SGW-62137
Revision 0

200 WEST PUMP-AND-TREAT PERFORMANCE AGAINST REMEDIAL ACTION OBJECTIVES SPECIFIED IN THE 200-ZP-1 OPERABLE UNIT RECORD OF DECISION

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

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APPROVED
By Mary P. Curry at 1:39 pm, Aug 23, 2018

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Executive Summary

This document summarizes the activities performed in fiscal year 2017 to evaluate the progress toward meeting the remedial action objectives (RAOs) specified in the 200-ZP-1 Groundwater Operable Unit (OU) Record of Decision[1] (ROD) after 5 years of operation.

The primary infrastructure component of the 200-ZP-1 OU remedy was the installation of a pump-and-treat (P&T) system to contain and ultimately recover a large fraction of contamination (i.e., 95% of the dissolved mass of carbon tetrachloride and the other contaminants of concern [COCs]) early in the remedy lifecycle. It is expected that the effectiveness of the P&T system will diminish over time, whereas natural attenuation processes will remain relatively constant. As a result, natural attenuation is intended to be the dominant mechanism for continued reduction of contaminant concentrations via monitored natural attenuation (MNA) over a 100-year post-P&T timeframe. Other remedy elements include flow-path control and institutional controls (ICs). The overarching requirement is to meet groundwater cleanup levels identified in the 200-ZP-1 OU ROD[1] within 125 years.

Groundwater remediation at the 200-ZP-1 OU is conducted in accordance with the 200-ZP-1 OU ROD.[1] The COCs for the 200-ZP-1 OU are carbon tetrachloride, total chromium, hexavalent chromium, nitrate, iodine-129, trichloroethylene, technetium-99, and tritium. Extracted water is treated at the 200 West P&T, as well as water from the 200-UP-1 and 200-BP-5 OUs, 200-DV-1 OU perched water, and Environmental Restoration Disposal Facility leachate. Treated water is reinjected into the aquifer to attain hydraulic containment of the iodine-129 plumes and flow-path control for the 200-ZP-1 and 200-UP-1 OU plumes.

[1] EPA, Ecology, and DOE, 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=00098825.

The RAOs presented in the 200-ZP-1 OU ROD[1] are site-specific objectives that define the extent of cleanup necessary to achieve the specific level of remediation at the site:

- **RAO #1:** Return 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving cleanup levels (provided in Table 11 of the 200-ZP-1 OU ROD). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated timeframe to achieve cleanup levels is within 150 years.[2]
- **RAO #2:** Apply ICs to prevent the use of groundwater until cleanup levels (provided in Table 11 of the 200-ZP-1 OU ROD) have been achieved. Within the entire OU groundwater plumes, ICs must be maintained and enforced until cleanup levels are achieved, which is estimated to be within 150 years.
- **RAO #3:** Protect the Columbia River and its ecological receptors from degradation and unacceptable impact caused by contaminants originating from the 200-ZP-1 OU. This final objective is applicable to the entire 200-ZP-1 OU groundwater plume. Protection of the Columbia River from impacts caused by 200-ZP-1 OU contaminants must last until the cleanup levels are achieved, which is estimated to be within 150 years.

Following the remedy implementation process presented in the remedial design/remedial action work plan (RD/RAWP) for the 200-ZP-1 OU,[3] several activities were performed to assess the progress toward achieving intermediate targets and goals as an indication of progress towards attaining the RAOs. The evaluation included performance monitoring, data evaluation, and groundwater flow and contaminant transport modeling. The results of the evaluation demonstrated the following:

2 The 200-ZP-1 OU RAOs identify the estimated timeframe to achieve cleanup levels as 150 years. Further requirements in the 200-ZP-1 OU ROD (EPA et al., 2008) identify the cleanup timeframe as 125 years, which is more conservative than the RAOs.

3 DOE/RL-2008-78, 2009, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*, Rev. 0 REISSUE, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0096137.

- The 200 West P&T showed excellent progress compared to the initial 5-year performance expectations for the remedy. Plume containment for the 200-ZP-1 OU has been substantially achieved at the targeted concentration of 100 µg/L, with containment also extending to lower concentration portions of the plumes.
  In addition, all COC plume concentrations have significantly decreased after 5 years of P&T operations. The P&T remedy performance has met the performance targets described in the 200-ZP-1 OU RD/RAWP,[3] except for a small area of containment in the northeast corner of the plume.

- New information collected during remedy implementation suggests that remedy performance projections from the feasibility study (FS) for the 200-ZP-1 OU[4] need to be updated. Key changes identified were (1) a much lower abiotic attenuation rate for carbon tetrachloride is expected compared to the rate used in the 200-ZP-1 OU FS; (2) a higher fraction of carbon tetrachloride mass is now known to be present at greater depth, including below the Ringold Formation member of Wooded Island – lower mud unit (Ringold Formation member of Wooded Island – unit A) than assumed in the FS and 200-ZP-1 OU RD/RAWP;[3] and (3) the range of uncertainty on the initial plume mass has narrowed and suggests that mass is not as large as the upper bound defined in the RD/RAWP.

- The performance assessment was extended in 2017 to include trend evaluations of the 5 years of available performance data, updated plume data from characterization and monitoring efforts in the 200 West P&T well network, and an update from Pacific Northwest National Laboratory[5] on the estimated carbon tetrachloride abiotic attenuation equating to a 630-year half-life.

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[4] DOE/RL-2007-28, 2008, *Feasibility Study Report for the 200-ZP-1 Groundwater 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=0808050315. http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=00098828.

[5] PNNL-22062, 2012, *Abiotic Degradation Rates for Carbon Tetrachloride and Chloroform: Final Report*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22062.pdf.

Based on these changes, achieving the mass removal goal of 95% for carbon tetrachloride will be more difficult than was anticipated in the 200-ZP-1 OU FS[3] and ROD.[1] In addition, conditions are less favorable for the MNA component of the remedy to attain the cleanup level for carbon tetrachloride within the 100-year post-P&T period due to a slower abiotic attenuation rate. As a result, a higher percentage of mass removal by the P&T may be required to meet the RAOs.

Efforts are in progress to evaluate long-term carbon tetrachloride remediation options, identify other potential changes to the remediation approach, and address the current and future remedy cost. This information and a path forward will be included in a revision to the RD/RAWP.[3]

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Terms

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
CPGWM	Central Plateau Groundwater Model
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
ERDF	Environmental Restoration Disposal Facility
FS	feasibility study
IC	institutional control
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
OU	operable unit
P&T	pump and treat
RAO	remedial action objective
RD/RAWP	remedial design/remedial action work plan
RLM	Ringold Formation member of Wooded Island – lower mud unit
ROD	Record of Decision
TCE	trichloroethylene
UCL_{95}	95 percent upper confidence limit
WMA	Waste Management Area

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1 Introduction and Background Information

This evaluation report supports the achievement of U.S. Department of Energy (DOE) Performance Measure PM-30-1-18: "Maintain effective, efficient, and compliant operations and management activities as required to support groundwater remediation." The completion criteria state that by September 30, 2018, the contractor shall demonstrate that the remedial action objectives (RAOs) for each groundwater operable unit (OU) shall be met. For the 200-ZP-1 OU, the completion criteria state that the contractor is to complete the analyses to assess current performance against the RAOs in the Record of Decision (ROD) (EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington* [hereinafter referred to as the 200-ZP-1 OU ROD]). Based on the analysis, the criteria state that the contractor will then provide recommendations for future actions needed to achieve the RAOs and the associated timeframe. These actions are to be documented in either the remedial design/remedial action work plan (RD/RAWP) (a DOE/RL document) or in a CH2M HILL Plateau Remediation Company (CHPRC) soil and groundwater document.

The DOE Hanford Site is a 1,517 km^2 (586 mi^2) federal facility located in southeastern Washington State along the Columbia River (Figure 1). The 200-ZP-1 OU is one of four groundwater OUs in the Central Plateau. The 200 West pump-and-treat (P&T) system is a major component of the remedial actions selected for cleanup of the 200-ZP-1, 200-UP-1, and 200-BP-5 Groundwater OUs; 200-DV-1 OU perched water; and leachate collected at the Environmental Restoration Disposal Facility (ERDF).

The selected remedy is a combination of P&T, monitored natural attenuation (MNA), flow-path control, and institutional controls (ICs). The 200-ZP-1 OU ROD (EPA et al., 2008) requires that a groundwater P&T system be designed, installed, and operated in accordance with an approved RD/RAWP (DOE/RL-2008-78, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*). These remedy components are combined to meet the RAOs established the ROD, which include meeting groundwater cleanup levels for all contaminants of concern (COCs) in the 200-ZP-1 OU within 125 years. Mass removal is primarily accomplished by operation of the 200 West P&T, which is designed to capture and treat contaminated groundwater and reduce the mass of COCs from each OU. The treated groundwater is reinjected into the aquifer to attain hydraulic containment and flow-path control for the 200-ZP-1 and 200-UP-1 plumes. The 200-UP-1 OU P&T system is designed to meet the ROD objectives using well networks for targeted plumes and treatment of water routed to the 200 West P&T.

1.1 Purpose

The purpose of this evaluation report is to assess the current performance of the 200 West P&T system in meeting the RAOs specified in the 200-ZP-1 OU ROD (EPA et al, 2008). The RAOs are site-specific objectives that define the extent of cleanup necessary to achieve the specific level of remediation at the site. In 2017, DOE directed CHPRC to document that the RAOs for each groundwater OU will be met by completing an analyses of the current performance and, based on the analyses, to provide recommendations for future actions needed to achieve the RAOs and associated cleanup timeframe identified in the ROD. This report documents the result of that analysis, thus completing Performance Measure PM-30-1-18 for the 200-ZP-1 OU.

