SGW-59455
Revision 0

300-FF-5 Operable Unit Stage A Uranium Sequestration System Installation Report

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

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

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

SGW-59455
Revision 0

300-FF-5 Operable Unit Stage A Uranium Sequestration System Installation Report

Date Published
March 2016

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

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

P.O. Box 1600
Richland, Washington 99352

APPROVED
By Ashley Jenkins at 12:56 pm, Mar 07, 2016

Release Approval Date

Approved for Public Release;
Further Dissemination Unlimited

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

1.1 Purpose 1-1
1.2 Site Description 1-1
1.3 Objectives 1-3
1.4 Sequestration System Overview 1-6

2 Sequestration System Design and Installation 2-1

2.1 Injection and Monitoring Wells 2-1
2.1.1 Injection Wells 2-1
2.1.2 Monitoring Wells 2-6
2.1.3 Unexpected Conditions 2-11
2.1.4 Summary 2-13
2.2 Infiltration System 2-14
2.2.1 Unexpected Conditions 2-15
2.2.2 Summary 2-19
2.3 Chemical Mixing Skids and Site Infrastructure 2-20
2.3.1 Chemical Mixing Skids 2-20
2.3.2 Site Infrastructure 2-21
2.3.3 Unexpected Conditions 2-22
2.3.4 Summary 2-24
2.4 River Pumps 2-25
2.4.1 Unexpected Conditions 2-26
2.4.2 Summary 2-28
2.5 Chemical Tanks 2-28
2.5.1 Unexpected Conditions 2-29
2.5.2 Chemical Properties 2-30
2.5.3 Summary 2-31
2.6 Electrical Resistivity Tomography Network 2-32
2.6.1 Unexpected Conditions 2-32
2.6.2 Summary 2-32

3 Summary and Lessons Learned 3-1

3.1 Summary of Installation Duration and Resources 3-1
3.2 Post-Job Review and Lessons Learned 3-1
3.2.1 Define Work Scope 3-1
3.2.2 Hazard Identification and Work Planning 3-2
3.2.3 Work Packages and Hazard Control 3-3
3.2.4 Work Processes and Execution 3-3

3.2.5 Feedback 3-5
4 References 4-1

Figures

Figure 1-1. 300 Area Industrial Complex and the Stage A Enhanced Attenuation Area 1-2
Figure 1-2. Cross Section of the General Geologic Features of the 300 Area Industrial Complex 1-4
Figure 1-3. Principal Subsurface Features within the 300 Area Industrial Complex 1-5
Figure 2-1. Location of Injection Wells and Monitoring Wells in the Stage A Treatment Area 2-3
Figure 2-2. Terrasonic Drill Rig in the 300 Area 2-4
Figure 2-3. Geologic Samples for Archiving 2-5
Figure 2-4. Weatherproof Well Vault Installed on an Injection Well 2-5
Figure 2-5. Exposed Casing of Well 399-1-95 2-12
Figure 2-6. Sonotube Concrete Form and Weatherproof Vault on Well 399-1-95 2-13
Figure 2-7. Infiltration System in the Stage A Treatment Area 2-16
Figure 2-8. Excavation and Partially Exposed Injection and Monitoring Wells in the Stage A Treatment Area 2-17
Figure 2-9. Installation HDPE Drip Lines 2-17
Figure 2-10. Backfilling the Infiltration System 2-18
Figure 2-11. Infiltration System Pipe Header and Distribution Lines 2-18
Figure 2-12. Chemical Mixing Skids in the 300 Area 2-21
Figure 2-13. Aerial Photograph of the Stage A Treatment Area 2-23
Figure 2-14. Submersible Pump, Fish Screen, and Mounting Skidplate 2-27
Figure 2-15. Installation of Submersible Pump and Skidplate 2-27
Figure 2-16. Installation of a Phosphate Storage Tank at the Stage A EA Area 2-29
Figure 2-17. Chemical Storage Tank Farm 2-31
Figure 2-18. Electrical Resistivity Tomography Arrays for the Stage A Treatment Area 2-33
Figure 2-19. Electrode Installation Detail (Not to Scale) 2-34

Tables

Table 2-1. Injection Well Construction Specifications 2-2
Table 2-2. Injection Well Development Summary 2-6
Table 2-3. Stage A PRZ/Aquifer Injection Wells 2-7
Table 2-4. Monitoring Well Construction Specifications 2-8
Table 2-5. PRZ Monitoring Wells Development Summary....2-9
Table 2-6. Aquifer Monitoring Well Development Summary 2-9
Table 2-7. Stage A PRZ Monitoring Wells....2-10
Table 2-8. Stage A Aquifer Monitoring Wells....2-11
Table 2-9. Summary of Project Resources Needed for the Injection and Monitoring Wells....2-13
Table 2-10. Volume of Water, Affected Surface, and Estimated Depth of Water for Infiltration System Tests 2-19
Table 2-11. Summary of Project Resources Needed for the Infiltration System 2-20
Table 2-12. Summary of Project Resources Needed for the Chemical Mixing Skids and Site Infrastructure 2-24
Table 2-13. Summary of Project Resources Needed for the River Pumps 2-28
Table 2-14. Summary of Project Resources Needed for the Chemical Tanks 2-31
Table 2-15. Summary of Project Resources Needed for the Electrical Resistivity Tomography Network 2-34
Table 3-1. Summary of Installation Duration, Resources, and Cost by Component 3-1

This page intentionally left blank.

Terms

bgs	below ground surface
CHPRC	CH2M HILL Plateau Remediation Company
DOE	U.S. Department of Energy
dpm	disintegrations per minute
EA	enhanced attenuation
EPA	U.S. Environmental Protection Agency
ERT	electrical resistivity tomography
gpm	gallons per minute
HDPE	high-density polyethylene
ID	inside diameter
NMFS	National Marine Fisheries Service
OD	outside diameter
OU	operable unit
PLC	programmable logic controller
PRZ	periodically rewetted zone
PVC	polyvinyl chloride
RDR/RAWP	remedial design report/remedial action work plan
ROD	record of decision
RWP	radiological work permit
USFWS	U.S. Fish and Wildlife Service
WBS	work breakdown structure

This page intentionally left blank.

1 Introduction

The 300 Area encompasses approximately 105 km^2 (40 mi^2) adjacent to the Columbia River in the southern portion of the Hanford Site. The 300 Area includes a smaller operations area, called the 300 Area Industrial Complex, comprising several facilities and waste disposal sites that supported uranium fuel production and research and development activities. Much of the 300 Area, including the 300 Area Industrial Complex, has been remediated. The remediation process is divided into two source operable units (OUs), 300-FF-1 and 300-FF-2, which include liquid and solid waste disposal sites. The remediation process also includes groundwater in the 300-FF-5 OU. Contaminant releases at the waste disposal sites resulted in several groundwater contaminant plumes within the underlying 300-FF-5 OU. Completion of the cleanup is being accomplished under the 300 Area record of decision (ROD) approved by the U.S. Environmental Protection Agency and U.S Department of Energy (EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*). Uranium is identified as a contaminant of concern in both soil and groundwater.

Part of the selected remedy for uranium contamination in the 300 Area is enhanced attenuation (EA) using phosphate solutions to sequester uranium and reduce its mobility in the vadose zone, periodically rewetted zone (PRZ), and top of the aquifer. Uranium sequestration is being implemented at a selected location in the 300 Area Industrial Complex using a staged approach. Stage A consists of infiltration and injection of phosphate solutions within an approximately 0.3 ha (0.75 ac) area. If the Stage A phosphate applications indicate that a high likelihood of treatment effectiveness can be expected, Stage B will be performed in a similar manner in an adjacent area of approximately 0.91 ha (2.25 ac). Figure 1-1 is an aerial view of the 300 Area Industrial Complex showing the Stage A EA Area. The figure also shows the adjacent waste disposal facilities that contributed to the underlying contamination.

1.1 Purpose

The purpose of this report is to document the final design and installation of the Stage A uranium sequestration system. This report also provides information and lessons learned on the installation of the Stage A system. The system is designed to infiltrate and inject phosphate solutions in the vadose zone, PRZ, and top of the unconfined aquifer in order to sequester mobile uranium. System design and installation criteria are found in SGW-58976, *Field Instructions for Uranium Sequestration in the 300 Area*. Site layout plans and equipment design sheets are contained in ECR-15-000692, *300 Area Chemical Injection System (Attachment A)*. Sequestration activities were performed in accordance with requirements established in the remedial design report/remedial action work plan (RDR/RAWP) (DOE/RL-2014-13-ADD2, *Remedial Design Report/Remedial Action Work Plan Addendum for the 300 Area Groundwater*), and DOE/RL-2014-42, *300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan*.

1.2 Site Description

This section provides a general summary of site geology and hydrogeology. This information will help explain the technologies and methods that were used to install the Stage A uranium sequestration system.

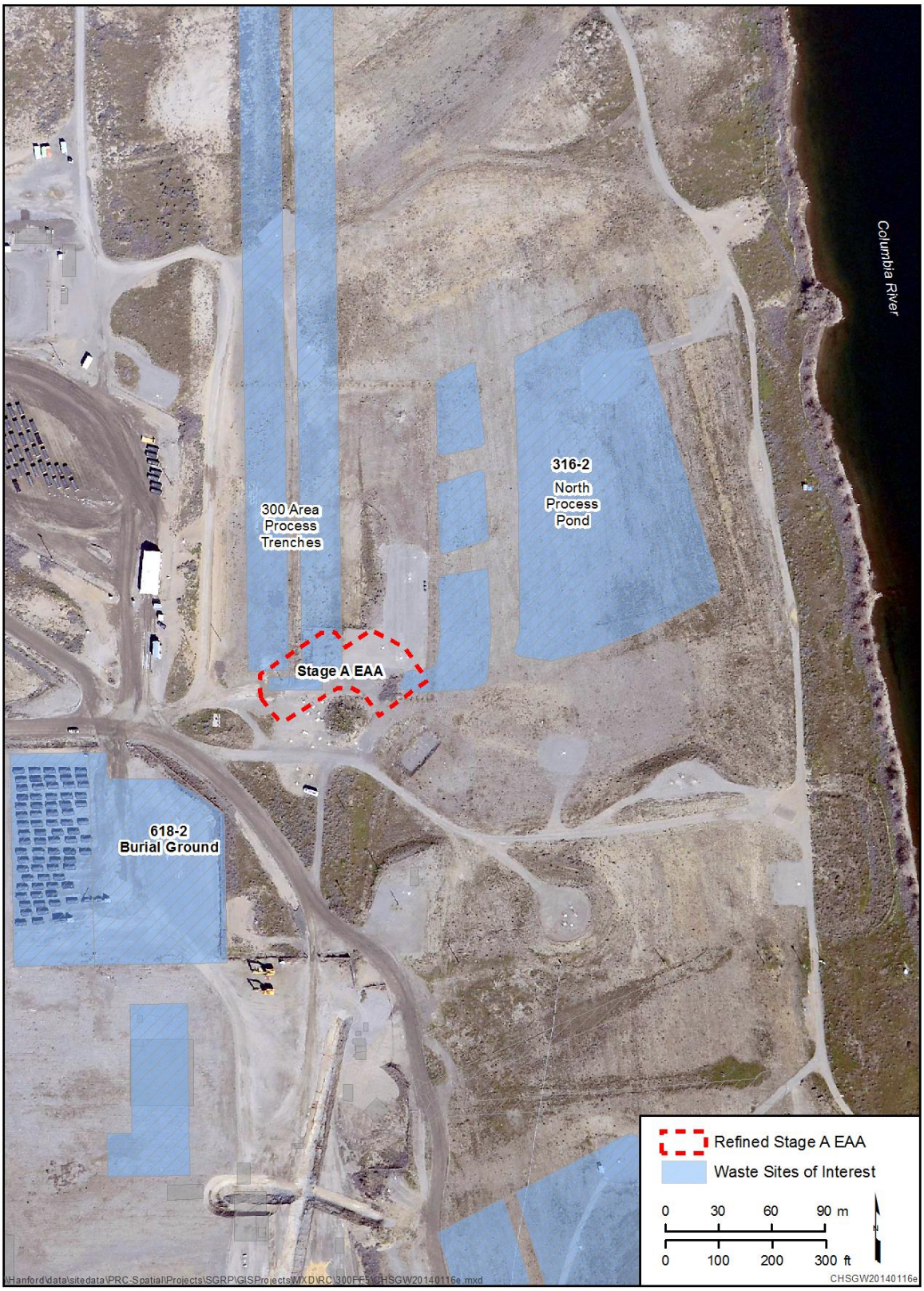


Figure 1-1. 300 Area Industrial Complex and the Stage A Enhanced Attenuation Area

Figure 1-2 shows a cross section of the general geologic features in the 300 Area Industrial Complex. The ground surface in the 300 Area Industrial Complex is relatively flat, except for a steep slope on the east down to the Columbia River, which is the only surface water feature in the area. The surface elevation for the 300 Area Industrial Complex is approximately 115 m (377 ft).

The vadose zone comprises backfill materials and unconsolidated sand and gravels of the Hanford formation. In the 300 Area Industrial Complex, the average thickness of the vadose zone is 10 m (33 ft). However, the vadose zone thickness varies with the seasonal stages of the Columbia River and distance inland from the river.

The unconfined aquifer occurs in the highly permeable, gravel dominated Hanford formation and in the underlying, less permeable sands and gravels of the Ringold Formation unit E. A finer grained interval with very low permeability occurs at the top of the Ringold Formation unit E in parts of the 300 Area Industrial Complex. Below unit E, the Ringold Formation lower mud unit is a confining layer characterized by very low permeability fine grained sediment. This hydrologic unit prevents further downward movement of groundwater contamination to the deeper aquifers. The thickness of the unconfined aquifer along the Columbia River shoreline is about 25 m (80 ft).

