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CALENDAR YEAR 2019 ANNUAL SUMMARY REPORT FOR PUMP AND TREAT OPERATIONS IN THE HANFORD CENTRAL PLATEAU OPERABLE UNITS

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

U.S. DEPARTMENT OF ENERGY | Richland Operations Office

P.O. Box 550
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

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Executive Summary

This report presents the 2019 summary of operational data and evaluations for the Hanford Site 200-UP-1 and 200-ZP-1 Groundwater Operable Unit (OU) pump and treat (P&T) systems, the 200-DV-1 OU perched water extraction system, and the 200-BP-5 OU groundwater extraction system.

Extracted groundwater and perched water from all four OUs and Environmental Restoration Disposal Facility (ERDF) leachate are routed to the 200 West P&T central treatment facility, and the treated water is then returned to the aquifer using injection wells. In 2018, the 200 West P&T began treating purgewater from the modular storage units (MSUs) as part of a pilot test.[1] In April 2019, the MSU pilot test was completed to make the transfer of purgewater from the MSUs to the 200 West P&T facility a routine feed stream. The test demonstrated that MSU water can be successfully treated at the 200 West P&T without impact to the facility operations.[2] Before transferring water from the MSUs, the addition of sodium hypochlorite is effective in controlling algae and bacteria with collateral benefits of reducing the concentrations of iron and manganese that contribute to well fouling.

The 200 West P&T is operating to treat extracted water from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs; 200-DV-1 OU perched water; and ERDF leachate. The 200-UP-1 OU has two separate groundwater extraction systems: one for Waste Management Area (WMA) S-SX and one for the U Plant area. The 200 West P&T provides multiple unit processes to remove contaminants of concern (COCs) from the influent groundwater stream from the four OUs (details of the processes are described in Chapter 2). Maintenance and upgrades to the 200 West P&T are focused on reaching and maintaining nominal design capacity and meeting remedy optimization needs. Upgrades during 7 years of operation have included installing uranium ion-exchange treatment and adding/realigning wells to integrate treatment for the multiple feed streams from the four OUs. Other upgrades included a tie-in for treatment of ERDF leachate and MSU

[1] DOE/RL-2018-28, 2018, *Optimization Test Plan for Treating Water from Modular Storage Units at 200 West Pump & Treat Facility*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0065718H.

[2] DOE/RL-2018-70, 2019, *Optimization Pilot Test Results of Treating Water from Modular Storage Units at 200 West Pump & Treat Facility*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-02519.

water, as well as treatment process upgrades to install newer design membrane cassettes in two of the four aerated membrane tanks for more efficient operation. Polyvinyl chloride piping was upgraded to stainless steel to ensure safe operations. The stainless-steel upgrades included the discharge piping and header sections of the effluent pumps, solids handling piping for centrifuge operations, piping in the injection transfer buildings, and fluidization components in the fluidized bed reactors.

Decreased injection well capacity was first identified in 2013[3] and was caused by biofouling in the effluent conveyance system components and injection wells. Well maintenance activities have been ongoing to routinely clean and rehabilitate the injection wells to maintain injection capacity. In 2019, a sodium hypochlorite disinfection system was installed for the plant effluent water to limit biological fouling of the injection wells. Other upgrades performed included installing piping to route groundwater from extraction transfer building #2 (tank #2) directly to the air strippers to enable increased capacity through the 200 West P&T central treatment facility.

The overall 200 West P&T performance evaluation for 2019 concluded that during 7 years of operation, the P&T system is successfully providing treatment for the four OUs and meeting annual treatment volume targets and goals (Figure ES-1) while managing needs for design capacity throughput, maintenance, and facility upgrades. The cumulative mass removed for treated contaminants by the 200 West P&T from startup in July 2012 through December 2019 is presented in Figure ES-2.

[3] DOE/RL-2014-26, 2014, *Calendar Year 2013 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0083706.

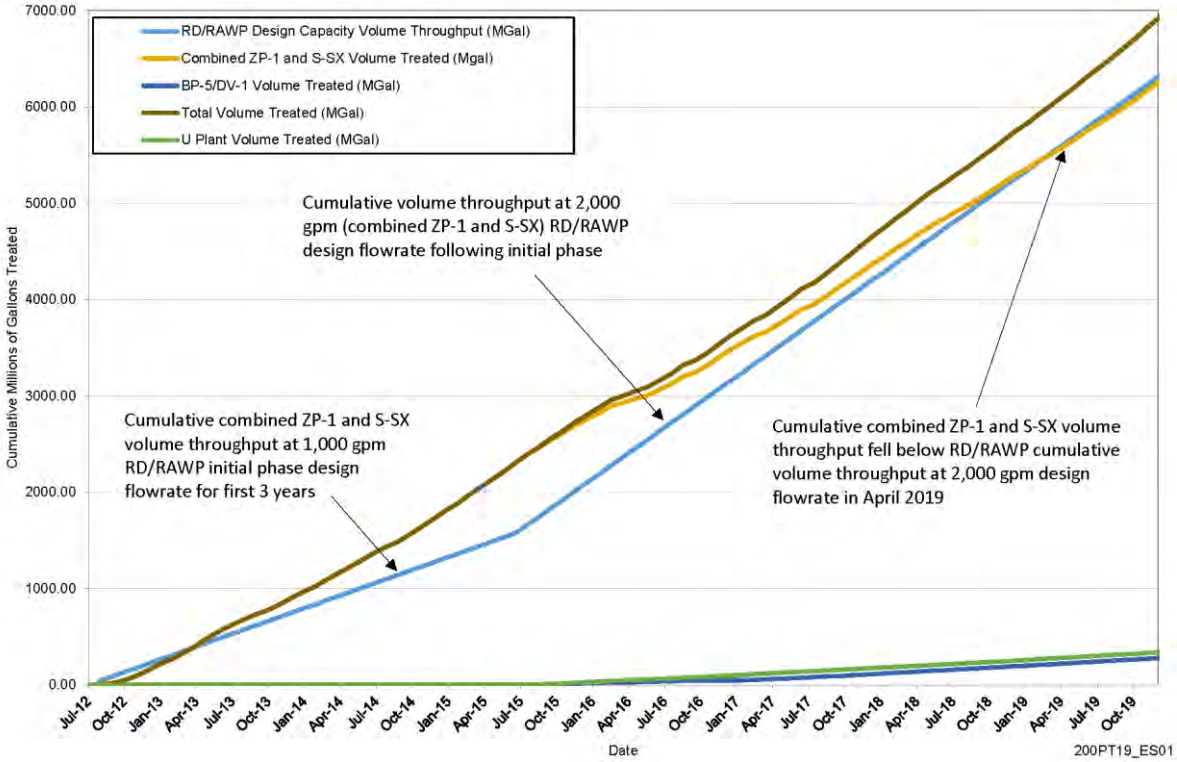

Figure ES-1. 200 West P&T Actual Cumulative Volume Treated Compared to Design Capacity Throughput

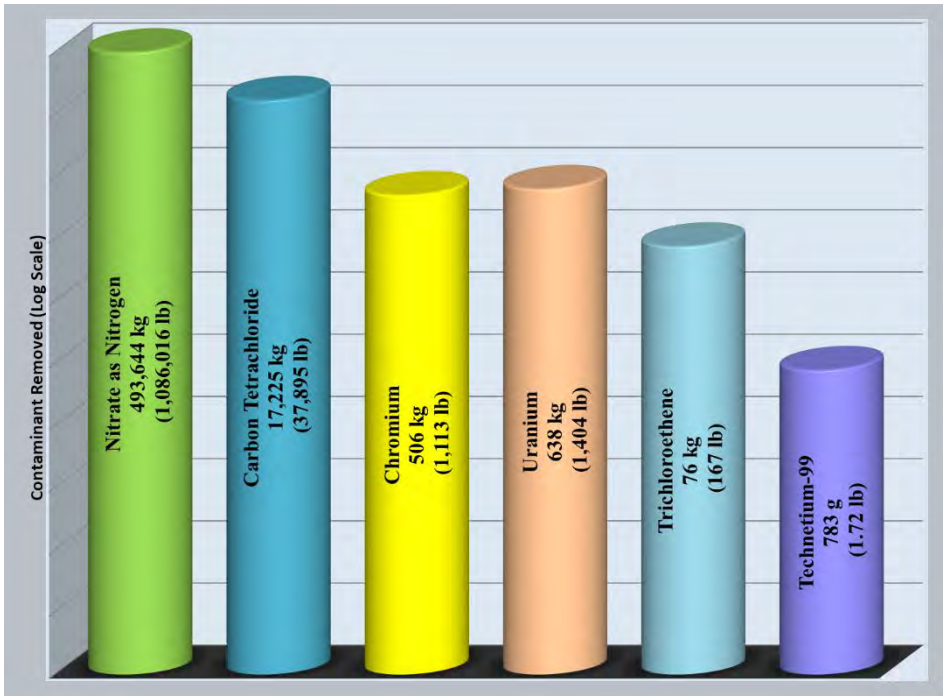

Figure ES-2. Cumulative Contaminant Mass Removed by the 200 West P&T

In 2018, the cumulative volume treated from the 200-ZP-1 OU and S-SX Tank Farms extraction wells was projected to fall below the cumulative design capacity at the current facility throughput. The actual cumulative total of 200-ZP-1 OU and S-SX Tank Farms extracted groundwater that was treated fell below the 200-ZP-1 P&T remedial design/remedial action work plan (RD/RAWP)[4] design capacity in April 2019 (Figure ES-1).

In 2019, modeling analysis was conducted using updated information collected since issuance of the 200-ZP-1 OU Record of Decision (ROD)[5] and evaluated whether the current remedy configuration will meet the remedial action objective (RAO) for carbon tetrachloride, which is the primary risk COC. The analysis indicated that without modification, carbon tetrachloride remediation would not meet cleanup levels within the 125-year timeframe outlined in the 200-ZP-1 OU ROD. The analysis also suggested that sufficient nitrate treatment may have occurred so the cleanup level for nitrate could be met through monitored natural attenuation (MNA) in the 125-year remedy timeframe.

In October of 2019, an optimization study[6] was initiated for the 200-ZP-1 OU to improve the likelihood of achieving cleanup of carbon tetrachloride in the timeframe specified in the 200-ZP-1 OU ROD.[5] The primary objective of the study is to provide data necessary to optimize carbon tetrachloride remediation and support consideration of potential future 200-ZP-1 OU remedy modifications. To accomplish the primary objective, the study will be designed with the following data collection and analysis considerations:

- Quantify the increased carbon tetrachloride mass removal rate and associated plume area, as well as concentration reductions, under an optimized facility configuration.
- Evaluate the effectiveness of carbon tetrachloride plume containment under the optimized configuration.

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[4] 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: https://pdw.hanford.gov/document/0096137.

[5] 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: https://pdw.hanford.gov/document/00098825.

[6] DOE/RL-2019-38, 2019, *200-ZP-1 Operable Unit Optimization Study Plan, DOE/RL-2019-38*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03236.

- Interpret optimization study results to compare anticipated remedy performance for carbon tetrachloride under the optimized configuration with predicted pre-optimization study performance to support recommendations for potential remedy modifications.
- Quantify nitrate plume behavior under the optimized configuration to confirm that transition to MNA is appropriate.
- Confirm (through monitoring) that treated effluent quality will meet injection criteria (except for nitrate).
- Evaluate whether RAOs are expected to be achieved for all of the COCs under the optimized remedy within the timeframe of the 200-ZP-1 OU ROD.[5]

The suspension and layup of the active biological treatment system began in October 2019 and is one of the key components of the optimization study.[6] Phase 1 layup activities included removing bulk carbon from the fluidized bed reactors and completing a pipe stress analysis for using 16 in. bypass line to route 200 West P&T influent from the equalization tank directly to the air strippers. The remainder of Phase 1 activities to be completed in 2020 include layup of rotary drum thickeners and centrifuges and associated equipment, removal of the residual sludge from the holding tanks for disposal at the MSU, hydrostatic testing of the 16 in. bypass line with stainless-steel upgrades, and operational acceptance testing on the bypass line.

200-UP-1 Operable Unit

The 200-UP-1 OU P&T systems are designed to meet interim remedial action ROD[7] objectives using extraction and injection well networks for targeted plumes and treating water routed to the 200 West P&T. Performance monitoring and assessments for 2019 included the following:

- At WMA S-SX, the groundwater extraction system consists of three extraction wells that began operating in 2012. Since startup, technetium-99, chromium, and nitrate concentrations have declined in a majority of monitoring wells that had baseline concentrations above cleanup levels.

[7] EPA, Ecology, and DOE, 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington. Available at: https://pdw.hanford.gov/document/0091413.

- For technetium-99 at WMA S-SX, the 95% upper confidence limit (UCL) values declined from 19,768 to 6,954 pCi/L between 2011 and 2019 due to operation of the groundwater extraction system. Comparisons of the 95% UCL values calculated from the monitoring data to numerical model simulations, and comparisons of the actual mass (or activity) of contaminants extracted from the aquifer to model predictions, indicate that the WMA S-SX groundwater extraction system is operating as predicted and the system will achieve cleanup objectives. However, ongoing groundwater contamination sources from the vadose zone may be large enough that groundwater plumes may re-form following shutdown of the WMA S-SX groundwater extraction system unless the sources are remediated or groundwater near the sources is hydraulically contained.
- The U Plant groundwater extraction system began operating in September 2015 using two extraction wells, and a third extraction well was added to the system in September 2017. Uranium concentrations declined in seven of the nine monitoring wells that had baseline concentrations above the 30 µg/L cleanup level. Technetium-99 concentrations declined in the two monitoring wells that had baseline concentrations above the 900 pCi/L cleanup level, and the concentration was below the cleanup level in 2019 in one of these wells.
- The iodine-129 hydraulic containment system began operating in October 2015 using three injection wells downgradient of the plume front. Water-level monitoring data indicate that the system has slowed eastward plume migration.

Fate and transport simulations for the U Plant groundwater extraction system at flow rates similar to current operating conditions have shown that the maximum uranium concentration may not decline below the 30 µg/L cleanup level within the 125-year cleanup timeframe. When sufficient data from additional monitoring wells are available, additional numerical model simulations are planned to assess the system modifications needed to meet remedial objectives.

For the southeastern chromium plume, a remedial design investigation report was published in 2019[8] that updated the conceptual site model and evaluated remedial options.

200-ZP-1 Operable Unit

The 200-ZP-1 OU P&T system is designed to meet the ROD[5] objectives using an injection and extraction well network and treating water at the 200 West P&T. The 2019 hydraulic containment assessment showed that nearly 100% of the carbon tetrachloride plume in the unconfined aquifer that exhibits concentrations greater than the 100 µg/L target was contained (Figure ES-3). Figure ES-3 shows the percentage of the carbon tetrachloride plume that is hydraulically contained by the 200 West P&T for a range of concentration thresholds (to achieve the 200-ZP-1 OU ROD target for 95% carbon tetrachloride mass removal).

Overall performance of 200-ZP-1 OU P&T activities for the first 7 years of operation has demonstrated that plume containment and mass extraction have met the performance targets described in the 200-ZP-1 P&T RD/RAWP,[4] except for a small area of contamination in the northeastern plume area. A new extraction well began operating in December 2019 to contain carbon tetrachloride contamination above the 100 µg/L target in the northeastern plume area.

The average, 95% UCL, and median calculated from the performance monitoring well network show that carbon tetrachloride concentrations have been declining since startup of the 200 West P&T (Figure ES-4).

[8] DOE/RL-2017-60, 2019, *Remedial Design Investigation Report for the 200-UP-1 Operable Unit Southeast Chromium Plume*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03137.

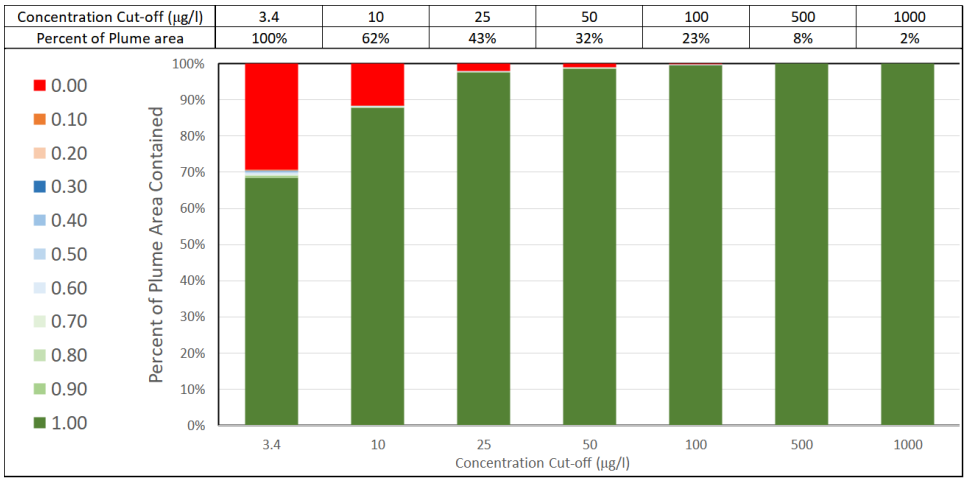
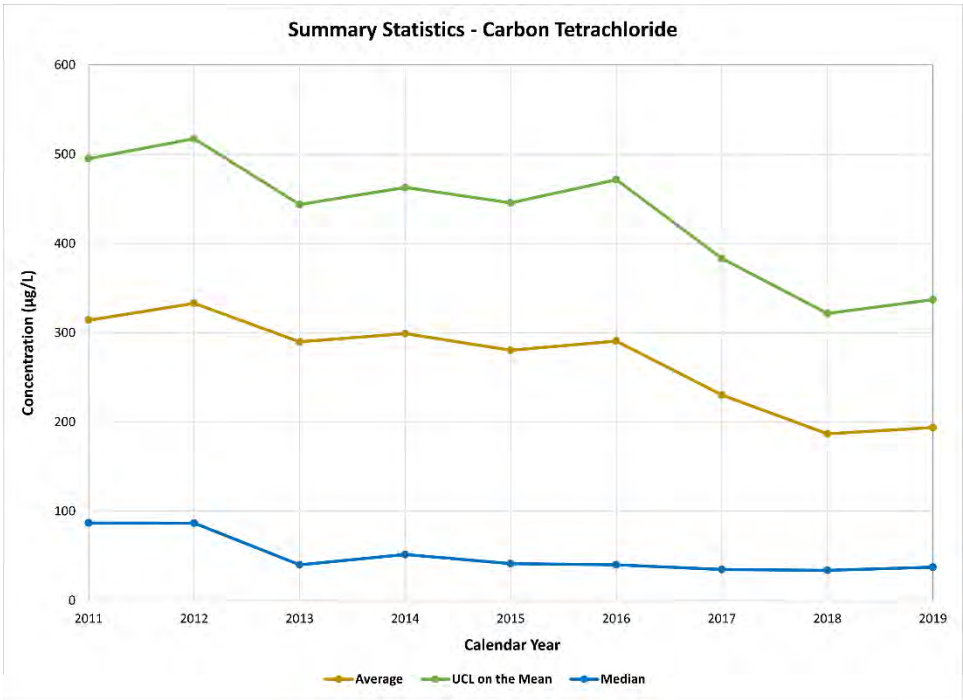


Figure ES-3. Percent Containment of Targeted Concentrations of Carbon Tetrachloride Above the Ringold Lower Mud Unit Computed Using the Central Plateau Groundwater Model



Note: Performance monitoring wells are identified in DOE/RL-2009-115, 2016, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0074328H.

Figure ES-4. Summary Statistics for Carbon Tetrachloride for Performance Monitoring Plan Wells

The annual performance assessment of the 200-ZP-1 OU remedy included evaluating concentration trends at individual wells using available performance data, updating three-dimensional contaminant plume estimates, and evaluating slower abiotic degradation rates published in the final carbon tetrachloride degradation study report.[9] The updated three-dimensional contaminant plume estimated 25% additional carbon tetrachloride mass in the Ringold Formation member of Wooded Island – unit A (Rwia) compared to 12% assumed in the 200-ZP-1 OU feasibility study (FS),[10] and over a third more carbon tetrachloride contamination is present in the Ringold Formation member of Wooded Island – unit E (Rwie) than was assumed in the 200-ZP-1 OU FS. The report concluded that hydrolysis rates are an order of magnitude slower than previously thought, with the best estimate for carbon tetrachloride half-life in aqueous systems from abiotic degradation alone at about 630 years (compared to the 41.3-year to 100-year half-life used in the 200-ZP-1 P&T RD/RAWP[3]).

The change in half-life assumption from abiotic degradation alone results in a reduced degradation contribution to mass reduction (and related reductions in concentrations) over the lifecycle of the P&T remedy. The longer 630-year half-life substantially increases the amount of time for mass to attenuate following shutdown of the P&T system. Biotic and abiotic degradation are identified as natural attenuation processes for carbon tetrachloride in the 200-ZP-1 P&T RD/RAWP.[4] An evaluation of biotic degradation rates for carbon tetrachloride was initiated in 2018, and the results were published in June 2019.[11] The study evaluated multiple lines of evidence for continuing in situ biotic degradation of carbon tetrachloride that supports conditions suitable for both biotic degradation and for abiotic-biotic reductive degradation in the 200 West Area aquifer. The study found that the additional biotic pathways evaluated would not result in an overall (i.e., net sum of abiotic and biotic) degradation half-life close to or <100 years, but rather on the order of 200 to 400 years. Additional efforts to determine a more

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[9] PNNL-22062, 2012, *Abiotic Degradation Rates for Carbon Tetrachloride and Chloroform: Final Report*, RPT-DVZ-AFRI-012, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22062.pdf.

[10] 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: https://pdw.hanford.gov/document/0808050315. https://pdw.hanford.gov/document/00098828.

[11] PNNL-28846, 2019, *Carbon Tetrachloride: Evaluation of Biotic Degradation Mechanisms and Rates*, 73793-RPT-0001, Pacific Northwest National Laboratory, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-02702.

specific estimate of the half-life value (i.e., a more specific value between 100 and 400 years) would require additional laboratory study. The need for these efforts depends on the impact that a more specific estimate of this rate would have on remedy decisions for the carbon tetrachloride in the Rwie and Rwia within the aquifer. In particular, due to the slower transport velocity in the Rwia, as well as anticipated geologic differences (i.e., greater fraction of less permeable zones in the Rwia), a half-life >100 years may still be of significance for attenuating the Rwia carbon tetrachloride plume.

The performance evaluation indicates that remedy performance projections from the 200-ZP-1 OU FS[10] need to be updated to incorporate (1) the slower abiotic natural attenuation rate for carbon tetrachloride, (2) the larger carbon tetrachloride mass within the Rwie and Rwia, and (3) evaluation of the biotic degradation of carbon tetrachloride. Given these changes, achieving the mass removal goal for carbon tetrachloride will be more difficult than anticipated in the 200-ZP-1 OU FS and 200-ZP-1 OU ROD[5] and unlikely to achieve final groundwater cleanup levels for carbon tetrachloride in the timeframe identified in the ROD.

The 200-ZP-1 OU optimization study[6] initiated in October 2019 provides an overall approach to evaluate changes to the treatment facility and the well network to increase carbon tetrachloride treatment capacity. The study will collect data to provide technically defensible information to help optimize remedy performance and support remedy decisions. The optimization study will evaluate treatment facility modifications, 200 West P&T operational effectiveness, and cost implication for increasing the P&T system's treatment design capacity for carbon tetrachloride. The optimization study will also evaluate the ability to meet RAOs for nitrate and other COCs with suspension of active biological treatment.

Based on the modeling analysis, a third air stripper tower and additional extraction and injection wells are necessary to accommodate greater total overall operating capacity for the 200 West P&T. Suspension of active biological treatment would allow the treatment capacity for carbon tetrachloride to increase up to approximately 14,200 L/min (3,750 gal/min) maximum throughput capacity. Combined, these changes will focus on increasing carbon tetrachloride treatment capacity and mass removal, streamlining operations, reducing costs, and providing data for plume remediation performance.

The 200-ZP-1 OU PMP[12] was amended via TPA-CN-0875[13] to incorporate near-term sampling and analysis for the 200-ZP-1 OU optimization study[6] after suspension of active biological treatment for nitrate at the 200 West P&T. Eighteen wells were identified for adding analytes for observation and increased sample frequency for the first year of the optimization study implementation. A sampling and analysis plan is being developed to sample and monitor changes in the aquifer for the duration of the optimization study.

In the last quarter of 2019, following suspension of nitrate treatment, nitrate concentrations in the effluent increased to near influent concentrations as predicted through the model simulations. In addition, biofouling of injection wells has been reduced without further chemical amendments for biological treatment, the combined injection well rehabilitation program, and the addition of sodium hypochlorite disinfection system. The combined efforts have increased the injection well capacity since suspension of the active biological treatment in October 2019.

200-DV-1 Operable Unit

The 200-DV-1 OU perched water extraction was initiated in 2011 and is producing water with uranium, technetium-99, and nitrate concentrations that are much higher than concentrations from the other OUs. The extraction rate is low because of the thin, saturated zone and the low permeability of the perched water zone. In 2019, a hydraulic analysis examined extraction well configuration options for increasing the rate of contaminated perched water removal[14] and to guide planning for installation of additional extraction and monitoring wells within the perched water zone. The locations for 12 perched water wells (8 extraction and 4 monitoring) were planned in 2019 to increase extraction capacity and support refinement of the conceptual site model. The first two extraction wells are scheduled to be installed in 2020.

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[12] DOE/RL-2009-115, 2016, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: https://pdw.hanford.gov/document/0074328H.

[13] TPA-CN-0875, 2019, *Tri-Party Agreement Change Notice Form: DOE/RL-2009-115, Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action, Revision 2*, dated November 6, U.S. Department of Energy, Richland Operations Office, and U.S. Environmental Protection Agency, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03254.

[14] SGW-63236, 2019, *200-DV-1 Future Perched Water Well Construction White Paper*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: https://pdw.hanford.gov/document/AR-03701.

A sampling and analysis plan is anticipated to be prepared in 2020 for drilling, constructing, and installing the additional vertical extraction and monitoring wells. Data will be collected to characterize the subsurface hydrogeology and contamination. The data will also be used to support phased implementation of additional extraction capacity, as well as to provide input to future remedy decisions that may include other remediation approaches and/or control of the hydrogeological system.

200-BP-5 Operable Unit

The 200-BP-5 OU removal action continued during 2019, and the targeted uranium and technetium-99 plumes have significantly decreased in size and concentration since the removal action was initiated in 2015. An additional extraction well was connected to the extraction system in 2018 and began pumping in 2019 to provide additional technetium-99 removal.

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Terms

AEA	*Atomic Energy Act of 1954*
AWLN	automated water-level network
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFM	capture frequency map
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
CPGWM	Central Plateau Groundwater Model
Cr(VI)	hexavalent chromium
DCS	derived concentration standard
DOE	U.S. Department of Energy
DQO	data quality objective
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ETB	extraction transfer building
F&T	fate and transport
FBR	fluidized bed reactor
FS	feasibility study
FY	fiscal year
GAC	granular activated carbon
HDPE	high-density polyethylene
IC	institutional control
ITB	injection transfer building
IX	ion exchange
MBR	membrane bioreactor
MCL	maximum contamination level
MDA	minimum detectable activity
MNA	monitored natural attenuation

MSU	modular storage unit
MTCA	Model Toxics Control Act
NTCRA	non-time-critical removal action
O&M	operations and maintenance
OSP	optimization study plan
OU	operable unit
P&T	pump and treat
P2R Model	Plateau to River Model
PFP	Plutonium Finishing Plant
PMP	performance monitoring plan
PNNL	Pacific Northwest National Laboratory
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RAO	remedial action objective
RD/RAWP	remedial design/remedial action work plan
REDOX	Reduction-Oxidation (Plant)
RI	remedial investigation
Rlm	Ringold Formation member of Wooded Island – lower mud unit
ROD	Record of Decision
Rwia	Ringold Formation member of Wooded Island – unit A
Rwie	Ringold Formation member of Wooded Island – unit E
SALDS	State-Approved Land Disposal Site
SAP	sampling and analysis plan
SGSIM	sequential Gaussian simulation
SST	single-shell tank
SVE	soil vapor extraction
TCE	trichloroethene
TED	total effective dose

UCL	upper confidence limit
VOC	volatile organic compound
VPGAC	vapor-phase granular activated carbon
WMA	waste management area

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1 Introduction

This report presents the 2019 operational results and evaluations for the Hanford Site 200-UP-1 and 200-ZP-1 Groundwater Operable Unit (OU) pump and treat (P&T) systems, the 200-DV-1 OU perched water extraction system, and the 200-BP-5 OU groundwater extraction system. In 2019, extracted groundwater and perched water were routed from all four OUs to the 200 West P&T, and the treated water was returned to the aquifer using injection wells. These systems are operated by CH2M HILL Plateau Remediation Company (CHPRC) for the U.S. Department of Energy (DOE). Figure 1-1 shows the locations of the following:

- 200 West P&T
- Waste Management Area (WMA) S-SX groundwater extraction system
- U Plant area groundwater extraction system
- Iodine-129 hydraulic containment injection wells
- 200-DV-1 OU perched water extraction wells
- 200-BP-5 OU groundwater extraction wells
- Environmental Restoration Disposal Facility (ERDF)
- Modular storage units (MSUs)
- Associated transfer pipelines to convey the water to the 200 West P&T

This report also presents the analyses of remedy performance since the implementation of the 200-ZP-1 OU optimization study at the 200 West P&T, as outlined in DOE/RL-2019-38, *200-ZP-1 Operable Unit Optimization Study Plan* (hereinafter referred to as the 200-ZP-1 OU optimization study plan [OSP]), which began in October 2019.

The 200 West P&T began operating in July 2012, replacing the interim 200-ZP-1 OU system and implementing groundwater remediation for the 200-ZP-1 OU in accordance with 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 Record of Decision [ROD]). The 200 West P&T has been expanded since startup to treat groundwater as identified in remedial decisions for other identified groundwater OUs. The 200 West P&T is designed to treat a maximum of 9,500 L/min (2,500 gal/min) of water, with a sustained nominal flow of 7,600 L/min (2,000 gal/min) when recirculation and downtime for operations and maintenance (O&M) activities are included.

In 2019, 33 extraction and 29 injection wells were in use to supply groundwater for treatment at the 200 West P&T and inject treated water into the aquifer. During 2019, the average combined influent flow rate through the 200 West P&T was 8,150 L/min (2,150 gal/min). During 2019, the total volume treated through the P&T system was 4.2 billion L (1.1 billion gal), removing 1,917 kg of carbon tetrachloride; 245,982 kg of nitrate; 68.5 kg of hexavalent chromium (Cr(VI)); 10.5 kg of trichloroethene (TCE); 109 g (1.85 Ci) of technetium-99; and 103.0 kg of uranium. Since startup in 2012, the 200 West P&T has processed 25.6 billion L (6.8 billion gal), removing 17,040 kg of carbon tetrachloride; 2,186,276 kg of nitrate; 505.8kg of chromium (total and Cr(VI)); 76.0 kg of TCE; 774 g (13.2 Ci) of technetium-99; and 630.6 kg of uranium. Chapters 3, 4, 5, and 6 of this report provide discussion on contaminant mass removed associated with the remedial action objectives (RAOs)/removal action objectives for the 200-UP-1 OU, 200-ZP-1 OU, 200-DV-1 perched water, and 200-BP-5 OU, respectively.

Remedial actions for extracted groundwater treated at the 200 West P&T under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) are identified below and are described in further detail in subsequent chapters of this report:

- **200-UP-1 OU:** Groundwater remediation in the 200-UP-1 OU is addressed by EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit* (hereinafter referred to as the 200-UP-1 OU interim action ROD). A final ROD for the 200-UP-1 OU will be pursued when future impacts to groundwater from contaminant sources and the vadose zone contributions are adequately understood and when an iodine-129 treatment technology evaluation has been completed. The 200-UP-1 OU contaminants of concern (COCs) are uranium, technetium-99, total chromium and Cr(VI), nitrate, iodine-129, tritium, and carbon tetrachloride. Carbon tetrachloride originated from waste disposal sites associated with the Plutonium Finishing Plant (PFP) in the 200-ZP-1 OU. Active remedies in the 200-UP-1 OU consist of the WMA S-SX groundwater extraction system, the U Plant groundwater extraction system, and the iodine-129 plume hydraulic containment system.

  The WMA S-SX groundwater extraction system is focused on removing technetium-99 from the aquifer. Technetium-99 occurs as a groundwater contaminant beneath and downgradient of the SX Tank Farms in the southern portion of the 200 West Area. The WMA S-SX groundwater extraction system consists of three extraction wells, aboveground pipelines, and a transfer building to capture and pump contaminated groundwater near the S-SX Tank Farms to the 200 West P&T. The WMA S-SX groundwater extraction system began operating in 2012. Section 3.1.1 discusses the remedial system operational and contaminant removal results for 2019.

  The U Plant P&T system, which began operating in September 2015, is focused on removing uranium and technetium-99 from the aquifer. It consists of three extraction wells and aboveground piping to convey extracted groundwater to the 200 West P&T. Groundwater from the U Plant area extraction wells is pumped to the 200 West P&T where it is combined with 200-BP-5 OU extracted groundwater, 200-DV-1 OU extracted perched water, and ERDF leachate before flowing through the uranium ion-exchange (IX) treatment system. Following uranium removal, the water is combined with groundwater from the WMA S-SX and 200-ZP-1 extraction wells requiring radiological treatment and then pumped to the technetium-99 IX treatment system. The treated water from the radiological treatment building is then combined with groundwater from the remaining 200-ZP-1 extraction wells (not requiring radiological treatment) and routed through the 200 West P&T central treatment facility to remove nonradiological COCs. The treated water is returned to the aquifer using injection wells. Section 3.2.1 discusses the remedial system operational and contaminant removal results for 2019.

  The iodine-129 hydraulic containment system consists of three injection wells in operation since October 2015 that inject treated water east of the iodine-129 plume to slow eastward plume migration. Hydraulic containment is provided by increasing the water table elevation downgradient of the plume while treatment technologies are evaluated. Section 3.3.1 discusses the remedial system operational results for 2019.

- **200-ZP-1 OU:** The 200-ZP-1 OU ROD (EPA et al., 2008) provides the regulatory framework for the OU remediation. The ROD identifies a timeframe of 125 years from the startup of remedial operations until attainment of final cleanup levels. The remedy includes treatment by the 200 West P&T in combination with monitored natural attenuation (MNA) to achieve cleanup levels for all COCs in 125 years. The goal of P&T operations is to reduce the mass of COCs throughout the 200-ZP-1 OU by a minimum of 95% in 25 years following 200 West P&T startup. The COCs are carbon tetrachloride, total chromium and Cr(VI), iodine-129, nitrate, technetium-99, TCE, and tritium.

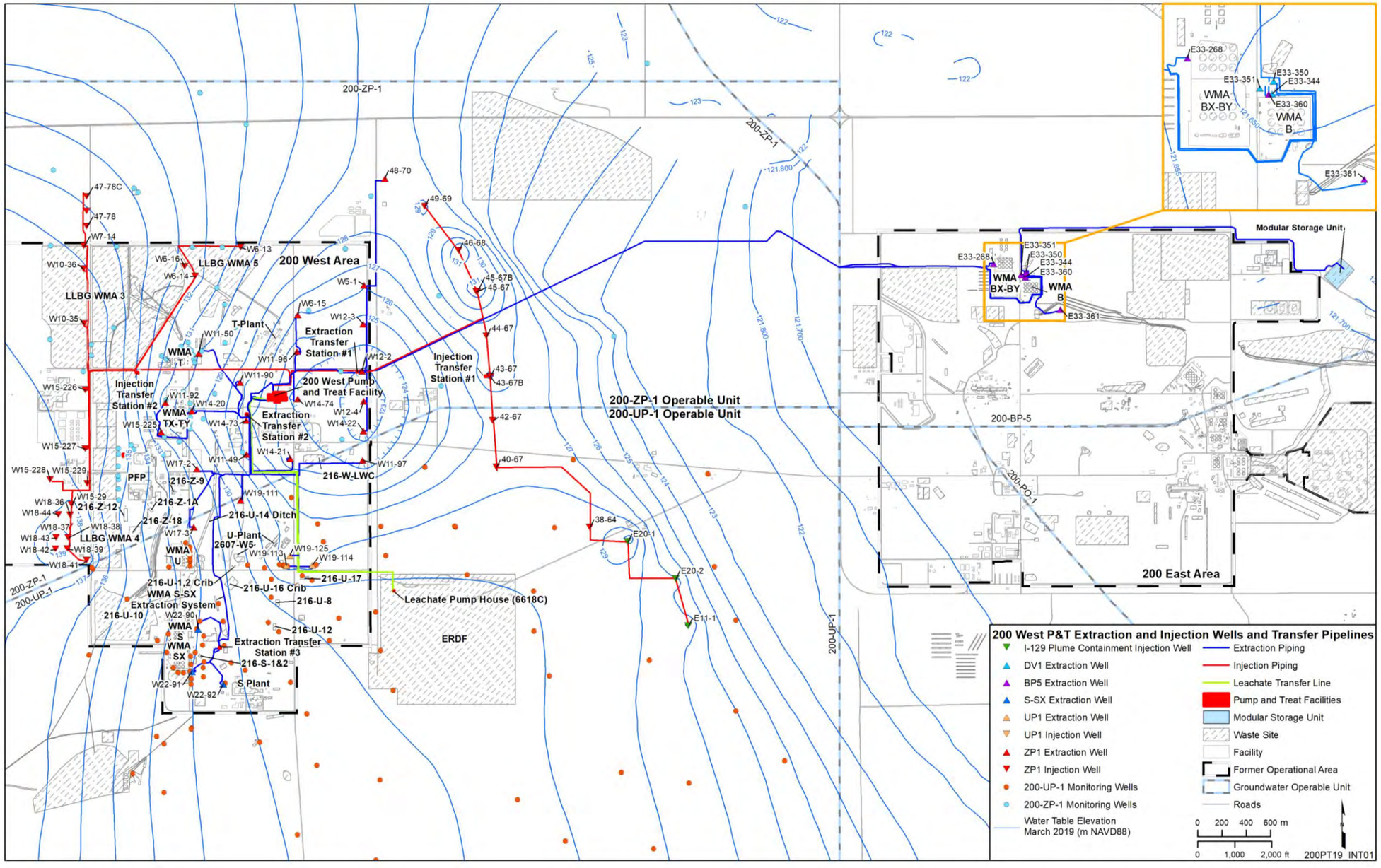

Figure 1-1. Hanford Site 200 West P&T Extraction and Injection Wells and Transfer Pipelines

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The 200-ZP-1 OU extraction and injection well network (Figure 1-1) is designed to hydraulically contain and recover 200-ZP-1 OU contaminants. Extracted groundwater is transferred to the 200 West P&T for treatment. Some treated water from the 200 West P&T is injected to the northeast and east of the 200-ZP-1 OU extraction wells to reduce and reverse the natural eastward hydraulic gradient in the aquifer and to minimize the potential for groundwater to flow northward through Gable Gap, toward the Columbia River, which is referred to in the 200-ZP-1 OU ROD (EPA et al., 2008) and DOE/RL-2009-115, Rev. 2, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action* (hereinafter referred to as the 200-ZP-1 OU performance monitoring plan [PMP]), as flow-path control.

Using injection wells, groundwater mounding is intended to slow natural eastward flow and maintain the majority of targeted COCs within the hydraulic capture zone of the extraction wells, also enabling natural attenuation to reduce concentrations beyond the capture zone. Injection wells installed to the west (i.e., upgradient of the 200-ZP-1 OU extraction wells) were designed to recharge the aquifer and steepen hydraulic gradients to the east, therefore accelerating flushing of the most highly contaminated portions of the aquifer toward the extraction wells. Section 4.6 discusses the progress toward meeting the 200-ZP-1 OU remedial action targets, goals, and objectives for 2019. In October 2019, the 200 West P&T implemented an optimization study to expand the treatment capacity throughput, accelerate carbon tetrachloride mass recovery, and began the necessary facility modifications supporting the optimization study. Section 2.3 discusses more details of the facility modifications, and Section 4.2 discusses the progress of the optimization study.

- **200-BP-5 OU:** Groundwater removal from the 200-BP-5 OU started in September 2015 as part of a treatability test (DOE/RL-2015-75, *Aquifer Treatability Test Report for the 200-BP-5 Groundwater Operable Unit*). In December 2016, operations transitioned to a non-time-critical removal action (NTCRA) in accordance with the removal action memorandum (DOE/RL-2016-41, *Action Memorandum for 200-BP-5 Operable Unit Groundwater Extraction*) to recover elevated levels of groundwater contamination while waiting on completion of the CERCLA remedial investigation (RI)/feasibility study (FS) process and the issuance of a 200-BP-5 OU interim action ROD. In February 2018, DOE/RL-2017-11, *Removal Action Work Plan for the 200-BP-5 Operable Unit Groundwater Extraction*, was issued. The primary contaminants subject to the removal action are technetium-99 and uranium. Extracted groundwater also contains the co-contaminants cyanide, iodine-129, nitrate, and tritium. The extracted groundwater is treated at the 200 West P&T to meet the treated effluent criteria for the P&T system.

- **200-DV-1 OU:** Extraction of perched water from the 200-DV-1 OU began in August 2011 as a treatability test (DOE/RL-2011-40, *Field Test Plan for the Perched Water Pumping/Pore Water Extraction Treatability Test*). In 2016, operations transitioned to a NTCRA in accordance with the action memorandum (DOE/RL-2014-34, *Action Memorandum for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction*). In 2016, extracted perched water was transferred to the 200 West P&T by truck. Since 2017, the perched water extraction wells have been connected to the 200-BP-5 OU groundwater cross-site pipeline for conveyance to the 200 West P&T. The primary COCs in the extracted perched water are uranium, technetium-99, and nitrate. Total chromium, Cr(VI), and tritium are also COCs. In 2019, a hydraulic analysis examined extraction well configuration options for increasing the rate of contaminated perched water removal (SGW-63236, *200-DV-1 Future Perched Water Well Evaluation*). This analysis, as well as other existing information for the perched water zone and the overall hydrogeological system, was used to guide planning to install additional extraction and monitoring wells within the perched water zone.

- **ERDF:** Leachate from ERDF also is treated at the 200 West P&T. An explanation of significant differences issued in 2015 (EPA et al., 2015, *Explanation of Significant Differences for the U.S. Department of Energy Environmental Restoration Disposal Facility Hanford Site – 200 Area, Benton County, WA*) allows the 200 West P&T to be used as an option for treating ERDF leachate. Treatment of ERDF leachate continued during 2019.

- **MSU:** MSU purgewater treatment was initiated as part of an optimization pilot test (DOE/RL-2018-28, *Optimization Test Plan for Treating Water from Modular Storage Units at 200 West Pump & Treat Facility*), which began in May 2018 and was completed in April 2019 to minimize well fouling and improve the injective capacity of the injection wells. Approximately 2.75 million L (726,500 gal) of MSU water were transferred and successfully treated during the MSU pilot study (DOE/RL-2018-70, *Optimization Pilot Test Results of Treating Water from Modular Storage Units at 200 West Pump & Treat Facility*).

Chapter 2 discusses the performance of 200 West P&T operations, including modifications made to support the 200-ZP-1 OU OSP. Chapter 3 discusses the performance of the 200-UP-1 OU groundwater remedy, and Chapter 4 discusses the performance of the 200-ZP-1 OU groundwater remedy, including the progress of the 200-ZP-1 OU optimization study. Chapter 5 discusses the performance of the 200-DV-1 OU perched water extraction system, and Chapter 6 discusses the performance of the 200-BP-5 OU groundwater extraction. Chapter 7 provides the references cited in the report.
The following information is included in Chapters 2 through 6:

- Activities and developments during 2019, including 200-ZP-1 OSP implementation and progress
- Summary of extraction well data (including extraction flow rates)
- Remedy performance (including mass removed and volume treated)
- Concentration trends for COCs in extraction and key monitoring wells
- Groundwater contaminant plumes
- Conclusions regarding 2019 remedy performance

Implementation of the optimization study, along with ongoing planned additional feed streams to the 200 West P&T, result in additional reporting needs to:

- Report on the optimization study interim results
- Incorporate relevant information from future comprehensive plume evaluations
- Organize cost data to evaluate optimization study impacts

These considerations will be incorporated into future updates of this report beginning in fiscal year (FY) 2021.

2 200 West Pump and Treat Remedial System Operation

This chapter discusses the remedial system operational activities for the 200 West P&T during 2019. These activities include the following general functions:

- Extracting contaminated groundwater from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs and contaminated perched water from the 200-DV-1 OU (discussed in Section 2.1)
- Conveying contaminated water to the 200 West P&T (discussed in Section 2.2)
- Treating extracted water at the 200 West P&T central treatment facility to remove contaminants (discussed in Section 2.3)
- Conveying treatment facility effluent water to injection points (discussed in Section 2.4)
- Emplacing effluent into the aquifer at locations underlying 200-ZP-1 and 200-UP-1 OUs via injection wells in accordance with regulatory agreed to conditions (discussed in Section 2.5)

Groundwater extraction wells are placed, designed, and operated to meet the RAOs/removal action objectives applicable for the individual OUs. Individual OU remedy performance is discussed in Chapters 3 through 6. Conveyance components (e.g., pipelines and transfer buildings [discussed in Section 2.3.1]) bring the extracted groundwater to the centrally located 200 West P&T process building for treatment. The 200 West P&T provides multiple unit processes to remove COCs from the influent groundwater stream, and Section 2.3 discusses the removal and removal efficiency of these processes.

Highlights

- The 200 West P&T remediates groundwater from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs; perched water from 200-DV-1 OU; and ERDF leachate.
- The treated effluent meets cleanup levels identified in the groundwater OU remedial/removal action decision documents, which include carbon tetrachloride, total chrome and Cr(VI), nitrate, technetium-99, TCE, uranium, and total and free cyanide.
- Biofouling in the effluent conveyance system components and injection wells continued to interfere with injection and drive well cleaning and rehabilitation. Continued well rehabilitation along with mitigation efforts that included chlorination of the injection system, pigging, and coagulant replacement were completed, which improved injection well capacity and decreased well rehabilitation events.
- Initial treatment of MSU water using the 200 West P&T was successfully demonstrated via an optimization pilot test plan to reduce the amount of well foulants using pre-treatment and to mitigate injection well fouling as recommended by Savannah River National Laboratory and PNNL personnel. The pilot test was successfully completed in April 2019.
- An optimization study was initiated, which resulted in the suspension of nitrate treatment system that contributed directly to the biofouling. Plant modifications were initiated to increase overall treatment capacity throughput and to accelerate the removal of carbon tetrachloride, which is the primary risk driver for the 200-ZP-1 OU. Two additional contributing elements for implementing the optimization study are a longer than expected abiotic degradation of carbon tetrachloride (630 year half-life) and a much larger mass of carbon tetrachloride found in the aquifer.

The system design includes IX, anoxic and aerobic bioreactors, and air stripping processes to treat contaminated groundwater to reduce concentrations of carbon tetrachloride, total chromium and Cr(VI), nitrate, technetium-99, TCE, uranium, and cyanide in groundwater. The effluent conveyance system transports the treated groundwater from the 200 West P&T to a series of injection wells located upgradient (west) and downgradient (east) of the 200-ZP-1 OU and 200-UP-1 OU contaminant plumes. Upgradient injection wells recharge the aquifer and steepen hydraulic gradients to the east, therefore accelerating flushing of the most highly contaminated portions of the aquifer toward the extraction wells. Downgradient injection wells slow natural eastward flow and maintain the majority of targeted COCs within the hydraulic capture zone of the extraction wells. Downgradient injection wells are also located to hydraulically contain the 200-UP-1 iodine-129 groundwater plume while iodine-129 treatment technology evaluation is being performed.

Figure 2-1 shows the layout of the Central Plateau groundwater remedial system elements. Figure 2-2 provides an aerial photograph of the 200 West P&T central treatment facility. Groundwater remediation using the 200 West P&T is critical for achieving the RAOs for the Central Plateau OUs. Progress toward meeting the RAOs/removal action objectives for groundwater treated through the 200 West P&T are discussed in the following sections for each OU:

- 200-UP-1 OU groundwater from the S-SX groundwater extraction system (Section 3.1.3.3)
- 200-UP-1 OU groundwater from the U Plant area groundwater extraction system (Section 3.2.3.3)
- Groundwater remediation from the 200-ZP-1 OU (Section 4.7)
- Perched water from the 200-DV-1 OU (Section 5.1.3)
- Groundwater extracted from the 200-BP-5 OU (Section 6.2.5)

The 200 West P&T treats contaminated water from several groundwater OUs, including 200-UP-1 and 200-BP-5; perched water from the 200-DV-1 OU; and ERDF leachate. In 2019, no new feed streams were added to the 200 West P&T. However, MSU purgewater treatment was initiated as part of an optimization pilot test (DOE/RL-2018-28) in May 2018 and was completed in April 2019 to minimize well fouling and improve the injective capacity of the injection wells. Section 2.2 describes the MSU activities for 2019.

In 2019, the 200-ZP-1 OU OSP (DOE/RL-2019-38) was initiated to evaluate treatment facility modifications, 200 West P&T operational effectiveness, and cost implications for increasing the 200 West P&T treatment design capacity for carbon tetrachloride. As identified in the 200-ZP-1 OU OSP, data and information acquired following the issuance of the 200-ZP-1 OU ROD (EPA et al., 2008) suggest that conditions are less favorable and highly unlikely to allow carbon tetrachloride to reach the cleanup level under the current remedy configuration in the timeframe specified in the ROD. A predictive analysis was conducted using the newer information to evaluate whether the current remedy configuration could meet the RAOs for carbon tetrachloride, which is the primary risk driver due to its high concentration relative to the cleanup level and corresponding large mass within the aquifer. The analysis indicated that without modification, carbon tetrachloride remediation would not meet cleanup levels within the 125-year timeframe. The analysis also suggested that sufficient nitrate treatment may have occurred to transition to MNA, since nitrate concentrations are less than an order of magnitude above the cleanup level. The 200-ZP-1 OU OSP provides an overall approach to conduct well network optimization to increase overall treatment capacity and accelerate carbon tetrachloride treatment and mass removal.

The optimization study will also evaluate transitioning to MNA for nitrate and the effect of suspending the biological treatment component of the 200 West P&T. Combined, these changes will focus on increasing carbon tetrachloride treatment capacity and mass removal, streamlining operation, reducing costs, and providing data for plume remediation performance. The performance monitoring data will be used in conjunction with predictive modeling to support evaluation of potential future remedy modification. In particular, performance monitoring data will be used to evaluate enhancement of carbon tetrachloride remediation and the ability to meet RAOs for nitrate and other COCs without biological treatment. The total duration of the data collection and monitoring task is estimated to be approximately 5 to 7 years.

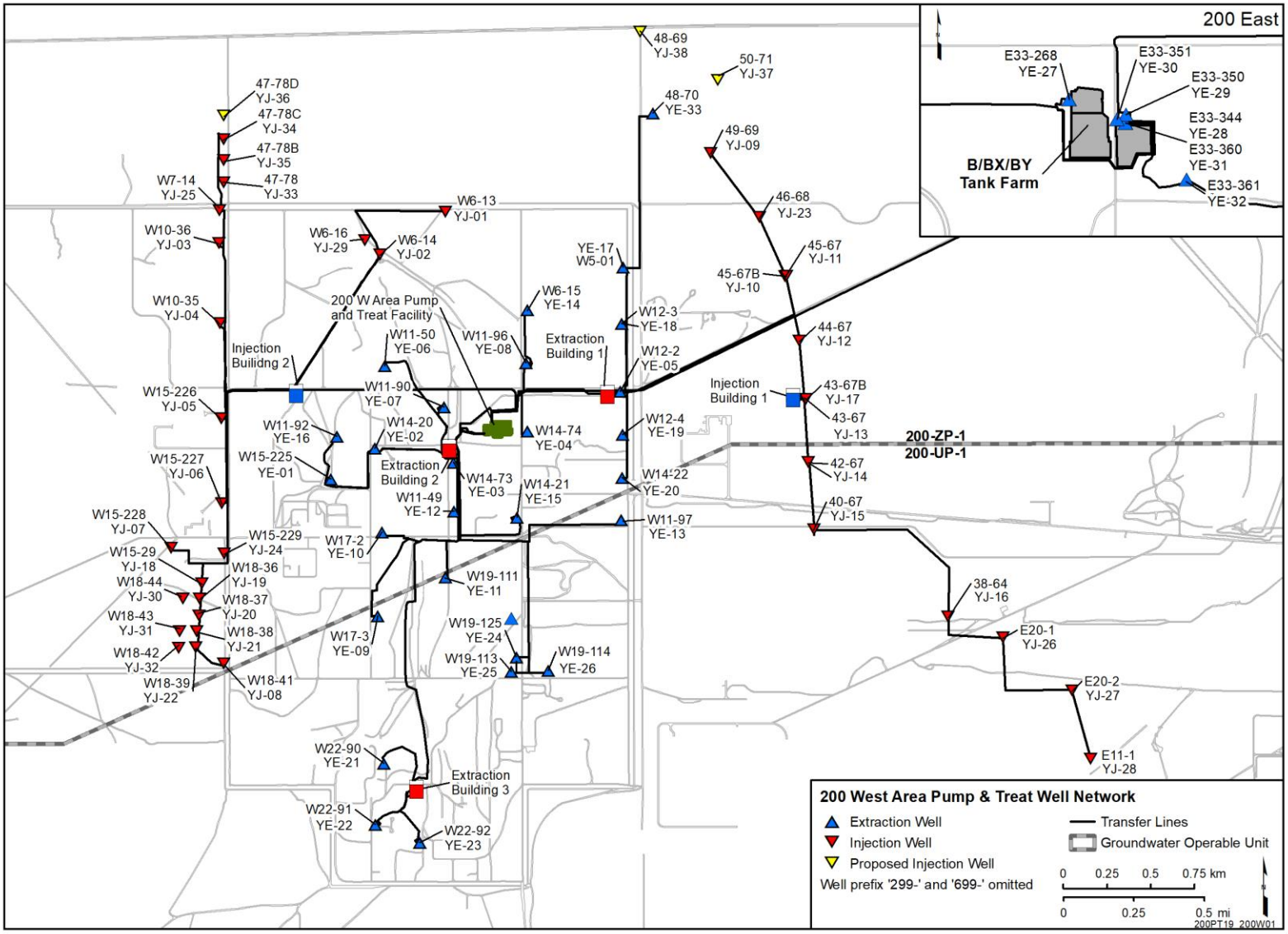

Figure 2-1. 200 West P&T Project Components, Well Locations, and Piping Routes

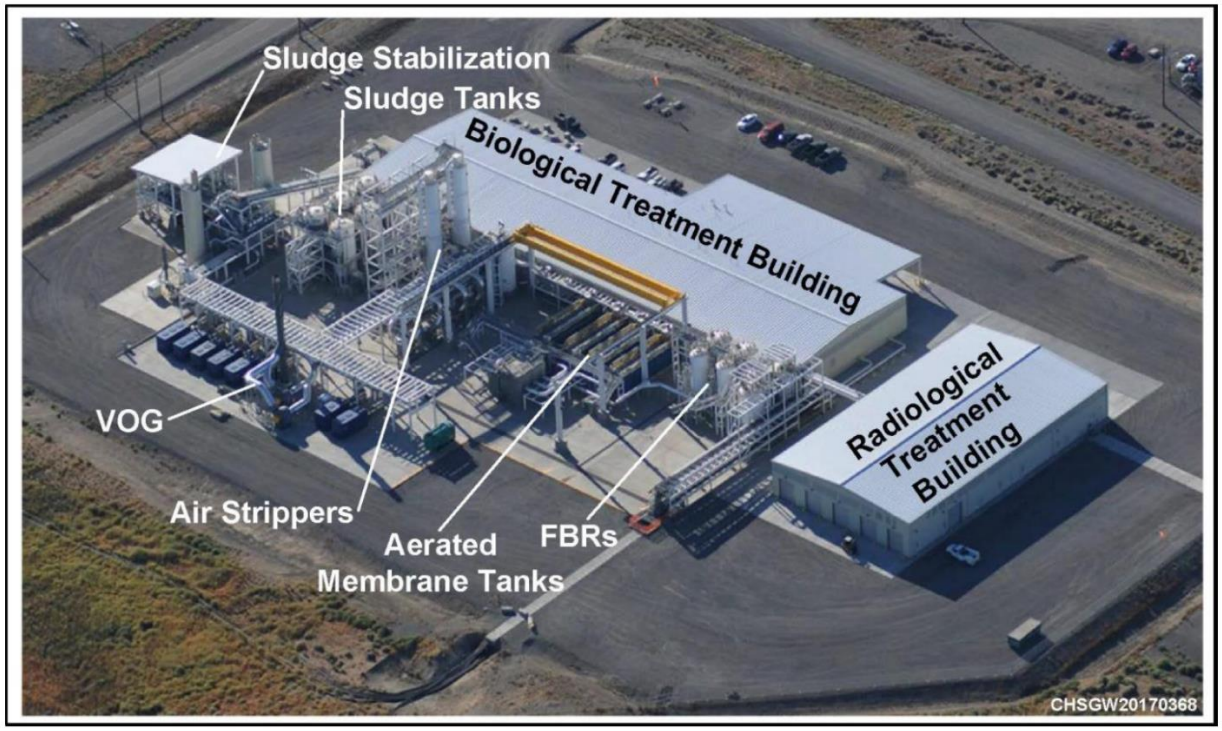

Figure 2-2. 200 West P&T Central Treatment Facility

Other aspects of the optimization study involve conducting plant modifications to add a third air stripper tower and adding additional extraction and injection wells. Significant changes to the injection well network are expected after groundwater simulations for optimizing well configurations are completed, which will provide input to the data quality objective (DQO) and data evaluation processes. Section 2.3 provides further discussion on modifications to the treatment facility.

2.1 Groundwater Extraction Well Network in the Hanford Central Plateau

During 2019, a total of 33 extraction wells were connected to 200 West P&T from the Central Plateau OUs as follows:

- Six extraction wells from the 200-UP-1 OU (includes three wells in WMA S-SX)
- Twenty-one wells from the 200-ZP-1 OU
- Three extraction wells from the 200-BP-5 OU
- Three extraction wells removing perched water from the 200-DV-1 OU

The Central Plateau extraction well networks are designed to hydraulically contain and recover groundwater contaminants within the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs and perched water from the 200-DV-1 OU. Table 2-1 summarizes the extraction well operations for 2019.

Table 2-1. Flow Rates and Total Run Times for 200 West P&T Extraction Wells, 2019

Well ID	Well Name	Engineering ID	Average Flow Rate, L/min (gal/min)[a]	Pump Run Time (% Out of 8,760 Hours)[b]	Target Flow Rate, L/min (gal/min)[c]	Percent Time Pumping at or Above Target Flow Rate[d]	Purpose
C7017	299-W15-225	YE01B	344.7 (91)	87.7	272 (72)	69	200-ZP-1[g] extraction
C7018	299-W14-20	YE02B	380 (100)	99.7	325 (86)	81	
C7021	299-W14-73	YE03B	391 (103)	80.3	287 (76)	62	
C7024	299-W14-74	YE04	372 (98)	97.8	306 (81)	76	
C7027	299-W12-2	YE05B	366 (97)	99.7	303 (80)	73	
C7020	299-W11-50	YE06B	226 (60)	94.2	212 (56)	90	
C7022	299-W11-90	YE07B	335 (88)	100.0	287 (76)	85	
C7754	299-W11-96	YE08	306 (81)	97.5	246 (65)	93	
C7577	299-W17-3	YE09B	401 (106)	94.2	310 (82)	82	
C7576	299-W17-2	YE10B	346 (91)	63.6	253 (67)	58	
C8718	299-W19-111	YE11B	108 (29)	26.3	79 (21)	25	
C7019	299-W11-49	YE12B	444 (117)	98.6	359 (95)	82	
C8719	299-W11-97	YE13B	414 (109)	94.8	325 (86)	83	
C8720	299-W6-15	YE14B	294 (78)	97.8	250 (66)	93	
C7494	299-W14-21	YE15B	347 (92)	98.6	295 (78)	92	
C7025	299-W11-92	YE16B	389 (103)	93.7	306 (81)	78	
C8721	299-W5-1	YE17B	330 (87)	100.0	268 (71)	72	
C7028	299-W12-3	YE18B	344 (91)	100.0	280 (74)	73	
C7029	299-W12-4	YE19B	465 (123)	99.7	401 (106)	82	
C7030	299-W14-22	YE20B	399 (105)	97.8	325 (86)	77	
C9988	699-48-70[e]	YE-33	293 (77)	100.0	276 (73)	100	
C8095	299-W22-90	YE21B	92 (24)	84.1	79 (21)	81	S-SX[h] extraction
C8096	299-W22-91	YE22B	113 (30)	99.7	106 (28)	97	
C8097	299-W22-92	YE23B	94 (25)	99.2	83 (22)	96	

Table 2-1. Flow Rates and Total Run Times for 200 West P&T Extraction Wells, 2019

Well ID	Well Name	Engineering ID	Average Flow Rate, L/min (gal/min)[a]	Pump Run Time (% Out of 8,760 Hours)[b]	Target Flow Rate, L/min (gal/min)[c]	Percent Time Pumping at or Above Target Flow Rate[d]	Purpose
C9594	299-W19-125	YE24B	182 (48)	100.0	166 (44)	89	200-UP-1[i] extraction
C8927	299-W19-113	YE25B	178 (47)	99.5	166 (44)	94	
C8928	299-W19-114	YE26B	273 (72)	100.0	231 (61)	88	
C8243	299-E33-268[f]	YE27B	0 (0)	—	0 (0)	—	200-BP-5[j] extraction
C8923	299-E33-360	YE31B	480 (127)	100.0	390 (103)	98	
C8924	299-E33-361[e]	YE32	205 (54)	100.0	181 (48)	96	
C5859	299-E33-344	YE28B	0.36 (0.10)	—	—	—	200-DV-1[k] extraction
C8914	299-E33-350	YE29B	1.43 (0.38)	—	—	—	
C8915	299-E33-351	YE30B	0.86 (0.23)	—	—	—	

References:

DOE/RL-2008-78, Rev. 0 REISSUE, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*.

DOE/RL-2013-07, *200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*.

DOE/RL-2017-11, *Removal Action Work Plan for the 200-BP-5 Operable Unit Groundwater Extraction*.

a. Average flow rate when extraction well is operational. Flow rates are rounded to the nearest whole number, except when flow rates are <3.78 L/min (1 gal/min).

b. Percentage total run time is calculated by [(hours well in operation during the year) ÷ (number of hours in the calendar year)].

c. Pumping rate target for 2019 based on modeling and operational capabilities.

d. Percentage time pumping at or above target is calculated by [(hours well pumping rate is equal to or greater than target) ÷ (number of hours in the calendar year)].

e. Extraction from these wells started in 2019. Extraction started from well 299-E33-361 in May and well 699-48-70 in December.

f. No pumping from well during 2019.

g. The 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) estimates that each extraction well will be capable of producing approximately 379 L/min (100 gal/min) on a sustained basis based on the aquifer hydraulic properties and anticipated well screen lengths.

h. The combined Waste Management Area S-SX extraction rate identified in the 200-UP-1 OU RD/RAWP (DOE/RL-2013-07) is 303 L/min (80 gal/min).

i. The combined U Plant extraction rate identified in the 200-UP-1 OU RD/RAWP (DOE/RL-2013-07) is 568 L/min (150 gal/min).

j. The expected total flow rate from the extraction wells in the 200-BP-5 OU removal action work plan (DOE/RL-2017-11) is 189 to 568 L/min (50 to 150 gal/min)

k. The perched wells operate differently than most wells. For these wells, pumping is intermittent, with the pumps on for 2 to 5 minutes before excessive drawdown triggers the level control switch and water levels recover for 16 to 26 minutes.

ID = identification
OU = operable unit
P&T = pump and treat
RD/RAWP = remedial design/remedial action work plan

During 2019, the extraction well performance was evaluated monthly for mass removal and efficiency to determine if maintenance (other than routine) was required. Based on these evaluations, two extraction wells (299-W17-2 and 299-W19-111) operated at or above the target flow rate <60% of the year. The pump in well 299-W17-2 required corrective maintenance and was nonoperational in late 2018 through May 2019 and averaged 341 L/min (90 gal/min) while operational. Well 299-W19-111 has always been a low-flow well due to a well screen that was damaged during installation and has operated at low flow due to the broken well screen, as well as low contaminant concentrations observed at this well. In 2019, this well was operated more often than in the past to help increase the total flow to the 200 West P&T to reach the 9,500 L/min (2,500 gal/min) maximum design capacity. Extraction well 299-E33-268 is the initial 200-BP-5 OU groundwater extraction well and has been offline since June 2017. The well is located near the upgradient edge of the technetium-99 plume and was turned off to increase pumping from 200-BP-5 OU groundwater extraction well 299-E33-360 (downgradient) to increase technetium-99 removal. Chapter 6 provides further discussion on 200-BP-5 OU groundwater extraction.

In early October 2019, the 200-ZP-1 OU OSP (DOE/RL-2019-38) was implemented, which included the addition of extraction wells. Ten new extraction wells are planned to support the OSP, enabling an increased flow for the 200-ZP-1 OU of 11,621 L/min (3,070 gal/min). Five wells are planned to be drilled and constructed in FY 2020 and five in FY 2021 that will support the increased capacity flow for the 200-ZP-1 OU to 11,621 L/min (3,070 gal/min) by the start of FY 2022.

2.2 Conveyance of Extracted Groundwater to the 200 West Pump and Treat System

The extracted groundwater conveyance system is comprised primarily of aboveground, heat-welded, high-density polyethylene (HDPE) pipe connecting extraction wells to the 200 West P&T and/or to intermediate extraction transfer buildings (ETBs). The extraction conveyance system operated as designed during 2019.

The ETBs generally contain a tank (or tanks) to collect water from wells in the area and pumps to transfer the stored water to the 200 West P&T. The storage tanks in the ETBs are fitted with separate, vapor-phase granular activated carbon (VPGAC) absorbers. In 2019, all of the ETBs were operational. One ETB supports extraction activities near the S-SX Tank Farms in the 200-UP-1 OU. Groundwater pumped from 200-BP-5 OU extraction wells is collected in a transfer tank located in the B Complex area (200 East Area) and then pumped to the 200 West P&T. A separate collection tank in the B Complex area collects extracted perched water from the 200-DV-1 OU. The collected perched water is then pumped to the 200-BP-5 OU collection tank for transfer to the 200 West P&T with groundwater from the 200-BP-5 OU. The extraction conveyance systems include >16 km (10 mi) of surface-lain HDPE pipe in addition to the ETBs. The extraction conveyance system did not experience any issues during 2019.

In April 2019, the MSU pilot test (DOE/RL-2018-28) for treating MSU water through the 200 West P&T was completed. The MSU water consists of purgewater from well construction, development, groundwater sampling purgewater, and well rehabilitation activities. Prior to 2017, evaporation was sufficient to provide capacity in the MSUs. As the frequency of well rehabilitation increased due to fouling of injection well screens and aggressive well rehabilitation, evaporation was unable to resolve the MSU capacity needs. Evaporation was augmented with periodic treatment at the Effluent Treatment Facility. In spring 2017, evaporation was insufficient, and the Effluent Treatment Facility was unable to reliably treat the MSU water. In summer 2017, a technical assessment was performed to determine the capability of the 200 West P&T for MSU water treatment (SGW-61287, *Impact of Modutank Water on the 200 West Pump and Treat*). The initial evaluation indicated that the water in the MSUs met the feed

stream acceptance criteria for the 200 West P&T, leading to implementation of the optimization test. The MSU pilot test focused on characterizing selected physical and chemical characteristics of the MSU water, with emphasis on the COCs, optimization to mitigate well fouling, and development of a process for effective purgewater processing.

The MSU pilot test demonstrated that MSU water can be successfully treated at the 200 West P&T without impact to the facility operations (DOE/RL-2018-70, *Optimization Pilot Test Results of Treating Water from Modular Storage Units at 200 West Pump & Treat Facility*), making the transfer of MSU purgewater from the MSUs to the 200 West P&T a routine feed stream. DOE/RL-2009-39, *Investigation-Derived Waste Purgewater Management Plan Action Memorandum*, was modified in August 2019 (TPA-CN-0841, *Tri-Party Agreement Change Notice Form: DOE/RL-2009-39, Investigation-Derived Waste Purgewater Management Plan Action Memorandum, Rev. 0*) to allow shipping MSU water to the 200 West P&T for treatment.

The MSUs are located to the east, approximately 8 km (5 mi) from the 200 West P&T (Figure 2-3). The HDPE pipe was installed from the MSUs to the cross-site transfer line located near the BX-BY Tank Farms (Figure 1-1).

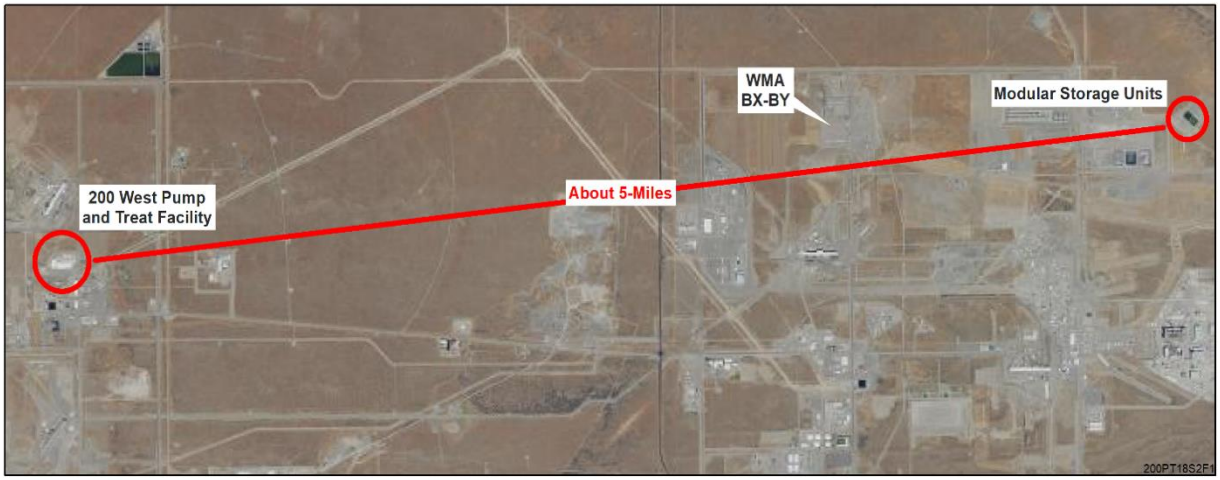

Figure 2-3. Location of the MSUs on the Hanford Site

2.3 200 West Pump and Treat Remedial System Overview

This section summarizes the 200 West P&T, flow rates, and data collected to monitor performance. Data collection associated with 200 West P&T system operations began in July 2012 following facility startup. Table 2-2 lists the 200 West P&T performance parameters for 2019 for the combined total water processed through the treatment facility. Performance parameters and decisions regarding optimization and system performance to meet RAOs/removal action objectives for the 200-UP-1, 200-ZP-1, and 200-BP-5 OUs are discussed in Chapters 3, 4, and 6, respectively. Performance parameters for 200-DV-1 OU perched water extraction is discussed in Chapter 5.

Table 2-2. 200 West P&T Performance for 2019

Performance	2019	Since 2012[a]
Total groundwater processed (million L [million gallons])	4,237.8 (1,118.7)	25,642.7 (6,769.7)
Mass Removed[b]		
Carbon tetrachloride (kg)	1,917	17,040
Hexavalent chromium[c] (kg)	68.52	505.77
Iodine-129[d] (pCi)	__[d]	__[d]
Nitrate (as NO_3) (kg)	245,982	2,186,276
Technetium-99 (g)	108.8	774.1
Trichloroethene (kg)	10.5	76.0
Uranium (kg)	102.98	630.62
Average Mass Removal Efficiency[e]		
Carbon tetrachloride	99.9%	99.9%
Chromium (total and hexavalent)[f]	84.2%	82.1%
Iodine-129[d]	N/A	N/A
Nitrate (as NO_3)[f]	73.6%	75.3%
Technetium-99	92.5%	95.7%
Trichloroethene	89.4%	89.6%
Uranium	98.6%	98.9%
System availability[g]	>90%	>90%

a. The 200 West pump and treat began operating in July 2012.

b. Mass removed is the contaminant mass removed by each extraction well minus the contaminant mass in the effluent reinjected through injection wells. The contaminant mass removed by each extraction well is the sampled well contaminant concentration multiplied by the total volume extracted from the well between sample intervals. The contaminant mass in the effluent is the sampled effluent concentration multiplied by the total reinjected effluent volume between sample intervals.

c. Hexavalent chromium mass removed also applies to the contaminant of concern total chromium because chromium dissolved in groundwater is primarily hexavalent chromium.

d. Removal efficiency was not calculated for iodine-129 because concentrations were at or below the minimum detectable activity in >50% of the influent and effluent samples.

e. Mass removal efficiency = {[(influent tank concentration) – (effluent tank concentration)] ÷ (influent tank concentration)} × 100. Influent concentration of radiological constituents is measured at the radiological treatment building and chemical constituent influent concentrations are measured at the biological treatment facility influent tank.

f. Biological treatment for nitrate was shut off in October 2019 and nitrate and chromium (total and hexavalent) were no longer treated; average mass removal efficiency for chromium and nitrate reflect removal efficiency during biological treatment.

g. System availability = [(total time online) ÷ (total possible run time)].

N/A = not applicable

2.3.1 200 West Pump and Treat Remedial System Components

The 200 West P&T includes seven primary system components: (1) radiological treatment, (2) central treatment, (3) sludge handling, (4) sludge stabilization, (5) chemical feed system, (6) air stripping, and (7) off-gas treatment. The major components for each of the systems are as follows:

- The radiological treatment system includes IX resins to remove technetium-99 and uranium.
- The biological treatment systems include anoxic/anaerobic biodegradation fluidized bed reactors (FBRs), chemical precipitation, and aerobic biodegradation/membrane filtration (membrane bioreactors [MBRs]) for anions, metals, and organics. This system operated through the first three quarters of 2019 until active biological treatment was suspended to conduct the 200-ZP-1 OU optimization study. Other changes in 2019 included the addition of a disinfection system to prevent biological growth from fouling the injection wells.
- The sludge handling system includes rotary drum thickeners, aerated sludge and centrate holding tanks, centrifuge dewatering, and filtrate and centrate return systems. Layup of the sludge handling system is planned for FY 2020 in support of the 200-ZP-1 OU OSP (DOE/RL-2019-38), as described in Section 2.3.1.8.
- The sludge stabilization system includes lime silos, pug mills, and screw conveyors. Layup of the sludge stabilization system is planned for FY 2020 in support of the 200-ZP-1 OU OSP (DOE/RL-2019-38), as described in Section 2.3.1.8.
- The chemical feed system includes storage and feed facilities for the following: acid for pH adjustment, nutrients for the biological system, a coagulant to aid in solids removal, and sodium hypochlorite for disinfection. The chemicals that have been suspended due to layup activities with the suspension of active biological treatment include the following:
  - Nutrients for the biological system: carbon substrate, micronutrient, and phosphoric acid
  - Cleaning chemicals for the MBR system: sodium hypochlorite, sodium thiosulfate, citric acid, and sodium hydroxide
- The air stripping system includes two packed tower air strippers.
- The off-gas treatment system includes conveyance of air stripper and tank off-gas emissions, as well as VPGAC vessels for off-gas treatment and a stack for dispersing the treated off-gas.

The 200 West P&T includes two separate buildings: the radiological treatment facility to house the radiological treatment equipment (e.g., filters and IX columns); and the biological treatment facility, which includes the balance of the unit processes (Figure 2-2). Several major components (e.g., aeration/ microfiltration pumps, rotary drum thickener, and carbon substrate tanks) are located within the biological treatment building. A pad equipped with a containment curb and sump to provide secondary containment is located adjacent to the biological treatment building. Treatment components (e.g., equalization tank, FBR, and aeration tanks/microfiltration) are located on this pad.

In 2019, the radiological building contained three IX trains:

- One IX train with a nominal flow capacity of 1,136 L/min (300 gal/min) and maximum of 1,515 L/min (400 gal/min) was installed in 2015 and treats uranium-contaminated water from the 200-UP-1 OU, perched water from the 200-DV-1 OU, and contaminated water from the 200-BP-5 OU.

- Two IX trains that remove technetium-99 from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs and the perched water from the 200-DV-1 OU at a combined nominal flow capacity of 2,271 L/min (600 gal/min) and maximum of 3,030 L/min (800 gal/min).

Figure 2-4 shows the various components and pathways for the 200 West P&T process train and identifies the component systems that were suspended starting in October 2019 for the 200-ZP-1 OU optimization study. Overviews of each system component and operation during 2019 are provided in the following sections.

2.3.1.1 Radiological Treatment

Radiologically contaminated groundwater extracted from wells targeting technetium-99 and uranium plumes in the 200-ZP-1, 200-UP-1, 200-BP-5, and 200-DV-1 OUs and collected leachate from ERDF are transferred to the radiological treatment building (Figure 2-4). At the radiological treatment building, the influent is treated through IX trains to reduce uranium and technetium-99 concentrations. The radiological treatment system will be expanded in the near-term to add an additional IX train to support increased extraction of technetium-99 from the 200-BP-5/200-PO-1 OUs. The system contract was awarded in 2019 and is expected to be delivered in September 2020.

During 2019, the uranium IX resin train operated at 1,326 L/min (350 gal/min), which is greater than the designed nominal flow rate of 1,136 L/min (300 gal/min). In 2019, uranium IX column resin changeout was not necessary due to declining uranium concentrations from the 200-UP-1 OU and 200-BP-5 OU groundwater extraction wells (see Chapters 3 and 6, respectively), resulting in less uranium loading on the IX resin. The last uranium IX column resin changeout was in October 2017. The technetium-99 IX train operated at an average of 2,264 L/min (598 gal/min), which is essentially the designed nominal flow rate of 2,271 L/min (600 gal/min). The last technetium-99 IX column resin changeout for train A was in September 2018 and for train B was in November 2016.