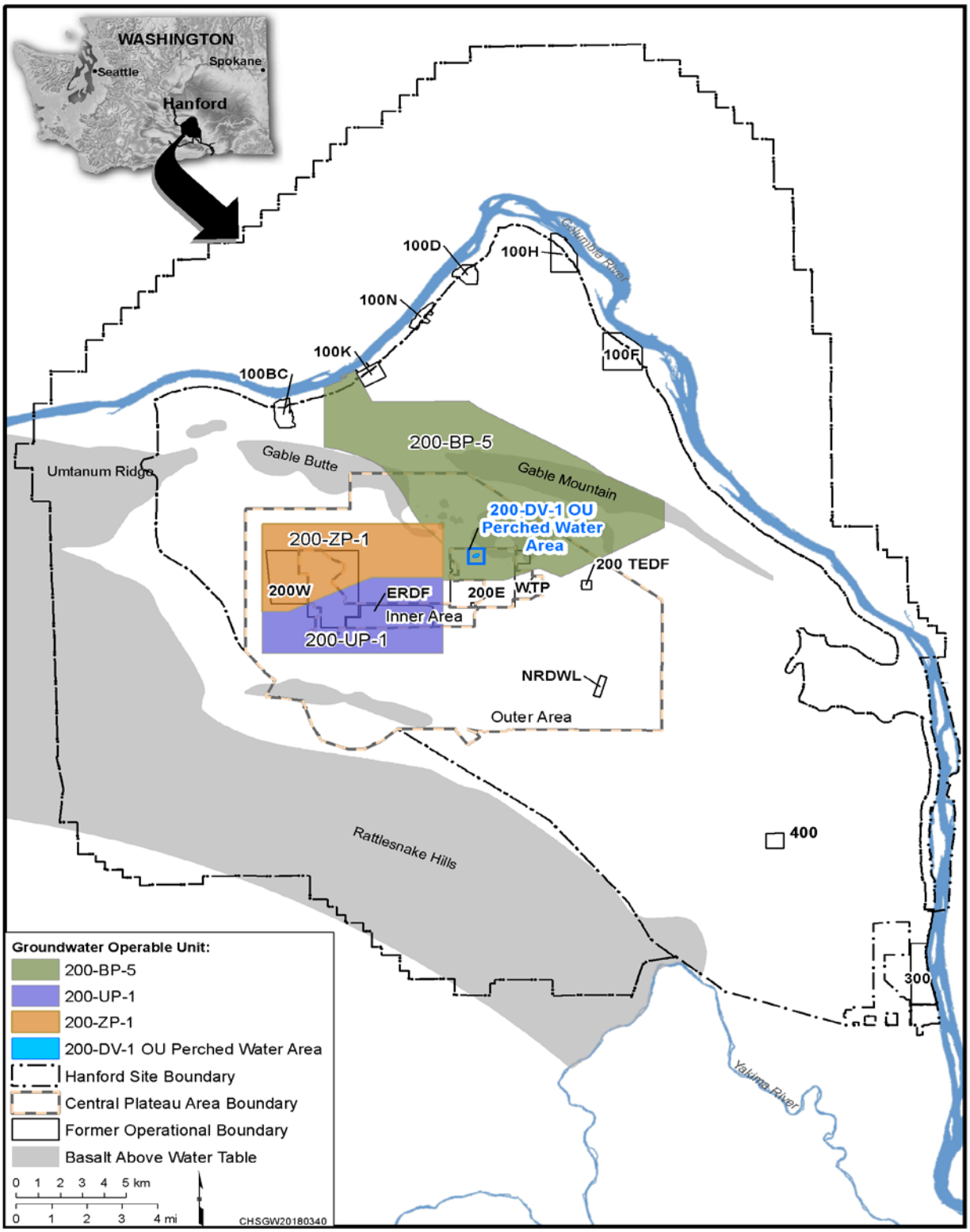


Figure 1. Hanford Site Central Plateau Groundwater OUs

1.2 Nature and Extent of Contamination

The 200-ZP-1 OU COCs are carbon tetrachloride, total chromium, hexavalent chromium, nitrate, trichloroethylene (TCE), iodine-129, technetium-99, and tritium. The COCs and their respective cleanup levels are identified in Table 11 of the 200-ZP-1 OU ROD (EPA et al., 2008). Cyanide and uranium have been detected in 200-ZP-1 OU wells and are being monitored in a subset of 200-ZP-1 OU wells as contaminants of interest for the OU. The RD/RAWP (DOE/RL-2008-78) provides additional information on the nature and extent of these contaminants.

The 200-ZP-1 OU remedial investigation and feasibility study (FS) (DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit* [hereinafter referred to as the 200-ZP-1 OU FS]) indicated that groundwater contamination is present from the top (i.e., water table) to the base of the unconfined aquifer, which is about 61 m (200 ft) thick. The depth to the water table in the 200 West Area varies from about 50 m (164 ft) in the southwest corner to >100 m (328 ft) in the north. Groundwater flow is primarily to the east, except in the northern portion of the 200 West Area where the flow is to the east-northeast. More than 100 monitoring wells are currently within the footprint of the 200-ZP-1 OU. DOE/RL-2009-115, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*, includes sampling for more than 80 wells. Chapters 2 and 3 of the RD/RAWP (DOE/RL-2008-78) discuss the hydraulic monitoring and contaminant monitoring well locations.

As stated in the 200-ZP-1 OU ROD (EPA et al., 2008), contaminant distributions within the 200-ZP-1 OU can be generally represented by three categories:

- A high-concentration zone near the ponds, cribs, and trenches that were used to dispose liquid wastes. A comprehensive investigation in 2004 and 2007 determined that there is no evidence for the presence of dense nonaqueous-phase liquid in groundwater acting as a continuing source (DOE/RL-2006-58, *Carbon Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Interim Characterization Report*; DOE/RL-2007-22, *Carbon-Tetrachloride Dense Non-Aqueous Phase Liquid (DNAPL) Source Term Characterization Report Addendum*).

- A larger, dispersed or low-concentration zone that has migrated from the discharge locations or overlies a deeper, high-concentration zone. This less-contaminated groundwater can occur above the high-concentration zone if large quantities of lower concentration effluent were discharged during or after the high-concentration waste discharges.

- An area of technetium-99 contamination near Waste Management Area (WMA) T and WMA TX-TY. The results from depth-discrete groundwater sampling in these areas show that the peak concentration of technetium-99 is typically found within the upper 15 m (50 ft) of the aquifer.

Carbon tetrachloride is the primary COC, forming a plume >18 km^2 (7 mi^2) that extends north, south, and east from the source areas. The primary sources were discharges of liquid waste from the Plutonium Finishing Plant plutonium-separation processes to the 216-Z-1A, 216-Z-9, and 216-Z-18 Cribs and trenches. Except for nitrate, the remaining contaminant plumes within the 200-ZP-1 OU are within the boundaries of the carbon tetrachloride plume. Figure 2 presents a cut-away view of the three-dimensional carbon tetrachloride plume simulation.

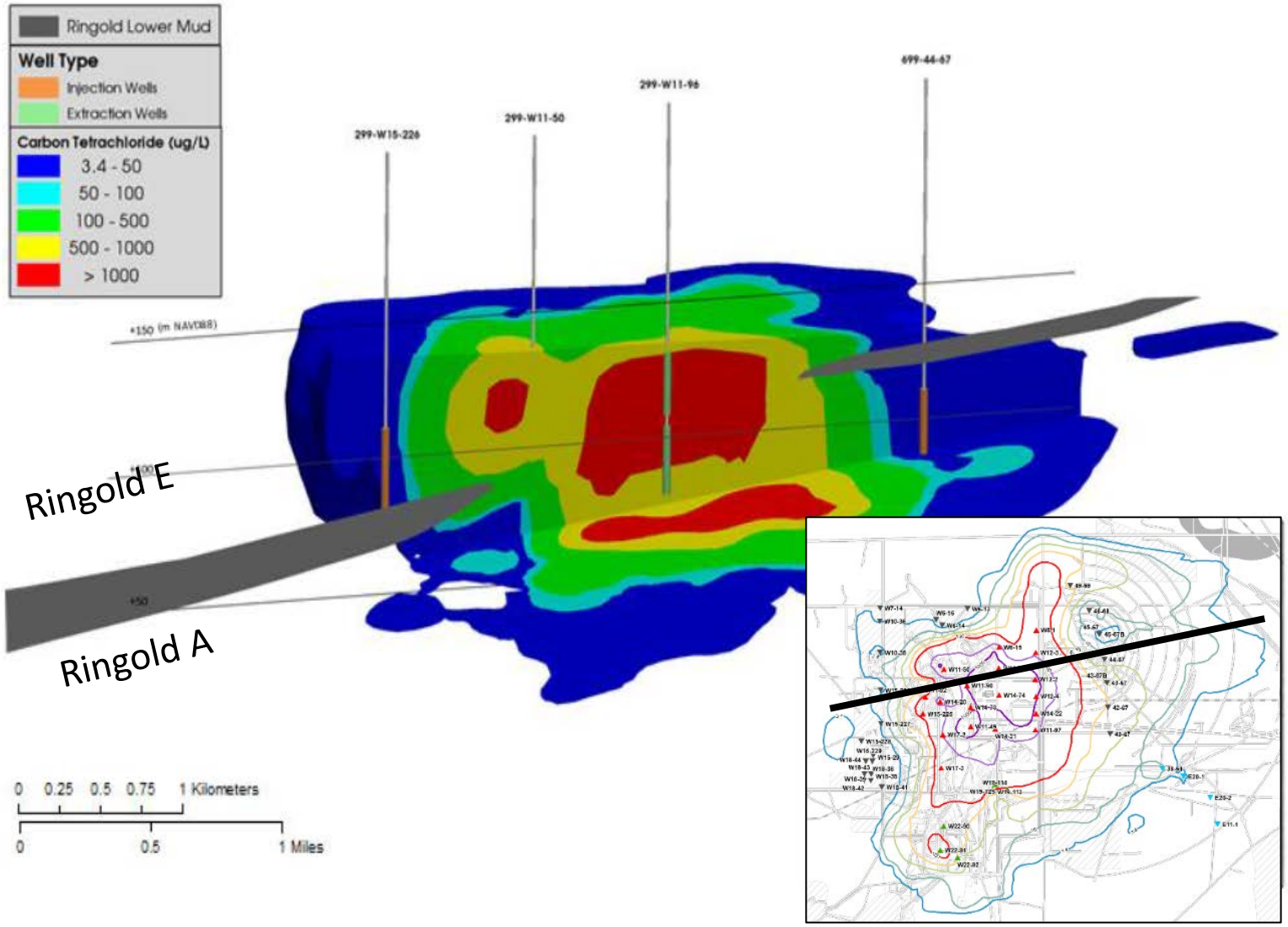


Figure 2. 200-ZP-1 OU Cut-Away View of the Three-Dimensional Carbon Tetrachloride Plume Simulation, 2015