Rising groundwater elevations resulting from seasonally higher Columbia River stages saturate deeper portions of the vadose zone, while lower river stages result in falling groundwater elevations that drain water from these same deeper portions of the vadose zone. These fluctuating groundwater elevations create the PRZ shown in Figure 1-3. Generally, wells adjacent to the river within the 300 Area Industrial Complex show higher variation in response to river stage changes than wells located at increasing distance from the shoreline. Depending upon operations of Priest Rapids Dam upriver and McNary Dam downriver from the Hanford Site, the PRZ in the 300 Area Industrial Complex ranges from 0.32 to 2.2 m (1 to 7 ft) in thickness.

In the 300 Area Industrial Complex, the vadose zone, PRZ, and upper part of the unconfined aquifer occur within the unconsolidated sands and gravels of the Hanford formation. Groundwater flow velocities through the upper aquifer in the Hanford formation are rapid, up to 18 m/d (59 ft/d). The groundwater flow direction changes in response to changes in the river stage. Groundwater flow direction beneath the 300 Area Industrial Complex is predominantly to the south-southeast when the river stage is low (typical throughout most of the year). However, when the river stage is high (typically late spring and early summer), groundwater flow direction may change to south-southwest.

1.3 Objectives

The objectives of the Stage A phosphate applications to sequester uranium include the following (SGW-58976):

1. Implement Stage A uranium sequestration on 0.3 ha (0.75 ac) using phosphate injection in 9 wells spanning a length of 75 m (246 ft) and using phosphate infiltration in the vadose zone from near-surface infiltration lines covering the area.

2. Optimize the use of two injection skids to maximize the amount of phosphate solution in the vadose zone and PRZ through infiltration followed by well injections into the PRZ. Use two submersible river pumps to deliver filtered river water to the mixing skids.

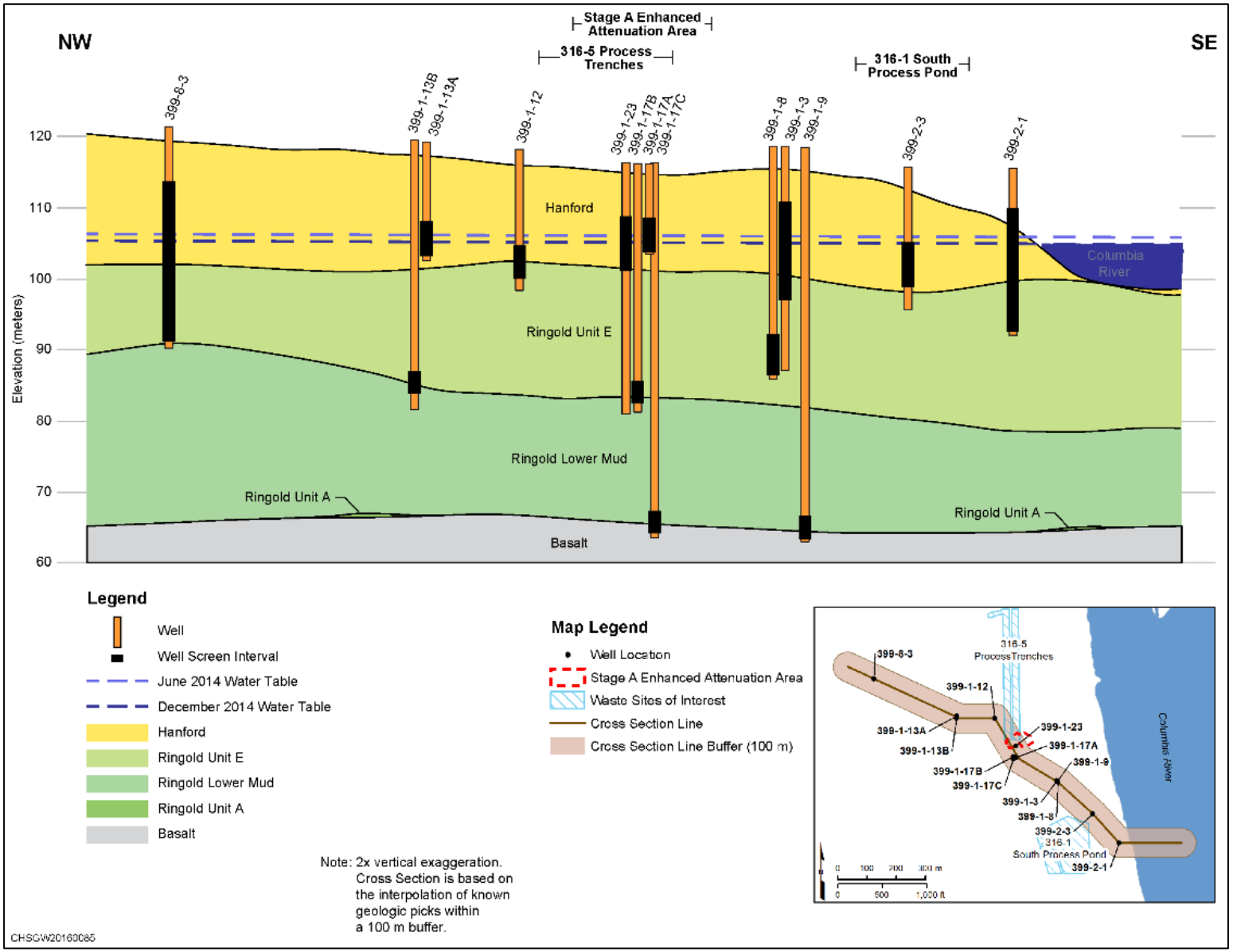
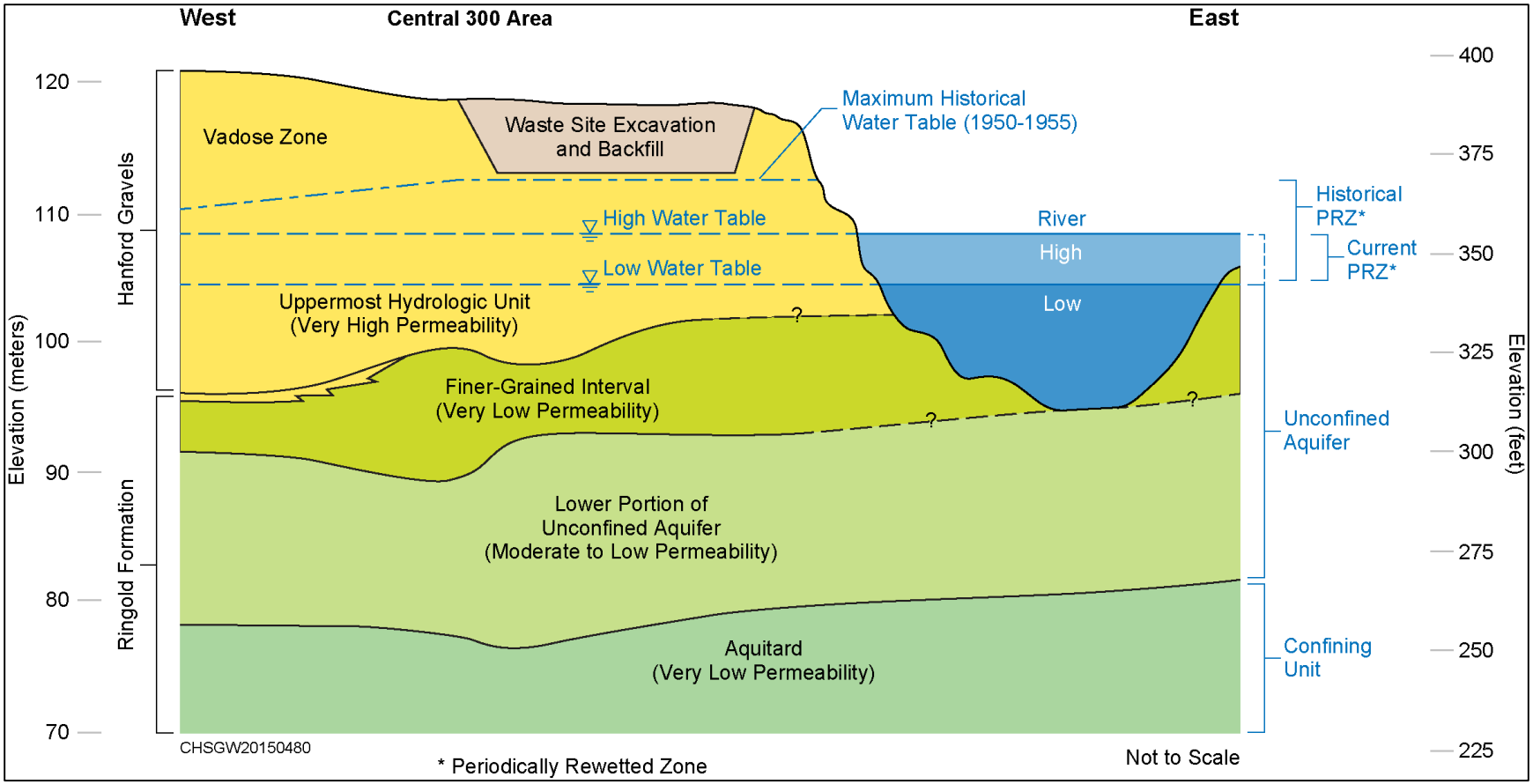


Figure 1-2. Cross Section of the General Geologic Features of the 300 Area Industrial Complex



Modified from DOE/RL-2011-47, *Proposed Plan for Remediation of the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 1-3. Principal Subsurface Features within the 300 Area Industrial Complex

3. Refine the use of the high concentration formulation of monosodium phosphate and pyrophosphate solutions previously used in pilot test applications.
4. Monitor delivery of phosphate solutions at selected monitoring wells using downhole instrumentation, electrical resistivity tomography (ERT), and groundwater monitoring in accordance with sampling and analysis protocols.
5. Evaluate the treatment effectiveness of the Stage A phosphate application based on the phosphate distribution efficiency, overall decrease in uranium leachability in vadose zone and PRZ soil samples, decrease in uranium mobilization to groundwater, and changes to hydraulic conductivity of the aquifer due to precipitation of phosphate minerals.
6. Apply successful experience and lessons learned from the Stage A application of phosphate solutions to a larger scale for Stage B.

1.4 Sequestration System Overview

Phosphate solutions are applied using infiltration and injection in a 0.3 ha (0.75 ac) area during Stage A of the EA remedy implementation in the 300 Area Industrial Complex. Nine injection wells are used to inject the phosphate solution into the groundwater in the upper portion of the unconfined aquifer. Each injection well is constructed with a grout seal at the interface of the bottom of the PRZ and top of aquifer to allow isolated injection (using inflatable packers) into either the PRZ or top of the aquifer. Phosphate solution is injected on an intermittent basis before, during, and after infiltration.

After starting the injection into the groundwater, phosphate solutions are delivered to a network of infiltration distribution lines (irrigation drip line or perforated tubing) installed approximately 1.8 m (6 ft) below ground surface (bgs). Phosphate infiltration is continuous (24-hour-per-day operation) over the Stage A treatment area to infiltrate the solution into the vadose zone. ERT is used to monitor the advancement of the phosphate infiltration wetting front in the vadose zone and PRZ.

During and following infiltration, phosphate solution is injected into the PRZ in all nine injection wells. Groundwater monitoring is conducted, using the Stage A network of monitoring wells along with other nearby wells in the 300 Area that may be affected, to assess changes in uranium concentrations and the lateral spread of phosphate.

2 Sequestration System Design and Installation

This chapter describes the design and installation of infrastructure required for the Stage A uranium sequestration system, which is composed of the following components:

- Injection and monitoring wells
- Infiltration system
- Chemical mixing skids and other site infrastructure
- Submersible pumps placed in the Columbia River
- Chemical feed tanks
- ERT

Each of these components was installed as a separate part of the work breakdown structure (WBS) for the project in accordance with SGW-58976. The following sections focus on design and installation of each component of the system.

2.1 Injection and Monitoring Wells

The following subsections describe drilling and construction of injection and monitoring wells within the Stage A EA area. The wells were installed in accordance with SGW-58553, *Description of Work for the Installation of Twenty Two Monitoring Wells and Nine Injection Wells in the 300-FF-5 Operable Unit*.

2.1.1 Injection Wells

The Stage A injection system includes nine combination PRZ/aquifer injection wells. Each injection well is constructed with two screened intervals,—one screen in the PRZ and one screen in the upper part of the aquifer. The screens are separated by a grout seal at the interface of the bottom of the PRZ and top of aquifer to allow isolated injection (using inflatable packers) into either the PRZ or top of the aquifer. Figure 2-1 shows the location of the nine injection wells within the Stage A treatment area.

The injection wells were drilled using a Terrasonic© 150 cc sonic drill rig. Figure 2-2 shows the Terrasonic drill rig onsite in the 300 Area. The nine injection wells were drilled between July 15 and July 28, 2015, in accordance with SGW-58553. A summary of the drilling and well construction details is contained in SGW-59465, *Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operabl*e *Unit, FY 2015*.

The target depth of the injection well boreholes was approximately 5 m (18 ft) deeper than the seasonally low water table. The seasonally low water table in this region was estimated to be 9.8 m (32 ft), and the boreholes were drilled to a depth of approximately 15.4 m (50 ft). Geologic archive samples were collected at 1.5 m (5 ft) intervals, or at changes in lithology, and placed in pint jars and chip trays. Figure 2-3 shows a geologic archive sample.

Drilling activities were monitored twice daily for radiological activity under a radiological work permit (RWP). On June 10, 2015, elevated radioactivity (18,000 disintegrations per minute (dpm) beta/gamma at ~ 5.5 m [18 ft] bgs) was discovered in soil sediments from borehole C8935 (well 399-1-73). Following this discovery, the RWP was revised and full time radiological monitoring continued for the duration of the drilling project.