2.3.1.2 Biological Groundwater Treatment System

The biological groundwater treatment system is designed to remove a variety of contaminants (most notably carbon tetrachloride and nitrate). It is composed of two FBRs and four aerated membrane tanks. In October 2019, the active biological treatment system was suspended to support the 200-ZP-1 OU optimization study. With suspension of active biological treatment, facility modifications were completed to install piping to route nonradiologically contaminated water from ETB-2 (tank #2) to the discharge header of the aerated membrane tank system to bypass the biological treatment system (Figure 2-4). This modification was implemented to enable increased capacity through the 200 West P&T as one aspect of the 200-ZP-1 OU OSP (DOE/RL-2019-38). Layup of the additional facility modifications planned for FY 2020 in support of the optimization study is described in Section 2.3.1.8.

2.3.1.3 Sludge Handling

Sludge handling during 2019 operated within design parameters and without issues, generating 1,316 m^3 (46,438 ft^3) of consolidated waste. In 2019, a total of 92 roll-off boxes (14 m^3 [494 ft^3] per roll-off box) were shipped to ERDF. This unit operation was suspended in the fall following cleanout of the active biological treatment system. Layup of the sludge handling system is planned for FY 2020 in support of the 200-ZP-1 OU OSP (DOE/RL-2019-38), as described in Section 2.3.1.8.

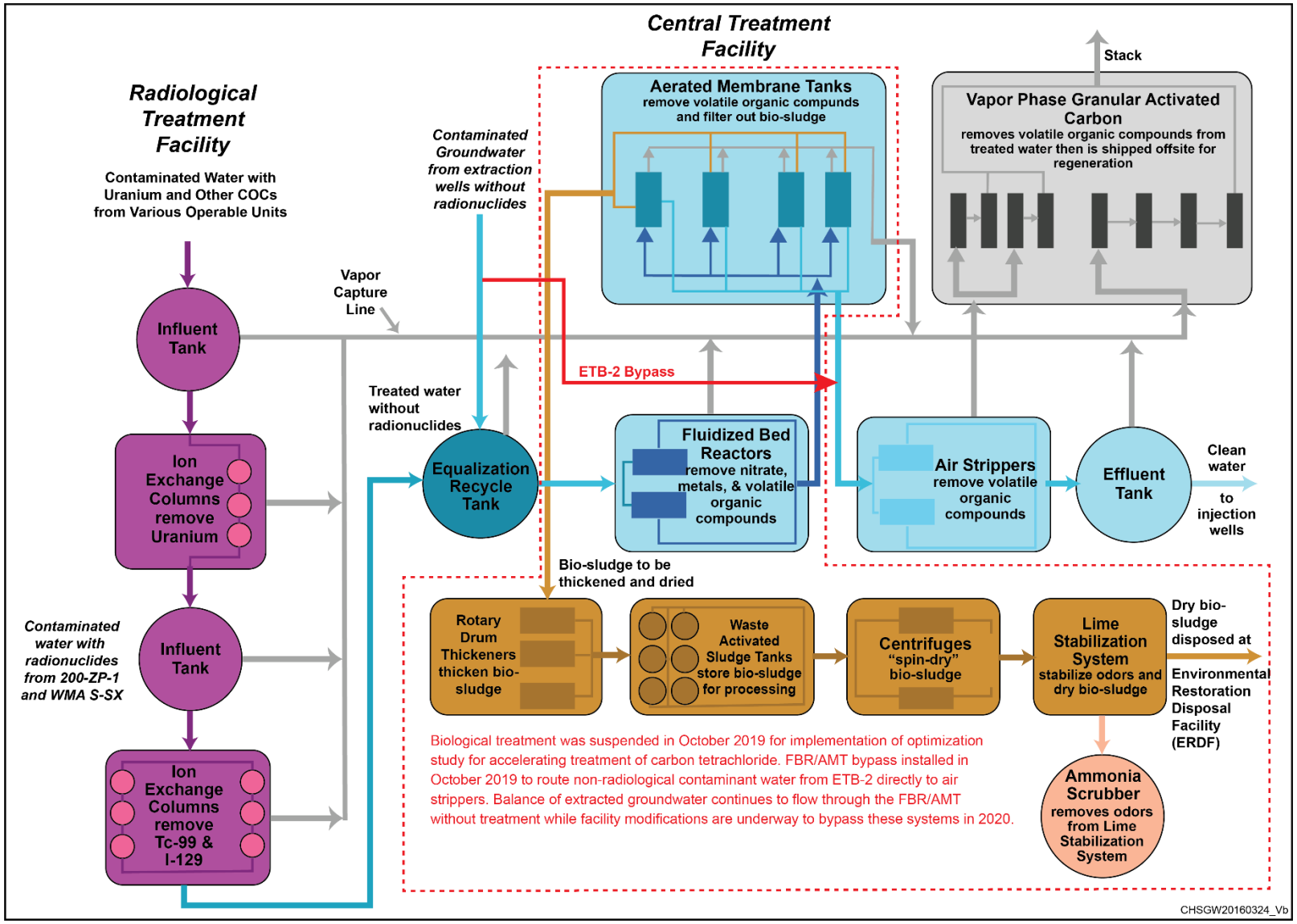

Figure 2-4. 200 West P&T Treatment Process Train

2.3.1.4 Sludge Stabilization

During 2019, the sludge stabilization system performed to design capacity, and the combined biosolids and debris were managed and shipped to ERDF. Waste was managed in accordance with the 200-ZP-1 OU waste management plan (Appendix B of DOE/RL-2009-124, *200 West Pump and Treat Operations and Maintenance Plan* [hereinafter referred to as the 200 West P&T O&M plan]). All solids met ERDF waste acceptance criteria (ERDF-00011, *Environmental Restoration Disposal Facility Waste Acceptance Criteria*). This unit operation was suspended following cleanout of the biological treatment system. Layup of the sludge stabilization system is planned for FY 2020 in support of the 200-ZP-1 OU OSP (DOE/RL-2019-38), as described in Section 2.3.1.8.

2.3.1.5 Air Stripping System

During 2019, the air stripper system was operational except during routine maintenance or troubleshooting activities. All volatile COCs were removed to below cleanup levels without incident.

A third air stripper tower to expand treatment capability supporting the optimization study is being procured. The contract was awarded in September 2019 and is expected to be delivered in late August 2020.

2.3.1.6 Off-Gas Treatment System

During 2019, the VPGAC system operated as designed. Eight active granular activated carbon (GAC) canisters were changed out, and four GAC units were regenerated offsite and then returned to use. All volatile contaminants were within acceptable source impact level limits (WAC 173-460-150, "Controls for New Sources of Toxic Air Pollutants," "Table of ASIL, SQER and de minimis Emission Values"). Changeout, regeneration, and disposal of GAC is managed in accordance with the 200-ZP-1 OU waste management plan (Appendix B of the 200 West P&T O&M plan [DOE/RL-2009-124]).

2.3.1.7 Reliability and Redundancy Provisions

To achieve the cleanup goals, reliability and redundancy provisions have been included in the 200 West P&T design (DOE/RL-2010-13, *200 West Area Groundwater Pump-and-Treat Remedial Design Report*). The provisions are in place to ensure that the system has flexibility to continue operating during routine and preventive maintenance activities, as well as backup provisions in the case of unscheduled maintenance or equipment failure. The reliability and redundancy provisions were maintained during 2019.

Additional improvements to the facility to increase system reliability included the following:

- In preparation of active biological suspension and bypassing the FBR and aerated membrane tank systems, a pipe stress analysis was performed on the 16 in. polyvinyl chloride (PVC) bypass line. In response, a section comprised of two 45-degree PVC bends and a section of 90-degree PVC bend was replaced with stainless steel. This change will reduce the risk of failure on the 16 in. bypass line.
- A sodium hypochlorite disinfection system was installed at the 200 West P&T to inject sodium hypochlorite at the treatment facility. This system disinfects the plant effluent water to prevent biological fouling of the injection wells and can be operated remotely through the supervisory control data acquisition system to reduce worker contact with the chemicals. Temporary systems at two injection transfer buildings (ITBs) (ITB-1 and ITB-2) were suspended when the full system began operating.

- The instrument air compressor supply system was upgraded to stainless steel in certain sections to ensure that the system operates within requirements defined in ASME B31.3, *Process Piping*. Pressure relief valves were also installed in various sections of the instrument air supply to provide over-pressurization protection and maintain compliance.

2.3.1.8 Optimization Study Facility Modifications, Data Collection, and Monitoring

Targeted study components in the 200-ZP-1 OU optimization study will focus on changes to the facility design sampling, facility monitoring, and well network configuration to increase overall facility treatment capacity and to accelerate the carbon tetrachloride mass removal. This section highlights the new configuration and associated sampling points, as well as other operational data collection needs that are focused on only the Ringold Formation member of Wooded Island – unit E (Rwie) for approximately 5 to 7 years. Table 2-3 lists the treatment processes (current and during the optimization study period) for each COC. Processed water is expected to meet the cleanup criteria for all COCs except nitrate, which will rely on MNA processes during the optimization study period.

Several preliminary activities (Task 1 activities outlined in DOE/RL-2019-38) will be performed to prepare for biological deactivation, including cleaning the air strippers to prepare for increased volatile organic compound (VOC) loading and stopping the feed of nutrients to the biological systems:

- **FBR/aerated membrane tank:** The GAC media will be removed from the FBRs, and the splitter box will be cleaned out. The chemical feed lines and pumps will be flushed to limit deterioration of pumps, valves, and instrumentation. The membrane cassettes will be removed from the aerated membrane tanks, the tanks will be flushed to remove remaining solids, and the cassettes will be retrofitted with well screens to prevent solids from passing to the air stripper. The FBR and aerated membrane tank modifications will allow the existing pumps and lines to be used to transfer water to the air strippers until modifications are made to the 16 in. bypass line.

- **Sludge handling system:** The sludge handling system will be cleared of remaining solids, beginning with the three rotary drum thickeners and the centrifuges. The associated pumps, piping, and polymer feed systems will be flushed to limit deterioration. The three aerated sludge holding tanks and aerated centrate holding tanks will be flushed to remove loose solids. The sumps that collect centrate and filtrate and the associated lines and pumps will be flushed.

- **Automated control system:** The automated control system (which operates the facility when the plant is not staffed) and computer interface will be changed to reflect the change in status of the various treatment systems that are impacted.

Table 2-3. Summary of 200 West P&T Current and Optimization Study Period Treatment Processes

Description	COC[a]								
	Carbon Tetrachloride	Trichloroethene	NO_3 (as N)	Chromium (Total)	Hexavalent Chromium	Iodine-129	Tritium	Technetium-99	Uranium
Final cleanup level[b]	3.4 µg/L[c]	1 µg/L[c]	10,000 µg/L	100 µg/L	48 µg/L[c]	1 pCi/L	20,000 pCi/L	900 pCi/L	30 µg/L
Average influent concentration	555 µg/L	3.32 µg/L	30,000 µg/L	28.6 µg/L	27.6 µg/L	0.53 pCi/L	2,296 pCi/L	1,745 pCi/L	335 µg/L
Current treatment processes	Bioreactors + air strippers/GAC		Bioreactors	Treatment not needed (influent below cleanup levels)				Ion-exchange resin	
Treatment processes during optimization study period	Air strippers/GAC		Blending + MNA	Treatment not needed (influent below cleanup levels)				Ion-exchange resin	

a. The COCs are identified in the respective 200-ZP-1 OU, 200-UP-1 OU, 200-BP-5 OU, and 200-DV-1 OU perched water remedial/removal action work plans for treatment through the 200 West pump and treat.

b. Cleanup levels are the federally specified maximum contaminant level unless otherwise noted.

c. Cleanup level specified for the 200-ZP-1 OU ROD (EPA et al., 2008, *Record of Decision Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington*).

COC = contaminant of concern
GAC = granular activated carbon
MNA = monitored natural attenuation
OU = operable unit
ROD = Record of Decision

In 2019, the suspension of the active biological treatment system included and subsequently planned for the following activities:

- Approximately 50% complete of Phase 1 of the layup of the active biological treatment system
  - Upgrades to ETB-2 bypass line tie-in
  - Removal of bulk carbon from the fluidized bed reactors
  - Completion of a pipe stress analysis on the 16 in. bypass line
- Complete Phase 1 layup activities in FY 2020:
  - Long-term shutdown and layup of rotary drum thickeners, centrifuges, and associated equipment
  - Removal of the residual sludge from the holding tanks for disposal at the MSU
  - Hydrostatic testing of the 16 in. bypass line

Facility performance monitoring for the 200 West P&T is guided by the requirements of the 200 West P&T O&M plan (DOE/RL-2009-124) and is supplemented by the 200-ZP-1 OU OSP (DOE/RL-2019-38). Figure 2-5 depicts the facility performance sampling locations for the 200 West P&T. Additional sample points will be added as the facility is modified and as needed.

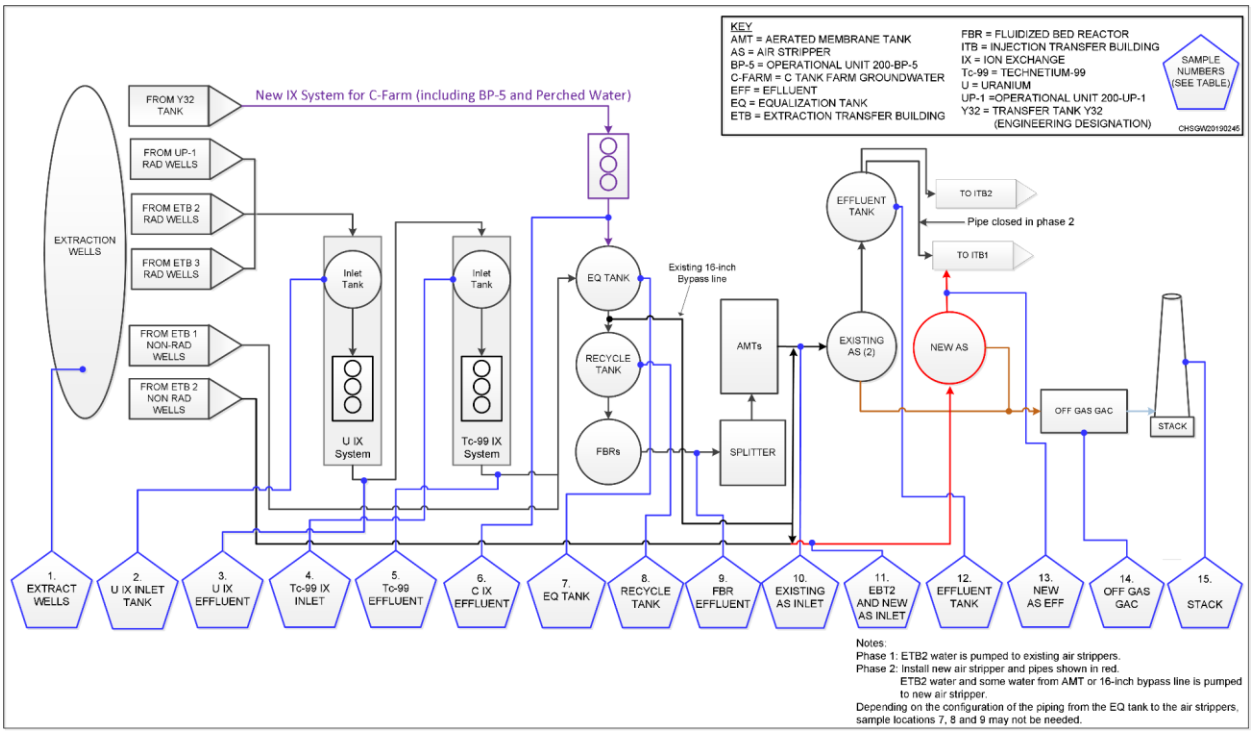

Figure 2-5. Schematic of Facility Performance Sampling Locations in the 200 West P&T

Transition to no active biological treatment (which began when the FBRs were restarted after the GAC was removed) consisted of collecting samples of the different sample points. Sampling frequency was increased at the 200 West P&T to evaluate treatment of carbon tetrachloride without the biological system. Water samples throughout the plant were taken on a weekly basis to determine steady-state conditions and performance of the air stripping towers. Weekly air samples were also taken at the GAC off-gas vessels and the treated off-gas stack.

The objective was to sample to steady state from the effluent tank. The facility developed a context for data by defining "steady state":

- Review influent concentrations just prior to suspension of biological treatment.
- Observe downward trend.
- Use results from March 26 through July 25, 2019, as representative of steady state.
- Use a range of 0 to detection limit as representative of steady state for constituents that are typically below the detection limit.

A steady state was reached after 5 weeks, and the sampling frequency was adjusted to the typical monthly interval. The results of the effluent concentrations for achieving steady state are presented in Table 2-4 and in SGW-64827, *Evaluation of Air Stripper Performance at 200 West Pump and Treat*.

Table 2-4. Effluent Concentrations for Achieving Steady State

Contaminant	Carbon Tetrachloride (µg/L)	Nitrate as Nitrogen (mg/L)	Uranium (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L	Technetium-99 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)
MCL or cleanup level	3.4	10	30	100	48	900	1	20,000
Steady-state effluent concentration	< 0.3	25.2	1.14	25.5	26	134.2	< 0.65	1,825

MCL = maximum contamination level

The air stripping towers were tested at an increased carbon tetrachloride concentration, as documented in SGW-64827. An additional test is planned to evaluate air stripping performance when flowing through the 16 in. bypass line. The results were as follows:

- **Air stripper A test:** On September 11, 2019, air stripper A was tested at a total flow of 4,796 L/min (1,267 gal/min) (2,449 L/min [647 gal/min] from ETB-2 bypass, plus balance of the plant at 2,347 L/min [620 gal/min]).
  - Carbon tetrachloride concentration at the influent to air stripper A: 158 µg/L
  - Carbon tetrachloride concentration at the plant effluent: <0.30 µg/L
  - 99.9% removal (assuming 0.15 µg/L in the effluent)

- **Air stripper B test:** On September 18, 2019, air stripper B was tested at a total flow of 5,413 L/min (1,430 gal/min) (2,445 L/min [646 gal/min] from ETB-2 bypass + balance of the plant at 2,953 L/min [780 gal/min]).
  - Carbon tetrachloride concentration at the influent to air stripper B: 150 µg/L
  - Carbon tetrachloride concentration at the plant effluent: < 0.30 µg/L
  - 99.9% removal (assuming 0.15 µg/L in the effluent)

2.3.2 Aquifer Remediation Overview

This section discusses extraction well sampling data and the analysis of remedial system monitoring data for 2019. A summary is also provided for overall remedial system performance in relation to the aquifer.

2.3.2.1 Extraction Well Sampling Data

Extraction wells are sampled quarterly and analyzed for all COCs, as well as natural attenuation products (DOE/RL-2009-124). Table 2-5 lists the average COC concentrations for January through December 2019.

Chapters 3 through 6 discuss the COC data from the 200-UP-1 OU, 200-ZP-1 OU, 200-DV-1 perched water, and 200-BP-5 OU extraction and monitoring wells, respectively.

2.3.2.2 Treatment Plant Influent and Effluent Flow Rates

For 2019, the 200 West P&T operated at an average flow rate (from 32 extraction wells) of 8,126 L/min (2,145 gal/min). At designed conditions, the nominal operating flow rate is 7,600 L/min (2,000 gal/min), with a maximum flow rate of 9,500 L/min (2,500 gal/min). Table 2-6 shows the volume of groundwater processed and the average calculated flow rate through the 200 West P&T each month. Monthly average flow through the system varied between 7,383 and 9,377 L/min (1,949 and 2,475 gal/min) in 2019 (extraction well 699-48-70 was added in December 2019 when the peak monthly average flow occurred).

Overall, an increase in injection well capacity occurred in 2019 compared to 2018 as individual wells were rehabilitated (35 injection wells, with 6 wells receiving two treatments, compared to 32 injection wells rehabilitated in 2018), along with operation of the chlorination system and pigging that was completed in early 2019. This increased injection capacity (24 injection wells at >50% of their initial capacity) resulted in an increase in extraction flow rates through the 200 West P&T during the second half of 2019, and none of the extraction wells required maintenance.

Figures 2-6 through 2-9 present the 2019 monthly average pumping rates for the extraction and injection wells. ETB-1 and ETB-2 are located in the 200-ZP-1 OU, and ETB-3 is located in the 200-UP-1 OU. Two ITBs (ITB-1 and ITB-2) are located in the 200-ZP-1 OU. Figure 2-10 shows the monthly online availability and the percent of maximum flow capacity for the 200 West P&T for 2019. The 200 West P&T was online >90% of the time. The 200 West P&T sustained monthly flow >80% of the maximum capacity for each month except April, when a flow control valve malfunctioned, causing the tank to overfill and flood the floor in ITB-2. The facility reduced the flows while undergoing repairs for a 2-week period. The 12-month rolling average operational run time during 2019 exceeded the expected average 80% run time specified in the 200 West P&T O&M plan (DOE/RL-2009-124).

Table 2-5. 200 West P&T Extraction Well Average Concentrations, 2019

Well Name	PLC ID	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium[a] (µg/L)
299-W15-225	YE-1	59.2	3.8	3.3	<0.6	30.0	46.3	<0.3	373.3	0.9
299-W14-20	YE-2	416.3	12.9	12.2	<0.8	80.6	1,280.0	1.6	1,126.0	1.1
299-W14-73	YE-3	832.0	11.3	10.6	<0.8	105.6	180.2	5.3	1,288.3	0.9
299-W14-74	YE-4	953.3	31.2	33.2	<0.8	108.8	121.2	6.4	4,257.5	1.3
299-W12-2	YE-5	824.8	27.4	28.2	<0.7	112.3	94.2	2.4	407.5	1.1
299-W11-50	YE-6	558.5	23.5	22.6	<0.9	97.9	1,300.0	2.8	983.5	1.0
299-W11-90	YE-7	921.5	89.7	86.5	0.9	231.5	844.3	7.7	6,850.0	2.0
299-W11-96	YE-8	966.2	90.8	99.7	<0.8	286.9	270.0	8.0	8,950.0	1.6
299-W17-3	YE-9	153.5	4.8	4.1	<0.8	49.8	183.8	1.0	<336.0	1.0
299-W17-2	YE-10	387.0	6.9	6.4	<0.6	104.4	142.3	2.0	<343.0	0.9
299-W19-111	YE-11	316.7	3.1	2.7	<0.7	7.3	30.5	4.1	<319.7	0.6
299-W11-49	YE-12	630.0	4.1	3.8	<0.6	53.4	151.3	5.3	<332.3	0.7
299-W11-97	YE-13	251.5	<3.0	2.0	<0.7	24.5	<36.1	2.6	726.3	1.2
299-W6-15	YE-14	870.8	138.5	152.3	1.0	406.5	313.5	7.2	8,830.0	1.8
299-W14-21	YE-15	573.3	2.6	1.7	<0.6	10.3	25.5	4.0	<330.6	0.9
299-W11-92	YE-16	77.1	3.8	3.3	<0.7	28.8	49.2	0.3	522.3	1.1
299-W5-1	YE-17	190.7	47.4	47.6	0.7	283.3	343.7	0.7	1,822.3	1.4
299-W12-3	YE-18	460.0	43.1	42.0	<0.7	231.0	282.5	1.3	999.0	1.5
299-W12-4	YE-19	599.8	25.3	25.6	<0.7	33.6	<33.9	3.0	<322.4	1.2
299-W14-22	YE-20	406.8	5.2	4.9	<0.7	24.8	36.5	2.8	<321.0	1.2

Table 2-5. 200 West P&T Extraction Well Average Concentrations, 2019

Well Name	PLC ID	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (mg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium[a] (µg/L)
299-W22-90	YE-21	82.2	22.9	21.6	<0.6	26.1	359.3	<0.3	1,025.8	2.7
299-W22-91	YE-22	55.1	30.9	30.5	<0.9	30.5	3,657.5	<0.3	2,405.0	2.6
299-W22-92	YE-23	70.6	13.9	13.4	<0.8	14.2	894.3	<0.3	2,335.0	3.9
299-W19-125	YE-24	111.9	3.6	2.6	0.8	26.3	183.3	2.8	<296.8	1.6
299-W19-113	YE-25	73.6	3.2	2.6	<0.8	98.4	631.5	0.8	526.3	120.5
299-W19-114	YE-26	54.5	3.1	2.9	0.8	44.2	365.3	2.3	775.6	18.3
299-E33-268	YE-27	<0.3	5.2	11.6	3.8	80.0	930.0	<0.3	2,097.5	37.4
299-E33-344	YE-28	<0.3	83.0	83.7	2.3	458.4	29,680.0	<0.3	11,934.0	43,200.0
299-E33-350	YE-29	<0.3	87.0	88.3	3.0	792.9	42,966.7	<0.3	14,163.3	58,855.6
299-E33-351	YE-30	<0.3	50.4	49.9	6.2	1,810.0	40,033.3	<0.3	8,005.0	33,800.0
299-E33-360	YE-31	<0.3	6.0	6.5	2.5	206.3	6,233.3	<0.3	2,550.0	78.7
299-E33-361[b]	YE-32	<0.3	8.7	7.5	2.1	100.1	1,074.7	<0.3	1,027.0	26.5
699-48-70[c]	YE-33	61.3	54.3	40.2	<0.7	275.8	188.9	0.4	713.8	1.4

Note: The less than symbol (<) indicates values less than detection limits.

a. Uranium is included to track mass treated from groundwater from the 200-UP-1 and 200-BP-5 Operable Units.

b. Extraction well 299-E33-361 added in May 2019.

c. Extraction well 699-48-70 added in December 2019.

ID = identification

PLC = programmable logic controller

Table 2-6. Total Water Processed for the 200 West P&T, 2019

Month	Volume Treated (million L [million gal])	Total Average Flow Rate from Extraction Wells (L/min [gal/min])
January	363.5 (96.0)	8,148.2 (2,151.1)
February	300.4 (79.3)	7,467.9 (1,971.5)
March	341.7 (90.2)	7,667.3 (2,024.2)
April	297.1 (78.4)	7,383.4 (1,949.2)
May	364.8 (96.3)	8,171.3 (2,157.2)
June	343.3 (90.6)	7,966.3 (2,103.1)
July	390.1 (103.0)	8,750.7 (2,310.2)
August	336.2 (88.8)	7,533.4 (1,988.8)
September	360.9 (95.3)	8,427.5 (2,224.8)
October	353.2 (93.2)	8,060.0 (2,127.8)
November	367.9 (97.1)	8,561.1 (2,260.1)
December	418.6 (110.5)	9,376.7 (2,475.4)
	Total: 4,237.8 (1,118.8)	**Average: 8,126.2 (2,145.3)**

2.3.2.3 Treatment Plant Influent and Effluent Sampling Data

Influent and effluent are sampled monthly. Table 2-7 presents the average COC concentrations in the influent and effluent for the 200 West P&T from January through December 2019. The effluent COC concentrations were below the cleanup levels listed in Table 2-7 (except for nitrate starting in October 2019). The laboratory sample results for nitrate were 97 mg/L in October, 104 mg/L in November, and 111 mg/L in December, which is above the 45 mg/L cleanup level. These higher nitrate concentrations are due to the suspension of active biological treatment and will remain >45 mg/L for the duration of the optimization study (5 to 7 years). However, the concentrations are within the anticipated concentration range of three times the MCL, as stated in the 200-ZP-1 OU OSP (DOE/RL-2019-38).

Preparation for a composite sampler pilot study was initiated in December 2019 to evaluate representativeness of effluent grab samples. With changes to the facility suspending active biological treatment, the study will be conducted to evaluate the effectiveness of sampling methods (e.g., composite and grab) and sampling frequencies on the representativeness of the data collected.

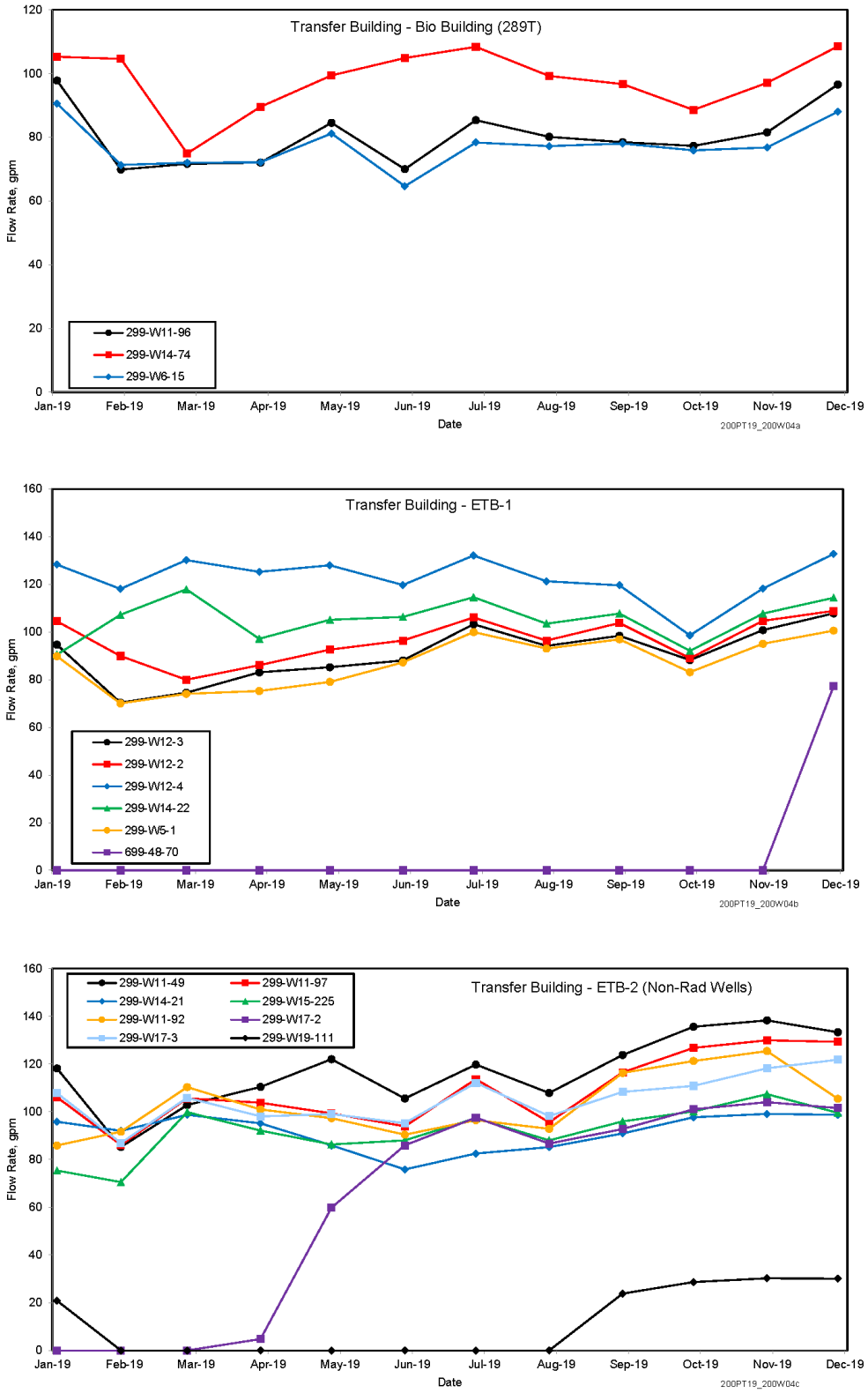

Figure 2-6. 200 West P&T Average Monthly Flow Rates for Extraction Wells Without Radiological Contaminants, 2019

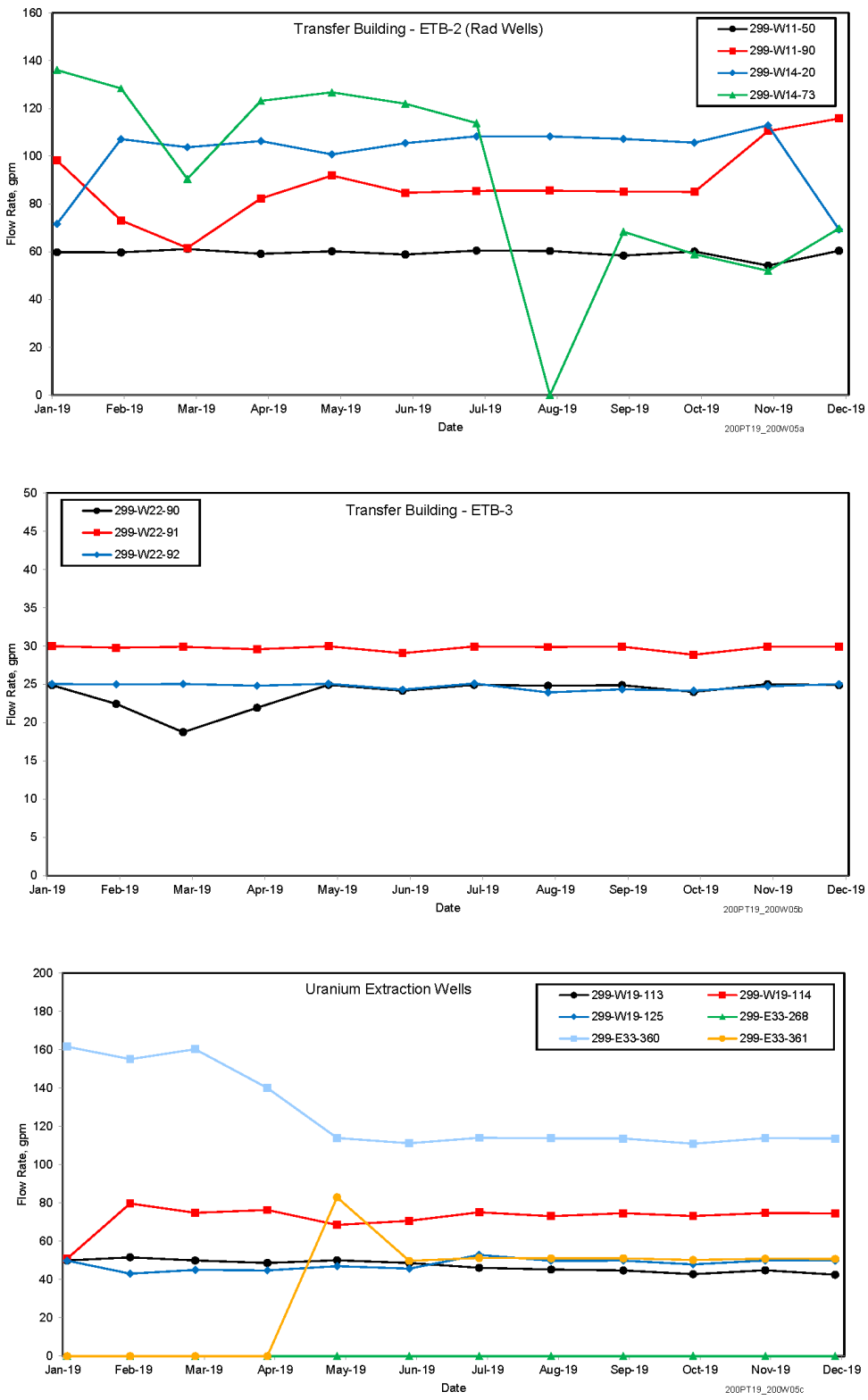

Figure 2-7. 200 West P&T Average Monthly Flow Rates for Extraction Wells with Radiological Contaminants, 2019

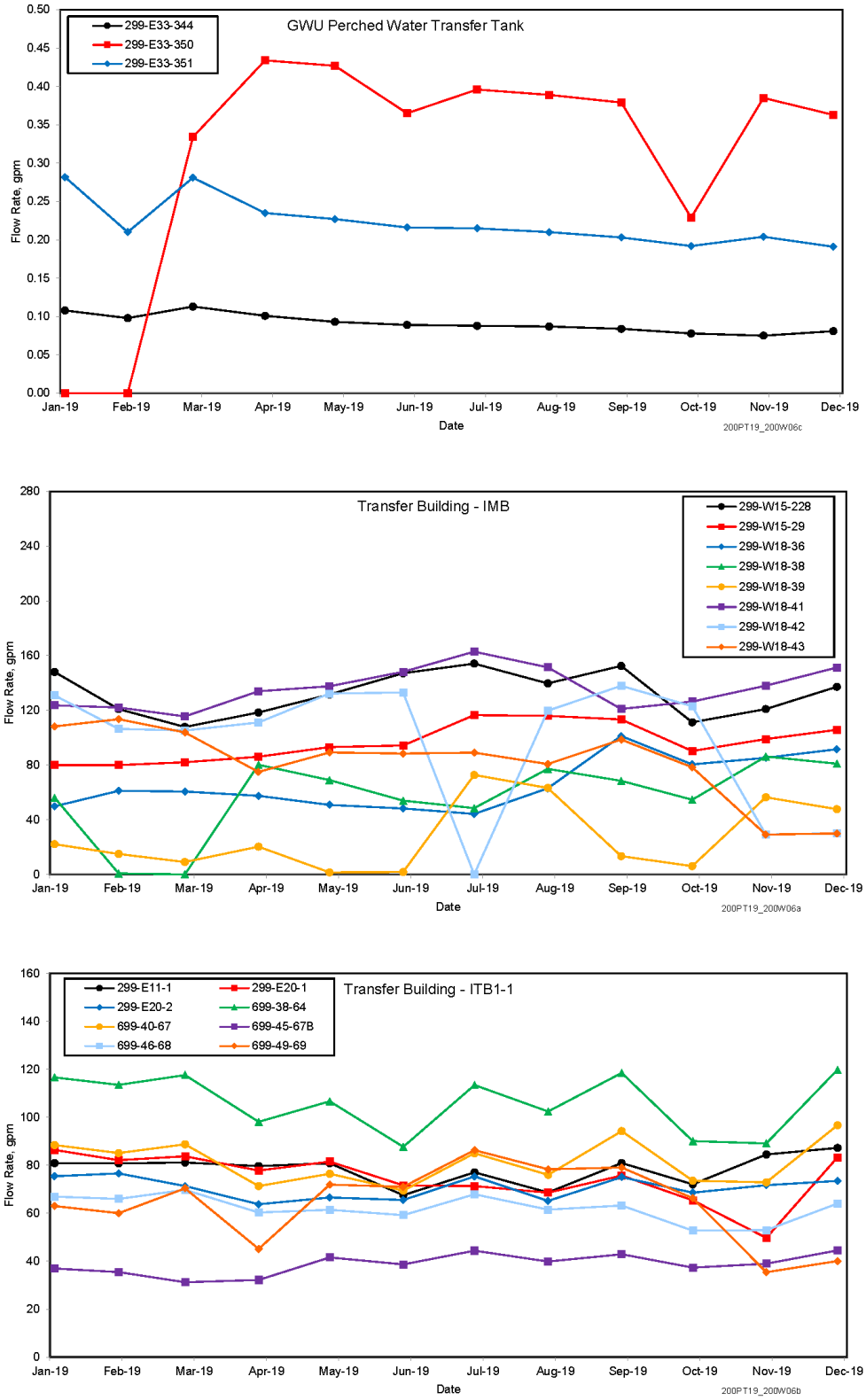

Figure 2-8. 200 West P&T Average Monthly Flow Rates for Perched Water Extraction Wells (Top) and for Injection Wells (Middle and Bottom), 2019

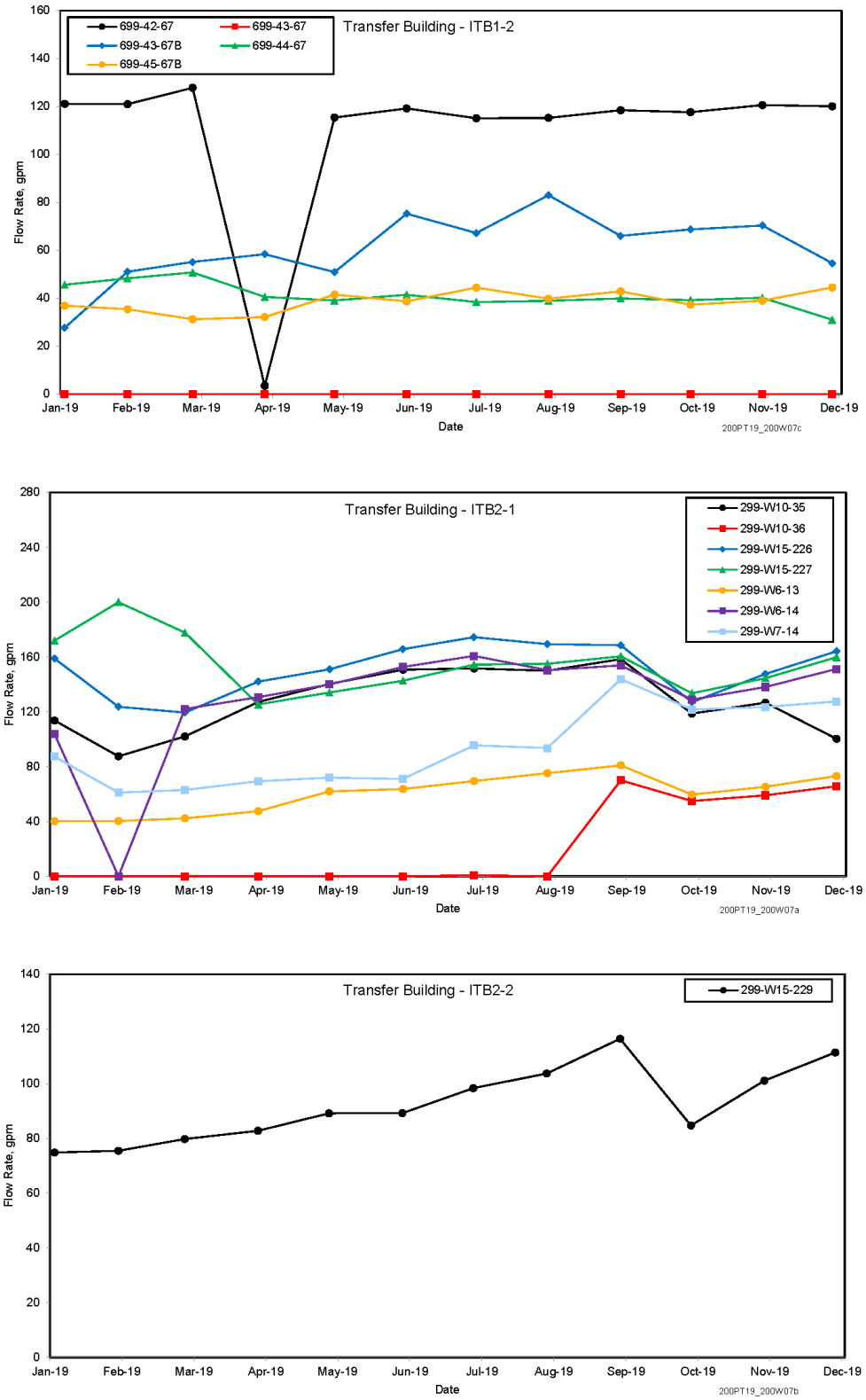

Figure 2-9. 200 West P&T Average Monthly Flow Rates for Injection Wells, 2019

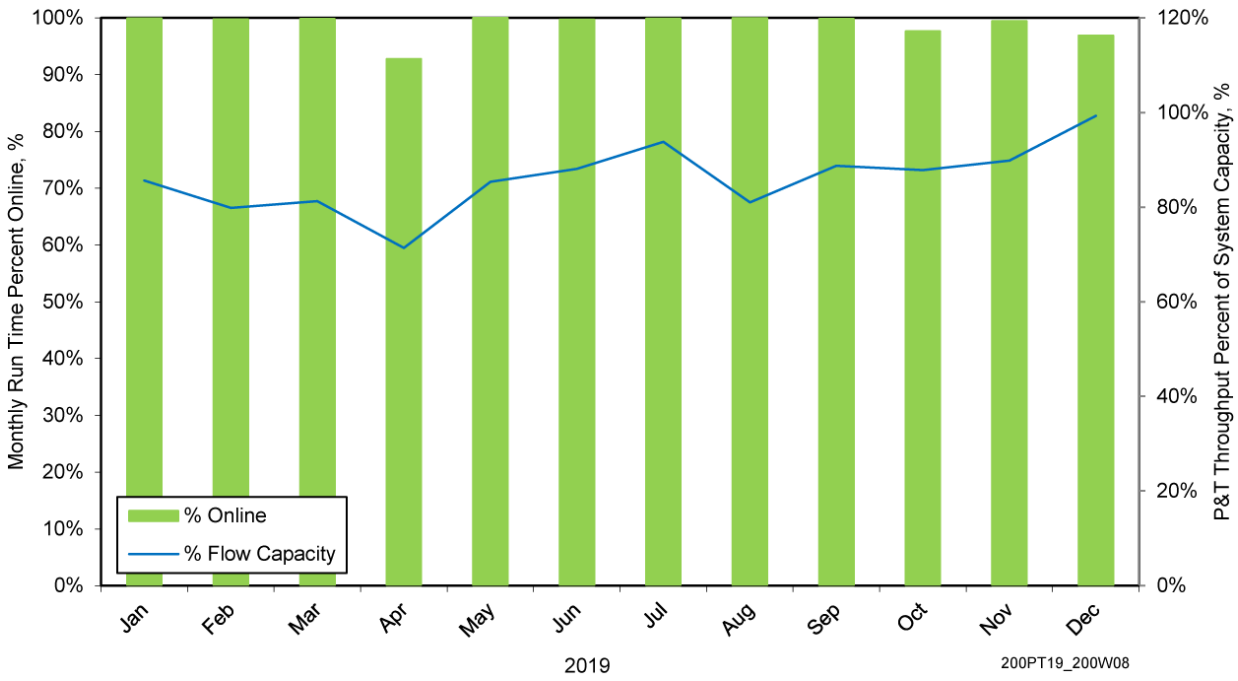

Figure 2-10. Monthly Online Availability for the 200 West P&T, 2019

With the addition of extracted groundwater from the 200-BP-5 OU in 2015, cyanide was included as a constituent for process monitoring at various points throughout the 200 West P&T process (Figure 2-11). Cyanide is a co-contaminant in extracted groundwater from the B Complex area in the 200-BP-5 OU. This water is combined with other water containing radiological contamination and is treated by the IX treatment system (Figure 2-11). Process and effluent samples were analyzed for total and free cyanide in 2019, and the highest monthly concentrations are listed in Table 2-8. Total cyanide concentrations in 200 West P&T effluent were all below the cyanide maximum contaminant level (MCL) of 200 µg/L. Free cyanide was not detected in the 200 West P&T effluent in 2019 (Table 2-8) (SGW-64683-VA, *200-ZP-1 Optimization Study – Groundwater Monitoring Plan*). After 3 years of sampling cyanide, it was concluded that the metal cyanide complexes are removed by the IX resin (SGW-62439, *Evaluation of Cyanide Treatment within the 200 West Area Groundwater Treatment Facility*).

2.3.2.4 Treatment Plant Mass Removed

Treatment system performance is evaluated on an annual basis in terms of contaminant mass removed by the 200 West P&T, treatment facility processes, and operational efficiencies. As shown in Table 2-2, a total of 4.2 billion L (1.1 billion gal) of groundwater was processed through the 200 West P&T in 2019. Table 2-2 also provides the total mass of COCs removed in 2019 by the P&T system. Figures 2-12 through 2-15 show the removal efficiency calculated by influent and effluent concentrations at the central process facility. The fluctuation in removal efficiency for Cr(VI) and total chromium (Figure 2-13) reflects variability in influent concentration, analytical precision, and the suspension of active biological treatment in October 2019. Variations in nitrate removal (Figure 2-14) reflect process adjustments associated with optimizing the biological treatment process to meet the requirements of stable operation, minimizing biofouling and the suspension of the active biological treatment in October 2019 (Section 2.5), and accommodating flow changes that occur during preventative maintenance activities. The IX resin is changed out when the lead columns have little to no capacity for the target contaminants. There were no uranium or technetium-99 IX resin changeouts performed in 2019.

Table 2-7. 200 West P&T Average Influent and Effluent Concentrations, 2019

Month	Carbon Tetrachloride Cleanup Level (3.4 µg/L)		Total Chromium Cleanup Level (100 µg/L)		Hexavalent Chromium Cleanup Level (48 µg/L)		Iodine-129 Cleanup Level (1 pCi/L)		Nitrate as Nitrate Cleanup Level (45 mg/L)		Technetium-99 Cleanup Level (900 pCi/L)		Trichloroethene Cleanup Level (1 µg/L)		Tritium Cleanup Level (20,000 pCi/L)		Uranium[a] Cleanup Level (30 µg/L)	
	Influent[b]	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent[b]	Effluent	Influent	Effluent	Influent	Effluent
January	534	<0.18	27.30	4.94	26	4.2	1.88	<0.91	133	29	1,040	78	3.4	<0.25	2,260	2,495	127.0	0.9
February	526	<0.18	26.95	3.4	25.5	1.5	1.48	0.60	126	27	1,350	75	3.4	<0.25	2,220	2,720	166.5	0.7
March	465	<0.18	22.50	13.5	21.7	4.4	0.9975	0.73	100	32	1,350	63	3.0	<0.25	1,760	1,615	217.0	1.4
April	550	<0.3	25.55	4.8	26.9	5.7	1.505	<0.90	103	41	1,330	97	3.6	<0.3	1,660	1,890	200.0	1.0
May	545	1.61	25.05	3.1	23.5	3.9	2	0.51	104	22	1,490	71	3.6	<0.3	1,830	1,933	187.0	0.9
June	480	<0.3	22.85	<3.0	20.8	2.2	2.175	<0.90	104	26	1,480	110	3.1	<0.3	1,780	1,870	160.0	0.8
July	434	<0.3	22.65	4.4	22.5	3.0	0.915	<0.92	116	38	1,640	110	2.9	<0.3	1,900	2,450	181.0	1.0
August	469	<0.3	34.80	<3.0	31.7	4.4	1.435	<0.74	150	29	1,800	84	3.0	<0.3	2,800	2,485	152.0	0.8
September	453	<0.3	33.00	3.1	31.9	2.7	1.4	<0.42	137	39	1,600	101	3.0	<0.3	2,500	1,355	170.5	0.7
October	418	<0.3	26.47[c]	13.3[d]	26.8[c]	10.7[d]	1.33	0.92	119[c]	97[d]	1,550	214	3.0	<0.3	2,250	1,900	156.5	1.4
November	429	<0.3	25.78[c]	11.9[d]	26.0[c]	12.6[d]	0.9	<0.80	113[c]	104[d]	1,480	88	3.0	<0.3	2,330	1,645	158.0	1.2
December	450	<0.32	28.15[c]	25.5[d]	29.5[c]	26.6[d]	1.91	<0.64	121[c]	111[d]	1,190	132	3.0	<0.32	2,690	1,785	149.5	1.1

Notes:

Influent values are the average of pre-resin samples taken at the radiological treatment facility for radionuclides constituents and the biological treatment system inlet samples for chemical constituents. Effluent values are the average of biological treatment system effluent samples.

The less than symbol (<) indicates that the sample result was below the listed detection limit.

a. Uranium is included to track groundwater treated at the 200-UP-1 and 200-BP-5 Operable Units.

b. Carbon tetrachloride and trichloroethene influent concentrations are calculated based on flow-weighted average from extraction wells because volatilization in conveyance of extracted groundwater leads to lower concentrations measured in influent tank samples.

c. Influent concentration for contaminants of concern not treated through the radiological treatment building is calculated based on flow-weighted average of flow from the central treatment facility influent tank and flow from ETB-2 (tank #2) following the installation of the ETB-2 (tank #2) line directly to the air strippers at the end of September 2019.

d. Concentration of chromium, hexavalent chromium, and nitrate increased in the effluent after October 2019 with suspension of biological treatment at the 200 West pump and treat.

ETB = extraction transfer building

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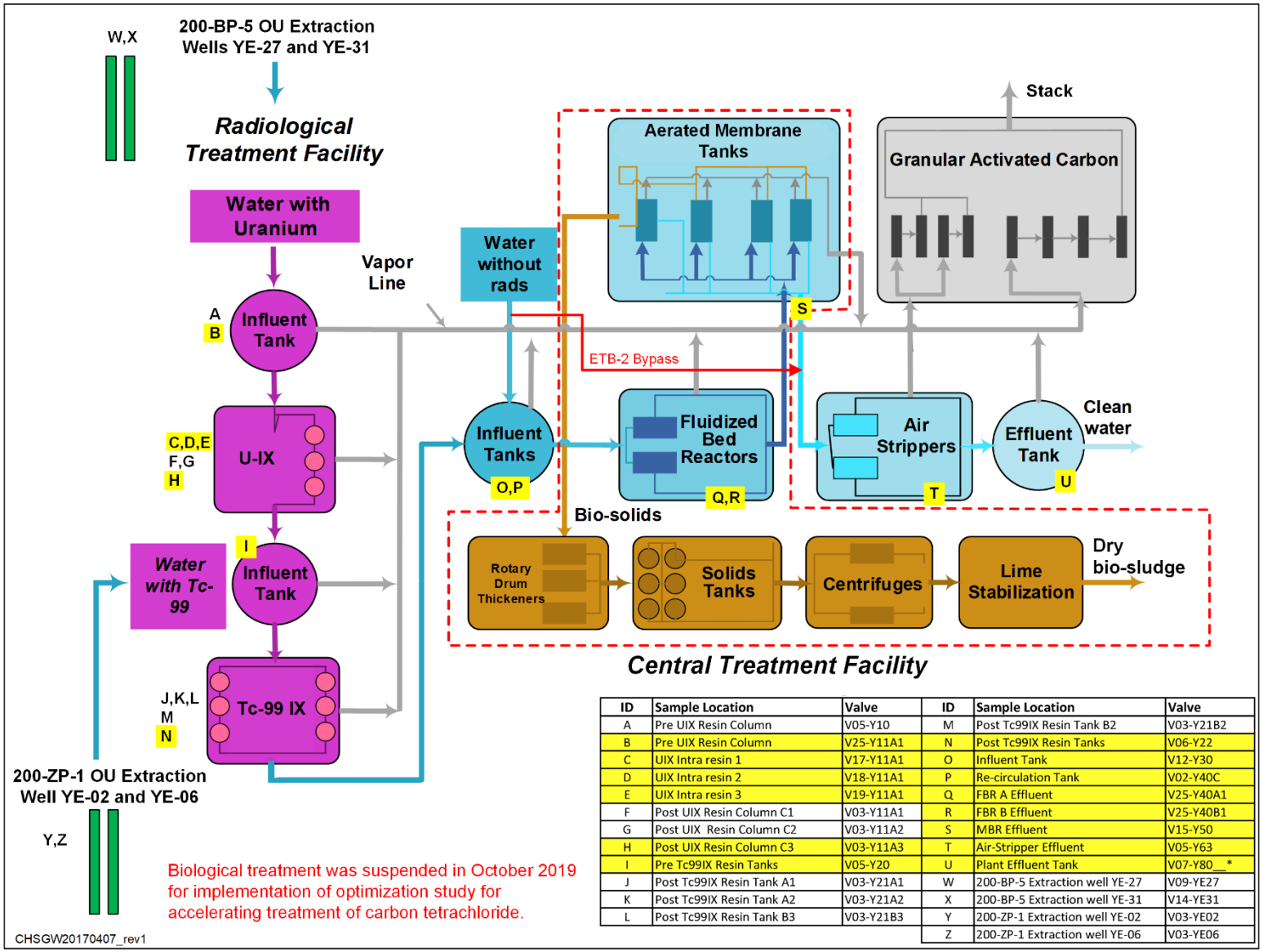


ID	Sample Location	Valve	ID	Sample Location	Valve
A	Pre UIX Resin Column	V05-Y10	M	Post Tc99IX Resin Tank B2	V03-Y21B2
B	Pre UIX Resin Column	V25-Y11A1	N	Post Tc99IX Resin Tanks	V06-Y22
C	UIX Intra resin 1	V17-Y11A1	O	Influent Tank	V12-Y30
D	UIX Intra resin 2	V18-Y11A1	P	Re-circulation Tank	V02-Y40C
E	UIX Intra resin 3	V19-Y11A1	Q	FBR A Effluent	V25-Y40A1
F	Post UIX Resin Column C1	V03-Y11A1	R	FBR B Effluent	V25-Y40B1
G	Post UIX Resin Column C2	V03-Y11A2	S	MBR Effluent	V15-Y50
H	Post UIX Resin Column C3	V03-Y11A3	T	Air-Stripper Effluent	V05-Y63
I	Pre Tc99IX Resin Tanks	V05-Y20	U	Plant Effluent Tank	V07-Y80__*
J	Post Tc99IX Resin Tank A1	V03-Y21A1	W	200-BP-5 Extraction well YE-27	V09-YE27
K	Post Tc99IX Resin Tank A2	V03-Y21A2	X	200-BP-5 Extraction well YE-31	V14-YE31
L	Post Tc99IX Resin Tank B3	V03-Y21B3	Y	200-ZP-1 Extraction well YE-02	V03-YE02
			Z	200-ZP-1 Extraction well YE-06	V03-YE06

Figure 2-11. Measurement Locations for Total and Free Cyanide Throughout the 200 West P&T

Table 2-8. Maximum Monthly Cyanide Concentrations in 200 West P&T Effluent, 2019

Sample Collection Date	Total Cyanide (µg/L)	Free Cyanide (µg/L)
January	1.67 (U)	1.4 (B)
February	1.67 (U)	1 (U)
March	1.67 (U)	1 (U)
April	3.16 (B)	1.16 (B)
May	1.76 (B)	1 (U)
June	1.67 (U)	1 (U)
July	1.67 (U)	1 (U)
August	5.08*	1.34 (B)
September	1.67 (U)	1 (U)
October	1.67 (U)	1 (U)
November	1.67 (U)	1 (U)
December	1.67 (U)	1 (U)

*The reported value of 5.08 µg/Lis suspect since three other samples in August were below the 1.67 µg/L laboratory detection limit.

Data qualifiers:

B = detected at a value less than the contract-required detection limit; greater than or equal to the instrument detection limit/method detection limit

U = not detected

Figure 2-16 shows the cumulative mass removed by the 200 West P&T from July 2012 (when the 200 West P&T began operating) through December 2019. It should be noted that in 2017, a quarterly sampling event was missed for 200-BP-5 OU extraction well 299-E33-360. As a result of the change in concentrations over the period of the missed sample event from that extraction well, the calculated mass removed for uranium is overstated by approximately 200 kg.

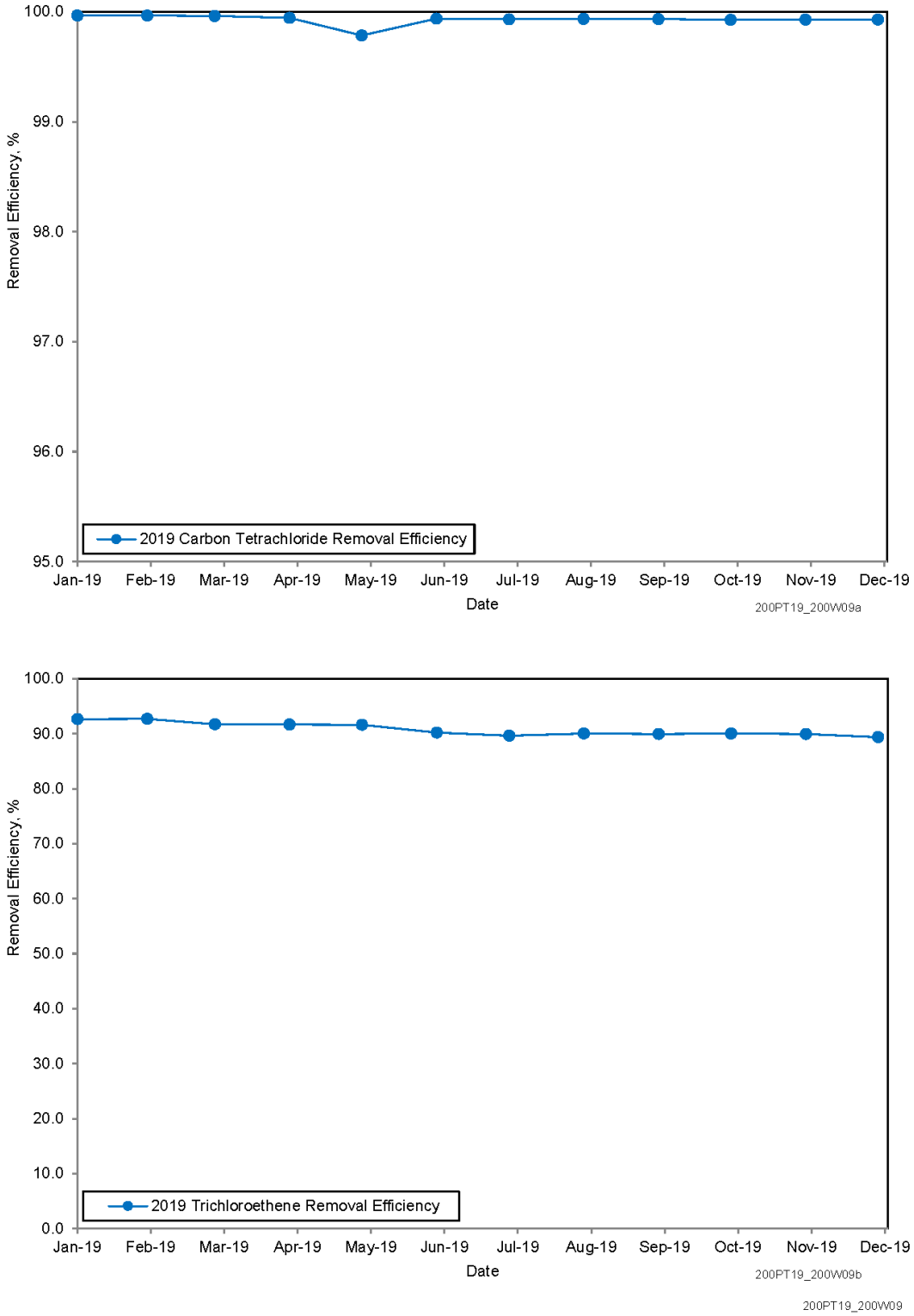


Figure 2-12. COC Removal Efficiency for Carbon Tetrachloride and TCE for the 200 West P&T

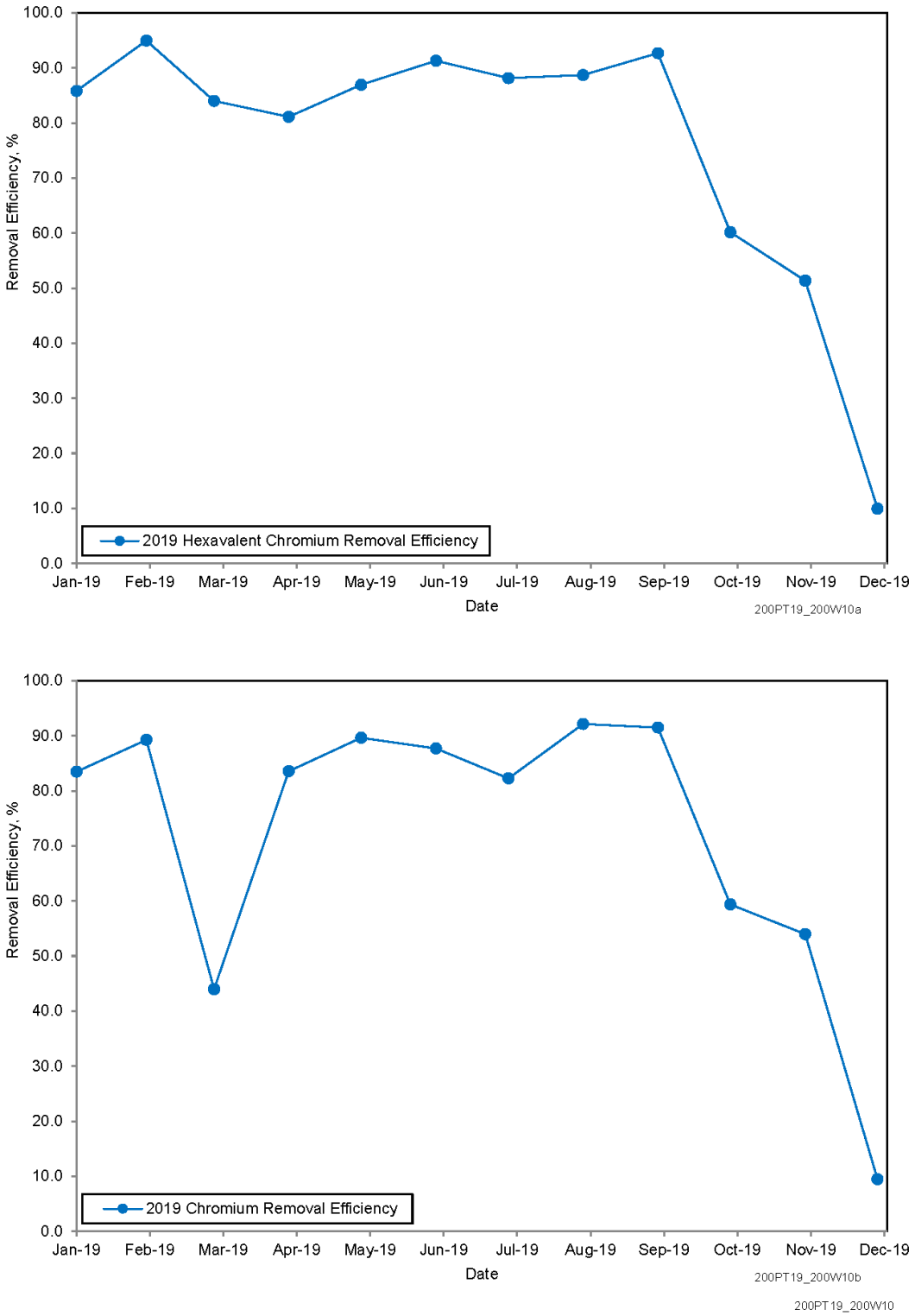


Figure 2-13. COC Removal Efficiency for Cr(VI) and Total Chromium for the 200 West P&T

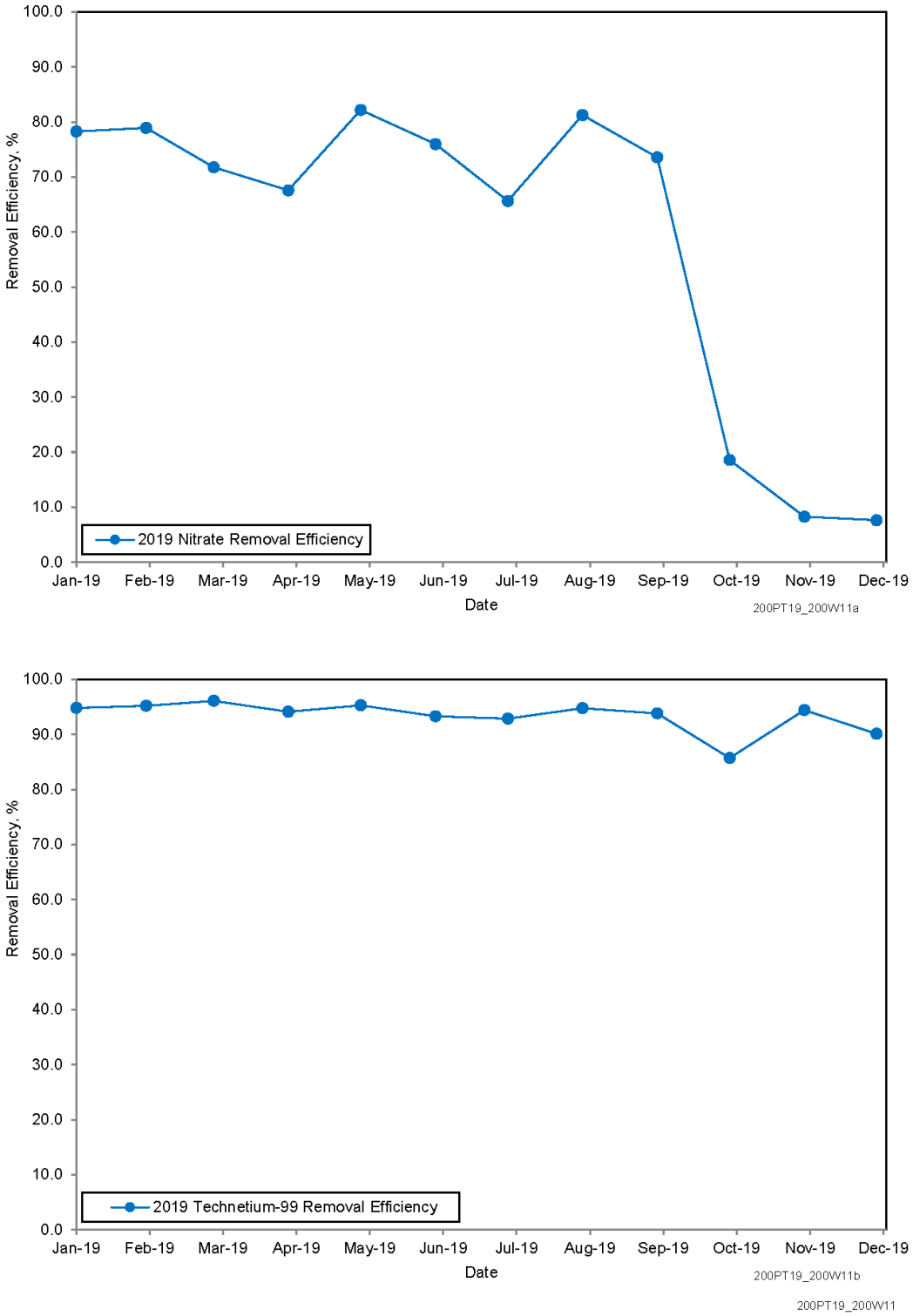


Figure 2-14. COC Removal Efficiency for Nitrate (as Nitrate) and Technetium-99 for the 200 West P&T

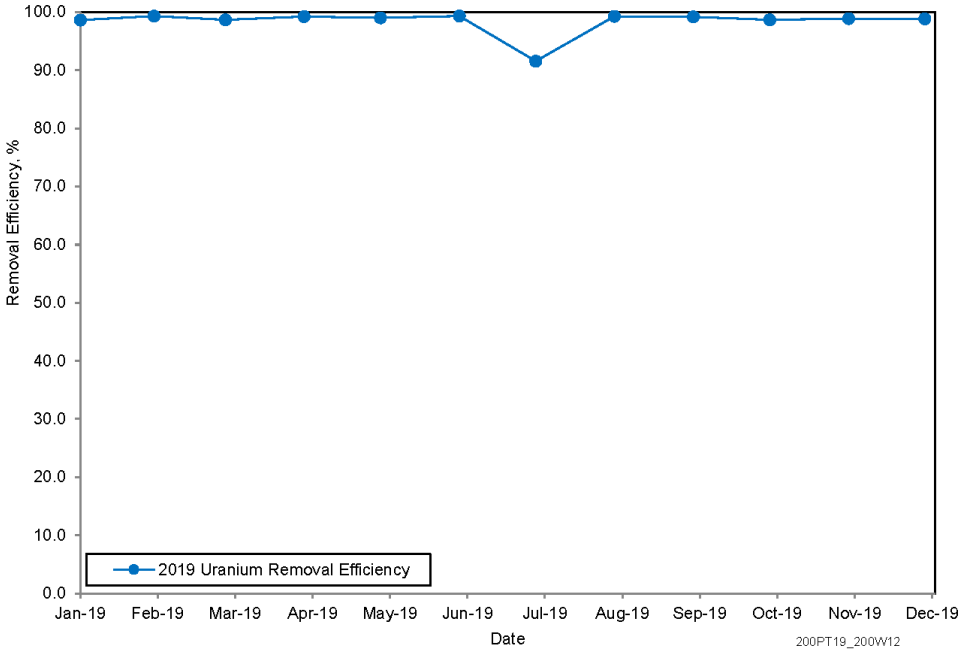
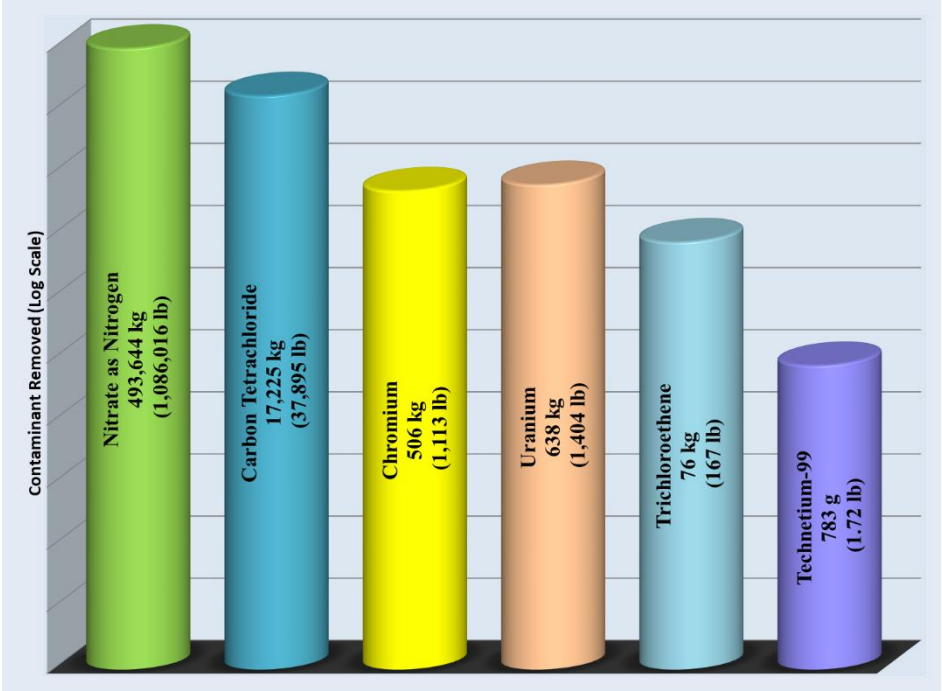


Figure 2-15. COC Removal Efficiency for Uranium for the 200 West P&T



Note: The reported uranium mass removed is likely overstated by approximately 200 kg due to missed quarterly sample in 2017 masking the rapid decline in concentrations from extraction of contaminated water.

Figure 2-16. Cumulative Contaminant Mass Removed by the 200 West P&T, 2012–2019

2.4 Treatment System Effluent Conveyance System

The 200 West P&T effluent conveyance system encompasses all of the water-handling equipment downstream of the air strippers, which are the last unit process in the water treatment train. The effluent conveyance components include the effluent tank at the plant, pumps and piping to transfer effluent water to the two ITBs, and additional pumps and piping to move water to the individual injection wells surrounding the 200-ZP-1 OU plumes. Effluent conveyance includes about 8,000 m (26,247 ft [or 5 mi]) of surface-lain HDPE piping.

Biological growth in the effluent conveyance system components has been identified as a source of active and inert solids contributing to fouling of the 200 West P&T injection wells. Numerous mitigation tasks and plant modification performed in 2019 to minimize well fouling have proven to be effective. Disinfection of the treated effluent using sodium hypochlorite along with continued well cleaning, as well as the suspension of the active biological treatment for nitrate, have restored injection capacity. A more complete description of the mechanisms of regrowth and the role of disinfection is provided in SGW-62607, *Disinfection Pilot Test on Injection Well YJ-14 to Investigate and Mitigate Well Fouling at 200 West Pump and Treat Facility*.

2.5 Treatment System Effluent Injection Wells

A total of 29 injection wells were in service for the 200 West P&T during 2019 (Figure 2-1). Table 2-9 summarizes the injection well flow rates, target flow rates, and run times. Twenty-six injection wells are associated with the 200-ZP-1 OU plume remediation area to maintain hydraulic containment. Three injection wells located in the 200-UP-1 OU (299-E20-1, 299-E20-2, and 299-E11-1) provide hydraulic containment for the 200-UP-1 iodine-129 plume. Groundwater extraction from other OUs (200-UP-1, 200-BP-5, and 200-DV-1 perched water) results in net export of groundwater to the 200-ZP-1 OU. In the past, injection wells have exhibited persistent fouling, resulting in reduced injection capacity. At times, the low injection capacity of the injection well field limited throughput at the 200 West P&T.

Injection well capacity and performance over time are evaluated quarterly via changes in specific injection capacity. Specific injection capacity is derived by dividing the injection rate by the height of the water column in the well above the static water level:

$$Specific\ injection\ capacity\ \left(\frac{gal/min}{ft}\right) = \frac{Injection\ rate\ (gal/min)}{Dynamic\ water\ level\ (ft) - static\ water\ level\ (ft)}$$

To maintain required injection flow rates, dynamic head levels in injection wells were maintained between 9.1 and 70.1 m (30 and 230 ft) above static water level during 2019. Figure 2-17 illustrates the impacts of biofouling to the injection well network capacity resulting from reduced well-specific injection capacity. There was an overall decline in injection well network capacity from the time of system startup through the fall of 2018. Injection well capacity began improving with the initiation of a pilot-scale well disinfection effort. Improvement continued during 2019 due to the installation of a permanent disinfection system to feed sodium hypochlorite at the central treatment facility combined with the continued well rehabilitation program. The piping and installation of the chlorination system were completed in 2019. With the suspension of active biological treatment in October 2019, injection well fouling is anticipated to be minimized even further. Table 2-9 lists the specific injection capacities for the injection wells at the beginning and end of 2019.