2 Basis for Remedial Action

The 200-ZP-1 OU ROD (EPA et al., 2008) states that a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) response action is necessary for the 200-ZP-1 OU groundwater because of the following conditions:

- The cumulative excess carcinogenic risk to an individual exceeds 10^{-4} using reasonable maximum exposure assumptions for potential beneficial use of the groundwater.
- The noncarcinogenic hazard index number is greater than one (>1), using reasonable maximum exposure assumptions for potential beneficial use of the groundwater.
- Chemical-specific standards (e.g., drinking water standards) that define acceptable risk levels are exceeded, and exposure to contaminants above these acceptable levels is predicted for the reasonable maximum exposure for potential beneficial use of the groundwater.

The selected remedies in the 200-ZP-1 OU ROD (EPA et al., 2008) include P&T, flow-path control, MNA, and ICs to address COCs in groundwater. Completion of the remedial action will minimize the release or threat of release of hazardous substances that pose a risk to human health and the environment and will provide an end state consistent with the 200-ZP-1 OU ROD.

2.1 Remedial Action Objectives

The RAOs are site-specific objectives that define the extent of cleanup necessary to achieve cleanup goals within the 200-ZP-1 OU.

- **RAO #1:** Return 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving cleanup levels (provided in Table 11 of the 200-ZP-1 OU ROD). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated timeframe to achieve cleanup levels is within 150 years.[6]
- **RAO #2:** Apply ICs to prevent the use of groundwater until cleanup levels (provided in Table 11 of the 200-ZP-1 OU ROD) have been achieved. Within the entire OU groundwater plumes, ICs must be maintained and enforced until cleanup levels are achieved, which is estimated to be within 150 years.[6]
- **RAO #3:** Protect the Columbia River and its ecological resources from degradation and unacceptable impact caused by contaminants originating from the 200-ZP-1 OU. This final objective is applicable to the entire 200-ZP-1 OU groundwater plume. Protection of the Columbia River from impacts caused by 200-ZP-1 OU contaminants must last until the cleanup levels are achieved, which is estimated to be within 150 years.[6]

Table 1 lists the final cleanup levels for the 200-ZP-1 OU COCs. The cleanup levels were developed using a combination of federal maximum contaminant level; the criteria and equations in WAC 173-340, "Model Toxics Control Act—Cleanup" (MTCA), Method B cleanup levels for potable groundwater (WAC 173-340-720, "Groundwater Cleanup Standards," particularly WAC 173-340-720(4)(b)(iii)(A) and (B), and WAC 173-340-720(7)(b)); and the federal and state water standards for radionuclides.

6 The RAOs identify the estimated timeframe to achieve cleanup levels as 150 years. Further requirements in the 200-ZP-1 OU ROD (EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site Benton County, Washington*) identify this timeframe as 125 years, which is more conservative than the RAOs.

Table 1. Final Cleanup Levels for 200-ZP-1 OU Groundwater

COC (Units)	90th Percentile Concentration	Federal MCL	State MCL	MTCA Method B Cleanup Levels		Final Cleanup Level
				Noncarcinogens	Carcinogens at 10^{-5} Risk Level	
Carbon tetrachloride (µg/L)	2,900	5	5	5.6	3.4	3.4
Chromium (total) (µg/L)	130	100	100	24,000	—	100
Hexavalent chromium (µg/L)	203	N/A[a]	N/A[a]	48	—	48
Nitrate (µg/L	81,050	10,000	10,000	25,600	—	10,000
Trichloroethylene (µg/L)	10.9	5	5	2.4	1[b]	1[c]
Iodine-129 (pCi/L)	1.2	1	1	—	—	1
Technetium-99 (pCi/L)	1,442	900	900	—	—	900
Tritium (pCi/L)	36,200	20,000	20,000	—	—	20,000

Notes: This table is from Table 11 of EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington*.

Units are µg/L for nonradionuclides and pCi/L for radionuclides.

Federal MCL values from 40 CFR 141, "National Primary Drinking Water Regulations," with iodine-129 and technetium-99 values from EPA 816-F-00-002, *Implementation Guidance for Radionuclides*.

State MCL values from WAC 246-290, "Group A Public Water Supplies."

a. There is no MCL specific to hexavalent chromium.

b. The MTCA Method B cleanup levels for carbon tetrachloride and trichloroethylene are from Ecology's Cleanup Levels and Risk Calculations (CLARC) table, current as of September 25, 2008.

c. DOE will clean up COCs for the 200-ZP-1 Operable Unit subject to the requirements of WAC 173-340, "Model Toxics Control Act–Cleanup" (carbon tetrachloride and trichloroethylene), so the excess lifetime cancer risk does not exceed 1×10^{-5} at the conclusion of the remedy.

COC = contaminant of concern
DOE = U.S. Department of Energy
Ecology = Washington State Department of Ecology
EPA = U.S. Environmental Protection Agency
MCL = maximum contaminant level
MTCA = WAC 173-340, "Model Toxics Control Act—Cleanup"
N/A = not applicable

2.2 Selected Remedy

Section 10.0 of the 200-ZP-1 OU ROD (EPA et al., 2008) provides a detailed analysis of possible alternatives for remediating the 200-ZP-1 OU, addressing the key factors of scale, complexity, and restoration timeframe. Because there is no single technology capable of meeting the cleanup levels for the 200-ZP-1 OU, the selected remedial alternative uses multiple components (i.e., P&T, MNA, flow-path control, and ICs).

The primary component of the 200-ZP-1 OU remedy is installation of a P&T system to contain and capture a large fraction of the mass of contamination (i.e., 95% of the dissolved mass of carbon tetrachloride, including mass removal of 95% of all the COCs for the 200-ZP-1 OU) early in the remedy lifecycle (25 years). When the 200-ZP-1 OU ROD (EPA et al., 2008) was issued, estimates based on available characterization data indicated that carbon tetrachloride concentrations in the groundwater >100 µg/L corresponded to approximately 95% of the mass of carbon tetrachloride residing in the aquifer.

Groundwater modeling calculations completed for the 200-ZP-1 OU FS (DOE/RL-2007-28) estimated that a system comprised of 27 extraction wells and 27 injection wells, with an estimated 6,057 L/min (1,600 gal/min) pumping rate, was required to reduce the mass of COCs by 95% in 25 years.

The flow-path control remedy component is achieved by reinjecting the treated groundwater into the aquifer to the northeast and east of the groundwater contamination. The treated reinjected water in these locations will slow the natural eastward flow of most of the groundwater and, as a result, keep COCs within the capture zone, as well as increase the time available for natural attenuation processes to reduce the concentrations for contaminants not captured by the extractions wells.

The MNA remedy component is implemented to address the remaining portion of the carbon tetrachloride and nitrate not captured by the P&T system (i.e., the remaining 5% of the mass). Modeling calculations conducted as part of the 200-ZP-1 OU FS (DOE/RL-2007-28) indicate that the timeframe necessary to reduce the remaining carbon tetrachloride, nitrate, and tritium concentrations to acceptable levels would be approximately 100 years using a 41-year abiotic degradation half-life. This was acceptable since the Hanford Site is expected to remain under federal control with ICs in place until at least the year 2150.

Monitoring is conducted to evaluate performance of the P&T system, flow-path control, and MNA. The ICs component of the remedy is implemented and maintained in accordance with DOE/RL/2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

3 200 West Pump-and-Treat System

This chapter describes the approach for designing and implementing the 200-ZP-1 OU remedy. Groundwater modeling and calculations were used to estimate the contaminant distribution and treatment system influent concentrations, functional requirements, final design of the P&T remedy, and implementation of the remedy at startup. Adjustments to the system design and operating parameters are expected to occur throughout the lifecycle of the remedy based on evaluations of actual system performance in achieving the near-term targets, intermediate-term goals (e.g., system-wide operating rates, desirable reinjected water quality, hydraulic containment, and mass recovery), and progress toward attaining the final RAOs.

The RD/RAWP (DOE/RL-2008-78) uses a phased approach to implement the P&T remedy. The objective of the phased approach was to initiate groundwater treatment as soon as possible, allow efficient construction of the essential components of the P&T system, and provide a high probability of achieving the performance objective in reducing 95% of the dissolved mass of the COCs within 25 years. The P&T remedy was proposed in three phases. Phase 1 included system design, initial construction of a nominal capacity 3,800 L/min (1,000 gal/min) system, and startup. Phase 2 included initial operations, construction of the design nominal capacity of 7,600 L/min (2,000 gal/min), and system optimization. Phase 3 involves long-term operations, monitoring, and system optimization. The remedial design and supporting groundwater modeling were based on this phased implementation. However, due to the *American Recovery and Reinvestment Act of 2009*, the 200 West P&T build-out was at 7,600 L/min (2,000 gal/min) nominal capacity (Phases 1 and 2), as was installation of most of the well field. Remediation progress is summarized in the annual P&T report (DOE/RL-2017-68, *Calendar Year 2017 Annual Summary Report for the Pump-and-Treat Operations in the Hanford Central Plateau Operable Units)*.