© Terrasonic is a copyright of Terra Sonic International, Marietta, Ohio.

Table 2-1 presents the construction specifications for the injection wells. All of the injection wells were constructed using Schedule 80 polyvinyl chloride (PVC) pipe for the sumps and risers with 17.1 cm (6.75 in.) outside diameter (OD) and 15.2 cm (6 in.) inside diameter (ID). Each well has two screened intervals: one in the vadose zone, and the other below the water table, with blank casing in between.

Well heads were capped using a 0.3 m (1 ft) diameter by 0.3 m (1 ft) deep, weatherproof, flush-mounted well vault placed in a 0.6 m by 0.6 m (2 ft by 2 ft) concrete pad set approximately 2.5 cm (1 in.) above ground surface. Figure 2-4 shows a weatherproof well vault installed on an injection well. The well name, well identification number, and finish date were embossed on a bronze marker placed in the concrete pad on the north side of the well. Washington State Department of Ecology unique well identification tags were installed on the well casing inside the well vault.

The wells were developed by over pumping in order to obtain maximum flow rates. The upper screens of injection wells were not developed since the upper screens are located above the seasonal low water mark and were dry. Drawdown and recovery tests were monitored using a level TROLL® 700 pressure transducer/data logger. Well development information can be found in Table 2-2.

Table 2-1. Typical Injection Well Construction Specifications

Construction Parameter	Specification
Estimated depth to water, low river stage (bgs)	9.8 m (32 ft)
Drill depth (bgs)	15.2 m (50 ft)
Screen and casing diameter	15 cm (6 in)
Cement grout surface seal interval	~4.9 m (16 ft)*
Bentonite chips interval	~0.9 m (~3 ft)*
Bentonite pellet seal interval	~0.9 m (~3 ft)*
PRZ filter pack interval	3.4 m (11 ft)
PRZ screen interval	3.1 m (10 ft)
Bentonite pellet seal interval	0.9 m (3 ft)
Blank casing interval	0.9 m (3 ft)
Aquifer filter pack interval	4 m (13 ft)*
Aquifer screen interval	3.1 m (10 ft)
Sump interval	0.9 m (3 ft)

Reference: SGW-58553, *Description of Work for the Installation of Twenty Two Monitoring Wells and Nine Injection Wells in the 300-FF-5 Operable Unit.*

* Interval may vary, depending on site conditions.

bgs = below ground surface
PRZ = periodically rewetted zone

® TROLL is a registered trademark of In-Situ Inc., Fort Collins, Colorado.

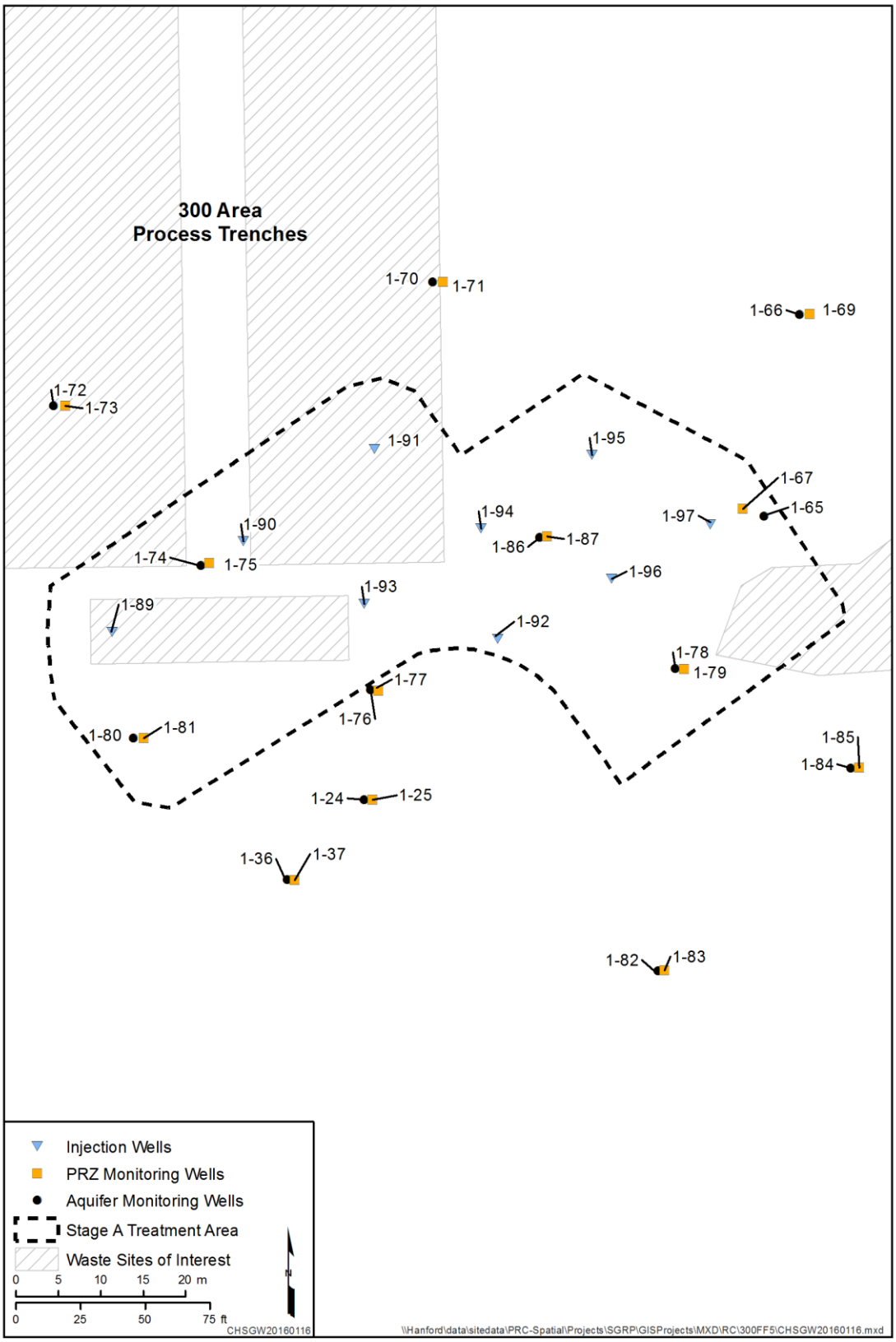


Figure 2-1. Location of Injection Wells and Monitoring Wells in the Stage A Treatment Area

Figure 2-2. Terrasonic Drill Rig in the 300 Area

Figure 2-3. Geologic Samples for Archiving

Figure 2-4. Weatherproof Well Vault Installed on an Injection Well

Table 2-2. Injection Well Development Summary

Well/Borehole Number	Date Developed	Initial Water Level (m/ft bgs)	Duration Pumped (Minutes)	Total Liters/Gallons Pumped
399-1-89/C9460	8/04/2015	9.6/31.37	69	~11,648/3,077
399-1-90/C9461	8/04/2015	9.6/31.65	32	~7,737/2,044
399-1-91/C9462	8/04/2015	9.7/32.00	42	~11,148/2,945
399-1-92/C9463	8/05/2015	9.8/32.20	54	~15,524/4,101
399-1-93/C9464	8/05/2015	9.8/32.05	20	~4,126/1,090
399-1-94/C9465	8/05/2015	9.8/32.16	47	~11,364/3,002
399-1-95/C9466	8/06/2015	9.5/31.30	30	~1,893/500
399-1-96/C9467	8/05/2015	9.6/31.35	59	~13,514/3,570
399-1-97/C9468	8/06/2015	9.5/31.05	35	~1,760/465

Reference: SGW-59465, *Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operable Unit, FY 2015*.

bgs = below ground surface

Table 2-3 provides a summary of the injection wells installed for the Stage A uranium sequestration system. The table includes the well/borehole number, construction date, surveyed coordinates, total depth, screened interval in the PRZ, and screened interval in the aquifer for each well. Grout seal, bentonite seals, and sand filter pack were installed in accordance with the specifications in Table 2-1. Additional information on construction and completion of the wells is contained in SGW-59465.

2.1.2 Monitoring Wells

There are 26 individual monitoring wells, consisting of 13 collocated well pairs (including 2 existing well pairs and 1 well from the post-ROD investigation), that make up the monitoring system. For each well pair, one well is screened in the PRZ, and one well is screened in the aquifer to enable monitoring of each discrete zone. As shown in Figure 2-1, the monitoring well system includes three monitoring well pairs upgradient of the Stage A EA area, six monitoring well pairs within the Stage A EA area, and four monitoring well pairs downgradient of the Stage A EA area.

The PRZ and aquifer monitoring well boreholes were drilled using a Terrasonic 150 cc sonic drill rig. In accordance with SGW-58553, 21 monitoring wells were drilled between June 9 and July 13, 2015. A summary of the drilling and well construction details is contained in SGW-59465. The boreholes were drilled to allow construction of a 5 cm (2 in.) diameter monitoring well.

Ten PRZ monitoring well boreholes were drilled between June 10 and June 30, 2015. All of the PRZ boreholes were drilled from ground surface to approximately 12.3 m (40 ft) bgs. Eleven aquifer monitoring well boreholes were drilled between June 9 and July 13, 2015. The aquifer boreholes were drilled from ground surface to approximately 14.6 m (48 ft) bgs.

Table 2-3. Stage A PRZ/Aquifer Injection Wells

Well/Borehole Number	Construction Date	Coordinates (NAD83 State Plane)		Total Depth (m/ft) bgs	PRZ Screened Interval (m/ft) bgs		Aquifer Screened Interval (m/ft) bgs	
		Northing (m)	Easting (m)		Top	Bottom	Top	Bottom
399-1-89/C9460	7/16/15	116467.59	594087.17	15.5/50.5	6.3/20.4	9.4/30.4	10.9/35.4	14/45.4
399-1-90/C9461	7/20/15	116478.21	594102.77	15.5/50.3	6.3/20.4	9.4/30.4	10.9/35.4	14/45.4
399-1-91/C9462	7/21/15	116489.07	594118.24	15.4/50	6.2/20	9.2/30	10.8/35	13.8/45
399-1-92/C9463	7/22/15	116466.66	594132.82	15.4/50	6.2/20.3	9.3/30.3	10.9/35.3	13.9/45.3
399-1-93/C9464	7/15/15	116470.77	594116.97	15.4/50	6.2/20	9.2/30	10.8/35	13.8/45
399-1-94/C9465	7/22/15	116479.65	594130.8	15.4/50	6.2/20.2	9.3/30.2	10.8/35.2	13.9/45.2
399-1-95/C9466	7/27/15	116488.32	594143.85	15.4/50	6.4/20.9	9.5/30.9	11/35.9	14.1/45.9
399-1-96/C9467	7/23/15	116473.85	594146.2	15.4/50	6.1/19.9	9.2/29.9	10.7/34.9	13.8/44.9
399-1-97/C9468	7/28/15	116480.09	594157.77	15.4/50	6.1/19.9	9.2/29.9	10.7/34.9	13.8/44.9

References: NAD83, *North America Datum of 1983*.

SGW-59465, Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operable Unit, FY 2015.

Geologic archive samples were collected at 1.5 m (5 ft) intervals, or at changes in lithology, and placed in pint jars and chip trays. Drilling activities were monitored twice daily for radiological activity under an RWP. Radiological monitoring was revised to full-time and the RWP was revised, following the June 10, 2015, discovery of elevated radioactivity (18,000 dpm beta/gamma at ~ 5.5 m [18 ft] bgs) in soil sediments from borehole C8935 (well 399-1-73). Full-time radiological monitoring continued for the duration of the drilling project.

Soil samples were collected from aquifer monitoring well boreholes C8940 (well 399-1-76) and C9451 (well 399-1-80). Continuous split-spoon samples were collected in each borehole from approximately 3.1 m (10 ft) bgs to 10 m (32.5 ft) bgs. The boreholes were then completed to the final depth of 15.4 m (50 ft) bgs. The samples were characterized in accordance with SGW-56993, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation*.

Table 2-4 presents the construction specifications for the 21 monitoring wells that were installed. All of the monitoring wells were constructed using Schedule 40 PVC pipe for the sumps and risers with 6.1 cm (2.4 in.) OD and 5.1 cm (2 in.) ID. The well screens were 20 slot 6.1 cm (2.4 in.) OD and 5.1 cm (2 in.) ID Schedule 40 PVC on top of a 0.9 to 1.5 m (3 to 5 ft) long PVC sump with end cap. Silica sand was used for the sand pack. Sodium bentonite chips and pellets were used for bentonite sealing material. Neat cement-bentonite grout was placed to within 0.6 m (2 ft) of the ground surface.

Table 2-4. Typical Monitoring Well Construction Specifications

Construction Parameter	Specification	
	PRZ Well	Aquifer Well
Estimated depth to low water (bgs)	9.75 m (32 ft)	9.75 m (32 ft)
Estimated drill depth (bgs)	12.19 m (40 ft)	14.63 m (48 ft)
Screen and casing diameter	0.61 cm (2 in)	0.61 cm (2 in)
Cement grout surface seal interval	3.1 m (10 ft)	3.1 m (10 ft)
Bentonite chips interval	5.2 m (17 ft)*	7.7 m (25 ft)*
Bentonite pellet seal interval	0.9 m (3 ft)	0.9 m (3 ft)
Filter pack interval	3.1 m (10 ft)*	3.1 m (10 ft)*
Screen interval	1.5 m (5 ft)	1.5 m (5 ft)
Sump interval	0.9 m (3 ft)	0.9 m (3 ft)

* Interval may vary, depending on site conditions.
bgs = below ground surface
PRZ = periodically rewetted zone

Reference: SGW-58553, Description of Work for the Installation of Twenty Two Monitoring Wells and Nine Injection Wells in the 300-FF-5 Operable Unit.

