td>
</tr>
<tr>
<td></td>
<td>MSD</td>
<td>≤20% RPD(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td></td>
<td>EB, FTB</td>
<td>&lt;2 times MDL</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td></td>
<td>Field duplicate</td>
<td>≤20% RPD(^f)</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td><strong>Herbicides/Pesticides</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbicides</td>
<td>MB</td>
<td>&lt;CRDL</td>
<td>Flagged with “C”</td>
</tr>
<tr>
<td>Pesticides</td>
<td>LCS</td>
<td>50-150% recovery(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>50-150% recovery(^c)</td>
<td>Flagged with “N”</td>
</tr>
<tr>
<td></td>
<td>MSD</td>
<td>≤20% RPD(^c)</td>
<td>Data reviewed(^d)</td>
</tr>
<tr>
<td></td>
<td>EB, FTB</td>
<td>&lt;2 times MDL</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td></td>
<td>Field duplicate</td>
<td>≤20% RPD(^f)</td>
<td>Flagged with “Q”</td>
</tr>
</tbody>
</table>
## Table A-4. Field and Laboratory Quality Control Elements and Acceptance Criteria

<table>
<thead>
<tr>
<th>Method*</th>
<th>QC Element</th>
<th>Acceptance Criteria</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radionuclides</td>
<td>MB</td>
<td>&lt;CRDL</td>
<td>Flagged with “C”</td>
</tr>
<tr>
<td></td>
<td>LCS</td>
<td>80-120% recovery</td>
<td>Data reviewed</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>75-125% recovery</td>
<td>Flaged with “N”</td>
</tr>
<tr>
<td></td>
<td>MSD</td>
<td>$\leq$20% RPD</td>
<td>Data reviewed</td>
</tr>
<tr>
<td></td>
<td>EB, FTB</td>
<td>&lt;2 times MDL</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td></td>
<td>Field duplicate</td>
<td>$\leq$20% RPD</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td>Semi-Volatile Organic Compounds</td>
<td>MB</td>
<td>&lt;MDL</td>
<td>Flagged with “B”</td>
</tr>
<tr>
<td></td>
<td>LCS</td>
<td>Statistically derived</td>
<td>Data reviewed</td>
</tr>
<tr>
<td></td>
<td>MS/MSD</td>
<td>Statistically derived</td>
<td>Data reviewed</td>
</tr>
<tr>
<td></td>
<td>MSD</td>
<td>$\leq$20% RPD</td>
<td>Data reviewed</td>
</tr>
<tr>
<td></td>
<td>SUR</td>
<td>Statistically derived</td>
<td>Data reviewed</td>
</tr>
<tr>
<td></td>
<td>EB, FTB</td>
<td>&lt;2 times MDL</td>
<td>Flagged with “Q”</td>
</tr>
<tr>
<td></td>
<td>Field duplicate</td>
<td>$\leq$20% RPD</td>
<td>Flagged with “Q”</td>
</tr>
</tbody>
</table>

a. Refer to Tables A-2 and A-3 for specific analytical methods.
b. Does not apply to pH.
c. Laboratory-determined, statistically derived control limits may also be used. Such limits are reported with the data.
d. After review, corrective actions are determined on a case-by-case basis. Corrective actions may include a laboratory recheck or flagging the data as suspect (“Y” flag) or rejected (“R” flag).
e. Applies to total organic carbon and total organic halides only.
f. Applies only in cases where one or both results are greater than 5 times the detection limit.
g. Determined by the laboratory based on historical data. Control limits are reported with the data.
h. For the common laboratory contaminants acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the acceptance criteria is <5 times the MDL.

CRDL = contract-required detection limit  
MDL = method detection limit  
QC = quality control

**Data flags:**

B, C = possible laboratory contamination (analyte was detected in the associated method blank)  
N = result may be biased (associated matrix spike result was outside the acceptance limits)  
Q = problem with associated field QC sample (blank and/or duplicate results were out of limits)  
DUP = laboratory matrix duplicate  
EB = equipment blank  
FTB = full trip blank
A-13

Table A-4. Field and Laboratory Quality Control Elements and Acceptance Criteria

<table>
<thead>
<tr>
<th>Method</th>
<th>QC Element</th>
<th>Acceptance Criteria</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>FXR</td>
<td>field transfer blank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICP</td>
<td>inductively coupled plasma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICP/MS</td>
<td>inductively coupled plasma/mass spectrometry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCS</td>
<td>laboratory control sample</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MB</td>
<td>method blank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDL</td>
<td>method detection limit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>matrix spike</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSD</td>
<td>matrix spike duplicate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RPD</td>
<td>relative percent difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUR</td>
<td>surrogate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Field transfer blanks (FXRs) are preserved volatile organic analysis sample bottles that are filled at the sample collection site with high-purity reagent water that has been transported to the field. After collection, FXR bottles are sealed and placed in the same storage containers with the samples from the associated sampling event. FXR samples are analyzed for volatile organic compounds only. FXRs are used to evaluate potential contamination caused by conditions in the field.