Table 2-9. Flow Rates, Total Run Times, and Specific Injection Capacity for 200 West P&T Injection Wells, 2019

Well ID	Well Name	Engineering ID	Average Flow Rate, L/min (gal/min)	Target Flow Rate, L/min (gal/min)[a]	Pump Run Time (% Out of 8,760 Hours)[b]	Well Specific Injection Capacity at Beginning/ End of 2019 (gal/min per ft)[c]	Purpose
C8064	299-W6-13	YJ-01A	227.6 (60.1)	159 (42)	91.2	0.27/1.49	200-ZP-1 injection [d]
C8065	299-W6-14	YJ-02A	542.5 (143.2)	446 (118)	71.2	1.43/1.5	
C8066	299-W10-36	YJ-03A	230.2 (60.8)	159 (42)	29.6	0.32/1.42	
C7573	299-W10-35	YJ-04A	478.7 (126.4)	363 (96)	93.7	0.90/3.13	
C7574	299-W15-226	YJ-05A	570.3 (150.6)	454 (120)	95.6	1.13/2.38	
C7575	299-W15-227	YJ-06A	585.1 (154.5)	462 (122)	92.3	1.46/4.48	
C8716	299-W15-228	YJ-07A	507.8 (134.1)	401 (106)	83.6	1.19/4.71	
C8920	299-W18-41	YJ-08A	516.8 (136.4)	401 (106)	84.7	1.57/35.9	
C8786	699-49-69	YJ-09A	254.7 (67.2)	196 (52)	74.0	0.24/0.84	
C8717	699-45-67B	YJ-10A	146.6 (38.7)	121 (32)	86.3	0.06/0.25	
C7578	699-45-67	YJ-11A	161.7 (42.7)	136 (36)	82.5	0.24/1.37	
C8068	699-44-67	YJ-12A	159.3 (42.1)	136 (36)	87.1	0.18/0.43	
C7579	699-43-67	YJ-13A	0 (0)	0 (0)	0.0	NC/NC	
C8069	699-42-67	YJ-14A	450.5 (118.9)	386 (102)	84.7	1.09/1.29	
C8070	699-40-67	YJ-15A	310.5 (82)	250 (66)	95.9	0.45/0.77	
C8921	699-38-64	YJ-16A	404.9 (106.9)	340 (90)	95.6	0.54/1.01	
C8386	699-43-67B	YJ-17A	230.2 (60.8)	155 (41)	83.8	NC/NC	
B2409	299-W15-29	YJ-18	365.8 (96.6)	303 (80)	95.3	0.44/1.10	
B2747	299-W18-36	YJ-19	252.5 (66.6)	189 (50)	97.5	0.78/1.65	
B2757	299-W18-38	YJ-21	259.1 (68.4)	196 (52)	66.3	0.4/2.11	
B2758	299-W18-39	YJ-22	110.4 (29.1)	68 (18)	84.1	0.00/0.57	
C8067	699-46-68	YJ-23A	235.7 (62.2)	204 (54)	95.9	0.38/0.78	
C8944	299-W15-229	YJ-24A	348.1 (91.9)	295 (78)	90.7	0.45/2.64	
C9521	299-W7-14	YJ-25A	359.3 (94.8)	242 (64)	88.8	0.86/3.51	
C9564	299-W18-43	YJ-31	314.5 (83)	242 (64)	82.7	4.28/11.52	
C9563	299-W18-42	YJ-32	401.4 (106)	306 (81)	80.3	1.87/20.4	
C9482	299-E20-1	YJ-26	283.9 (75)	234 (62)	95.1	0.82/1.16	200-UP-1 iodine-129 containment [e]
C9483	299-E20-2	YJ-27	269 (71)	227 (60)	93.7	1.35/4.05	
C9484	299-E11-1	YJ-28	300.3 (79.3)	257 (68)	92.1	1.83/4.96	

Table 2-9. Flow Rates, Total Run Times, and Specific Injection Capacity for 200 West P&T Injection Wells, 2019

Well ID	Well Name	Engineering ID	Average Flow Rate, L/min (gal/min)	Target Flow Rate, L/min (gal/min)[a]	Pump Run Time (% Out of 8,760 Hours)[b]	Well Specific Injection Capacity at Beginning/ End of 2019 (gal/min per ft)[c]	Purpose

a. Injection rate target for 2019.

b. Percentage total run time is calculated as follows: [(days well in operation during the year) ÷ (number of days in the calendar year)].

c. Specific injection capacity is in units of gallons per minute flow per foot of dynamic head above static water level.

d. DOE/RL-2008-78, Rev. 0 REISSUE, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*, estimates that each injection well will have an injection capacity of at least 454 L/min (120 gal/min).

e. The estimated injection rate for iodine-129 plume containment identified in DOE/RL-2013-07, *200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*, is 189 L/min (50 gal/min) for each of the three injection wells.

ID = identification

NC = not calculated (wells YJ-13 and YJ-17 do not have independent flow measurement)

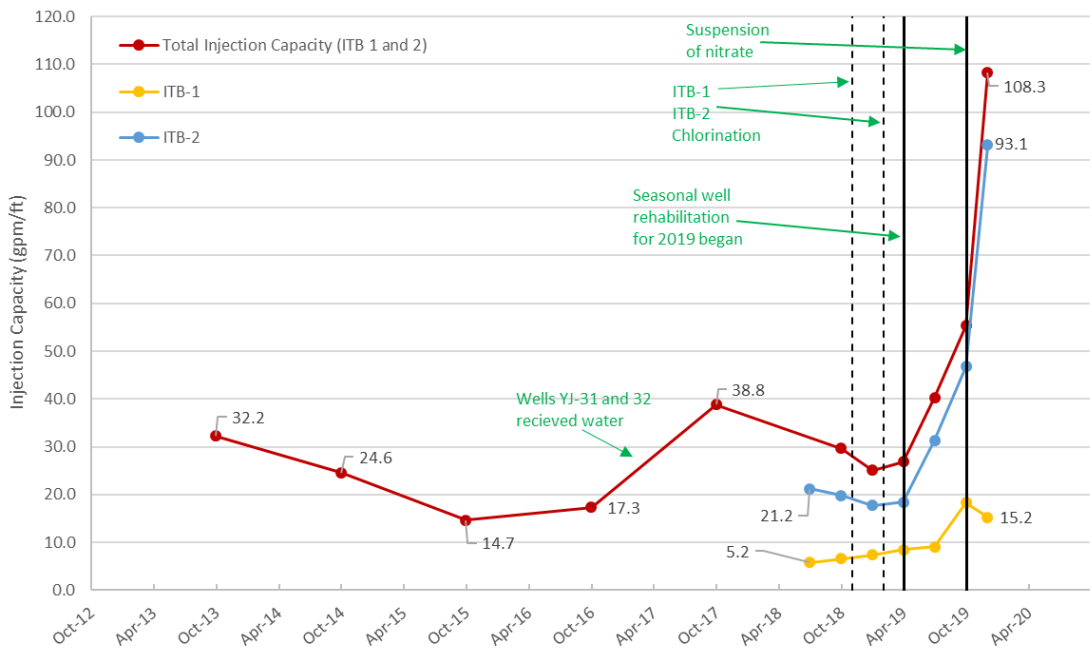


Figure 2-17. 200 West P&T Injection Well Network Capacity Summary, 2013–2019

The specific injection capacity is affected by the accumulation of biological growth or solids on the well screen and surrounding formation, or the introduction of suspended gas bubbles (which can reduce the injection capacity). Changes in well conditions are evaluated by comparing the initial specific injection capacity (at the time of construction) to the current specific injection capacity. Table 2-10 lists the specific injection capacities for the injection wells during the fourth quarter of 2019 compared to the initial specific injection capacity conditions. Although the static water level was adjusted in nine injection wells in November 2019 (causing an inflated increase), specific injection capacity has been restored. In some cases, the specific injection capacity exceeds the initial capacity. The surrounding formation has

been found to have naturally occurring bacteria that can restrict flow (PNNL-27082, *Letter Report: Analysis of Injection Well Samples for Biofouling Constituents*). Nutrients added to the biological process that passed treatment spurred this growth, causing reductions in specific injection. Beginning in 2013, the wells were repeatedly rehabilitated; however, within a few weeks the biological growth would return and limit flow. The introduction of sodium hypochlorite beginning in fall 2018 prevented biological growth. This disinfection practice also made rehabilitation efforts more effective by preventing the return of biological growth. In those cases where the specific injection capacity now exceeds the original capacity, it is theorized that the combination of disinfection and well rehabilitation has reduced the amount of biological material and solids originally present in the well pack and adjacent formation. The dose of sodium hypochlorite is carefully controlled to target a residual of 1 mg/L at the treatment facility. The residual at the wells is typically <1 mg/L. Sodium hypochlorite is naturally unstable, has a short half-life (90 days for standard bulk solution or 30 days for 0.5% to 2.5% diluted solution), and dissipates quickly as it passes through the well packing and in the formation.

Table 2-10. Well Specific Injection Capacity – Baseline Compared to 2019

Well ID	Well Name	Engineering ID	Initial Specific Injection Capacity (gal/min per ft)[a]	Average Quarterly Specific Injection Capacity 4th Quarter 2019 (gal/min per ft)[a]	Percentage of Initial Well Specific Injection Capacity (%)[b]
C8064	299-W6-13	YJ-01A	0.56[c]	1.49	266
C8065	299-W6-14	YJ-02A	1.48[c]	1.50	101
C8066	299-W10-36	YJ-03A	1.56[c]	1.42	91
C7573	299-W10-35	YJ-04A	2.36[c]	3.13	133
C7574	299-W15-226	YJ-05A	1.42[c]	2.38	168
C7575	299-W15-227	YJ-06A	1.39[c]	4.48	322
C8716	299-W15-228	YJ-07A	3.79	4.71	124
C8920	299-W18-41	YJ-08A	1.68	35.9	2,137
C8786	699-49-69	YJ-09A	1.46	0.84	58
C8717	699-45-67B	YJ-10A	0.4	0.25	63
C7578	699-45-67	YJ-11A	1.23	1.37	111
C8068	699-44-67	YJ-12A	1.35[c]	0.43	32
C7579	699-43-67	YJ-13A	1.92	—[d]	—
C8069	699-42-67	YJ-14A	1.00[c]	1.29	129
C8070	699-40-67	YJ-15A	2	0.77	39
C8921	699-38-64	YJ-16A	0.55	1.01	184
C8386	699-43-67B	YJ-17A	0.99	—[d]	—
B2409	299-W15-29	YJ-18	1.09[c]	1.10	101
B2747	299-W18-36	YJ-19	2.57	1.65	64
B2757	299-W18-38	YJ-21	18.84[c]	2.11	11
B2758	299-W18-39	YJ-22	0.50[c]	2.11	11

Table 2-10. Well Specific Injection Capacity – Baseline Compared to 2019

Well ID	Well Name	Engineering ID	Initial Specific Injection Capacity (gal/min per ft)[a]	Average Quarterly Specific Injection Capacity 4th Quarter 2019 (gal/min per ft)[a]	Percentage of Initial Well Specific Injection Capacity (%)[b]
C8067	699-46-68	YJ-23A	1.03	0.78	76
C8944	299-W15-229	YJ-24A	4.37	2.64	60
C9521	299-W7-14	YJ-25A	5.04	3.51	70
C9564	299-W18-43	YJ-31	11.74	11.52	98
C9563	299-W18-42	YJ-32	7.18	20.4	284
C9482	299-E20-1	YJ-26	1.46	1.16	79
C9483	299-E20-2	YJ-27	1.92	4.05	211
C9484	299-E11-1	YJ-28	3.64	4.96	136

a. Specific injection capacity is in units of gallons per minute flow of dynamic head above static water level.

b. Well rehabilitation should be considered where the specific injection capacity decreases to 75% of its baseline value.

c. Initial well capacity value is based on data specific injection capacity as of June 28, 2013.

d. Not calculated; wells YJ-13 and YJ-17 do not have independent flow measurement.

ID = identification

The 2019 daily injection capacity for the 200 West P&T network is shown in Figure 2-18 with general timeframes for when well rehabilitation activities were conducted.

An evaluation of whether the chlorination disinfection system can remain permanently offline (since the suspension of active biological treatment for nitrate was completed in FY 2019) will be conducted in the coming months/year.

2.6 Radiological Dose and Drinking Water Standard Analysis of 200 West Pump and Treat Effluent

The *Atomic Energy Act of 1954* (AEA) groundwater monitoring plan was established for sitewide monitoring of groundwater at the Hanford Site (DOE/RL-2015-56, *Hanford Atomic Energy Act Sitewide Groundwater Monitoring Plan*). AEA groundwater monitoring and evaluation of liquid effluents is required at P&T systems in accordance with DOE O 458.1 Chg 3 (Admin Chg), *Radiation Protection of the Public and the Environment*. This DOE order requires monitoring of effluents to prevent unacceptable exposure of public and ecological receptors to radiation and managing discharges that could result in new or increased plumes that would require mitigation action or remediation.

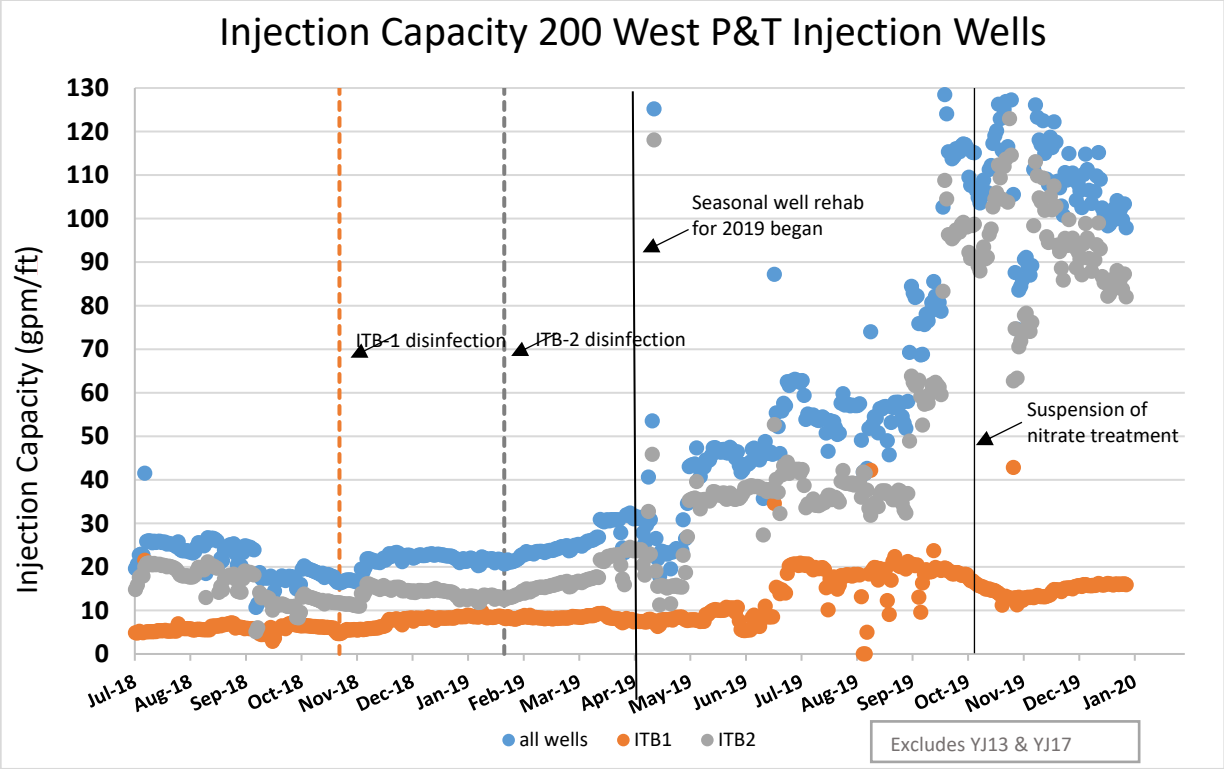


Figure 2-18. 200 West P&T Injection Well Network Capacity Daily Averages, 2019

Effluent water from the 200 West P&T was evaluated for compliance with the requirements of DOE O 458.1 under the AEA groundwater monitoring plan (DOE/RL-2015-56). This evaluation included calculating the total effective dose (TED) produced by radioisotopes in the effluent water following treatment of extracted groundwater to remove identified contaminants. The resulting dose was compared to the target dose limit of 100 mrem/yr to the public established in DOE O 458.1. The cumulative TED is based on using the derived concentration standards (DCSs) defined in DOE-STD-1196-2011, *Derived Concentration Technical Standard*. Additional guidance for screening of radiological dose related to liquid effluent discharges at DOE facilities is provided in DOE-HDBK-1216-2015, *DOE Handbook – Environmental Radiological Effluent Monitoring and Environmental Surveillance*, which provides recommended criteria for radiological effluent monitoring based on the DCSs to ensure effective effluent monitoring that identifies problematic effluent conditions before they exceed target metrics.

This evaluation further compares the radioisotopes present in effluent water to the following radiological drinking water standards (DWSs): 4 mrem/yr MCL dose for beta/photon emitters and 30 µg/L uranium mass concentration MCL. Table 2-11 summarizes the recommended criteria described in DOE-HDBK-1216-2015.

The majority of the 200 West P&T is covered by criterion #3. A complete description of the sampling and analysis results that support this categorization is presented in Section 2.6.1.

Table 2-11. Recommended Criteria for Liquid Radiological Effluent Monitoring

Criterion Number	Derived Concentration Standards Sum of Fractions	AND	Potential Annual Dose from Exposure to a Likely Receptor (mrem)*	Minimum Criteria for Liquid Radiological Effluent Monitoring
1	≥1		—	Apply best available technology to reduce effluent releases (except tritium). Use continuous monitoring/sampling, but where effluent streams are low flow and potential public dose is very low (<1 mrem/yr), alternative sampling approaches may be appropriate.
2	≥0.01 to 1	and	>1	Continuously monitor or sample. Identify radionuclides contributing >/=10% of the dose. Determine accuracy of results (± accuracy and percent confidence level).
3	≥0.001 to 0.01	and	<1	Monitor using a graded approach to select the appropriate method and duration. Identify radionuclides contributing>/=10% or more of the dose. Assess annually the facility inventory and potential for radiological effluent release.
4	<0.001		—	No monitoring required. Evaluate annually the potential for liquid radiological effluent release.

Source: Table 3-1 in DOE-HDBK-1216-2015, *DOE Handbook – Environmental Radiological Effluent Monitoring and Environmental Surveillance*.

*To further clarify, the potential annual dose from exposure is the calculated cumulative total effective dose value.

— = not applicable

2.6.1 Evaluation of Effluent Water Total Effective Dose for the 200 West Pump and Treat in 2019

Effluent monitoring at the 200 West P&T was performed by sampling and analyzing the stream exiting the plant prior to pumping effluent to the injection well field. Sampling and analysis were performed on a monthly basis for target radionuclides identified as contaminants of interest for the groundwater remedial actions supported by the treatment system. The target radionuclides for the 200 West P&T under the AEA groundwater monitoring plan (Table A-34 in DOE/RL-2015-56) are tritium, iodine-129, strontium-90, carbon-14, uranium, cesium-137, cobalt-60, and technetium-99. Table 2-12 summarizes the results of monthly sampling and analysis. Where multiple measurements were determined for an analyte during a single sampling and analysis event, the maximum value was selected for use in this evaluation.

Table 2-12. Summary of Effluent Radioisotope Sampling and Analysis Results for the 200 West P&T, 2019

Sample Location	Sample Date	Tritium (pCi/L)	Iodine-129 (pCi/L)*	Strontium-90	Carbon-14	Uranium (µg/L)	Uranium-234 (pCi/L)	Uranium-235 (pCi/L)	Uranium-238 (pCi/L)	Cesium-137	Cobalt-60 (pCi/L)*	Technetium-99 (pCi/L)
Effluent tank - V20-Y80	1/7/220019	2,590	(0.83)	NM	NM	0.912	0.34	0.01	0.30	NM	NM	81.7
Effluent tank - V20-Y80	2/19/2019	2,860	0.598	NM	NM	0.748	0.28	0.01	0.25	NM	(1.33)	82.9
Effluent tank - V20-Y80	3/20/2019	NM	NM	NM	NM	1.99	0.75	0.03	0.66	NM	NM	NM
Effluent tank - V20-Y80	3/26/2019	1,660	0.726	NM	NM	0.95	0.36	0.01	0.32	NM	NM	63
Effluent tank - V20-Y80	4/22/2019	1,950	(0.838)	NM	NM	1.03	0.39	0.02	0.34	NM	(6.96)	104
Effluent tank - V20-Y80	5/20/2019	2,260	0.508	NM	NM	0.947	0.36	0.01	0.32	NM	NM	86.3
Effluent tank - V20-Y80	6/19/2019	1,900	(0.818)	NM	NM	0.775	0.29	0.01	0.26	NM	(7.73)	116
Effluent tank - V20-Y80	7/25/2019	2,510	(0.861)	NM	NM	0.983	0.37	0.01	0.33	NM	NM	111
Effluent tank - V20-Y80	8/13/2019	2,540	(0.599)	NM	NM	0.773	0.29	0.01	0.26	NM	(7.62)	85.6
Effluent tank - V20-Y80	9/5/2019	NM	NM	NM	NM	0.836	0.31	0.01	0.28	NM	NM	NM
Effluent tank - V20-Y80	9/11/2019	1,500	(0.333)	NM	NM	0.718	0.27	0.01	0.24	NM	NM	101
Effluent tank - V20-Y80	10/9/2019	2,970	(0.675)	NM	NM	1.11	0.42	0.02	0.37	NM	(8.48)	650
Effluent tank - V20-Y80	10/16/2019	1,400	0.921	NM	NM	2.08	0.78	0.03	0.69	NM	(9.19)	113
Effluent tank - V20-Y80	10/23/2019	1,580	(0.26)	NM	NM	1.15	0.43	0.02	0.38	NM	(6.18)	118
Effluent tank - V20-Y80	11/4/2019	1,540	(0.659)	NM	NM	1.16	0.44	0.02	0.39	NM	(5.79)	105
Effluent tank - V20-Y80	11/21/2019	1,850	(0.773)	NM	NM	1.23	0.46	0.02	0.41	NM	(5.51)	92.2
Effluent tank - V20-Y80	12/2/2019	NM	NM	NM	NM	1.01	0.38	0.02	0.34	NM	NM	98.2
Effluent tank - V20-Y80	12/5/2019	1,990	(0.436)	NM	NM	1.1	0.41	0.02	0.37	NM	(6.59)	139
Effluent tank - V20-Y80	12/9/2019	NM	NM	NM	NM	1.35	0.51	0.02	0.45	NM	NM	131

Table 2-12. Summary of Effluent Radioisotope Sampling and Analysis Results for the 200 West P&T, 2019

Sample Location	Sample Date	Tritium (pCi/L)	Iodine-129 (pCi/L)*	Strontium-90	Carbon-14	Uranium (µg/L)	Uranium-234 (pCi/L)	Uranium-235 (pCi/L)	Uranium-238 (pCi/L)	Cesium-137	Cobalt-60 (pCi/L)*	Technetium-99 (pCi/L)
Effluent tank - V20-Y80	12/16/2019	1,860	(0.45)	NM	NM	1.14	0.43	0.02	0.38	NM	(7.68)	148
Effluent tank - V20-Y80	12/23/2019	NM	NM	NM	NM	1.3	0.49	0.02	0.43	NM	NM	136
Effluent tank - V20-Y80	12/30/2019	NM	(0.83)	NM	NM	1.2	0.45	0.02	0.40	NM	NM	124

*Values in parentheses were reported as not detected. Value presented is the reported minimum detectable activity concentration for samples reported as analyzed but not detected.

NM = not measured

Individual radioisotope activity concentrations were subsequently converted to estimated effective dose using the DCS values in Table 2-13. Table 2-14 shows the individual radioisotope dose contributions for each effluent sampling event at the 200 West P&T and the cumulative TED estimates for 2019. The TED was calculated using two approaches: (1) a conservative approach incorporating the minimum detectable activity (MDA) for nondetect measurements as a value, and (2) an approach assuming a value of zero for nondetect measurements and using only the reported detected values for calculations. Table 2-9 presents the resulting TED and DCS sum of fractions that were compared to the criteria. The cumulative TED and DCS sum-of-fraction values shown in Table 2-14 indicate that the results of all sampling events in 2019 (except for one on October 9) met monitoring criterion #3 using the nonconservative and conservative approach. The October 9 sampling event met the monitoring criterion #2; however, there were higher reported radionuclide detect and nondetect values for cobalt-60, technetium-99, and tritium for October 9 that drove the cumulative TED and DCS sum of fractions to exceed 1 mrem/yr.

2.6.2 Comparison of 200 West Pump and Treat Effluent Water Radiological Constituents to Drinking Water Standards for Beta/Photon Emitters and Uranium in 2019

The radiological constituents listed in Table 2-12 were also evaluated against the drinking water dose MCL of 4 mrem/yr for beta/photon emitters. The total uranium concentration was also evaluated against the 30 µg/L uranium MCL. The cumulative beta/photon dose MCL is based on a sum-of-fractions calculation using the derived concentration values published by the U.S. Environmental Protection Agency (EPA) (40 CFR 141, “National Primary Drinking Water Regulations”; specifically, Table 5 in 65 FR 76708, “National Primary Drinking Water Regulations: Analytical Method for Uranium” [Proposed Rule]). Table 2-15 presents the results of this comparison. The beta/photon MCL dose analysis was performed in two ways: (1) using the reported MDA as a value for measurements reported as nondetects, and (2) assuming a value of zero for nondetect measurements and using only the reported detected values for calculations.

The conservative approach resulted in values for the drinking water beta/photon MCL dose to exceed 4 mrem/yr at seven sampling events. The exceedances for the dates of January 7, April 22, June 19, July 25, October 9, October 16, and November 21, 2019, ranged from 4.09 to 6.52 mrem/yr. The nonconservative approach resulted in none of the values exceeding the drinking water beta/photon MCL dose of 4 mrem/yr.

Uranium mass concentration in 200 West P&T effluent (Table 2-12) was consistently <2.1 µg/L in all sample events, confirming that the effluent uranium concentration meets the MCL uranium mass concentration standard of <30 µg/L.

Table 2-13. DCSs for Radioisotopes Evaluated in 200 West P&T Effluent

DCS	Tritium	Iodine-129	Strontium-90	Carbon-14	Uranium[a]	Uranium-234	Uranium-235	Uranium-238	Cesium-137	Cobalt-60	Technetium-99
DCS (µCi/mL)[b]	1.90E-03	3.30E-07	3.30E-07	6.20E-05	—	6.80E-07	7.20E-07	7.50E-07	3.00E-06	7.20E-06	4.40E-05
DCS (pCi/L)[c]	1.90E+06	3.30E+02	3.30E+02	6.20E+04	—	6.80E+02	7.20E+02	7.50E+02	3.00E+03	7.20E+03	4.40E+04

a. Uranium in mass concentration is not assigned a DCS value.

b. DCS from Table 5 of DOE-STD-1196-2011, *Derived Concentration Technical Standard*.

c. DCS converted to pCi/L for direct comparison to measurement results.

DCS = derived concentration standard

Table 2-14. Calculated Individual Radioisotope Dose Contributions and TED for 200 West P&T Effluent, 2019

Sample Location	Sample Date	Individual Isotope Effective Dose Contribution										TED Cumulative (mrem/yr)[b]	DCS Sum of Fraction Cumulative Fraction[b]	TED Detects Only (mrem/yr)[c]	DCS Sum of Fraction Detects Only Fraction[c]
		Tritium (mrem/yr)	Iodine-129 (mrem/yr)[a]	Strontium-90 (mrem/yr)	Carbon-14 (mrem/yr)	Uranium-234 (mrem/yr)	Uranium-235 (mrem/yr)	Uranium-238 (mrem/yr)	Cesium-137 (mrem/yr)	Cobalt-60 (mrem/yr)[a]	Technetium-99 (mrem/yr)				
Effluent tank - V20-Y80	1/7/2019	1.36E-01	(2.5E-01)	NM	NM	5.0E-02	1.9E-03	4.0E-02	NM	NM	1.9E-01	0.7	0.007	0.4	0.004
Effluent tank - V20-Y80	2/19/2019	1.51E-01	1.8E-01	NM	NM	4.1E-02	1.6E-03	3.3E-02	NM	1.85E-02	1.9E-01	0.6	0.006	0.6	0.006
Effluent tank - V20-Y80	3/20/2019	NM	NM	NM	NM	1.1E-01	4.2E-03	8.8E-02	NM	NM	NM	0.2	0.002	0.2	0.002
Effluent tank - V20-Y80	3/26/2019	8.74E-02	2.2E-01	NM	NM	5.2E-02	2.0E-03	4.2E-02	NM	NM	1.4E-01	0.5	0.005	0.5	0.005

Table 2-14. Calculated Individual Radioisotope Dose Contributions and TED for 200 West P&T Effluent, 2019

Sample Location	Sample Date	Individual Isotope Effective Dose Contribution										TED Cumulative (mrem/yr)[b]	DCS Sum of Fraction Cumulative Fraction[b]	TED Detects Only (mrem/yr)[c]	DCS Sum of Fraction Detects Only Fraction[c]
		Tritium (mrem/yr)	Iodine-129 (mrem/yr)[a]	Strontium-90 (mrem/yr)	Carbon-14 (mrem/yr)	Uranium-234 (mrem/yr)	Uranium-235 (mrem/yr)	Uranium-238 (mrem/yr)	Cesium-137 (mrem/yr)	Cobalt-60 (mrem/yr)[a]	Technetium-99 (mrem/yr)				
Effluent tank - V20-Y80	4/22/2019	1.03E-01	(2.5E-01)	NM	NM	5.7E-02	2.2E-03	4.6E-02	NM	9.67E-02	2.4E-01	0.8	0.008	0.4	0.004
Effluent tank - V20-Y80	5/20/2019	1.19E-01	1.5E-01	NM	NM	5.2E-02	2.0E-03	4.2E-02	NM	NM	2.0E-01	0.6	0.006	0.6	0.006
Effluent tank - V20-Y80	6/19/2019	1.00E-01	(2.5E-01)	NM	NM	4.3E-02	1.6E-03	3.4E-02	NM	1.07E-01	2.6E-01	0.8	0.008	0.4	0.004
Effluent tank - V20-Y80	7/25/2019	1.32E-01	(2.6E-01)	NM	NM	5.4E-02	2.1E-03	4.4E-02	NM	NM	2.5E-01	0.7	0.007	0.5	0.005
Effluent tank - V20-Y80	8/13/2019	1.34E-01	(1.8E-01)	NM	NM	4.3E-02	1.6E-03	3.4E-02	NM	1.06E-01	1.9E-01	0.7	0.007	0.4	0.004
Effluent tank - V20-Y80	9/5/2019	NM	NM	NM	NM	4.6E-02	1.8E-03	3.7E-02	NM	NM	NM	0.1	0.001	0.1	0.001
Effluent tank - V20-Y80	9/11/2019	7.89E-02	(1.0E-01)	NM	NM	4.0E-02	1.5E-03	3.2E-02	NM	NM	2.3E-01	0.5	0.005	0.4	0.004
Effluent tank - V20-Y80	10/9/2019	1.56E-01	(2.0E-01)	NM	NM	6.1E-02	2.3E-03	4.9E-02	NM	(1.18E-01)	1.5	2.07	0.021	1.7	0.017
Effluent tank - V20-Y80	10/16/2019	7.37E-02	2.8E-01	NM	NM	1.1E-01	4.4E-03	9.2E-02	NM	(1.28E-01)	2.6E-01	0.9	0.009	0.8	0.008
Effluent tank - V20-Y80	10/23/2019	8.32E-02	(7.9E-02)	NM	NM	6.3E-02	2.4E-03	5.1E-02	NM	8.58E-02	2.7E-01	0.6	0.006	0.5	0.005
Effluent tank - V20-Y80	11/4/2019	8.11E-02	(2.0E-01)	NM	NM	6.4E-02	2.4E-03	5.1E-02	NM	(8.04E-02)	2.4E-01	0.7	0.007	0.4	0.004
Effluent tank - V20-Y80	11/21/2019	9.74E-02	(2.3E-01)	NM	NM	6.8E-02	2.6E-03	5.5E-02	NM	7.65E-02	2.1E-01	0.7	0.007	0.4	0.004

Table 2-14. Calculated Individual Radioisotope Dose Contributions and TED for 200 West P&T Effluent, 2019

Sample Location	Sample Date	Individual Isotope Effective Dose Contribution										TED Cumulative (mrem/yr)[b]	DCS Sum of Fraction Cumulative Fraction[b]	TED Detects Only (mrem/yr)[c]	DCS Sum of Fraction Detects Only Fraction[c]
		Tritium (mrem/yr)	Iodine-129 (mrem/yr)[a]	Strontium-90 (mrem/yr)	Carbon-14 (mrem/yr)	Uranium-234 (mrem/yr)	Uranium-235 (mrem/yr)	Uranium-238 (mrem/yr)	Cesium-137 (mrem/yr)	Cobalt-60 (mrem/yr)[a]	Technetium-99 (mrem/yr)				
Effluent tank - V20-Y80	12/2/2019	NM	NM	NM	NM	5.6E-02	2.1E-03	4.5E-02	NM	NM	2.2E-01	0.3	0.003	0.3	0.003
Effluent tank - V20-Y80	12/5/2019	1.05E-01	(1.3E-01)	NM	NM	6.1E-02	2.3E-03	4.9E-02	NM	9.15E-02	3.2E-01	0.8	0.008	0.5	0.005
Effluent tank - V20-Y80	12/9/2019	NM	NM	NM	NM	7.4E-02	2.8E-03	6.0E-02	NM	NM	3.0E-01	0.4	0.004	0.4	0.004
Effluent tank - V20-Y80	12/16/2019	9.79E-02	(1.4E-01)	NM	NM	6.3E-02	2.4E-03	5.1E-02	NM	1.07E-01	3.4E-01	0.8	0.008	0.6	0.006
Effluent tank - V20-Y80	12/23/2019	NM	NM	NM	NM	7.2E-02	2.7E-03	5.8E-02	NM	NM	3.1E-01	0.4	0.004	0.4	0.004
Effluent tank - V20-Y80	12/30/2019	NM	NM	NM	NM	6.6E-02	2.5E-03	5.3E-02	NM	NM	2.8E-01	0.4	0.004	0.4	0.004

Note: Yellow-shaded cells indicate sampling events with a TED >1 mrem/yr.

a. Values in parentheses were reported as not detected. Value presented is dose contribution based on MDA concentration for samples reported as analyzed but not detected. These values were used as part of a conservative approach to calculate the TED and DCS sum of fractions.

b. Cumulative TED and DCS sum-of-fraction values were calculated first using a conservative approach where nondetect values were replaced with the MDA value and included in the calculation.

c. Cumulative TED and DCS sum-of-fraction values meet criterion #3, except for October 9, 2019 (met criterion #2), in Table 2-11 using the nonconservative approach.

DCS = derived concentration standard

MDA = minimum detected activity

NM = not measured

TED = total effective dose

Table 2-15. Summary of Drinking Water Beta/Photon-Emitter MCL Comparison for 200 West P&T Effluent, 2019

Sample Location	Sample Date	Contributing Radioisotopes							Sum of Fractions[b]	Drinking Water Beta/Photon Dose (mrem/yr)[b]	Sum of Fractions Detects Only	Drinking Water Beta/Photon Dose from Detects Only (mrem/yr)
		Tritium	Iodine-129[a]	Strontium-90	Carbon-14	Cesium-137	Cobalt-60[a]	Technetium-99				
		Derived Concentrations (pCi/L)										
		20,000	1	8	2,000	200	100	900				
		Beta/Photon MCL Fraction										
Effluent tank	1/7/2019	0.130	(0.83)	NM	NM	NM	NM	0.091	1.05	4.20	0.220	0.881
	2/19/2019	0.143	0.60	NM	NM	NM	(0.013)	0.092	0.85	3.39	0.235	0.940
	3/26/2019	0.083	0.73	NM	NM	NM	NM	0.070	0.88	3.52	0.153	0.612
	4/22/2019	0.098	(0.84)	NM	NM	NM	(0.070)	0.116	1.12	4.48	0.213	0.852
	5/20/2019	0.113	0.51	NM	NM	NM	NM	0.096	0.72	2.87	0.209	0.836
	6/19/2019	0.095	(0.82)	NM	NM	NM	(0.077)	0.129	1.12	4.48	0.224	0.896
	7/25/2019	0.126	(0.86)	NM	NM	NM	NM	0.123	1.11	4.44	0.249	0.995
	8/13/2019	0.127	(0.60)	NM	NM	NM	(0.076)	0.095	0.90	3.59	0.222	0.888
	9/11/2019	0.075	(0.33)	NM	NM	NM	NM	0.112	0.52	2.08	0.187	0.749
	10/9/2019	0.149	(0.68)	NM	NM	NM	(0.085)	0.189	1.63	6.52	0.871	3.483
	10/16/2019	0.070	0.92	NM	NM	NM	(0.092)	0.722	1.21	4.83	0.196	0.782
	10/23/2019	0.079	(0.26)	NM	NM	NM	(0.062)	0.126	0.53	2.13	0.210	0.840
	11/4/2019	0.077	(0.66)	NM	NM	NM	(0.058)	0.117	0.91	3.64	0.194	0.775
	11/21/2019	0.093	(0.77)	NM	NM	NM	(0.055)	0.102	1.02	4.09	0.195	0.780
	12/2/2019	NM	NM	NM	NM	NM	NM	0.109	0.11	0.44	0.109	0.436
	12/5/2019	0.100	(0.44)	NM	NM	NM	(0.066)	0.154	0.76	3.02	0.254	1.016

Table 2-15. Summary of Drinking Water Beta/Photon-Emitter MCL Comparison for 200 West P&T Effluent, 2019

Sample Location	Sample Date	Contributing Radioisotopes							Sum of Fractions[b]	Drinking Water Beta/Photon Dose (mrem/yr)[b]	Sum of Fractions Detects Only	Drinking Water Beta/Photon Dose from Detects Only (mrem/yr)
		Tritium	Iodine-129[a]	Strontium-90	Carbon-14	Cesium-137	Cobalt-60[a]	Technetium-99				
		Derived Concentrations (pCi/L)										
		20,000	1	8	2,000	200	100	900				
		Beta/Photon MCL Fraction										
	12/9/2019	NM	NM	NM	NM	NM	NM	0.146	0.15	0.58	0.146	0.582
	12/16/2019	0.093	(0.45)	NM	NM	NM	(0.077)	0.164	0.78	3.14	0.257	1.030
	12/23/2019	NM	NM	NM	NM	NM	NM	0.151	0.15	0.60	0.151	0.604
	12/30/2019	NM	NM	NM	NM	NM	NM	0.138	0.14	0.55	0.138	0.551

Note: Yellow-shaded cells indicate that a sampling event exceeds the MCL of 4 mrem/yr.

a. Values in parentheses were reported as not detected. Value presented is dose contribution based on MDA concentration for samples reported as analyzed but not detected. These values were used as part of a conservative approach to calculate the MCL sum of fractions.

b. MCL sum of fractions was calculated first using the conservative approach where nondetect values were reported using the MDA as the reported measured value.

MCL = maximum contaminant level

MDA = minimum detectable activity

NM = not measured

2.6.3 Conclusions of Evaluation of Radiological Constituents in 200 West Pump and Treat Effluent Water for 2019

The evaluation of radiological dose and uranium mass concentration for 200 West P&T effluent water in 2019 indicates that the effluent met the following standards and criteria:

- The calculated DCS-based sum of fractions and TED of the effluent were consistently <1 mrem/yr, which is below the 100 mrem/yr public dose limit using the conservative and nonconservative approach for all sampling events except for October 9.
- The calculated DCS-based sum of fractions and resulting TED of the effluent were consistent with recommended monitoring criteria, indicating that monthly sampling and analysis with annual review remains at an appropriate frequency.
- The measured uranium mass concentration in effluent was consistently an order of magnitude below the 30 µg/L uranium MCL.
- The calculated MCL-based beta/photon-emitter dose was below the 4 mrem/yr MCL dose using the nonconservative approach for all sampling events. Using the conservative approach, 7 of the 22 sampling events in 2019 exceeded the 4 mrem/yr MCL.

No changes in the effluent monitoring sampling and analysis frequency or analytical suite are indicated for 2020.

2.7 200 West Pump and Treat Costs

This section presents the actual burdened cost breakdown for 200 West P&T operations for 2019 and the cost per unit mass for specific COCs. This encompasses the 200-ZP-1 OU remedy costs since the cost estimates in the 200-ZP-1 OU ROD (EPA et al., 2008) integrate the 200 West P&T as part of the overall remedy. Costs are separated into specific activities that can be categorized as either operational or capital expenses. The primary categories of expenditures are described as follows:

- **Design:** Includes initial design activities to support P&T system construction, permitting, aquifer response modeling, peer reviews, quality assurance (QA), and all other design documentation. It is not applicable in the current cost discussion but is included to provide historical perspective. It also includes the design of system upgrades and modifications.
- **Treatment system capital construction:** Includes fees paid to the construction subcontractor for capital equipment, initial facility construction, construction of new wells, redevelopment of existing wells, and modifications to the P&T system. Includes all construction subcontractor and CHPRC labor required for oversight and support of initial well installation.
- **Project support:** Includes activities related to project coordination and technical consultation as required during the course of the facility design, construction, acceptance testing, and operation. Adjustments are made to reported numbers to represent the actual amount that project support accrued from program/project management and project controls.
- **O&M:** Includes facility supplies, labor, and craft supervision costs associated with operating and maintaining the facility. It also includes costs associated with routine field screening and engineering support as required during P&T operations and periodic maintenance.

- **Performance monitoring:** Includes system and groundwater sampling and sample analysis as required in accordance with the 200-ZP-1 OU P&T remedial design/remedial action work plan (RD/RAWP) (DOE/RL-2008-78, Rev. 0 REISSUE, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan*), the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2), and the 200 West P&T O&M plan (DOE/RL-2009-124). It also includes preparation of annual performance evaluation reports and subsequent reports, as required by the remedial design report, RD/RAWP, and PMP. Sampling activities for routine groundwater monitoring are integrated for all groundwater OUs for sampling integration to reduce overall labor with sample trips and analytical costs. These costs have been pooled in a separate project account and have not been included in the individual project performance monitoring costs. To account for all performance monitoring costs associated with implementation of remedial actions for the 200 West P&T remedial action, a portion of the pooled costs based on sample trips and analyses performed for the 200 West P&T have been included to the performance monitoring costs in this year's report.

- **Waste management:** Includes the estimated cost for managing GAC, IX resins, bioreactor sludge, and other miscellaneous waste related to the 200 West P&T in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. Waste designation sampling and analysis are included.

- **GAC regeneration:** Includes subcontractor costs for transporting GAC containers, regenerating and returning the GAC containers, and disposing carbon tetrachloride waste.

- **Well installation:** Includes costs for installing new CERCLA monitoring, extraction, and injection wells in the 200-ZP-1 OU.

Table 2-16 lists the costs for the 200 West P&T. Most of the costs from 2009 through 2012 (89.4%) are associated with design and construction of the 200 West P&T. Although the P&T system did not begin operating until July 2012, the O&M cost reflected in the table for 2009 through 2011 includes treatability testing associated with designing the 200 West P&T, sampling and analyzing groundwater from new well installations for the system, and preparing the initial revisions to the 200 West P&T O&M plan (DOE/RL-2009-124) and the 200-ZP-1 OU PMP (DOE/RL-2009-115).

The total cost for the 200 West P&T during 2019 was $25.1 million (sum of the categories shown in Table 2-16). The 20% increase compared to the 2018 total cost is associated with drilling of new wells, adding new extraction wells, and performing facility modifications to enable suspension of biological treatment that started in October 2019. The 2011 through 2018 performance monitoring costs reported in previous P&T reports (e.g., DOE/RL-2018-68, *Calendar Year 2018 Annual Summary Report for Pump and Treat Operations in the Hanford Central Plateau Operable Units*) in Table 2-16 have been adjusted to include the percentage of pooled groundwater monitoring cost apportioned to the 200 West P&T operations following startup of the 200 West P&T. The percentage of the 2019 costs, in decreasing order, includes O&M (69.6%), well installation (17.2%), treatment system capital (3.9%), performance monitoring (3.5%), waste management (2.3%), design (1.5%), project support (1.2%), and regeneration (0.7%).

Table 2-16. Cost Breakdown for the 200 West P&T

Description	Actual Costs (in $1,000s)										
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Design	7,981.7	4,563.6	—	—	—	—	70.1	9.7	26.9	0.1	382.1
Treatment system capital	4,631.5	55,476	141,525.1	27,725	—	—	2,514.5	1,100.7	1,315.6	287.5	984.8
Project support	9.5	113.6	48.4	310.3	451.7	354	136.4	59.4	1,101.7	292.8	312.9
Operations and maintenance[a]	5.7	2,303.2	289.1	12,693	18,460.9	19,046.4	18,833.5	18,510.7	19,454.1	17,042.3	17,491.9
Performance monitoring[b]	—	96.5	327.7	668.2	825.6	470.8	487.3	794.5	1,028.6	857.4	878.8
Waste management	—	—	—	40.5	$485.5	226.7	260.6	51.2	860.3	590.1	586.1
Granular activated carbon regeneration	—	—	—	—	$22.4	204.5	145.2	330.5	160.2	223.1	181.6
Well installation	4,240	4,959	3,136.2	1,394.3	1,687.6	7,924.6	3,302.8	1,086.2	3,055.1	1,669.4	4,326.8
Totals	**16,868.4**	**67,511.9**	**145,053.4**	**42,512.1**	**21,640.0**	**28,227.1**	**25,594.5**	**21,942.9**	**27,002.6**	**20,962.7**	**25,145.0**

a. Since 2013, the annual cost for biological treatment of nitrate has been approximately $9 million of the total operations and maintenance cost with startup of the biological treatment system in July 2012.

b. Performance monitoring costs have been adjusted back through 2011 to include pooled sampling costs for groundwater monitoring apportioned to the 200 West pump and treat.

— = not applicable

The 200 West P&T is primarily associated with the 200-ZP-1 OU groundwater remedy as the designed target for the 200-ZP-1 OU contaminant plumes. However, the total O&M cost (including waste management and GAC regeneration) includes treatment of extracted groundwater from other OUs. To properly associate treatment costs, the O&M cost is proportioned in Table 2-17 by individual OUs based on the percentage of wells maintained and mass treated from extracted groundwater from each OU to the total mass treated by the 200 West P&T. The O&M proportioned cost is reflected in the cost sections for each specific OU in Chapters 3 through 6.

Table 2-17. Proportioned 200 West P&T O&M Costs (by OU)

Description	Actual Costs (in $1,000s)					
	200-ZP-1	**WMA S-SX**	**U Plant**	**Iodine-129**	**200-DV-1**	**200-BP-5**
Proportioned operations/treatment cost[a]	$12,917.60	$154.67	$233.85	—	$461.65	$643.60
Proportioned maintenance cost[b]	$2,973.62	$174.92	$174.92	$174.92	$174.92	$174.92
Proportioned O&M cost[c]	**$15,891.23**	**$329.59**	**$408.77**	**$174.92**	**$636.57**	**$818.52**

a. Cost proportion based on percent of mass treated from extracted groundwater from each operable unit to the total mass of each contaminant treated by the 200 West P&T.

b. Cost proportion based on number of extraction and injection wells or each operable unit to the total number of wells connected to the 200 West P&T.

c. Includes 200 West P&T costs for O&M, waste management, and granular activated carbon regeneration.

— = not applicable
O&M = operations and maintenance
P&T = pump and treat
WMA = waste management area

The cost per unit volume treated and mass recovered by the 200 West P&T was calculated based on capital construction cost for the 200 West P&T (amortized over the 25-year design life), plus annual O&M costs, divided by the annual volume of groundwater treated or mass removed. The amortized cost of the 200 West P&T is $10.9 million, and the 2019 O&M cost was $17.5 million. In 2019, the 200 West P&T treated 4.2 billion L (1.1 billion gal), removing a combined total of 248,190 kg of contaminants (Table 2-2). The cost for groundwater treatment in 2019 was $0.0085/L, and the cost for contaminant mass removal in 2019 was $145.23/kg.

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3 200-UP-1 Operable Unit Remedial Actions

The groundwater remedial actions for the 200-UP-1 OU are discussed in this chapter. At the end of 2019, three active remedies were operating: the WMA S-SX groundwater extraction system, the U Plant area groundwater extraction system, and the iodine-129 plume hydraulic containment system. The WMA S-SX groundwater extraction system, which began operating in July 2012, removes technetium-99, chromium, nitrate, and carbon tetrachloride from the aquifer east of the S and SX Tank Farms. The U Plant groundwater extraction system came online in September 2015 and removes uranium, technetium-99, nitrate, and carbon tetrachloride from groundwater downgradient of the 216-U-1 and 216-U-2 Cribs. The iodine-129 plume hydraulic containment system began operating in October 2015 with the objective of slowing eastward migration of the iodine-129 plume while treatment technologies for the plume were investigated. The technology evaluation was completed in September 2019, as discussed in Section 3.3.

Highlights

- The WMA S-SX groundwater extraction system is operating as projected, and the system is predicted to achieve its cleanup objectives. However, continuing sources of groundwater contamination may be great enough that groundwater plumes could re-form following shutdown of the groundwater extraction system. An updated strategy may be needed to address continuing contaminant sources at WMA S-SX, particularly for technetium-99.
- The U Plant groundwater extraction system continued operation in 2019, although F&T simulations identified optimization needs for uranium plume remediation. Three new wells were installed in 2019 to further characterize the uranium plume. Once sufficient analytical data are obtained from these wells, additional F&T simulations are planned to evaluate system performance and determine if modifications are needed to achieve remediation objectives.
- Iodine-129 hydraulic containment continued in 2019, and water-level data indicate that the system has slowed eastward plume migration.
- For the southeast chromium plume, a remedial design investigation report was published in 2019 (DOE/RL-2017-60), which updated the conceptual model, evaluated remedial options, and recommended 5 years of additional of groundwater monitoring before a remedy decision is made.

This chapter provides the results of contaminant monitoring, hydraulic analyses, flow rates and volumes for the extraction and injection wells, and contaminant removal from the aquifer. MNA for the nitrate and tritium plumes and ongoing monitoring of the chromium plume southeast of the 200 West Area also are discussed in this chapter.

The 200-UP-1 OU addresses groundwater contaminant plumes beneath the southern one-third of the 200 West Area and adjacent portions of the surrounding area (Figure 1-1). The primary sources of groundwater contamination in the OU were waste sites associated with historical operation of the Reduction-Oxidation (REDOX) Plant for plutonium/uranium separation and operation of U Plant for uranium recovery. The contaminants technetium-99, uranium, chromium, nitrate, iodine-129, and tritium form groundwater plumes in the area that originated from past discharges overlying the 200-UP-1 OU. A widespread carbon tetrachloride plume is also present in the northern portion of the OU, which originated from waste disposal sites associated with PFP in the 200-ZP-1 OU. For the 200-UP-1 OU monitoring wells, carbon tetrachloride results are presented in Chapter 4. Mass removal results for carbon tetrachloride are presented in Sections 3.1 and 3.2 for the WMA S-SX and U Plant area groundwater extraction systems, respectively.

The 200-UP-1 OU ROD (EPA et al., 2012) identified the selected remedy for groundwater remediation in the 200-UP-1 OU, which consists of the following components:

- Groundwater extraction and treatment for uranium, technetium-99, total chromium, Cr(VI), nitrate, and carbon tetrachloride

- MNA for the entire tritium plume and parts of the nitrate and carbon tetrachloride plumes not captured by the groundwater extraction remedies
- Hydraulic containment for iodine-129 while treatment technologies are investigated
- Remedy performance monitoring
- Institutional controls (ICs)

Although not explicitly stated in the 200-UP-1 OU ROD (EPA et al., 2012), MNA is presumed to be a remedy component for portions of the technetium-99 and uranium plumes.

The RAOs identified in the 200-UP-1 OU ROD (EPA et al., 2012) are as follows:

- **RAO #1:** Return the 200-UP-1 OU groundwater to beneficial use as a potential drinking water source.
- **RAO #2:** Prevent human exposure to contaminated 200-UP-1 OU groundwater that exceeds acceptable risk levels for drinking water.

Table 3-1 lists the cleanup levels specified in the 200-UP-1 OU ROD (EPA et al., 2012). DOE/RL-2013-07, Rev. 0, *200-UP-1 Groundwater Operable Unit Remedial Design/Remedial Action Work Plan*, describes the implementation of the ROD. Remedy performance monitoring is described in DOE/RL-2015-14, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*. Sampling to meet 200-OU-1 OU PMP requirements was implemented in January 2016, which describes groundwater monitoring data collection activities associated with implementing the remedial action for the OU. This chapter documents the remedial action assessment activities performed in 2019 and is organized as follows:

- Sections 3.1, 3.2, and 3.3 address operation of the WMA S-SX groundwater extraction system, the U Plant groundwater extraction system, and the iodine-129 plume hydraulic containment system, respectively. Each section addresses the operation of the remedy, hydraulic analysis results, and contaminant monitoring.
- Section 3.4 describes ongoing characterization of the chromium plume southeast of the 200 West Area.
- Section 3.5 addresses MNA.
- Section 3.6 discusses sampling QA/quality control (QC) information.
- Section 3.7 provides the remedial system costs.
- Section 3.8 summarizes the 2019 remedy performance for the 200-UP-1 OU.

Although Cr(VI) and total chromium are listed in the 200-UP-1 OU ROD (EPA et al., 2012) as separate COCs, dissolved chromium in Hanford Site groundwater is almost entirely Cr(VI) (Chapter 7 in WHC-SD-EN-TI-302, *Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site*; Appendix C of DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*). Total chromium and Cr(VI) have different cleanup levels of 100 µg/L and 48 µg/L, respectively, as specified in the 200-UP-1 OU ROD. In this chapter, sample results for total dissolved chromium and Cr(VI) will typically be referred to simply as chromium, and the lower cleanup level of 48 µg/L is applied.

Table 3-1. Cleanup Levels for 200-UP-1 OU COCs

COC	Units	90th Percentile Groundwater Concentrations	Federal DWS[a]	WAC 173-340 Method B Cleanup Levels		Cleanup Level
				Noncarcinogens at Hazard Quotient = 1	Carcinogens at 1×10^{-6} Risk Level	
Iodine-129	pCi/L	3.5	1	N/A	N/A	1[b]
Technetium-99	pCi/L	4,150	900	N/A	N/A	900
Tritium	pCi/L	51,150	20,000	N/A	N/A	20,000
Uranium	µg/L	206	30	N/A	N/A	30
Nitrate[c] (as NO_3^-)	mg/L	133	45 [c]	113.6	N/A	45
Nitrate[c] (as N)	mg/L	30.1	10[c]	25.6	N/A	10
Total chromium	µg/L	99	100	24,000	N/A	100
Hexavalent chromium	µg/L	52	N/A[d]	48	N/A	48
Carbon tetrachloride	µg/L	189	5	5.6	0.34[e]	3.4[f]

References:

Table 14 in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*.

WAC 173-340-705, "Model Toxics Control Act—Cleanup," "Use of Method B."

a. Federal DWS is from 40 CFR 141, "National Primary Drinking Water Regulations." The values listed for tritium, iodine-129, and technetium-99 are the derived activity concentration values from Appendix I of EPA 816-F-00-002, *Implementation Guidance for Radionuclides*. These values are used to calculate the cumulative dose for comparison to the 4 mrem/yr maximum contaminant level.

b. Currently identified groundwater treatment technology is insufficient to reach the 1 pCi/L derived concentration for iodine-129.

c. Nitrate concentration may be expressed in terms of the mass of the entire NO_3 ion (nitrate as NO_3) or in terms of the mass of nitrogen within the NO_3 ion (nitrate as N). The federal DWS for nitrate is 10 mg/L (as N), which is approximately 45 mg/L (as NO_3).

d. There is no federal DWS for hexavalent chromium.

e. This value is based on estimated risk from an individual contaminant at the 1×10^{-6} risk level.

f. This cleanup level is a risk-based calculation for carbon tetrachloride. This value represents a cumulative 1×10^{-5} risk in accordance with WAC 173-340-720(7)(a), "Groundwater Cleanup Standards."

COC = contaminant of concern

DWS = drinking water standard

N/A = not applicable

3.1 S-SX Tank Farms Remedial System

The S-SX Tank Farms consist of underground storage tanks: 12 single-shell tanks (SSTs) in the S Tank Farm, and 15 SSTs in the SX Tank Farm. The tanks held high-level waste from plutonium/uranium separation activities conducted at the REDOX Plant. One SST in the S Tank Farm and eight SSTs in the SX Tank Farm are known or assumed to have experienced a leak/release (HNF-EP-0182, Rev. 336, *Waste Tank Summary Report for Month Ending December 31, 2015*). To minimize future leaks/releases, most of the drainable liquid in the tanks has been removed and transferred to double-shell tanks (i.e., the tanks have been interim stabilized).

Releases from the SSTs have resulted in groundwater contamination beneath and downgradient of the S-SX Tank Farms (PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas S-SX at the Hanford Site*; DOE/RL-2016-09, *Hanford Site Groundwater Monitoring Report for 2015*). Major contaminant plumes associated with the tank farms include technetium-99, chromium, and nitrate, which occur above their respective cleanup levels shown in Table 3-1. Depth-discrete sample results during drilling indicate that the technetium-99, chromium, and nitrate plumes occur within the upper 10 m (33 ft) of the aquifer near the S Tank Farm and within the upper 20 m (66 ft) of the aquifer near the SX Tank Farm (DOE/RL-2009-122, *Remedial Investigation/ Feasibility Study for the 200-UP-1 Groundwater Operable Unit*). Iodine-129 has also been found in groundwater and is attributed to releases from the tanks, but it occurs at low concentrations. Carbon tetrachloride in the groundwater originated from PFP operations overlying the 200-ZP-1 OU, although some PFP waste streams were disposed to the 216-U-10 Pond (U Pond), which is a possible source of carbon tetrachloride upgradient from the S-SX Tank Farms. Tritium and some of the nitrate also originated from a source upgradient of the S-SX Tank Farms (i.e., 216-S-25 Crib).

The selected remedy in the 200-UP-1 OU ROD (EPA et al., 2012) to address technetium-99 contamination in groundwater beneath and downgradient of the S-SX Tank Farms includes groundwater extraction using three extraction wells with a total average pumping rate of 303 L/min (80 gal/min) for 15 years. The groundwater extraction system, which began operating in July 2012, consists of one well downgradient from the S Tank Farm (299-W22-90 [YE-21]) and two wells downgradient from the SX Tank Farm (299-W22-91 [YE-22] and 299-W22-92 [YE-23]) (Figure 3-1). The system was designed to extract technetium-99-contaminated groundwater and reduce the size of the plumes. The system also extracts collocated chromium plumes and portions of the nitrate and carbon tetrachloride plumes. The extraction wells were designed to intercept the observed depth of the technetium-99 plume based on discrete-depth sampling conducted during drilling (Figures A-2 and A-3 in the 200-UP-1 OU RD/RAWP [DOE/RL-2013-07, Rev. 0]). Wells 299-W22-90 and 299-W22-92 are screened to 15.1 m (50 ft) below the baseline water table, and well 299-W22-91 is screened to 18.7 m (61.5 ft) below the baseline water table. Baseline conditions were assessed prior to startup of the groundwater extraction system.

The extracted groundwater is pumped to the 200 West P&T central treatment facility using aboveground pipelines and a transfer building (DOE/RL-2013-07, Rev. 0). The 200 West P&T central treatment facility consists of two main processes (described in Chapter 2):

- Radiological treatment process using IX resins
- Central treatment process that uses anoxic and aerobic biodegradation[1] for nitrate, metals, and organic contaminants; membrane filtration to remove particulate matter; and air stripping to remove VOCs

Groundwater pumped from the WMA S-SX extraction wells is combined with groundwater pumped from the U Plant area extractions wells (as well as 200-ZP-1, 200-BP-5, and 200-DV-1 OU extraction wells that require radionuclide treatment), and the combined water is passed through the IX resin. The effluent from this process is then combined with groundwater from the remaining extraction wells (not requiring radionuclide treatment) and passed through the 200 West P&T central treatment process. The treated water is then returned to the aquifer using injection wells, most of which are located within the 200-ZP-1 OU. Operation of the 200 West P&T is discussed further in Chapter 2.

[1] As discussed in Section 2.3, biological treatment was suspended in October 2019 as part of the 200-ZP-1 OU optimization study (DOE/RL-2019-38).

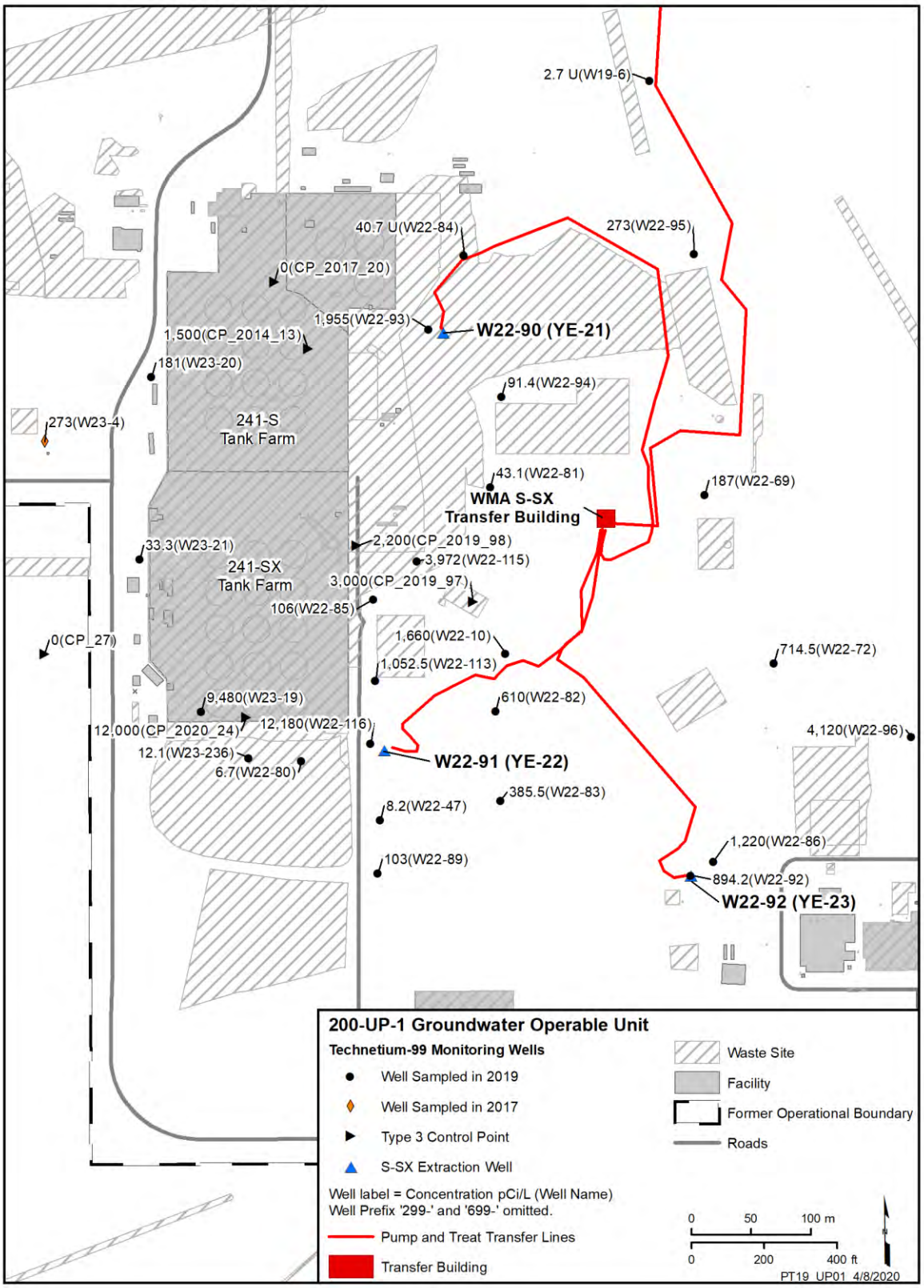

Figure 3-1. WMA S-SX Groundwater Extraction System and Monitoring Wells

3.1.1 Remedial System Operation

The WMA S-SX groundwater extraction system operated with all three wells during 2019, except when the wells were offline for maintenance. Extraction well 299-W22-90 was offline from February 7 through March 20, March 26 through April 1, and April 4 through April 8 during 2019. The initial shutdown on February 7 was due to a transducer communication error, and effluent in the discharge pipeline then was frozen for some time. From March 20 through March 26, troubleshooting efforts were made, but the transducer still did not work properly until April 9, when operations were fully restored. Extraction well 299-W22-92 was offline on August 12 due to reduced treatment capacity at the plant during repair of an air stripper and on November 3 due to interrupted power flow that required manual reset. Data used to monitor remedial system operation consist of flow rates from the extraction wells, sample results from the extraction wells, and influent/effluent sample results from the treatment system.

3.1.1.1 Extraction Well Flow Rates

The average flow rates and total volumes of extracted groundwater for the WMA S-SX extraction wells in 2019 are shown in Table 3-2, and the weekly average flow rates are shown in Figure 3-2.
The combined average flow rate of 281 L/min (74.2 gal/min) was 93% of the design nominal pumping rate of 303 L/min (80 gal/min). As shown in Table 3-2, the total volume of water extracted from the aquifer during 2019 was 148 million L (39.0 million gal); the total since startup in July 2012 was 1.144 billion L (302 million gal).

Table 3-2. Flow Rates for the WMA S-SX Groundwater Extraction System

Well Name	Operational Average Flow Rate in 2019		Overall Average Flow Rate in 2019		Total Volume in 2019	
	L/min	gal/min	L/min	gal/min	L (in 1,000s)	gal (in 1,000s)
299-W22-90	92.3	24.4	77.7	20.5	40,837	10,788
299-W22-91	113	29.7	111	29.4	58,477	15,448
299-W22-92	93.7	24.7	92.0	24.3	48,347	12,772
System totals	**299**	**78.8**	**281**	**74.2**	**147,661**	**39,008**

Notes:

Operational average flow rate is calculated as the mean daily flow for days when the well was operational.

Overall average flow rate is calculated as the total pumped volume divided by the total minutes in a year.

System total flow rates represent the average for the system when all three wells are operational or the overall system average for the year.

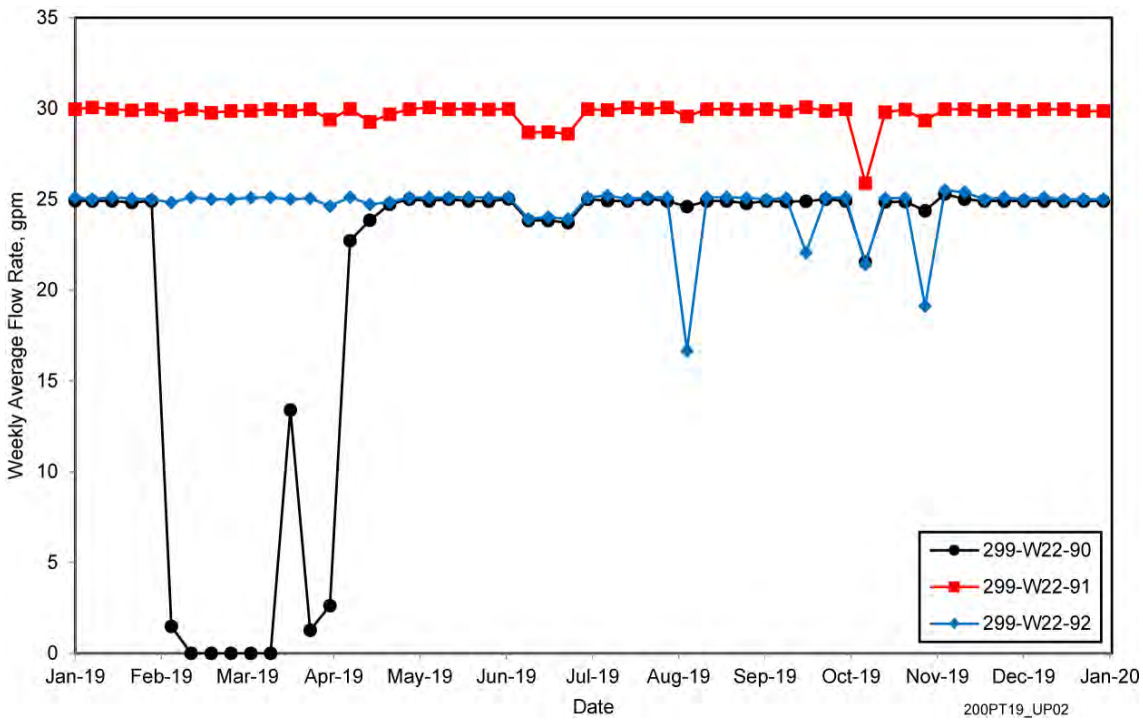

Figure 3-2. Weekly Average Pumping Rates for the WMA S-SX Groundwater Extraction System, 2019

3.1.1.2 Extraction Well Mass Removal

The WMA S-SX extraction wells are sampled quarterly, and the 2019 results are shown in Table 3-3. The sample results and extraction well flow rates were used to estimate the total mass (or activity) removed from the aquifer for the primary constituent (technetium-99) and the secondary constituents (chromium, nitrate, and carbon tetrachloride) (Table 3-4). The cumulative mass of technetium-99, chromium, and nitrate removed from groundwater by the WMA S-SX system is shown in Figures 3-3 through 3-5, along with the predicted mass removed based on fate and transport (F&T) modeling (ECF-200UP1-17-0094, *Fate and Transport Analysis for WMA S-SX Groundwater Plumes in the 200-UP-1 Operable Unit*). The F&T modeling results are provided for two scenarios: (1) a scenario assuming no ongoing sources of contamination to the aquifer, and (2) a scenario that included estimates of mass contributions to the aquifer from ongoing sources (S-SX Tank Farms for technetium-99, chromium, and nitrate, and the 216-S-25 Crib for nitrate).

Source terms (i.e., estimates of the contaminant mass release rate from continuing sources to groundwater) for F&T modeling were based on observed concentrations in groundwater and were calculated using a control volume approach (ECF-200W-17-0030, *Calculation of Source Terms for the 200 West Pump-and-Treat System Optimization Modeling, FY 2017*).

The actual mass (or activity for radionuclides) removed from the aquifer by the WMA S-SX groundwater extraction system is compared to the F&T modeling predictions in Figures 3-3 through 3-5. Mass recovery for technetium-99 through 2019 is about 13% greater than predicted by the modeling scenario with sources and about 25% greater than the modeling scenario without sources. Total recovery of chromium and nitrate through 2019 is between the predicted values for modeling scenarios with and without sources. These comparisons indicate ongoing groundwater contamination from sources at WMA S-SX, particularly for technetium-99 near the SX Tank Farm, where concentrations remain elevated at extraction well 299-W22-91 (Table 3-3). An updated strategy may be needed to address continuing contaminant sources at WMA S-SX, particularly for technetium-99.

Table 3-3. Extraction Well Sample Results for the WMA S-SX Groundwater Extraction System

Well Name	Constituent	1/16/2019	6/12/2019	9/24/2019	12/2/2019
299-W22-90 (YE-21)	Technetium-99 (pCi/L)	320	366	366	385
	Nitrate (mg/L as NO_3)	19	21.9	20.9	24.5
	Hexavalent chromium (µg/L)	18.8	26.9	21.4	24.4
	Total chromium (µg/L)	26.1	25.2	26.3	26.6
	Carbon tetrachloride (µg/L)	77.4	92.4	73	85.8
299-W22-91 (YE-22)	Technetium-99 (pCi/L)	3420	3670	3820	3720
	Nitrate (mg/L as NO_3)	30	29.1	28.9	34
	Hexavalent chromium (µg/L)	29	30.8	30.6	33.1
	Total chromium (µg/L)	31	29.2	30.5	31.3
	Carbon tetrachloride (µg/L)	62.7	53	48.5	56.1
299-W22-92 (YE-23)	Technetium-99 (pCi/L)	940	942	813	882
	Nitrate (mg/L as NO_3)	15	13.8	11.7	13.1
	Hexavalent chromium (µg/L)	14.9	15.9	12.2	12.7
	Total chromium (µg/L)	15.9	13.9	13.8	13.3
	Carbon tetrachloride (µg/L)	62.5	79.9	69.6	70.5

Notes:
For duplicate results, the average value is shown.
For total chromium, unfiltered sample results are shown.

Table 3-4. Contaminant Mass (or Activity) Removed from the Aquifer by the WMA S-SX Groundwater Extraction System

Constituent	Mass (Activity) Removed	
	During 2019	Since Startup in 2012
Technetium-99, g (Ci)	16.2 (0.275)	202.8 (3.44)
Cr(VI), kg	3.33	—*
Chromium (total, unfiltered), kg	3.48	53.0
Nitrate (as NO_3), kg	3,553	39,366
Carbon tetrachloride, kg	10.2	85.1

*Continuous record of Cr(VI) mass removed is not readily available.
Cr(VI) = hexavalent chromium

Tritium is present in groundwater extracted from WMA S-SX but is not removed by the treatment system. For the three extraction wells, tritium concentrations in 2019 ranged from 743 to 2,800 pCi/L, which is well below the 20,000 pCi/L cleanup level. The average monthly tritium effluent concentration from the 200 West P&T central treatment facility (Table 2-5) ranged from 1,355 to 2,720 pCi/L during 2019. MNA for tritium in the 200-UP-1 OU is discussed in Section 3.5.

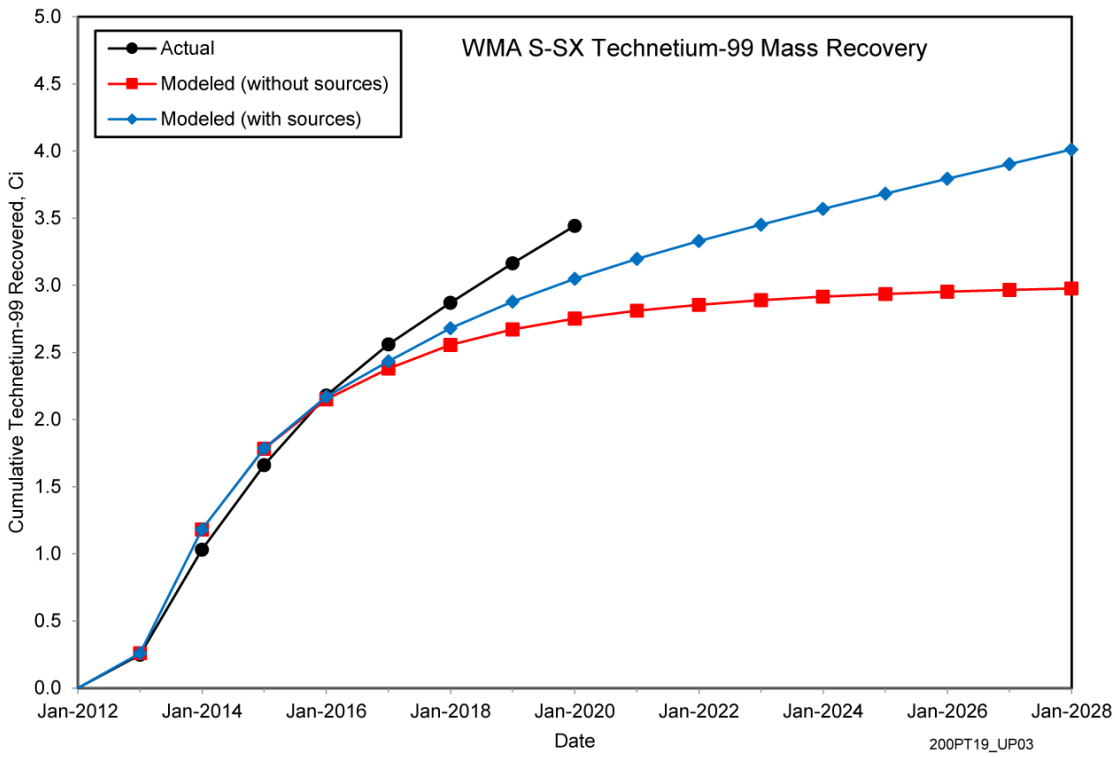

Figure 3-3. Cumulative Technetium-99 Mass Removal by the WMA S-SX Groundwater Extraction System – Modeled and Actual Results

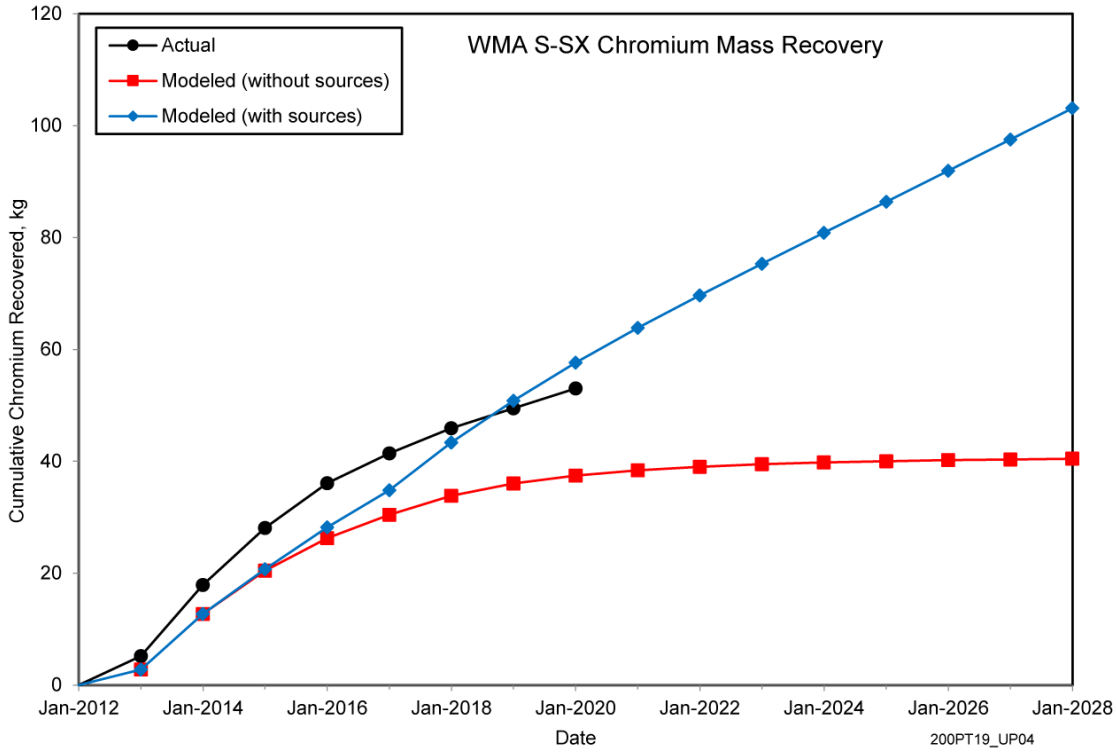

Figure 3-4. Cumulative Chromium Mass Removal by the WMA S-SX Groundwater Extraction System – Modeled and Actual Results

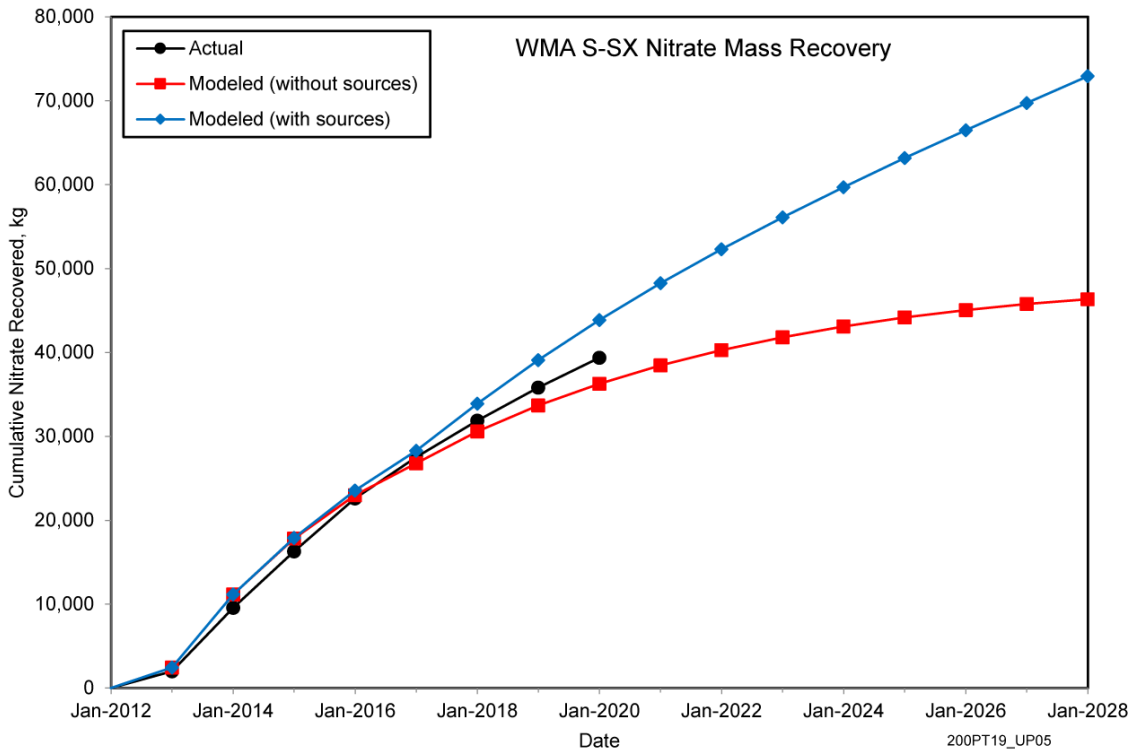

Figure 3-5. Cumulative Nitrate Mass Removal by the WMA S-SX Groundwater Extraction System – Modeled and Actual Results

3.1.2 Water-Level Monitoring

Water-level monitoring is performed to evaluate the effect of the WMA S-SX groundwater extraction system on the water table and the effectiveness of the system in capturing the contaminant plumes. The following sections describe the data interpretation for 2019.