Well heads were capped using a 0.3 m (1 ft) diameter by 0.3 m (1 ft) deep, weatherproof, flush-mount well vault placed in a 0.6 m by 0.6 m (2 ft by 2 ft) concrete pad set approximately 2.5 cm (1 in.) above ground surface. All of the monitoring wells were developed using a 12 volt submersible pump capable of pumping up to 8 L/min (2 gallons per minute [gpm]). The actual pumping rate was approximately 1 gpm. Development was considered complete when the purge water was visibly clear. Well development

information for the PRZ monitoring wells and aquifer monitoring wells can be found in Tables 2-5 and 2-6, respectively.

Table 2-7 lists the 10 PRZ monitoring wells installed for Stage A uranium sequestration system and the three existing wells that are being used as part of the PRZ monitoring system. Table 2-8 lists the 11 aquifer monitoring wells installed for Stage A uranium sequestration system and the two existing wells that are being used as part of the aquifer monitoring system. The tables include the well/borehole number, completion date, surveyed coordinates, total depth, and screened interval for each well. Additional information on the wells is contained in SGW-59465.

Table 2-5. PRZ Monitoring Wells Development Summary

Well/Borehole Number	Date Developed	Initial Water Level (m/ft) bgs	Duration Pumped (Minutes)	Total Liters/Gallons Pumped
399-1-69/C8930	7/16/2015	9.4/30.70	36	~136/36
399-1-71/C8932	7/09/2015	9.5/30.80	37	~140/37
399-1-73/C8935	7/16/2015	9.7/31.74	25	~95/25
399-1-75/C8939	7/09/2015	9.2/30.20	39	~148/39
399-1-77/C8941	7/15/2015	9.9/32.65	50	~189/50
399-1-79/C9450	7/13/2015	9.8/32.10	31	~117/31
399-1-81/C9452	7/09/2015	9.6/31.50	10	~38/10
399-1-83/C9454	7/13/2015	10/32.72	21	~79/21
399-1-85/C9456	7/14/2015	9.5/31.80	52	~197/52
399-1-87/C9458	7/20/2015	9.6/31.60	39	~148/39

Reference: SGW-59465, *Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operable Unit, FY 2015*.

Table 2-6. Aquifer Monitoring Well Development Summary

Well/Borehole Number	Date Developed	Initial Water Level (m/ft) bgs	Duration Pumped (Minutes)	Total Liters/Gallons Pumped
399-1-70/C8931	6/29/2015	9.4/30.85	17	~64/17
399-1-72/C8934	7/16/2015	9.7/31.69	41	~155/41
399-1-74/C8937	7/9/2015	9.2/30.20	44	~167/44
399-1-76/C8940	7/15/2015	10/32.7	30	~114/30
399-1-78/C8942	7/11/2015	9.5/31.20	36	~136/36
399-1-65/C9408	6/30/2015	9.2/30.33	72	~273/72
399-1-66/C9409	7/13/2015	9.5/31.15	70	~265/70

Table 2-6. Aquifer Monitoring Well Development Summary

Well/Borehole Number	Date Developed	Initial Water Level (m/ft) bgs	Duration Pumped (Minutes)	Total Liters/Gallons Pumped
399-1-80/C9451	7/15/2015	9.7/31.78	103	~390/103
399-1-82/C9453	7/14/2015	9.9/32.36	29	~110/29
399-1-84/C9455	7/14/2015	9.8/32.00	80	~303/80
399-1-86/C9457	7/20/2015	8.9/29.14	58	~220/58

Reference: SGW-59465, *Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operable* Unit, *FY 2015*.

Table 2-7. Stage A PRZ Monitoring Wells

Well/Borehole Number	Construction Date	Coordinates (NAD83 State Plane)		Total Depth (m/ft) bgs	Screened Interval (m/ft) bgs	
		Northing (m)	Easting (m)		Top	Bottom
399-1-67/C8936*	01/26/2015	116481.59	594162.36	12.5/40.7	7.4/24	10.5/34
399-1-69/C8930	06/17/2015	116505.03	594169.73	12.3/40	9.4/30.7	11/35.7
399-1-71/C8932	06/16/2015	116508.84	594126.33	12.5/40.5	9.4/30.4	10.9/35.4
399-1-73/C8935	06/15/2015	116494.22	594081.69	12.5/40.5	8.7/28.3	10.2/33.3
399-1-75/C8939	06/29/2015	116475.62	594098.69	12.3/40.1	9.4/30.6	11/35.6
399-1-77/C8941	06/30/2015	116460.56	594118.72	12.4/40.2	9.4/30.4	10.9/35.4
399-1-79/C9450	06/18/2015	116463.09	594154.88	12.4/40.2	9.3/30.3	10.9/35.3
399-1-81/C9452	06/30/2015	116454.92	594090.9	12.5/40.7	9.4/30.6	11/35.6
399-1-83/C9454	06/24/2015	116427.4	594152.48	12.3/40	9.4/30.4	10.9/35.4
399-1-85/C9456	06/25/2015	116451.42	594175.5	12.3/40	9.4/30.6	11/35.6
399-1-87/C9458	06/23/2015	116478.8	594138.62	12.6/41	9.4/30.6	11/35.6
399-1-25/C5352*	11/17/2006	116450.35	594116.88	15.4/50	12.9/42	14.5/47
399-1-37/C5630*	6/1/2007	116438.15	594110.22	11.7/37.9	9.5/31	11.1/36

* Existing wells.
References: NAD83, North America Datum of 1983.
SGW-59465, Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operable Unit, FY 2015.
PRZ = periodically rewetted zone

Table 2-8. Stage A Aquifer Monitoring Wells

Well/Borehole Number	Construction Date	Coordinates (NAD83 State Plane)		Total Depth (m/ft) bgs	Screened Interval (m/ft) bgs	
		Northing (m)	Easting (m)		Top	Bottom
399-1-65/C9408	07/18/15	116481.19	594164.48	49.7	12.6/40.9	14.1/45.9
399-1-66/C9409	07/17/15	116504.97	594168.41	50.1	12.2/39.5	13.7/44.5
399-1-70/C8931	06/16/15	116508.83	594125.04	48.9	12.7/41.3	14.2/46.3
399-1-72/C8934	06/10/15	116494.16	594080.16	48.1	12.2/39.7	13.8/44.7
399-1-74/C8937	06/29/15	116475.26	594097.65	50.1	12.4/40.2	13.9/45.2
399-1-76/C8940	07/13/15	116460.62	594117.79	50.9	12.4/40.2	13.9/45.2
399-1-78/C8942	06/22/15	116463.17	594153.7	50.3	12.5/40.5	14/45.5
399-1-80/C9451	07/14/15	116454.78	594089.52	50.5	12.5/40.6	14/45.6
399-1-82/C9453	06/24/15	116427.47	594151.78	50.5	12.5/40.5	14/45.5
399-1-84/C9455	06/25/15	116451.41	594174.47	60	14.8/48	16.3/53
399-1-86/C9457	06/23/15	116478.66	594137.74	50.5	12.5/40.4	14/45.4
399-1-24/C5351*	11/16/2006	116449.68	594116.45	12.9/42	9.8/32	11.4/37
399-1-36/C5629*	5/10/2007	116438.76	594108.45	15.4/50	12.6/41	14.2/46

* Existing wells

References: NAD83, *North America Datum of 1983*.

SGW-59465, *Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operable Unit, FY 2015*.

2.1.3 Unexpected Conditions

During excavation for the infiltration system, it was observed that the grout seal of injection well 399-1-95 was deficient and did not completely seal the annulus of the well. Figure 2-5 shows the exposed PVC well casing.

On November 5, 2015, the backfill around well 399-1-95 was excavated in order to expose the deficient grout seal that had been discovered during installation of the infiltration system. The backfill around the well was excavated to a depth of 1.14 m (3.7 ft) below grade. The well pad was broken up and removed. A 25.4 cm (10 in.) diameter Sonotube® concrete form was placed around the well casing to the depth of excavation. Cement grout was poured into the concrete form and allowed to cure. Figure 2-6 shows the Sonotube concrete form and weatherproof vault on well 399-1-95.

® Sonotube is a registered trademark of Sonoco, Hartsville, South Carolina.

On November 7, 2015, the Sonotube was removed, and the grout seal was inspected. The repair was noted as complete, and the area around well 399-1-95 was backfilled. A 0.6 m by 0.6 m (2 ft by 2 ft) concrete pad was poured around the top of the well casing, and the brass marker was replaced.

Figure 2-5. Exposed Casing of Well 399-1-95

Figure 2-6. Sonotube Concrete Form and Weatherproof Vault on Well 399-1-95

2.1.4 Summary

Table 2-9 provides a summary of the resources required for installing and developing the injection and monitoring wells and the duration of the activity.

Table 2-9. Summary of Project Resources Needed for the Injection and Monitoring Wells

Resource	Description	Quantity (Hours/$)	Duration* (Days)	
			Installation	Developing
Craft	Electrician	5	Injection wells – 8 Monitoring wells – 20	Injection wells – 3 Monitoring wells – 9
	Pipefitter	12		
	Nuclear Chemical Operator	202		
	Health Physics Technician	229		
Engineering and Science	Environmental Scientist	197		
	Geologist/Hydrologist	11.5		
	Other Scientists	5		

Table 2-9. Summary of Project Resources Needed for the Injection and Monitoring Wells

Resource	Description	Quantity (Hours/$)	Duration* (Days)	
			Installation	Developing
Management and Administration	First Line Supervisor	229		
	Managers & Executives	12		
	Project Manager	29		
	Office Clerk	24		
	Planner/Scheduler	102		
	Technical Writer/Editor	40.5		
Subcontracts	Drilling Contractor	$786,000		
	Field Geologist Contractor	$71,000		

* Based on a 4-day work week.

2.2 Infiltration System

A phosphate infiltration system was installed within the Stage A EA area in accordance with SGW-58976. The infiltration network consists of high-density polyethylene (HDPE) liquid distribution lines installed bgs. Figure 2-7 shows the layout of the infiltration system in the Stage A treatment area. The Ore-Max™ Max-Emitterline irrigation drip line was used for the liquid distribution lines. The drip lines consist of continuous HDPE tubing with emitters installed internally and welded to the inside of the tubing. The emitters are rated at 8 L/hr (2 gal/hr) each and spaced 0.36 m (14 in.) apart along drip lines. The drip lines are spaced approximately 2 m (6.5 ft) apart, resulting in a total of 44 lines aligned southeast to northwest. The liquid distribution lines were placed approximately 1.8 m (6 ft) bgs to prevent accumulation and wicking of sodium and phosphate up into the surficial soil. However, by the end of infiltration, surface moisture was observed in an area in the center of the EA.

The Stage A phosphate infiltration system was installed beginning on August 18, 2015. On August 18, 19, and 20, the existing surface material was excavated to a depth of approximately 0.9 m to 1.8 m (3 to 6 ft) below current grade throughout the infiltration area. The material was excavated with care to avoid disturbing the injection wells and monitoring wells previously installed in the Stage A treatment area. Figure 2-8 shows the excavation and partially exposed wells. Approximately 4,863 m^3 (6,360 yd^3) of material were removed from the Stage A treatment area and stockpiled nearby. A global positioning system was used to ensure that the bottom of the filtration area was excavated to an elevation of 113.6 m (372.7 ft) above mean sea level.

On August 20, 2015, HDPE irrigation drip lines were installed in the bottom of the excavation. The drip lines were approximately 2 m (6.5 ft) apart and were bedded with sand. Figure 2-9 shows the installation and bedding of the drip lines. Each drip line was installed with a pressure regulator set at 103.4 kPa (15 psi) and was connected to a 7.6 cm (3 in.) lay-flat-style flexible header.

On August 21 and 24, the Stage A treatment area was backfilled with stockpiled material from the excavation and leveled to the original grade. On August 25, 2015, coarse gravel was applied to the

™ Ore-Max is a trademark of the Ore-Max Division of Wade Rain, Inc., Portland, Oregon.

surface, and the area was watered and compacted with a small roller. Figure 2-10 shows the backfill and coarse gravel on the surface. Installation of the infiltration system was completed on August 26, 2015.

During the week of October 5, 2015, the infiltration lines were connected to the lay-flat header, which was connected to the phosphate distribution system. Figure 2-11 shows the header pipe and distribution lines. On October 22 and October 23, 2015, the phosphate distribution system and infiltration system were tested. The first test used approximately 3,975 L (1,050 gal) of river water. The second test included only about one half of the infiltration system and used approximately 6,814 L (1,800 gal) of river water. The second test was conducted to determine if the infiltration system could be operated as two separate segments. Based on the results of the second test, this approach was not implemented.

2.2.1 Unexpected Conditions

The following subsections document unexpected conditions encountered during installation and testing of the infiltration system and should be considered for future installations.

2.2.1.1 Higher than Expected System Pressure

During testing of the infiltration system, the fluid pressure within the system was higher than initially modeled. As the river water flow rate was increased to 100 gpm, the pressure within the infiltration system rose to over 60 psi. At this pressure, the chemical mixing pumps could not overcome the head pressure from the river pumps. The system was unable to deliver the designed total flow rate of 135 gpm.

Additional testing of the infiltration network indicated that a fluid pressure between 30 and 35 psi would optimize system operation. In order to balance the capacity of the chemical pumps, river water flow rates were reduced until a pressure of 35 psi was achieved in the infiltration network. At that pressure, the chemical pumps were able to deliver the prescribed ratios of 1:17 monosodium phosphate to filtered river water and 1:27 pyrophosphate to filtered river water. However, the maximum flow rate achieved for the infiltration network under this modified system operation was between 53 and 57 gpm, which is well below the design flow rate of 135 gpm.

Higher than modeled pressure within the infiltration system may have been caused by collapsed or kinked subsurface infiltration lines or plugged emitters. The system also included pressure regulators between the lay-flat headers and the distribution lines that were set at 15 psi.