The 200 West P&T system was designed with the capability to treat contaminated groundwater from the 200-UP-1 OU. Initially, the system could treat up to 300 L/min (80 gal/min) of contaminated groundwater from the S-SX Tank Farm. After startup of the remedial action for the 200-UP-1 OU, additional CERCLA response action decisions were reached for other OUs and the ERDF (EPA et al., 1995, *Record of Decision, U.S. DOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*), proposing the use of the 200 West P&T for groundwater contamination. The 200 West P&T was modified to include the necessary treatment capabilities (i.e., uranium ion-exchange and new extraction well connections) for 200-BP-5 OU groundwater, 200-DV-1 OU perched water, and ERDF leachate. Calculations were performed to prepare for the new feed streams. It was also determined that the COCs in groundwater from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs; perched water from the 200-DV-1 OU; and ERDF leachate were acceptable for treatment at the 200 West P&T (SGW-57790, *Characterization Data for New Waste Streams (200-UP-1, ERDF Leachate, 200-BP-5 and Perched Water) for the 200 West Pump-and-Treat Facility*). Figure 3 depicts the current 200 West P&T extraction and injection well network (as of September 2017).

Following the remedy implementation process presented in the RD/RAWP (DOE/RL-2008-78), several activities assessed the progress toward achieving near-term targets and intermediate-term goals as an indication of progress towards attaining the final RAOs after 5 years of operation. The evaluation was performed through performance monitoring, data trend evaluation, groundwater flow and contaminant transport modeling, and optimization. Chapters 5 and 6 outline the results of the RAO assessment.

4 Modeling Approach

This chapter describes the groundwater flow and contaminant transport models, including mathematical optimization codes, and the plume concentration calculations that were developed and used during this assessment to monitor progress toward meeting near-term targets (primarily hydraulic containment and intermediate-term goals for mass recovery). The Central Plateau Groundwater Model (CPGWM) (CP-47631, Rev. 3, *Model Package Report: Central Plateau Groundwater Model, Version 6.3.3*) underwent a major update in early fiscal year 2017 (ECF-200-ZP1-17-0095, *Fate and Transport Analysis for the Groundwater Plume Remedies in the 200-ZP-1 and the 200-UP-1 Operable Units Using the Central Plateau Model*). It was used to perform the necessary flow modeling prerequisite to using MT3DMS transport code (Zheng and Wang, 1999, *MT3DMS: A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*) for analysis.

Based on the large operational timeframes of the various components of the 200-ZP-1 OU remedy, progress toward attaining final cleanup levels is difficult to measure directly or infer during the early years of operation. For this reason, remedy performance is primarily evaluated in terms of attaining interim targets and goals that have been established primarily through groundwater flow and contaminant transport modeling. These targets and goals are either directly measurable or can be inferred or assessed in the near-term and to assess progress toward meeting the RAOs, which cannot be measured or easily assessed in the near term. Although the targets and goals are important to assessing remedy performance, the success of the remedy will ultimately be measured against the RAOs. For this reason, these targets and goals may be modified over time to reflect new information or changes in the groundwater remedy, and to improve the likelihood of attaining the RAOs.

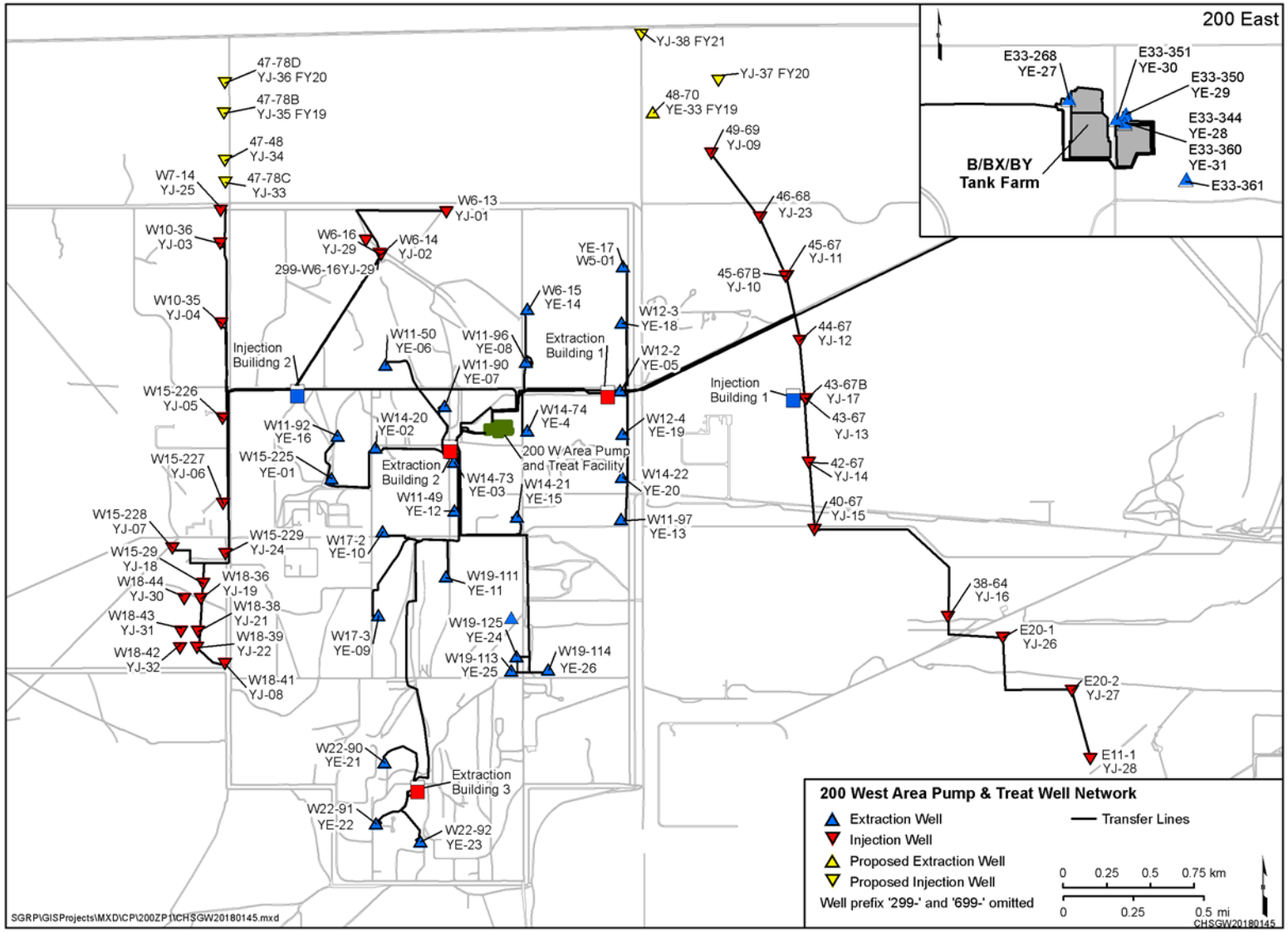


Figure 3. 200 West P&T Extraction and Injection Wells, September 2017

The CPGWM encompasses and extends beyond the 200-ZP-1 OU. The CPGWM is used for two related but contrasting uses: (1) to compare modeled and measured quantities from previous years' performance monitoring data collection, including groundwater levels, concentrations, and derived interpretation of those quantities such as estimates of hydraulic containment; and (2) to provide projections of likely future conditions and remedy progress toward attaining short-term targets, intermediate-term goals, and RAOs. These projections can be used to predict future performance of the remedy as currently implemented, as well as to evaluate alternative scenarios to optimize the remedy to better meet RAOs.

Chapter 5 summarizes the performance of the first 5 years of the 200-ZP-1 OU remedial action, based on remedy performance monitoring data and groundwater modeling predictions about future remedy performance. Section 5.3.3 provides optimization scenarios for the 200-ZP-1 OU remedy.

The following sections describe how the CPGWM is used to predict future performance of the 200-ZP-1 OU remedy as currently implemented and provide an evaluation of remedy optimization alternatives.

4.1 Groundwater Flow Modeling

Groundwater flow modeling was performed using the CPGWM, which was developed using a modified version the U.S. Geological Survey three-dimensional groundwater flow model, MODFLOW (Harbaugh, 2000, *MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*).

MODFLOW is run in a transient, phreatic mode using a finely discretized three-dimensional finite difference grid that incorporates the 200-ZP-1 OU hydrogeologic structure and an areal grid for accurate prediction of pumping drawdown and injection mounding of the phreatic surfaces. Of key emphasis from the MODFLOW simulations are the results obtained for hydraulic containment and other hydraulic barriers.