The large volume of water pumped by the 200-ZP-1 OU and U Plant extraction wells causes a regional water table response (Figure 4-10) that affects water levels and gradients near WMA S-SX. The monitoring well network for the 200-ZP-1 OU remedy also includes a large number of wells used to obtain manual depth-to-water measurements and wells equipped with transducers for automated water levels. For these reasons, groundwater levels near the WMA S-SX system are interpreted using data from both the WMA S-SX and 200-ZP-1 OU monitoring networks.

3.1.2.1 Hydraulic Capture Analysis

Groundwater levels and pumping rates were interpreted to estimate the hydraulic capture zones for the WMA S-SX groundwater extraction wells (ECF-HANFORD-20-0049, *Description of Groundwater Calculations to Support Performance Assessment for the Calendar Year 2019 (CY 2019) 200 Areas Pump and Treat Report*). Figure 3-6 shows the estimated, time-dependent capture zone at the WMA S-SX groundwater extraction system during December 2019, as well as the mapped technetium-99 plume in groundwater. The capture zones were estimated by mapping the groundwater elevation data for December 2019 using multi-event universal kriging and tracking particles on the mapped surface for a duration of 8 years (i.e., until 2027, which is 15 years after the start of groundwater extraction [i.e., estimated time required to meet RAOs]). This results in an instantaneous depiction of the extent of capture under December 2019 conditions (i.e., groundwater flow lines depict the approximate area of the aquifer that would be captured by the extraction wells over an 8-year period if the water table

configuration during December 2019 represented steady-state conditions). The calculated groundwater flow lines indicate the focus area of hydraulic containment and mass recovery for the WMA S-SX extraction wells under current conditions.

Figure 3-6 indicates that the system will capture most of the technetium-99 plumes that occur between the extraction wells and tank farms at concentrations ≥900 pCi/L. Concentrations in the plume portions not being captured (e.g., east of extraction wells) were predicted to decline to below the cleanup level through natural attenuation by the year 2057; while this timeframe is beyond the 15 years predicted in the 200-UP-1 OU ROD, it is well within the overall 125-year cleanup timeframe for Central Plateau groundwater (ECF-200UP1-17-0094). In some monitoring wells outside of the interpreted capture zones (or near the edge of a capture zone), technetium-99 concentrations have increased in recent years, notably at wells 299-W22-10, 299-W22-113, and 299-W22-115 (between extraction wells 299-W22-90 and 299-W22-91), at well 299-W22-96 (downgradient of extraction well 299-W22-92), and at well 299-W22-87 (downgradient of the S Tank Farm) (Figures 3-6 and 3-7). Near the northern portion of the SX Tank Farm, where well 299-W22-115 was installed in 2015 to replace well 299-W22-45, increasing technetium-99 concentrations may indicate a source in this area. In addition, modeling indicates that ongoing sources of technetium-99 contamination may be great enough to form new groundwater plumes with concentrations above the cleanup level unless the sources are remedied or groundwater near the sources is hydraulically contained (ECF-200UP1-17-0094). An updated strategy may be needed to address continuing contaminant sources at WMA S-SX, particularly for technetium-99.

The remedy for the chromium and nitrate plumes in the WMA S-SX vicinity is natural attenuation. However, portions of these plumes are being captured by the groundwater extraction system (Figures 3-8 and 3-9) because they are collocated with the technetium-99 plumes. The F&T modeling indicates that the portions of the chromium and nitrate plumes not captured by the groundwater extraction system will attenuate to below their respective cleanup levels by the year 2033 for chromium and 2038 for nitrate, which are within the timeframes predicted in the 200-UP-1 OU ROD (EPA et al., 2012): 25 years for chromium and 35 years for nitrate. However, similar to technetium-99, ongoing contamination sources may be great enough that the plumes with concentrations above cleanup levels may re-form unless the sources are remediated or groundwater near the sources is hydraulically contained (ECF-200UP1-17-0094). Capture of the chromium and nitrate plumes at WMA S-SX is not a requirement in the 200-UP-1 OU ROD for the groundwater extraction system, so this capture analysis is provided for informational purposes only.

3.1.3 Contaminant Monitoring

This section summarizes the 2019 results for groundwater sampling near the WMA S-SX groundwater extraction system. A comprehensive discussion of groundwater contamination within the OU is provided in the 200-UP-1 OU RI/FS (DOE/RL-2009-122). The 200-UP-1 OU RD/RAWP (DOE/RL-2013-07, Rev. 0) provides cross-sectional maps showing the vertical distribution of the plumes. Chapter 11 in DOE/RL-2019-66, *Hanford Site Groundwater Monitoring Report for 2019*, includes additional discussion of recent monitoring results for the entire OU.

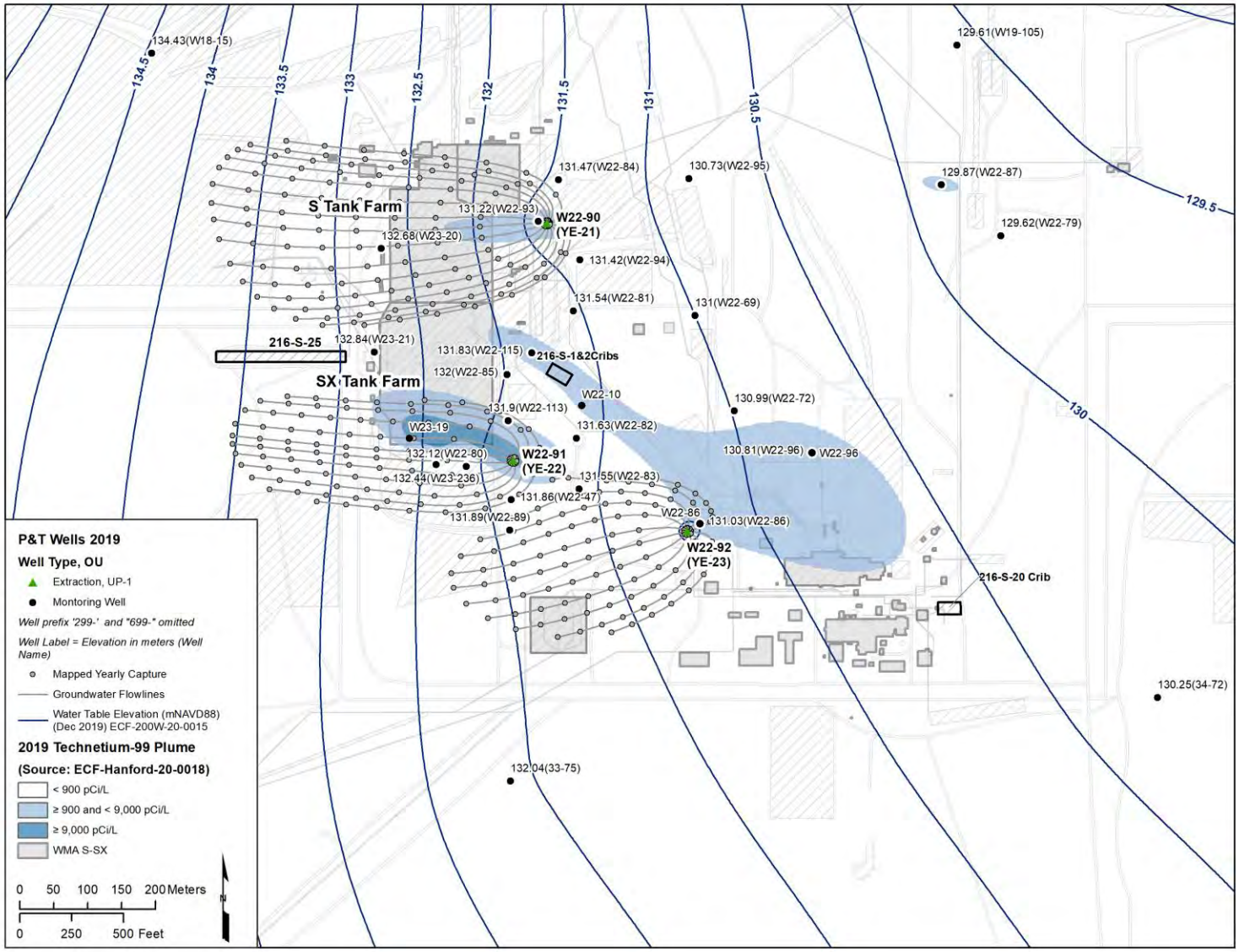

Figure 3-6. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System Under December 2019 Conditions (Steady-State Assumption) Compared to the 2019 Technetium-99 Plumes

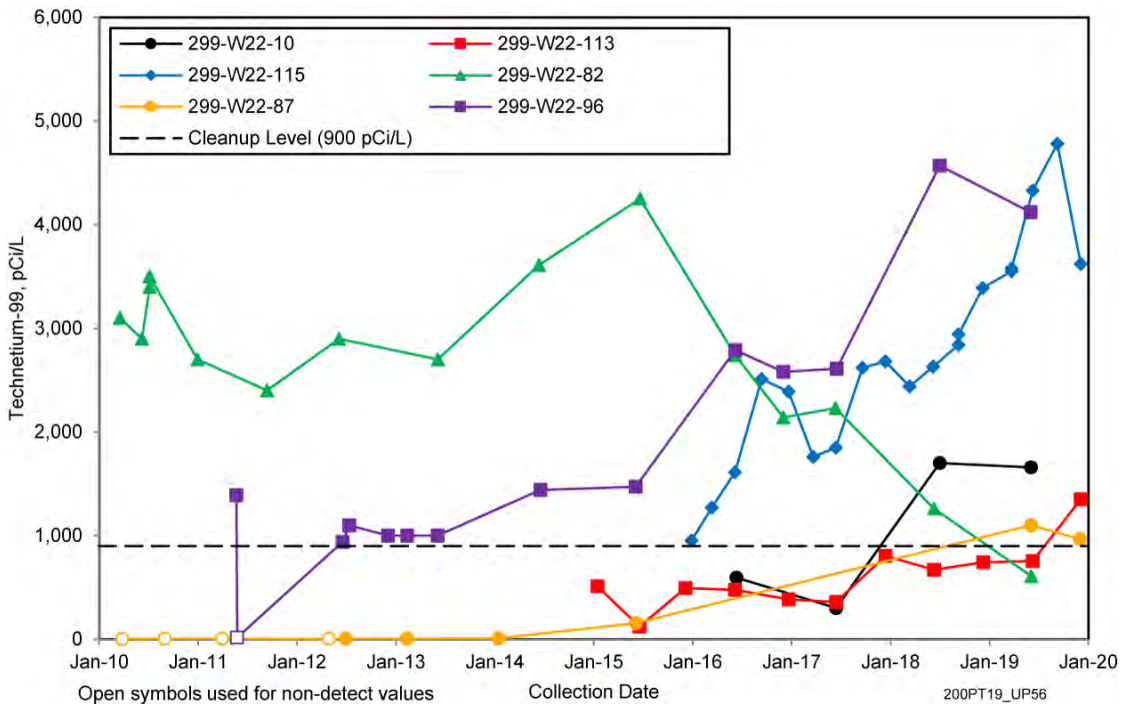

Figure 3-7. Technetium-99 in Selected WMA S-SX Wells Outside Capture Zones of Extraction Wells

Groundwater contamination baseline conditions from which cleanup progress is evaluated were established during 2012 (Section 2.3.1 in DOE/RL-2013-14, *Calendar Year 2012 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*). In the following sections, sample results for technetium-99, chromium, and nitrate for 2019 are compared to baseline concentrations. When more than one sample result was available in a well, the last sample collected during 2019 was used to evaluate cleanup progress; for duplicate samples, the average concentration was used. Plume depictions are based on annual average concentrations in the wells and are the same as those presented in Chapter 11 in DOE/RL-2019-66. Section 2.3.2 in DOE/RL-2013-14 provides background information on the plumes, including sources and historical plume trends.

3.1.3.1 Technetium-99, Chromium, and Nitrate Monitoring Results

Technetium-99, chromium, and nitrate are discussed together in this section because they are all mobile tank waste constituents and form similar plumes in groundwater downgradient from the S-SX Tank Farms (Figures 3-10, 3-11, and 3-12).

The 2019 technetium-99, chromium, and nitrate sample results from monitoring wells in the WMA S-SX vicinity are compared to baseline (2012) concentrations in Tables 3-5, 3-6, and 3-7, respectively. These comparisons are also shown in Figures 3-13 and 3-14 for technetium-99, Figures 3-15 and 3-16 for chromium, and Figures 3-17 and 3-18 for nitrate. In Figures 3-13, 3-15, and 3-17, the comparisons are depicted by bar charts. In Figures 3-14, 3-16, and 3-18, the monitoring well locations are shown in relation to the WMA S-SX extraction wells, and concentration magnitudes are depicted with circles. For these figures, the circle diameters reflect a log-scaled ratio of concentrations relative to the cleanup levels; baseline concentrations are shown with hollow circles, and 2019 concentrations are shown with shaded circles. A hollow annulus between concentric circles therefore shows a concentration decrease, a shaded annulus shows a concentration increase, and no annulus shows minimal concentration change.

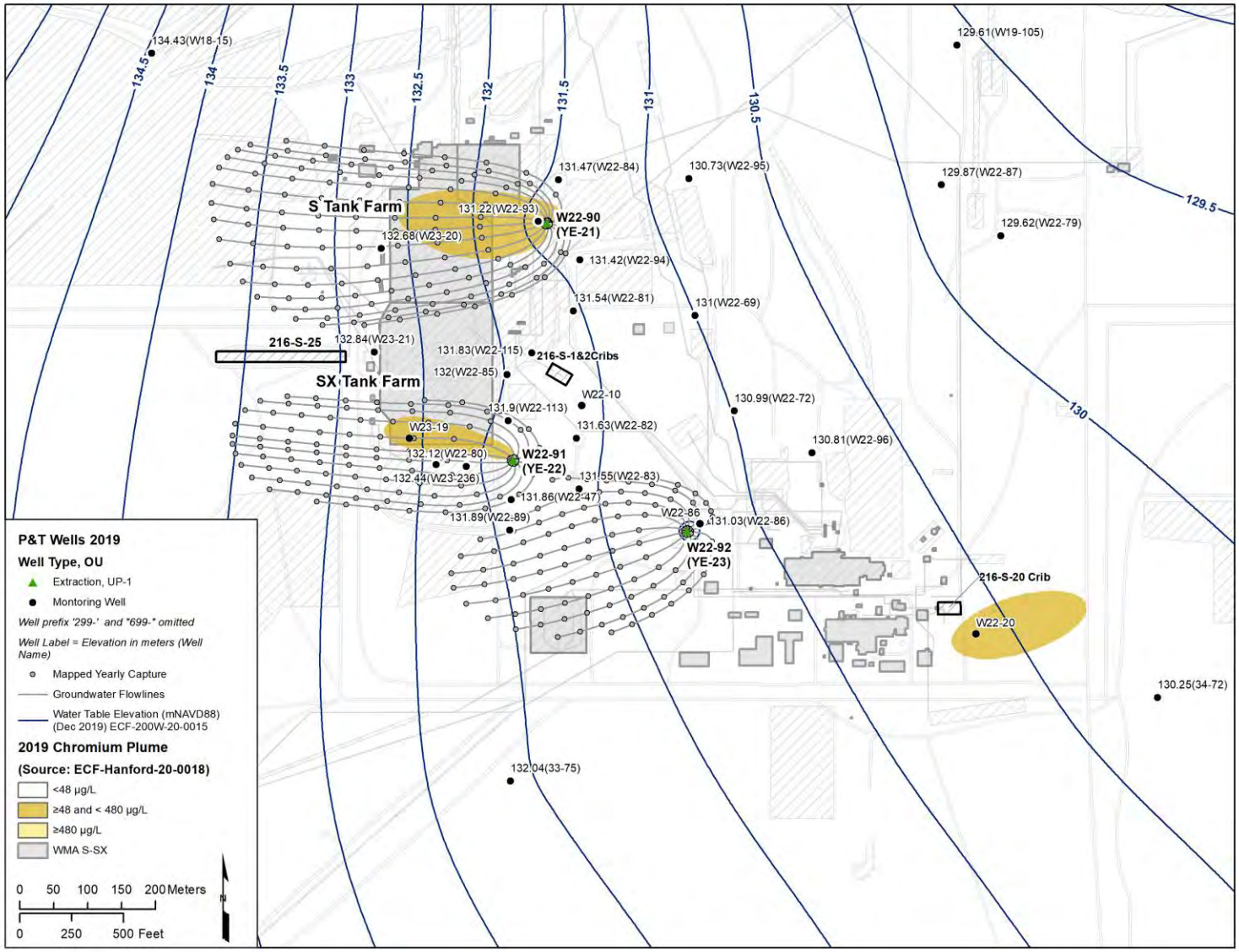

Figure 3-8. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System Under December 2019 Conditions (Steady-State Assumption) Compared to the 2019 Chromium Plumes

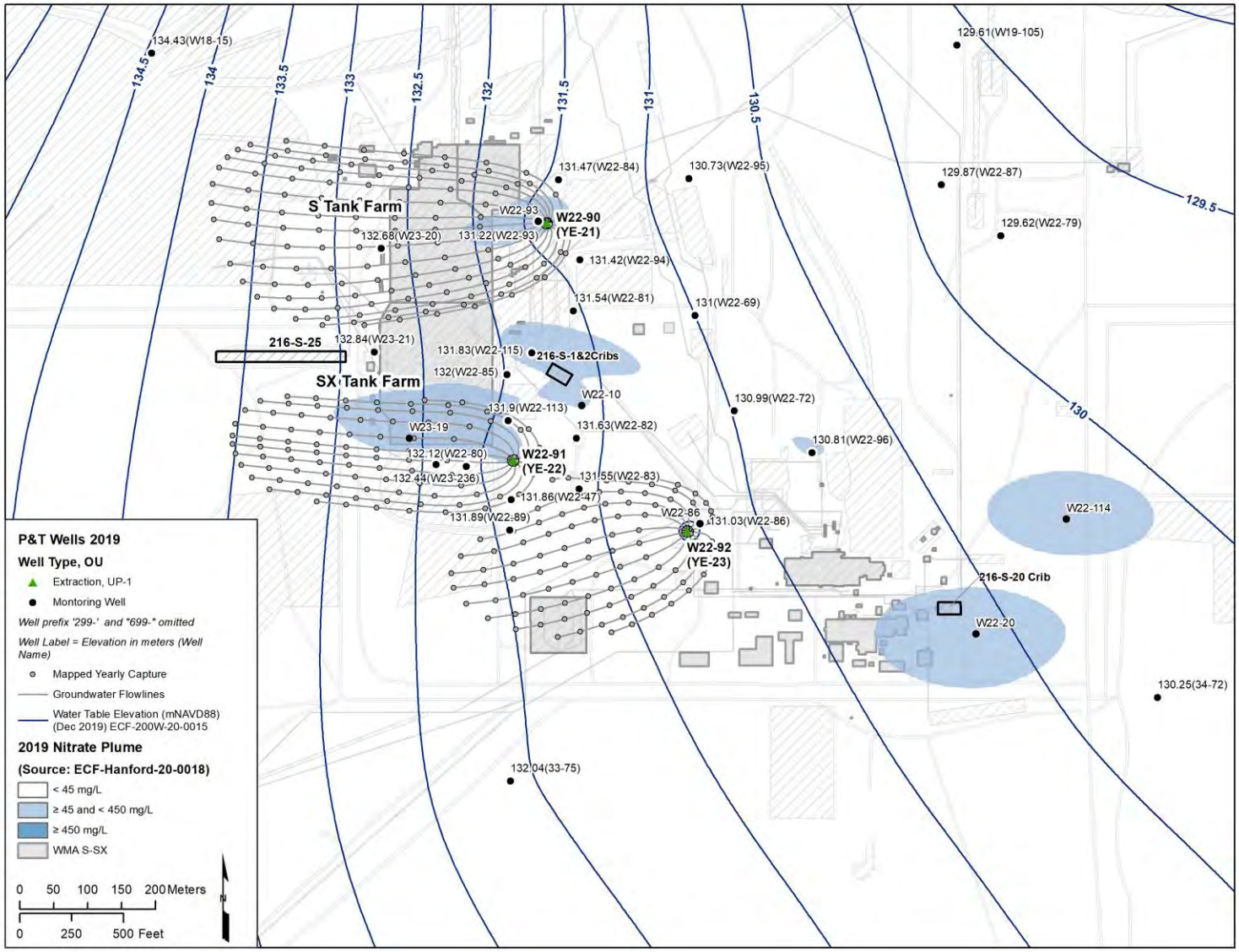

Figure 3-9. Groundwater Flow Lines Illustrating Hydraulic Capture for the WMA S-SX Groundwater Extraction System Under December 2019 Conditions (Steady-State Assumption) Compared to the 2019 Nitrate Plumes

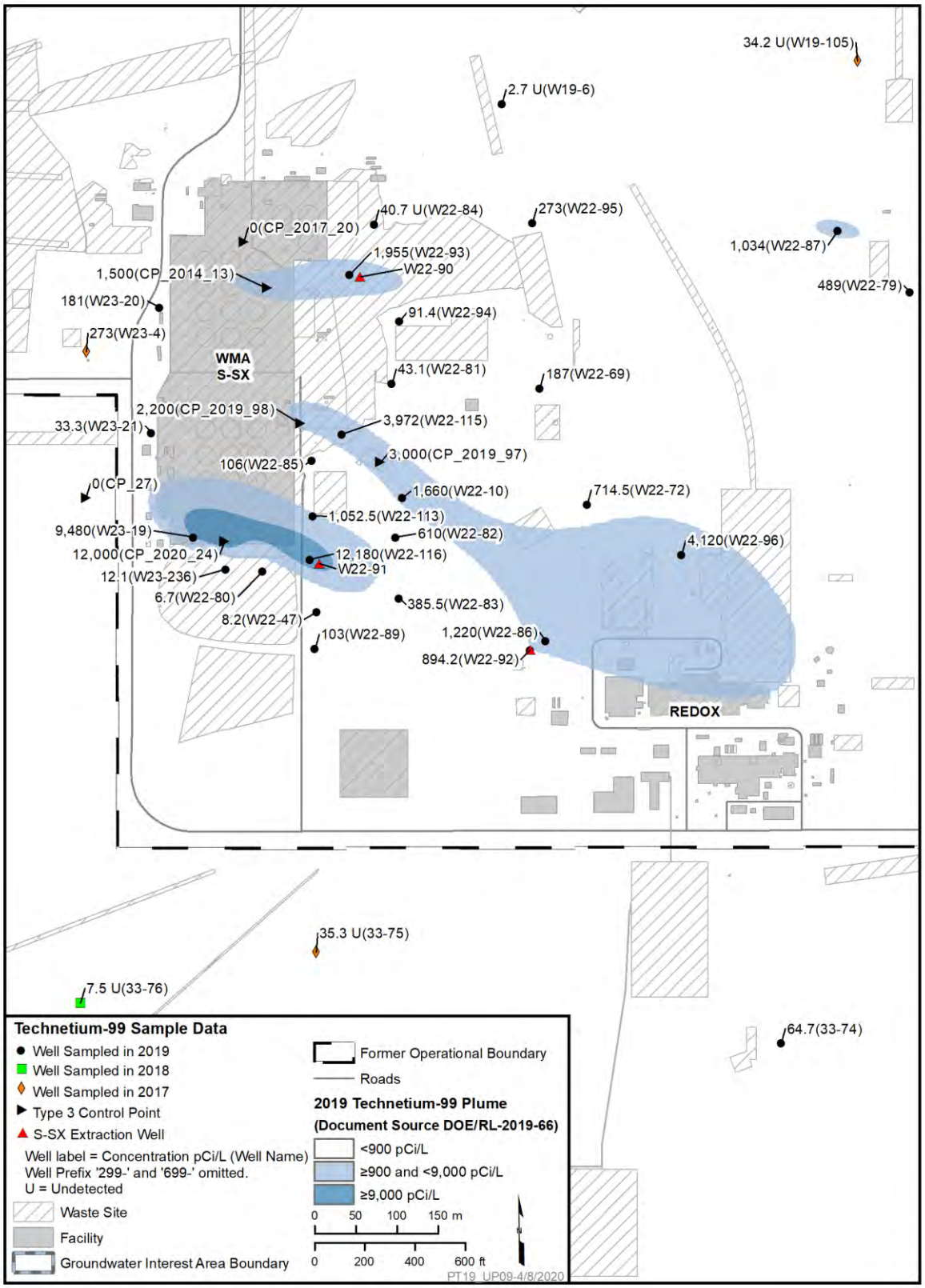

Figure 3-10. Technetium-99 Plumes in Groundwater Near the S-SX Tank Farms, 2019

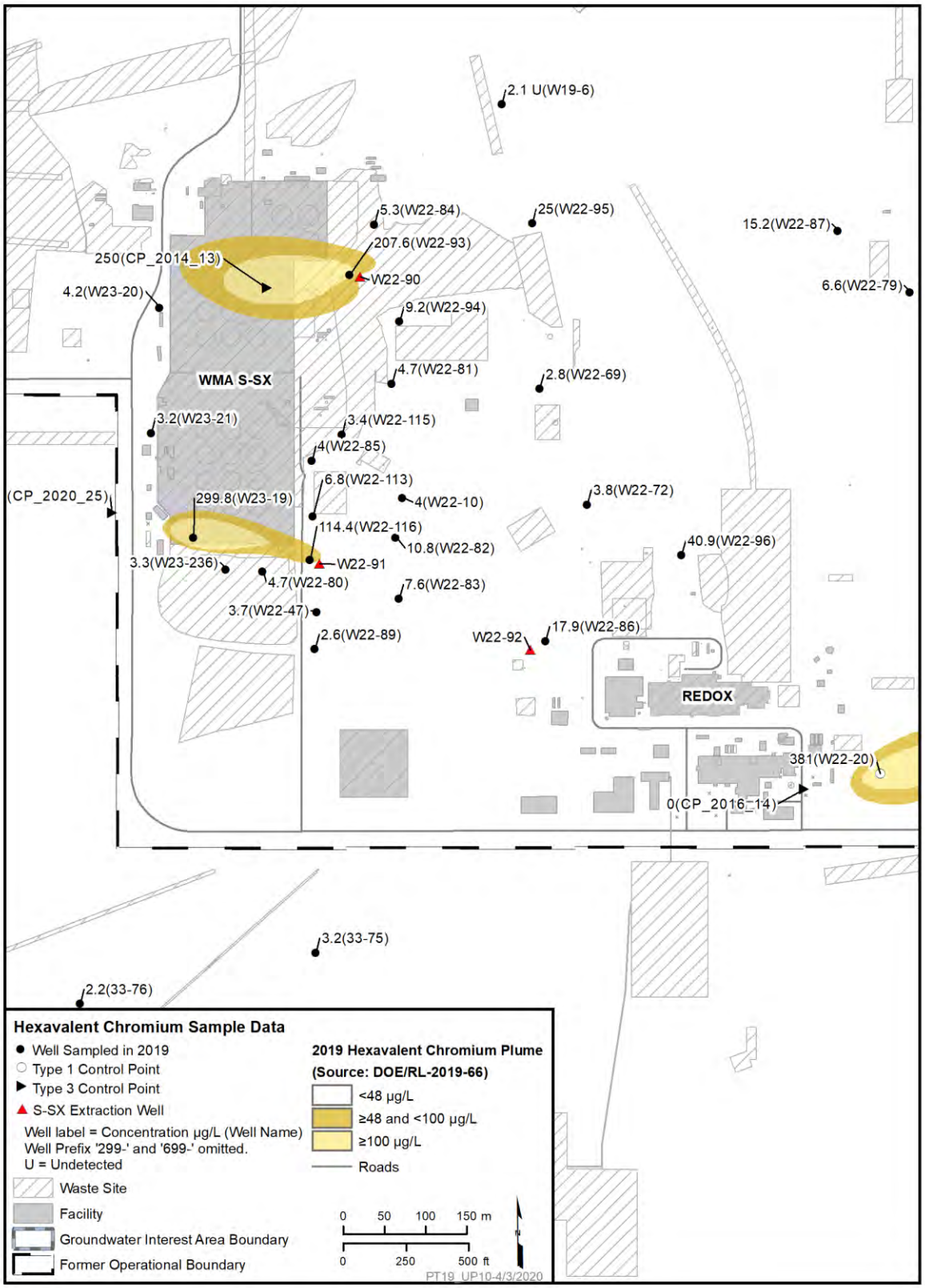

Figure 3-11. Cr(VI) Plumes in Groundwater Near the S-SX Tank Farms, 2019

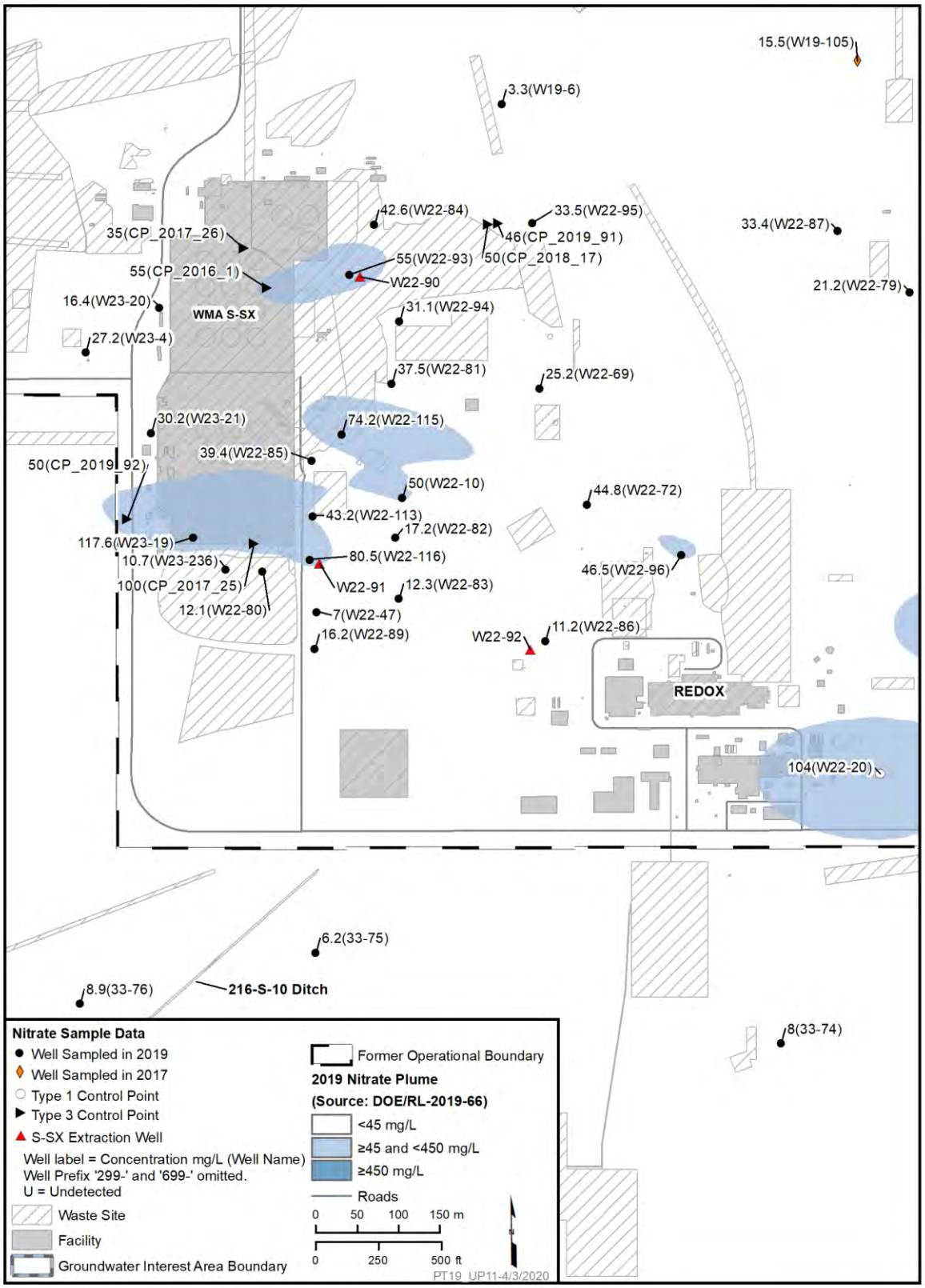

Figure 3-12. Nitrate Plume in Groundwater Near the S-SX Tank Farms, 2019

Table 3-5. Comparison of 2012 (Baseline) to 2019 Technetium-99 Concentrations for the S-SX Tank Farms Vicinity

Well Name	Baseline (2012) Technetium-99 (pCi/L)[a]	2019 Technetium-99 (pCi/L)[a, b]	Percent Change[c]
299-W22-47	15,000	8.18	-100
299-W22-69	220	187	-15
299-W22-72	135	714.5	429
299-W22-80	19	6.69	—
299-W22-81	67.5	43.15	—
299-W22-82	2,900	610	-79
299-W22-83	17,700	178	-99
299-W22-84	630	<37.3	-94
299-W22-85	140	106	-24
299-W22-86	11,000	1,220	-89
299-W22-89	<6.5	<7.61	—
299-W22-93[d]	10,500	2,410	-77
299-W22-94[e]	880	91.4	-90
299-W22-95[f]	310	273	-12
299-W22-96	1,020	4,120	304
299-W22-113[g]	2,300	1350	-41
299-W22-115[h]	520	3,620	596
299-W22-116[i]	5,750	13,500	135
299-W23-19	45,000	7,060	-84
299-W23-20	6.7	18.3	—
299-W23-21	86.2	33.3	—
299-W23-236[j]	18	12.1	—

Notes:

The cleanup level specified in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, for technetium-99 is 900 pCi/L.

For dry wells that that have been replaced, the baseline to 2019 comparison is affected by well design. The replacement wells were installed with 10.7 m (35 ft) screens at the water table. The wells that were replaced had much shorter saturated screened intervals at the water table because they were going dry.

All replacement wells are located adjacent to dry wells that were replaced, except for well 299-W22-95, which was located about 90 m (300 ft) north of well 299-W22-26 because of an anticipated groundwater flow direction change.

Yellow-shaded cells identify monitoring wells within 61 m (200 ft) of an extraction well.

a. Less than (<) values reference the minimum detectable activity.

b. For wells sampled multiple times during 2019, the result shown is from the last sample of the year. For duplicate samples collected on the same day, the average concentration is shown. If a well was not sampled in 2019, the latest result is shown.

c. Percent change shown only for those wells with a baseline or 2019 sample result at least one-tenth the cleanup level (90 pCi/L).

Table 3-5. Comparison of 2012 (Baseline) to 2019 Technetium-99 Concentrations for the S-SX Tank Farms Vicinity

Well Name	Baseline (2012) Technetium-99 (pCi/L)[a]	2019 Technetium-99 (pCi/L)[a, b]	Percent Change[c]

d. Baseline sample result is for well 299-W22-44, which is dry. The replacement well is 299-W22-93.
e. Baseline sample result is for well 299-W22-48, which is dry. The replacement well is 299-W22-94.
f. Baseline sample result is for well 299-W22-26, which is dry. The replacement well is 299-W22-95.
g. Baseline sample result is for well 299-W22-49, which is dry. The replacement well is 299-W22-113.
h. Baseline sample result is for well 299-W22-45, which is nearly dry. The replacement well is 299-W22-115.
i. Baseline sample result is for well 299-W22-50, which is dry. The replacement well is 299-W22-116.
j. Baseline sample result is for well 299-W23-15, which is nearly dry. The replacement well is 299-W23-236.

Table 3-6. Comparison of 2012 (Baseline) to 2019 Chromium Concentrations for the S-SX Tank Farms Vicinity

Well Name	Baseline (2012) Chromium[a, b] (µg/L)	2019 Chromium (µg/L)[a, b, c]	Percent Change[d]
299-W22-47	183	3.8	-98
299-W22-69	12.5	2.95	—
299-W22-72	<5.0 [d]	4.12	—
299-W22-80	25.4	5.25	-79
299-W22-81	9.7	3.35	—
299-W22-82	32.1	8.75	-73
299-W22-83	253	6.41	-97
299-W22-84	47.5	4.74	-90
299-W22-85	6.3	4.09	—
299-W22-86	149	17.85	-88
299-W22-89	<5.0	3.12	—
299-W22-93[e]	353	238.2	-33
299-W22-94[f]	23.4	9.81	-58
299-W22-95[g]	9.9	23.55	138
299-W22-96	5.1	40.9	702
299-W22-113[h]	8.2	3.89	-53
299-W22-115[i]	8.4	3.21	-62
299-W22-116[j]	63.7	114.8	80
299-W23-19	1,010	212.7	-79
299-W23-20	<5.0	3.87	-23
299-W23-21	6.3	3.17	-50
299-W23-236[k]	6	3.71	-38

Table 3-6. Comparison of 2012 (Baseline) to 2019 Chromium Concentrations for the S-SX Tank Farms Vicinity

Well Name	Baseline (2012) Chromium[a, b] (µg/L)	2019 Chromium (µg/L)[a, b, c]	Percent Change[d]

Notes:

The cleanup level specified in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, for hexavalent chromium is 48 µg/L.

For dry wells that that have been replaced, the baseline to 2019 comparison is affected by well design. The replacement wells were installed with 10.7 m (35 ft) screens at the water table. The wells that were replaced had much shorter saturated screened intervals at the water table because they were going dry.

All replacement wells are located adjacent to dry wells that were replaced, except for well 299-W22-95, which was located about 90 m (300 ft) north of well 299-W22-26 because of an anticipated groundwater flow direction change.

Yellow-shaded cells identify monitoring wells within 61 m (200 ft) of an extraction well.

a. Chromium values reflect average of hexavalent and total filtered chromium results.

b. Less than (<) values (if shown) reference the detection limit.

c. For wells sampled multiple times during 2019, the result shown is from the last sample of the year.

d. Percent change shown only for those wells with a baseline or 2019 sample result at least one-tenth the cleanup level (4.8 µg/L).

e. Baseline sample result is for well 299-W22-44, which is dry. The replacement well is 299-W22-93.

f. Baseline sample result is for well 299-W22-48, which is dry. The replacement well is 299-W22-94.

g. Baseline sample result is for well 299-W22-26, which is dry. The replacement well is 299-W22-95.

h. Baseline sample result is for well 299-W22-49, which is dry. The replacement well is 299-W22-113.

i. Baseline sample result is for well 299-W22-45, which is nearly dry. The replacement well is 299-W22-115.

j. Baseline sample result is for well 299-W22-50, which is dry. The replacement well is 299-W22-116.

k. Baseline sample result is for well 299-W23-15, which is nearly dry. The replacement well is 299-W23-236.

Table 3-7. Comparison of 2012 (Baseline) to 2019 Nitrate Concentrations for the S-SX Tank Farms Vicinity

Well Name	Baseline (2012) Nitrate (mg/L as NO_3)	2019 Nitrate (mg/L as NO_3)[a]	Percent Change
299-W22-47	99.4	7.04	-93
299-W22-69	20.7	25.9	25
299-W22-72	29.6	45.6	54
299-W22-80	12.8	13.5	5
299-W22-81	27.4	40.2	47
299-W22-82	62	16.7	-73
299-W22-83	117	12	-90
299-W22-84	35.3	41.5	18
299-W22-85	63.7	40.1	-37
299-W22-86	70.6	11.3	-84
299-W22-89	13.1	16.6	27

Table 3-7. Comparison of 2012 (Baseline) to 2019 Nitrate Concentrations for the S-SX Tank Farms Vicinity

Well Name	Baseline (2012) Nitrate (mg/L as NO_3)	2019 Nitrate (mg/L as NO_3)[a]	Percent Change
299-W22-93[b]	177	58	-67
299-W22-94[c]	51.4	32.7	-36
299-W22-95[d]	39.8	32.2	-19
299-W22-96	18.3	46.5	154
299-W22-113[e]	84.6	44.7	-47
299-W22-115[f]	79.2	75.3	-5
299-W22-116[g]	71.8	86.3	20
299-W23-19	355	68.6	-81
299-W23-20	10.4	15.5	49
299-W23-21	84.6	32.8	-61
299-W23-236[h]	7.24	10.7	48

Notes:

The cleanup level specified in the EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, for nitrate (as NO_3) is 45 mg/L.

For dry wells that that have been replaced, the baseline to 2019 comparison is affected by well design. The replacement wells were installed with 10.7 m (35 ft) screens at the water table; the wells that were replaced had much shorter saturated screened intervals at the water table because they were going dry.

All replacement wells are located adjacent to dry wells that were replaced, except for well 299-W22-95, which was located about 90 m (300 ft) north of well 299-W22-26 because of an anticipated groundwater flow direction change.

Yellow-shaded cells identify monitoring wells within 61 m (200 ft) of an extraction well.

a. For wells sampled multiple times during 2019, the result shown is from the last sample of the year. For duplicate samples collected on the same day, the average concentration is shown. If a well was not sampled in 2019, the latest result is shown.

b. Baseline sample result is for well 299-W22-44, which is dry. The replacement well is 299-W22-93.

c. Baseline sample result is for well 299-W22-48, which is dry. The replacement well is 299-W22-94.

d. Baseline sample result is for well 299-W22-26, which is dry. The replacement well is 299-W22-95.

e. Baseline sample result is for well 299-W22-49, which is dry. The replacement well is 299-W22-113.

f. Baseline sample result is for well 299-W22-45, which is nearly dry. The replacement well is 299-W22-115.

g. Baseline sample result is for well 299-W22-50, which is dry. The replacement well is 299-W22-116.

h. Baseline sample result is for well 299-W23-15, which is nearly dry. The replacement well is 299-W23-236.

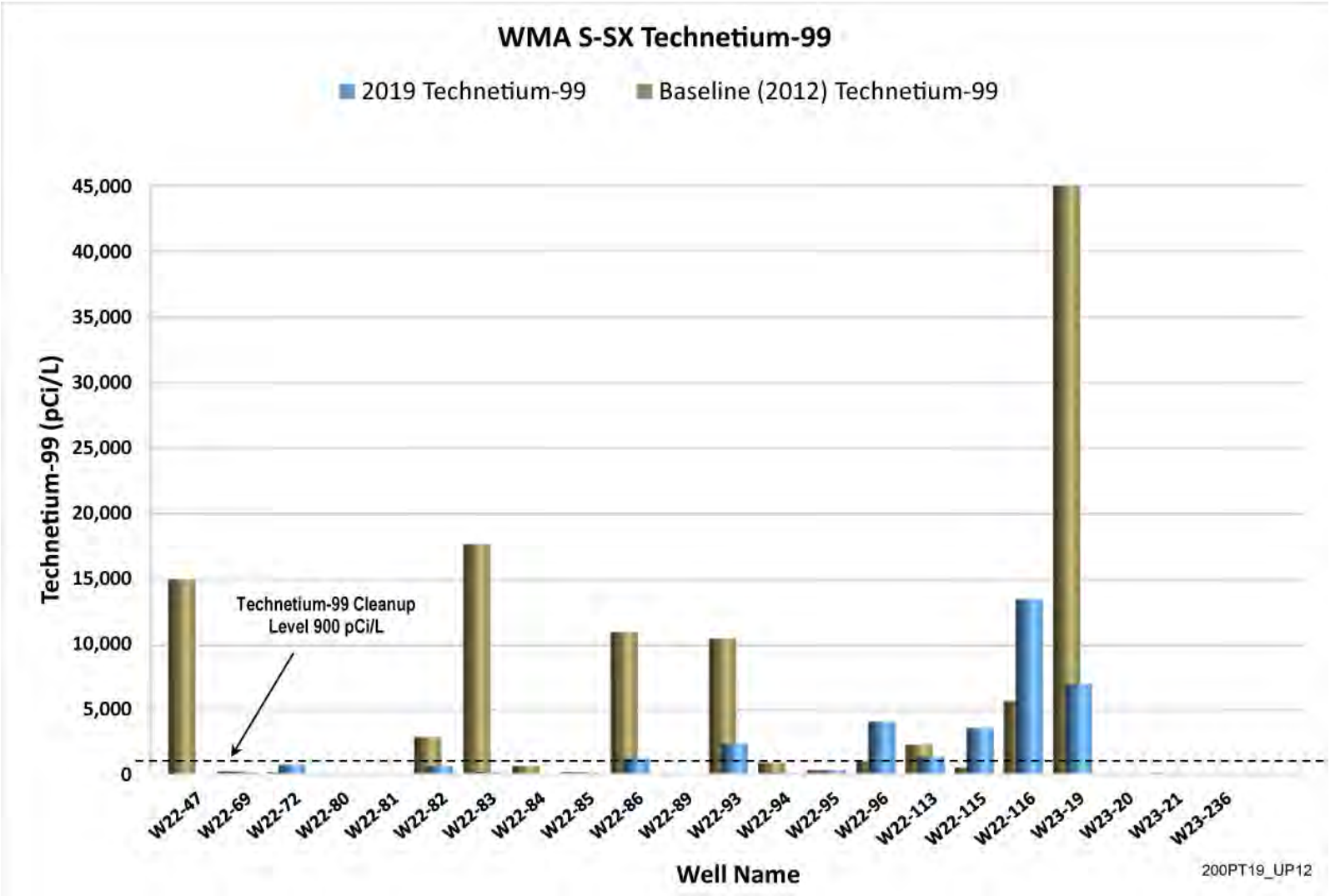

Figure 3-13. Comparison Chart of Baseline to 2019 Technetium-99 Concentrations for Selected Wells Near the S-SX Tank Farms

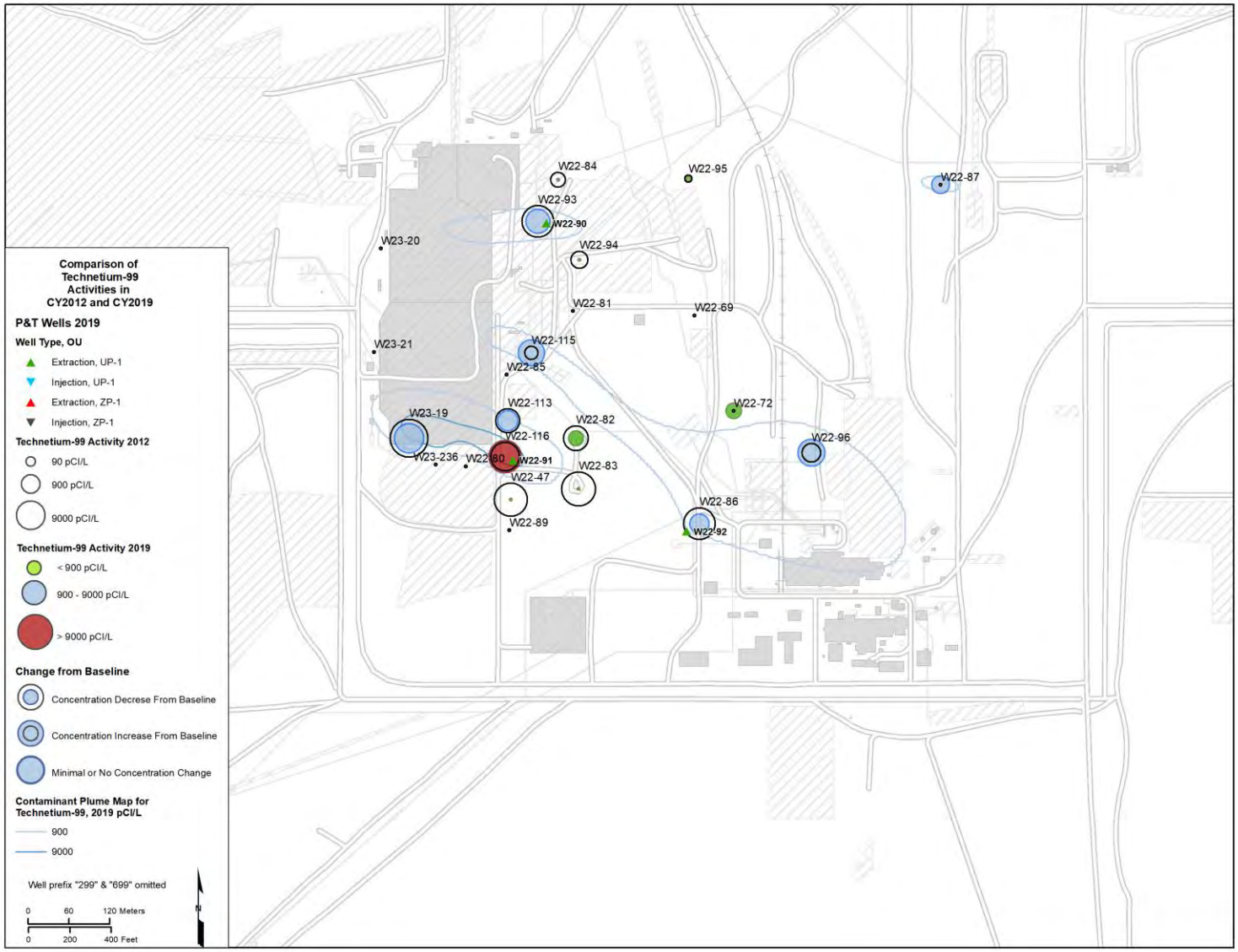

Figure 3-14. Comparison Map of Baseline to 2019 Technetium-99 Concentrations for Selected Wells Near the S-SX Tank Farms

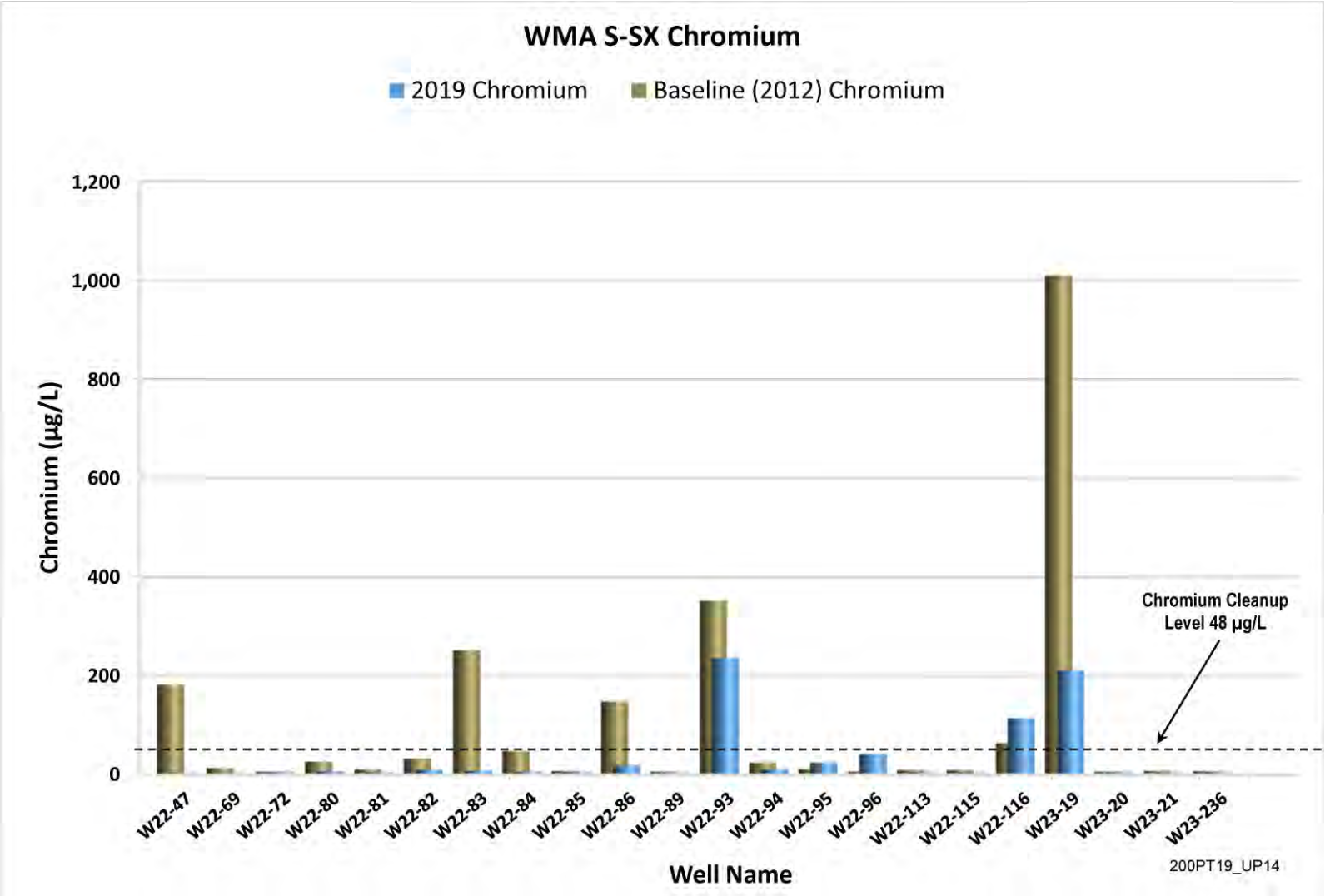

Figure 3-15. Comparison Chart of Baseline to 2019 Dissolved Chromium Concentrations for Selected Wells Near the S-SX Tank Farms

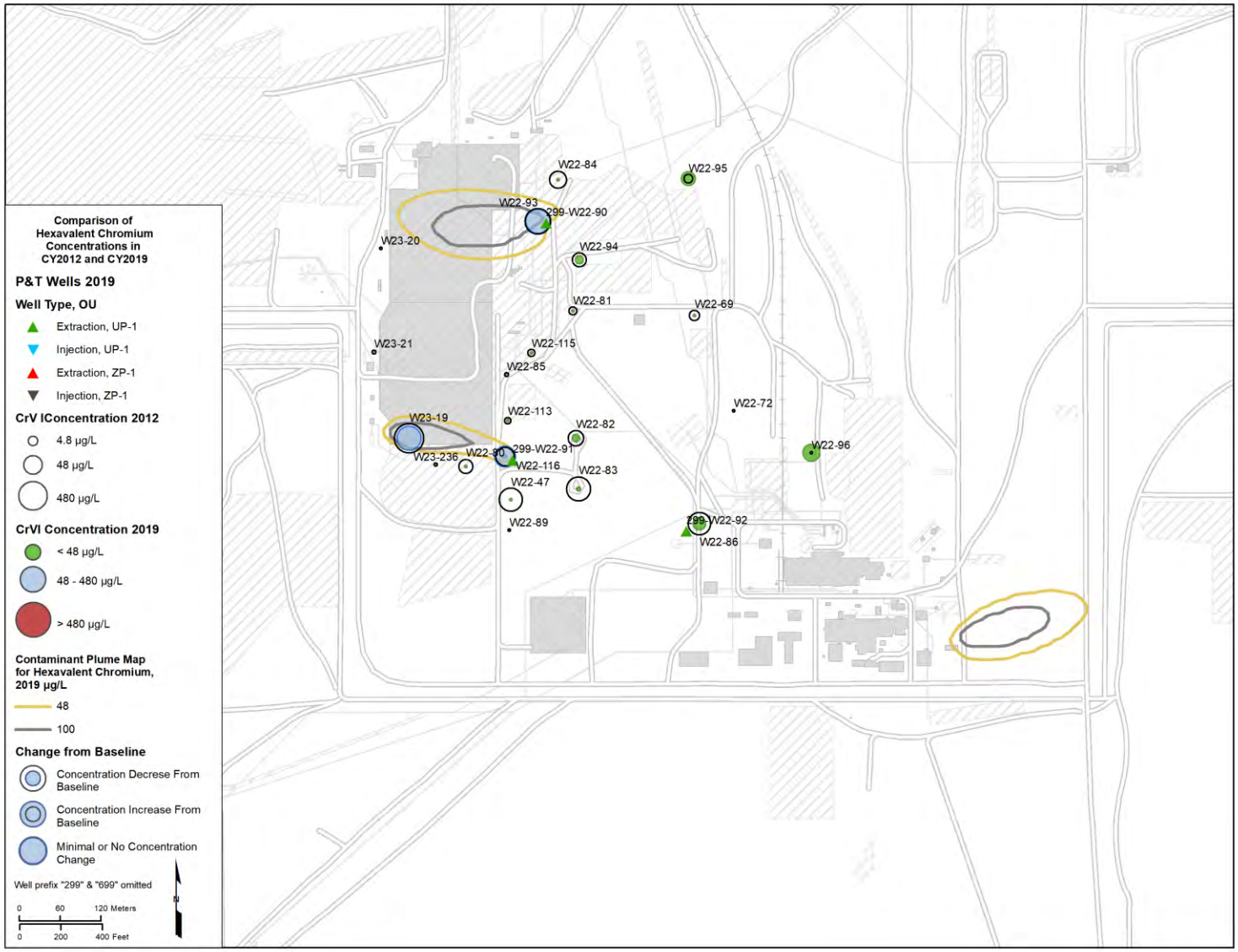

Figure 3-16. Comparison Map of Baseline to 2019 Dissolved Chromium Concentrations for Selected Wells Near the S-SX Tank Farms

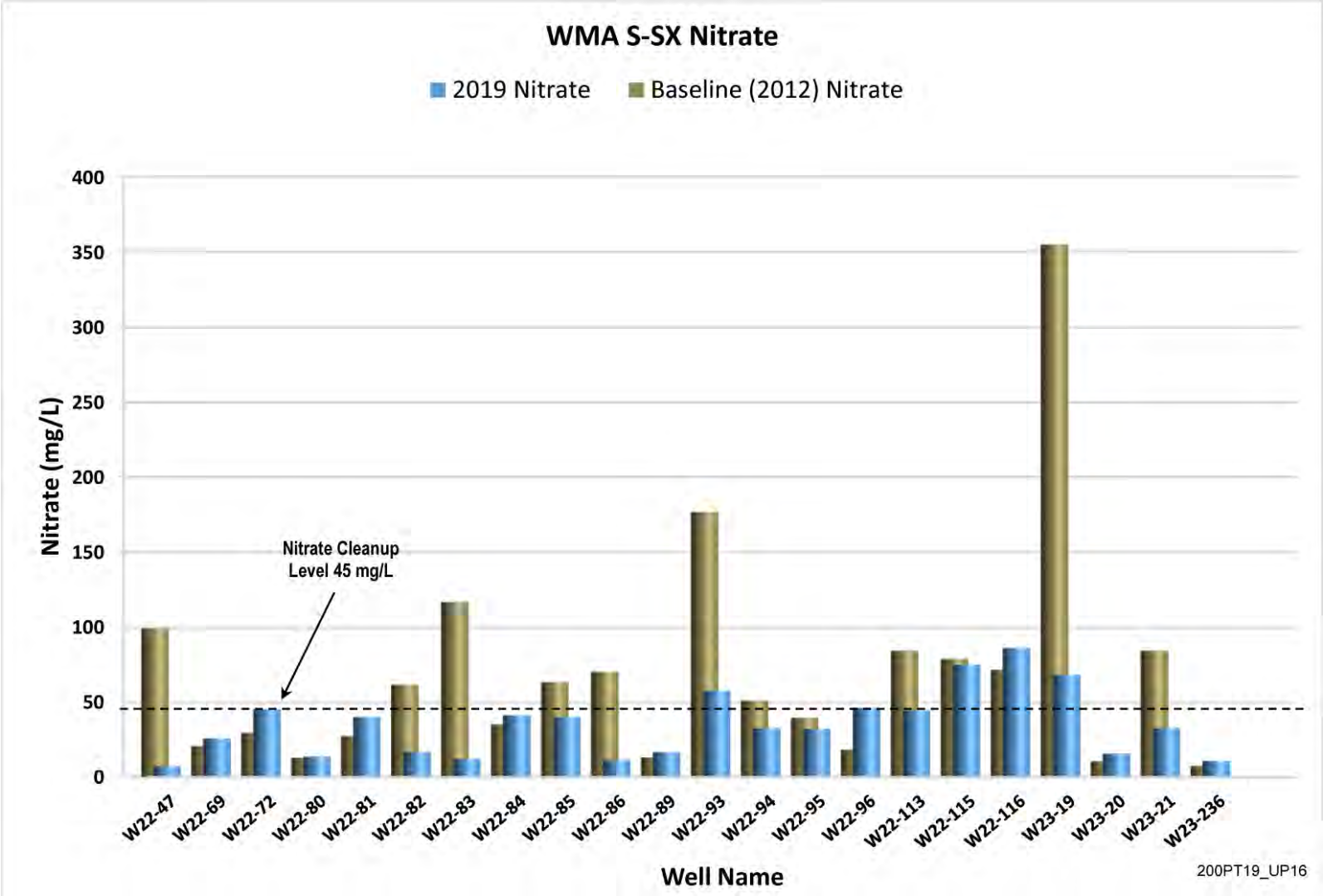

Figure 3-17. Comparison Chart of Baseline to 2019 Nitrate Concentrations for Selected Wells Near the S-SX Tank Farms

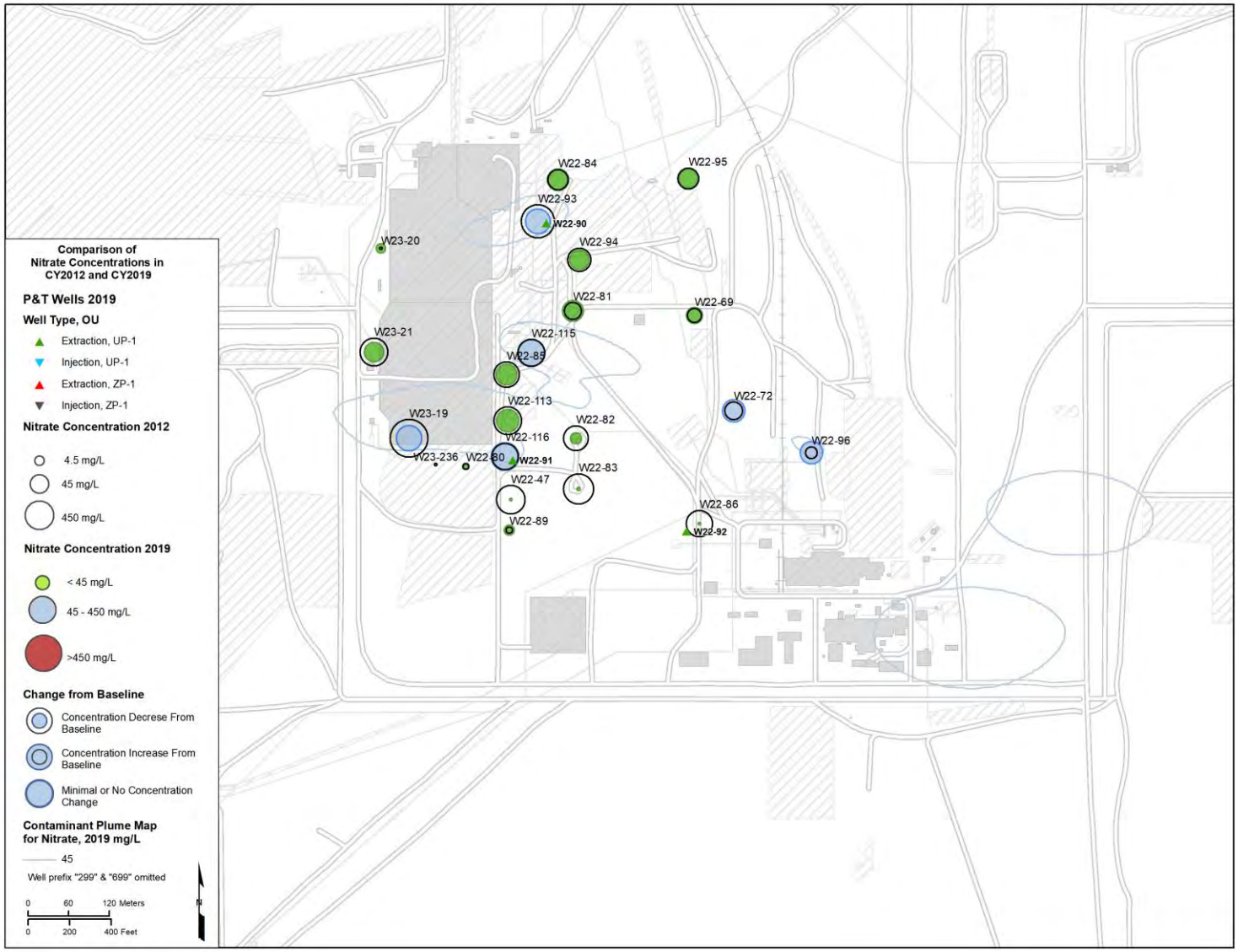

Figure 3-18. Comparison Map of Baseline to 2019 Nitrate Concentrations for Selected Wells Near the S-SX Tank Farms

Several WMA S-SX monitoring wells have become sample dry in recent years or are nearly sample dry and have been replaced (as noted in Tables 3-5, 3-6, and 3-7). To evaluate cleanup progress, concentrations in the new wells are compared to the baseline concentrations established during 2012 from the corresponding dry wells. Comparisons to baseline for replaced wells are likely affected by well design. The replacement wells were installed with 10.7 m (35 ft) screens at the water table. The wells that were replaced had much shorter saturated screened intervals at the water table because they were going dry. Declining concentrations in sample results between the original and replacement wells may reflect dilution due to the screened interval difference. Concentration increases in sample results between the original and replacement wells may be from plume migration or may also reflect an increase in contamination with varying depth at the new wells. Vertical contamination profile data are not available for the older replaced wells for direct comparison at the depths of the new wells.

For wells with baseline or 2019 concentrations above a cleanup level, concentrations declined at most wells from 2012 to 2019. Such declines were observed at 7 of 10 wells for technetium-99 (Table 3-5), at 5 of 6 wells for chromium (Table 3-6), and at 11 of 14 wells for nitrate (Table 3-7).

Well 299-W23-19 is located within the SX Tank Farm and has historically had the highest technetium-99 and chromium concentrations in the OU and among the highest nitrate concentrations (Figures 3-13 through 3-18; Tables 3-5 through 3-7). The 2019 concentrations were 6,620 pCi/L for technetium-99 compared to a baseline of 45,000 pCi/L (85% decline), 213 µg/L for dissolved chromium compared to a baseline of 1,010 µg/L (79% decline), and 69 mg/L for nitrate compared to the baseline of 355 mg/L (81% decline). This well is located within the source area and concentrations have varied over time (Figure 3-19), presumably due to variations in the mass flux of contamination entering the aquifer from the vadose zone. Given the decreasing concentrations at well 299-W23-19, well 299-W22-116 (located immediately upgradient of extraction well 299-W22-91) had the highest technetium-99 and nitrate concentrations and the second highest chromium concentrations within WMA S-SX in 2019 (Figures 3-13 through 3-18).

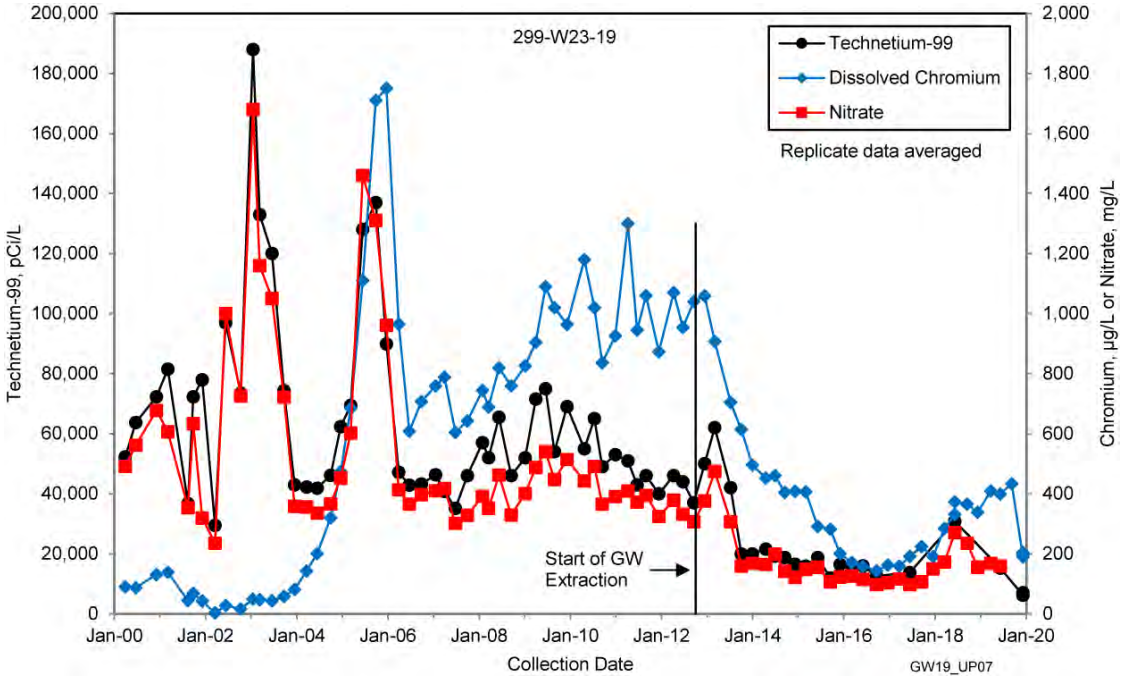

Figure 3-19. Technetium-99, Dissolved Chromium, and Nitrate Concentrations in Well 299-W23-19 Within the SX Tank Farm

For WMA S-SX extraction wells 299-W22-90, 299-W22-91, and 299-W22-92, concentrations of technetium-99, chromium, and nitrate have declined since the startup of pumping in 2012 (Figures 3-20 through 3-22). Declining concentrations in extraction wells are due to a combination of contaminant removal from the aquifer and concentration averaging (i.e., dilution). Dilution occurs as groundwater is drawn from both the targeted portions of the contaminant plumes and from areas (laterally and vertically) where concentrations are lower. For this reason, monitoring well sampling provides the best indicator of remedy performance.

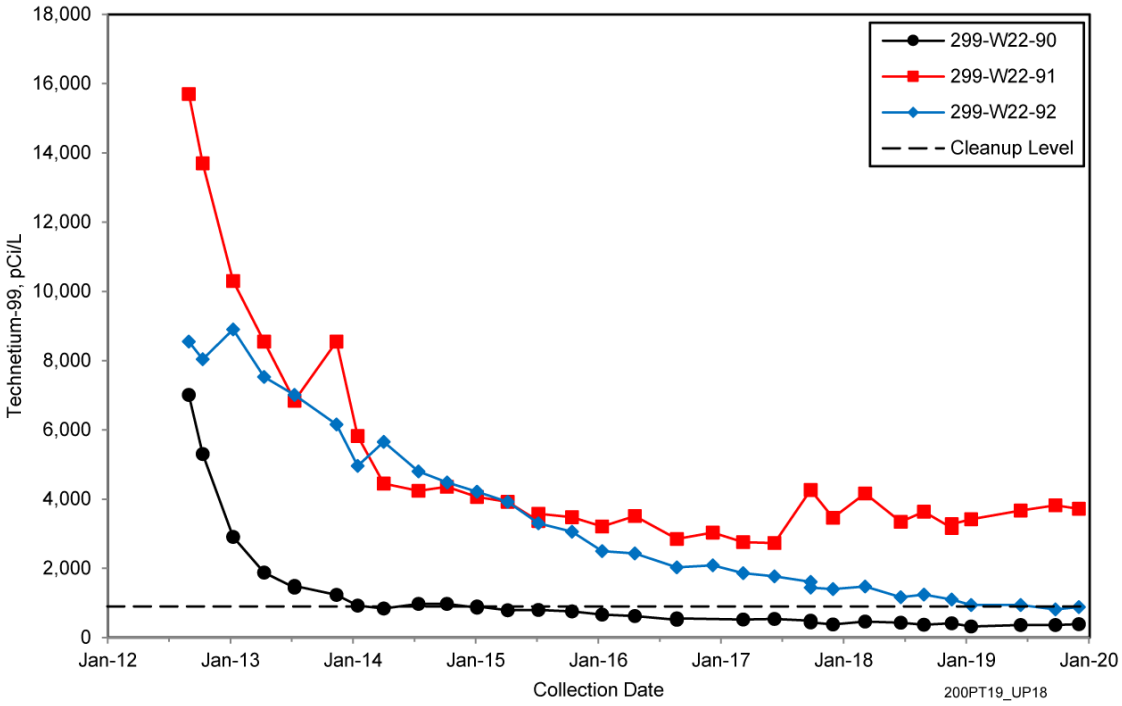

Figure 3-20. Technetium-99 Concentrations in WMA S-SX Extraction Wells After the Start of Groundwater Extraction

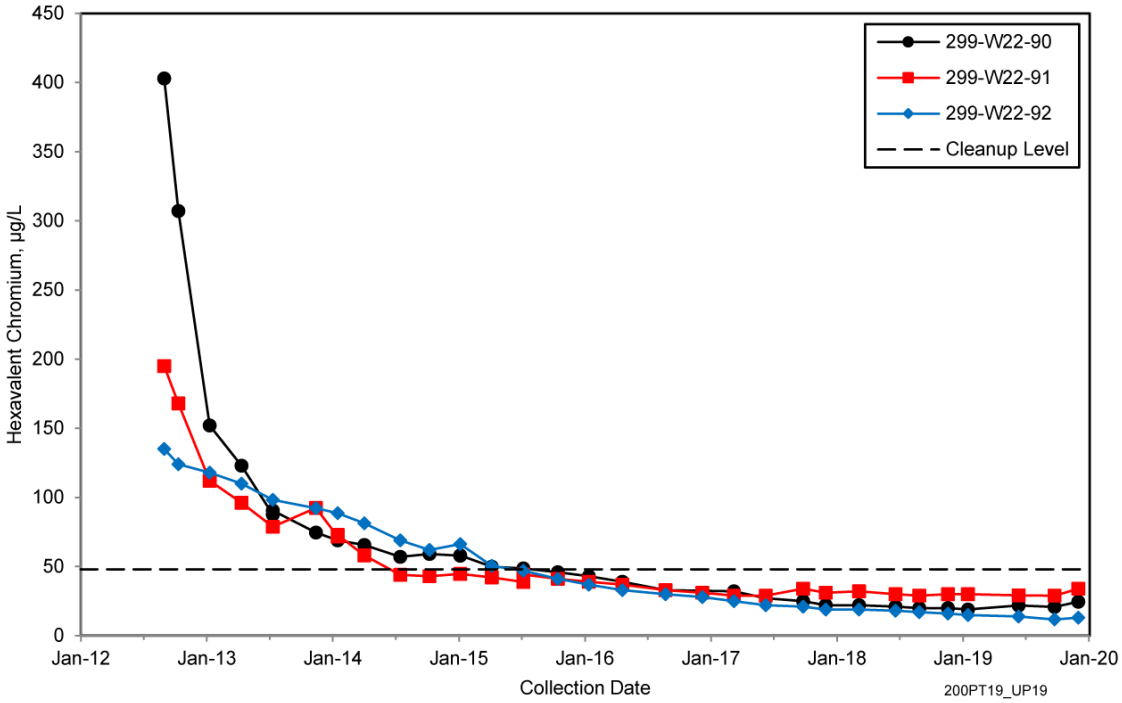

Figure 3-21. Dissolved Chromium Concentrations in WMA S-SX Extraction Wells After the Start of Groundwater Extraction

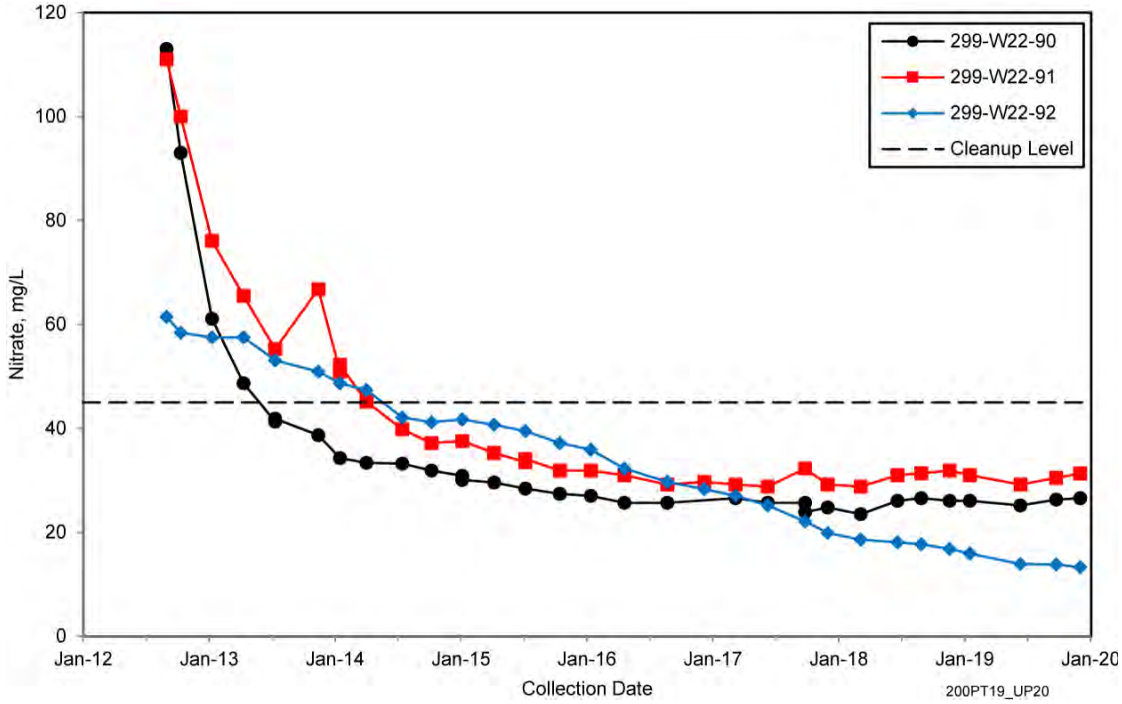

Figure 3-22. Nitrate Concentrations in WMA S-SX Extraction Wells After the Start of Groundwater Extraction

3.1.3.2 Carbon Tetrachloride Monitoring Results

Carbon tetrachloride concentrations above the 3.4 µg/L cleanup level are widespread in 200-UP-1 OU groundwater (Figure 4-12). The plume originated from PFP waste disposal sites in the 200-ZP-1 OU, and some of the ditches from PFP extended to U Pond (west of the S-SX Tank Farms), which may also have been a carbon tetrachloride source. Carbon tetrachloride cleanup is not an objective of the WMA S-SX groundwater extraction system, but the extraction wells do remove carbon tetrachloride from the aquifer and do contribute to the overall larger remedy for this constituent. Evaluation of carbon tetrachloride results for monitoring wells and assessment of the overall remedy are presented in Chapter 4 for both the 200-UP-1 and 200-ZP-1 OUs.