On Wednesday November 11, 2015, after 5 days of infiltration at the reduced flow rate of approximately 53 gpm, the 15 psi pressure regulators were replaced with 20 psi regulators. After this change, the flow rates increased by approximately 50 percent up to 80 gpm for the duration of the project. Due to the reduced flow rates, the duration for infiltration was extended by four days in order to achieve the design infiltration volume.

The lower than modeled flow rates could also have been caused by the sand bed around the emitters, which may have reduced the pore space immediately adjacent to the emitters. The modeled flow of 8 L/hr (2 gal/hr) from each emitter assumes zero resistance outside of the drip line. By adding sand around the drip lines during installation, resistance outside the drip lines could have been increased and require a pressure greater than 15 psi to achieve the desired 8 L/hr (2 gal/hr) flow rate.

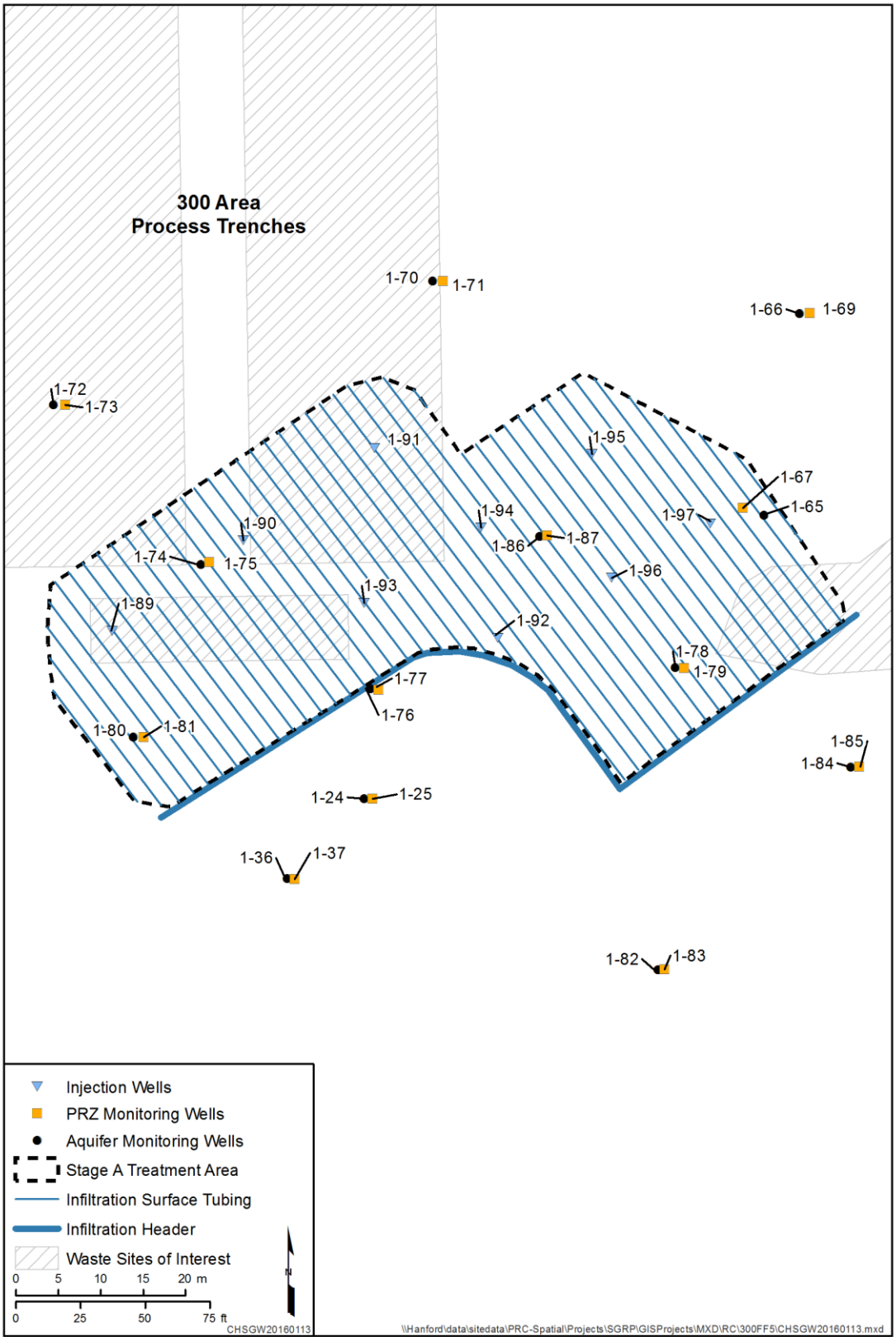


Figure 2-7. Infiltration System in the Stage A Treatment Area

Figure 2-8. Excavation and Partially Exposed Injection and Monitoring Wells in the Stage A Treatment Area

Figure 2-9. Installation HDPE Drip Lines

Figure 2-10. Backfilling the Infiltration System

Figure 2-11. Infiltration System Pipe Header and Distribution Lines

2.2.1.2 Change in Installation Approach

A request for proposal was issued for installation of the infiltration system, assuming horizontal boreholes would be drilled and the infiltration piping would be pulled through each borehole. During the field walk down with the contractors, it was determined that approach would not be viable due to the presence of large boulders. The contractors proposed excavating the entire area to a depth of approximately 1.8 m (6 ft) bgs, placing the drip lines, bedding the drip lines with sand, and then backfilling the excavated area. This resulted in the following issues:

- Excavation around the injection and monitoring wells required additional controls and care to ensure the integrity of the wells.
- The resultant cost was almost double the original estimated cost.

2.2.1.3 Evaluation of the Impact of Adding River Water to the Vadose Zone During Testing of the Infiltration System

The infiltration system was tested using river water on two different occasions. Table 2-10 summarizes the volume of water, affected surface area, and estimated depth of water for each of the tests.
The estimated discharged depth of water per affected surface area is determined by dividing the discharge volume by the affected surface area. The estimated depth of discharged water is 0.131 cm (0.052 in.) for test 1 and 0.510 cm (0.20 in.) for test 2. The combined total estimated depth of discharged water for the two tests is 0.641 cm (0.25 in.).

Based on records from the Hanford Meteorological Station, average precipitation for the Hanford Site over the last 5 years (2010 to 2014) for the period of September to November is approximately 4.3 cm (1.69 in.). Over this time frame, precipitation for the period of September to November has ranged from a low of 2.4 cm (0.94 in.) to a high of 6.9 cm (2.71 in.). Based on the average precipitation for the time period of September to November, the addition of 0.641 cm (0.25 in.) of water to the test area is well within the natural variability of seasonal precipitation for the area and is expected to have minimal effect on moisture levels in the vadose zone within the Stage A treatment area. Assuming all of the discharged water infiltrates vertically, and considering an average volumetric soil moisture content of 0.1, the vertical extent of infiltrated water is calculated to be about 6.4 cm or 2.5 in. (divide 0.641 cm by 0.1 [0.25 in. by 0.1]), which is negligible compared to the depth to the PRZ.

Table 2-10. Volume of Water, Affected Surface, and Estimated Depth of Water for Infiltration System Tests

Parameter	Test 1	Test 2	Total
Discharge volume (gal)	1,050	1,800	--
Discharge volume (m^3)	3.975	6.814	--
Affected surface area (m^2)	3,035.145	1,335.464	--
Estimated depth of water per affected surface area (cm)	0.131	0.510	0.641

2.2.2 Summary

Table 2-11 provides a summary of the resources required for installation and testing of the infiltration system and the duration of the activity.

Table 2-11. Summary of Project Resources Needed for the Infiltration System

Resource	Description	Quantity (Hours/$)	Duration* (Days)	
			Installation	Testing
Craft	Carpenter Electrician Pipefitter Health Physics Technician	16 4 40 67	10	2
Engineering and Science	Environmental Scientist Other Scientists	56 17		
Management and Administration	First Line Supervisor Managers & Executives Project Manager Office Clerk Procurement/Contracting	44 10 7 15.5 53		
Subcontracts	Infiltration System Contractor	$325,000		

* Based on a 4-day work week.

2.3 Chemical Mixing Skids and Site Infrastructure

The following subsections describe installation and testing of the chemical mixing skids and other site infrastructure in the Stage A treatment area in accordance with SGW-58976.

2.3.1 Chemical Mixing Skids

Two remediation skids were designed and constructed as part of the apatite permeable reactive barrier remedy for the 100-NR-2 OU (DOE/RL-2010-29, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*). Each remediation skid is capable of delivering phosphate solution at a flow rate of up to 1,136 L/min (300 gpm). Feed water from the Columbia River is transferred via aboveground piping to the remediation skids, where it is blended with the phosphate concentrate in a static inline mixing chamber. The river water is filtered through filter housings prior to blending with the phosphate concentrate solutions. Following mixing, a manifold distributes the diluted phosphate solutions to transfer hoses for distribution. Skid 1 delivers phosphate solution to as many as six injection wells at a target rate of 189 L/min (50 gpm) per well. Skid 2 delivers phosphate solution to the infiltration network at a target rate of 511 L/min (135 gpm).

The two chemical mixing skids originally designed and built for the 100-NR-2 OU were moved to the 300 Area and set up and tested between August 24 and October 7, 2015. Figure 2-12 shows the mixing skids set up in the 300 Area.

Prior to installing the chemical mixing skids, several site preparation activities were completed. In order to stay within manufacturer requirements for the variable frequency drive (mounted on the skids), the mixing skids had to be located closer to the river pumps and could not be placed in the well field as originally planned. To mitigate this issue, a gravel skid pad and service road were prepared approximately 30.8 m (100 ft) inland of the river shoreline access point. The mixing skids were set up on the skid pad and connected to the well field.

Power for each mixing skid was supplied by two 125 kVa generators rented for the duration of the project and connected to each mixing skid. Each mixing skid was connected to a portable filter bank composed of six inline filters to remove particulates and debris from river water prior to distribution to the mixing skids.

River water distribution components included submersible river hose, upland river supply rubber hose, and injection well rubber hose. Original plans (SGW-58976) included using lower cost fire hose, but fire hose was not available at the time of procurement. The upland river supply hose was a 10 cm (4 in.) diameter rubber hose connected by cam-locks. A total length of 260 m (850 ft) of submersible river hose and upland river supply hose was used for each of the two skids for a total of 518 m (1,700 ft) of 10 cm (4 in.) diameter rubber hose.

Injection well hose was 7.6 cm (3 in.) diameter rubber hose. The hose was connected to all nine injection wells and ran to mixing skid 1 where final connections could be made as the injection schedule required. The total amount of hose needed to supply all nine injection wells was approximately 785 m (2,575 ft).

The mixing skids were tested using river water during the week of September 21, 2015. During the week of October 5, 2015, the chemical mixing system and phosphate distribution lines were connected and tested. The tests included functional checks of flow meters, pressure gauges, programmable logic controllers (PLCs), and variable frequency drives. River water from the tests was collected in water trucks and dispersed on nearby roads for dust suppression. During the tests, minor leaks were observed and repaired. Also, the emergency stop button was found to be inoperable and was repaired.

Figure 2-12. Chemical Mixing Skids in the 300 Area

2.3.2 Site Infrastructure

Support equipment was provided to ensure a safe and manageable work environment. Support infrastructure included personnel accommodations, power supply, lighting, and equipment laydown. A gravel road was constructed from the Stage A treatment area to the shoreline access point to accommodate hose and power installation. A gravel pad was created adjacent to this road, between the treatment area and the river, where the mixing skids and generators were placed.

A small operations trailer was brought onsite to provide shelter and a lunchroom. The trailer was a 2.4 m by 6.1 m (8 ft by 20 ft) ground level Conex office. The Conex office had been fitted with vinyl wrapped gypsum walls, two windows, an access door, two counter tops, electrical outlets, lighting, and a wall

mounted heating and cooling system. A generator was brought onsite to provide a dedicated power supply to the office. A small trailer was brought onsite to support ERT operations. Additionally, two 125 kVa generators were leased to supply dedicated power to each mixing skid.

Four light plants were arranged to provide adequate light coverage to all main working areas during night operations. Light plants were staged one each at the chemical tanks, mixing skids, the western end of the infiltration header, and at the ERT trailer. The ERT trailer was powered by a light plant, which remained operational around the clock to provide steady power for the ERT system. An additional light plant was added at the intersection of the main entrance to the site and the highway to help identify the site entrance.

A 93 m^2 (1,000 ft^2) equipment laydown area was set up south of the operations trailer where ground had been leveled during excavation for the installation of the drip lines.

Figure 2-13 is an aerial view of the Stage A uranium sequestration system showing the location of the river pumps, chemical mixing skids, chemical storage tanks, and the general location of the Stage A treatment area. The injection wells and ERT network can be seen within the Stage A treatment area.

2.3.3 Unexpected Conditions

The following topics document unexpected conditions encountered during installation and testing of the mixing skids and site infrastructure and should be considered for future installations.

2.3.3.1 Loose River Hose Connections

During testing of skid 2, a problem with delivery of river water was identified. Within minutes of starting the river pumps, water flow at the skid stopped and pressure at the pre-filters went to zero. However, the PLC at the skid indicated that the river pump continued to pump. The maintenance crew went to the river to check the connection of the river hose to the submersed river pump by pulling on the hose and discovered the hose had disconnected from the river pump. The hose clamp that fastened the cam-lock fitting to the hose had come loose, and the hose had slipped off the cam-lock fitting, which remained fastened to the river pump.

On September 30, 2015, the river pump installation subcontractor lifted the pump, and the hose was re-secured to the cam-lock fitting. During this period, additional hose clamps were added to the ends of all submerged sections of hose. Upon disconnecting one of the hose fittings near the river shoreline, a pipefitter was sprayed by river water that had not completely drained from the line higher in elevation. Following this event, drain valves were installed on the hose near the river shoreline to ensure that lines could be emptied as needed.