Equipment blanks (EBs) are samples in which high-purity reagent water is passed through the pump or placed in contact with the sampling surfaces of the equipment to collect blank samples identical to the sample set that will be collected. EB bottles are placed in the same storage containers with the samples from the associated sampling event. EB samples are analyzed for the same constituents as the samples from the associated sampling event. EBs are used to evaluate the effectiveness of the cleaning process to ensure that samples are not cross-contaminated from previous sampling events.

For the field blanks (i.e., FTBs, FXRs, and EBs), results above two times the method detection limit (MDL) are identified as suspected contamination. However, for the common laboratory contaminants acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the limit is five times the MDL.

Field duplicates, also known as replicates, are two samples that are collected as close as possible to the same time and same location and they are intended to be identical. Field duplicates are stored and transported together and are analyzed for the same constituents. Field duplicates are used to determine precision for both sampling and laboratory measurements. The results of the field duplicates must have precision within 20 percent, as measured by the relative percent difference. Only field duplicates with at least one result greater than five times the MDL or minimum detectable activity are evaluated.

A2.9 Laboratory Quality Control Samples

The laboratory QC samples (e.g., method blanks, laboratory control sample/blank spike, and matrix spike) are defined in Chapter 1 of SW-846, Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B, and will be run at the frequency specified in that reference unless superseded by agreement.

A2.10 Quality Control Requirements

Table A-4 lists the acceptance criteria for QC samples.
Holding time is the elapsed time period between sample collection and analysis. The contractor’s environmental QA program plan (CHPRC-00189) provides a table with holding times. Exceeding the required holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Recommended holding times depend on the analytical method, as specified in SW-846 or EPA-600/4-79-020, *Methods for Chemical Analysis of Water and Wastes*. Data associated with exceeded holding times are flagged with an “H” in the HEIS database. Data that exceed the holding time will be maintained but potentially may not be used in statistical analyses.

Additional QC measures include blind standards submitted under the groundwater monitoring program (CHPRC-00189), laboratory audits and participation in nationally based performance evaluation studies. The contract laboratories participate in national studies such as the EPA-sanctioned Water Pollution and Water Supply Performance Evaluation studies. Periodic audits of the analytical laboratories are performed to identify and solve quality problems, or to prevent such problems from occurring. Audit results are used to improve performance, and the summaries of audit results and performance evaluation studies are presented in the annual groundwater monitoring report.

QC failure will be determined and evaluated during data validation and the data quality assessment (DQA) process. Data will be qualified, as appropriate.

**A2.11 Instrument/Equipment Testing, Inspection, and Maintenance**

Measurement and testing equipment used in the field or in the laboratory that directly affects the quality of analytical data will be subject to preventive maintenance measures to minimize measurement system downtime. Laboratories and onsite measurement organizations must maintain and calibrate their equipment. Maintenance requirements (e.g., documentation of routine maintenance) will be included in the individual laboratory and the onsite organization’s QA plan or operating procedures (as appropriate). Maintenance of laboratory instruments will be performed in a manner consistent with SW-846, or with auditable DOE Hanford Site and contractual requirements. Consumables, supplies, and reagents will be reviewed in accordance with SW-846 requirements and will be appropriate for their use.

**A2.12 Instrument/Equipment Calibration and Frequency**

Calibration of field equipment is performed in accordance with HASQARD (DOE/RL-96-68), Volume 3, as well as the manufacturer’s procedures for calibration. Calibration is conducted using certified equipment or standards with a known valid relationship to a nationally recognized performance standard. Analytical laboratory instruments and measuring equipment are calibrated in accordance with the laboratory’s QA plan.

**A2.13 Inspection/Acceptance of Supplies and Consumables**

Supplies and consumables that are used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes that describe the contractor’s acquisition system and the responsibilities and interfaces necessary to ensure that items procured/acquired for contractor meet the specific technical and quality requirements. The procurement system ensures that purchased items comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users prior to use.

Supplies and consumables that are procured by the analytical laboratories are procured, checked, and used in accordance with the laboratories’ QA plans.
A2.14 Nondirect Measurements

Nondirect measurements include data obtained from sources such as computer databases, programs, literature files, and historical databases. If evaluation includes data from historical sources, whenever possible such data will be validated to the same extent as the data generated as part of this effort. All data used in evaluations will be identified by source.

A2.15 Data Management

SMR, in coordination with the project manager, is responsible for ensuring that analytical data are appropriately reviewed, managed, and stored in accordance with applicable programmatic requirements that govern data management procedures. Electronic data access, when appropriate, will be via a database (e.g., HEIS or a project-specific database). Where electronic data are not available, hardcopies will be provided in accordance with Section 9.6 of the TPA Action Plan (Ecology et al., 1989b). The HEIS database will be identified as a repository of data for the Hanford Facility Operating Record unit file.