For the WMA S-SX extraction wells, carbon tetrachloride concentration response to pumping differs from that of the other constituents. As shown in Figure 3-23, concentrations have fluctuated since pumping began, without strong upward or downward trends. The limited response of carbon tetrachloride concentrations to pumping from these extraction wells is likely due to the widespread carbon tetrachloride distribution in the aquifer.

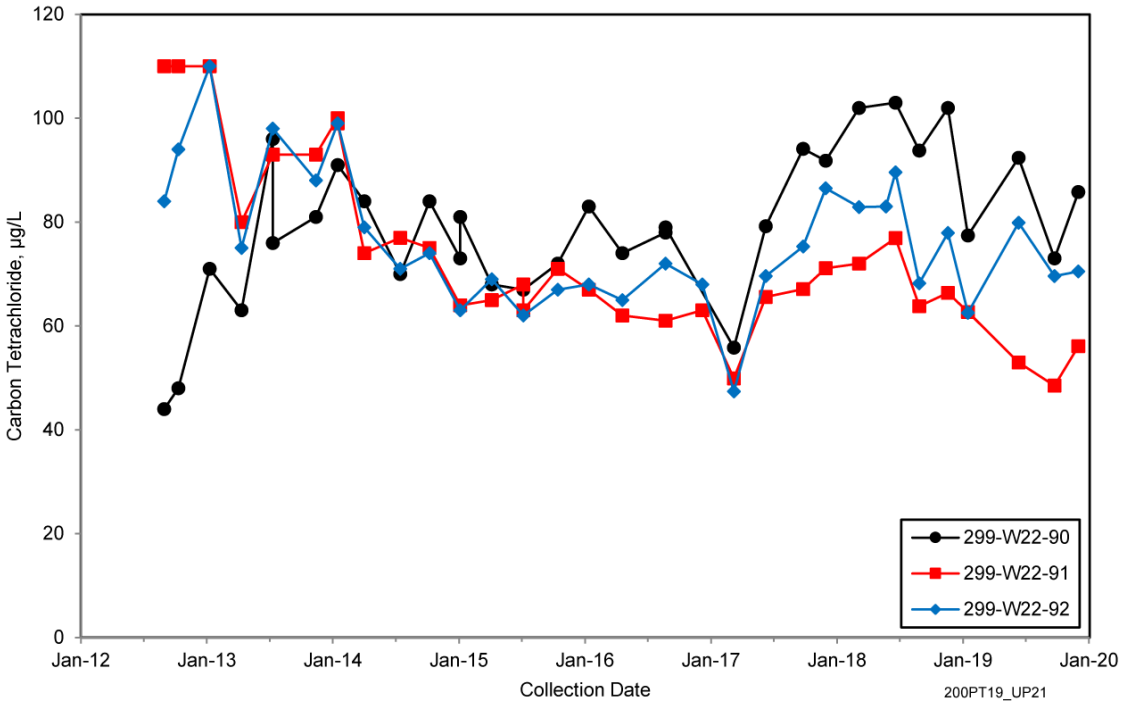

Figure 3-23. Carbon Tetrachloride Concentrations in WMA S-SX Extraction Wells After the Start of Groundwater Extraction

3.1.3.3 Performance Monitoring Evaluation

Progress toward achieving cleanup levels at WMA S-SX was evaluated by calculating the one-sided 95% upper confidence limit (UCL) for mean plume concentration, as described in Section 2.3 of the 200-UP-1 OU RD/RAWP (DOE/RL-2013-07, Rev. 0) and Section 3.1.3 of the 200-UP-1 OU PMP (DOE/RL-2015-14). Although technetium-99 is the primary COC for which the groundwater extraction system was designed, the 95% UCL was also calculated for chromium and nitrate (in accordance with DOE/RL-2015-14) for comparison to modeling results. Annual 95% UCL values were calculated beginning in 2008 (4 years prior to startup of the WMA S-SX groundwater extraction system in 2012). The wells used for the calculation are identified in Table 3-2 of DOE/RL-2015-14 and are primarily within the baseline plume footprint (i.e., baseline concentrations above the 900 pCi/L cleanup level).

The calculations are documented in ECF-200UP1-20-0032, *Calculation of 95 Percent Upper Confidence Limits on Plume Monitoring Data for the 200-UP-1 Groundwater Operable Unit through Calendar Year 2019.*

The 95% UCL values calculated from measured groundwater concentration data for 2008 through 2019 are shown in Figures 3-24 through 3-26 for technetium-99, chromium, and nitrate, respectively; these values are compared to 95% UCL values calculated from the F&T modeling results. As described in Section 3.1.1.2, F&T simulations of the WMA S-SX groundwater extraction system were performed both with and without ongoing sources of contamination to the aquifer. The 95% UCL values for both sets of modeling results are shown in Figures 3-24 through 3-26. The 95% UCL values for the monitoring data have generally trended downward since the start of pumping in 2012, consistent with model predictions. The exception is the 95% UCL for technetium-99, which increased from 2017 to 2018 and then decreased slightly in 2019. The 95% UCL increase can primarily be attributed to the concentration increase at well 299-W23-19 from 13,700 pCi/L in 2017 to 30,900 pCi/L in 2018 (Figure 3-19), and while the concentration decreased at well 299-W23-19 in 2019, concentrations increased at wells 299-W22-93 and 299-W22-116. Despite the recent increase, the 95% UCL for technetium-99 is 65% lower than its value at the start of pumping, and the chromium and nitrate 95% UCL values are 74% and 66% lower, respectively. The 95% UCL values for the modeling results are higher when ongoing sources were included in the simulations due to addition of contaminant mass to the aquifer. Similar to the mass removal predictions discussed in Section 3.1.1.2, comparisons of 95% UCL values between the monitoring data and modeling results can be used to distinguish the importance of ongoing aquifer contamination sources. The monitored 95% UCL values for technetium-99 and chromium currently appear to be more consistent with the model results that included the source terms, whereas the monitored 95% UCL values for nitrate appear to be more consistent with the scenarios that did not include the source terms.

The 2017 F&T simulations of the WMA S-SX groundwater extraction system have shown that in the absence of substantial ongoing sources of contamination to the aquifer, maximum concentrations of technetium-99, chromium, and nitrate would decline to below their respective cleanup levels by the years 2057, 2033, and 2038, respectively, all within the overall 125-year cleanup timeframe for Central Plateau groundwater (ECF-200UP1-17-0094). Comparisons of the 95% UCL calculated from the monitoring data to the model simulations, and comparisons of the actual mass (or activity) of contaminants extracted from the aquifer to model predictions (Section 3.1.1.2), indicate that the WMA S-SX groundwater extraction system is operating as predicted; thus, the system is expected to achieve the cleanup objectives. However, as noted in ECF-200UP1-17-0094, ongoing sources of groundwater contamination may be great enough that groundwater plumes may re-form following system shutdown unless the source areas are remediated or groundwater near the source areas is hydraulically contained. An updated strategy may be needed to address continuing contaminant sources at WMA S-SX, particularly for technetium-99.

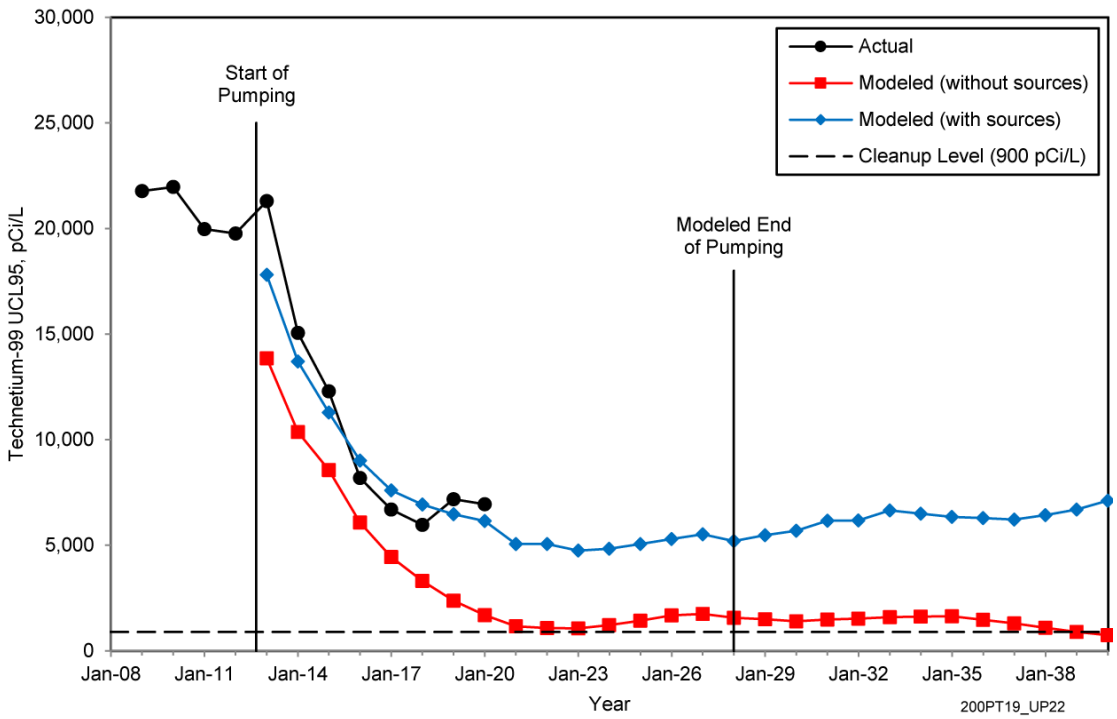

Figure 3-24. 95% UCL on the Mean Concentration of Technetium-99 for Monitoring Wells Within the WMA S-SX Groundwater Extraction System Vicinity

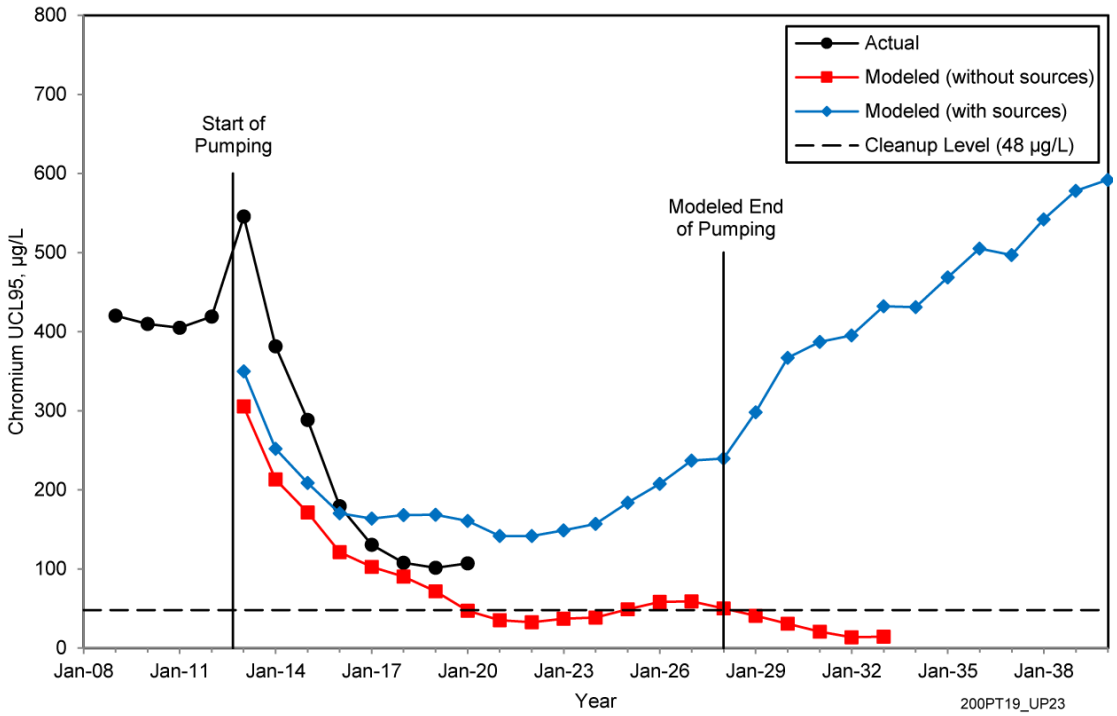

Figure 3-25. 95% UCL on the Mean Concentration of Chromium for Monitoring Wells Within the WMA S-SX Groundwater Extraction System Vicinity

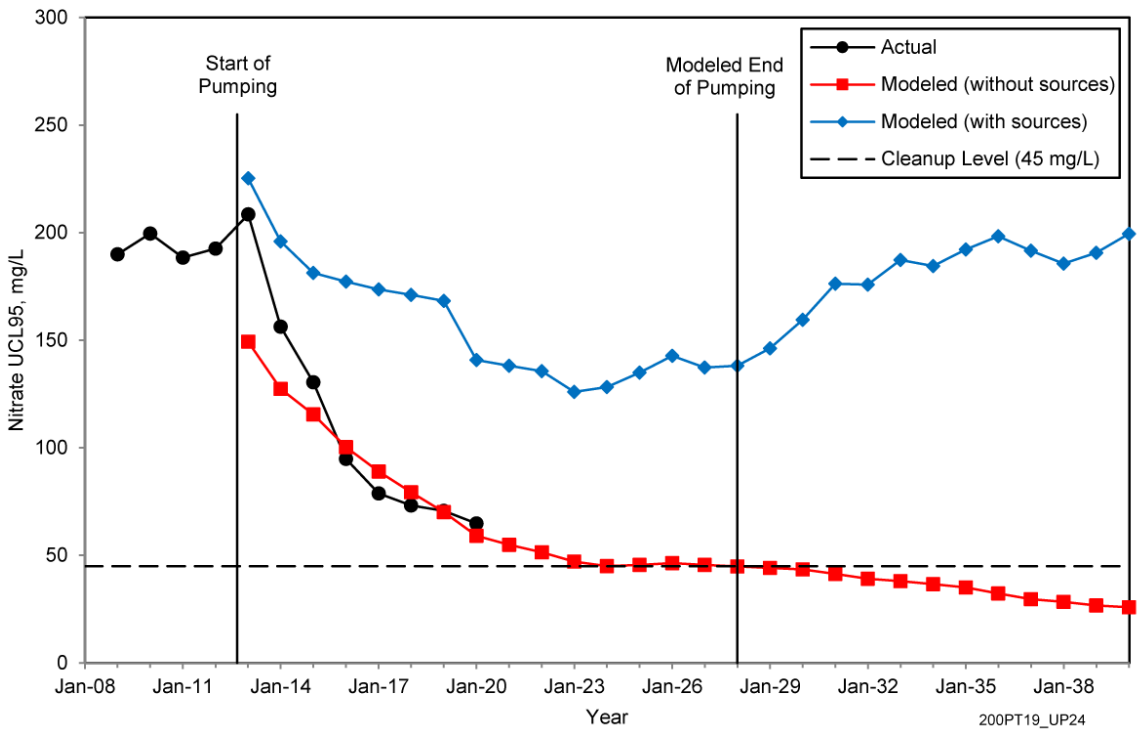

Figure 3-26. 95% UCL on the Mean Concentration of Nitrate for Monitoring Wells Within the WMA S-SX Groundwater Extraction System Vicinity

3.2 U Plant Area Groundwater Extraction System

The uranium plume near U Plant originated from the 216-U-1 and 216-U-2 Cribs, which received nearly 16 million L (4.2 million gal) of effluent between 1951 and 1967 containing an estimated 4,000 kg of uranium (ARH-CD-745, *Input and Decayed Values of Radioactive Liquid Wastes Discharged to the Ground in the 200 Areas Through 1975*). These cribs were also a source of technetium-99 and nitrate to groundwater. Late in their service lifecycle, the cribs received acidic waste that mobilized the uranium in the vadose zone. Effluent disposed to the nearby 216-U-16 Crib in 1984 and 1985 migrated north along the Cold Creek unit as perched water and transported mobilized uranium beneath the 216-U-1 and 216-U-2 Cribs, adding mass to the groundwater plume (Section 2.2 in WHC-EP-0133, *U1/U2 Uranium Plume Characterization, Remedial Action Review and Recommendation for Future Action*).

Figure 3-27 shows the 2019 interpretation of the uranium plume in the U Plant area. To refine the uranium plume extent, three new wells were installed in 2019: 299-W19-126, 299-W19-131, and 299-W20-1 (Figure 3-27). At well 299-W19-126, installed west of U Plant, all characterization samples collected during drilling had concentrations below the 30 µg/L cleanup level, but the routine sample collected in December 2019 had a concentration of 31 µg/L. As such, the interpreted plume extent for 2019 was extended slightly to the north in this area. Well 299-W19-131 was installed approximately 160 m (525 ft) east of well 299-W19-101 (the easternmost well within the interpreted 2018 plume boundary), and well 299-W20-1 was installed approximately 350 m (1,148 ft) east of well 299-W19-101. At well 299-W19-131, all characterization samples collected during drilling had uranium concentrations <22 µg/L, and the routine sample collected in December 2019 had a concentration of 13 µg/L. At well 299-W20-1, the shallowest characterization sample collected during drilling had a uranium concentration of 46.7 µg/L, and the routine sample collected in December 2019 had a concentration of 32 µg/L. In addition, the uranium concentration at well 299-W19-48 decreased from 31.7 µg/L in 2018

to 20.7 µg/L in 2019. Based on these results, the 2019 plume interpretation shows the eastern plume extent separated from the main uranium plume, and a small plume is shown farther to the east at well 299-W20-1 (Figure 3-27). Given that reducing conditions caused by the drilling process can suppress initial uranium concentrations measured in new wells, these wells will be sampled quarterly for at least one year, and concentration changes may affect future plume interpretations.

The U Plant area groundwater extraction system consists of three extraction wells: 299-W19-113 and 299-W19-114 began operating in September 2015, and well 299-W19-125 began operating in September 2017. Extracted groundwater is conveyed via aboveground, dual-walled pipelines to the 200 West P&T central treatment facility. Groundwater treatment consists of two main processes:

- Radiological pre-treatment process using IX resins
- Central treatment process using anoxic and aerobic biodegradation[2] for nitrate, metals, and organic contaminants; membrane filtration to remove particulate matter; and air stripping to remove VOCs

Groundwater from the U Plant area extraction wells is combined with groundwater from the B Complex extraction wells in the 200 East Area (Chapters 5 and 6) and passes through the uranium IX treatment train. The water then is combined with groundwater from WMA S-SX and 200-ZP-1 OU extraction wells requiring radiological treatment and is sent through another IX resin to remove technetium-99. The effluent from this process is then combined with groundwater from the remaining extraction wells (not requiring radiological treatment) and passed through the 200 West P&T central treatment process. The treated groundwater is returned to the aquifer using injection wells. Operation of the 200 West P&T is discussed further in Chapter 2.

The current U Plant area groundwater extraction system is the third system used for remediating the plumes from the 216-U-1 and 216-U-2 Cribs. The first system operated near the cribs from June 13, 1985, to November 26, 1985 (WHC-EP-0133), and removed 687 kg of uranium from the groundwater using an IX treatment system. The second system was an interim action that began operating as a treatability test in March 1994 and continuing until March 2011. The system was focused on the area south and southeast of U Plant (approximately 300 to 600 m [984 to 1,969 ft] downgradient from the cribs). The extraction wells varied, but wells 299-W19-36 and 299-W19-43 were used during the later years of system operation. A rebound study was conducted between January 2005 and January 2006, and the system was restarted in April 2007 (DOE/RL-2008-02, *200-UP-1 and 200-ZP-1 Operable Units Pump and Treat System Annual Report for FY07*). This system removed a total of 220.5 kg of uranium from the aquifer (DOE/RL-2012-03, *Calendar Year 2011 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*).

The following sections describe the operation of the current (i.e., the third) groundwater extraction system, as well as the results of water-level and contaminant monitoring.

[2] As discussed in Section 2.3, biological treatment was suspended in October 2019 as part of the 200-ZP-1 OU optimization study (DOE/RL-2019-38).

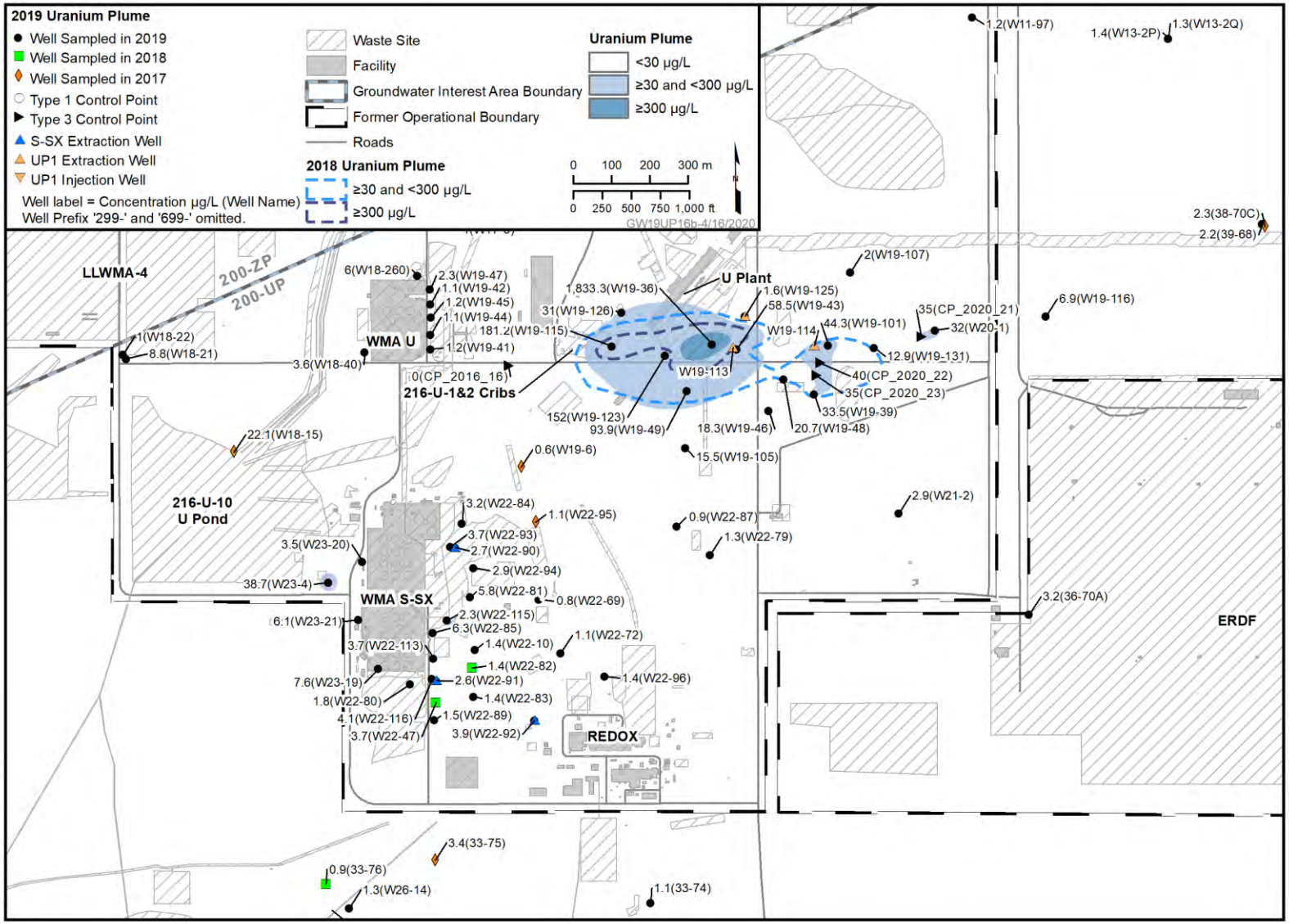

Figure 3-27. U Plant Area Groundwater Extraction System and the Uranium Plume, 2019

3.2.1 Remedial System Operation

The U Plant groundwater extraction wells operated nearly 100% of the time in 2019, with the exception of extraction well 299-W19-113 that was offline on December 8, 2019. Following a short-duration shutdown of the treatment system, the pump in well 299-W19-113 did not automatically restart with the other wells and was manually restarted on December 9, 2019. Data used to monitor remedial system operation consist of flow rates from the extraction wells, sample results from the extraction wells, and influent/effluent sample results from the treatment system.

3.2.1.1 Extraction Well Flow Rates

Table 3-8 shows the average flow rates and total volumes of extracted groundwater for the U Plant area extraction wells for 2019, and Figure 3-28 shows the weekly average flow rates. In June 2019, low water-level readings in extraction well 299-W19-113 caused short-duration shutdowns (of less than one day) and the need for sand filter changeouts was increasing. In response, the target pumping rate was reduced from approximately 189 to 170 L/min (50 to 45 gal/min). In February 2019, the target pumping rate for extraction well 299-W19-114 was increased from approximately 189 to 284 L/min (50 to 75 gal/min).

The combined average flow rate for the year of 625 L/min (165 gal/min) was 110% of the design nominal pumping rate of 568 L/min (150 gal/min). As shown in Table 3-8, the total volume of water extracted from the aquifer during 2019 was 329 million L (87 million gal), and the total since startup in September 2015 was 1.281 billion L (338 million gal).

Table 3-8. Flow Rates for the U Plant Area Groundwater Extraction System

Well Name	Operational Average Flow Rate in 2019		Overall Average Flow Rate in 2019		Total Volume in 2019	
	L/min	gal/min	L/min	gal/min	L (in 1,000s)	gal (in 1,000s)
299-W19-113	178	47.1	176	46.4	92,345	24,395
299-W19-114	273	72.1	270	71.3	141,794	37,458
299-W19-125	182	48.0	180	47.5	94,473	24,957
System totals	**633**	**167**	**625**	**165**	**328,612**	**86,810**

Notes:

Operational average flow rate calculated as the mean daily flow for days when well was operational.

Overall average flow rate calculated as the total pumped volume divided by the total minutes in a year.

System total flow rates represent the average for the system when all three wells are operational or the overall system average for the year.

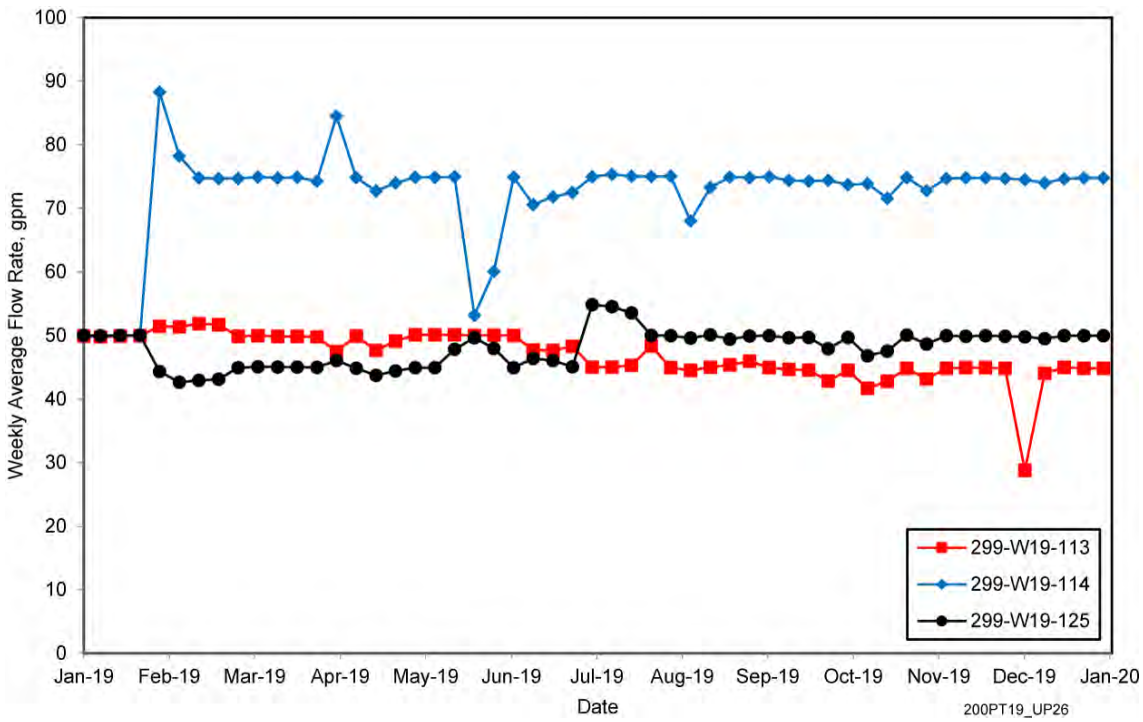

Figure 3-28. Weekly Average Pumping Rates for the U Plant Groundwater Extraction System, 2019

3.2.1.2 Extraction Well Mass Removal

The U Plant area extraction wells are sampled quarterly, and the 2019 results are shown in Table 3-9. The sample results and the extraction well flow rates were used to estimate the total mass (or activity) of uranium, technetium-99, nitrate, and carbon tetrachloride removed from the aquifer (Table 3-10). Figures 3-29 and 3-30 show the cumulative mass of uranium and technetium-99 removed from groundwater in the U Plant area, as well as the predicted mass based on F&T modeling conducted in 2017 and 2018 (ECF-200UP1-17-0093, *Fate and Transport Analysis of U Plant Groundwater Plumes in the 200-UP-1 Operable Unit*; ECF-200UP1-18-0018, *200-UP-1 U Plant 2017 Uranium Plume Pump and Treat System Analysis*). The F&T modeling results are provided for two scenarios: (1) a scenario assuming no ongoing sources of contamination to the aquifer, and (2) a scenario that included estimates of mass contributions to the aquifer from ongoing sources (216-U-1 and 216-U-2 Cribs for uranium and technetium-99).

Source terms (i.e., estimates of the contaminant mass release rate from continuing sources to groundwater) for F&T modeling were based on observed concentrations in groundwater and were calculated using a control volume approach (ECF-200W-17-0030). To estimate the 216-U-1 and 216-U-2 Cribs source terms, it was assumed that releases to groundwater were at steady state and concentrations in the aquifer were in equilibrium with the sources. Groundwater sample results and plume maps were used to estimate the contaminant mass flux in the aquifer perpendicular to a vertical plane downgradient from the cribs, which was assumed to be equal to the source release rate. The source terms were assumed to be active throughout the 125-year duration of the model simulations. It should be noted that due to the assumptions made in these calculations, estimates of the source terms are uncertain, and model results of future plume conditions should be regarded only as an indication of the potential for future groundwater contamination.

Table 3-9. Extraction Well Sample Results for the U Plant Area Groundwater Extraction System

Well Name	Constituent	1/16/2019	6/12/2019	9/25/2019	12/3/2019
299-W19-113 (YE-25)	Uranium (µg/L)	134	115	115	118
	Technetium-99 (pCi/L)	851	534	541	600
	Nitrate (mg/L as NO_3)	128	83.2	91.6	90.7
	Carbon tetrachloride (µg/L)	85.3	78	61	70.2
299-W19-114 (YE-26)	Uranium (µg/L)	20	18.7	16.2	17.5
	Technetium-99 (pCi/L)	399	278	364	354
	Nitrate (mg/L as NO_3)	48.7	43.1	44.7	44
	Carbon tetrachloride (µg/L)	48.1	52.5	38.6	93.6
299-W19-125 (YE-24)	Uranium (µg/L)	1.63	1.56	—	1.6
	Technetium-99 (pCi/L)	220	139	—	167
	Nitrate (mg/L as NO_3)	29.7	24.7	25.3	25.4
	Carbon tetrachloride (µg/L)	124	121	—	114

Note: For duplicate results, the average value is shown.

Table 3-10. Contaminant Mass (or Activity) Removed from the Aquifer by the U Plant Area Groundwater Extraction System

Constituent	Mass (Activity) Removed	
	During 2019	Since Startup
Uranium, kg	14.0	58.9
Technetium-99, g (Ci)	7.2 (0.123)	71.5 (1.22)
Nitrate (as NO_3), kg	18,093	135,364
Carbon tetrachloride, kg	26.3	105.4

The actual mass of uranium removed from the aquifer is 17% lower than F&T modeling predictions (Figure 3-29), and the actual activity of technetium-99 removed from the aquifer is 39% higher than predicted (Figure 3-30). For uranium, the initial mass in groundwater may have been less than was estimated (ECF-200UP1-17-0093; ECF-00UP1-18-0018), and the pumping rate at well 299-W19-113 has been reduced as previously described. For technetium-99, it appears the initial activity in groundwater may have been greater than estimated (ECF-200UP1-17-0093). As shown in Figures 3-29 and 3-30, the predicted mass recovery values for modeling with and without sources track closely for each constituent throughout the simulated duration of the remedy (22 years). The source cribs are far enough from the extraction wells that uranium was not predicted to migrate from the cribs to the wells within the active remedy duration (uranium migrates slower than groundwater flow because of sorption to aquifer sediments). Some of the technetium-99 released from the source was predicted to reach the extraction wells near the end of the remedy timeframe, but it only causes a small increase in the simulated mass recovery. An updated strategy may be needed to address continuing contaminant sources in the U Plant area, particularly for uranium.

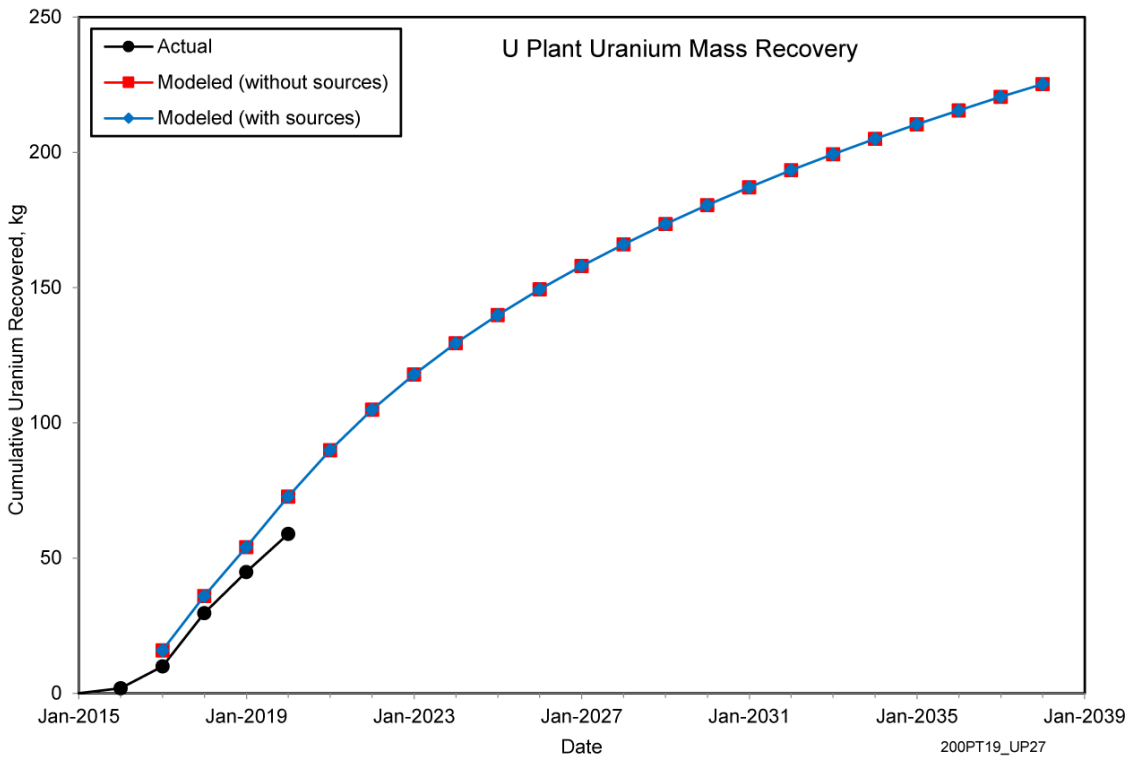

Figure 3-29. Cumulative Uranium Mass Removal by the U Plant Groundwater Extraction System – Modeled and Actual Results

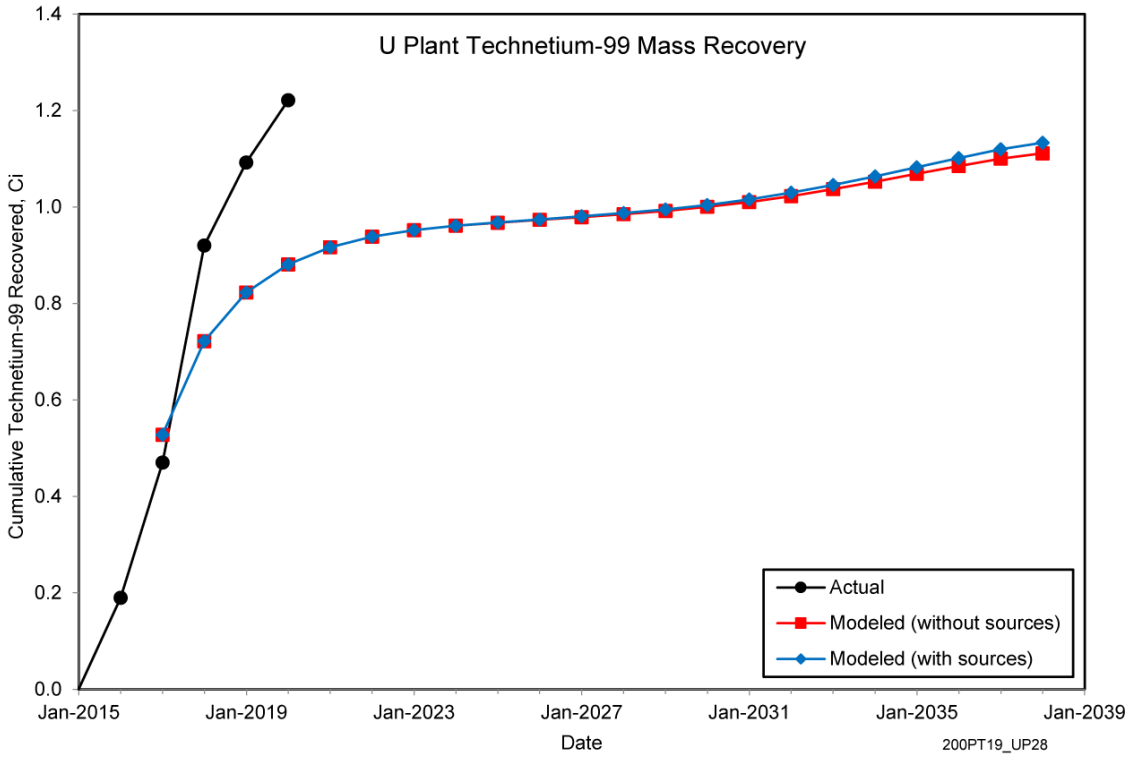

Figure 3-30. Cumulative Technetium-99 Mass Removal by the U Plant Groundwater Extraction System – Modeled and Actual Results

3.2.2 Water-Level Monitoring

Water-level monitoring is performed to evaluate the effect of the U Plant groundwater extraction system on the water table and to evaluate the effectiveness of the system in capturing the contaminant plumes. The following sections describe the data interpretation for 2019. When reviewing and interpreting water-level data, the flow rates recorded at each extraction well are also reviewed to provide an understanding of the probable causes for changes in groundwater levels.

3.2.2.1 Hydraulic Capture Analysis

Groundwater levels and pumping rates were used to map the water table in the U Plant area and estimate the hydraulic capture zones for the groundwater extraction wells. Figure 3-31 provides the March 2015 baseline water table map for the U Plant area constructed using universal kriging. The map shows the water table conditions prior to startup of the U Plant area groundwater extraction system in September 2015. Groundwater flow in this area is toward the northeast, which is influenced by drawdown of the water table by the 200-ZP-1 OU groundwater extraction system.

Figure 3-32 shows the water table estimated capture zone for December 2019 and the uranium plume in groundwater (ECF-HANFORD-20-0049). The capture zones were estimated by mapping the groundwater elevation data for December using multi-event universal kriging and tracking particles on the mapped surface for a duration of 18 years (i.e., until the year 2037). This results in an instantaneous depiction of the extent of capture under December 2019 conditions (i.e., the groundwater flow lines show the approximate area of the aquifer that would be captured by the extraction wells over an 18-year period if the water table configuration during December 2019 represented steady-state conditions). The calculated groundwater flow lines indicate the focus area of hydraulic containment and mass recovery for the U Plant area extraction wells under current conditions. Based on the 2019 interpretation of plume geometry, the system is expected to capture most of the areal extent of the uranium plume >30 µg/L and 100% of the plume >300 µg/L.

Figures 3-33 and 3-34 show the December 2019 capture zones for the technetium-99 and nitrate plumes, respectively. The technetium-99 plume south of the U Plant is completely contained within the capture zones. For nitrate, all concentrations in the U Plant area are currently <10 times the cleanup level (i.e., <450 mg/L). The selected remedies for nitrate are P&T for the high-concentration plume area at U Plant and MNA for the remainder of the plume.

Figure 3-35 compares the capture zones for the extraction wells (determined by mapping the December 2019 water-level measurements [ECF-HANFORD-20-0049]) and the capture zones predicted by model simulation (ECF-200UP1-18-0018). The simulated capture zones were generated by reverse particle tracking from the extraction wells starting at the simulated end of pumping in year 2037, with the three extraction wells each operating at 190 L/min (50 gal/min). There is generally good agreement between the mapped and predicted capture zones, although the mapped capture zones tend to be smaller in width. An exact agreement is not expected because of the different methods and time periods used to generate the capture zones.

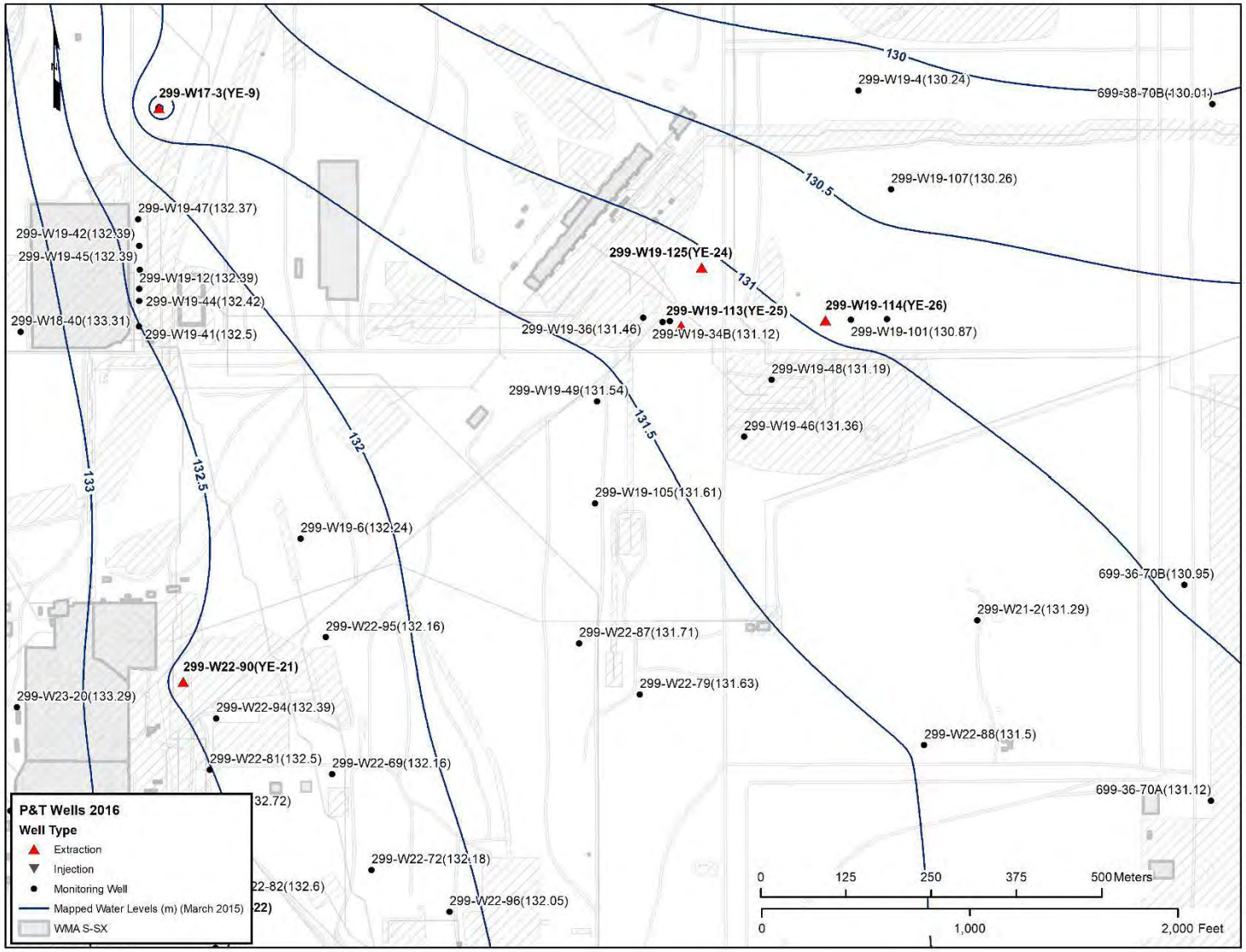

Figure 3-31. Baseline Water Table for the U Plant Area, March 2015

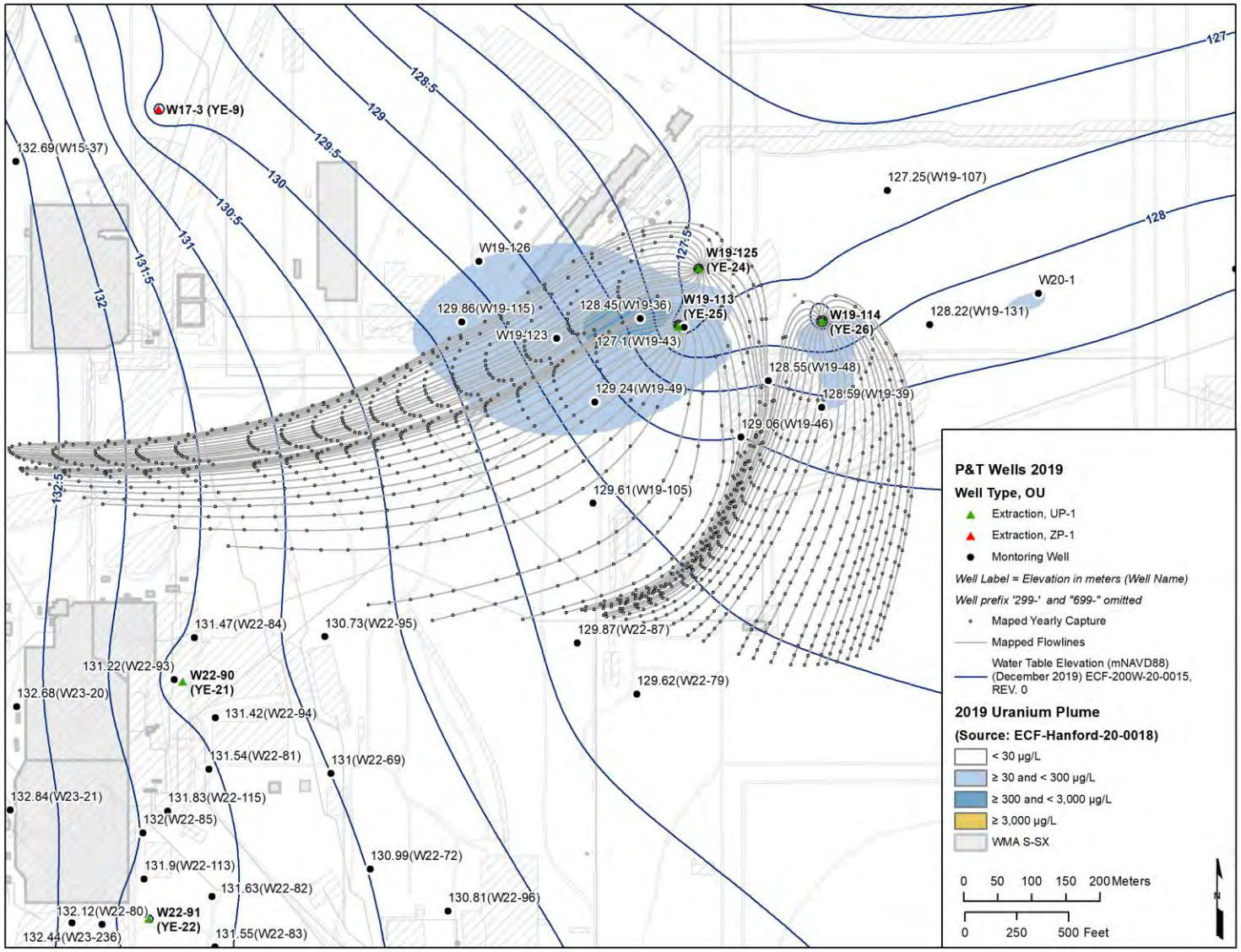

Figure 3-32. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area Groundwater Extraction System Under December 2019 Conditions (Steady-State Assumption) Compared to the Uranium Plume

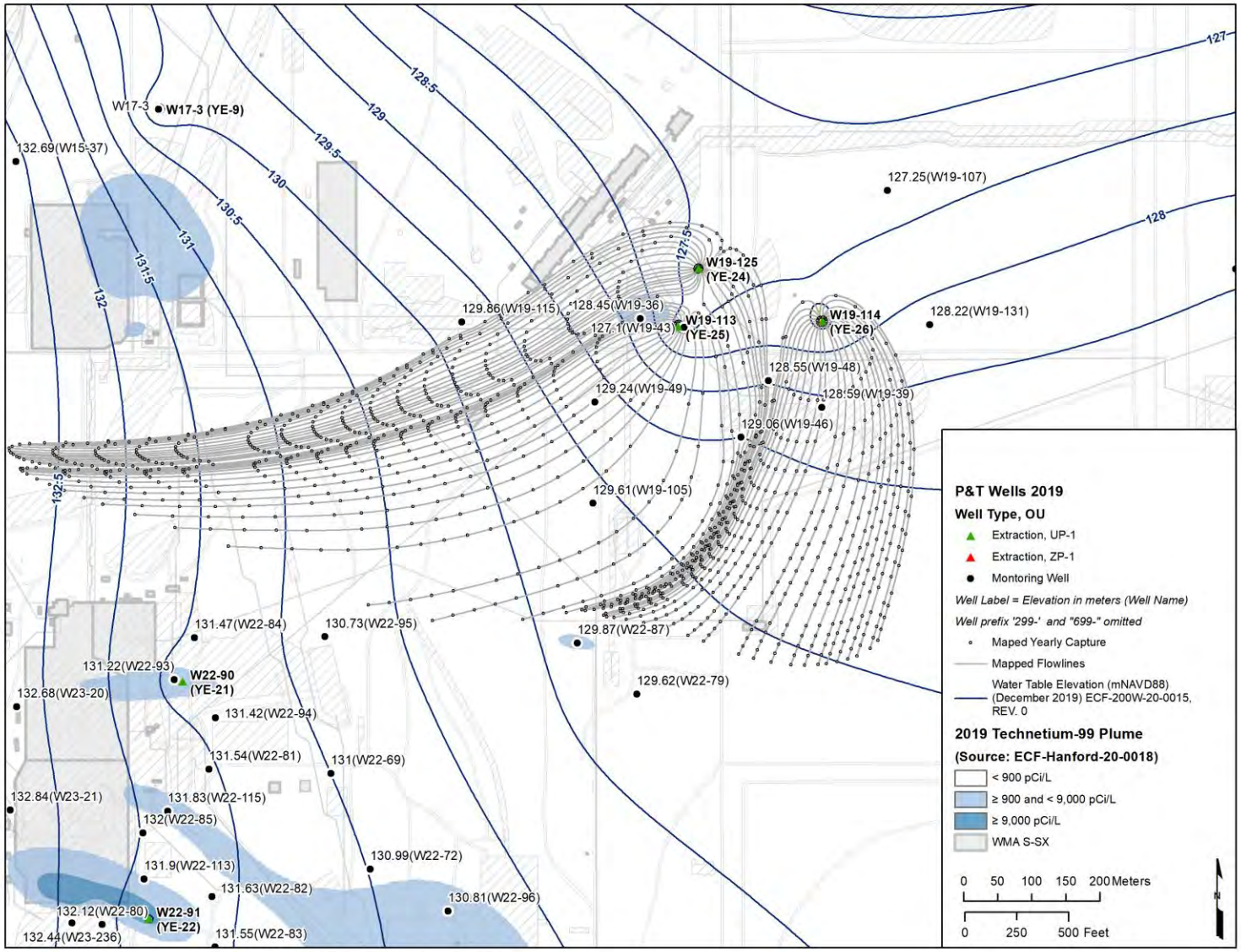

Figure 3-33. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area Groundwater Extraction System Under December 2019 Conditions (Steady-State Assumption) Compared to the Technetium-99 Plume

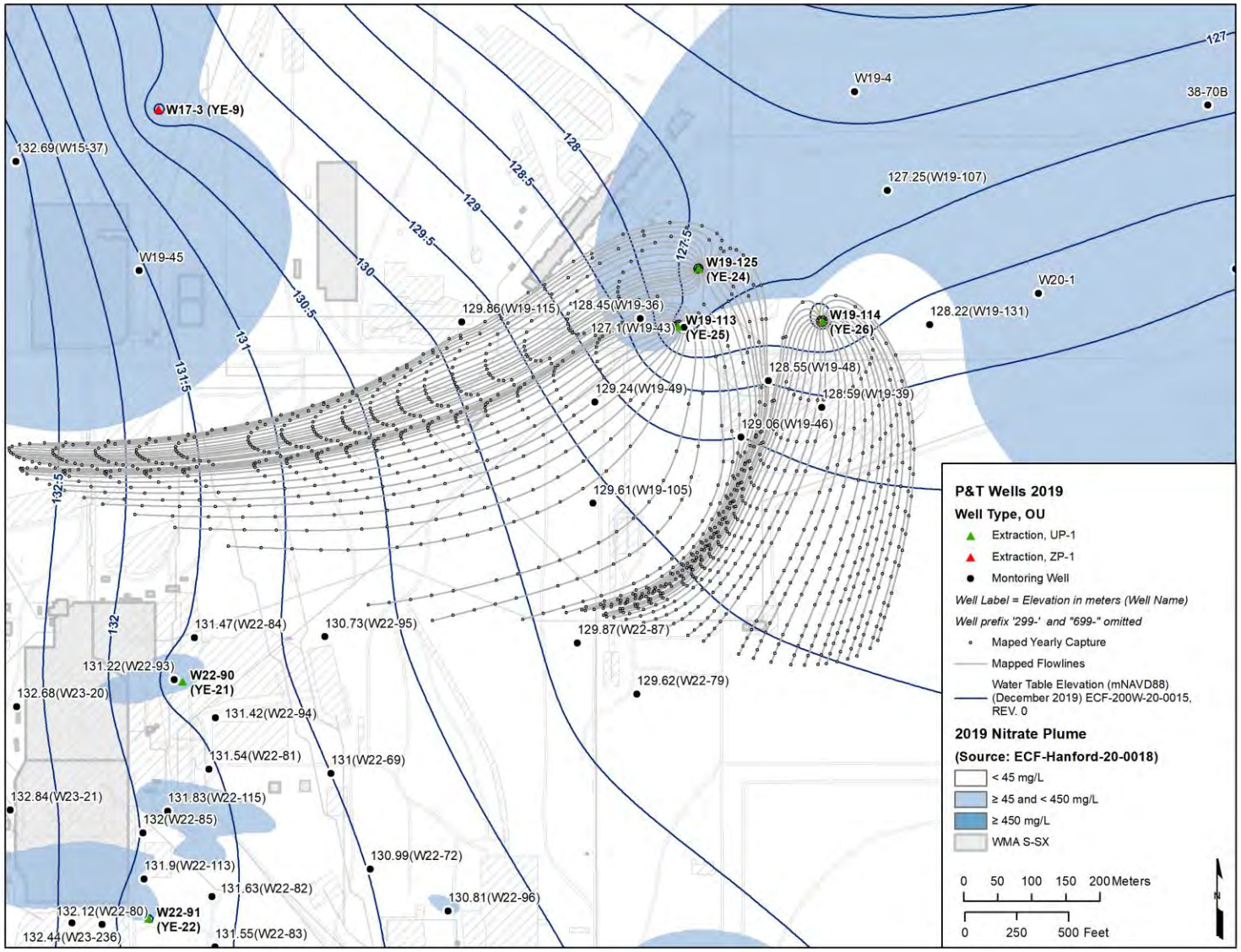

Figure 3-34. Groundwater Flow Lines Illustrating Hydraulic Capture for the U Plant Area Groundwater Extraction System Under December 2019 Conditions (Steady-State Assumption) Compared to the Nitrate Plume

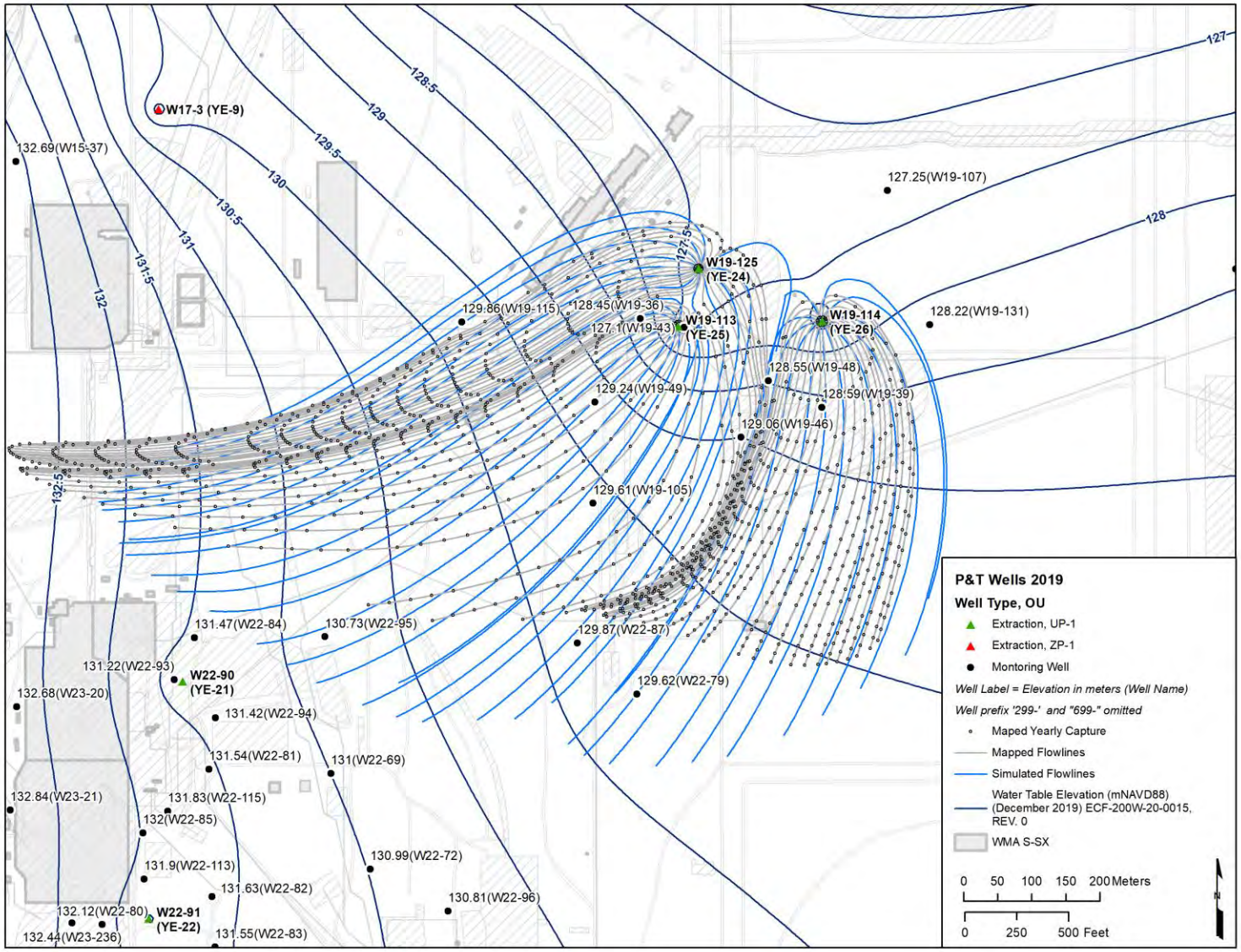

Figure 3-35. Comparison of Mapped Hydraulic Capture for the U Plant Area Groundwater Extraction System Using Water-Level Measurements from December 2019 (Steady-State Assumption) Compared to the Design Capture Zone Determined by Groundwater Modeling

3.2.3 Contaminant Monitoring

This section summarizes the 2019 results for groundwater sampling near the U Plant area groundwater extraction system. A comprehensive discussion of groundwater contamination within the OU is provided in the 200-UP-1 OU RI/FS (Chapter 4 in DOE/RL-2009-122). The vertical distribution of the plumes is shown as cross-sectional maps in the 200-UP-1 OU RD/RAWP (Figures A-1 through A-4 in Appendix A of DOE/RL-2013-07, Rev. 0). Chapter 11 in DOE/RL-2019-66 provides further discussion on recent monitoring results for the entire OU.

Groundwater contamination baseline conditions from which cleanup progress is evaluated were established during 2015 (Section 2.3.3 in DOE/RL-2016-20, *Calendar Year 2015 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations*). In the following sections, sample results for uranium and technetium-99 during 2019 are compared to baseline concentrations. When more than one sample result was available in a well, the last sample collected during 2019 was used in the comparisons to represent cleanup progress; for duplicate samples, the average concentration was used. Plume depictions are based on annual average concentrations in the wells and are the same as those presented in Chapter 11 of DOE/RL-2019-66. For nitrate in the U Plant area, which is part of the regional nitrate plume, the concentration comparisons are presented in Section 3.5.

3.2.3.1 Uranium and Technetium-99 Monitoring Results

The 2019 uranium and technetium-99 sample results from monitoring wells in the U Plant area are compared to baseline (2015) concentrations in Tables 3-11 and 3-12, respectively. These comparisons are also shown in Figures 3-36 and 3-37 for uranium and in Figures 3-38 and 3-39 for technetium-99. In Figures 3-36 and 3-38, the comparisons are depicted by bar charts. In Figures 3-37 and 3-39, the monitoring well locations are shown in relation to the U Plant extraction wells, and concentration magnitudes are depicted with circles. For these figures, the circle diameters reflect a log-scaled concentration ratio relative to the cleanup level, baseline concentrations are shown with hollow circles, and 2019 concentrations are shown with shaded circles. A hollow annulus between concentric circles therefore shows a concentration decrease, a shaded annulus shows a concentration increase, and no annulus shows minimal concentration change.

From 2015 to 2019, uranium concentrations declined in seven of nine monitoring wells with baseline or 2019 concentrations above the 30 µg/L cleanup level (Table 3-11; Figure 3-36). The primary exception is well 299-W19-36, where concentrations increased from a baseline of 1,550 µg/L in July 2015 to 5,000 µg/L in August 2017, and then declined to 1,700 µg/L through August 2019 (Figure 3-40). Following installation of well 299-W19-123 in March 2018, uranium concentrations increased from 115 to 153 µg/L; reducing conditions caused by the drilling process may have suppressed the initial concentrations measured at this well.

For the extraction wells, uranium concentrations increased at well 299-W19-113 from 45 µg/L in October 2015 to 169 µg/L in September 2017 and then generally declined to 118 µg/L through December 2019 (Figure 3-41). The increased concentration is attributed to high uranium concentrations being drawn toward the extraction well from the west, where similar concentration changes have been observed at nearby monitoring well 299-W19-36 (Figure 3-40). For extraction well 299-W19-114, uranium concentrations generally have been stable since extraction began (Figure 3-41). For extraction well 299-W19-125, uranium concentrations are low and have ranged between 1.43 and 2.40 µg/L during its operation (Figure 3-41).

Table 3-11. Comparison of Baseline to 2019 Uranium Concentrations for the U Plant Vicinity

Well Name	Baseline (2015) Uranium (µg/L)	2019 Uranium (µg/L)[a]	Percent Change[b]
299-W19-34A	1.44	1.12	—
299-W19-36	1,550	1,700	10
299-W19-39	65	33.5	-48
299-W19-43	223	57	-74
299-W19-46	63.3	18.3	-71
299-W19-48	102	20.7	-80
299-W19-49	223	93.9	-58
299-W19-101	78	44.3	-43
299-W19-105	25.7	15.5	-40
299-W19-107	1.35	2	—
299-W19-115[c]	734	134	-82
299-W19-116[d]	10	6.04	-40
299-W19-123[e]	115	153	33
299-W20-1[f]	—	32	—

Notes:

The cleanup level specified for uranium in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, is 30 µg/L.

Yellow-shaded cells identify monitoring wells within 61 m (200 ft) of an extraction well.

a. For wells sampled multiple times during 2019, the result shown is from the last sample of the year. For duplicate samples collected on the same day, the average concentration is shown. If a well was not sampled in 2019, the latest result is shown.

b. Percent change is shown only for those wells with a baseline or 2019 sample result at least one-tenth the cleanup level (3 µg/L).

c. Baseline sample result is for well 299-W19-18, which is dry. The replacement well is 299-W19-115.

d. Baseline sample result was from March 2016.

e. Baseline sample result from March 2018.

f. Well installed in 2019; no baseline sample.

Table 3-12. Comparison of Baseline to 2019 Technetium-99 Concentrations for the U Plant Vicinity

Well Name	Baseline (2015) Technetium-99 (pCi/L)[a]	2019 Technetium-99 (pCi/L)[a, b]	Percent Change[c]
299-W19-34A	486	80.5	-83
299-W19-36	51,400	3,495	-93
299-W19-43	8,080	92.8	-99
299-W19-48	139	372	168
299-W19-49	304	34.5	-89
299-W19-101	234	92.7	-60
299-W19-107	273	185	-32
299-W19-115[d]	580	225	-61
299-W19-116[e]	450	380	-16
299-W20-1[f]	—	925	—

Notes:

The cleanup level specified for technetium-99 in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, is 900 pCi/L.

Yellow-shaded cells identify monitoring wells within 61 m (200 ft) of an extraction well.

a. Less than (<) values (if shown) reference the minimum detectable activity.

b. For wells sampled multiple times during 2019, the result shown is from the last sample of the year. For duplicate samples collected on the same day, the average concentration is shown. If a well was not sampled in 2019, the latest result is shown.

c. Percent change is shown only for those wells with a baseline or 2019 sample result at least one-tenth the cleanup level (90 pCi/L).

d. Baseline sample result is for well 299-W19-18, which is dry. The replacement well is 299-W19-115.

e. Baseline sample result was from March 2016.

f. Well installed in 2019; no baseline sample.