2.3.3.2 Installation of Grounding Rods

Due to the large cobbles in the shallow subsurface, driving grounding rods for the generators and light plants using conventional methods was unsuccessful. Alternative grounding methods were evaluated, including running ground wire to the permanent monitoring wells that were completed with carbon steel casing. However, it was determined that this method could potentially interfere with ERT imaging. Finally, a backhoe was used to lay grounding rods horizontally at the location of each generator and light plant.

Figure 2-13. Aerial Photograph of the Stage A Treatment Area

2-23

2.3.4 Summary

Table 2-12 provides a summary of the resources required for installation and testing of the chemical mixing skids, site infrastructure, and duration of the activities.

Table 2-12. Summary of Project Resources Needed for the Chemical Mixing Skids and Site Infrastructure

Resource	Description	Quantity (Hours/$)	Duration* (Days)	
			Installation	Testing
Engineering and Drafting Design	Electrical Engineer	97	Infrastructure design prior to field installation and testing	
	Mechanical Engineer	182		
	Plant Engineer	70		
	Safety Engineer	9		
	Other Engineers	2		
	Drafter	289		
Craft	Carpenter	162	24	3
	Electrician	474		
	Pipefitter	461		
	Teamsters	461		
	Nuclear Chemical Operator	575		
	Utilities/System Operator	19.5		
	Health Physics Technician	28		
	Instrument Technician	69		
Engineering and Science	Civil Engineer	4.5		
	Electrical Engineer	146.5		
	Mechanical Engineer	243.5		
	Plant Engineer	215		
	Safety Engineer	84		
	Drafters	66.5		
	Chemist	2		
	Environmental Scientist	461		
	Geologist/Hydrogeologist	8		
	Other Scientists	149		
Management and Administration	First Line Supervisor	984.5		
	Managers & Executives	34		
	Project Manager	68		
	Office Clerk	17		
	Procurement/Contracting	53		
	Planner/Scheduler	57.5		
	Trainers/Instructor	1		
	Technical Writer/Editor	4		

Table 2-12. Summary of Project Resources Needed for the Chemical Mixing Skids and Site Infrastructure

Resource	Description	Quantity (Hours/$)	Duration* (Days)	
			Installation	Testing
Subcontracts	Office Conex Supplier	$3,400		
Materials	Light Plants and Generators	$11,000		
	Hoses and Fittings	$133,000		

* Based on a 4-day work week.

2.4 River Pumps

Feed water for the phosphate solutions is obtained using two separate submersible pumps (Grundfos No. 385S200-3A), each capable of supplying up to 1,136 L/min (300 gpm). Feed water is piped from the Columbia River to the chemical mixing skids. A 10 cm (4 in.) water conveyance line was run from the water source approximately 30.8 m (100 ft) to the chemical mixing skids.

Withdrawal of water from the Columbia River and infiltration/injection of phosphate solution during the uranium sequestration process has the potential to affect three fish species listed under the *Endangered Species Act of 1973* and/or their critical habitat.

On April 14, 2015, DOE requested written concurrence from the National Marine Fisheries Service (NMFS) that pumping water from the Columbia River in the 300 Area to support the EA is not likely to have adverse effects on two species listed as threatened or endangered or critical habitats designated under the *Endangered Species Act of 1973*. Based on analysis cited in an NMFS letter (WCR-2015-2480, "Endangered Species Act Section 7(a)(2) Concurrence Letter for Installation and Operations of a Uranium Sequestration Groundwater Treatment System near the Shoreline of the Columbia River at the 300 Area of the Hanford Site, Benton Country, Washington (HUC 170200160602) City of Richland-Columbia River"), NMFS concurred with DOE that the proposed action is not likely to have adverse effects on upper Columbia River spring-run Chinook salmon and steelhead and designated critical habitats.

Similarly, informal consultation for bull trout (*Salvelinus confluentus*), which is listed as threatened, was initiated with the U. S. Fish and Wildlife Service (USFWS). In a USFWS letter (01EWFW00-2015-I-0567, dated May 5, 2015), USFWS concurred with DOE that the proposed action is not likely to have adverse effects on bull trout and designated critical habitat.

A cultural resources survey of the proposed location of aboveground water lines and EA area was conducted on May 27, 2014, and documented in MSA-1502630, "Ecological and Cultural Clearance for Columbia River Access and Submersible Pumps in the Columbia River for the 300 Area Sequestration Remedial Activities, Hanford Site, Benton Country, Washington (HCRC# 2014-300-004, ECR-2015-303)". The survey did not identify any previously unrecorded cultural material. Based on the cultural resources survey, a pipe route for the water lines from the river pumps was selected to avoid known cultural resources.

On September 9, 2015, two platform-mounted submersible pumps with fish screens were placed in the Columbia River to feed river water through a filter bank to each chemical mixing skid. The submersible

pumps, mounted on skidplates, were transferred to the approved pumping location by boat and set into the river one at a time. Figure 2-14 shows a submersible pump on the mounting skidplate.

The river pumps were loaded onto a boat at Leslie Groves boat launch in north Richland, then transported to the 300 Area shoreline at the designated river access point. Upon arrival at the river, shoreline electricians and pipefitters had power cables and 10 cm (4 in.) diameter river hoses ready to connect to the pump skids. After connections were made, the river pumps and connected power cable and feed hose were transported into the river channel.

The pumps were set in the river approximately 9.2 m (30 ft) apart using a boat mounted hoist in approximately 2.4 m (8 ft) of water and approximately 30.8 m (100 ft) from shore. Each pump was tethered upstream with a 30.8 m (100 ft) anchor line and a 15.4 m (50 ft) metal winch line attached to a 15.4 m (50 ft) sinking rope line as a leader. When the pumps are removed from the river at the conclusion of the project, a grapple will be used to retrieve this line, and the pumps will be winched into the boat. Figure 2-15 shows a submersible pump and skidplate assembly being lowered into the Columbia River near the 300 Area.

2.4.1 Unexpected Conditions

The following subsections document unexpected conditions encountered during installation and testing of the river pumps and should be considered for future installations.

2.4.1.1 Loose Hose Clamps

During transport of the second skidplate, it was discovered that hose clamps securing the cam-lock fittings onto the discharge hoses were not tight enough, and the hoses could pull apart. Action was taken at that time to tighten all hose clamps on the water hose on land. The crew on the river also lifted each submerged river pump and hose connection and tightened all hose clamps.

However, the river current interfered with the ability to lay the river hose in a uniform manner, and the hoses from each pump crossed one another on the river bottom. For this reason, it was not certain at the time that all the submerged hose connection points had been evaluated and tightened when the pumps were installed. It became evident that some connections were loose when the mixing pumps and distribution systems were tested.

2.4.1.2 River Access Controls Due to Culturally Sensitive Area

A cultural resources survey of the proposed location of aboveground water lines and EA area was conducted on May 27, 2014. The survey did not identify any previously unrecorded cultural material. However, it was determined that the eastern boundary of the project area along the river shoreline overlapped with the boundary of an archeological site.

An overland route for the water lines connected to the river pumps was designated in order to avoid known cultural resources. Because of the cultural sensitivity of the area and the potential for adverse effects, the following work control measures were implemented to ensure that no cultural materials or features would be damaged or displaced during project activities:

- All staff associated with this project received cultural resources awareness training before performing work.
- All project activities that took place east of the shoreline road were monitored by a qualified archaeologist who directed foot traffic and the placement of project equipment and components away from artifacts and features.
- Archaeologists performed periodic inspections of the hose route during the operational life of the equipment to monitor progress and continued protection of archaeological sites.

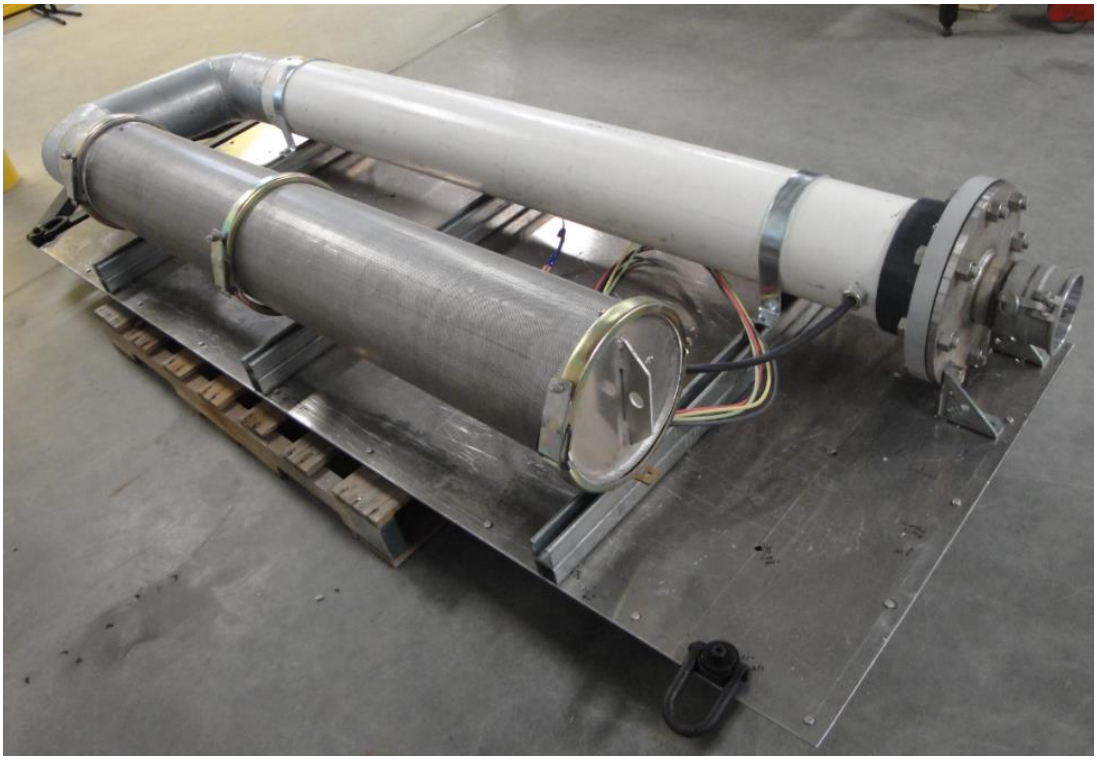


Figure 2-14. Submersible Pump, Fish Screen, and Mounting Skidplate

Figure 2-15. Installation of Submersible Pump and Skidplate

The State Historic Preservation Office and consulting parties were given 7-day advanced notification prior to monitoring activities. Tribal representatives were invited to participate and observe project activities that required monitoring.

2.4.2 Summary

Table 2-13 provides a summary of the resources required for installation and testing of river pumps and the duration of the activity.

Table 2-13. Summary of Project Resources Needed for the River Pumps

Resource	Description	Quantity (Hours/$)	Duration* (Days)	
			Installation	Testing
Craft	Carpenter	8	1	1
	Electrician	69		
	Pipefitter	51.5		
	Teamster	40		
	Instrument Technician	35		
Engineering and Science	Electrical Engineer	16		
	Mechanical Engineer	36		
	Plant Engineer	12		
	Drafter	8		
	Environmental Scientist	65.5		
	Other Scientists	17		
Management and Administration	First Line Supervisor	159		
	Managers and Executives	6.5		
	Project Manager	5		
	Office Clerk	1		
	Procurement/Contracting	53		
Subcontracts	River Pump Boat Contract	$24,000		
	Mission Support Alliance	$9,900		
	Cultural/Ecological Support			

* Based on a 4-day work week

2.5 Chemical Tanks

Phosphate chemicals are delivered to the site in concentrated liquid form. Two concentrated phosphate solutions are prepared: monosodium phosphate at a concentration of about 103,000 +/- 10 percent mg/L, and pyrophosphate at a concentration of about 20,000 +/- 10 percent mg/L. At these concentrations, the estimated volumes of concentrated phosphate solutions required for Stage A are 501,344 L (132,441 gal) of monosodium phosphate and 301,595 L (79,673 gal) of pyrophosphate. Concentrated phosphate solutions were delivered to the 300 Area in tanker trucks and stored in eight 30,283 L (8,000 gal) tanks.

Eight 30,283 L (8,000 gal) storage tanks were installed at the Stage A EA area between September 29 and October 1, 2015. The tanks and delivery station are arranged so that potential spills are contained by temporary catch basins. Figure 2-16 shows installation of one of the mixing tanks.

The tank configuration included two tanks containing pyrophosphate solution and six tanks containing monosodium phosphate solution. Once in place, a chemical distribution header was made using suction resistant 7.6 cm (3 in.) diameter clear flexible hose. The header was configured to allow for flow of both solutions to both skids, resulting in four chemical feed lines traversing the EA from the chemical tanks to the mixing skids. Figure 2-17 shows the completed tank farm and chemical distribution header. The length of 7.6 cm (3 in.) diameter chemical feed hose required to connect the header to the mixing skids was approximately 107 m (350 ft) for each feed line for a total of 430 m (1,400 ft).

The tanks were leak tested on October 20, 2015 by filling each to a height of approximately 1.2 m (4 ft) with river water. The tanks were then emptied on October 22 and 23, 2015 through mixing skid 2 and out to the infiltration field. No leaks were observed during this test.

In preparation for chemical receipt, two eyewash stations were also brought onsite and set up at the chemical tank and mixing skid areas. Heat blankets were used to ensure that contents stayed above freezing.

2.5.1 Unexpected Conditions

The following topics document unexpected conditions encountered during installation of the chemical feed tanks and should be considered for future installations.

Figure 2-16. Installation of a Phosphate Storage Tank at the Stage A EA Area

2.5.1.1 Tank Transport Jurisdiction

Transport of the eight chemical tanks was initially planned using the chemical supplier who had previously supplied and transported tanks to CH2M HILL Plateau Remediation Company (CHPRC) for the 100-NR-2 OU project. The supplier had previously procured a specialized tilt trailer designed to

transport tanks in a U.S. Department of Transportation compliant manner. However, CHPRC authorized the supplier to transport the tanks without completing a formal work turndown process involving the Hanford Site bargaining units. Transport of the tanks was stopped, and a plant force work review was completed. This led to discussions with the bargaining units and management and initiation of a procurement to obtain a tilt trailer capable of moving the tanks. After further discussion, transport of the tanks was resumed and completed by the supplier.