All field activities will be recorded in the field logbook, or on appropriate data forms.

Laboratory errors are reported to SMR on a routine basis. For reported laboratory errors, a Sample Issue Resolution will be initiated in accordance with contractor procedures. This process is used to document analytical issues and to establish resolution with the project manager. The Sample Issue Resolution records become a permanent part of the analytical data package for future reference and for records management.

A3 Assessment and Oversight

The elements in this section address the activities for assessing the effectiveness of project implementation and the associated QA and QC activities. The purpose of the assessment is to ensure that this QAPjP is implemented as prescribed.

A3.1 Assessments and Response Actions

The contractor management, Regulatory Compliance, Quality, and/or Health and Safety organizations may conduct random surveillances and assessments to verify compliance with the requirements outlined in this QAPjP.

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with the laboratories’ QA plans. The primary contractor conducts oversight of offsite analytical laboratories to qualify them for performing Hanford Site analytical work.

A3.2 Reports to Management

Reports to management on data quality issues will be made when these issues are identified. Issues reported by the laboratories are communicated to SMR, which initiates a Sample Issue Resolution record in accordance with contractor procedures. This process is used to document analytical or sample issues and to establish resolution with the project manager.
A4 Data Validation and Usability

The elements in this section address the QA activities that occur after the data collection phase of the project is completed. Implementation of these elements determines whether the data conform to the specified criteria, thus satisfying the project objectives.

A4.1 Data Review, Verification, and Validation

The criteria for verification may include: review for completeness (e.g., all samples were analyzed as requested), use of the correct analytical method/procedure, transcription errors, correct application of dilution factors, appropriate reporting of dry weight versus wet weight, and correct application of conversion factors. Laboratory personnel may perform data verification.

A4.2 Verification and Validation Methods

The work activities will follow documented procedures and processes for data validation and verification, as summarized below. Validation of groundwater data consists of assessing whether the data collected truly reflect aquifer conditions. Verification means assessing data accuracy, completeness, consistency, availability, and internal control practices to determine overall reliability of the data collected. Other DQOs that will be met include proper chain-of-custody, sample handling, use of proper analytical techniques as applied for each constituent, and the quality and acceptability of the laboratory analyses conducted.

Groundwater monitoring staff perform checks on laboratory electronic data files for formatting, allowed values, data flagging (i.e., qualifiers), and completeness. Hardcopy results are verified to check for (1) completeness, (2) notes on condition of samples upon receipt by the laboratory, (3) notes on problems encountered during analysis of the samples, and (4) correct reporting of results. If data are incomplete or deficient, staff work with the laboratory to correct the problem found during the analysis.

The data validation process provides the requirements and guidance for validation of groundwater data that are routinely collected. Validation is a systematic process of reviewing verified data against the set of criteria (listed in Table A-4) to determine whether the data are acceptable for their intended use.

Results of laboratory and field QC evaluations, groundwater monitoring blind standard results, laboratory performance evaluation samples, and holding-time criteria are considered when determining data usability. Staff review the data to identify whether observed changes reflect changes in groundwater quality or potential data errors, and they may request data reviews of laboratory, field, or water-level data for usability purposes. The laboratory may be asked to check calculations or re-analyze the sample, or the well may be resampled. Results of the data reviews are used to flag the data appropriately in the HEIS database (e.g., “R” for reject, “Y” for suspect, or “G” for good) and/or to add comments.

A4.3 Reconciliation with User Requirements

The DQA process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the data evaluation is to determine if quantitative data are of the correct type and are of adequate quality and quantity to meet the project DQOs. The project manager is responsible for determining if DQA is necessary and for ensuring that, if required, one is performed. The results of the DQA will be used in interpreting the data and determining if the objectives of this activity have been met.
A5 References


DOE O 414.1D, 2005, Quality Assurance, U.S. Department of Energy, Washington, D.C. Available at:


Distribution

U.S. Department of Energy, Richland Operations Office – Electronic Distribution

R. D. Hildebrand
N. M. Jaschke (4 hard copies/ 16 CDs)
J. G. Morse

U.S. Environmental Protection Agency – Electronic Distribution

D. R. Einan

Washington State Department of Ecology – Electronic Distribution ONLY

F. W. Bond

CH2M HILL Plateau Remediation Company – Electronic Distribution ONLY

R. L. Cathel
D. P. Capelle
W. R. Faught
R. W. Oldham
F. A. Ruck III
G. S. Thomas
C. D. Wittreich

Administrative Record – Electronic Distribution

H. M. Childers (1 copy)

Document Clearance - Electronic Distribution

Dist-1