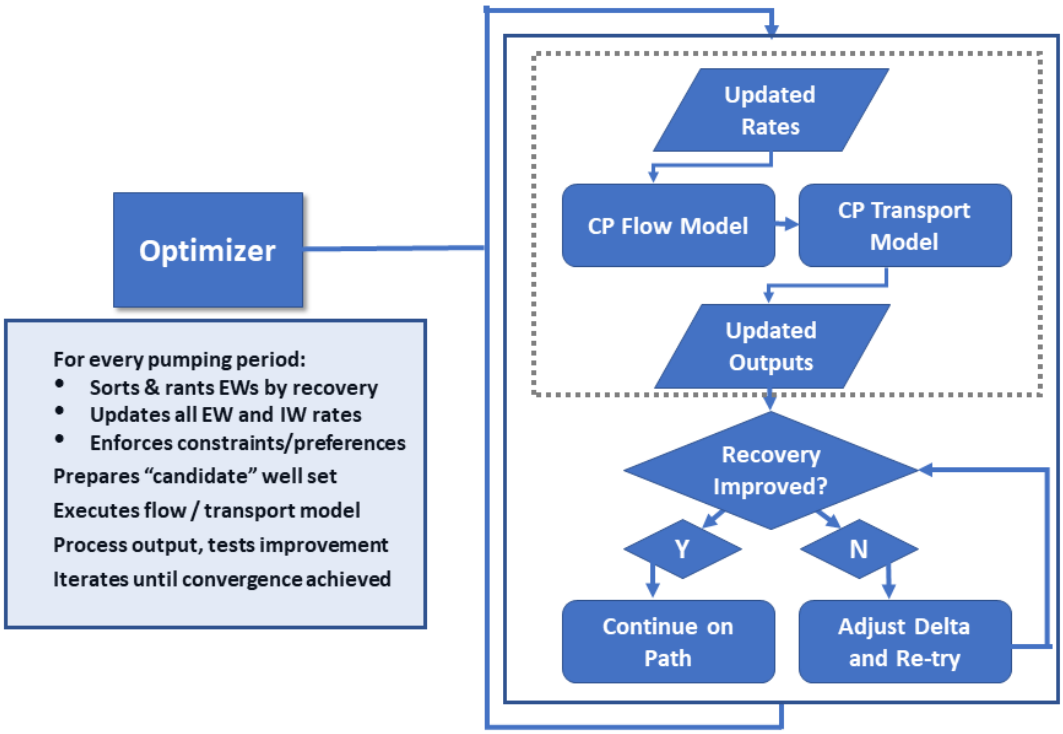
The CPGWM was used to perform the necessary flow modeling prerequisite for using MT3DMS for transport analysis. Only injection and extraction well flow rates were varied for this analysis.

4.2 Contaminant Transport Modeling

Contaminant transport simulations were performed using MT3DMS, a three-dimensional transport model that simulates advection, dispersion, source/sinks, and chemical reactions (Zheng and Wang, 1999). The flow model provides the velocity field needed for transport simulations. Contaminant transport simulations were performed to estimate the recent and likely future movement and the fate of the 200-ZP-1 OU COCs.

4.3 System Optimization

Mathematical optimization was used to determine the pumping rates in order to increase the mass recovered from the 200-ZP-1 injection and extraction wells for the scenarios discussed herein (ECF-200ZP1-0095). Potential and existing well locations were specified, and the algorithm (Figure 4) assigns flow rates to achieve the best mass recovery. Section 5.3.4 discusses the results.



Notes: Modified from SGW-50390, *FY 2011 Simulation-Optimization of the 200-ZP-1 Remedy Using the Central Plateau Model*.

EW = extraction well; IW = injection well

Figure 4. Schematic of the 200-ZP-1 OU Optimization Code

4.4 UCL_{95} Calculations on Mean Plume Concentration

Remediation performance was evaluated by calculating the 95% upper confidence limit (UCL_{95}) on mean plume concentrations (OSWER 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*). The UCL_{95} provides a comprehensive evaluation of plume concentrations in a single metric. It is calculated using sample results or simulated concentrations at monitoring wells.

5 Baseline Performance Assessment

This chapter summarizes the performance assessment performed in 2017 to document the baseline conditions of the 200-ZP-1 OU remedy and the measured progress toward attaining the 200-ZP-1 OU remedy targets, goals, and RAOs outlined in the 200-ZP-1 OU ROD (EPA et al., 2008) and the RD/RAWP (DOE/RL-2008-78) after 5 years of operation.

The 200 West P&T began operating in July 2012 with the initial capacity to extract and treat groundwater at 3,786 L/min (1,000 gal/min) for the first 3 years of operation. Current operating conditions have increased treatment capacity to a nominal 7,571 L/min (2,000 gal/min) to include extracted water from other OUs (200-UP-1 and 200-BP-5 OUs, and 200-DV-1 perched water) and ERDF leachate).

In 2013, decreased injection well capacity was identified, and the injection wells have exhibited persistent fouling, resulting in reduced injection capacity. The foulant material was determined to originate from the biological treatment remedy. The well fouling can, at times, limit the treatment capacity. A number of studies and treatment options (e.g., aggressive well cleaning and improving the effluent water quality) have been implemented to reduce the injection well fouling and minimize the overall impacts to water treatment throughput. Efforts are continuing to minimize the fouling as outlined in SGW-62183, *200 West Pump and Treat Well Fouling Mitigation: Implementation and Management Plan*.

The following sections outline the progress of near-term targets, intermediate-term goals, and final RAOs compared to initial conditions.

5.1 Near-Term Targets

Near-term targets for the 200 West P&T remedy component identified in the RD/RAWP (DOE/RL-2008-78) are as follows:

- Attaining specified (i.e., target) total system-wide operating rates and specified rates at individual extraction and injection wells
- Achieving desirable reinjected treated water quality

In 2017, the 200 West P&T remedy met the near-term targets for the system-wide design capacity. The system treated 3,881.8 million L (1,025.5 million gal) of water with a flow rate of 7,431 L/min (1,963 gal/min), which is higher than identified in the RD/RAWP (DOE/RL-2008-78) (Figure 5). Additional extraction and injection wells were installed beyond the planned 27 extraction and 27 injection wells. Throughout 2017, the P&T network included 31 extraction wells and 32 injection wells. The near-term targets for reinjected treated water quality have been met.

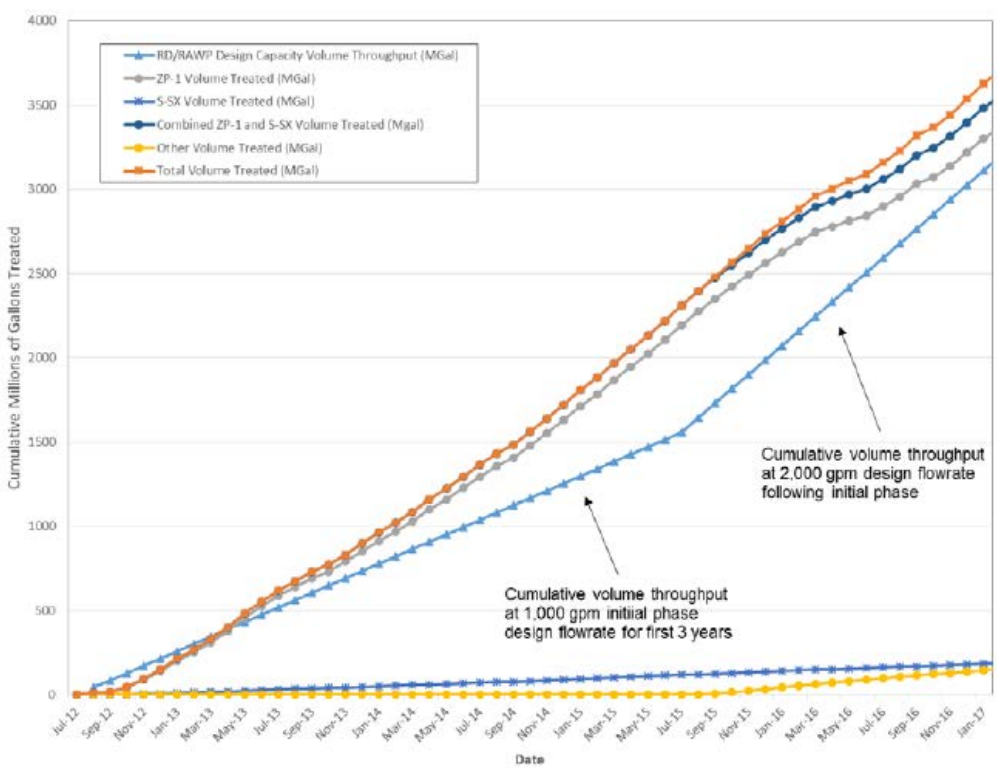


Figure 5. 200 West P&T Actual Cumulative Volume Treated Compared to Design Capacity Throughput

The 200-ZP-1 OU target was 3,785 L/min (1,000 gal/min) for the first 3 years of pumping and 7,571 L/min (2,000 gal/min) for the remaining 22 years of pumping. Since the original construction was for the 7,571 L/min (2,000 gal/min) treatment capacity (including flows from the other OUs), the 200-ZP-1 OU has been operating above the cumulative flow target through year 5. Through December 2017, the design capacity volume throughput target was 15.5 billion L (4.1 billion gal) and the actual volume treated was 16.28 billion L (4.3 billion gal). In calendar year 2017, the highest cumulative throughput was 7,310 L/min (1,931 gal/min). Therefore, the future predictions suggest that the 200-ZP-1 OU falls below the RD/RAWP (DOE/RL-2008-78) cumulative volume throughput at 7,571 L/min (2,000 gal/min) design flow rate sometime in July 2021 (Figure 6).