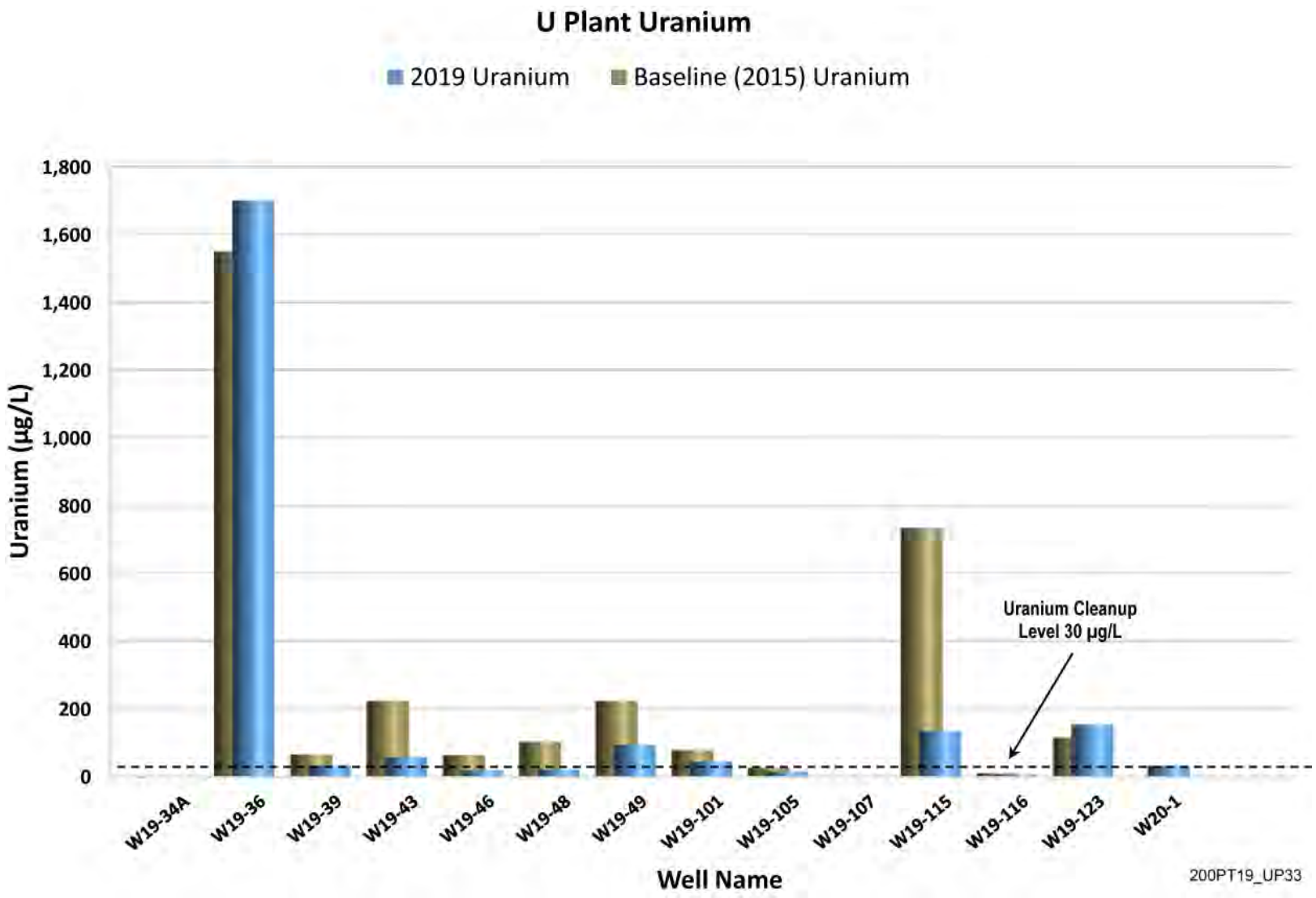

Figure 3-36. Comparison Chart of Baseline to 2019 Uranium Concentrations for Selected Monitoring Wells in the U Plant Vicinity

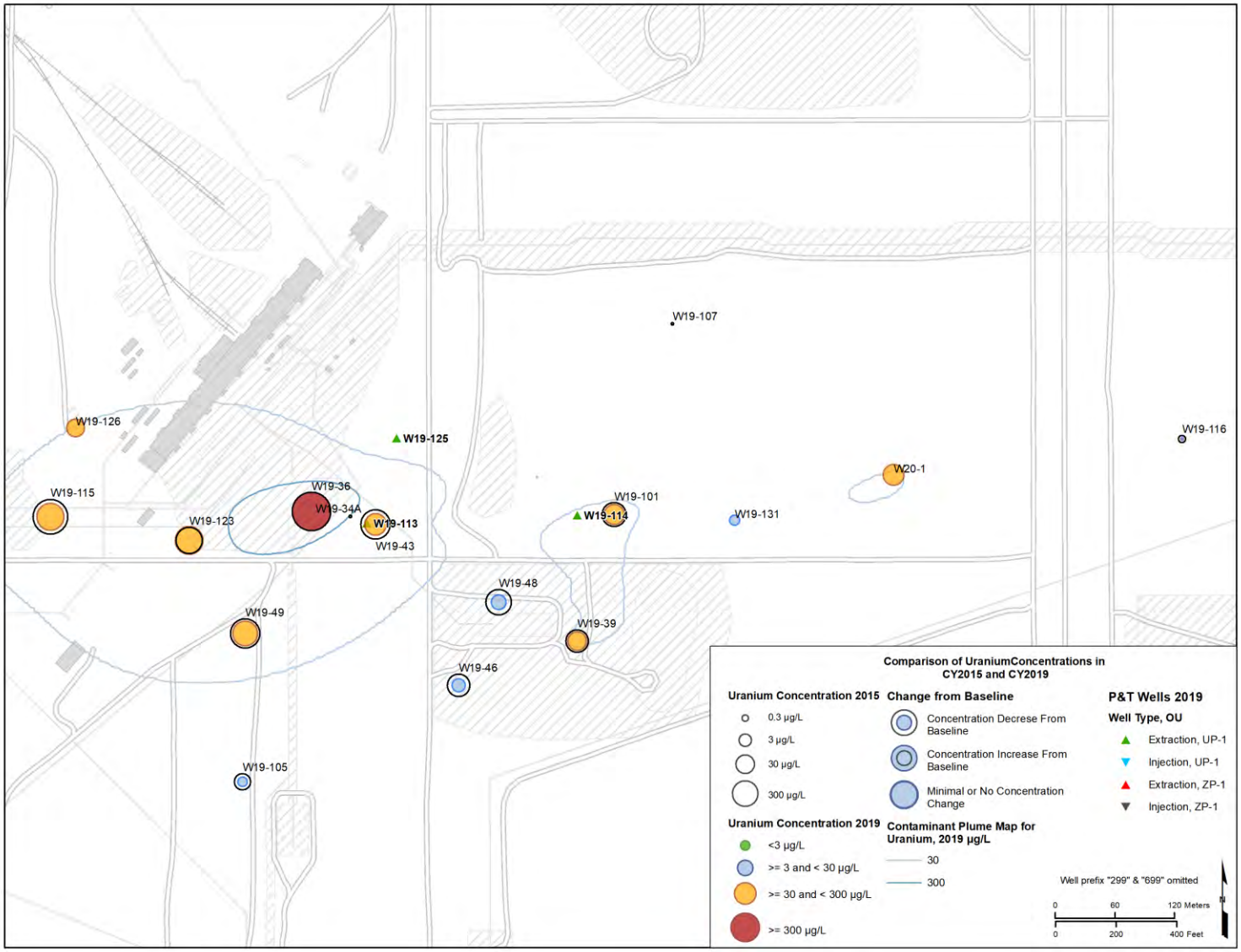

Figure 3-37. Comparison Map of Baseline to 2019 Uranium Concentrations for Selected Monitoring Wells in the U Plant Vicinity

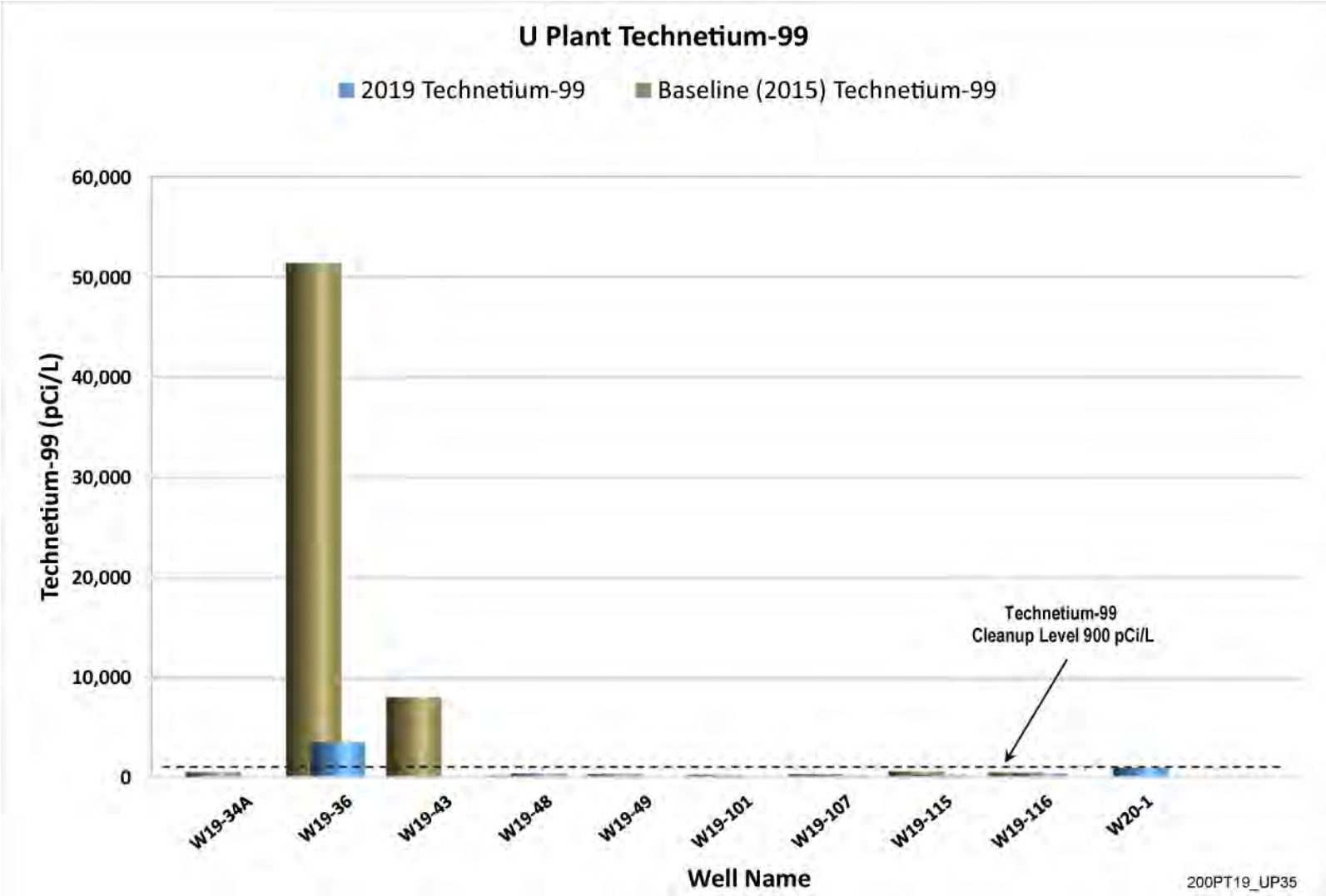

Figure 3-38. Comparison Chart of Baseline to 2019 Technetium-99 Concentrations for Selected Monitoring Wells in the U Plant Vicinity

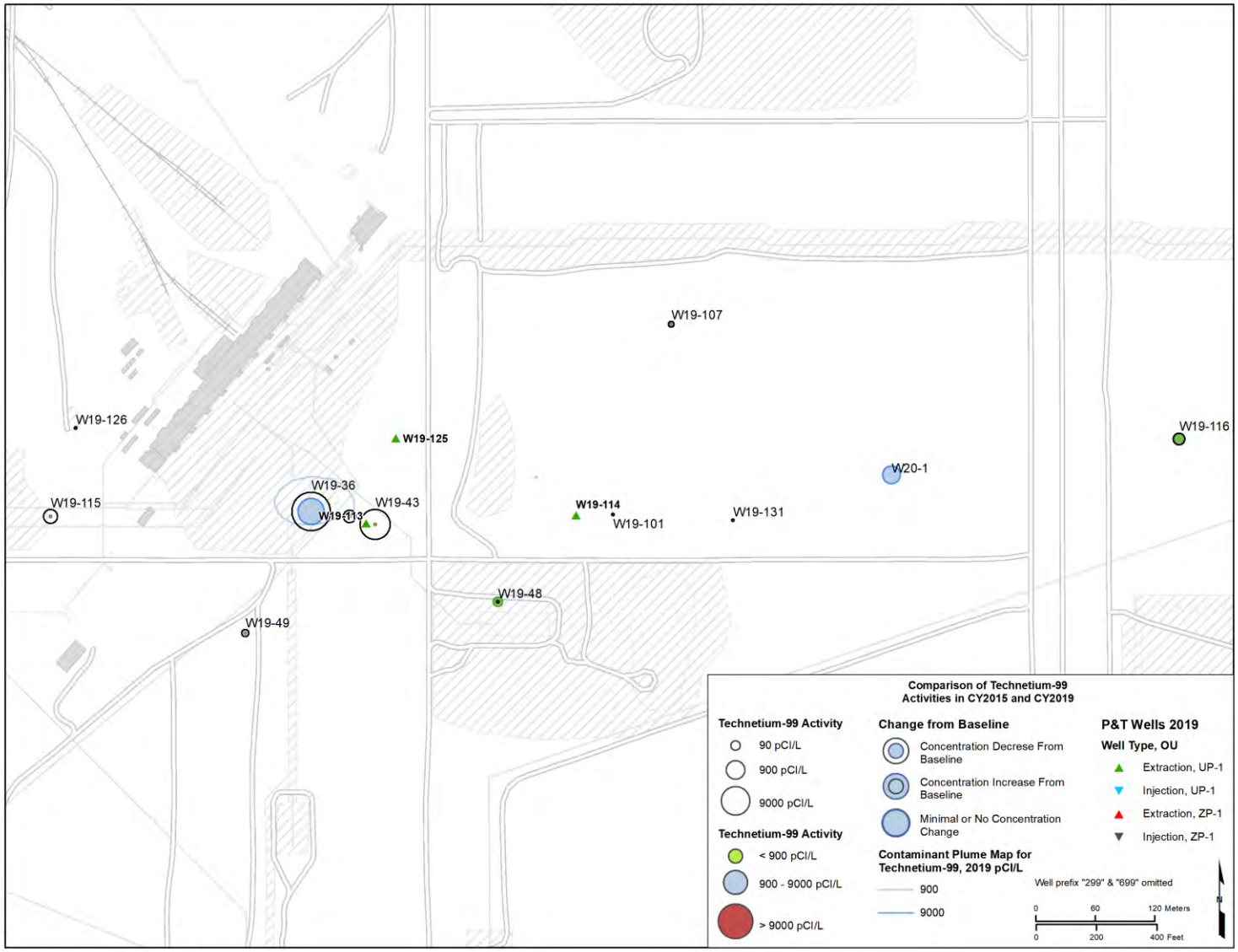

Figure 3-39. Comparison Map of Baseline to 2019 Technetium-99 Concentrations for Selected Monitoring Wells in the U Plant Vicinity

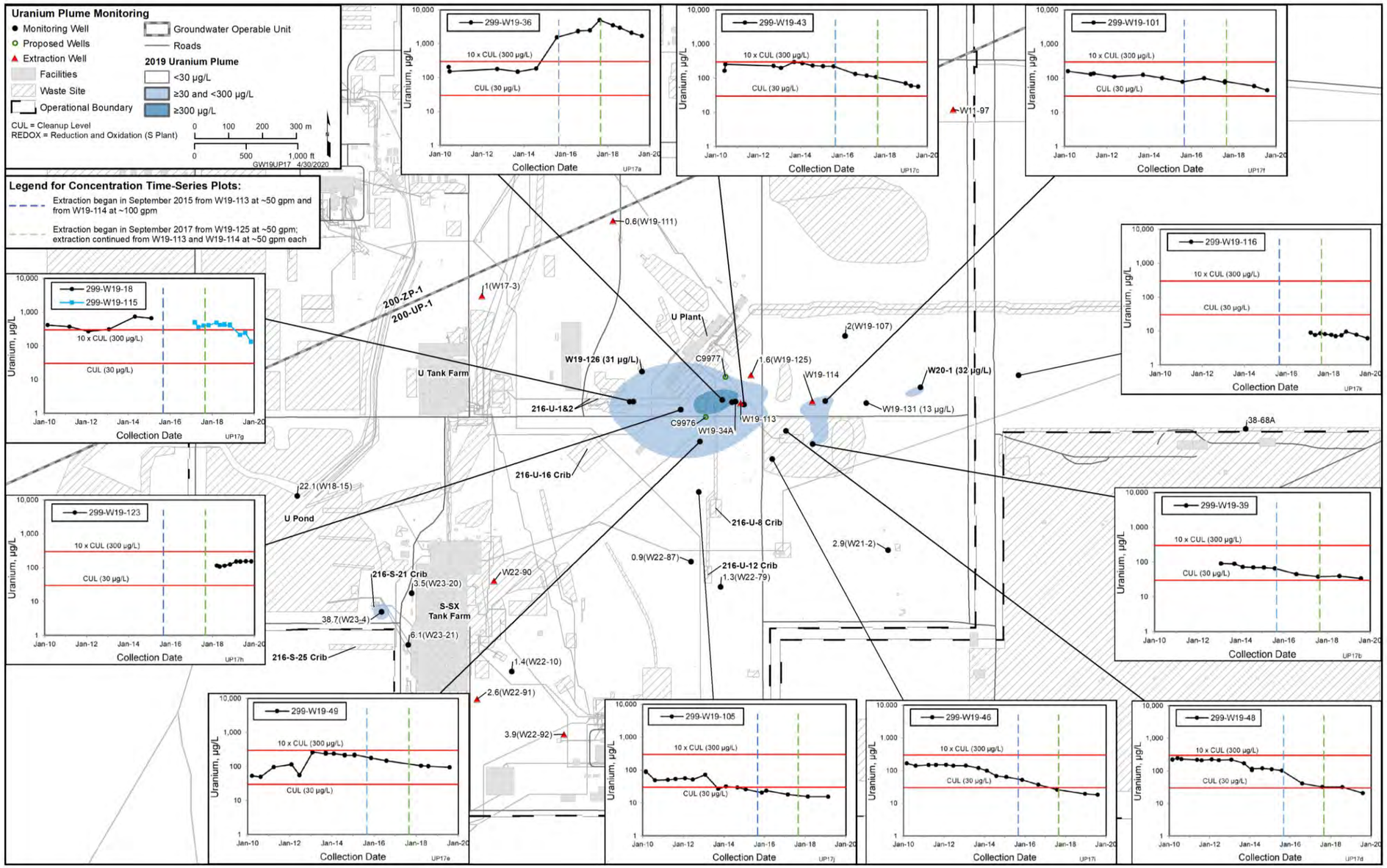

Figure 3-40. Uranium Concentrations in Selected U Plant Area Monitoring Wells

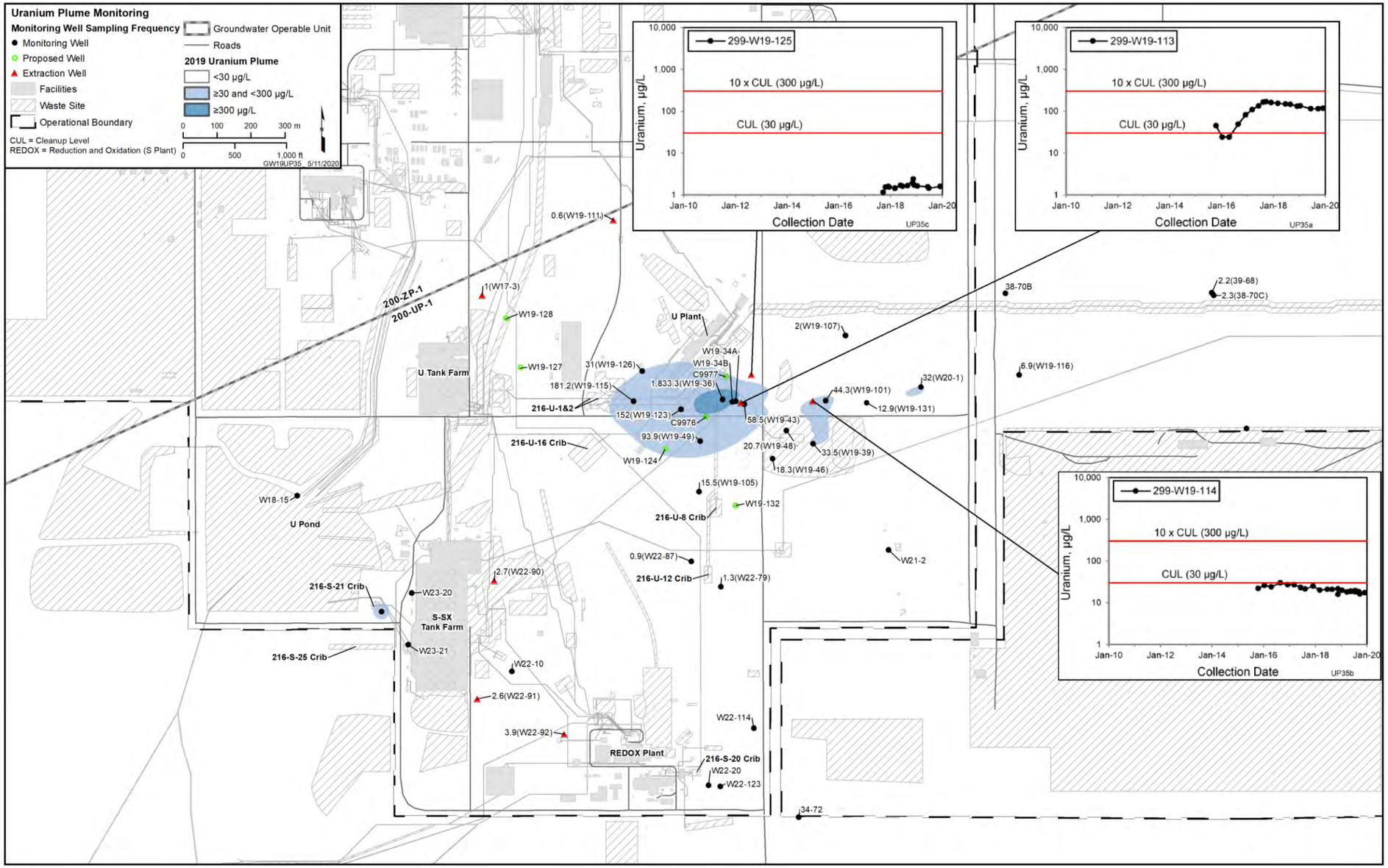

Figure 3-41. Uranium Concentrations in U Plant Area Extraction Wells

Figure 3-42 shows the technetium-99 plume in the U Plant area. For monitoring wells, baseline concentrations in this area exceeded the 900 pCi/L cleanup level at wells 299-W19-36 and 299-W19-43, with concentrations of 51,400 and 8,080 pCi/L, respectively (Table 3-12). As shown in Figure 3-43, technetium-99 concentrations began to decrease at well 299-W19-36 prior to groundwater extraction, and concentrations continued to decline during the extraction period. At well 299-W19-43, concentrations declined to below the cleanup level once groundwater extraction began. In 2019, the technetium-99 cleanup level was also exceeded at new well 299-W20-1 with a concentration of 925 pCi/L (the first and only routine sample collected from this well in 2019).

For extraction wells 299-W19-113 and 299-W19-114, technetium-99 concentrations were 8,610 and 980 pCi/L, respectively, in October 2015, shortly after extraction began. As shown in Figure 3-44, concentrations have steadily declined at well 299-W19-113 to below the cleanup level in 2019. For well 299-W19-114, concentrations declined below the cleanup level once extraction began. For well 299-W19-125, concentrations have been below the cleanup level throughout its extraction period (Figure 3-44).

3.2.3.2 Carbon Tetrachloride Monitoring Results

Carbon tetrachloride cleanup is not an objective of the U Plant remedy, but the extraction wells do remove carbon tetrachloride from the aquifer and contribute to the overall remedy for this constituent. Evaluation of carbon tetrachloride results for monitoring wells and an assessment of the overall remedy are presented in Chapter 4 for each of the 200-UP-1 and 200-ZP-1 OUs.

As discussed in Section 3.1.3.2, carbon tetrachloride is widespread throughout the 200 West Area. In the U Plant area extraction wells, the carbon tetrachloride concentrations continued to exceed the 3.4 µg/L cleanup level throughout 2019, with December concentrations of 70.2 µg/L at well 299-W19-113, 93.6 µg/L at well 299-W19-114, and 117 µg/L at well 299-W19-125.

3.2.3.3 Performance Monitoring Evaluation

Progress toward achieving cleanup levels for the U Plant area uranium plume was evaluated by calculating the 95% UCL for mean plume concentration, as described in the 200-UP-1 OU RD/RAWP (DOE/RL-2013-07, Rev. 0) and the 200-UP-1 OU PMP (DOE/RL-2015-14). The calculations were performed for uranium from 2008 through 2019. For technetium-99 in the U Plant area, the 95% UCL was not included because concentrations exceed the cleanup level at only two wells. For nitrate in the U Plant area, the data are included with the regional 95% UCL calculation (see Section 3.5).
The calculations for any given year used data from the previous 2 years to ensure that a sufficient number of samples was available. Where more than one sample result was available within a year, the last sample result was used; for duplicate analyses, the average was used. The wells used for the calculation are identified in DOE/RL-2015-14 and are primarily within the footprint of the baseline plume; the calculations are documented in ECF-200UP1-20-0032.

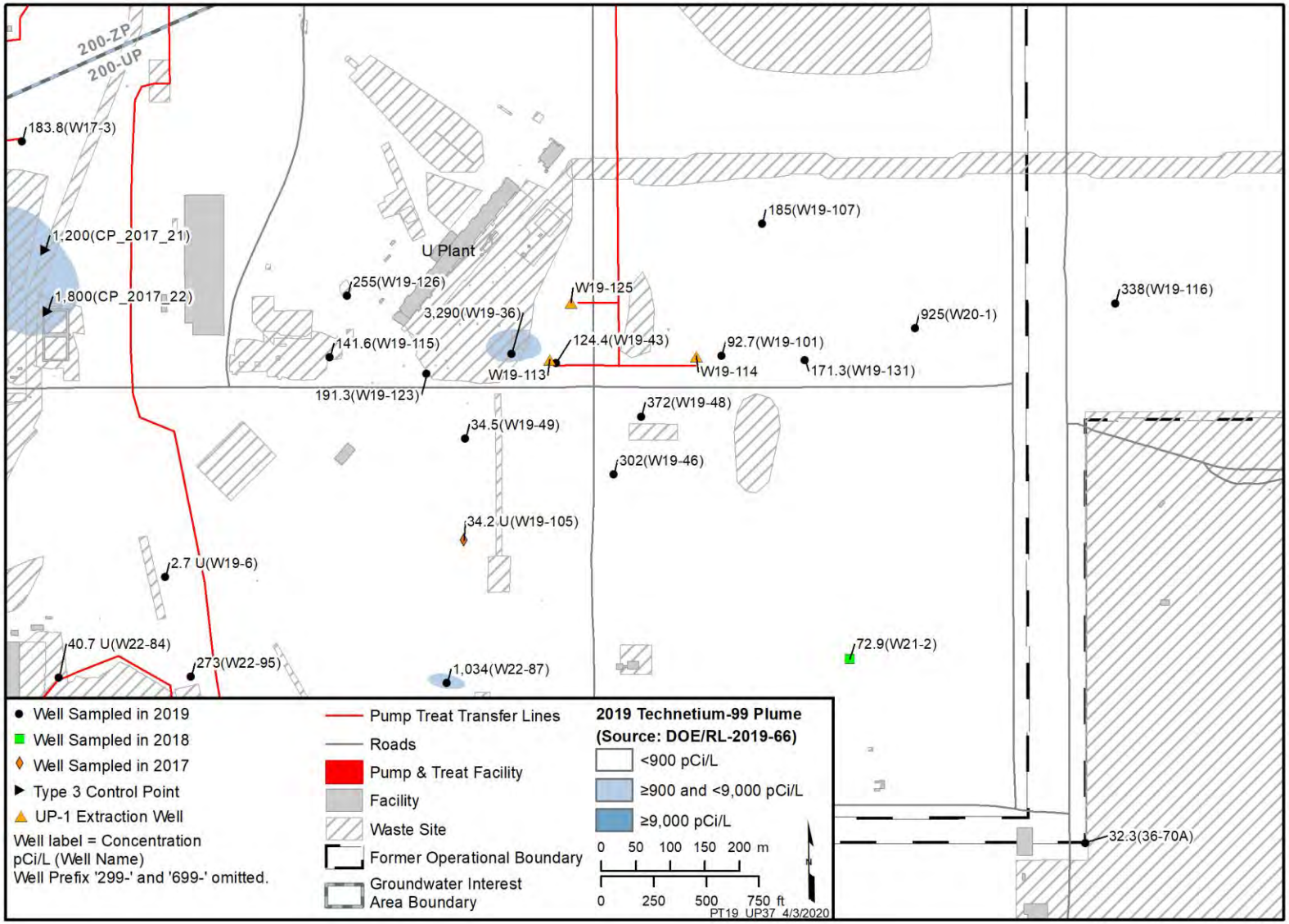

Figure 3-42. U Plant Area Technetium-99 Plume, 2019

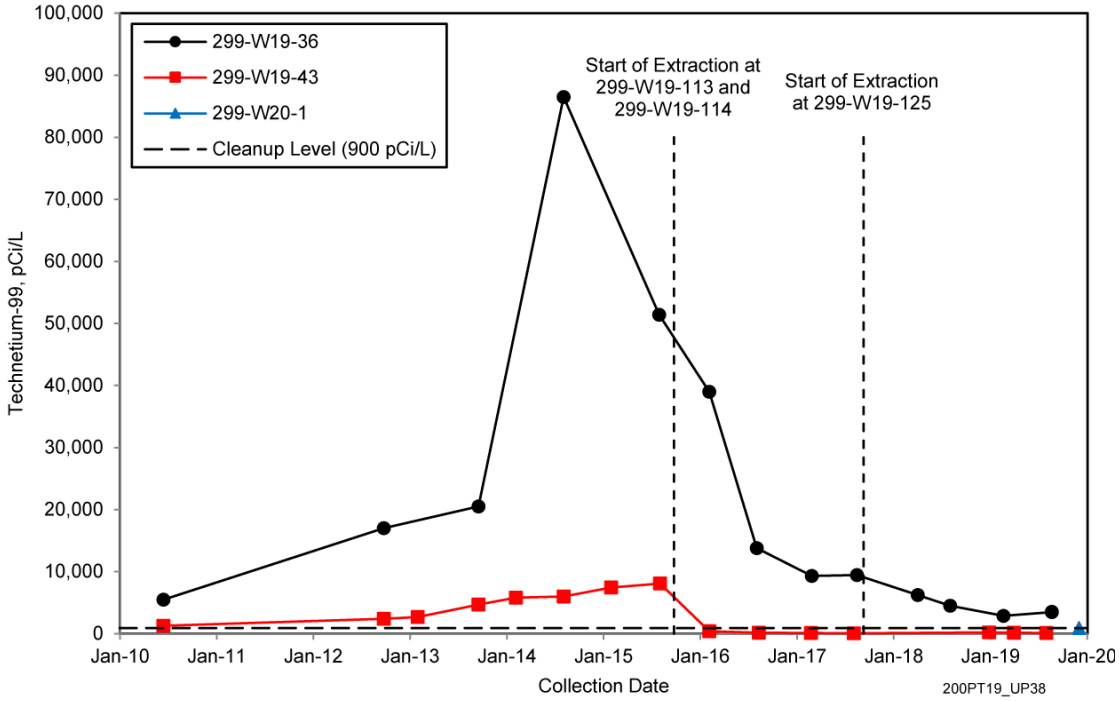

Figure 3-43. Technetium-99 Concentrations in Selected U Plant Area Monitoring Wells

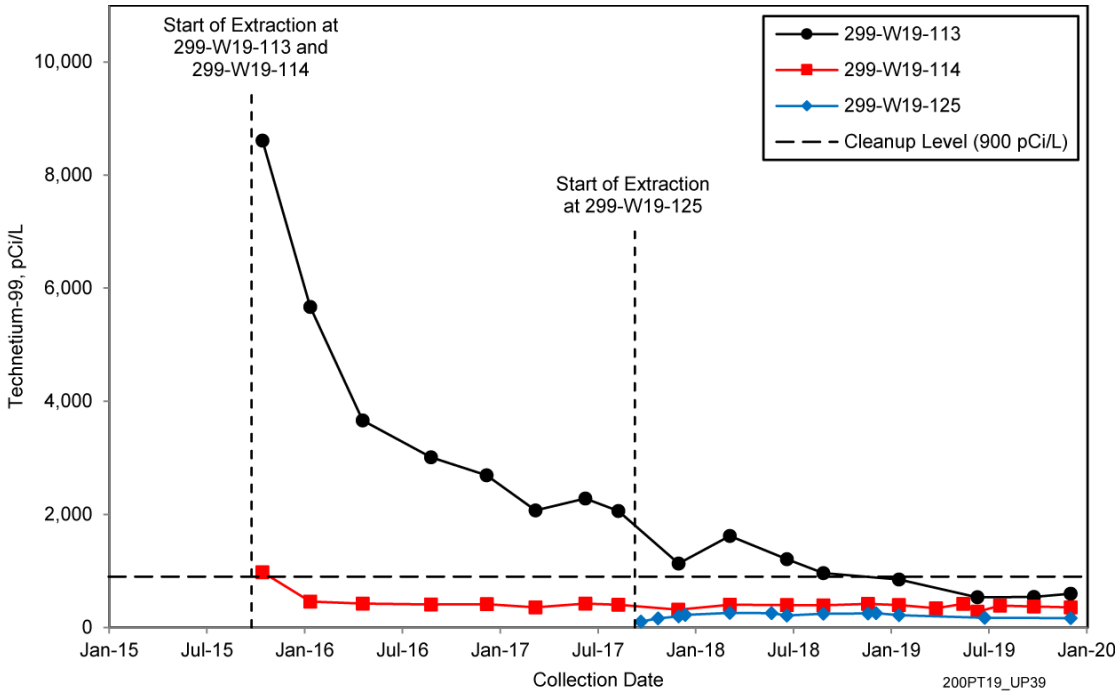

Figure 3-44. Technetium-99 Concentrations in U Plant Area Extraction Wells

Figure 3-45 shows the uranium 95% UCL values for 2008 through 2019, along with 95% UCL values predicted from the F&T modeling beginning in 2018. As described in Section 3.2.1.2, the F&T simulations were performed with and without ongoing sources of contamination to the aquifer, and Figure 3-45 shows the 95% UCL values for both sets of modeling results. The calculated 95% UCL for actual uranium monitoring data shows an increase beginning in 2015 due to increasing concentrations at well 299-W19-36 (Figure 3-40). The model simulations used the 2017 uranium plume interpretation as the starting condition, which included the high concentration at well 299-W19-36; therefore, the initially modeled 95% UCL value of 984 µg/L is similar to the 2017 value of 844 µg/L from the monitoring data. The 95% UCL for the monitoring data decreased in 2018 and 2019, primarily due to declining uranium concentrations at well 299-W19-36. Data in future years are needed to confirm if this is the beginning of a downward trend consistent with the modeling predictions. The predicted 95% UCL values for the modeling results with and without sources are very similar until they begin to differ near the end of the planned active remediation period (Figure 3-45). Uranium sorbs to the aquifer sediments and, therefore, migrates slower than groundwater flow, which results in a longer time period before the modeled 95% UCL is affected by the continuing source.

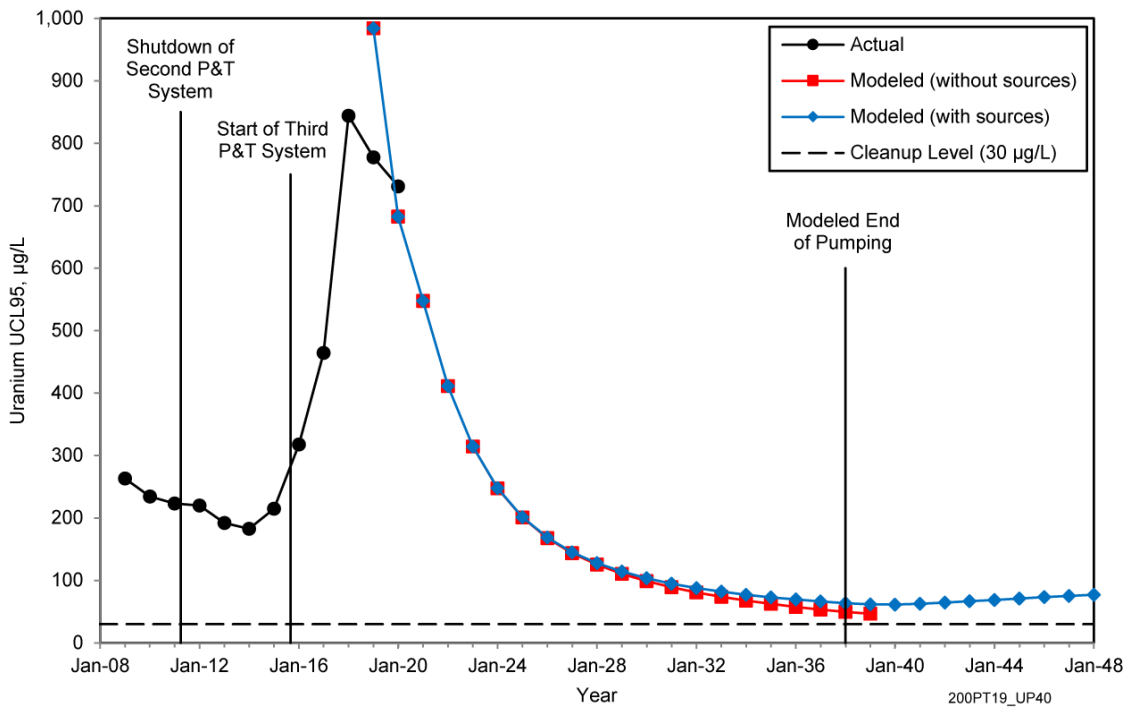

Figure 3-45. 95% UCL on the Mean Concentration of Uranium for Monitoring Wells Within the U Plant Groundwater Extraction System Vicinity

The F&T simulations for the U Plant groundwater extraction system (using the 2017 uranium plume interpretation as the starting condition) indicate that the existing U Plant area remedy will not reduce maximum uranium concentration below the 30 µg/L cleanup level within 25 years (as predicted in the 200-UP-1 OU ROD [EPA et al., 2012]) nor within the overall 125-year cleanup timeframe for Central Plateau groundwater (ECF-200UP1-18-0018). A similar conclusion was reached based upon previous simulations using the 2015 uranium plume interpretation as the starting condition (ECF-200UP1-17-0093). The slow uranium migration rate results in a long time period before the plume would disperse. More recent model simulations (ECF-200UP1-18-0018) suggest that a system consisting of additional extraction wells and injection wells may be needed to achieve the cleanup levels, but the success of such a system is dependent on the initial plume conditions. Once sufficient analytical data are

obtained from the new wells installed in 2019 (299-W19-126, 299-W19-131, and 299-W20-1), additional numerical simulations are planned to evaluate system performance and determine if modifications are needed to achieve remediation objectives.

For technetium-99 in the U Plant area, F&T simulations indicate that cleanup objectives will be achieved by the current groundwater extraction system if a continuing contamination source is not present (ECF-200UP1-17-0093). With a continuing source (from the 216-U-1 and 216-U-2 Cribs), the technetium-99 plume may re-form after the active remediation period unless the source is remediated or groundwater near the source is hydraulically contained. Similarly, a uranium plume (with concentrations above the cleanup level) may re-form without source remediation or hydraulic containment (ECF-200UP1-17-0093; ECF-200UP1-18-0018). However, it should be emphasized that estimates of future plume conditions from ongoing sources are subject to uncertainty due to the assumptions that source terms are based upon (ECF-200UP1-17-0093; ECF-200UP1-18-0018).

3.3 Iodine-129 Plume Hydraulic Containment System

Iodine-129 plumes in the 200-UP-1 OU originated from the 216-U-1 and 216-U-2 Cribs near U Plant and REDOX Plant waste sites; the latter were the primary sources (Figure 3-46). To the east of the 200 West Area, these plumes merge and become indistinguishable, and the main iodine-129 plume with concentrations greater than the 1 pCi/L cleanup level extends approximately 3.5 km (2.2 mi) east of the REDOX Plant waste sites (Figure 3-46). The selected remedy for this plume is hydraulic containment while treatment technologies were evaluated (EPA et al., 2012). The technology evaluation was completed in September 2019, as summarized in Section 3.2.2.5 of DOE/RL-2013-07, Rev. 1, Draft A. The conclusion of this evaluation was that the practicability of all candidate remediation technologies for the iodine-129 plume is low, driven by site and contaminant properties that hinder effectiveness and/or implementability of the technologies. Because a viable remediation technology is not available for the iodine-129 plume, a technical impracticability waiver will be pursued beginning in FY 2020 in accordance with 40 CFR 300.430(f)(l)(ii)(c), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Investigation/Feasibility Study and Selection of Remedy." This work will be supported by additional F&T modeling of the plume, and simulations will be performed with and without continued operation of the hydraulic containment injection wells.

Injection wells to the east of the iodine-129 plume boundary are used for hydraulic containment. Operation of these wells increases the water table elevation downgradient of the plume to slow its eastward migration. Numerical modeling indicated that three wells located downgradient of the plume with injection rates of 189 to 379 L/min (50 to 100 gal/min) per well would be sufficient for hydraulic containment (ECF-200UP1-14-0053, *Containment System for 200-UP-1 Iodine*). The injected water is post-treatment effluent from the 200 West P&T central treatment facility, and average concentrations in the water meet all cleanup levels specified in the 200-UP-1 OU ROD (EPA et al., 2012; Table 2-5) except for nitrate, as discussed in Section 2.3.

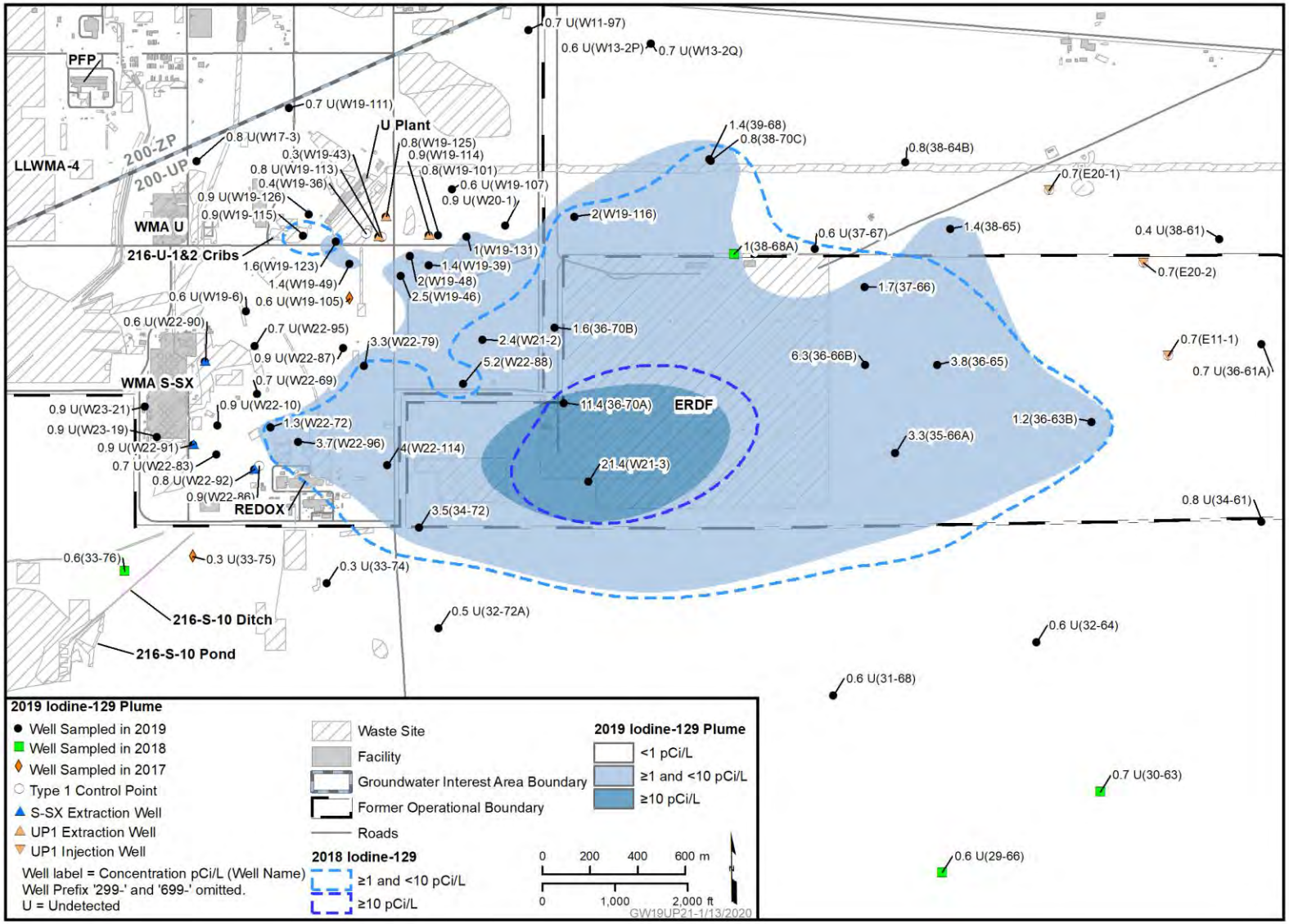

Figure 3-46. Iodine-129 Plume, 2019

3.3.1 Remedial System Operation

The three hydraulic containment injection wells (299-E11-1, 299-E20-1, and 299-E20-2) were drilled during 2015 and began operating on October 28, 2015. Figure 3-46 shows the well locations in relation to the iodine-129 plume. All three injections wells were operational during 2019 with the exception of the following. In June, all three wells were redeveloped, with well 299-E20-1 offline from June 6 to June 16, well 299-E20-2 offline from June 6 to June 23, and well 299-E11-1 offline from June 7 to June 30. All three wells also were offline on August 11 and 12, when the total 200 West P&T flows were reduced by approximately 50% to fix a faulty air stripper. On August 25, an effluent supply pipe ruptured, which reduced the flow to 0 L/min at wells 299-E20-1 and 299-E20-2 and to approximately 4.5 L/min (1.2 gal/min) at well 299-E11-1. Table 3-13 shows the average flow rates and total volumes of injected water during 2019 for the injection wells, and Figure 3-47 shows the weekly average flow rates.

The iodine-129 plume hydraulic containment injection wells were designed to operate at a minimum nominal flow rate of 189 L/min (50 gal/min) to a maximum of 380 L/min (100 gal/min) per well. As shown in Table 3-13, the overall average flow rate for all three wells was 796 L/min (210 gal/min), or 140% of the minimum nominal flow rate. The total volume of water injected into the aquifer during 2019 was 418 million L (110 million gal). The total volume of water injected since system startup was 1.606 billion L (424.3 million gal).

Table 3-13. Flow Rates for the Iodine-129 Hydraulic Containment Injection System

Well Name	Operational Average Flow Rate in 2019		Overall Average Flow Rate in 2019		Total Volume in 2019	
	L/min	gal/min	L/min	gal/min	L (in 1,000s)	gal (in 1,000s)
299-E20-1	284	75.0	269	71.2	141,608	37,409
299-E20-2	269	71.0	251	66.2	131,789	34,815
299-E11-1	300	79.3	275	72.7	144,739	38,236
System totals	**853**	**225**	**796**	**210**	**418,137**	**110,460**

Notes:

Operational average flow rate calculated as the mean daily flow for days when well was operational.

Overall average flow rate is calculated as the total pumped volume divided by the total minutes in a year.

System total flow rates represent the average for the system when all three wells are operational or the overall system average for the year.

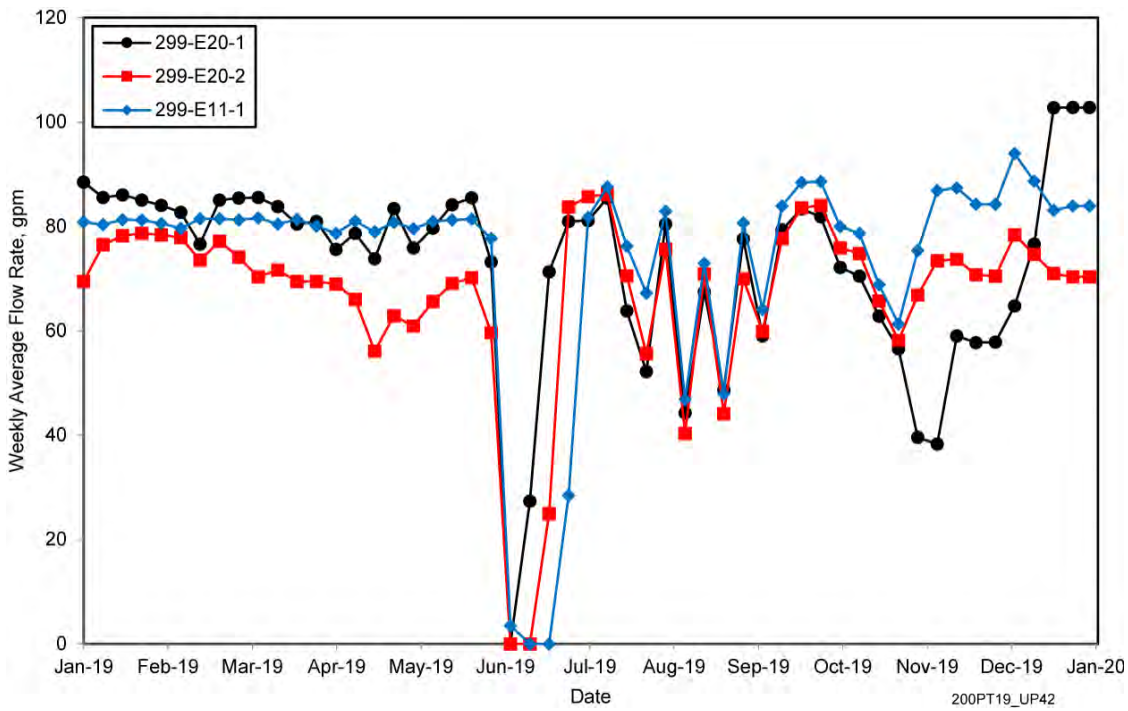

Figure 3-47. Weekly Average Injection Rates for Iodine-129 Plume Hydraulic Containment Wells, 2019

3.3.2 Water-Level Monitoring

Water-level measurements are used to determine the effectiveness of the hydraulic containment remedy. The collection of monthly water-level measurements began in September 2015 from a network of wells near the injection wells. Figure 3-48 shows the water table for December 2019. Small groundwater mounds are evident around the injection wells. The groundwater flow direction is toward the east-northeast, and the magnitude of the hydraulic gradient increases from west to east toward the eastern plume boundary. The larger gradient magnitude is caused, at least in part, by a decrease in aquifer thickness and the resulting decrease in transmissivity. The Ringold Formation member of Wooded Island – lower mud unit (Rlm), which forms the base of the unconfined aquifer, increases in elevation toward the east and results in a thinner aquifer. The hydraulic conductivity of the aquifer sediments may also decrease toward the east, which would contribute to the reduced transmissivity and larger hydraulic gradient.

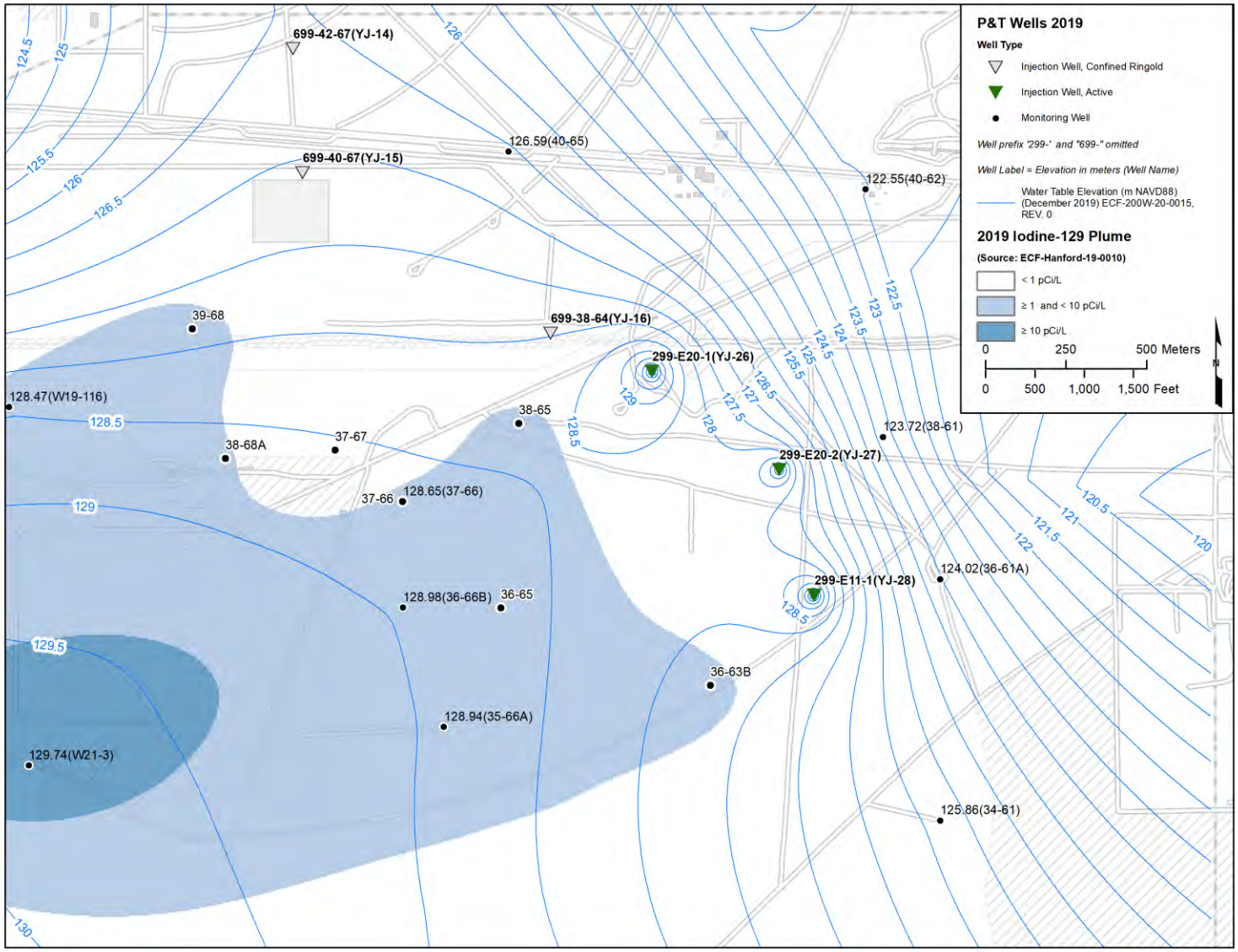

Figure 3-48. Water Table for the Iodine-129 Plume Hydraulic Containment Remedy, December 2019

Hydraulic gradients east-northeast of the iodine-129 plume were assessed to evaluate the effectiveness of the hydraulic containment remedy. The methods used to prepare this 2019 annual report are detailed in ECF-HANFORD-20-0049. Figures 3-49 and 3-50 show the mapped and simulated hydraulic gradients, respectively. The arrows in the figures indicate the hydraulic gradient direction, and the arrow length indicates the hydraulic gradient magnitude. Without the groundwater injection wells, the natural hydraulic gradient in this area is toward the east-northeast, as shown in the left panel (panel a) in each figure (representing baseline conditions). The gradient direction and magnitude under current conditions is shown by the arrow orientations and lengths in the right panel (panel b) in each figure. Larger changes in gradient direction and magnitude due to the injection of treated effluent are shown by larger differences in the arrow directions and lengths between panels a and b. The changes in hydraulic gradient magnitude from baseline conditions are shown in the right panels (panel b) of the figures by coloring; a decrease in the gradient magnitude is shown with red, and an increase in gradient magnitude is shown with green. As expected, gradient magnitude changes are the largest near the injection wells. The mapped water table (Figures 3-48 and 3-49) shows that groundwater flow continues to be toward the east-northeast over much of the area between the eastern boundary of the iodine-129 plume and the injection wells. South-southwest of the southernmost injection well (299-E11-1), the local gradient is interpreted to be east-southeast, although there are no monitoring wells in the area to verify this interpretation. The gradient magnitudes have decreased, as indicated by the red color west of the injection wells in Figure 3-49 and 3-50. The reduced gradient magnitude is also shown by the larger spacing between water table contours for the current conditions (panel b) compared to baseline conditions (panel a). The result of the change in gradient magnitude is that the migration rate for the leading edge of the iodine-129 plume has been reduced.

3.3.3 Contaminant Monitoring

Within the 200-UP-1 OU in 2019, well 299-W21-3 had the highest annual mean concentration of iodine-129 at 21.4 pCi/L. The 1 pCi/L iodine-129 cleanup level was exceeded in 23 other wells at concentrations ranging from 1.09 to 11.7 pCi/L.

As shown in Figure 3-46, the interpreted extent of the iodine-129 plume (where concentrations exceed the cleanup level) changed from 2018 to 2019 based on the following results:

- At well 699-38-65, the 2019 concentration for iodine-129 was 1.45 pCi/L. This well was not sampled for iodine-129 in 2018 due to a problem with the pump, and iodine-129 was not detected in 2017, so this resulted in an extension of the plume boundary to the northeast in 2019. However, in 2016 the mean iodine-129 concentration was 1.3 pCi/L at well 699-38-65, so the plume boundary previously extended to this well.

- The plume also extends farther to the northwest based on increased concentrations at five wells that had not been sampled since 2015 or 2016, when concentrations were below the cleanup level. In this area, the plume extent also includes new well 299-W19-131, where the average concentration was 1.0 pCi/L.

- Another new well, 699-37-67, was drilled in 2019 northeast of ERDF, and the iodine-129 concentration was below the 0.62 pCi/L MDA in December 2019. Therefore, the plume extent was refined to show concentrations below the cleanup level in this area.

- Near the 216-U-1 and 216-U-2 Cribs, the iodine-129 concentrations decreased to below the cleanup level at well 299-W19-115 and increased to above the cleanup level at well 299-W19-49. Therefore, this smaller plume is shown to have shifted to the southeast. The assumed separation between this smaller plume and the main plume is based on low concentrations at wells to the north and south.

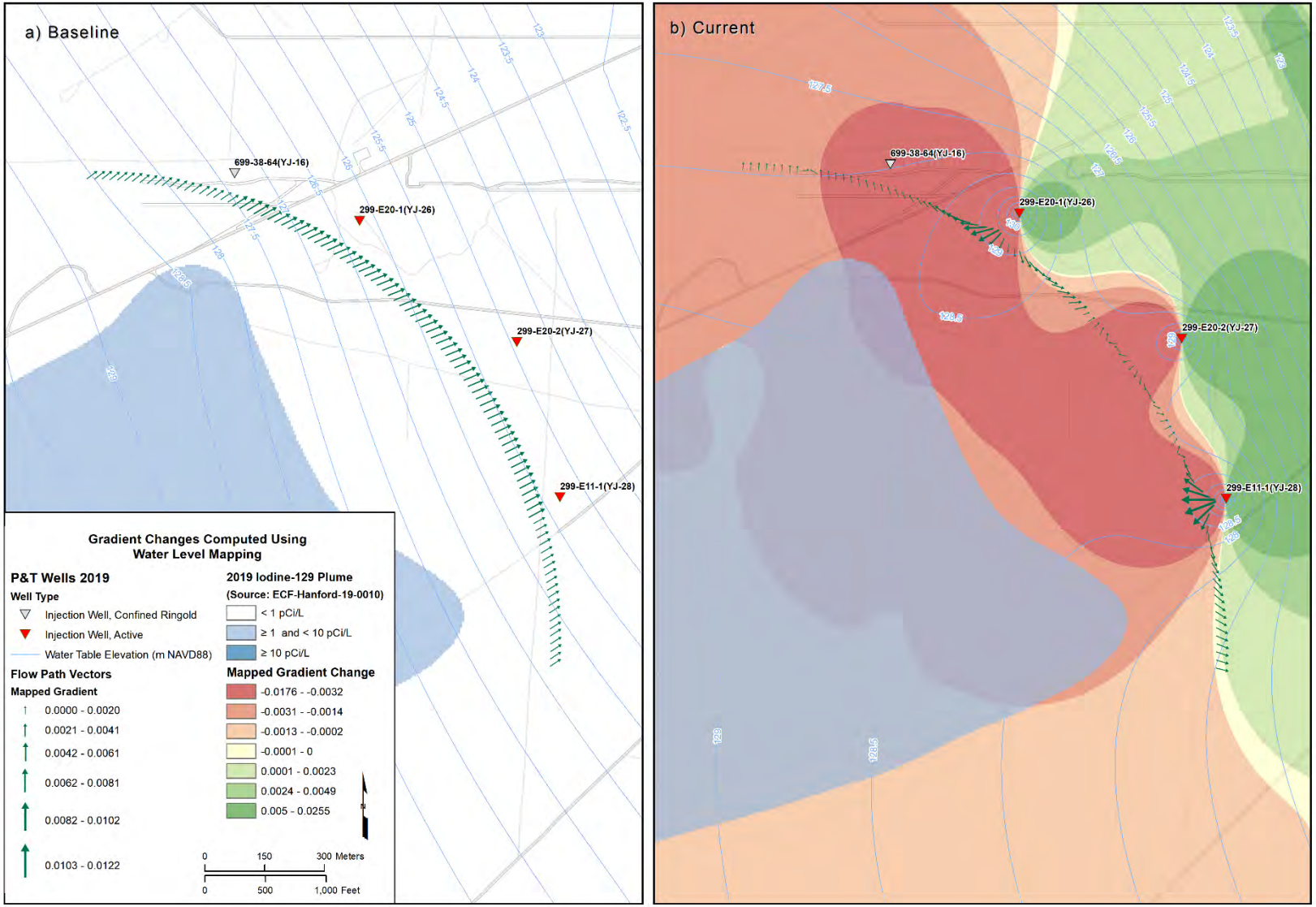

Figure 3-49. Mapped Hydraulic Gradient and Gradient Changes for the Iodine-129 Plume

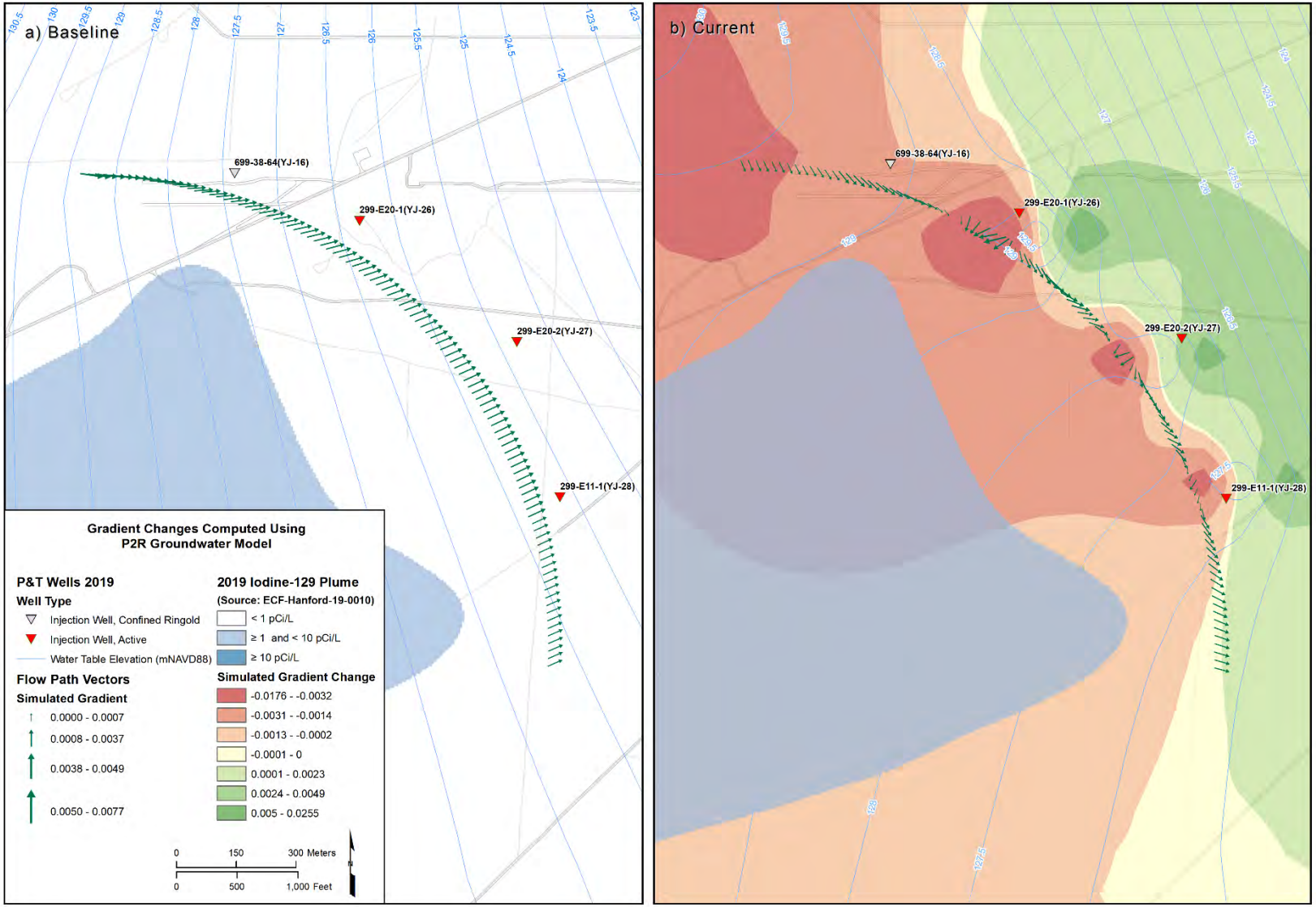

Figure 3-50. Simulated Hydraulic Gradient and Gradient Changes for the Iodine-129 Plume

Interpretation of the 1 pCi/L plume boundary for iodine-129 is subject to the high analytical error relative to the 1 pCi/L cleanup level and the MDA that is typically near the cleanup level. For example, the 1.45 pCi/L result at well 699-38-65 had an analytical error of ± 0.978 pCi/L and an MDA of 0.805 pCi/L.

3.4 Southeast Chromium Plume

Chromium occurs in groundwater southeast of the 200 West Area at concentrations above the 48 µg/L cleanup level (Figure 3-51). This plume originated from effluent disposal to the 216-S-20 Crib during the 1950s and effluent disposal to the REDOX Plant ponds and ditches south of the 200 West Area (Section 4.2.4 in DOE/RL-2009-122). An estimated 5,900 kg of chromium were disposed to the 216-S-20 Crib, and an estimated 3,000 kg were disposed to the 216-S-10 Pond and Ditch (Appendix C of RPP-26744, *Hanford Soil Inventory Model, Rev. 1*).

The extent of the southeast chromium plume was previously uncertain due to a lack of monitoring wells, particularly on the south side of the plume. In 2016 and 2017, 11 new wells were installed to define the extent of contamination, and 5 older wells were added to the monitoring network. Based on the monitoring results from these wells, the interpreted extent of the southeast chromium plume approximately doubled from 5.7 km^2 in 2016 to 11.0 km^2 in 2017 (Figure 3-52); in 2019, the interpreted plume extent increased slightly to 11.2 km^2 (DOE/RL-2019-66). DOE/RL-2017-60, *Remedial Design Investigation Report for the 200-UP-1 Operable Unit Southeast Chromium Plume*, was issued in October 2019 to update the conceptual site model and evaluate remedial options for the southeast chromium plume. Before a remedy decision is made, 5 years of additional of groundwater monitoring and evaluation was recommended beginning in FY 2020.

The highest chromium concentrations generally occur within the approximate center of the southeast chromium plume (Figure 3-51). In 2019, the highest average concentrations were 140 µg/L at well 699-30-57 and 129 µg/L at well 699-30-63. Chromium also is elevated at well 699-30-66 (Figure 3-51), which is completed deep in the aquifer just above the Rlm. During drilling in 2016 and 2017, discrete-depth sampling results indicated that higher concentrations (>100 µg/L) are present deeper in the western portion of the plume and shallower in the eastern portion of the plume (see cross section in Figure 4-3 of DOE/RL-2017-60). These data show that chromium is present throughout the aquifer thickness in this region due to dispersion as the plume migrated east from the source sites.

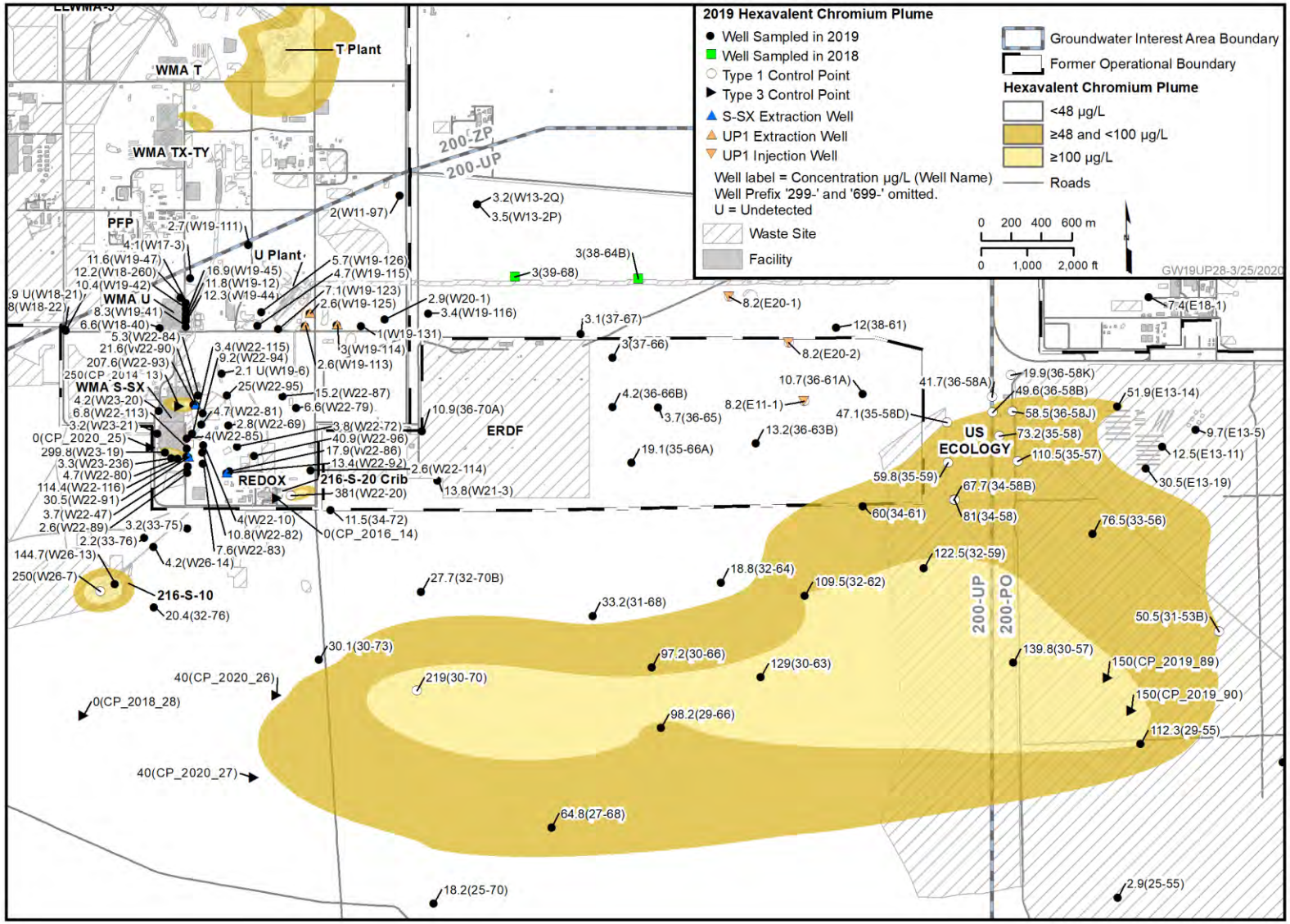

Figure 3-51. 200-UP-1 OU Southeast Chromium Plume Map, 2019

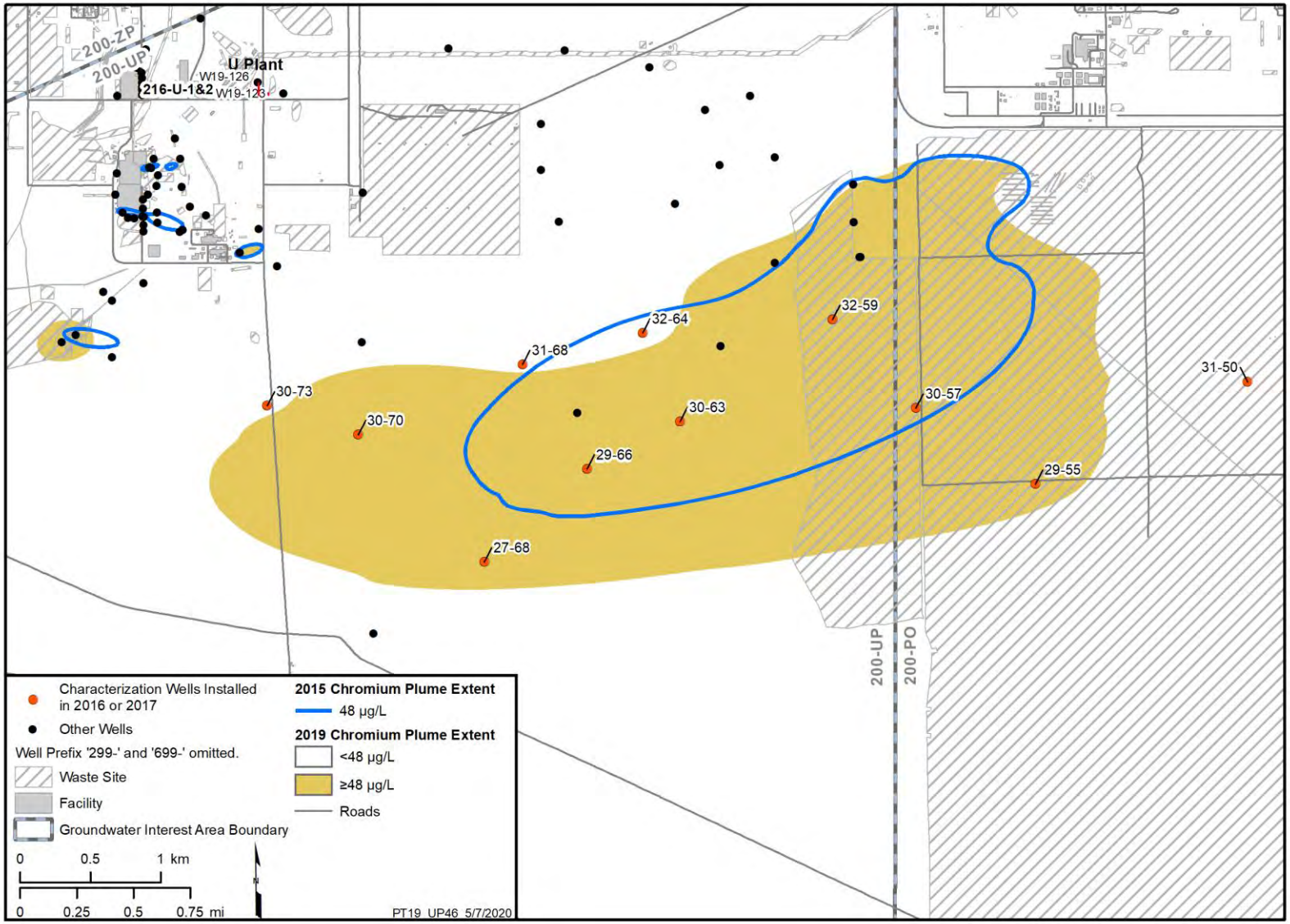

Figure 3-52. Comparison of the 2015 and 2019 Interpretations of the Southeast Chromium Plume and Characterization Wells Installed in 2016 and 2017

3.5 Monitored Natural Attenuation

MNA is specified in the 200-UP-1 OU ROD (EPA et al., 2012) to be used in conjunction with active remedies (or as a standalone remedy in the case of tritium) to achieve RAOs. Two primary MNA mechanisms were identified (dispersion for all COCs and radiological decay for tritium), which are supported by F&T modeling performed for the 200-UP-1 OU RI/FS (DOE/RL-2009-122). This section addresses MNA for the tritium and the nitrate plumes (separate from WMA S-SX). The 2019 plume maps are shown in Figure 3-53 for tritium and Figure 3-54 for nitrate.

The P&T remedies for groundwater at the S-SX Tank Farms and U Plant areas (described in Sections 3.1 and 3.2) actively reduce levels of nitrate contamination at these locations. The larger diffuse (low-concentration) nitrate plume areas not captured by the extraction wells is addressed through MNA to achieve the RAOs.

The F&T modeling of the tritium and nitrate plumes was updated during 2017 (ECF-200ZP1-17-0095, *Fate and Transport Analysis for the Groundwater Plume Remedies in the 200-ZP-1 and 200-UP-1 Operable Units Using the Central Plateau Groundwater Model*; ECF-200W-17-0030; DOE/RL-2017-68, *Calendar Year 2017 Annual Summary Report for Pump-and-Treat Operations in the Hanford Central Plateau Operable Units*). Results of F&T modeling were provided for two scenarios: (1) a scenario assuming no ongoing sources of contamination to the aquifer, and (2) a scenario that included estimates of mass contributions to the aquifer from ongoing sources. The modeling results indicated that under conditions of optimized pumping at the 200 West P&T and assuming no ongoing sources of contamination to the aquifer, nitrate and tritium concentrations in the 200-UP-1 OU would decline to below cleanup levels within the 125-year cleanup timeframe for Central Plateau groundwater (i.e., by the year 2137) by dispersion and radiological decay (for tritium). In general, however, an MNA remedy will not be successful if continuing contamination sources to the aquifer are substantial enough to cause exceedances of groundwater cleanup levels beyond the cleanup timeframe. When potential nitrate sources to the aquifer were included in the modeling, the results indicated that some contamination areas would remain unless the sources are remedied or groundwater near the sources is hydraulically contained; however, the resulting plumes would be smaller than the current plumes. Modeling of the tritium plume indicated that concentrations will decline to below the cleanup level by year 2137, with or without ongoing sources, because the sources also diminish over time due to radiological decay. The results indicate that the MNA remedy for tritium will be successful without source remediation. However, for MNA to be fully effective for nitrate, source remediation or containment of groundwater near the sources may be needed in the future.

As identified in Chapter 2, active biological treatment for nitrate at the 200 West P&T was suspended starting in October 2019 as part of the 200-ZP-1 OU optimization study (DOE/RL-2019-38). Extraction wells within the 200-UP-1 OU will continue to remove nitrate from higher concentration areas, and most effluent from the 200 West Area groundwater treatment facility is injected outside of the OU. For effluent injection within the 200-UP-1 OU, nitrate attenuation will be evaluated as part of the 200-ZP-1 OU optimization study and in future P&T reports. To support these evaluations, additional monitoring downgradient of the injection wells may be performed.

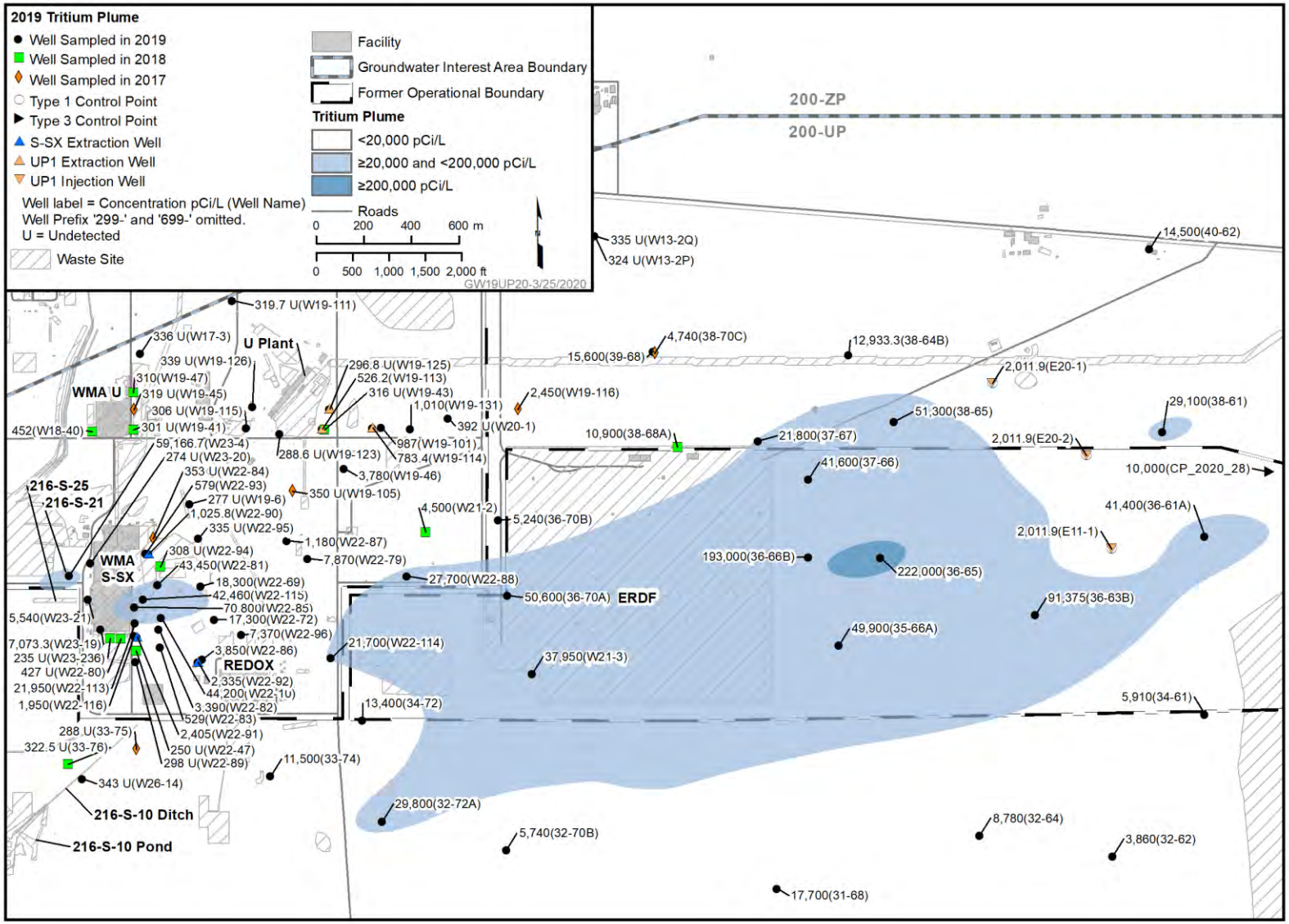

Figure 3-53. 200-UP-1 OU Tritium Plume Map, 2019

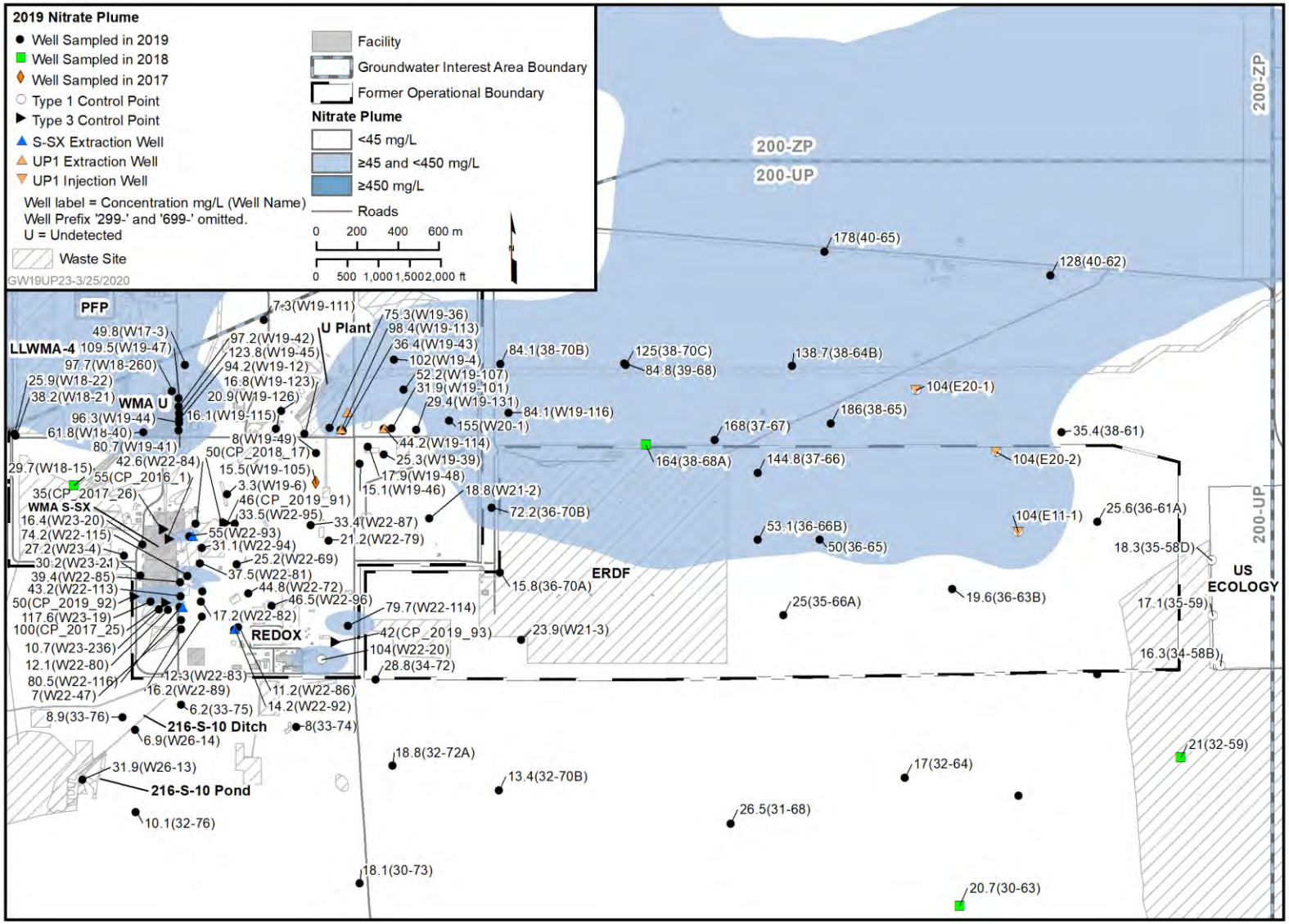

Figure 3-54. 200-UP-1 OU Nitrate Plume Map, 2019

3.5.1 Performance Monitoring Evaluation

MNA is evaluated using two methods. For individual wells in the MNA network, the current sample results are compared to baseline concentrations. MNA also is evaluated at the plume scale by calculating the one-sided 95% UCL on the mean of the plume concentrations, as specified in the 200-UP-1 OU RD/RAWP (DOE/RL-2013-07, Rev. 0) and the 200-UP-1 OU PMP (DOE/RL-2015-14). To assess remedy progress, the 95% UCL values calculated from monitoring data are compared to the values calculated from model simulation results.