2.5.2 Chemical Properties

On October 27, 2015, the chemical supplier delivered two truckloads of monosodium phosphate solution and two truckloads of pyrophosphate solution, at approximately 24,605 L (6,500 gal) per truckload, to the storage tanks. When CHPRC Operations personnel arrived at the site on October 28, 2015, they observed that sight tubes on the six monosodium phosphate tanks had substantial chemical precipitate. The ambient temperature was as low as 40°F the morning of October 28, 2015. The precipitate was determined to be not acceptable, and the supplier was called to empty the six monosodium phosphate tanks and return the product to its facility while awaiting instructions.

The chemical properties of monosodium phosphate were discussed at length with CHPRC Engineering, chemists, and the supplier. The cause of the precipitation was determined to be formation of disodium phosphate instead of monosodium phosphate. Disodium phosphate is significantly less soluble than monosodium phosphate. It was determined that exact stoichiometric proportions of the reactants (phosphoric acid and sodium hydroxide) used to formulate the monosodium phosphate were not used and that the initial pH of the solution was not low enough to drive the reaction equilibrium to the formation of sodium monophosphate. The supplier was instructed to adjust the pH of the returned solution.
Two truckloads of this solution were delivered on November 3, 2015. As the contents of the first truck were emptied into the tanks, no precipitate was observed. However, as the second truck was emptied, precipitate began to form in the bottom of the sight tubes. The operation was stopped, the tanks were drained, and the product was returned to the supplier’s facility for additional analysis and formulation. Improved chemical formulation quality assurances steps were implemented to ensure correct stoichiometric proportions and initial pH were achieved.

The final chemical formulation was to adjust the initial pH of the solution to a pH of 4.2 while using stoichiometric proportions of the reactants and then adjusting the 10 percent monosodium phosphate solution to a final pH of 6.8 to 7.1 using potassium hydroxide instead of sodium hydroxide.
Additional steps were taken to protect the solution against precipitation in cold weather. Monosodium phosphate solution was delivered to the site at temperatures between 100 and 120°F, which is the approximate temperature achieved directly after mixing. In situations where the solution was stored and allowed to cool below this temperature, the supplier was instructed to reheat the solution prior to delivery. Chemical feed lines between the tanks and mixing skids were wrapped in a combination of heat blankets and insulating concrete blankets to retain heat in the solutions. Requirements for vendor supplied laboratory analysis and data reporting were also expanded.

2.5.2.1 Leaking Chemical Tank

On October 29, 2015, CHPRC Operations personnel observed monosodium phosphate product seeping out from beneath one of the tanks, indicating a potential leak in the tank. That tank was isolated, drained, and taken out of service. The tank will be removed at a later date.

Figure 2-17. Chemical Storage Tank Farm

2.5.3 Summary

Table 2-14 provides a summary of the resources required for installation and testing of chemical tanks and the duration of the activity.

Table 2-14. Summary of Project Resources Needed for the Chemical Tanks

Resource	Description	Quantity (Hours/$)	Duration* (Days)	
			Installation	Testing
Craft	Carpenter	13.5	3	1
	Electrician	63		
	Pipefitter	63.5		
	Nuclear Chemical Operator	68		
Engineering and Science	Plant Engineer	49.5		
	Mechanical Engineer	70		
	Drafter	1		
	Environmental Scientist	85		
	Other Scientists	21		
Management and Administration	Project Manager	48		
	Office Clerk	5		
	Procurement/Contracting	53		
Subcontracts	Chemical Vendor	$620,000		

* Based on a 4-day work week

2.6 Electrical Resistivity Tomography Network

Infiltration of phosphate solutions into the soil is expected to increase electrical conductivity significantly in the vadose zone/PRZ by increasing both saturation and pore fluid specific conductance. These changes enable use of time-lapse ERT for remote monitoring of the advancement of the wetting front of the phosphate solution through the vadose zone and PRZ.

ERT network installation commenced on September 24, 2015 and concluded on October 23, 2015. As shown in Figure 2-18, the Stage A treatment area is monitored along two, two-dimensional sections bisecting the length and width of the infiltration area. The longer profile (A) is monitored with a line of 64 electrodes at 1.5 m (5 ft) spacing. The shorter profile (B) is monitored with a line of 48 electrodes at 1.5 m (5 ft) spacing.

For safety purposes, each electrode and cable takeout was buried, so that 0.2 to 0.3 m (8 to 12 in.) of soil/gravel is in place over the top of the electrode (Figure 2-19). Electrodes are carbon steel rods, approximately 0.5 m (1.5 ft) in length, oriented vertically with takeout wire attached to the top 5 to 10 cm (2 to 4 in.) of the electrode. Electrodes were buried using a combination of hand shovels and portable power tools (impact hammer). The final depth of the electrode extends as deep as 0.75 m (2.5 ft) bgs. The holes where electrodes were installed were backfilled and leveled to prevent tripping, contact, and/or inadvertent removal of electrodes. The ERT system power operates off a 110 volt power supply. The power source is a small light plant with generator capabilities.

2.6.1 Unexpected Conditions

ERT probe installation was stopped shortly after it began because not all of the steps required to release and begin excavation work per the Hanford Site excavating, trenching, and shoring procedure had been completed. During the event critique, potential for contacting surface voltage was discussed and, subsequently, hazardous energy controls were put into place, including use of a 2 m (6.5 ft) wide barrier outlining the ERT probe array. This barrier restricts access to a zone where noticeable surface voltage could be encountered. Subcontract workers were required to attend CHPRC lockout/tagout training, and additional work controls were invoked.

ERT installation was on hold for more than three weeks while the issues were being resolved. Several issues were resolved during this time. The design of the ERT array was changed (Figure 2-18) to minimize the lockout/tagout control area. Connecting wires were rerouted to remove a tripping hazard. ERT equipment was discovered to not be Underwriters Laboratories listed, and permission from the electrical inspector was required. Finally, additional electrical controls and inspections were put into place during installation of the ERT array.

2.6.2 Summary

Table 2-15 provides a summary of the resources required for installation and testing of the ERT network and the duration of the activity.

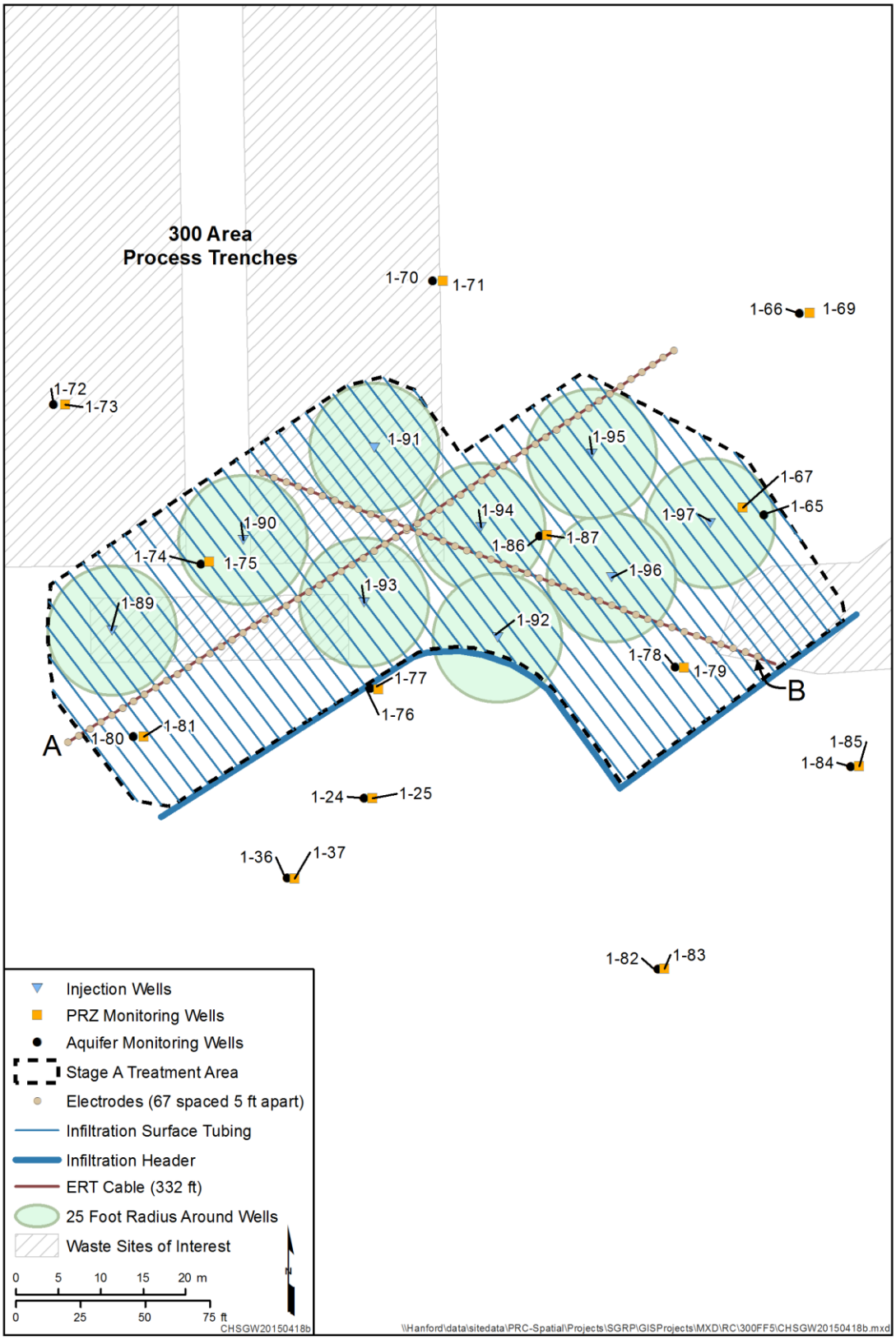


Figure 2-18. Electrical Resistivity Tomography Arrays for the Stage A Treatment Area

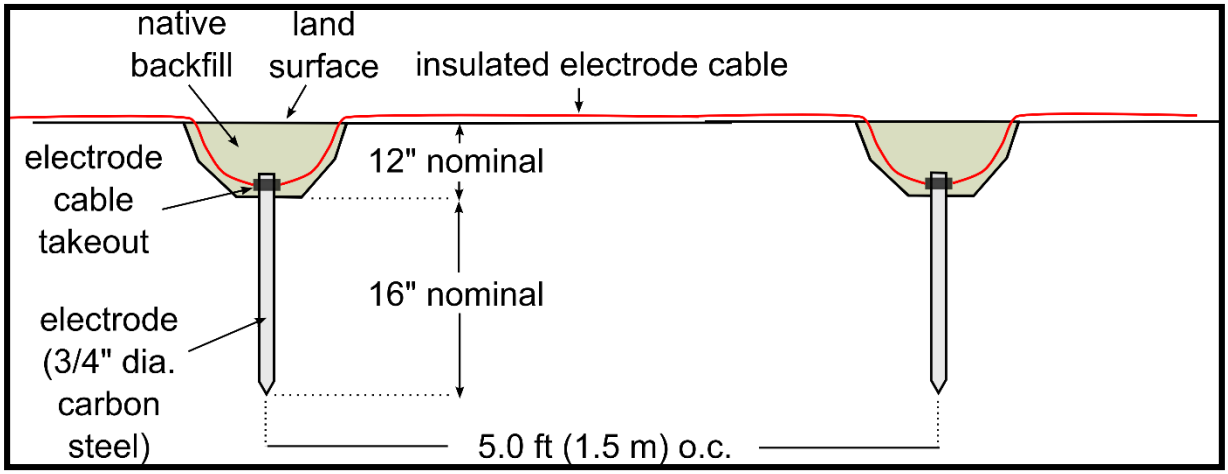


Figure 2-19. Electrode Installation Detail (Not to Scale)

Table 2-15. Summary of Project Resources Needed for the Electrical Resistivity Tomography Network

Resource	Description	Quantity (Hours/$)	Duration[a] (Days)	
			Installation	Testing
Craft	Carpenter	35	16	1
	Electrician	96		
	Utilities/System Operator	3		
Engineering and Science	Civil Engineer	1.5		
	Electrical Engineer	32.5		
	Mechanical Engineer	24.5		
	Plant Engineer	50		
	Safety Engineer	8.5		
	Drafter	1		
	Environmental Scientist	44.5		
	Geologist/Hydrologist	3		
	Other Scientists	29.5		
Management and Administration	First Line Supervisor	112.5		
	Managers & Executives	0.5		
	Project Manager	4		
	Office Clerk	1		
	Procurement/Contracting	53		
	Planner/Scheduler	29.5		
	Technical Writer/Editor	4		
Subcontracts	ERT Contractor	$120,000		

* Based on a 4-day work week.

3 Summary and Lessons Learned

Installation of the final component of the Stage A uranium sequestration system (i.e., ERT network) was completed on October 23, 2015. The project startup review was completed on November 3, 2015 and the operating procedure was approved on November 5, 2015. The Stage A uranium sequestration system was accepted and verified for operation on November 5, 2015.

The following sections provide a summary of project duration, resources, and cost and a review of the lessons learned that will be applicable to the Stage B uranium sequestration system if it is implemented.

3.1 Summary of Installation Duration and Resources

Table 3-1 provides a summary by WBS element of the duration and resources used for installation of the Stage A uranium sequestration system in the 300 Area. Durations and resources for each WBS element have been brought forward from the summary tables in Chapter 2. This information could be useful when planning to implement the Stage B uranium sequestration system.