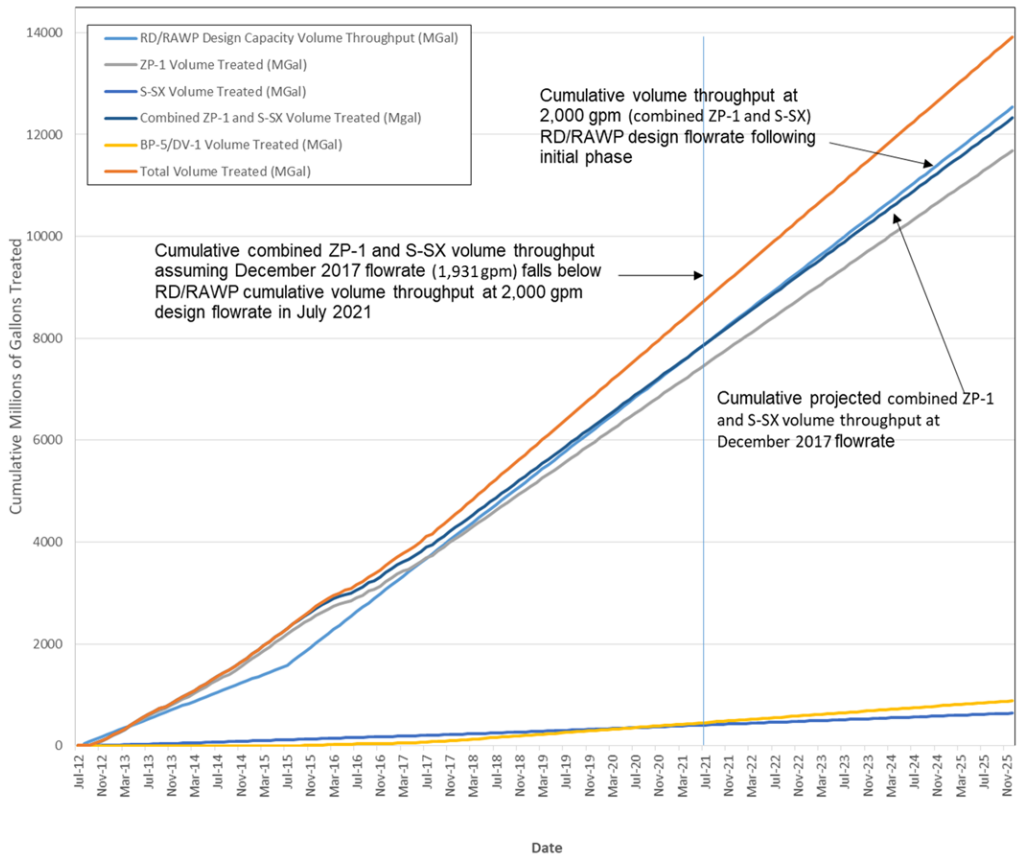


Figure 6. 200-ZP-1 OU RD/RAWP Design Capacity Volume Throughput

5.2 Intermediate-Term Goals

Intermediate-term goals for the 200 West P&T remedy component identified in the RD/RAWP (DOE/RL-2008-78) are as follows:

- Achieving hydraulic containment of the carbon tetrachloride plume at concentrations >100 µg/L
- Achieving flow-path control
- Reducing the mass of contaminants throughout the 200-ZP-1 OU by at least 95% in 25 years

In 2017, the 200 West P&T remedy intermediate-term goals were substantially achieved at the targeted concentration, with containment also extending to some of the lower concentration portions of the plume after 5 years of P&T operation.

The majority of the carbon tetrachloride plume (about 95%) targeted by the 200 West P&T is hydraulically contained (Figure 7). Flow-path control is being maintained in the core of the region contaminated by carbon tetrachloride at concentrations >100 µg/L, thereby preventing or greatly reducing eastward migration. However, in the area north of the eastern (downgradient) line of injection wells, a small region of contamination >100 µg/L may not be hydraulically contained. Predictions using the CPGWM suggest that this is an area where additional containment is needed to prevent downgradient migration of the >100 µ/L plume.

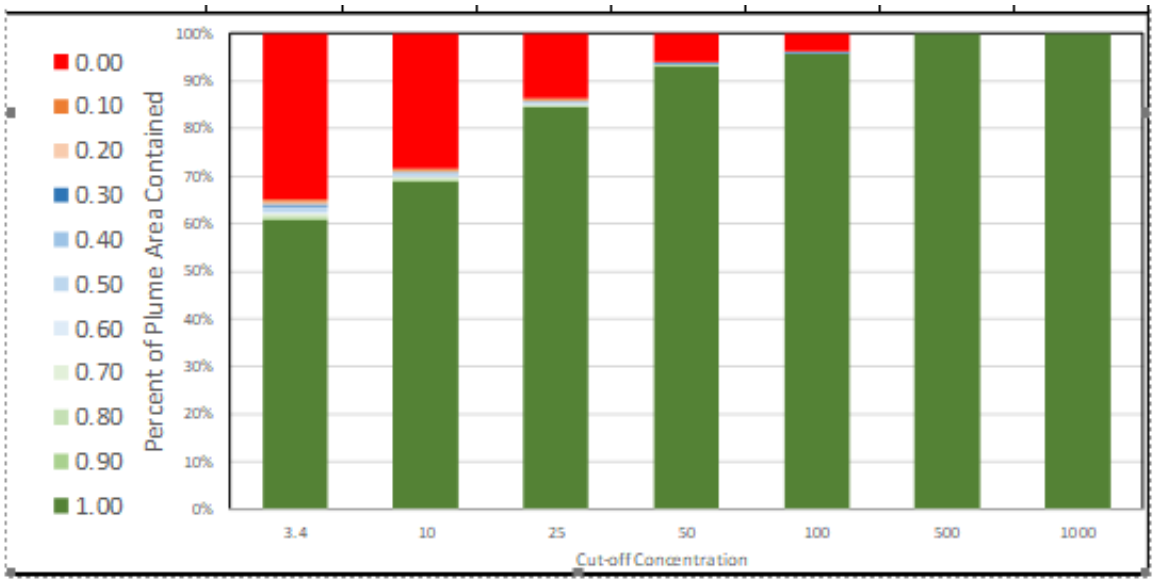


Figure 7. Percent Containment of Targeted Concentrations of Carbon Tetrachloride

The P&T remedy is removing more carbon tetrachloride than anticipated in the mass recovery goal of the RD/RAWP (DOE/RL-2008-78) (Figure 8). The P&T remedy has significantly reduced contaminant concentrations of all the COCs in the monitoring network after 5 years of operation, as shown in Table 2.

5.3 Long-Term Performance Assessment

This section presents the baseline performance assessment of the 200-ZP-1 P&T system and the remediation scenarios that may be needed to achieve the RAOs. The information is largely based on ECF-200-ZP1-7-0095.

5.3.1 Carbon Tetrachloride – Degradation Half-Life

The final design of the 200-ZP-1 groundwater remedy presented in the RD/RAWP (DOE/RL-2008-78) is based, in large part, on the calculations made for the 200-ZP-1 OU FS (DOE/RL-2007-28). The values representing the (primarily abiotic) degradation of carbon tetrachloride at typical groundwater temperatures were not available because the study of these values was still in progress. Instead, values were derived from published literature and projections from the initial findings of a Pacific Northwest National Laboratory study (PNNL-13560, *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program*) were also considered. The two abiotic degradation rate constants derived equate to 41.3- and 100-year half-lives and were used in the fate and transport modeling in the FS and subsequent reports.

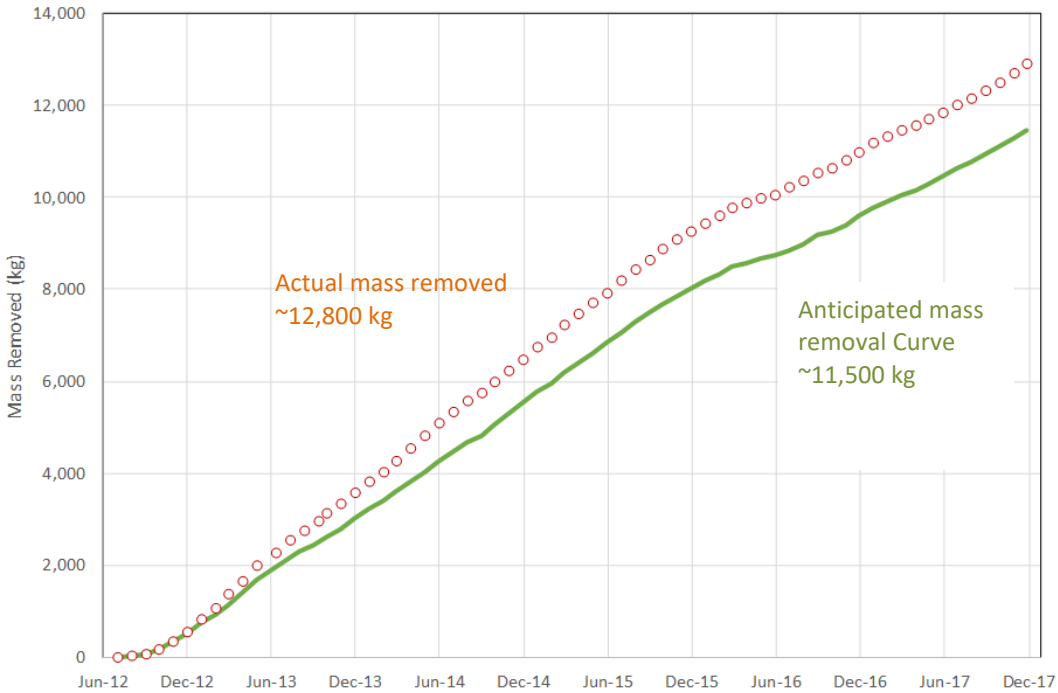


Figure 8. Actual Versus Projected Mass Removed

Table 2. Contaminant Concentration Reduction

Year	CCl_4 (µg/L)	Cr^{+6} (µg/L)	I-129 (µg/L)	$NO_3 - NO_3$ (mg/L)	Tc-99 (pCi/L)	TCE (µg/L)	H_3 (pCi/L)
2012[a]	413	93	2.3	132	3,058	2.9	26,393
2017[a]	250	33	1.6	85	1,841	1.9	8,056
% Change	-39%	-65%	-30%	-36%	-40%	-34%	-69%
Mass Removed	kg	kg	Ci	kg	Ci	kg	Ci
	(2,836) 12,890	(34) 409	(0.1)[b] N/A[b]	(95,746) 1,524,760	(0.08) 10.2	(5.8) 56	N/A[b]

a. Calculated using performance monitoring plan (PMP) well network for wells with data for all years.

b. Not directly treated/removed.