The 2019 tritium and nitrate sample results from the monitoring wells used to evaluate MNA are compared to 2016 baseline concentrations in Tables 3-14 and 3-15, respectively. These comparisons are also shown in Figures 3-55 and 3-56 for tritium and in Figures 3-57 and 3-58 for nitrate. In Figures 3-55 and 3-57, the comparisons are depicted by bar charts. In Figures 3-56 and 3-58, the monitoring well locations are shown in relation to the plumes, and concentration magnitudes are depicted with circles. For these figures, the circle diameters reflect a log-scaled ratio of concentration relative to the cleanup level, baseline concentrations are shown with hollow circles, and 2019 concentrations are shown with shaded circles. A hollow annulus between concentric circles shows a concentration decrease, a shaded annulus shows a concentration increase, and no annulus shows minimal concentration change.

Table 3-14. Comparison of Baseline to 2019 Tritium Concentrations for the Regional Plume

Well Name	Baseline (2016) Tritium (pCi/L)	2019 Tritium (pCi/L)[a]	Percent Change
299-W21-3	82,900	30,600	-63
299-W22-69	3,130	18,300	485
299-W22-72	15,600	17,300	11
299-W22-83	4,720	529	-89
299-W22-86	9,350	3,850	-59
299-W22-88	7,660	27,700	262
299-W22-96	12,600	7,370	-42
299-W22-113	39,700	22,600	-43
299-W22-114[b]	28,200	21,700	-23
299-W22-115	60,200	36,000	-40
299-W23-4	50,300	57,700	15
299-W23-19	10,500	6,160	-41
299-W23-21	16,500	5,540	-66
699-31-68	22,000	17,700	-20
699-32-62	5,330	3,860	-28
699-32-72A	38,100	29,800	-22
699-33-74	15,100	11,500	-24
699-34-61	8,380	5,910	-29
699-34-72	9,610	13,400	39
699-35-66A	69,000	49,900	-28

Table 3-14. Comparison of Baseline to 2019 Tritium Concentrations for the Regional Plume

Well Name	Baseline (2016) Tritium (pCi/L)	2019 Tritium (pCi/L)[a]	Percent Change
699-36-61A	41,200	41,400	0
699-36-63B[c]	105,000	94,900	-10
699-36-65[d]	—	222,000	—
699-36-66B	250,000	193,000	-23
699-36-70A	42,400	53,200	25
699-36-70B	7,090	5,240	-26
699-37-66	53,200	41,600	-22
699-38-61	71,000	29,100	-59
699-38-65	53,900	51,300	-5
699-38-68A	11,900	10,900	-8
699-40-62	4,450	14,500	226

Notes:

The cleanup level specified in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, for tritium is 20,000 pCi/L.

Yellow-shaded cells identify monitoring wells within 61 m (200 ft) of an extraction well.

a. For wells sampled multiple times during 2019, the result shown is from the last sample of the year. For duplicate samples collected on the same day, the average concentration is shown. If a well was not sampled in 2019, the latest result is shown.

b. Baseline sample collected in April 2017.

c. Baseline sample collected in September 2017.

d. Well drilled in 2019; no baseline sample.

Table 3-15. Comparison of Baseline to 2019 Nitrate Concentrations for the Regional Plume

Well Name	Baseline (2016) Nitrate (mg/L)	2019 Nitrate (mg/L)[a]	Percent Change
299-W15-37	84.1	No sample	—
299-W18-15[b]	53.1	29.7	-44
299-W18-21	31.9	39.2	23
299-W18-40	79.7	57.1	-28
299-W19-4	165	102	-38
299-W19-34A	53.1	10.2	-81
299-W19-36	531	75.3	-86
299-W19-39	33.6	25.3	-25
299-W19-43	407	36.5	-91
299-W19-44	48.7	84.1	73
299-W19-45	128	136.5	7
299-W19-46	18.6	15.1	-19

Table 3-15. Comparison of Baseline to 2019 Nitrate Concentrations for the Regional Plume

Well Name	Baseline (2016) Nitrate (mg/L)	2019 Nitrate (mg/L)[a]	Percent Change
299-W19-47	70.8	104	47
299-W19-48	27.4	17.9	-35
299-W19-49	19.9	7.97	-60
299-W19-101	93	31.9	-66
299-W19-107	48.7	52.2	7
299-W19-115[c]	62	14.9	-76
299-W19-116[d]	111	79.7	-28
699-36-65[e]	—	50.0	—
699-36-66B	53.1	53.1	0
699-36-70B	88.5	72.2	-18
699-37-66	146	133	-9
699-38-64B[f]	217	164	-24
699-38-65	164	186	13
699-38-68A	159	164	3
699-38-70B	48.7	84.1	73
699-38-70C	124	125	1
699-39-68[g]	93	69.5	-25
699-40-62	115	128	11
699-40-65	212	178	-16

Notes:

The cleanup level specified in EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*, for nitrate (as NO_3) is 45 mg/L.

Yellow-shaded cells identify monitoring wells within 61 m (200 ft) of an extraction well.

a. For wells sampled multiple times during 2019, the result shown is from the last sample of the year. For duplicate samples collected on the same day, the average concentration is shown. If a well was not sampled in 2019, the latest result is shown.

b. Baseline sample collected in February 2017.

c. Baseline sample collected in March 2017

d. Baseline sample collected in February 2017.

e. Well drilled in 2019 - no baseline sample.

f. Baseline sample collected in September 2018.

g. Baseline sample collected in December 2018.

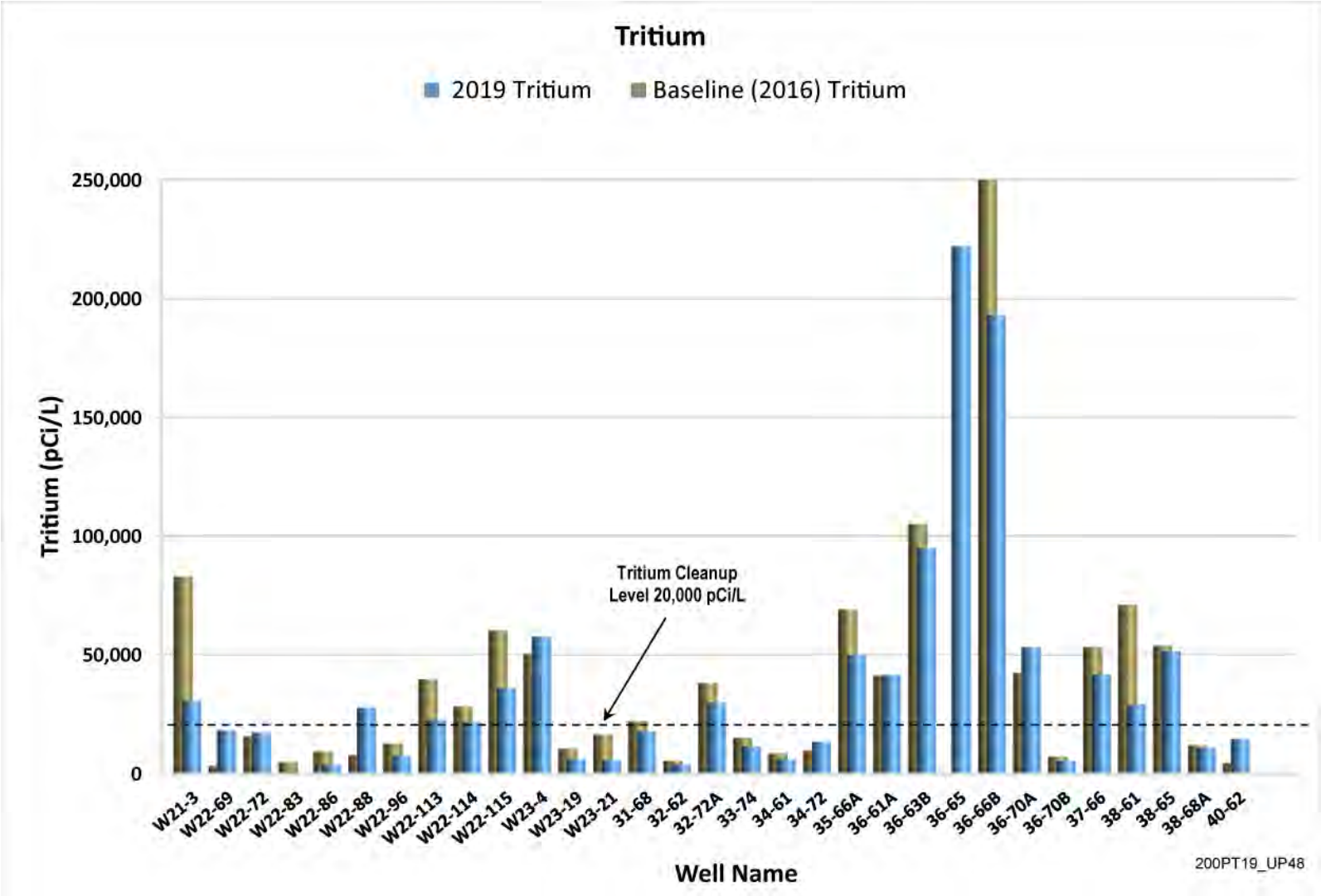

Figure 3-55. Comparison Chart of Baseline to 2019 Tritium Concentrations for MNA of the Regional Plume

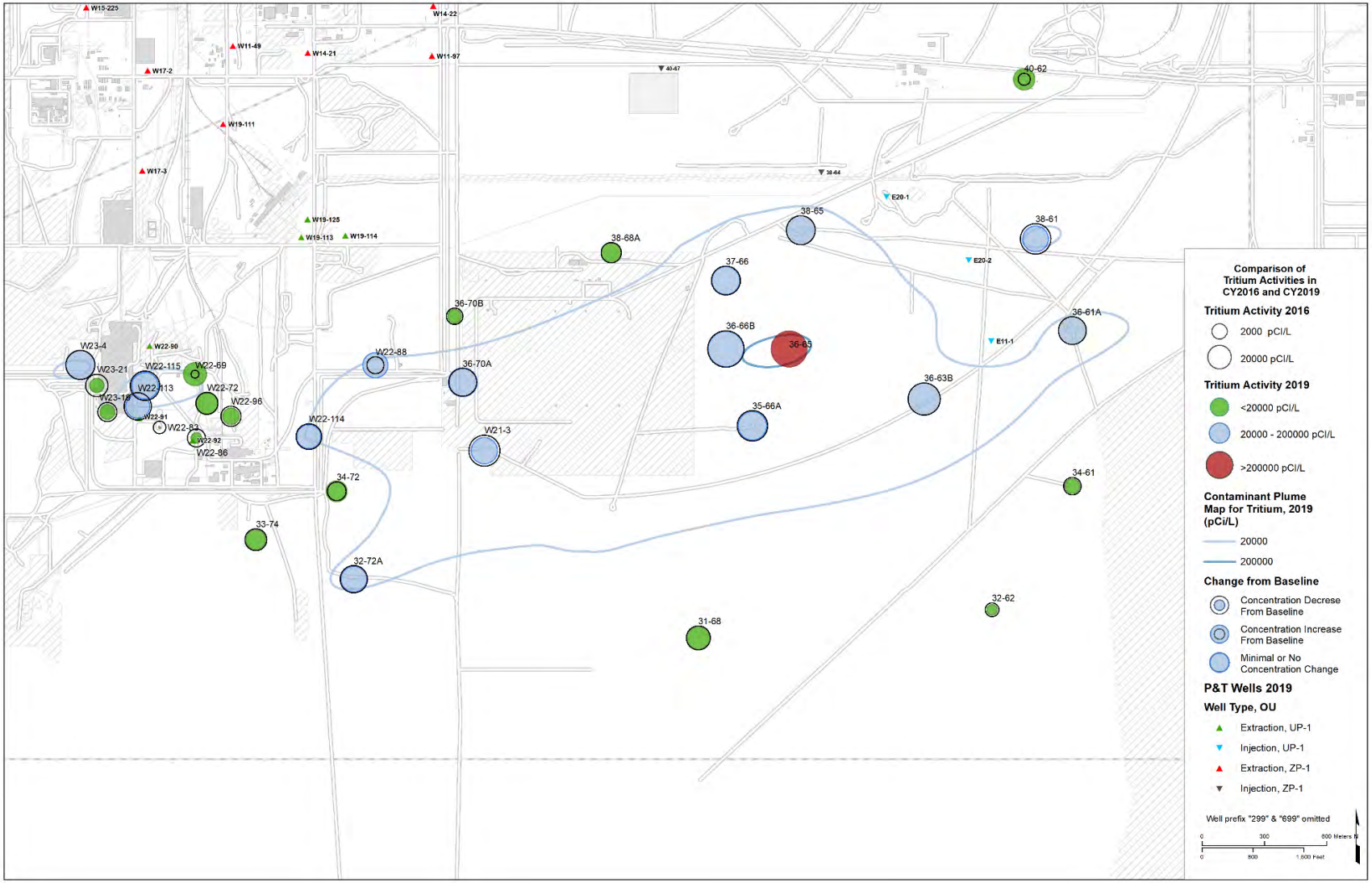

Figure 3-56. Comparison Map of 2019 Tritium Results to Baseline Concentrations for MNA

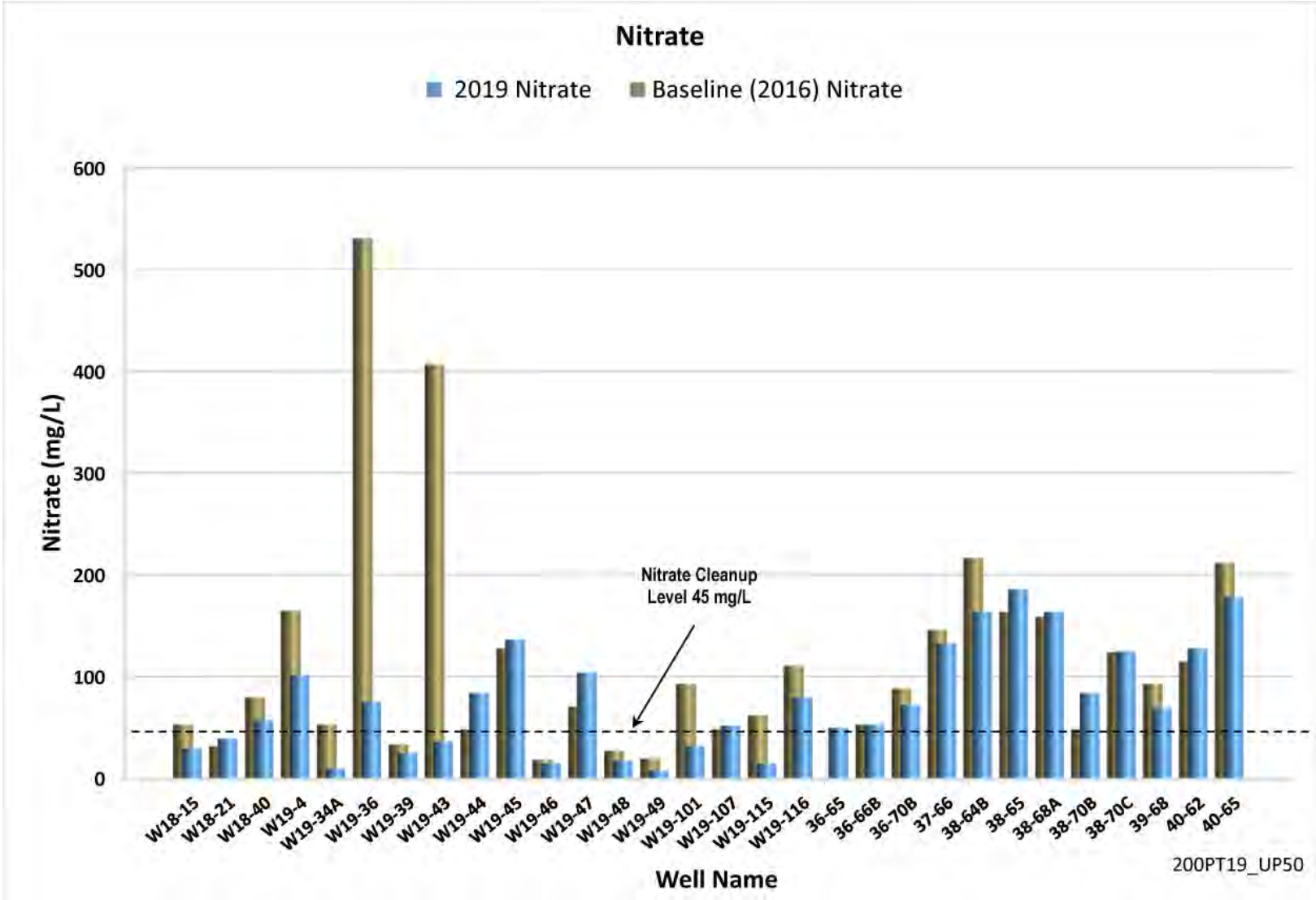

Figure 3-57. Comparison Chart of Baseline to 2019 Nitrate Concentrations for MNA of the Regional Plume

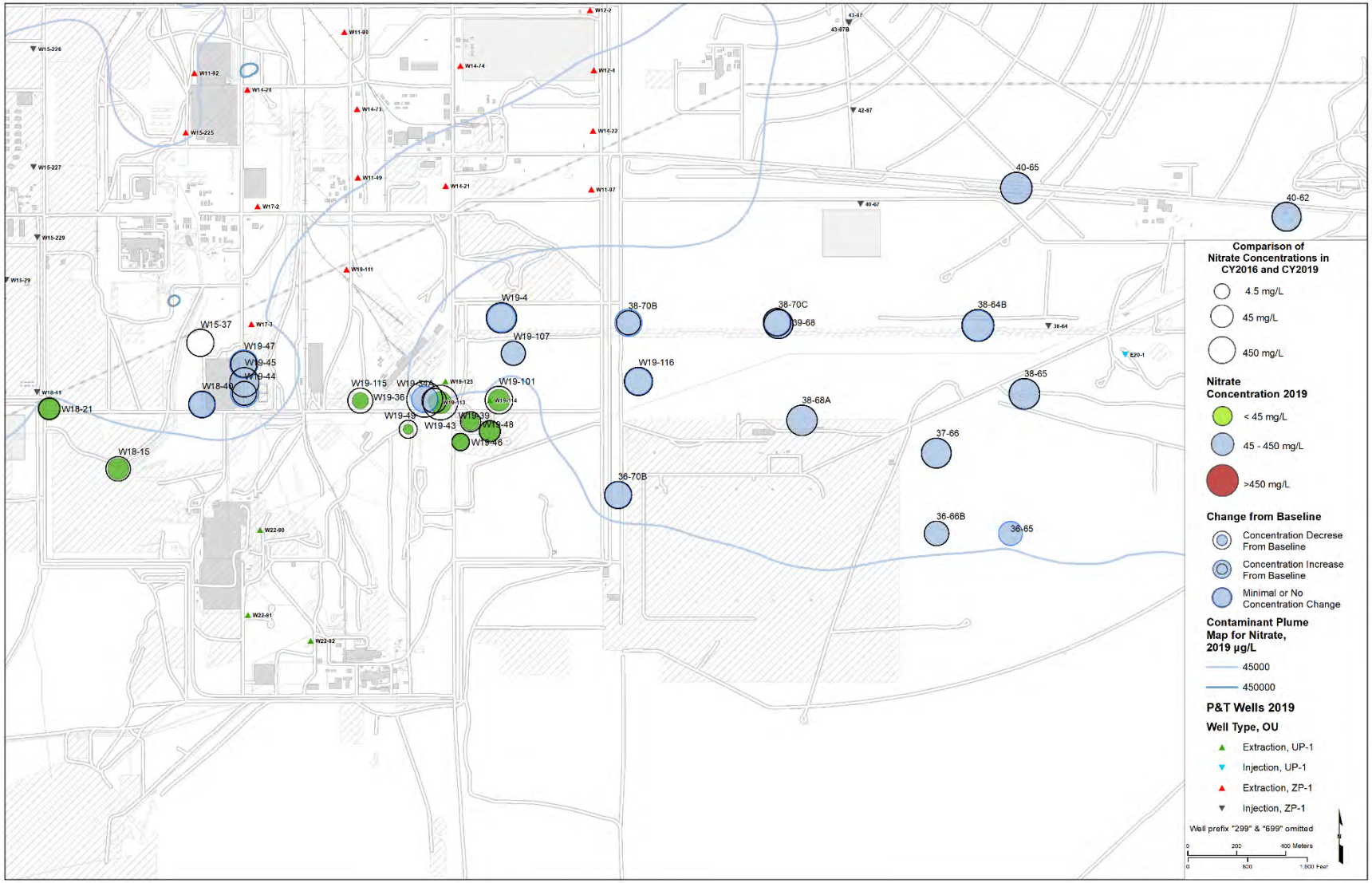

Figure 3-58. Comparison Map of Baseline to 2019 Nitrate Concentrations for MNA of the Regional Plume

Tritium concentrations have decreased in 12 of 15 monitoring wells with baseline or 2019 concentrations above the 20,000 pCi/L cleanup level (Table 3-14; Figure 3-55). Concentrations have increased at wells 299-W22-88 and 699-36-70A (located in the northwestern portion of the plume) and increased slightly at well 299-W23-4 (located downgradient of the 216-S-21 Crib) (Figure 3-56). The highest tritium concentration in 2019 was 222,000 pCi/L at new well 699-36-65. The highest tritium concentrations were previously observed upgradient at well 699-36-66B, where concentrations decreased from baseline of 250,000 to 193,000 pCi/L in 2019.

For nitrate, concentrations have decreased in 14 of 23 monitoring wells with baseline or 2019 concentrations above the 45 mg/L cleanup level (Table 3-15; Figure 3-57). The largest concentration increase (73%) occurred at well 299-W19-44, which is downgradient of WMA U, where nitrate concentrations also have increased at other wells (Figure 3-58). WMA U has been interpreted as a source of nitrate to the aquifer, although some nitrate is also migrating from upgradient of the tank farm area. To the east within the main body of the plume, nitrate concentrations have also increased at some wells (Figure 3-58).

To assess MNA progress for tritium and nitrate at the plume scale, 95% UCL values were calculated annually beginning in 2008 (ECF-200UP1-20-0032). The wells used for the calculations were selected throughout the OU where baseline concentrations exceeded the cleanup levels of 20,000 pCi/L for tritium or 45 mg/L for nitrate, as identified in the 200-UP-1 OU PMP (DOE/RL-2015-14). For wells associated with the WMA S-SX groundwater extraction system, the 95% UCL values for nitrate are evaluated separately, as presented in Section 3.1.3.3. The monitoring well networks used for 95% UCL calculation are periodically reviewed and revised as described in the PMP.

Figure 3-59 shows the tritium 95% UCL values from 2008 to 2019 for the monitoring data and modeling results. The decline from 2008 to 2009 was primarily due to well 699-35-70, which is within a high-concentration portion of the tritium plume. Well 699-35-70 went dry and was later replaced by well 299-W21-3 in 2016. The increase from 2011 to 2012 was primarily due to the addition of well 699-36-66B within the high-concentration portion of the plume. Since 2012, the 95% UCL values for the monitoring data declined from 111,057 to 52,983 pCi/L in 2019. The 95% UCL values for the modeling results (with or without the inclusion of ongoing sources) are similar and also show a declining trend. The declining trends (for both the actual and modeled 95% UCL values) can be attributed to dispersion and radiological decay. The overall agreement in the actual and modeled trends indicates that MNA for tritium is proceeding as expected, and RAOs are expected to be achieved.

Figure 3-60 shows the nitrate 95% UCL values from 2008 to 2019 for the monitoring data and modeling results. The actual 95% UCL increase from 2011 to 2012 was primarily due to increased nitrate concentrations at well 299-W19-43, where concentrations increased from 1,080 mg/L in 2010 to 3,340 mg/L in 2012. Since 2015, the declining 95% UCL values are largely associated with operation of extraction well 299-W19-113 (near well 299-W19-43), where nitrate concentrations decreased from 3,190 mg/L in 2015 to 36.5 mg/L in 2019. In 2018 and 2019, the actual 95% UCL values show good agreement with the modeled values (Figure 3-60). Continued calculation of 95% UCL values in future years is needed to evaluate how the actual and modeled results compare.

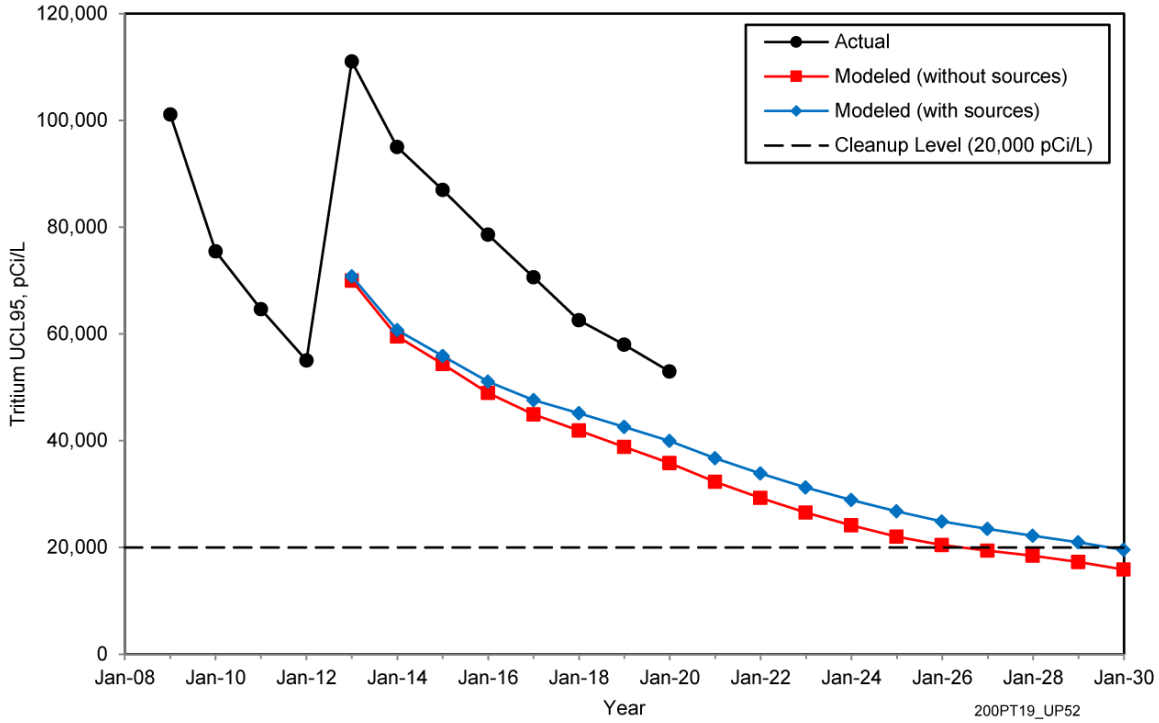

Figure 3-59. 95% UCL on the Mean Concentrations of Tritium for the 200-UP-1 OU

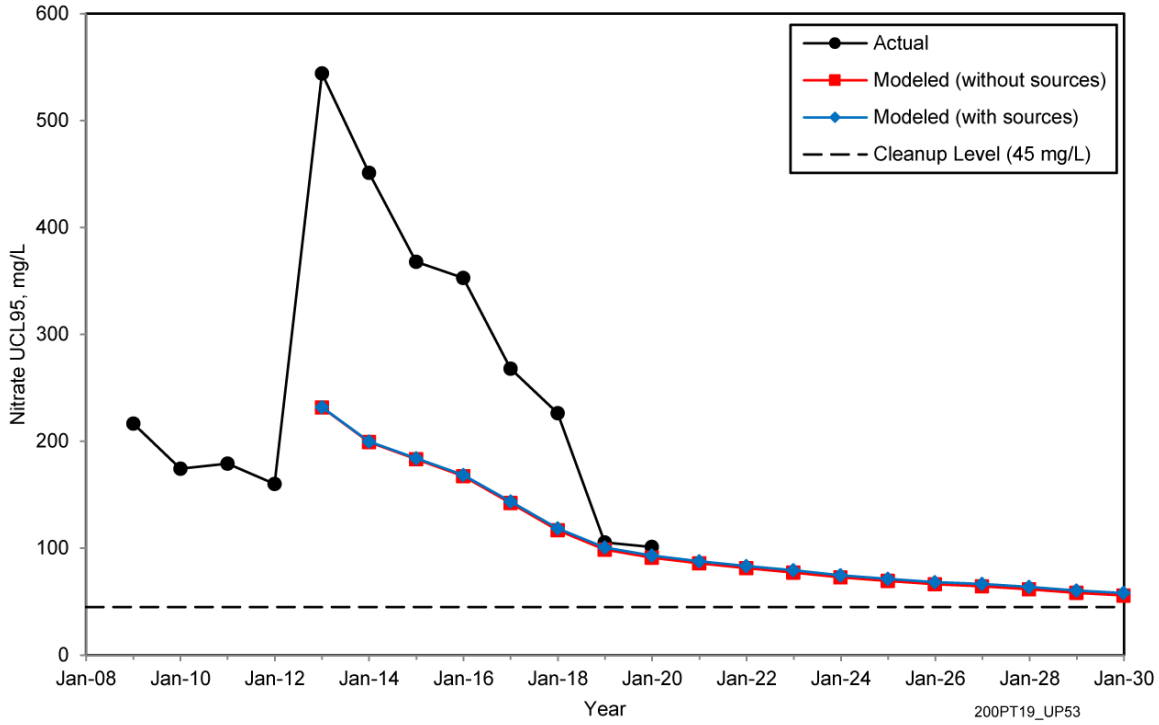

Figure 3-60. 95% UCL on the Mean Concentrations of Nitrate for the 200-UP-1 OU

3.6 Quality Assurance/Quality Control

The QA/QC for sampling and analysis results for the 200-UP-1 OU wells are presented in Appendix E of DOE/RL-2019-66, which includes an overall view of QA/QC issues that may affect interpretation of the groundwater data presented in this report.

3.7 Remedial System Costs

Tables 3-16 through 3-19 present the burdened cost breakdown for the WMA S-SX P&T system, U Plant area P&T system design and construction, iodine-129 plume hydraulic containment design and construction, and southeast chromium plume characterization for 2019. Costs are burdened and are based on actual operating costs incurred during 2019. The specific cost categories listed are as follows:

- **Design:** Consists of labor, equipment, materials, and subcontractor costs for design of the remedial systems. Design costs include all design documentation (drawings, calculations, and specifications), engineering studies, permitting, aquifer response numerical modeling, and associated activities.
- **Construction:** Consists of the costs for constructing the remedy, including labor, equipment, material, and subcontractor costs. Costs are included for installing extraction and injection wellhead mechanical and electrical racks, pipelines, transfer buildings, connections to the treatment facility, and associated equipment and utilities; and for conducting acceptance testing prior to turnover to operations. Construction of the WMA S-SX groundwater extraction system began in 2011 and was completed in 2012. Construction of the U Plant groundwater extraction system and design for the iodine-129 plume hydraulic containment system were initiated in 2014. Both systems were constructed in 2015, and extraction well 299-W19-125 was added to the U Plant P&T extraction system in 2017.
- **Project support:** Consists of labor, equipment, materials, and subcontractor costs for project management and support associated with implementing the remedial action. It includes management of project scope, schedule, and budget. It also includes project oversight/coordination of planning, regulatory documentation, remedial design, construction, operations, and monitoring activities. A change in this year's reporting is the inclusion of apportioned costs from pooled sampling to each OU. Sampling activities for routine groundwater monitoring are integrated for all groundwater OUs for sampling integration to reduce overall labor with sample trips and analytical costs. These costs have been pooled in a separate project account and have not been included in the individual project performance monitoring costs. To account for all performance monitoring costs associated with implementation of remedial actions for the 200-UP-1 OU remedial action, a portion of the pooled costs based on sample trips and analyses performed for the 200-UP-1 OU have been included to the performance monitoring costs in this year's report.
- **O&M:** Consists of labor, equipment, and material costs for operational testing and for O&M of the remedial systems. For the 200-UP-1 OU, this includes costs for extraction wells (including wellheads) and transfer building O&M for the WMA S-SX groundwater extraction system. Treatment system costs for the WMA S-SX P&T system and the U Plant P&T system reflect a portion of the overall 200 West P&T O&M cost based on the percentage of mass treated from extracted 200-UP-1 OU groundwater to the total mass treated by the 200 West P&T (Table 2-14).

Table 3-16. Cost Breakdown for the WMA S-SX Groundwater Extraction System

Description	Actual Costs (in $1000s)									
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Design	$250.0	—	—	—	—	—	—	—	—	—
Construction	$1,378.9	$3,952.5	$178.7	—	—	—	—	—	—	—
Project support	$7.6	$155.4	$0.9	$9.1	$3.3	$7.7	$12.3	$9.2	$13.2	$11.5
O&M[a]	—	—	$715.8	$1,084.2	$727.5	$506.9	$402.3	$346.2	$312.2	$329.6
Performance monitoring[b]	—	$90.3	$118.8	$141.5	$125.1	$94.6	$145.2	$118.0	$91.00	$164.0
Well installation	—	$1,177.4	—	—	—	—	—	—	—	—
Totals	**$1,636.5**	**$5,375.6**	**$1,014.2**	**$1,234.8**	**$855.9**	**$609.2**	**$559.8**	**$473.4**	**$416.4**	**$505.1**

a. The O&M cost has been adjusted to reflect apportioning the overall 200 West P&T O&M cost to the WMA S-SX extraction system based on the percentage of mass treated from extracted WMA S-SX groundwater to the total mass treated by the 200 West P&T.

b. Performance monitoring costs have been adjusted back through 2011 to include pooled sampling costs for groundwater monitoring apportioned to the S-SX P&T system.

— = no value in this cost rollup

O&M = operations and maintenance

P&T = pump and treat

WMA = waste management area

Table 3-17. Cost Breakdown for the U Plant Area P&T System

Description	Actual Costs (in $1,000s)					
	2014	2015	2016	2017	2018	2019
Design	$1,449.5	$69.3	$66.0	$108.9	$2.93	—
Construction	$2,461.4	$6,951.7	—	$1,525.1	$26.48	—
Project support	$291.3	$81.1	$12.2	$9.2	$13.17	$11.5
O&M[a]	—	$400.4	$592.4	$428.8	$399.40	$408.8
Performance monitoring[b]	—	$66.6	$544.4 [c]	$823.6	$303.2	$179.3
Well installation	$781.9	$766.4	$2676.1	$1,669.3	$360.01	$71.8
Totals	**$4,984.1**	**$8,335.5**	**$3,891.1**	**$4,565.0**	**$1,105.2**	**$671.4**

a. The O&M cost has been adjusted to reflect apportioning the overall 200 West P&T O&M cost to the U Plant P&T system based on the percentage of mass treated from extracted U Plant groundwater to the total mass treated by the 200 West P&T.

b. Performance monitoring costs have been adjusted back through 2011 to include pooled sampling costs for groundwater monitoring apportioned to the U Plant P&T system.

c. The increased performance monitoring cost is associated with sampling and characterization of new wells installations.

— = no value in this cost rollup

O&M = operations and maintenance

P&T = pump and treat

Table 3-18. Cost Breakdown for the Iodine-129 Hydraulic Containment System

Description	Actual Costs (in $1,000s)					
	2014	2015	2016	2017	2018	2019
Design	$121.3	$130.9	—	—	—	—
Construction	$36.6	$2,004.6	$5.6	$0.0	$0.00	$0.0
Project support	$63.0	$51.6	$12.2	$9.29	$13.17	$11.5
O&M[a]	—	—	$230.5	$214.0	$187.46	$174.9
Performance monitoring	—	—	—	—	—	$17.0[b]
Well installation	$1.6	$2,048.6	$15.1	$0.0	—	—
Totals	**$222.5**	**$4,235.7**	**$263.4**	**$223.2**	**$200.63**	**$203.4**

a. The O&M cost has been adjusted to reflect apportioning the overall 200 West P&T O&M cost to iodine-129 plume containment based on percentage of wells requiring maintenance.

b. Beginning in 2019, performance monitoring costs were allocated by groundwater operable unit.

— = no value in this cost rollup

O&M = operations and maintenance

P&T = pump and treat

Table 3-19. Cost Breakdown for Chromium Characterization

Description	Actual Costs (in $1,000s)			
	2016	2017	2018	2019
Design	—	—	—	—
Construction	—	—	—	—
Project support	$84.9	$352.8	$465.71	$79.9
Operations and maintenance	—	—	—	—
Performance monitoring	—	—	—	$241.7*
Well installation	$2,349.0	$3,267.0	$647.08	—
Totals	**$2,433.9**	**$3,619.85**	**$1,112.79**	**$321.7**

*Beginning in 2019, performance monitoring costs were allocated by groundwater operable unit.
— = no value in this cost rollup

- **Performance monitoring:** Consists of labor, equipment, and material costs for remedy performance monitoring of the aquifer typically defined in a monitoring plan. This category addresses the costs for collecting and/or evaluating data to assess changes in contaminant plume geometry, hydraulic controls (including plume capture or containment), and effectiveness of natural attenuation processes. It also includes costs for monitoring water levels and preparing annual reports.
- **Well installation:** Includes costs for installing new CERCLA monitoring, extraction, and injection wells at the 200-UP-1 OU.

3.8 Summary and Conclusions

The performance of the 200-UP-1 OU remedies is summarized as follows:

- The WMA S-SX groundwater extraction system operated at 93% of its design capacity in 2019. The combined pumping rate from the three extraction wells averaged 281 L/min (74.2 gal/min) compared to the design nominal pumping rate of 303 L/min (80 gal/min).
- During 2019, the WMA S-SX groundwater extraction system removed 147.6 million L (39.0 million gal) of water containing an estimated 16.2 g (0.275 Ci) of technetium-99; 3.48 kg of chromium; 3,553 kg of nitrate; and 10.2 kg of carbon tetrachloride from the aquifer. The total mass removed since startup is 202.8 g (3.44 Ci) of technetium-99; 53.0 kg of chromium; 39,366 kg of nitrate; and 85.1 kg of carbon tetrachloride.
- At WMA S-SX, technetium-99, chromium, and nitrate concentrations have declined in a majority of monitoring wells that had baseline concentrations above a cleanup level. The 95% UCL values for technetium-99 declined from 19,768 to 6,954 pCi/L between 2011 and 2019 due to operation of the groundwater extraction system.
- Comparisons of the 95% UCL values calculated from the monitoring data to numerical model simulations, and comparisons of the actual mass (or activity) of contaminants extracted from the aquifer to model predictions, indicate that the WMA S-SX groundwater extraction system is operating as predicted and is expected to achieve its cleanup objectives.

- Continuing sources of groundwater contamination may be great enough that groundwater plumes could re-form (with concentrations above the cleanup level) following shutdown of the WMA S-SX groundwater extraction system unless the sources are remediated or groundwater near the sources is hydraulically contained. In addition, near the northern portion of the SX Tank Farm, increasing technetium-99 concentrations may indicate a source in this area that is outside the extraction wells' capture zones. These results demonstrate the need to integrate groundwater plume remediation with source characterization and remediation, and an updated strategy may be needed to address continuing contaminant sources at WMA S-SX, particularly for technetium-99.

- The U Plant area groundwater extraction system operated at 110% of its design capacity in 2019. The combined pumping rate from the three extraction wells averaged 625 L/min (165 gal/min) compared to the design nominal pumping rate of 568 L/min (150 gal/min).

- During 2019, the U Plant area groundwater extraction system removed 328.6 million L (86.8 million gal) of water containing an estimated 14.0 kg of uranium; 7.2 g (0.123 Ci) of technetium-99; 18,093 kg of nitrate; and 26.3 kg of carbon tetrachloride from the aquifer. The total mass removed since startup is 58.9 kg of uranium; 71.5 g (1.22 Ci) of technetium-99; 135,364 kg of nitrate; and 105.4 kg of carbon tetrachloride.

- For the U Plant area monitoring wells, uranium concentrations have decreased at the majority of wells with baseline concentrations above the 30 µg/L cleanup level. At well 299-W19-36, concentrations decreased from a peak of 5,000 µg/L in 2017 to 1,700 µg/L in 2019 (near its baseline concentration of 1,550 µg/L). Technetium-99 concentrations decreased at both wells with baseline concentrations above the 900 pCi/L cleanup level. The 95% UCL values for uranium increased from 215 µg/L in 2014 (prior to startup of the current extraction system) to 844 µg/L in 2017 and then decreased to 731 µg/L in 2019. These changes can primarily be attributed to uranium concentration changes at well 299-W19-36. Because only two wells in the U Plant area had baseline technetium-99 concentrations above the cleanup level, the 95% UCL calculation is not prescribed in the 200-UP-1 OU PMP (DOE/RL-2015-14).

- The F&T simulations for the U Plant groundwater extraction system at flow rates similar to current operating conditions have shown that the maximum uranium concentration is not expected to decline to below the 30 µg/L cleanup level within 25 years (as predicted in the 200-UP-1 OU ROD [EPA et al., 2012]) nor within the overall 125-year cleanup timeframe for Central Plateau groundwater. The modeling also showed that uncertainty in plume concentrations is important for evaluating alternative groundwater extraction systems. Once sufficient analytical data are obtained from the new wells installed in 2019 (299-W19-126, 299-W19-131, and 299-W20-1), additional numerical simulations are planned to evaluate system performance and determine if modifications are needed to achieve remediation objectives.

- Continuing releases of uranium from the vadose zone beneath the 216-U-1 and 216-U-2 Cribs may be great enough that a plume may re-form following shutdown of the U Plant groundwater extraction system unless the source is remediated or groundwater near the source is hydraulically contained. Although this conclusion is tentative due to uncertainty in the estimated source mass flux to the aquifer, it demonstrates the need to integrate groundwater plume remediation with source characterization and remediation. An updated strategy may be needed to address continuing contaminant sources in the U Plant area, particularly for uranium.

- For technetium-99 in the U Plant area, F&T simulations indicate that cleanup objectives will be achieved by the current groundwater extraction system if a continuing contamination source is not present. With a continuing source (from the 216-U-1 and 216-U-2 Cribs), the technetium-99 plume may re-form (with concentrations above the cleanup level) after the active remediation period unless the source is remediated or groundwater near the source is hydraulically contained.

- The iodine-129 plume hydraulic containment injection wells were designed to operate at nominal flow rates of 189 to 379 L/min (50 to 100 gal/min) per well. During 2019, well 299-E20-1 operated at an average rate of 269 L/min (71.2 gal/min), well 299-E20-2 operated at an average rate of 251 L/min (66.2 gal/min), and well 299-E11-1 operated at an average rate of 275 L/min (72.7 gal/min). Water-level data indicate that the magnitude of the hydraulic gradient between the plume boundary and the injection wells has decreased, which has slowed eastward plume migration.

- A treatment technology evaluation for iodine-129 plume was completed in September 2019. The conclusion of this evaluation was that the practicability of all candidate remediation technologies for the iodine-129 plume is low driven by site and contaminant properties that hinder effectiveness and/or implementability of the technologies. Because a viable remediation technology is not available for the iodine-129 plume, a technical impracticability waiver will be pursued beginning in FY 2020 under 40 CFR 300.430(f)(l)(ii)(c).

- The southeast chromium plume continued to be evaluated in 2019, and a remedial design investigation report (DOE/RL-2017-60) was issued in October 2019 to update the conceptual model and evaluate remedial options. Data collected from additional characterization wells (installed in 2016 and 2017) indicate that the plume is about twice as large as previously interpreted. Results of depth-discrete sampling during well drilling and routine groundwater sampling from a well screened just above the Rlm indicate that chromium is present throughout the aquifer thickness in this region, with higher concentrations (>100 µg/L) present deeper in the western portion of the plume and shallower in the eastern portion of the plume. Before a remedy decision is made, 5 years of additional groundwater monitoring and evaluation was recommended beginning in FY 2020 (DOE/RL-2017-60).

- MNA for tritium was evaluated statistically by calculating the one-sided 95% UCL for mean plume concentration. The 95% UCL values for recent monitoring data and modeling results indicate declining trends attributed to dispersion and radiological decay. These evaluations indicate that MNA for tritium is proceeding as expected and RAOs will be achieved. In the F&T modeling results, inclusion of continuing contamination sources to the aquifer was found to not be an important factor because such tritium sources diminish over time due to radiological decay.

- MNA for nitrate was evaluated statistically by calculating the one-sided 95% UCL for mean plume concentration. From 2012 through 2017, the 95% UCL values for the monitoring data were substantially higher than the modeled values, primarily due to elevated concentrations at one well (299-W19-43) in the U Plant area. Groundwater extraction has since lowered the nitrate concentrations at this well, and the 95% UCL values for 2018 and 2019 show good agreement with the modeled values. Long-term modeling of nitrate MNA indicated that under conditions of optimized groundwater extraction and assuming no ongoing contamination sources to the aquifer, nitrate concentrations in the 200-UP-1 OU would decline to below the cleanup level by the year 2037, which is within the 35-year timeframe predicted in the 200-UP-1 OU ROD (EPA et al., 2012). When potential nitrate sources to the aquifer were included in the modeling, the results indicated that some areas of contamination would remain unless the sources are remedied or groundwater near the sources is hydraulically contained, although the resulting plumes would be smaller than the current plumes.

More recently, in September 2019, nitrate treatment was suspended at the 200 West P&T central treatment facility as a component of the 200-ZP-1 OU OSP (DOE/RL-2019-38). Updated F&T modeling performed in support of the OSP indicated that sufficient nitrate may already have been removed from the aquifer to transition to MNA. Extraction wells within the 200-UP-1 OU will continue to remove nitrate from higher concentration areas, and the 200-ZP-1 OU optimization study will evaluate transitioning to MNA for nitrate and the effects of suspending nitrate treatment for the 200 West P&T.

4 200-ZP-1 Operable Unit Remedial Actions

This chapter discusses the remedial activities performed in the 200-ZP-1 OU during 2019, including activities associated with the 200 West P&T related to achieving remedial objectives for the 200-ZP-1 OU. The 200-ZP-1 OU remedy has four components: groundwater P&T, MNA, flow-path control, and ICs. The 200-ZP-1 OU addresses groundwater contaminant plumes beneath the northern two-thirds of the 200 West Area.

This chapter also discusses the results of contaminant monitoring and hydraulic analyses; compares actual to targeted flow rates, volumes, and contaminant mass removal from the aquifer; updates the progress on implementation of the 200-ZP-1 OU optimization study; and discusses MNA progress. This information is used to assess intermediate targets and goals as an indication of progress toward attaining the RAOs so operational improvements can be made if needed. The evaluation performed in 2017 (SGW-62137, *200 West Pump-and-Treat Performance Against Remedial Action Objectives Specified in the 200-ZP-1 Operable Unit Record of Decision*) led to the development of the 200-ZP-1 OU optimization study. With approval of the 200-ZP-1 OU OSP (DOE/RL-2019-38) in September 30, 2019, implementation commenced in October 2019 with the suspension of active biological treatment.

Highlights

- Performance of 200-ZP-1 OU P&T activities through 7 years of operation has demonstrated that overall flow rates, plume containment, and mass extraction are consistent with targets established in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) for all COCs.
- The hydraulic containment assessment for 2019 showed further improvement compared to 2018, and nearly 100% of the carbon tetrachloride exhibiting concentrations above the 100 µg/L target was contained.
- The northeast region of the carbon tetrachloride plume identified as not contained in 2017 and 2018 was addressed by installing new extraction well 699-48-70, which appears to effectively contain carbon tetrachloride contamination above the 100 µg/L target. A small area of carbon tetrachloride >100 µg/L may be present to the east of the eastern line of injection wells.
- Summary statistics calculated for the performance monitoring well network continue to show steadily declining concentrations for most COCs since P&T system startup.
- As noted in the 2018 annual P&T report (DOE/RL-2018-68), current understanding suggests that carbon tetrachloride abiotic degradation rates are slower than assumed in the 200-ZP-1 OU FS (DOE/RL-2007-28) and the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE), greatly reducing the role of abiotic degradation to concentration and mass reductions (PNNL-22062). An evaluation of biotic degradation rates for carbon tetrachloride was initiated in 2018. The study concluded that biotic and abiotic mechanisms combined might result in a half-life on the order of 400 years (PNNL-28846). Degradation and other MNA processes will continue to be evaluated.
- Recognizing that the slower abiotic degradation rate for carbon tetrachloride and the larger mass of carbon tetrachloride within the Rwie and Rwia are unfavorable for attaining the carbon tetrachloride RAO in the timeframe anticipated in the 200-ZP-1 OU ROD (EPA et al., 2008), the following activities were initiated to generate information and improve knowledge to evaluate remedy reconfiguration:
  - An optimization study is expected to be completed in 6 years (FY 2020 through FY 2025), focused on Rwie remedy design and enhancement (DOE/RL-2019-38).
  - The Ringold A SAP (DOE/RL-2019-23) was issued to better characterize conditions within the Rwia concurrently with the 200-ZP-1 OU optimization study (DOE/RL-2019-38). Information from this effort will be combined with the 200-ZP-1 OU optimization study to evaluate and optimize overall remedy performance.

4.1 Remedial System Overview

This section summarizes the RAOs specified in the 200-ZP-1 OU ROD (EPA et al., 2008), the near-term goals and targets for the remedy (Section 4.1.1), and the remedial system design (Section 4.1.2) specified in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE). An overview of remedial system operations (Section 4.1.3) during 2019 is also presented. Section 4.2 summarizes several activities, analyses, and associated reports that were initiated or completed during 2019. Sections 4.3 through 4.8 discuss various

evaluations completed to assess performance of the 200-ZP-1 OU remedy. The conclusions are presented in Section 4.9.

4.1.1 Final Remedial Action Objectives and Near-Term Remedy Targets and Goals

The 200-ZP-1 OU ROD (EPA et al., 2008) provides the regulatory framework for remediating the OU, including providing the final cleanup levels to be attained by the groundwater remedy. The RAOs specified in the ROD are as follows:

- **RAO #1:** Return the 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving the cleanup levels (listed in Table 4-1). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated period to achieve cleanup levels is within 150 years.
- **RAO #2:** Apply ICs to prevent the use of groundwater until cleanup levels (listed in Table 4-1) have been achieved. Within the entire OU groundwater plumes, ICs must be maintained and enforced until the cleanup levels are achieved, which is estimated to be within 150 years.
- **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 the 200-ZP-1 OU contaminants must continue until cleanup levels are achieved, which is estimated to be within 150 years.

The 200-ZP-1 OU ROD (EPA et al., 2008) describes the operation of groundwater P&T for the first 25 years of the remedy timeframe, to be followed by a period of MNA, in order to achieve the cleanup levels for groundwater listed in Table 4-1.

The very long timeframes required for the components of the 200-ZP-1 OU groundwater remedy to make measurable progress toward attaining the groundwater cleanup levels listed in Table 4-1 make it difficult to directly measure or infer progress toward the RAOs during the early years of operation. For this reason, during the early years of operation, remedy performance is evaluated in terms of attaining nearer-term targets and goals. These targets and goals, which are either directly measurable or can be inferred or assessed in the near-term, were established through the CERCLA process (primarily during completion of DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*; and the 200-ZP-1 P&T RD/RAWP [DOE/RL-2008-78, Rev. 0 REISSUE]) using groundwater flow and contaminant transport modeling to indicate progress toward achieving RAOs. Although these near-term targets and intermediate-term goals are important to assess remedy performance in the nearer term, the success of the remedy will ultimately be measured against the RAOs as listed above.

Table 4-1. Final Cleanup Levels for the 200-ZP-1 OU

COC (Units)	90th Percentile Concentration	MCL		Model Toxics Control Act Method B Cleanup Levels		Final Cleanup Level
		Federal	State	Noncarcinogens	Carcinogens at 10^{-5} Risk Level	
Carbon tetrachloride (µg/L)	2,900	5	5	5.6	3.4[a]	3.4[b]
Chromium (total) (µg/L)	130	100	100	24,000	—	100
Hexavalent chromium (µg/L)	203	—[c]	—[c]	48	—	48
Iodine-129 (pCi/L)	1.2	1	1	—	—	1
Nitrate[d] (as NO_3) (µg/L)	359,052	45,000	45,000	113,408	—	45,000
Nitrate[d] (as N) (µg/L)	81,050	10,000	10,000	25,600	—	10,000
Technetium-99 (pCi/L)	1,442	900	900	—	—	900
Trichloroethene (µg/L)	10.9	5	5	2.4	1[a]	1[b]
Tritium (pCi/L)	36,200	20,000	20,000	—	—	20,000

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

Notes:

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

Federal drinking water standard is from 40 CFR 141, "National Primary Drinking Water Regulations." The values listed for tritium, iodine-129, and technetium-99 are the derived activity concentration values from EPA 816-F-00-002, *Implementation Guidance for Radionuclides*, Appendix I. These values are used to calculate the cumulative dose for comparison to the 4 mrem/yr MCL.

State MCL values are from WAC 246-290, "Group A Public Water Supplies." The Washington State MCL for radionuclides refers specifically to 40 CFR 141.66, "Maximum Contaminant Levels for Radionuclides."

a. WAC 173-340-705, "Model Toxics Control Act—Cleanup," "Use of Method B," cleanup levels for carbon tetrachloride and trichloroethene are from the Cleanup Levels and Risk Calculations (CLARC) database table (Ecology, 2008).

b. The U.S. Department of Energy will clean up COCs for the 200-ZP-1 Operable Unit subject to the requirements of WAC 173-340 (carbon tetrachloride and trichloroethene) so the excess lifetime cancer risk does not exceed 1×10^{-5} at the conclusion of the remedy.

c. There is no MCL specific to hexavalent chromium.

d. Nitrate may be expressed as total nitrate (NO_3) or as total nitrogen (N). The MCL for nitrate as NO_3 is 45,000 µg/L, and the same concentration expressed as N is 10,000 µg/L. (Note that U.S. Environmental Protection Agency drinking water regulations are published as 10 mg/L as nitrogen.)

— = not applicable

COC = contaminant of concern

MCL = maximum contaminant level

The near-term targets that the P&T system were designed to achieve are as follows:

- Specified total system-wide operating rates and specified rates at individual extraction and injection wells
- Specified treated water quality prior to reinjection

Targeted system-wide operating rates and the placement of individual extraction and injection wells are developed on the basis of groundwater flow modeling as being necessary to meet the first two goals described below (flow-path control and hydraulic containment [DOE/RL-2008-78, Rev. 0 REISSUE]). These goals are intended to be achieved early in the remedy lifecycle and to be maintained throughout operation of the P&T remedy, whereas the third goal (mass recovery) is intended to be achieved at the completion of the P&T component of the remedy:

- Achieve hydraulic containment of sufficient extent of the carbon tetrachloride plume in order to recover 95% of the mass. As stated in Section 4.3.1 of the 200-ZP-1 OU ROD (EPA et al., 2008):

  > *The pump-and-treat component will be designed and implemented in combination with monitored natural attenuation to achieve cleanup levels listed in Table 11 [of the ROD] for all COCs in 125 years. Carbon tetrachloride concentrations in the groundwater above 100 µg/L correspond to approximately 95% of the mass of carbon tetrachloride currently residing in the aquifer.*

  For this reason, hydraulic containment has focused on that region over which concentrations of carbon tetrachloride are >100 µg/L.

- Achieve flow-path control. As stated in Section 4.3.3 of the 200-ZP-1 OU ROD (EPA et al., 2008):

  > *Flow-path control is also required and shall be achieved by injecting the treated groundwater into the aquifer to the northeast and east of the groundwater contamination such that the treated injected 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 contaminant concentrations not captured by the extraction wells.*

- Reduce contaminant mass for all COCs (except tritium and iodine) throughout the 200-ZP-1 OU by 95%. This goal is designed to be achieved after 25 years of P&T operations.

Section 4.7 evaluates the status of the evaluation of progress toward achieving these targets and goals and describes what this evaluation indicates regarding progress toward attaining the final RAOs. In developing the foregoing targets and goals to indicate progress toward attainment of the RAOs, it was anticipated that modification may be required to reflect new information or changes in the remedy to improve the likelihood of attaining the RAOs. As detailed in the 2018 annual P&T report (DOE/RL-2018-68), improved knowledge of the increased extent of carbon tetrachloride contamination and the greatly reduced role of degradation in attenuating concentrations versus that assumed in the 200-ZP-1 OU FS (DOE/RL-2007-28) and the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) demonstrated are unfavorable for attaining the carbon tetrachloride RAO in the timeframe anticipated in the 200-ZP-1 OU ROD (EPA et al., 2008). These findings triggered the initiation of (1) a remedy optimization study; and (2) a SAP (DOE/RL-2019-23, *200-ZP-1 Operable Unit Ringold Formation Unit A Characterization Sampling and Analysis Plan* [hereinafter referred to as the Ringold A SAP]) to better characterize conditions within the Rwia, with the latter to be conducted concurrently with the optimization study. Information from these efforts will be combined to evaluate and optimize overall remedy performance. It is anticipated that these efforts will lead to revised goals and corresponding operational targets designed to achieve the RAOs within a reasonable timeframe.

4.1.2 Remedial System Design

The 200-ZP-1 OU ROD (EPA et al., 2008) presents the final groundwater remedy. However, previous remedial actions have been performed in the 200-ZP-1 OU to address groundwater contamination and contamination within the vadose zone that is a potential ongoing groundwater contamination source.

Within the vadose zone, soil vapor extraction (SVE) was used as an interim action to remove carbon tetrachloride (Smith and Stanley, 1992, "Action Memorandum: Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume"). Finalized in September 2011, the 200-PW-1 OU CERCLA ROD (EPA et al., 2011, *Record of Decision Hanford 200 Area Superfund Site 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*) selected SVE as the final remedial action for vadose zone carbon tetrachloride contamination at the 216-Z-9 Trench, 216-Z-1A Tile Field, and 216-Z-18 Crib. During SVE operations, vapor-phase carbon tetrachloride was extracted. Between 1992 and 2012 (the last year of SVE operation), 80,107 kg of carbon tetrachloride were removed from the vadose zone.

The 200-ZP-1 interim P&T system under the interim ROD (EPA/ROD/R10-95/114, *Superfund Record of Decision: Hanford 200-Area (USDOE) OU 200-ZP-1, Benton County, WA*) operated from 1996 through 2012. The 200-ZP-1 interim P&T system targeted carbon tetrachloride mass removal in the high-concentration area (> 2,000 µg/L) of the plume during its operation (DOE/RL-2012-36, *200-ZP-1 Interim Pump-and-Treat System Summary Performance Report for Calendar Year 2012*). The P&T component of the final groundwater remedy is designed to capture and treat contaminated water over a much wider area than the interim remedy. P&T is combined with MNA and flow-path control to achieve the cleanup levels for the 200-ZP-1 OU COCs in 125 years (Table 4-1). There is no cost-effective method for treating tritium; however, due to its short half-life, concentrations will be reduced to below the cleanup level by natural radioactive decay within the same 125-year period.

The P&T system extraction and injection well network is designed to hydraulically contain and recover 200-ZP-1 OU contaminants. Extracted groundwater is transferred for treatment through the 200 West P&T central treatment facility. The 200-ZP-1 OU extraction wells are 20 cm (8 in.) in diameter, with long screens that are placed to within 3 m (10 ft) of the well bottom. The extraction well screens target intervals with carbon tetrachloride concentrations >100 µg/L. The location of the extraction wells was designed to capture contaminants at elevated concentrations throughout the aquifer underlying the 200-ZP-1 OU (DOE/RL-2010-13). Some treated water from the 200 West P&T is injected to the northeast and east of the 200-ZP-1 OU extraction wells to reduce or reverse the natural eastward hydraulic gradient and to minimize the potential for groundwater to flow northward through Gable Gap and eastward toward the Columbia River (referred to in the 200-ZP-1 OU ROD [EPA et al., 2008] and 200-ZP-1 OU PMP [DOE/RL-2009-115, Rev. 2] as flow-path control). Groundwater mounding developed by this injection serves to initially help slow eastward migration, retaining the majority of the targeted COCs within the capture zone of the extraction wells and enabling natural attenuation processes to reduce concentrations beyond the capture zone. Injection wells installed to the west (upgradient of the 200-ZP-1 OU extraction wells) recharge the aquifer and steepen hydraulic gradients to the east to maintain saturation of the unconfined aquifer and accelerate flushing of the most highly contaminated portions of the aquifer toward the extraction wells. It takes an estimated 20 to 25 years to move one pore volume through the Rwie. Figure 4-1 shows the current wellfield and presents recent operating extraction and injection rates.

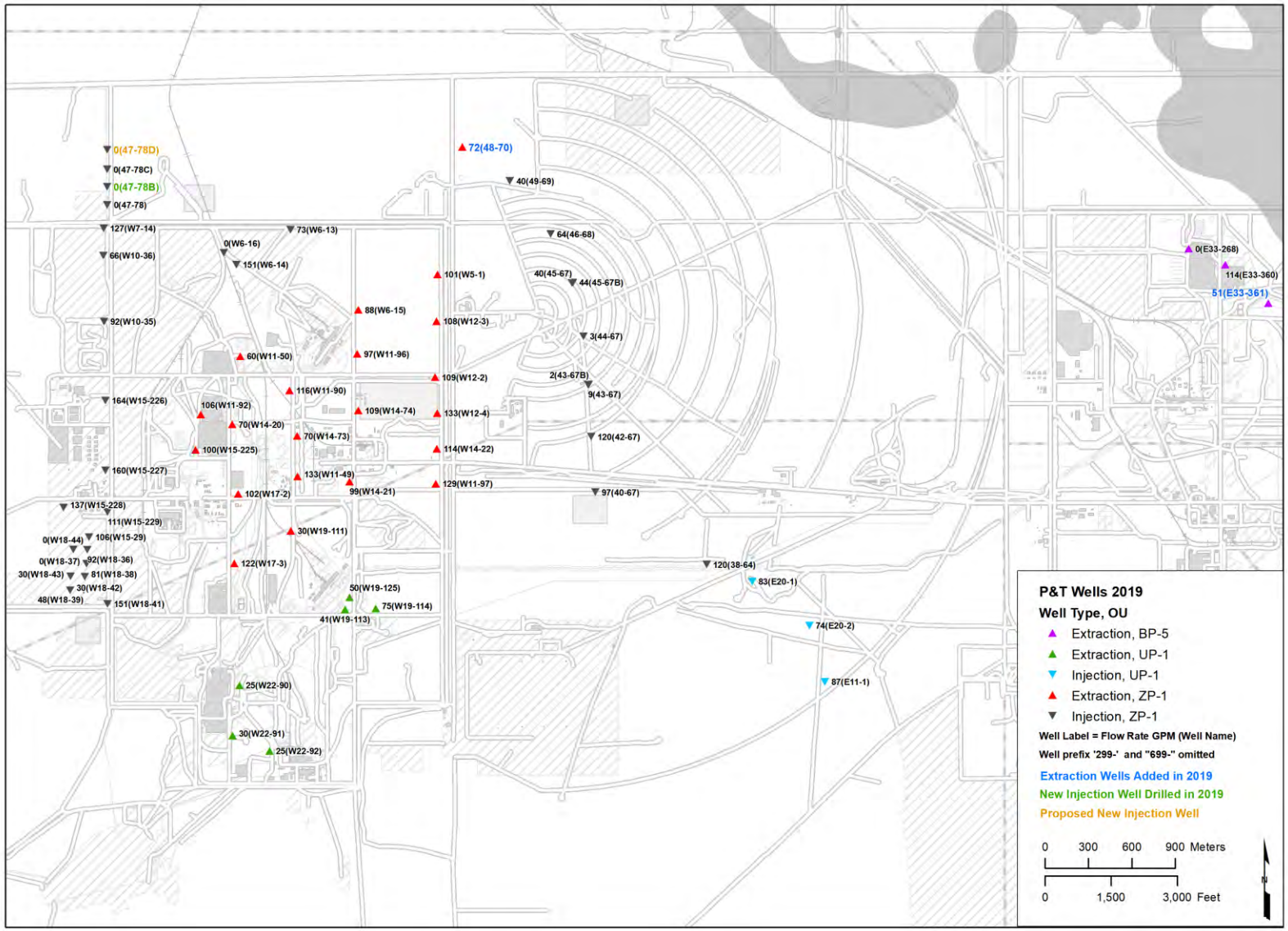

Figure 4-1. Groundwater Extraction and Injection Rates for 200 West P&T, December 2019

The scale of the 200-ZP-1 P&T remedy can be illustrated by the time required to flush the contaminated region. Given the estimated volume of groundwater that is contaminated by carbon tetrachloride at concentrations above a concentration of 100 µg/L (approximately 65 million m^3 [17 billion gal]) or above the cleanup level of 3.4 µg/L (approximately 176 million m^3 [47 billion gal]), it would be anticipated that the time required to flush the contaminated region once (i.e., one pore volume) would be on the order of about 16 to 44 years, respectively (assuming a typical operating rate of approximately 7,570 L/min [2,000 gal/min]). However, areas of greater concentration will require flushing more than once, leading to a greater operational duration than indicated by these calculations.

4.1.3 Remedial System Operations During 2019

Chapter 2 describes the operational performance of the 200 West P&T to support the 200-ZP-1 OU remedial system and 200 West P&T modifications as of implementation of the 200-ZP-1 OU optimization study (DOE/RL-2019-38) during 2019 to obtain information to improve the likelihood of achieving the carbon tetrachloride RAO in the timeframe specified in the 200-ZP-1 OU ROD (EPA et al., 2008). The evaluation performed in 2017 (SGW-62137) led to the development of the 200-ZP-1 OU optimization study. With the approval of the 200-ZP-1 OU OSP (DOE/RL-2019-38) on September 30, 2019, implementation commenced in October 2019 with the suspension of active biological treatment. During the period of the optimization study, additional operational data will be obtained to assess treatment system performance. Section 4.3.2 provides additional information on the optimization study and on the groundwater and operational data that will be collected during the study period to assess remedy performance and improvements. Chapter 2 presents data obtained during the very early period of the optimization study (in the latter months of 2019), including effluent concentrations for nitrate (and other constituents) following suspension of active biological treatment. Decisions regarding optimization and system performance in order to meet RAOs will be made based on evaluation of the data collected against the decision statements presented in the 200-ZP-1 OU PMP (Appendix A of DOE/RL-2009-115, Rev. 2) and information collected during the optimization study. Data collected from the implementation of the Ringold A SAP (DOE/RL-2019-23) will be used in conjunction with the data collected under the optimization study to assess whether additional remedy configuration improvements should be made.

4.2 Specific Remedial Activities During 2019

Several activities took place during 2019 to improve system performance or were implemented as components of the 200-ZP-1 OU optimization study. These activities included installing new wells, transitioning between groundwater flow and contaminant transport models, initiating focused optimization activities for the Rwie, evaluating the disposition and behavior of certain contaminants, and suspending active treatment of nitrate at the 200 West P&T. Each of these activities are discussed below. The Ringold A SAP (DOE/RL-2019-23) was developed in 2019 and was issued in February 2020.

4.2.1 Installation of New Wells

Injection well 699-47-78B (C9879/YJ-35) was drilled, installed, and developed from March 26 through November 25, 2019 (Figure 4-1). The well was drilled to a depth of 146.5 m (480.7 ft) below ground surface (bgs). Water was encountered at 74 m (241.7 ft) bgs. The screen length is 47 m (155 ft). During drilling, carbon tetrachloride concentrations ranged from nondetect to a maximum of 44.7 µg/L at 103 m (337.5 ft) bgs. Nitrate concentrations ranged from 32.9 mg/L to a maximum of 36.1 mg/L at 78 m (257 ft) bgs within the unconfined aquifer above the Rlm. Drilling was completed through the Rlm, with one sample collected in the underlying and confined Rwia. Carbon tetrachloride was not present (<0.3 µg/L) at 139 m (457 ft) bgs. The borehole was backfilled to the top of the Rlm prior to construction. This injection well was installed in the northwest region of the injection/extraction network and is designed

to recharge the aquifer and steepen hydraulic gradients to the east to accelerate flushing of the most highly contaminated portions of the aquifer.

Extraction well 699-48-70 (C9988/YE-33) was drilled, installed, and developed from April 2 through October 2, 2019 (Figure 4-1). The well was drilled to a depth of 122.5 m (401.8 ft) bgs. Water was encountered at 79 m (259.6 ft) bgs. The screen length is 39.6 m (130 ft). During drilling, carbon tetrachloride concentrations ranged from 2.4 µg/L to a maximum of 149 µg/L at 114 and 90 m (375 and 295 ft) bgs, respectively. Nitrate concentrations ranged from 49.1 mg/L to a maximum of 443 mg/L at 84 m (275 ft) bgs. The Rlm was not present at this location. This extraction well was installed to address the northeast region of the carbon tetrachloride plume that is not hydraulically contained, which was determined in 2018.

Appendix A of SGW-63812, *Borehole Summary Report for the Installation of Wells 699-47-78B (C9879) and 699-48-70 (C9988) in the 200-ZP-1 OU, FY2019*, provides additional information, including well summary sheets, borehole logs, geophysical log data reports, and final civil survey reports for each injection and extraction well.

4.2.2 Transition of Groundwater Flow and Contaminant Transport Models

Use of consistent modeling methods and tools is critical for supporting 200-ZP-1 OU decision making throughout the remedy lifecycle. F&T modeling conducted during the development and implementation of the remedy through 2019 used the Central Plateau Groundwater Model (CPGWM) (CP-47631, *Model Package Report: Central Plateau Groundwater Model, Version 8.4.5*), which was originally developed to support the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE). The development and application of the CPGWM typically focused on near-term plume behavior to determine optimal extraction and injection well locations and rates. Toward the end of 2019, a process began to retire the CPGWM and transition to the Plateau to River Model (P2R Model) to provide both near-field and far-field simulation capability integrated between the 200 West and 200 East Areas (CP-57037, *Model Package Report: Plateau to River Groundwater Model Version 8.3*). The model transition commenced in late 2019 and was completed in March 2020, which was in sufficient time for the modeling-based analyses presented in this P&T report to be completed using the P2R Model. In doing so, the P2R Model has been updated with inputs through the end of 2019, providing a basis for the use of the P2R Model to support future P&T reports, the activities of the optimization study (described below), and other remedy evaluation and performance activities for the foreseeable future. The P2R Model and CPGWM were developed using the same versions of the groundwater flow simulation code MODFLOW and contaminant transport simulation code MT3D, so both of the model core simulation capabilities are comparable.

4.2.3 Evaluation of Groundwater Contaminants

The occurrence and behavior of certain groundwater contaminants in the 200-ZP-1 OU were evaluated during 2019. Activities completed during 2019 included further progress on evaluating degradation rates for carbon tetrachloride and further assessing the presence and behavior of cyanide in groundwater.

4.2.3.1 Carbon Tetrachloride Degradation

The design of the final 200-ZP-1 OU groundwater remedy presented in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) was based, in large part, on calculations made to support the 200-ZP-1 OU FS (DOE/RL-2007-28), which was completed in 2007. The values used to represent the (primarily abiotic) degradation rate for carbon tetrachloride at that time were derived from limited published literature, including the findings of an initial study being conducted at that time by

Pacific Northwest National Laboratory (PNNL). Two rates for the (abiotic) degradation of carbon tetrachloride derived from the various documents and studies (representing half-lives of 41.3 and 100 years, respectively) were used in contaminant F&T modeling calculations conducted in the 200-ZP-1 OU FS and subsequent reports.

The final report on the study of abiotic carbon tetrachloride degradation (PNNL-22062, *Abiotic Degradation Rates for Carbon Tetrachloride and Chloroform: Final Report*), issued 3 years following issuance of the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE), concluded that rates of hydrolysis at groundwater temperatures are significantly slower than previously estimated, leading to a best estimate for the half-life of carbon tetrachloride via abiotic degradation processes alone of about 630 years. The much longer abiotic degradation rate greatly reduces the contribution of abiotic degradation to concentration and mass reductions, which has important implications for the 200-ZP-1 OU groundwater remedy, most critically for the anticipated duration of the natural attenuation period following termination of the P&T remedy component.

Biological degradation byproducts of carbon tetrachloride (chloroform and methylene chloride) are present in 200-ZP-1 OU groundwater, suggesting that biotic processes do occur in addition to abiotic hydrolysis, under conditions prevalent within 200-ZP-1 OU groundwater. During 2018, an evaluation of biotic degradation rates for carbon tetrachloride was initiated. This important study was completed in June 2019 (PNNL-28846, *Carbon Tetrachloride: Evaluation of Biotic Degradation Mechanism and Rates*). The study evaluated multiple lines of evidence for continuing in situ biotic degradation of carbon tetrachloride and suggested that there is an abundance of site-specific data (experimental, field, and monitoring) that supports conditions suitable for both biotic degradation and for abiotic-biotic reductive degradation in the 200 West Area aquifer. However, the study found that the additional biotic pathways evaluated would likely result in an overall (i.e., net sum of abiotic and biotic) degradation half-life that is or <400 years but not likely <100 years (PNNL-28846). Degradation and other MNA processes will continue to be evaluated to better understand the role that these processes may play in achieving 200-ZP-1 OU RAOs.

4.2.3.2 Cyanide Contaminant Monitoring

Cyanide in groundwater is regulated as free cyanide. Free cyanide refers to hydrogen cyanide and cyanide ion. Total cyanide includes free cyanide, dissociable (weak and moderately strong) metal cyanide complexes, and strong metal cyanide complexes such as ferrocyanide. The EPA established the MCL as 200 µg/L for free cyanide. The Washington State groundwater cleanup level is 4.8 µg/L for free cyanide analyzed as free cyanide. A total cyanide concentration <200 µg/L can be reported as free cyanide <200 µg/L. Free cyanide analytical methods are used if the total cyanide concentration is >200 µg/L.

Cyanide is not a COC for the 200-ZP-1 OU. Beginning in 2017, six monitoring wells in the T and TX-TY Tank Farms were sampled for cyanide when total cyanide was detected at levels exceeding the Model Toxics Control Act (MTCA) Method B (WAC 173-340, “Model Toxics Control Act—Cleanup”) cleanup standard of 4.8 µg/L for free cyanide in the 200 West P&T (SGW-62894, *Cyanide Sampling at the 200 West Pump and Treat, FY 2016 Through FY 2018*). Nickel ferrocyanide precipitation (scavenging) was used to remove cesium-137 and strontium-90 from waste solutions and settle out scavenged solids in underground storage tanks. After the chemicals were added to the tanks, settling was allowed to occur over 7 to 10 days, and then the supernatant was decanted and discharged to the ground via cribs and trenches. Tanks used for the scavenging process in WMAs T and TX-TY included tanks T-107, TX-118, TY-101, TY-103, and TY-104. Cyanide contamination had been observed downgradient of WMAs T and TX-TY during previous sampling in 2003 to 2012 at concentrations <200 µg/L. The DWS for cyanide is 200 µg/L based on free cyanide, defined by EPA as a cyanide amenable to chlorination. The regulations allow the use of total cyanide measurement for screening

purposes. Cyanide complexes such as ferrocyanide are generally measured in total cyanide analysis but are not typically detected in free and amenable cyanide measurements. The measurement of total cyanide (when ferrocyanide may account for much of the cyanide present) may result in overestimating the cyanide concentration relative to the DWS. In 2019, sample data showed that two monitoring wells (299-W10-26 and 299-W14-18) downgradient of WMA TX-TY exceeded the MTCA Method B limit of 4.8 µg/L for free cyanide (Figure 4-2). The sample results also indicated that cyanide concentrations were trending upward in monitoring wells 299-W10-26 and 299-W14-18 (above the 200 µg/L DWS) when screened by total cyanide analysis (although concentration decreased considerably at well 299-W10-26 the last quarter of 2019). Monthly cyanide monitoring (in filtered and unfiltered aliquots) began to monitor the trend (Figure 4-3). Total cyanide screening concentrations exceeding the 200 µg/L DWS were observed in wells 299-W10-26 and 299-W14-18.