Table 3-1. Summary of Installation Duration and Resources by Component

WBS Element	Duration[a] (Days)	Resources (Hours)		
		Craft	Engineering/ Science	Management/ Administration
Injection and Monitoring Wells	37	219	213.5	436.5
Infiltration System	12	87	73	129.5
Mixing Skids and Infrastructure	27	2,289.5	1,380	1,129
	--	--	649[b]	--
River Pumps	2	203.5	154.5	224.5
Chemical Tanks	4	208	226.5	106
ERT	17	134	195	204.5
Total Installation and Testing	**79[c]**	**3,141**	**2,891.5**	**2,230**

a. Includes installation and testing.

b. Infrastructure design prior to field installation and testing.

c. Duration from beginning of first activity (well installation) to end of last activity (ERT); some activities overlapped.

ERT = electrical resistivity tomography

WBS = work breakdown structure

3.2 Post-Job Review and Lessons Learned

Post-job review meetings covering the 300-FF-5 OU Stage A uranium sequestration activities were held on December 9 and 10, 2015. Representatives of the groups and disciplines that supported and executed installation of the Stage A system participated in the meetings. The following subsections summarize the findings and lessons learned from the post-job review meetings. Each subsection corresponds to one of the five core functions of the Integrated Safety Management System. This information will be considered during planning and execution of the Stage B uranium sequestration system.

3.2.1 Define Work Scope

The objective of this core function is to define the work activities necessary to achieve the goals of the project in a safe and environmentally sound manner. The following issues and recommendations were

identified during the Stage A post-job review meetings that should be considered for the Stage B uranium sequestration system:

- The RDR/RAWP (DOE/RL-2014-13-ADD2) required collection of water level measurements from the injection wells during the injections. It was not feasible to collect these measurements from the injection wells due to the use of well packers. Automation and wireless transmission of the water level measurements should be considered for Stage B.
- Concentrations and characteristics of the phosphate chemicals used for Stage A were below thresholds that would cause the chemicals to be regulated if there were a spill or release. This simplifies the requirements and controls for handling the chemicals. Ensuring that chemicals are unregulated is strongly recommended for Stage B application.
- Injection and infiltration systems operated as planned, and the objectives of Stage A were met. However, information and data collected during Stage A indicate that the systems could be improved for the Stage B uranium sequestration application. The operational objectives and completion criteria for Stage B need to be better defined. The 300-FF-5 OU Stage A performance report will include key findings from this evaluation related to work scope and provide recommendations for Stage B uranium sequestration application.

3.2.2 Hazard Identification and Work Planning

Objectives of this core function are to identify potential hazards and determine appropriate actions to mitigate the hazards. This information is then integrated into work planning. The following issues and recommendations were identified during the Stage A post-job review meetings that should be considered for the Stage B uranium sequestration system:

- Hazards for the work along the river shoreline were not adequately identified and addressed in the work planning documents. This included the difficulty of working on the slippery rocks along the shore, amount of slope down to the shoreline, amount of vegetation, and presence of snakes and insects. Workers need to be more engaged in the process of identifying and addressing hazards.
- Hazards for the work to place river pumps and water hoses were not adequately identified and addressed in the work planning documents. This includes lack of an adequate work platform on the boat and difficulty of lifting and handling the 15.4 m (50 ft) diameter discharge hoses. Workers need to be more engaged in the process of identifying and addressing hazards.
- Changing conditions were not adequately recognized and addressed in the work planning documents. The work was performed later in the year than planned, which resulted in additional hazards that were not anticipated. This included snake activity along the river shoreline, wasps around the skid equipment, lower ambient temperatures, and strong seasonal winds.
- Hazards associated with changes to the work approach were not adequately recognized and addressed in the work planning documents. This primarily impacted installation of the infiltration system and ERT network:
  - Hazards, safety requirements, and work controls for installation and operation of the ERT system were not clearly identified and implemented. For the ERT network, inadequate identification of hazards and incomplete work planning led to stopping work and conducting a critique that delayed the project. This also led to implementing lockout/tagout controls that had not been identified and concerns about installing grounding controls in the work area that further impacted the project.

  - The excavation permit did not adequately address the final work approaches used to install the infiltration system and ERT network. This was the result of both inadequate planning and revision to the excavation permit to account for changes in the installation approach of these two systems.

- Overhead electrical lines were removed from the area before Stage A field work began. This step was an effective project response, which eliminated potential hazards and the need for associated work controls.

3.2.3 Work Packages and Hazard Control

The objective of this core function is to develop and implement work control documents that implement hazard controls tailored to the type of work being conducted. The following issues and recommendations were identified during the Stage A post-job review meetings that should be considered for the Stage B uranium sequestration system:

- Installation of the piping systems was not adequately planned. The 15.4 m (50 ft) diameter hoses were difficult to handle, so moving the material and hoses became a safety concern; 7.7 m (25 ft) hose lengths would work better. Bands and hose clamps were not the correct size for the materials used.

- Mechanical and electrical activities were combined in the same work packages. This made the work packages large and complicated. Problems with one portion of the work would impact and stop other portions of the work that were in the same work package. It is recommended to separate the work into smaller, separate work packages. This should reduce the impact of delays and help coordinate tasks and workers. The statement of work for installation and operation of the ERT network was not clear and detailed enough to meet project needs. As a result, much of the ERT work was controlled by a CHPRC work package with daily releases of work via the Work Release for Construction/Services Organization Form.

- Implementing lockout/tagout requirements associated with controlling potential surface voltage from the ERT system was cumbersome and difficult. This could have been improved (and possibly eliminated) with better hazard recognition and work planning for the ERT network.

- Managing setup and testing under one work package may have led to more work control complications and more complicated worker interfaces, making the project more difficult to implement in the field. It is recommended to implement the Stage B installation as a construction (green field) project. This should simplify work packages and interfaces. This would also allow the project to use engineering sketches and rely more on skill of the craft to complete the work. Operation of the system would be guided using an operational test procedure after a single setup work package.

3.2.4 Work Processes and Execution

Objectives of this core function are to implement work processes and safety controls, confirm readiness before starting work, and perform work within the controls (e.g., procedures, pre-job briefings, lockout/tagout, and stop work authority), when needed. The following issues and recommendations were identified during Stage A post-job review meetings that should be considered for the Stage B uranium sequestration system:

- Automating the conductivity measurements in the wells could provide real time data. Automated conductivity measurements with wireless transmission is strongly recommended for the Stage B application because the data would be available in real time.

- CHPRC needs to monitor the field operation more closely when the infiltration system is backfilled. This activity has the potential to impact other parts of the system significantly.
- Operation of the drip line system was problematic. ERT measurements indicate that several drip lines did not operate as designed. The following recommendations were suggested for Stage B application:
  - Protect the infiltration lines with an inverted half pipe, or install the drip lines inside of a perforated pipe. This could alleviate potential issues with sand pack clogging the drip lines.
  - Run the infiltration drip lines out the other end of the excavation, and install pressure gauges and valves. This would provide the ability to monitor each line and determine how it is functioning.
- Redesign the product distribution system. There were too many red, flat hoses (three when one would have worked). There was also concern that the hoses were easily kinked or pinched and may have impacted operation of the system. It is recommended to investigate use of more rigid hose in certain applications or support the hoses to prevent kinking and pinching. Connectors used were designed for fire hose and did not work well on the flat hoses.
- Air compressors should be provided for blowing out water and chemical lines to prevent potential problems with the product distribution system.
- Because potential freezing temperatures were not anticipated during project planning, use of heat blankets on the product distribution system was not expected. This led to insufficient supplied electrical power for the heat blankets.
- More light plants should be provided for the site. This lesson resulted from conducting the field work later in the year than anticipated.
- Controls for river pumps should be placed closer to the river shoreline, so the intake system can be better monitored.
- Supplying sufficient power for the ERT system was an issue. A consistent and dedicated source of power for ERT during the Stage B application should be provided.
- Installing the ERT network at the same time that infiltration lines are installed should be evaluated for the Stage B application. This could address the surface voltage problems and lockout/tagout issues and provide more thorough coverage of the treatment area.
- The field work supervisor had difficulty managing the work at times due to the number of activities taking place and the number of people involved. The following recommendations were proposed for the Stage B application:
  - As much as possible, schedule tasks in a way to avoid too many parallel activities.
  - Prepare a plan for ropes, barriers, and signage to avoid confusion.
  - An aerial photograph of the area with an overlay of the site demarcations, access, lock and tag areas, and access may be a helpful communication tool.
  - Set up a more formal process for people to enter the job site in order to ensure proper access and briefing. A person should be dedicated to help with this.
- Office trailer space was not sufficient. A bigger office trailer should be provided for the Stage B application.

- Write the field instructions in a manner that works better for operations. An example is giving volume limits in L (gal) of chemicals instead of concentrations and mixing ratio. This will require reviewing the requirements (e.g., time, concentration, volume, flows, and mixing ratio) from the RDR/RAWP and converting them to values that are relevant and helpful to the field operation.
- The following positive items were identified during the post-job review:
  - Cultural and ecological reviews and briefings were well done and helped inform workers of the issues.
  - Wood structures that supported the hoses going into the skids worked well. More support structures may be helpful for other parts of the hose network.
  - The revised configuration of distribution hoses for the chemical feed tanks was effective.
  - Locating a light plant by the turnoff was effective.
  - Interface with the samplers and Teamsters worked well.

3.2.5 Feedback

The objective of this core function is continual improvement through feedback processes to ensure that operating experience and lessons learned are applied to current and future work. The following issues and recommendations were identified during installation of the Stage A system and should be considered for the Stage B uranium sequestration system:

- During excavation for the infiltration system, it was observed that the grout seal of injection Well 399-1-95 was deficient and did not completely seal the annulus of the well. A critique of the grout seal issue was conducted on August 31, 2015. A post-job review of the infiltration system installation process, conducted on September 20, 2015, provided recommendations for correcting the issue and preventing reoccurrence during future work. The grout seal of the well was excavated and successfully repaired on November 5, 6, and 7, 2015. Based on the information from the post-job review, it is recommended that the infiltration system be installed prior to installing the injection and monitoring wells.
- Installation of ERT probes was stopped shortly after it began because not all of the steps required to release and begin excavation work had been completed. A critique was conducted on September 28, 2015, and several issues were identified and resolved. During the event critique, the potential for contacting surface voltage was discussed, and subsequently hazardous energy controls were put in place. Installation of the ERT system went well following the critique. Based on the information from the event critique, it is recommended that the ERT probes be installed concurrent with the infiltration system.
- On October 28, 2015, CHPRC operators observed chemical precipitate in the sight tubes on the six monosodium phosphate feed tanks. After discussions with CHPRC and the chemical vendor, the chemical formulation was adjusted to reduce the potential for precipitation of the chemicals. The chemical was then kept at an elevated temperature to prevent precipitation in cold weather. Although this issue delayed the Stage A injections, the time and effort spent to understand the chemistry of the phosphate solutions and how to better handle them were effective. The chemical vendor and CHPRC scientists were very responsive to the needs of the project. Prior to stage B, bench scale tests should be performed to address potential pH and temperature issues.

This page intentionally left blank.

4 References

DOE/RL-2010-29, 2010, *Design Optimization Study for Apatite Permeable Reactive Barrier Extension for the 100-NR-2 Operable Unit*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=1010051004.

DOE/RL-2011-47, 2013, *Proposed Plan for Remediation of the 300-FF-1, 300-FF-2, and 300-FF-5 Operable Units*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0088360.

DOE/RL-2014-13-ADD2, 2015, *Remedial Design Report/Remedial Action Work Plan Addendum for the 300 Area Groundwater*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081151H.

DOE/RL-2014-42, 2015, *300-FF-5 Operable Unit Remedy Implementation Sampling and Analysis Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079669H.

Endangered Species Act of 1973, Pub. L. 93-205, as amended, 7 USC 136, 16 USC 1531, et seq. Available at: http://www.nmfs.noaa.gov/pr/pdfs/laws/esa.pdf.

EPA and DOE, 2013, *Hanford Site 300 Area Record of Decision for 300-FF-2 and 300-FF-5, and Record of Decision Amendment for 300-FF-1*, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland, Washington, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0087180.

MSA-1502630, 2015, "Ecological and Cultural Clearance for Columbia River Access and Submersible Pumps in the Columbia River for the 300 Area Sequestration Remedial Activities, Hanford Site, Benton Country, Washington (HCRC# 2014-300-004, ECR-2015-303)" (letter to R.M. Hermann, CHPRC, from A.L. Johnson), Mission Support Alliance, Richland, Washington, June 16.

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

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

SGW-56993, 2014, *Sampling Instruction for the 300-FF-5 Operable Unit Supplemental Post ROD Field Investigation*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079680H.

SGW-58553, 2015, *Description of Work for the Installation of Twenty Two Monitoring Wells and Nine Injection Wells in the 300-FF-5 Operable Unit*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-58976, 2015, *Field Instructions for Uranium Sequestration in the 300 Area*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

SGW-59465, 2015, *Borehole Summary Report for the Installation of Nine Injection Wells and Twenty-one Monitoring Wells in the 300-FF-5 Operabl*e Unit, *FY 2015*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

USFWS, 2015, Letter 01EWFW00-2015-I-0567 (from U.S. Fish and Wildlife Service, Wenatchee, Washington to U.S. Department of Energy, Richland Operations Office, Richland, Washington), May 5.

WCR-2015-2480, 2014, "Endangered Species Act Section 7(a)(2) Concurrence Letter for Installation and Operations of a Uranium Sequestration Groundwater treatment System near the Shoreline of the Columbia River at the 300 Area of the Hanford Site, Benton Country, Washington (HUC 170200160602) City of Richland-Columbia River" letter to K. Flynn, U.S. Department of Energy, Richland, Washington from W.W. Stelle, Jr.), National Marine Fisheries Service, U.S. Department of Commerce, Seattle, Washington, June 9.