( ) = mass removed by interim pump and treat system between 2009 and 2012

N/A = not applicable

TCE = trichloroethylene

Three years following issuance of the 200-ZP-1 OU RD/RAWP (DOE/RL-2008-78), the final report on the study of abiotic carbon tetrachloride degradation was issued (PNNL-22062, *Abiotic Degradation Rates for Carbon tetrachloride and Chloroform: Final Report*). The report concluded that rates of hydrolysis at groundwater temperatures are significantly slower than predicted by extrapolations from high-temperature studies; also, the half-life may also be strongly dependent on pH and temperature. The report also concluded that the best estimate for the half-life of carbon tetrachloride via abiotic processes in aqueous systems (such as those encountered at the Hanford Site) is 630 years. This half-life is 6 to 15 times greater than the half-lives used in the 2008 fate and transport simulations for the 200-ZP-1 OU. It is important to note that following shutdown of the 200 West P&T, natural attenuation

processes will be the dominant factor controlling changes in concentration over time; under these conditions, the difference between a 41.3- or 100-year half-life versus a 630-year half-life has profound implications for the time needed to meet the RAOs.

5.3.2 Mass Recovery of Carbon Tetrachloride

Projections of likely mass recovery and attainment of cleanup levels are based on the assumption that (1) the underlying groundwater model (i.e., CPGWM) reasonably represents conditions in the subsurface and the operations of the remedy; (2) the initial conditions (i.e., starting plumes) reasonably represent the actual distribution of contamination at the beginning of the model predictions; and (3) the simulations conducted using the groundwater model and the initial conditions reasonably represent actual conditions. For this assessment, the most recent release of the CPGWM (CP-47631, Rev. 4, *Model Package Report: Central Plateau Groundwater Model, Version 8.4.5*) was used as the basis for predicting future conditions.

Continued characterization and updated evaluations of contamination extent completed from 2012 through 2017 have provided improved knowledge and reduced uncertainty regarding the carbon tetrachloride distribution throughout the 200-ZP-1 OU and adjacent 200-UP-1 OU. The general areal extent of carbon tetrachloride estimated in groundwater from recent studies is broadly similar to the estimates obtained when preparing Revision 0 of the 200-ZP-1 OU RD/RAWP (DOE/RL-2008-78). However, some differences impact the future operation and optimization of the remedy.

First, estimates of mass in groundwater obtained via data interpolation are trending generally smaller over time. This is anticipated, and results from a combination of substantial reductions in concentrations in areas targeted by the P&T, and the recovery of substantial contaminant mass by the P&T system verify this. When the mass recovered by the P&T system (about 9,250 kg from July 2012 through December 2015, and about 12,800 kg from July 2012 through December 2017) is added back into the estimates of mass in groundwater from data interpolation, the resulting estimates of mass in groundwater corresponding to the July 2012 system startup date are generally consistent.

Second, recent estimates of carbon tetrachloride mass obtained using calendar year 2015 sample data compare more favorable between the weighted-average of multiple sequential Gaussian realizations (i.e., sequential Gaussian simulation method) versus the best estimate (i.e., quantile kriging method) than was the case when preparing the 200-ZP-1 OU RD/RAWP (DOE/RL-2008-78), although the estimate of mass using the weighted average of the sequential Gaussian simulation results is still greater. Narrowing the range of mass estimates reflects the increased knowledge derived from the additional monitoring wells and characterization data, as well as the use of several years of recorded P&T system mass recovery data to constrain the mass estimates.

Third, over time the fraction of the contaminant mass residing at greater depth in the aquifer, within and below the Ringold lower mud unit (RLM), is estimated to be greater than anticipated when preparing the RD/RAWP (DOE/RL-2008-78). Therefore, the extent of carbon tetrachloride present within and below the RLM is the focus of further characterization efforts identified during recent data gap and remedy optimization studies to further refine understanding of the presence and extent of contamination at these greater depths.

Collectively, characterization data and plume evaluations over the past 5 years result in (1) the areal extents and mass estimates being greater than anticipated in the 200-ZP-1 OU FS (DOE/RL-2007-28) baseline but within the range of uncertainty presented in the RD/RAWP (DOE/RL-2008-78); (2) narrowing of the range of uncertainty, suggesting that the mass is not as high as the upper-bound described in the RD/RAWP, but maybe larger than the best estimate at that time; and (3) the finding that

a higher fraction of the mass lies deeper in the aquifer, within and below the RLM than assumed in the 200-ZP-1 OU FS (DOE/RL-2007-28), the RD/RAWP, and the 200-ZP-1 OU ROD (EPA et al., 2008).

The 200-ZP-1 OU FS (DOE/RL-2007-28) anticipated that cleanup could be achieved using P&T to remove carbon tetrachloride present at concentrations ≥100 µg/L, enabling natural attenuation to reduce concentrations to cleanup levels following shutdown of the P&T system. With a substantially longer half-life, the MNA component of the remedy is less effective, and new performance projections will be needed to assess the requirements to achieve cleanup. If these projections determine that concentrations <100 µg/L have to be targeted by P&T, this will significantly increase the area requiring hydraulic containment.

5.3.3 Operational Considerations

In addition to challenges associated with the carbon tetrachloride attenuation rate and plume configuration, challenges exist for long-term performance associated with P&T system operations, in particular for nitrate treatment. Nitrate treatment has been identified as causing the primary limitation to P&T treatment capacity. Nitrate treatment also has a significant side effect of causing injection well fouling and associated injection well capacity issues, well maintenance costs, and the potential need for future mitigation actions for well fouling. Thus, significant costs and operational limitations exist for nitrate treatment. During the first 5 years of operation, more than 1.5 million kg of nitrate have been removed from the aquifer, and initial evaluation suggests the potential ability to achieve ultimate 200-ZP-1 OU RAO for nitrate and eliminate nitrate treatment in the 200 West P&T. Additional evaluation would be needed to provide information to support considering this change, as will be described in a future revision of the 200-ZP-1 OU RD/RAWP.

5.3.4 Projected Modeling Scenarios

After 5 years of operating the 200-ZP-1 remedy, the 200 West P&T has significantly reduced contaminant concentrations (Table 2), and the majority of the carbon tetrachloride plume is contained within the injection well network, as proposed in the RD/RAWP (DOE/RL-2008-78). To date, the initial intermediate-term goal of mass recovery has exceeded the expectations identified in the RD/RAWP. However, the long-term performance assessment indicates that the following changing conditions will result in remedy challenges:

- Significantly more carbon tetrachloride exists below the RLM (within the Ringold Formation – unit A [hereinafter referred to as Ringold unit A]), which is much more difficult and costly to remove.
- The carbon tetrachloride abiotic degradation rate is expected to be much slower (a 630-year half-life) than what was understood in the 200-ZP-1 OU FS (DOE/RL-2007-28) (41.3-year half-life).

Based on these challenges, an activity was initiated to provide information about potential remedy configurations and their ability to meet the RAOs. This evaluation relied on the updated groundwater model; the optimization code developed for the 200-ZP-1 remedy under SGW-50390, *FY 2011 Simulation-Optimization of the 200-ZP-1 Remedy Using the Central Plateau Model*; and estimates of potential alternative P&T configurations. Current estimates of the three-dimensional extent of carbon tetrachloride in groundwater combined with the most recent estimates of the half-life of carbon tetrachloride were used as input to the modeling calculations. The information presented herein are initial results to provide an estimate for the range of performance that can be expected from bounding cases of remedy configuration. More detailed evaluation would be needed to support remedy decisions as will be described in a future revision to the 200-ZP-1 OU RD/RAWP (DOE/RL-2008-78).

Groundwater contaminant simulations (alternative groundwater scenarios) were performed using different numbers of extraction and injection wells, locations, total pumping capacities, and durations. Each alternative identified the total number of supplemental extraction and injection wells required, the estimated extraction/injection rates, and the modifications that would be required for the 200 West P&T .

A summary of three pumping alternatives evaluated that meet the 2137 cleanup level is provided in Table 3. These bounding simulations provide perspective for evaluating future remedy options. For context, a baseline (Scenario 0) is provided with pumping at the current rate for the 25-year duration specified in the 200-ZP-1 OU ROD (EPA et al., 2008).

The modeling performed using the updated CPGWM suggests that pumping longer than the 25 years and/or increasing the treatment rate above what was assumed in the 200-ZP-1 OU FS (DOE/RL-2007-28) would be needed to meet the RAO timeframe outlined in the 200-ZP-1 OU ROD (EPA et al., 2008). While P&T performance has met performance targets in the first 5 years of operation, a change from the projected long-term remedy performance in the FS results from the slower attenuation rate of carbon tetrachloride (PNNL-22062) and a larger mass of carbon tetrachloride in Ringold unit A. Based on these changes, conditions are less favorable for attaining the RAO of a 95% mass reduction and reducing carbon tetrachloride concentration to <100 µg/L in 25 years of operation.

5.4 Recommendations for Future Actions

The information presented herein suggests that optimizing or modifying the 200-ZP-1 OU remedy may be needed based on the information obtained during the first 5 years of remedy operation. Additional information will be needed to support these remedy actions and decisions. This section provides initial recommendations for the remedy operation, information gathering, and remedy evaluation. Additional details and refinement of remedy actions will be documented in a future revision of the 200-ZP-1 OU RD/RAWP (DOE/RL-2008-78). Recommendations are divided into short- and long-term items.

5.4.1 Short Term – Next 3 to 5 Years

The short-term recommendations are intended to improve operations and mass removal and focus on optimization through continued collection of performance monitoring data, data trend evaluation, groundwater flow, and contaminant transport modeling:

- Maintain the current remedy pumping rate (Scenario 1 in Table 3) and perform remedy optimization activities.
- Achieve full containment of the 100 µg/L carbon tetrachloride plume.
- Focus efforts on carbon tetrachloride recovery from the Ringold Formation – unit E (above the RLM).
  - Define new extraction/injection well locations for the next 3 to 5 years.
- Further characterize the Ringold unit A (below the RLM) aquifer and contamination.
  - Better define areal extent of carbon tetrachloride below the RLM.
  - Collect needed hydraulic conductivity measurements.
- Evaluate biotic/reductive carbon tetrachloride attenuation.

Table 3. 200 West P&T Optimization Pumping Scenario Summary

Scenario	Description	2016 Initial Capacity, gal/min	2023 Capacity, gal/min	Pumping Duration[a] (years)	Pumping Ends	Total Additional Extraction Wells	Total Additional Injection Wells	Meets 2137 Cleanup[b]	Target Aquifer[c]
0	Continue pumping at 1,820 gal/min with 25-year duration	1,620	1,820	25	2037	42	20	No	Ringold unit E only
1	Continue pumping at 200-ZP-1 wells at 1,820 gal/min	1,620	1,820	83	2095	42	20	Yes	Ringold units E and A
2	Treat Ringold E then A; increase pumping to 4,070 gal/min	1,620	4,070	~40	2052	56	83	Yes	Ringold units E and A
3	Achieve 200-ZP-1 OU ROD requirements (EPA et al., 2008)	1,620	10,000	25	2037	145	145	Yes	Ringold units E and A

Reference: EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington*.

Assumptions:

- Scenarios 0, 1, and 2 assume nitrate treatment is discontinued in 2023.
- Scenario 1 assumes pumping at 1,820 gal/min until concentrations are low enough for MNA to achieve cleanup by 2137. This evaluates the impact of a 630-year half-life on the current cleanup strategy.
- Scenario 2 assumes pumping at 1,820 gal/min until 2023 when a 2,500 gal/min air stripper operating at 90% efficiency begins operation. Pump until Ringold E and Ringold A concentrations are low enough for MNA to achieve cleanup by 2137. This scenario investigates how rate increase improves cleanup time.
- Scenario 3 assumes the necessary capacity can be added to the pump and treat to achieve the 200-ZP-1 OU ROD (EPA et al., 2008) cleanup goals with 25 years of pumping. There are a number of challenges to achieving this scenario, including managing aquifer drawdown, and the cost and schedule to implement the number of injection and extraction wells needed to meet low enough concentrations to turn pumping off.

a. Based on 125-year ROD duration.

b. Based on 125-year ROD duration.

c. “Ringold unit A” refers to Ringold Formation member of Wooded Island – unit A, and “Ringold unit E” refers to Ringold Formation member of Wooded Island – unit E.

MNA = monitored natural attenuation

ROD = Record of Decision

- Evaluate the need to continue nitrate treatment.
  - Demonstrate ability to achieve the ultimate 200-ZP-1 OU RAO.
  - Examine improvement for other aspects of the remedy (e.g., remove capacity limitations and eliminate injection well fouling).
  - Identify a regulatory strategy to allow reinjection of nitrate above the maximum contaminant level for a specified time period.
- Evaluate groundwater remediation alternatives based on new information.
  - Prepare cost evaluation of various options.
  - Prepare a focused feasibility study.

5.4.2 Long Term – Beyond 5 Years

Long-term actions will be determined by working closely with the U.S. Environmental Protection Agency to develop a path forward for 200-ZP-1 remedy implementation

6 Remedial Action Objectives Progress

The RAOs identified in the 200-ZP-1 OU ROD (EPA et al., 2008) are site-specific goals that define the extent of cleanup necessary to achieve the specific level of remediation at the site. Good progress has been made toward meeting the near-term goals, intermediate-term targets, and final RAOs. The progress made in 2017, after 5 years of operation, is summarized below and discussed in further detail in the annual P&T report (DOE/RL-2017-68).

- **RAO #1:** Return 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving cleanup levels (provided in Table 11 of the 200-ZP-1 OU ROD). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated timeframe to achieve cleanup levels is within 150 years.[7]

  Progress: The interim 200-ZP-1 P&T system and the 200 West P&T have made good progress toward meeting this objective. The shallow portion of the aquifer (upper 15 m [50 ft]) with the carbon tetrachloride plume was captured by the interim remedial action until it was terminated in May 2012. Between 1996 and 2012, carbon tetrachloride plumes with concentrations >2,000 µg/L decreased in size, and 13,718 kg of mass was removed. After 5 years of operation, 12,891 kg of carbon tetrachloride have been removed, as well as significant reductions of nitrate, chromium, uranium, TCE, and technetium for the 200-ZP-1 OU (Figure 9). However, projections completed using the CPGWM suggest that the rate of mass recovery may not be sufficient to achieve the cleanup levels in the timeframe proposed in the 200-ZP-1 OU ROD (125 years) with the current well field and operational parameters and based on recent estimates of carbon tetrachloride half-life.

[7] The 200-ZP-1 OU RAOs identify the estimated timeframe to achieve cleanup levels as 150 years. Further requirements in the 200-ZP-1 OU ROD (EPA et al., 2008) identify the cleanup timeframe as 125 years, which is more conservative than the RAOs.

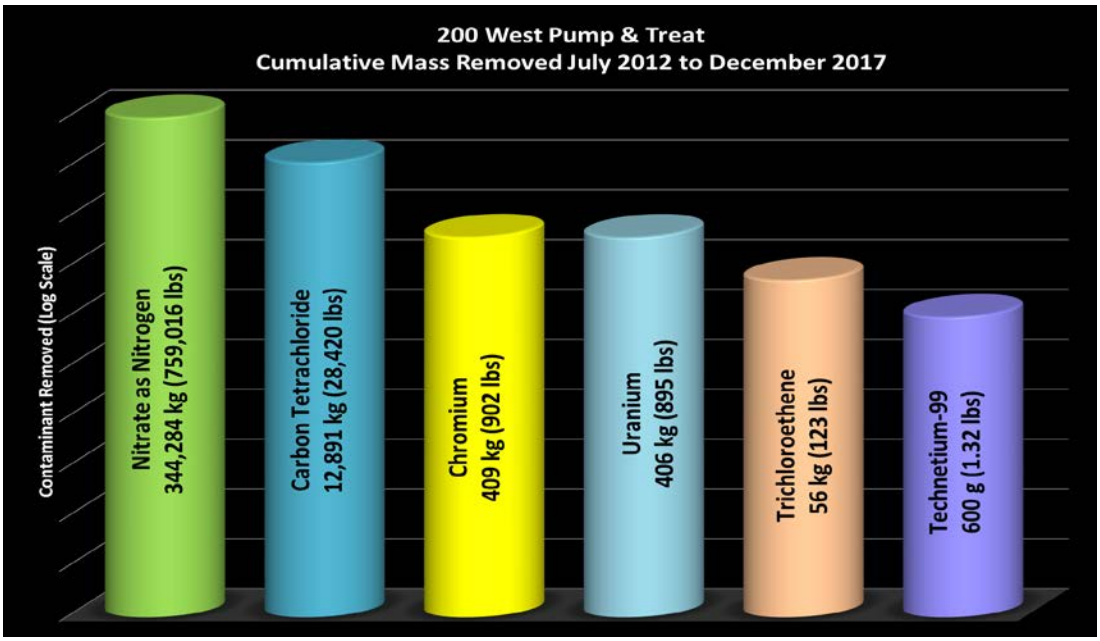


Figure 9. Cumulative Mass Removed of 200 West P&T COCs

- **RAO #2:** Apply ICs to prevent the use of groundwater until cleanup levels (provided in Table 11 of the 200-ZP-1 OU ROD) have been achieved. Within the entire OU groundwater plumes, ICs must be maintained and enforced until cleanup levels are achieved, which is estimated to be within 150 years.[7]

  Progress: The Hanford Sitewide IC plan (DOE/RL-2001-41) has been implemented to prevent the use of groundwater until cleanup levels have been achieved, which is estimated to be within 150 years.

- **RAO #3:** Protect the Columbia River and its ecological receptors from degradation and unacceptable impact caused by contaminants originating from the 200-ZP-1 OU. This final objective is applicable to the entire 200-ZP-1 OU groundwater plume. Protection of the Columbia River from impacts caused by 200-ZP-1 OU contaminants must last until the cleanup levels are achieved, which is estimated to be within 150 years.[7]

  Progress: The 200 West P&T and flow-path control components of the remedy are concurrently implemented to protect the Columbia River and its ecological resources from degradation and unacceptable impacts caused by contaminants from the 200-ZP-1 OU. After extraction and treatment (to reduce constituent levels to cleanup levels or below) at the 200 West P&T, the water is reinjected into the aquifer to the west to direct groundwater flow eastward toward the extraction wells. Treated groundwater is also reinjected to the northeast and east of the groundwater contamination to slow the natural eastward flow of most of the groundwater and, as a result, is largely maintaining the contaminants within the hydraulic capture zone of the extraction wells. The extent of the hydraulic capture induced by pumping the extraction and injection wells appears to cover the majority of the carbon tetrachloride plume at concentrations >100 µg/L as originally designed. However, a portion of the carbon tetrachloride plume at concentrations >100 µg/L (downgradient of the eastern line of extraction wells) is not being captured. Further modeling is being performed to determine whether concentrations in portions of the plumes not being captured will be reduced to below cleanup levels by MNA.

In summary, the 200 West P&T remedy activities have shown good progress toward meeting the RAOs to the initial 5-year performance expectation outlined in the RD/RAWP (DOE/RL-2008-78). However, due to slower abiotic degradation and more carbon tetrachloride than originally assumed in the 200-ZP-1 OU FS (DOE/RL-2007-28), the remedy as outlined in the RD/RAWP is no longer sufficient to meet the carbon tetrachloride RAO. Based on the change in conditions, the MNA remedy component for achieving the cleanup level for carbon tetrachloride within the 125-year timeframe is less favorable. Efforts are underway to provide information to evaluate carbon tetrachloride remediation optimization options, identify other potential changes to the remediation approach, and address the observed remedy cost issues. This information will be included in a future revision of the RD/RAWP.

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