Cyanide is also included as a constituent for process monitoring at various points throughout the 200 West P&T because of the addition of extracted groundwater from the 200-BP-5 OU containing cyanide and cyanide detected in monitoring wells downgradient of WMA TX-TY. Beginning in 2016 and continuing through 2019, total and free cyanide have been monitored to evaluate if the treated water injected into the aquifer meets the criteria specified in supporting regulatory documents.

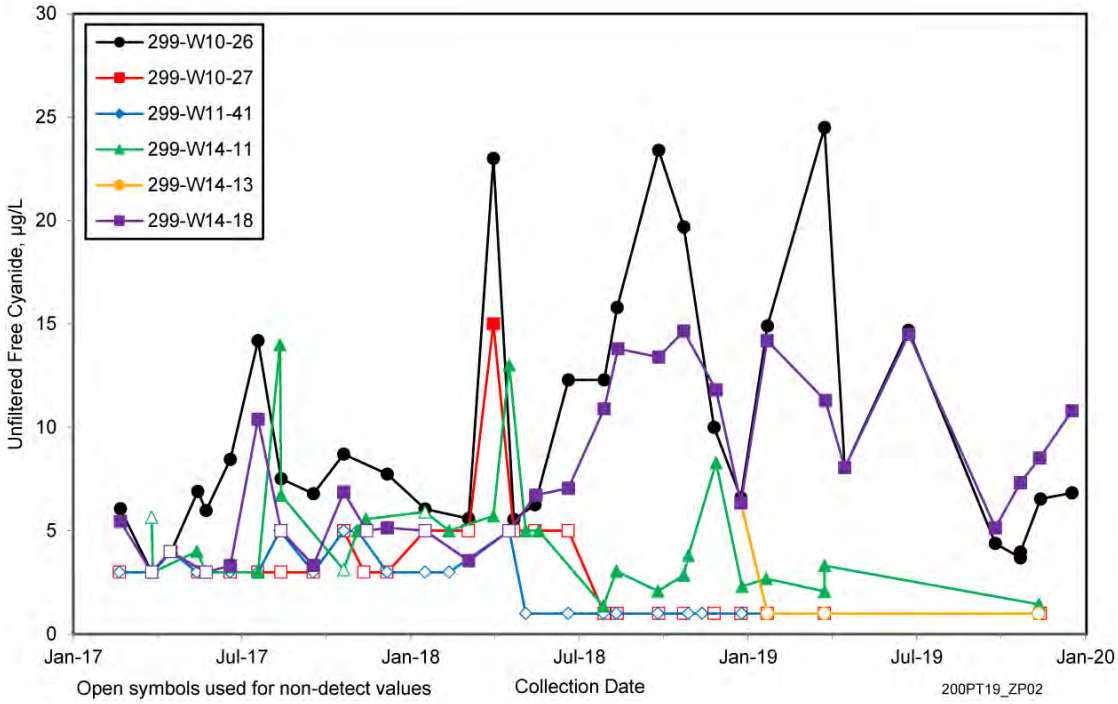

Figure 4-2. Free Cyanide Trends at Monitoring Wells Downgradient of WMAs T and TX-TY, 2019

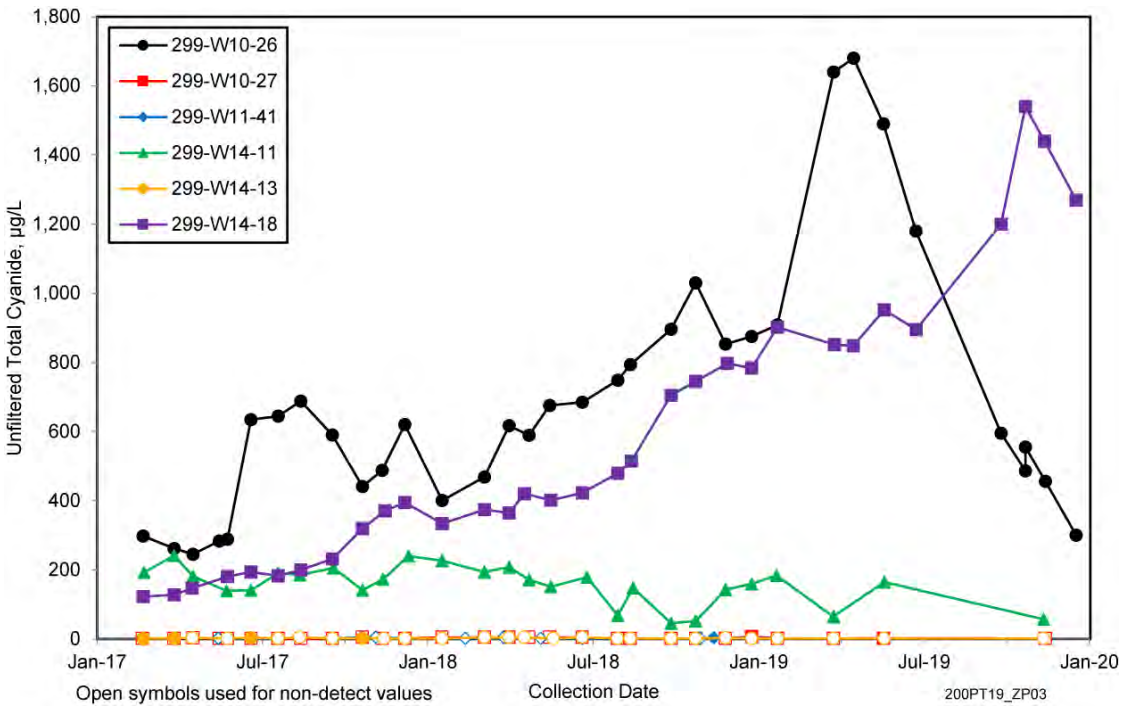

Figure 4-3. Total Cyanide Trends at Monitoring Wells Downgradient of WMAs T and TX-TY, 2019

4.3 Remedy Optimization Activities

This section discusses remedy optimization activities to evaluate potential remedy configuration modifications for the 200-ZP-1 OU and the 200 West P&T.

4.3.1 Background

In the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE), groundwater modeling was used to define the total extraction rate and locations and rates of extraction and injection wells to hydraulically contain the 100 µg/L carbon tetrachloride extent. The modeling relied upon plume extents and flow and transport parameters obtained following completion of the 200-ZP-1 OU FS (DOE/RL-2007-28). The RD/RAWP stated that conditions encountered in the field may impact mass recovery and that "…the estimated amount of the initial dissolved mass of carbon tetrachloride that may be recovered in 25 years (i.e., extracted and treated) ranges from 57 percent to 100 percent, depending on the actual site conditions…". In 2011, modeling demonstrated that dynamic wellfield operation could increase mass recovery despite the larger plume extents encountered following issuance of the 200-ZP-1 OU FS if the system capacity increased to 9,500 L/min (2,500 gal/min) (SGW-50390, *FY 2011 Simulation-Optimization of the 200-ZP-1 Remedy Using the Central Plateau Model*).

As detailed in the 2018 annual P&T report (DOE/RL-2018-68), improved knowledge of the increased extent of carbon tetrachloride contamination and the greatly reduced role of degradation in attenuating concentrations versus that assumed in the 200-ZP-1 OU FS (DOE/RL-2007-28) and the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) demonstrated that conditions are unfavorable for attaining the carbon tetrachloride RAO in the timeframe anticipated in the 200-ZP-1 OU ROD (EPA et al., 2008). During 2017 and 2018, expansion options for the 200 West P&T were modeled using the optimization code detailed in SGW-50390 as one basis for the calculations. These analyses, combining the updated estimates of the three-dimensional carbon tetrachloride extent in groundwater with contemporary estimates of the carbon tetrachloride abiotic degradation rate (as described above), were

used to support remedy improvements to achieve the carbon tetrachloride groundwater cleanup level. In particular, the greatly reduced contribution of carbon tetrachloride degradation to the overall remedy suggested that the groundwater P&T component of the remedy would need to operate longer, and to hydraulically contain and flush a larger volume of the aquifer (i.e., at lower concentrations), than anticipated in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE).

Evaluations conducted in 2019 suggested that several remedy implementation challenges must be addressed, including the ability of the current remedy configuration to meet the RAO for carbon tetrachloride, the complexity and operational issues associated with active biological nitrate treatment, and limitations of the 200 West P&T treatment capacity. With the most current information incorporated into modeling calculations to predict likely remedy performance under a range of alternate system configurations, the following significant conclusions were reached:

- Remedy reconfiguration is required if remediation of the most significant risk driver (carbon tetrachloride) is to meet final RAOs. Specifically, increased system-wide capacity accompanied by a larger number of extraction and injection wells would facilitate more rapid flushing of contaminated groundwater, which is necessary to accelerate carbon tetrachloride removal.

- Most nitrate in groundwater is present at concentrations well within an order of magnitude of the cleanup level. Considering current nitrate concentration trends (which are mostly downward or stable) and assuming there is no continuing source of nitrate, sufficient nitrate may have already been removed from the aquifer (resulting in substantial concentration reductions) to enable a transition to the MNA phase of the remedy that will still allow the nitrate cleanup level to be reached within the timeframe specified in the 200-ZP-1 OU ROD (EPA et al., 2008). In addition, difficulty was encountered maintaining injection well capacity due to organic and inorganic materials from the biological treatment process fouling the wells, which necessitated 35 injection well cleanings in 2019 and numerous treatment facility infrastructure and operational changes.

Based upon the foregoing work, the decision to suspend active biological treatment was made. This decision was supported by groundwater modeling conducted during 2018 and 2019. Suspending biological treatment allows for evaluating nitrate concentration trends in groundwater and determining (primarily through groundwater modeling) the projected benefit of the increased capacity of the reconfigured treatment system to accelerate carbon tetrachloride mass removal, thereby improving the likelihood of achieving the RAO in the timeframe stated in the 200-ZP-1 OU ROD (EPA et al., 2008). In addition, two major activities were initiated in collaboration among DOE, its contractors, and EPA:

- Initiation of the 200-ZP-1 OU optimization study (DOE/RL-2019-35) focused on the Rwie to generate information to evaluate potential remedy configuration modifications for the 200-ZP-1 OU and the 200 West P&T, given the increased operating capacity facilitated, in part, through the cessation of active biological treatment.

- The Ringold A SAP (DOE/RL-2019-23) was developed to address a data gap that identified the need to better understand the conceptual site model below the Rlm by further characterizing conditions within the Rwia.

Information obtained from these two activities will be combined to evaluate and optimize overall remedy performance. The following sections provide further information on the implementation, progress, and reporting associated with these activities.

4.3.2 200-ZP-1 Operable Unit Optimization Study

The 200-ZP-1 OU optimization study, which is focused on evaluating and enhancing the groundwater P&T remedy within the Rwie, is expected to be completed in 6 years (through FY 2025), as detailed in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 1). However, as discussed in Section 4.1.3 of the 200-ZP-1 OU OSP (DOE/RL-2019-38), additional time may be needed to collect sufficient data to meet study objectives, which could result in the optimization study continuing for an additional 2 years (through FY 2027). Full details of the activities that will be conducted during the optimization study, including how these will be combined to provide the basis for reconfiguring the remedy in order to achieve the RAOs within a reasonable timeframe, are provided in the 200-ZP-1 OU OSP. As described therein, the 200-ZP-1 OU optimization study will consist of the following four primary tasks:

1. Suspension of active biological treatment.
2. Facility and well network modifications to increase carbon tetrachloride treatment capacity.
3. Data collection and monitoring.
4. Data evaluation and reporting.

Annual groundwater P&T reports will be used to provide interim updates on the implementation and progress of the 200-ZP-1 OU optimization study and certain details of the interpretation of collected data. Detailed reporting, including presentation of groundwater flow and contaminant F&T modeling, will be provided through separated optimization study presentations, reports, and supporting environmental calculation files. Because the 200-ZP-1 OU optimization study is scheduled to commence during FY 2020, limited data are available at this time. However, future P&T reports will provide interim status reporting on each of these four major elements of the 200-ZP-1 OU optimization study, which are discussed in the following sections. Related presentations, reports, and supporting environmental calculation files that were prepared during 2019 associated with the optimization study include the following:

- 200-ZP-1 OU OSP (DOE/RL-2019-38)
- SGW-63161-VA, *Path Forward – 200-ZP-1 Remedy Implementation*
- SGW-63640-VA, *200-ZP-1 Remedy Update and Optimization*

4.3.2.1 Suspension of Active Biological Treatment Processes

Suspension of active biological treatment at the 200 West P&T is identified as Task 1 of the 200-ZP-1 OU optimization study and was initiated in late 2019. Biological treatment, which primarily addressed the reduction of nitrate recovered by the 200-ZP-1 OU extraction wells, was suspended to focus resources on carbon tetrachloride treatment capacity and to facilitate more efficient additional modifications of the 200 West P&T. Biological treatment processes were suspended on October 7, 2019; as anticipated, shortly thereafter an increase was noted in the concentration of nitrate in the treatment plant effluent. As detailed in the 200-ZP-1 OU OSP (DOE/RL-2019-38), monitoring will assess the effect of the active biological treatment suspension on groundwater conditions throughout 200 West Area, focusing initially on areas near injection wells where some increased nitrate concentrations are anticipated to occur. Sections 4.3.2.3 and 4.3.2.4 discuss aspects of the data collection and monitoring. Chapter 2 provides a more detailed description of the facility modifications needed to enable suspension of active biological treatment.

4.3.2.2 Facility and Well Network Modifications to Increase Carbon Tetrachloride Treatment Capacity

In the fourth quarter of 2019, throughput at the 200 West P&T averaged 8,598 L/min (2,271 gal/min), processing groundwater recovered from 32 extraction wells (out of 33 extraction wells in the P&T system) across five groundwater OUs and injecting treated water at 30 injection wells. During the 200-ZP-1 OU optimization study period, the facility treatment capacity will be increased to a peak capacity of about 14,200 L/min (3,750 gal/min), of which it is estimated that about 11,600 L/min (3,070 gal/min) will be available for the 200-ZP-1 OU. Implementation of the optimization study will result in progressive increases in the operating capacity available for the 200-ZP-1 OU remedy. Facility modifications are primarily associated with installing a third air stripper tower, GAC, and associated facility and well network plumbing, as well as installing additional extraction wells required to enhance capacity. Well locations and screen intervals will be guided by groundwater modeling analyses as described in 200-ZP-1 OU OSP (DOE/RL-2019-38), and wells will be installed in accordance with the 200-ZP-1 OU remediation well installation SAP (Appendix G of the 200-ZP-1 OU PMP [DOE/RL-2009-115, Rev. 3]).

New extraction wells are planned for installation in 2020 and 2021 to support increasing capacity flow for the 200-ZP-1 OU to 11,621 L/min (3,070 gal/min) by the start of FY 2022, Five new extractions wells are planned for 2020. Drilling and construction of the first two extraction wells (299-W11-103 and 299-W11-104) begin in early calendar year 2020 and the other three extraction wells (299-W12-5, 299-W14-27, and 299-W14-33) will be drilled later in 2020. Five additional wells (299-W14-31, 299-W14-32, 299-W14-30, 299-W14-28, and 699-40-70A) are planned to be drilled in 2021.

4.3.2.3 Data Collection and Monitoring

Planned data collection and monitoring include assessing the effects of biological treatment suspension and increased carbon tetrachloride treatment capacity. The period of data collection and monitoring begins with the suspension of biological treatment (early FY 2020). Primary data collection elements include information from the 200 West P&T (influent and effluent COC concentrations, as well as additional process operational monitoring data), mass recovery data, aquifer hydraulic head data, and COC concentrations at monitoring wells. Groundwater modeling was used to estimate the timeframe needed to demonstrate how remedy performance is affected by the revised operational configuration. Simulated trends in mass removal rate, concentrations of nitrate in facility effluent, and monitoring well concentrations suggest that operational changes will result in measurable differences within about 3 years after the facility flow rates are increased to targeted values. To allow sufficient time to interpret data obtained following facility modification (a 2-year duration), the period for data collection and monitoring associated with the 200-ZP-1 OU optimization study is expected to be completed in 6 years (through FY 2025), as detailed in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 1). However, as discussed in Section 4.1.3 of the 200-ZP-1 OU OSP (DOE/RL-2019-38), additional time may be needed to collect sufficient data to meet study objectives, which could result in the optimization study continuing for an additional 2 years (through FY 2027).

Data and information acquired following issuance of the 200-ZP-1 OU ROD (EPA et al., 2008) suggest that conditions are highly unlikely to allow carbon tetrachloride to reach the cleanup level under the current remedy configuration in the timeframe specified in the ROD. Accordingly, the optimization study is being performed to generate information to gain knowledge to address meeting the RAOs within a reasonable timeframe by evaluating potential configuration modifications for the 200-ZP-1 OU remedy and for the 200 West P&T and obtaining data from the 10 new extraction wells being drilled to support increased flow through capacity (11,621 L/min [3,070 gal/min]). These actions will be based upon analyses of data collected during the optimization study. Specific details for planned data collection and

monitoring are provided in SGW-64218-VA, which includes identifying the monitoring initiated in FY 2020, which is focused on locations near the injection wells where anticipated changes may be quickly evident. TPA-CN-0875, *Tri-Party Agreement Change Notice Form: DOE/RL-2009-115, Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action, Revision 2*, issued in November 2019, specifies near-term sampling and analysis to be completed soon after suspension of active biological treatment for nitrate. As detailed therein, near-term monitoring focuses on carbon tetrachloride, sulfate, and most importantly nitrate for which concentration increases are anticipated to occur within some monitoring wells close to injection wells late in 2020 or early in 2021.

The Ringold A SAP (DOE/RL-2019-23), which will be implemented in FY 2020, will assist in guiding sampling during the optimization study period. Further details are provided in Section 4.3.3 of this report.

4.3.2.4 Data Evaluation and Reporting

Data generated during the Rwie optimization study will be interpreted empirically and also compared to outputs of groundwater modeling analyses. Many of the data analysis methods will be based on those currently used within the annual groundwater P&T reports (e.g., evaluating hydraulic heads, drawdowns, and hydraulic containment; evaluating temporal and spatial patterns and trends in COCs concentrations; and evaluating mass recovery). This will be accompanied by evaluating and reporting operational data, primarily in the early period regarding changes in nitrate effluent concentrations. To this extent, the 200-ZP-1 OU optimization study monitoring data will be evaluated with the overall 200-ZP-1 OU remedy performance analysis and in future annual P&T reports. More detailed analyses (completed in terms of the specific Rwie optimization study objectives) will be provided via separate optimization study presentations, memoranda, and reports. Analyses of near-term monitoring data are anticipated to focus on the following:

- **Groundwater data:** Evaluation of concentration breakthroughs at proximal monitoring wells using F&T modeling and empirical analysis to refine estimates of effective (mobile) porosity, dilution, and other transport parameters in groundwater.
  - Monitoring and analysis will focus on nitrate concentrations, which is a conservative (i.e., nonreactive) solute, to support the estimation of effective (mobile) porosity and dilution in the subsurface.
  - Monitoring and analysis will also evaluate changes in carbon tetrachloride concentrations for use in estimating elution rates from sediments.
  - Monitoring and analysis will also evaluate changes in the biofouling concentrations to determine improvement for biofouling issues/injection capacity. Wells include 299-W15-152, 299-W15-83, 299-W17-3, 299-W19-21, and 299-W18-22.
- **Operational data:** Evaluation of nitrate concentrations, the presence and concentration of biofouling constituents, and the time-varying capacity of the receiving injection wells to determine if suspension of active biological treatment has led to improvements in injectivity at the P&T injection wells. This will provide information to support the determination of the necessity and corresponding frequency of further chlorination treatments to maintain or enhance injectivity.

  - Samples of 200 West P&T system effluent obtained in the fourth quarter of 2019 (Table 2-7) identified increases in nitrate concentration to near 200 West P&T influent concentrations as anticipated from suspension of the active biological treatment. Early analyses of groundwater data suggest that changes in groundwater concentrations are generally in alignment with expectations.

- It is anticipated that analyses of data obtained over the longer term will include interpreting anticipated time-varying groundwater system responses in response to periods of system shutdown and startup; assessing longer-term (potentially asymptotic) concentration trends within monitoring wells resulting from the changes to the remedy configuration, capacity, and operations; and determining how these changes in trends may accelerate progress to the well-by-well transition from performance monitoring to attainment monitoring throughout the 200-ZP-1 OU.

4.3.3 Rwia Characterization

To address conditions in the Rwia, the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 3) and the Ringold A SAP (DOE/RL-2019-23) were issued in early 2020. Section 4.3 in the PMP summarizes the DQOs and describes the multistage decision-making process to resolve the decision statements and address the decision rules. The Ringold A SAP addresses the phased installation of monitoring wells in and around the 200-ZP-1 OU to support characterization of the Rwia. Under the SAP, 12 monitoring wells are proposed for installation from FY 2020 through FY 2022 to obtain data to further characterize the nature and extent of contaminants, to refine the geologic framework for the Rwia, and to provide hydraulic properties for contaminant F&T modeling. The data collected will assist in guiding sampling over the duration of the optimization study. The data will also support the well design process, facilitate performance evaluation of the 200-ZP-1 OU remedy, and assist in making recommendations for optimizing or modifying the remedy. Data collection and analyses outlined in the SAP and revised PMP will be completed concurrently with the 200-ZP-1 OU optimization study. Future annual groundwater P&T reports will provide interim updates on the implementation and progress of the Rwia characterization activities and will present modeling results from the characterization activities and details regarding the interpretation of collected data.

4.4 Performance Monitoring Data and Methods of Evaluation

Data described in this section provide the primary technical basis for addressing three of the four components of the selected final remedy for groundwater in the 200-ZP-1 OU (groundwater P&T, flow-path control, and MNA) in order to assess remedy progress toward meeting the RAOs. The fourth remedy component, ICs, is addressed separately in DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions*.

4.4.1 Contaminant Monitoring

As described in the 200-ZP-1 OU ROD (EPA et al., 2008), the presence and distribution of groundwater contaminants in the OU generally fall into three categories:

- High-concentration zones close to ponds, cribs, and trenches that were used to dispose liquid waste. Existing data and previous studies do not (at this time) indicate the presence of significant, dense nonaqueous-phase liquid in groundwater acting as a continuing source.

- A larger, dispersed, lower concentration plume that has migrated from the discharge locations or overlies or surrounds high-concentration zones. This less-contaminated groundwater can occur above high-concentration zones where large quantities of lower concentration effluent were discharged during or following high-concentration waste discharges.

- An area of technetium-99 contamination near WMA T and WMA TX-TY. The results of depth-discrete groundwater sampling at wells installed in these areas show that the peak technetium-99 concentrations are typically found within the upper 15 m (50 ft) of the aquifer.

In addition to the foregoing, which described the state-of-knowledge during preparation of the 200-ZP-1 OU ROD (EPA et al., 2008), knowledge of the three-dimensional extent of contamination by carbon tetrachloride and the other COCs has increased as the number and locations of monitoring wells and other characterization sampling locations have increased. Evidence has grown suggesting that there may be ongoing sources of contamination to groundwater in some areas (e.g., for technetium-99 in the T Tank Farm area). The use of groundwater monitoring data to help assess for the likelihood and location of continuing sources is the subject of current work and planned for further study during 2020 and 2021.

Groundwater contaminants will continue to be monitored over the lifetime of the remedy to evaluate performance and optimize remedy effectiveness (DOE/RL-2009-115, Rev. 2).

4.4.1.1 Contaminant Monitoring Network

The 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) describes the monitoring well selection process and the well network to monitor and assess the progress toward remedy success. The PMP also describes the key decision statements from the 200 West P&T DQO process. Data are collected for the 200-ZP-1 OU COCs and for uranium (a 200-UP-1 OU source, which is present in some wells in the monitoring network). The PMP has undergone a number of revisions as the monitoring network has evolved. Most recently, the PMP was modified to meet the objectives for the 200-ZP-1 OU optimization study. Focused near-term sampling and analysis in accordance with the most recent revision of the PMP began in December 2019 as part of the 200-ZP-1 OU optimization study following suspension of active biological treatment for nitrate (as documented in TPA-CN-0875 for the PMP). As previously discussed, near-term data analyses will provide information on the anticipated changes in effluent concentrations stemming from suspension of biological treatment. It is anticipated the monitoring network, constituents, and associated evaluation activities may continue to be modified as new information is obtained and data and modeling analyses are completed during the optimization study period.

The 200 West P&T baseline data were collected between October 1, 2011, and December 31, 2012, from an extensive network of extraction, injection, and monitoring wells. The current monitoring program obtains data from a monitoring well network that was evaluated to develop a constituent-specific set of analyses for each well. The well network includes monitoring wells that are dedicated in accordance with the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) and wells that are sampled for other monitoring programs (i.e., the *Resource Conservation and Recovery Act of 1976* and the AEA) but provide data suitable for this purpose. Figures 4-4 and 4-5 show the locations of the 200-ZP-1 OU well network sampled in 2019 (extraction and monitoring wells) and the locations of wells sampled for groundwater quality distinguishing wells (sampled per the 200-ZP-1 OU PMP), respectively.

Wells 299-W6-17, 699-44-70B, and 699-46-61 were installed in 2019 for contaminant monitoring (Figure 4-4). Wells 299-W6-17 and 699-44-70B are located in the P&T hydraulic containment region, and well 699-46-61 is located downgradient of the P&T hydraulic containment region. Appendix A of SGW-63811, *Borehole Summary Report for the Installation of Wells 299-W6-17 (C9738), 699-44-70B (C9740), and 699-46-61 (C9936) in the 200-ZP-1 OU, FY2019*, provides additional information, including well summary sheets, borehole logs, geophysical log data reports, and final civil survey reports for each monitoring well.

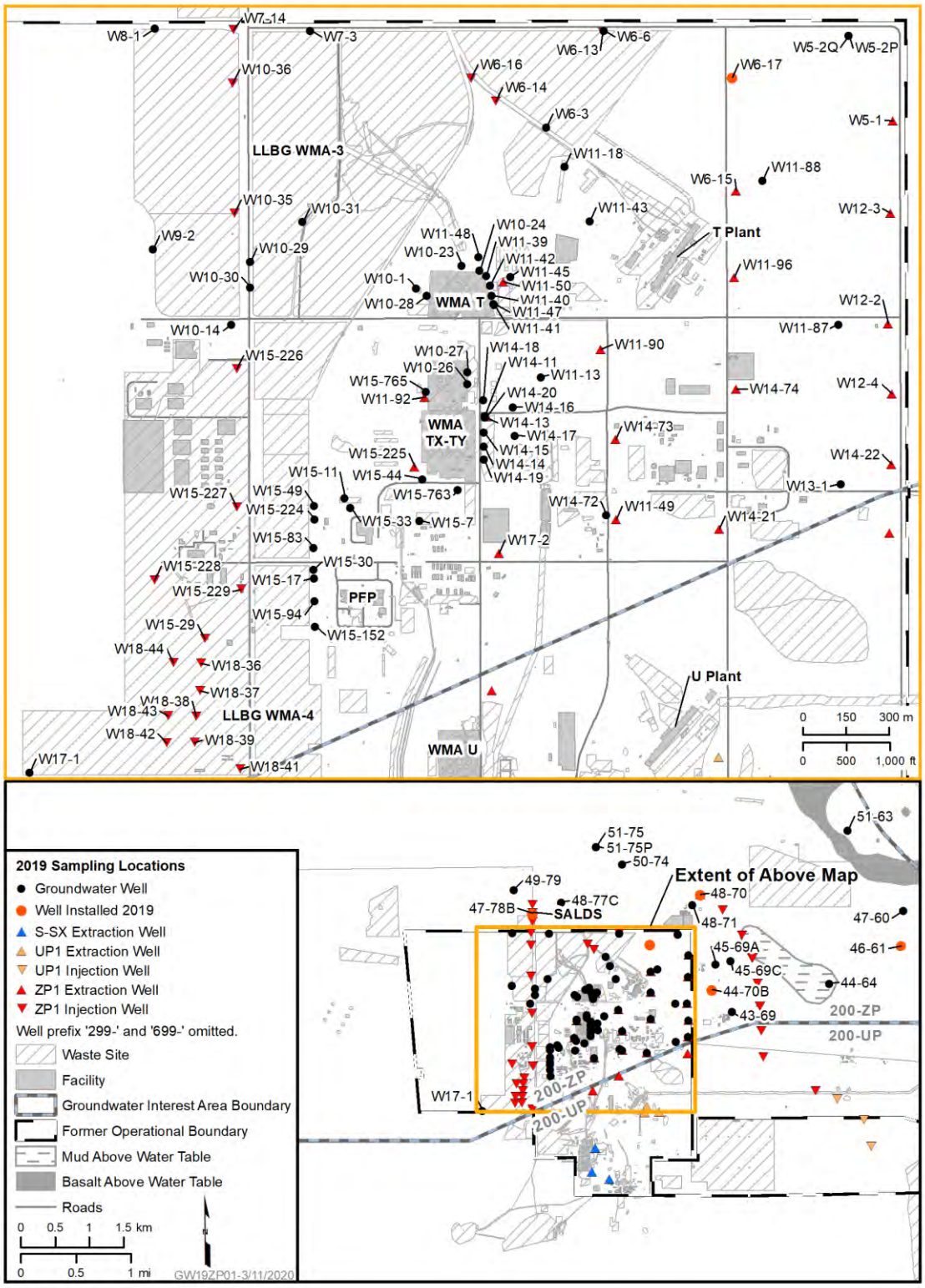

Figure 4-4. 200-ZP-1 OU Groundwater Well Network, 2019

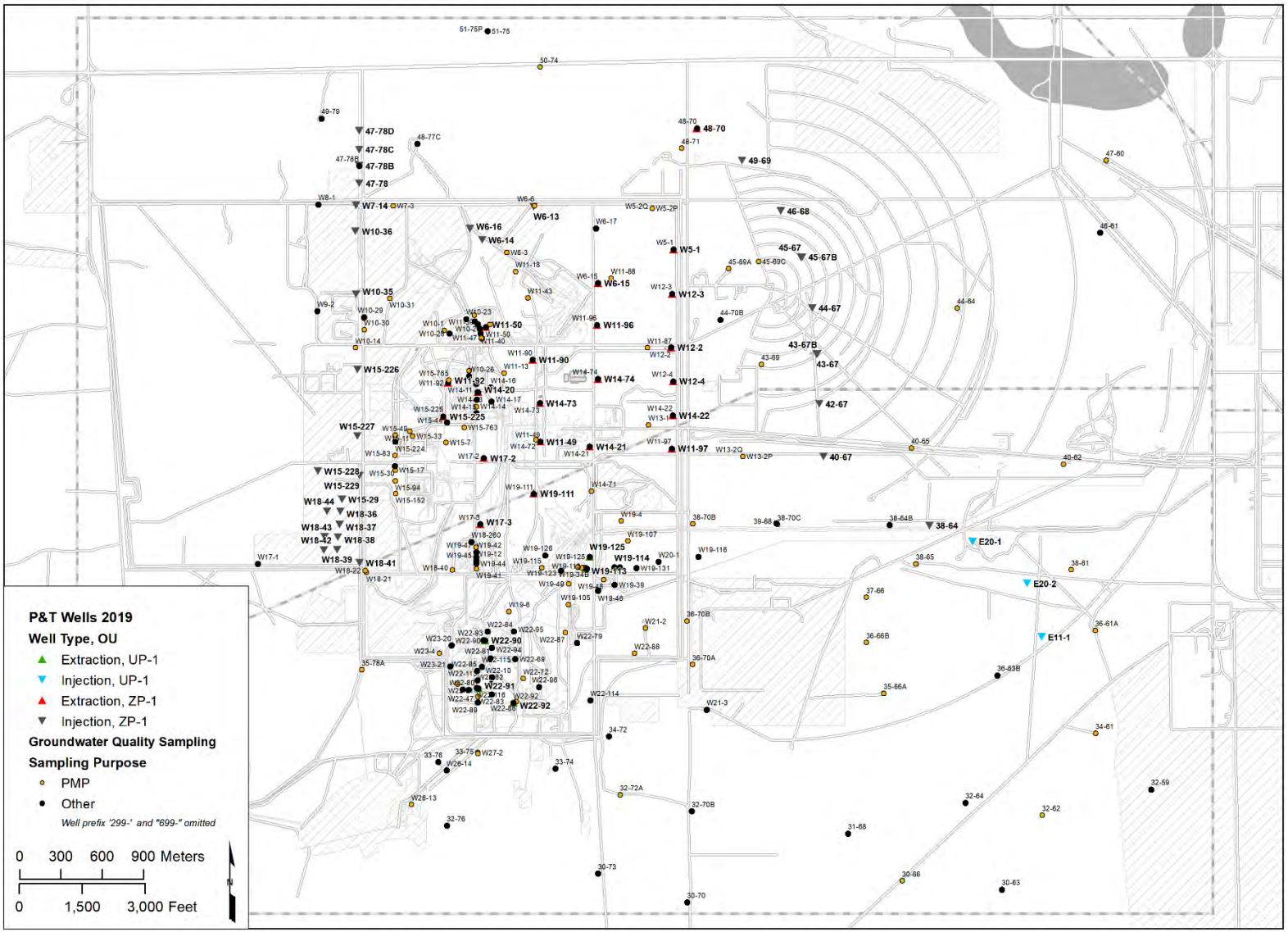

Figure 4-5. Location of Monitoring Wells Sampled for Groundwater Quality During 2019 (Distinguishing PMP Wells)

Well 266-W6-17 was drilled to a depth of 149.1 m (489 ft) bgs. The stratigraphic units encountered during drilling were the Hanford formation, Cold Creek unit, Rwie, and basalt. The Rlm was not present at this location. Water was encountered at 91.6 m (300.6 ft) bgs. Carbon tetrachloride concentrations in groundwater samples collected during drilling ranged from 42 µg/L to a maximum of 1,340 µg/L at 131.5 m (431.3 ft) bgs. Nitrate concentrations ranged from 84.1 mg/L to a maximum of 435 mg/L at 131.5 m (431.3 ft) bgs. The screen interval for the well was installed at 128.0 to 134.1 m (419.8 to 439.8 ft) bgs to monitor the depth with the highest carbon tetrachloride and nitrate concentrations.

Well 699-44-70B was drilled to a depth of 155.7 m (510.7 ft) bgs. Stratigraphic units encountered during drilling were the Hanford formation, Cold Creek unit, Rwie, Rlm, and basalt. Water was encountered at 98.5 m (323.1 ft) bgs. Carbon tetrachloride concentrations in groundwater samples collected during drilling ranged from 17.7 µg/L to a maximum of 247 µg/L at 126.9 m (416.5 ft) bgs. Nitrate concentrations ranged from 40.5 mg/L to a maximum of 62.5 mg/L at 145.3 m (476.6 ft) bgs. The screen interval for the well was installed at 122.0 to 128.1 m (400.2 to 420.3 ft) bgs to monitor the depth with the highest carbon tetrachloride and high nitrate concentrations (59.3 mg/L).

Well 699-46-61 was drilled to a depth of 108.5 m (356 ft) bgs. Stratigraphic units encountered during drilling were the Hanford formation and basalt. The Rlm was not present at this location. Water was encountered at 88.8 m (291.4 ft) bgs. Carbon tetrachloride was not detected in groundwater samples collected during drilling (concentrations <0.3 µg/L). Nitrate concentrations ranged from 50.9 mg/L to a maximum of 69 mg/L at 104 m (341.1 ft) bgs. The screen interval for the well was installed at 89.6 to 95.8 m (293.9 to 314.2 ft) bgs, monitoring just below the water table.

For each contaminant (excluding carbon tetrachloride and TCE), each well listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) was evaluated in the context of geographic location relative to the plume in the 200-ZP-1 OU and the concentration trends relative to the cleanup level. This evaluation included data collected as part of PMP efforts and included data beginning in 1990. For VOCs such as carbon tetrachloride and TCE, the monitoring well network extends into the 200-UP-1 OU (Figure 4-5) to track the plume and mass removal, remediate the plumes that have extended into the 200-UP-1 OU, and to meet the performance metrics identified in the 200-ZP-1 OU ROD (EPA et al., 2008).

4.4.1.2 Contaminant Monitoring Data

As described in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2), specific wells in the network are sampled for carbon tetrachloride, nitrate, TCE, total chromium and Cr(VI), iodine-129, technetium-99, and tritium. Annual sampling from the contaminant-specific well list provides data to (1) assess if any new COC releases could impact remedy effectiveness; (2) evaluate concentration trends in high-concentration areas of the plumes; and (3) determine if contamination is expanding downgradient, laterally or vertically. While the 200 West P&T is operating, plume- and constituent-specific analyses will be performed annually to determine if analytes will be added or removed for specific wells (with DOE and EPA concurrence). Contaminant-specific sampling is also augmented by sampling each well for all COCs to support CERCLA 5-year review preparation (most recently in 2016). Those expanded sampling efforts generate sufficient data for quantitative analysis to address the nine decision statements presented in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2).

Extraction well and P&T system data are also obtained and analyzed to help assess system performance over time. The extraction well data are also used to help rank the priority of the wells for operation in order to maximize the mass recovered by the system; to help constrain the parameters of the P2R Model to assist with remedy optimization; and to constrain estimates of the extent, volume, and mass of contamination in groundwater as depicted in the three-dimensional contaminant plumes that are used for predictive modeling purposes.

The 2019 contaminant monitoring results for the 200 West Area are summarized by COC in the following sections. Table 4-2 lists the 2019 average concentrations for the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) monitoring well network on a well-by-well basis. Two-dimensional contaminant plume maps presented in this section were primarily created using data from wells screened in the unconfined aquifer above the Rlm, although data from wells screened below the Rlm were also considered when available and suitably located. When more than one sampled data value was available for 2019, the average value was typically used. ECF-HANFORD-20-0018, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2019 Hanford Site Groundwater Monitoring Report*, provides details on preparing the two-dimensional plume maps presented herein. In addition to the two-dimensional plumes maps, three-dimensional depictions of the contamination extent were also prepared for some COCs for use in groundwater contaminant F&T calculations. Preparation of these plume depictions is detailed in ECF-200W-20-0052, *Updates to the 200-West Three-Dimensional Groundwater Concentration Plumes for Calendar Year 2015 for use as Initial Conditions in the Plateau to River (P2R) Groundwater Model*.

The following discussion summarizes the sampling conducted for COCs and compares sample data obtained during 2019 with data obtained during baseline monitoring in 2012.

4.4.1.2.1 Carbon Tetrachloride

Carbon tetrachloride is the primary risk driver COC in the 200-ZP-1 OU, resulting from waste discharges from activities related to plutonium processing prior to 1981. The 200-ZP-1 OU interim P&T system targeted carbon tetrachloride mass removal in areas >2,000 µg/L in the upper portion 15 m (50 ft) of the aquifer from 1996 through May 2012 (DOE/RL-2012-36, *200-ZP-1 Interim Pump-and-Treat System Summary Performance Report for Calendar Year 2012*). The number of extraction and monitoring wells exceeding carbon tetrachloride concentrations of 4,000 µg/L declined from 20 in 1996 to zero in 2012 as the extent of the high-concentration plume at the water table greatly reduced over the lifetime of the interim action P&T. However, during this time, continued investigations during drilling of new groundwater extraction and injection wells to support 200-ZP-1 OU characterization and final remedy implementation revealed carbon tetrachloride concentrations >1,000 µg/L throughout the entire thickness of the aquifer. The 200-ZP-1 OU ROD (EPA et al., 2008) targets the entire thickness of the plume and establishes a cleanup level for carbon tetrachloride of 3.4 µg/L.

Carbon tetrachloride concentrations in groundwater are declining due to remediation activities. In 2019, all of the 200-ZP-1 OU and 200-UP-1 OU monitoring wells had carbon tetrachloride concentrations <2,000 µg/L. Monitoring well 299-W11-87 exhibited the maximum carbon tetrachloride concentration (1,830 µg/L). Monitoring well 299-W13-1 and extraction wells 299-W11-90 and 299-W11-96 exhibited the next highest concentrations at 1,550 µg/L; 1,130 µg/L; and 1,170 µg/L, respectively. Of the 96 monitoring wells sampled in 2019 in the 200 West Area, 24 wells were below the cleanup level (3.4 µg/L). Table 4-3 lists the monitoring wells with stable, increasing, or decreasing concentrations versus baseline carbon tetrachloride conditions. The effectiveness of the 200 West P&T is shown by declining carbon tetrachloride concentrations in over one-half of the monitoring wells. Carbon tetrachloride concentrations declined in 60 of 96 monitoring wells sampled, 22 wells had increasing concentrations, and 14 wells had concentrations about the same as observed in 2012. Lower concentrations in extraction wells result, in part, from averaging because water from outside of the plumes (laterally and vertically) is also drawn in, thus diluting the concentrations.

Table 4-2. Average Concentration of COCs for 200-ZP-1 OU Monitoring Wells, 2019

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (µg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2019?
299-W10-1	130	18.38	4.41	<0.79	32,150	<38	0.55	468	1.1	Yes
299-W10-14	<0.18	15 (2015)	2.4 (2015)	<0.85	21,200	<6.18	<0.25	<296	0.86	Yes
299-W10-27	106	37.08	30.76	<0.62	135,350	79.2	0.46	<428 (2017)	2.56	Yes
299-W10-29	—	2.51	—	<0.61	38,100	4.61	—	<326	0.83	—[a]
299-W10-30	26.4	2.28	3.4 (2015)	<0.61	28,900	4.05	<0.3	<281.33	0.8	Yes
299-W10-31	9.4	3.3	3.1 (2015)	<0.91	48,700	<34.8	<0.25	<0 (0)	1.4	Yes
299-W10-33	<0.3 (2017)	3.7 (2017)	<1.5 (2017)	<0.85 (2015)	19,500 (2017)	<30.2 (2017)	<0.3 (2017)	<289 (2017)	1.37 (2017)	No[b]
299-W11-13	150	302.9	12.9	<0.77	229,000	1630	2.36	6,850	1.1 (2017)	Yes
299-W11-18	26.5	12.35	3.75	0.28	42,100	66.2	0.49	1,910	1.72	Yes
299-W11-33Q	52 (2018)	16.5 (2018)	21 (2018)	0.84 (2018)	62,000 (2018)	75.1 (2018)	0.96 (2018)	2,460 (2018)	1.1 (2017)	No[b]
299-W11-43	96.8	75.35	66.5	<0.84	155,000	70.4	1.06	2,070	2.65 (2017)	Yes
299-W11-45	640	18.25	17.36	<0.65	97,250	30.3	4.2	734	0.84	Yes
299-W11-47	487	36.68	36.25	1.31	160,500	6,460	1.73	<366	0.77	Yes
299-W11-48	879	19	21	<0.58	85,900	51	3.67	1,290	3.4 (2017)	Yes
299-W11-87	1,830	17.45	18.3	<1.07 (2015)	139,000	47.2 (2015)	5.46	<338	1.21 (2017)	Yes
299-W11-88	159	45.7	37.5	<0.75	274,000	157	<0.3	<625	1.2	Yes
299-W13-1	1,550	72.7 (2015)	11.7 (2015)	<0.19 (2015)	20,800	<9.39 (2015)	6.89	<337 (2015)	0.9 (2015)	Yes
299-W13-2P [c]	70	4.76	2.96	<0.61	32,200	7.16	1.7	<324	1.44	Yes
299-W13-2Q [c]	39	3.35	2.92	<0.67	34,100	<7.97	1.3	<335	1.3	Yes

Table 4-2. Average Concentration of COCs for 200-ZP-1 OU Monitoring Wells, 2019

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (µg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2019?
299-W14-11	380	23.67	20.83	2.15	149,750	3,760	1.5	1,510	2.07	Yes
299-W14-13	270	15.73	8.92	0.87	130,000	4,950	1.6	1,440	1.66	Yes
299-W14-14	128	8.59	7.24	<0.89	73,825	155	0.59	3,190	0.96	Yes
299-W14-71	408	—	—	—	—	—	10.8	—	—	Yes
299-W14-72	1,030	7.25 (2015)	2.1 (2015)	<0.29 (2015)	51,400	24.7 (2015)	9.84	<337 (2015)	0.73 (2015)	Yes
299-W15-11	40.2	8.38 (2015)	8.1 (2015)	<0.51 (2015)	61,100	65.5	<0.3	735 (2015)	0.86 (2015)	Yes
299-W15-152	4.73	6.4	8.5 (2015)	<0.72	56,666.67	99.2	<0.3	1,140	4.37	Yes
299-W15-17	3.79	13.8	1.6 (2015)	<0.56	49,400	27.3	<0.3	<324	1.13	Yes
299-W15-224	—	7.22	—	<0.81	68,400	89.6	—	1,110	1.36	—[a]
299-W15-30	—	5	—	<0.72	55,800	89.15	—	1,059	1.5	—[a]
299-W15-33	23.1	9.42 (2015)	7.2 (2015)	<0.29 (2015)	53,600	80.6	<0.33	649 (2018)	1.1 (2018)	Yes
299-W15-37	157 (2016)	—	—	—	84,100 (2016)	125 (2016)	0.37 (2016)	486 (2016)	1.56 (2016)	No[b]
299-W15-42	77 (2016)	11.2 (2015)	10 (2015)	<0.74 (2016)	93,000 (2016)	71.3 (2016)	0.69 (2016)	544 (2015)	1.61 (2015)	No[d]
299-W15-46	21 (2017)	7.97 (2015)	6.5 (2015)	<0.19 (2015)	83,700 (2017)	144 (2017)	<0.25 (2017)	790 (2015)	0.69 (2015)	No[d]
299-W15-49	15	6.19 (2015)	9.7 (2015)	<0.69 (2015)	56,200	98.2 (2018)	<0.3 (2018)	589 (2015)	0.83 (2015)	Yes
299-W15-50	110 (2017)	7.37 (2015)	7.9 (2015)	<0.15 (2015)	111,000 (2017)	141 (2017)	0.41 (2017)	646 (2015)	0.8 (2015)	No[d]
299-W15-7	29	6.83 (2015)	<1.5 (2015)	<0.85 (2015)	88,500	95.2	<0.31	658	0.78	Yes
299-W15-763	45	22.33	11.2	<0.5	133,000	139	<1	2,900	0.85	Yes

Table 4-2. Average Concentration of COCs for 200-ZP-1 OU Monitoring Wells, 2019

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (µg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2019?
299-W15-765	28	4.55	4.49	<0.92	41,000	65	<0.31	1,360	1.72	Yes
299-W15-83	16	6.3	5.8 (2015)	<0.52	61,950	119.25	<0.31	947	1.3	Yes
299-W15-94	5.1	6.3	8.25 (2015)	<0.66	52,900	103.35	<1	1,185	1.8	Yes
299-W18-1	4.8 (2017)	8 (2015)	6.6 (2015)	<0.47 (2017)	58,000 (2017)	92.5 (2017)	<0.25 (2017)	1,190 (2015)	2.74 (2015)	No[d]
299-W18-15	10 (2017)	—	—	—	29,700 (2018)	—	<0.3 (2017)	—	22.1 (2017)	No[d]
299-W18-16	23 (2017)	11.2 (2015)	12.3 (2015)	<0.25 (2015)	505,000 (2017)	181 (2017)	<0.25 (2017)	814 (2015)	2.85 (2015)	No[d]
299-W18-21	<0.32	8.36	—	<0.64	38,200	83.75	<0.3	2,255	8.84	Yes
299-W18-22	2.87	29.1	—	<0.6	25,900	16.6	<0.31	<302	1	Yes
299-W18-40	34	6.68	7.6	—	61,750	112	<0.3	452 (2018)	3.65	Yes
299-W19-105	40.6	—	—	<0.65 (2017)	15,500 (2017)	<34.2 (2017)	<0.3	<350 (2017)	15.5	Yes
299-W19-107	127	—	—	<0.55	52,200	185	45.3	—	2	Yes
299-W19-115 [e]	98	4.68	—	0.86	16,133.33	141.63	0.48	<306	181.25	Yes
299-W19-34A	54.8	—	—	0.61 (2015)	10,200	80.5	0.7	<272	1.12	Yes
299-W19-34B	44.3	—	—	—	10,200 (2018)	<37.8 (2018)	2.42	<304 (2018)	0.97 (2018)	Yes
299-W19-36	66.5	—	—	<2.69 (2015)	75,300	3,290	0.98	—	1,833.33	Yes
299-W19-4	150	—	—	<0.38 (2015)	102,000	15.9 (2015)	3.3	—	0.88 (2015)	Yes
299-W19-41	92.6	16.43	6.72	—	80,700	961.5	<0.3	<301 (2018)	1.23	Yes
299-W19-47	76.1	11.11	13.05	—	109,500	3,650	<0.3	310 (2018)	2.35	Yes
299-W19-48	6.1	—	—	2.05	17,900	372	<0.31	588.5 (2015)	20.7	Yes

Table 4-2. Average Concentration of COCs for 200-ZP-1 OU Monitoring Wells, 2019

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (µg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2019?
299-W19-49	67.3	—	—	1.38	7,970	34.5	<0.3	160 (2015)	93.9	Yes
299-W19-6	35.7	<3	<1.3	<0.65	3,290	<2.66	1.01	<277	0.6 (2017)	Yes
299-W21-2	11.2	—	—	2.41	18,800	72.9 (2018)	<0.3	4500 (2018)	2.93	Yes
299-W22-47	49	7.93	3.1	<0.4 (2016)	6,995	8.18	<1	<250 (2018)	3.7 (2018)	Yes
299-W22-72	38.45	3.99	5.16	1.35	44,833.33	714.5	<0.3	17,300	1.06	Yes
299-W22-86	26.3	17.48	19.4	<0.98	11,250	1,220	<0.3	3,850	2.01 (2016)	Yes
299-W22-87	10	14.35	15.9	<0.85	33,400	1,034	<0.31	1,180	0.87	Yes
299-W22-88	3.6	—	—	5.19	11,100 (2016)	<35.1 (2016)	<1	27,700	3.82 (2016)	Yes
299-W23-19	54.5	287.29	317	<0.92	117,640	9,480	<0.31	7,073.33	7.56	Yes
299-W23-4	37.45	—	—	—	27,166.67	273 (2017)	<0.3	59,166.67	38.73	Yes
299-W26-13	<0.3	148.5	150.33	<0.35 (2015)	31,933.33	<37.2 (2016)	<0.3	<311 (2016)	1.67	Yes
299-W27-2	1.91	43.45	3.07	—	6,330	—	<0.3	—	—	Yes
299-W5-2P [c]	195	114	103	0.75	527,000	400	1.51	3,270	1.32	Yes
299-W5-2Q [c]	310	110	99	<0.67	531,000	374	2	3,500	1.34	Yes
299-W6-11	—	—	—	—	53,100 (2018)	—	—	585.5 (2018)	—	—[a]
299-W6-12	—	—	—	—	—	—	—	101 (2018)	—	—[a]
299-W6-3	1.4	20.2 (2015)	9.2 (2015)	<0.16 (2015)	289,500	64.4	<0.25	<289 (2015)	0.95 (2015)	Yes
299-W6-6	<0.3	14.63 (2016)	12.2 (2015)	<0.58 (2016)	34,500	134	<0.3	2,665	1.07 (2015)	Yes
299-W7-3	0.58	12.6 (2016)	3 (2015)	<0.51	5,270	<8.37	<0.31	195.37	1.1	Yes

Table 4-2. Average Concentration of COCs for 200-ZP-1 OU Monitoring Wells, 2019

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (µg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2019?
699-30-66	0.52	98.65	95.4	<0.28 (2015)	21,900 (2015)	—	<1	368 (2015)	1.55 (2016)	Yes
699-32-62	0.35	120	109	<0.43 (2015)	18,900	43.7	<0.3	3,860	2.1	Yes
699-32-72A	0.79	—	—	<0.46	18,800	378	<0.3	29,800	0.78	Yes
699-33-75	3.97	3.83	2.48	<0.35 (2017)	6,200	<35.3 (2017)	<0.3	<288 (2017)	3.35 (2017)	Yes
699-34-61	0.49	101.8	51.4	<0.84	21,900	<28.8	1.91	5,910	1.87	Yes
699-35-66A	0.99	19.45	14.5 (2017)	3.31	24,600	158	<0.63	49,900	1.99	Yes
699-35-78A	21.2	—	—	—	8,410 (2015)	—	3.3	<268 (2018)	11 (2015)	Yes
699-36-61A	<0.19	13.5	11.2	<0.71	25,600	<11.8 (2016)	<0.31	41,400	3.01	Yes
699-36-66B	2.59	4.13	—	6.33	53,100	58.05	<0.65	193,000	2.5	Yes
699-36-70A	1.65	7.98	—	11.43	15,500	32.3	<0.3	50,600	3.22	Yes
699-36-70B	12	—	—	1.59	72,200	193 (2016)	0.34	5,240	5.02 (2016)	Yes
699-37-66	1.9	3.07	—	1.73	135,666.67	56.67	<0.5	41,600	1.7	Yes
699-38-61	<0.3	16	—	<0.39	35,400	—	<0.3	29,100	2.3	Yes
699-38-65	1	—	—	1.45	186,000	126 (2017)	<1	51,300	1.23 (2017)	Yes
699-38-68A	5.4 (2018)	—	—	0.98 (2018)	164,000 (2018)	619 (2018)	0.89 (2018)	10,900 (2018)	3.29 (2016)	No[f]
699-38-70B	62.6	—	—	<1.11 (2015)	84,100	41.3 (2016)	7.71	<341 (2016)	1.1 (2016)	Yes
699-38-70C	16	—	—	0.84	125,000	669	3.6	4,740 (2017)	2.3 (2017)	Yes
699-40-62	<0.18	—	—	0.33 (2015)	128,000	94.2 (2015)	<0.25	14,500	2.12 (2015)	Yes
699-40-65	5.41	—	—	<0.86 (2015)	178,000	472 (2018)	2.24	12,600 (2015)	—	Yes
699-43-69	250	56.05	16	<0.41 (2017)	30,500	<16.9 (2017)	2.7	<433 (2017)	1.4 (2017)	Yes

Table 4-2. Average Concentration of COCs for 200-ZP-1 OU Monitoring Wells, 2019

Well Name	Carbon Tetrachloride (µg/L)	Chromium (µg/L)	Hexavalent Chromium (µg/L)	Iodine-129 (pCi/L)	Nitrate as Nitrate (µg/L)	Technetium-99 (pCi/L)	Trichloroethene (µg/L)	Tritium (pCi/L)	Uranium (µg/L)	Sampled as Scheduled in 2019?
699-44-64	16	10.35	11.6	<0.74	53,100	34.8	2.1	<294	1.5	Yes
699-45-69A	<0.19	33.9 (2015)	8.2 (2015)	<0.54 (2015)	483	<9.24 (2015)	<0.31	<279 (2015)	1.54 (2015)	Yes
699-45-69C	20	29 (2016)	27 (2015)	<0.75 (2018)	235,000	82.8 (2018)	<0.31	<486 (2018)	1.7 (2018)	Yes
699-47-60	<0.65	11.78	3.09	<0.48	44,200	<41.5	<0.65	<284	2.43	Yes
699-48-71	163	21.7	6.1	<0.86	328,000	101	1.26	3,463.33	1.3 (2017)	Yes
699-50-74	<0.19	7.3 (2015)	4.5 (2015)	<0.32 (2015)	4,780	<42.5	<0.31	<305	1.2	Yes
699-51-63	<1	2.51 (2015)	1.6 (2015)	<0.35 (2015)	24,300	<11.4 (2015)	<1	<105 (2015)	2.22 (2015)	Yes

Notes:

Requirements are from DOE/RL-2009-124, *200 West Pump and Treat Operations and Maintenance Plan*; and DOE/RL-2009-115, Rev. 2, *Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action*.

Yellow-shaded cells identify monitoring wells within 100 m (328 ft) of an extraction well.

If sample data were not available for 2019, the year applicable to the sample data is provided in parenthesis following the value.

a. Well added for sampling in accordance with TPA-CN-0875, *Tri-Party Agreement Change Notice Form: DOE/RL-2009-115, Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action, Revision 2*. The change notice was approved in November 2019, so sampling was not performed as part of routine 2019 sampling.

b. Wells 299-W10-33, 299-W11-33Q, and 299-W15-37 were not sampled due to pump failures. Well maintenance has been scheduled.

c. The "P" and "Q" locations sample at different depths in the same well.

d. Wells 299-W15-46, 299-W15-50, 299-W18-1, 299-W18-15, and 299-W15-16 were not sampled because the wells are located inside the Plutonium Finishing Plant work zone.

e. Well 299-W19-115 replaces well 299-W19-18 (listed in DOE/RL-2009-115, Rev. 2), which has gone dry.

f. Well 699-38-68A was sample dry.

— = well not scheduled for analysis per DOE/RL-2009-115, Rev. 2

4.4.1.2.2 Chromium (Total and Hexavalent)

Chromium is found at levels above cleanup standards (100 µg/L for total chromium and 48 µg/L for Cr(VI)) beneath the SSTs at WMAs T and TX-TY. Chromium is analyzed in groundwater samples using two methods: (1) inductively coupled plasma, which yields a result for total chromium (trivalent and Cr(VI) combined); and (2) a colorimetric method (ultraviolet/visible light absorption), which yields a result for only the hexavalent form. The Hanford Environmental Information System database includes results for both total chromium and Cr(VI). Dissolved chromium in Hanford Site groundwater is nearly all in hexavalent form (WHC-SD-EN-TI-302; Appendix C of DOE/RL-2008-01), so filtered total chromium data effectively represent Cr(VI) concentrations.

In 2019, the 200-ZP-1 OU maximum chromium concentration was 576 µg/L (total chromium, unfiltered) in well 299-W11-13, where unfiltered chromium concentrations are an order of magnitude higher than filtered chromium. The high unfiltered chromium along with presence of high concentrations of nickel may be an indication of well corrosion products rather than groundwater concentrations. During 2019, 21 wells had decreases in concentration, 17 wells had increases in concentration, and 12 wells had stable concentrations. Table 4-3 compares the chromium concentrations in 2019 and 2012. The Cr(VI) exceeded the cleanup standard at 3 of the 50 monitoring wells in the 200-ZP-1 OU.

4.4.1.2.3 Iodine-129

Iodine-129 sources include past leaks from SSTs containing waste from chemical-processing and plant operations, as well as liquid waste disposal facilities (e.g., cribs and trenches) adjacent to the tank farms. The iodine-129 detection limit is approximately 0.7 pCi/L. During 2019, iodine-129 concentrations exceeded the 1 pCi/L cleanup standard in two monitoring wells in the 200-ZP-1 OU. The maximum concentration of 2.15 pCi/L was at monitoring well 299-W14-11 (Table 4-4), which is downgradient of WMA TX-TY.

Table 4-3 compares the iodine-129 concentrations in 2019 and 2012. Concentrations declined in the monitoring wells sampled in 2012 and 2019 (Table 4-3). Iodine-129 concentrations during 2019 were below the cleanup level of 1 pCi/L in 48 of the 50 monitoring wells as expected because the plume is small and concentrations are anticipated to rapidly diminish.

4.4.1.2.4 Nitrate (as Nitrate)

Nitrate concentrations are above the cleanup level (10 mg/L as nitrogen; 45 mg/L as nitrate) throughout much of the 200-ZP-1 OU. Nitrate sources include liquid waste disposal from T Plant processes to the cribs near WMA T and from PFP processes to 216-Z Cribs and Trenches. The highest nitrate concentration for 2019 was 553 mg/L at well 299-W14-18 (Table 4-4).

Table 4-3 compares nitrate concentrations in 2019 and 2012. A total of 25 monitoring wells had decreasing concentrations, 9 wells had increasing concentrations, and 16 wells had concentrations about the same as reported in 2012 (Table 4-3). Of the nine wells with increasing concentrations, two wells are located near extraction wells drawing in contaminated groundwater. The remaining seven wells had increasing concentrations due to apparent plume migration. Overall, nitrate concentrations in 200-ZP-1 OU monitoring wells were declining in most of the wells prior to the suspension of active biological treatment that started in October 2019.

Table 4-3. Comparison of COCs Concentration in Monitoring Wells in 2012 and 2019

Well	Carbon Tetrachloride (µg/L)		Hexavalent Chromium (µg/L)		Chromium (µg/L)		Iodine-129 (pCi/L)		Nitrate (mg/L)		Technetium-99 [pCi/L)		Trichloroethene (µg/L)		Tritium (pCi/L)	
	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019
299-W10-1	950	130	2	4.41	30	18.375	<0.2	<0.79	118	32.15	47	<38	4.2	0.55	443	468
299-W10-14	1	<0.18	2	2.4	10	15	<0.2	<0.85	21	21.20	<6	<6.175	0.3	<0.25	<320	<296
299-W10-27	580	106	105	30.76	115	37.075	<0.4	<0.62	726	135.35	460	79.2	3.4	0.46	2,800	<428
299-W10-30	6	26.4	2	3.4	3	2.28	<0.3	<0.61	34	28.90	<7	3.3	0.3	<0.30	<330	<281.33
299-W10-31	29	9.4	2	3.1	3	3.3	<0.2	<0.91	74	48.70	18	<34.8	0.3	<0.25	<330	<294
299-W10-33	<0.3	<0.3	2	<1.5	1	3.7	<0.2	<0.85	17	19.50	<7	<30.2	0.3	<0.30	<280	<289
299-W11-13	270	150	2	12.9	51	302.9	<0.2	<0.77	95	229.0	240	1,630	2.1	2.36	6,700	6850
299-W11-18	330	26.5	25	3.75	30	12.35	0.8	0.281	97	42.10	94	66.2	2.9	0.49	8,800	1910
299-W11-33Q	730	52	2	21	75	16.5	2.7	0.839	140	62.0	330	75.1	11	0.96	26,000	2,460
299-W11-43	780	96.8	187	66.5	167	75.35	<0.3	<0.84	385	155.0	290	70.4	11	1.06	15,000	2,070
299-W11-45	1,200	320.11	149	17.36	130	18.25	0.9	<.65	353	97.25	2,130	30.3	9.4	4.2	14,000	734
299-W11-47	1,200	487	129	36.25	132	36.67	0.6	1.31	589	160.50	4,300	6,460	6.6	1.73	2,200	<366
299-W11-48	400	879	87	21	62	19	<0.2	<0.58	193	85.90	73	51	3.8	3.67	4,900	1,290
299-W11-87	2,200	1830	8	18.3	6	17.45	<0.2	<1.07	66	139.0	26	47.2	6.2	5.46	<360	<338
299-W11-88	<0.3	159	2	37.5	4	45.7	<0.2	<0.75	82	274.0	<6	157	0.3	<0.30	<310	<625
299-W13-1	1,800	1,550	2	11.7	5	72.7	<0.2	<0.19	28	20.80	12	<9.39	5.6	6.89	<330	<337
299-W13-2P*	63	70	2	2.96	4	4.76	0.7	<0.61	24	32.20	9	7.16	1.6	1.7	<313	<324
299-W13-2Q*	63	39	2	2.92	4	3.35	0.7	<0.61	24	34.10	9	<7.97	1.6	1.3	<313	<335
299-W14-11	1,700	380	66	21.066667	48	23.666667	0.9	2.15	291	149.75	3,500	3,760	11	1.5	89,000	1,510
299-W14-13	390	270	339	8.915	296	15.728571	16	0.823	305	130.0	5,900	4,950	2.3	1.6	200,000	1,440
299-W14-14	470	128	20	7.2375	29	8.59	1	<0.89	160	73.83	400	155	1.9	0.59	6,400	3,190
299-W14-72	950	1,030	2	2.1	8	7.25	<0.2	<0.29	22	51.40	14	24.7	6.3	9.84	540	<337
299-W15-11	1,100	40.2	2	8.1	6	8.38	<0.2	<0.51	89	61.10	110	65.5	1.4	<0.30	730	735
299-W15-152	15	4.73	11	8.5	11	6.4	<0.2	<0.72	135	56.67	250	99.2	0.3	<0.30	1,400	1,140
299-W15-17	1	3.79	8	1.6	16	13.8	<0.4	<0.56	22	49.40	<6	27.3	0.3	<0.30	<300	<324
299-W15-33	80	23.1	8	7.2	8	9.42	<0.2	<0.29	108	53.60	210	80.6	0.3	<0.33	1,100	649
299-W15-42	270	77	5	10	8	11.2	<0.2	<0.74	115	93.0	93	71.3	0.8	0.69	810	544
299-W15-46	510	21	4	6.5	6	7.97	<0.2	<0.19	117	83.70	202	144	1.3	<0.25	825	790
299-W15-49	55	15	7	9.7	8	6.19	<0.2	<0.69	108	56.20	210	98.2	0.3	<0.30	670	589
299-W15-50	1,900	110	3	7.9	6	7.37	<0.2	<0.15	125	111.0	56	141	7.9	0.41	310	646
299-W15-7	580	29	2	<1.5	11	6.83	<0.2	<0.85	61	88.50	78	95.2	1	<0.31	1,000	658
299-W15-763	390	45	4	11.2	17	22.33	<0.2	<0.50	474	133.0	890	139	3.7	<1.0	13,000	2,900
299-W15-765	2,233	28	31	4.49	36	4.55	0.5	<0.92	143	41.0	6,300	65	6	<0.31	4,600	1,360
299-W15-83	13	16	8	5.8	14	6.3	<0.2	<0.52	127	61.95	250	119.25	0.3	<0.31	2,300	947
299-W15-94	20	5.1	7	8.25	19	6.3	<0.2	<0.66	120	52.90	260	103.35	0.3	<1.0	1,400	1,185

Table 4-3. Comparison of COCs Concentration in Monitoring Wells in 2012 and 2019

Well	Carbon Tetrachloride (µg/L)		Hexavalent Chromium (µg/L)		Chromium (µg/L)		Iodine-129 (pCi/L)		Nitrate (mg/L)		Technetium-99 [pCi/L)		Trichloroethene (µg/L)		Tritium (pCi/L)	
	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019
299-W18-1	13	4.8	5	6.6	11	8	<0.4	<0.47	117	58.0	220	92.5	0.3	<0.25	940	1,190
299-W18-16	150	23	6	12.3	11	11.2	<0.2	<0.25	540	505.0	200	181	0.3	<0.25	1,200	814
299-W5-2P*	232	195	95	103	95	114	0.9	0.75	606	527.0	461	400	1	1.51	3,802	3,270
299-W5-2Q*	232	310	95	99	95	110	0.9	<0.67	606	531.0	461	374	1	2	3,802	3,500
299-W6-3	<0.2	1.4	9	9.2	15	20.2	<0.2	<0.16	214	289.50	47	64.4	0.3	<0.25	<280	<289
299-W6-6	<0.1	<0.3	2	12.2	5	14.63	<0.2	<0.58	26	34.50	<7	134	0.3	<0.30	290	2,665
299-W7-3	<0.4	0.58	2	3	11	12.6	<0.2	<0.51	7	5.27	<7	<8.365	0.3	<0.31	<290	65.35
699-43-69	580	250	38	16	84	56.05	<0.2	<0.41	32	30.50	<7	<16.9	3	2.7	<310	<433
699-44-64	8	13	6	11.6	9	10.35	<0.2	<0.74	68	53.10	70	34.8	2.6	1.7	450	<73.4
699-45-69A	7	<0.19	2	8.2	9	33.9	<0.2	<0.54	36	0.48	59	<9.24	1	<0.31	3,100	<279
699-45-69C	39	20	25	27	2	29	<0.2	<0.75	190	235.0	18	82.8	0.3	<0.31	<300	<486
699-47-60	<0.1	<0.65	9	3.09	21	11.78	<0.2	<0.48	37	44.20	10	<41.5	0.3	<0.65	<270	<284
699-48-71	100	163	60	6.1	108	21.7	0.8	<0.86	374	328.0	270	101	0.5	1.26	1,500	3,463.33
699-50-74	<0.1	<0.19	3	4.5	7	7.3	<0.2	<0.32	9	4.78	<7	<42.5	0.3	<0.31	<340	<305
699-51-63	<0.1	<0.15	2	1.6	1	2.51	<0.2	<0.35	23	24.30	<7	<11.4	0.3	<1.0	<300	<105
299-W14-71	790	408	—	—	—	—	—	—	—	—	—	—	8.2	10.8	—	—
299-W15-37	110	157	—	—	—	—	—	—	—	—	—	—	0.4	0.37	—	—
299-W18-15	61	10	—	—	—	—	—	—	—	—	—	—	0.6	0.3	—	—
299-W18-21	0.8	0.32	—	—	—	—	—	—	—	—	—	—	0.3	0.3	—	—
299-W18-22	1.1	2.86	—	—	—	—	—	—	—	—	—	—	0.6	0.32	—	—
299-W18-40	150	34	—	—	—	—	—	—	—	—	—	—	0.3	0.3	—	—
299-W19-105	100	40.6	—	—	—	—	—	—	—	—	—	—	0.7	0.3	—	—
299-W19-107	190	127	—	—	—	—	—	—	—	—	—	—	2.6	2.2	—	—
299-W19-115	18	—	—	—	—	—	—	—	—	—	—	—	0.3	—	—	—
299-W19-34A	190	54.8	—	—	—	—	—	—	—	—	—	—	3.2	0.7	—	—
299-W19-34B	740	44.3	—	—	—	—	—	—	—	—	—	—	4.2	2.42	—	—
299-W19-36	170	66.5	—	—	—	—	—	—	—	—	—	—	3.4	0.98	—	—
299-W19-4	86	150	—	—	—	—	—	—	—	—	—	—	0.9	3.3	—	—
299-W19-41	130	92.6	—	—	—	—	—	—	—	—	—	—	0.3	0.3	—	—
299-W19-47	290	76.1	—	—	—	—	—	—	—	—	—	—	0.5	0.3	—	—
299-W19-48	140	6.1	—	—	—	—	—	—	—	—	—	—	0.8	0.31	—	—
299-W19-49	790	67.3	—	—	—	—	—	—	—	—	—	—	0.8	0.3	—	—
299-W19-6	37	35.7	—	—	—	—	—	—	—	—	—	—	1.1	2.94	—	—
299-W21-2	25	11.2	—	—	—	—	—	—	—	—	—	—	0.7	0.3	—	—
299-W22-47	110	49	—	—	—	—	—	—	—	—	—	—	0.3	1	—	—

Table 4-3. Comparison of COCs Concentration in Monitoring Wells in 2012 and 2019

Well	Carbon Tetrachloride (µg/L)		Hexavalent Chromium (µg/L)		Chromium (µg/L)		Iodine-129 (pCi/L)		Nitrate (mg/L)		Technetium-99 [pCi/L)		Trichloroethene (µg/L)		Tritium (pCi/L)	
	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019
299-W22-72	23	25.81	—	—	—	—	—	—	—	—	—	—	0.8	0.3	—	—
299-W22-86	92	26.3	—	—	—	—	—	—	—	—	—	—	0.8	0.3	—	—
299-W22-87	18	10	—	—	—	—	—	—	—	—	—	—	1	0.31	—	—
299-W22-88	5	3.6	—	—	—	—	—	—	—	—	—	—	0.3	1	—	—
299-W23-19	84	54.5	—	—	—	—	—	—	—	—	—	—	1	0.31	—	—
299-W23-4	140	37.45	—	—	—	—	—	—	—	—	—	—	0.6	0.3	—	—
299-W26-13	1	0.3	—	—	—	—	—	—	—	—	—	—	1	0.3	—	—
299-W27-2	4	1.91	—	—	—	—	—	—	—	—	—	—	0.3	0.3	—	—
699-30-66	1	0.52	—	—	—	—	—	—	—	—	—	—	1	1	—	—
699-32-62	3	0.35	—	—	—	—	—	—	—	—	—	—	1	0.3	—	—
699-32-72A	0.7	0.79	—	—	—	—	—	—	—	—	—	—	0.3	0.3	—	—
699-33-75	20	3.97	—	—	—	—	—	—	—	—	—	—	1	0.3	—	—
699-34-61	0.5	0.49	—	—	—	—	—	—	—	—	—	—	0.3	1.91	—	—
699-35-66A	5	0.99	—	—	—	—	—	—	—	—	—	—	5	0.625	—	—
699-35-78A	14	21.2	—	—	—	—	—	—	—	—	—	—	1	3.76	—	—
699-36-61A	0.5	0.19	—	—	—	—	—	—	—	—	—	—	0.3	0.31	—	—
699-36-66B	2	2.585	—	—	—	—	—	—	—	—	—	—	5	0.77	—	—
699-36-70A	5	1.65	—	—	—	—	—	—	—	—	—	—	5	0.3	—	—
699-36-70B	12	12	—	—	—	—	—	—	—	—	—	—	1	0.34	—	—
699-37-66	1	1.9	—	—	—	—	—	—	—	—	—	—	5	0.63	—	—
699-38-61	<0.2	0.3	—	—	—	—	—	—	—	—	—	—	0.3	0.3	—	—
699-38-65	1	1	—	—	—	—	—	—	—	—	—	—	0.3	1	—	—
699-38-68A	9	5.4	—	—	—	—	—	—	—	—	—	—	0.9	0.89	—	—
699-38-70B	490	62.6	—	—	—	—	—	—	—	—	—	—	6	7.71	—	—
699-38-70C	20	16	—	—	—	—	—	—	—	—	—	—	3.6	3.6	—	—
699-40-62	<0.2	0.18	—	—	—	—	—	—	—	—	—	—	0.5	0.25	—	—
699-40-65	3	5.41	—	—	—	—	—	—	—	—	—	—	1.9	2.24	—	—

Notes:

The less than symbol (<) indicates that the sample result was below the listed detection limit. For radionuclides, the value is less than the minimum detectable activity.

Blue-shaded cells identify monitoring wells within 100 m (328 ft) of an extraction well.

Orange-shaded cells indicate that the concentration increased >20% between 2012 and 2019.

Green-shaded cells indicate that the concentration decreased >20% between 2012 and 2019.

Unshaded cells indicate that the concentration was stable with <20% change between 2012 and 2019.

*The "P" and "Q" locations are sampled at different depths in the same well.

— = analyses not required

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Table 4-4. 200-ZP-1 OU Groundwater COC Monitoring Summary, 2019

Contaminant	Final Cleanup Level	Maximum Concentration	Plume Area[a] (km^2)
Carbon tetrachloride	3.4 µg/L	1,830 (299-W11-87)	19.98[b]
Hexavalent chromium	48 µg/L[c]	175 (299-W6-15 and 299-W6-17)	1.13
Chromium (total)	100 µg/L[d]	576 (299-W11-13)[e]	0.14
Iodine-129	1 pCi/L	2.15 (299-W14-11)	0.03
Nitrate[f]	45 mg/L	553 (299-W14-18)	18
Technetium-99	900 pCi/L	25,200 (299-W11-42)	0.13
Trichloroethene	1 µg/L	10.8 (299-W14-71)	6.41
Tritium	20,000 pCi/L	58,100 (699-48-77C)	0.14

References:

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

EPA et al., 2011, *Record of Decision Hanford 200 Area Superfund Site 200-CW-5 and 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units*.

EPA et al., 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*.

a. Estimated area above the listed cleanup level.

b. Area of full plume footprint (all depths in unconfined aquifer) is >3.4 µg/L.

c. The groundwater cleanup standard for hexavalent chromium is 48 µg/L.

d. The federal drinking water standard for total chromium is 100 µg/L.

e. The high unfiltered chromium concentration is suspected to be from well corrosion rather than groundwater concentrations. The next highest chromium concentration is detected in well 299-W11-39 at 220 µg/L.

f. Nitrate may be expressed as total nitrate (NO_3) or as total nitrogen (N). The maximum contaminant level for nitrate as NO_3 is 45 mg/L, and the same concentration expressed as N is 10 mg/L. (Note that U.S. Environmental Protection Agency drinking water regulations are published as 10 mg/L as nitrogen.).

Following suspension of the active biological treatment, sampling data from the treatment system effluent confirmed anticipated increases in the concentrations of nitrate and of other constituents. As planned (in accordance with meeting the objectives for the 200-ZP-1 optimization study), focused near-term sampling and analysis from selected groundwater monitoring wells (as documented in TPA-CN-0875 for the PMP [DOE/RL-2009-115, Rev. 2]) commenced in December 2019 in order to detect anticipated increases in nitrate concentration and associated changes in other constituents. The monitoring wells identified for this purpose were selected following a number of groundwater flow and constituent transport analyses as being suitably located to provide measurable concentration breakthroughs during the optimization study period. These calculations are documented in ECF-200ZP1-20-0056. As previously discussed, it is anticipated that along with other information, the data obtained from these wells (primarily nitrate, which is a conservative [nonreactive] solute, but also other constituents) will support estimation of effective (mobile) porosity, dilution and physical attenuation processes in the subsurface, and calibration of these parameters in the P2R Model for purposes of predictive modeling. This will also provide for updated F&T simulations to determine if nitrate does not require further active biological treatment.

4.4.1.2.5 Technetium-99

Technetium-99 sources in the 200-ZP-1 OU include releases from past SST and pipeline leaks at WMAs T and TX-TY, as well as liquid waste disposal from plutonium-processing operations to cribs and trenches adjacent to the WMAs. The highest concentration was 25,200 pCi/L in monitoring well 299-W11-42, located east (downgradient) of WMA TX-TY (Table 4-4). Technetium-99 exceeded the 900 pCi/L cleanup standard at four monitoring wells in the 200-ZP-1 OU in 2019. Table 4-3 compares the technetium-99 concentrations in 2019 and 2012. Technetium-99 concentrations declined in 22 of the 50 monitoring wells in the 200-ZP-1 OU between 2012 and 2019.

As the 200-ZP-1 P&T system has operated, growing evidence suggests that there may be one or more ongoing sources of technetium-99 contamination present in the T Tank Farm area. Lines of evidence for this interpretation include sustained concentrations in nearby monitoring wells and activity mass recovery at nearby extraction wells (ECF-HANFORD-20-0049, *Description of Groundwater Calculations to Support Performance Assessment for the Calendar Year 2019 (CY 2019) 200 Areas Pump-and-Treat Report*). Largely in response to these observations, groundwater monitoring data will be evaluated in 2020 and 2021 to assess the likelihood and location of continuing sources at this location and other locations in the Central Plateau. This work will include the preparing and analyzing detailed three-dimensional depictions of contamination using available data to assess the lateral and vertical distribution of contamination and to help determine whether local-scale remedial optimization for specific COCs can provide benefits to the overall system-wide remedy.

4.4.1.2.6 Trichloroethene

The TCE in the 200-ZP-1 OU is detected at levels above the cleanup standard (1 µg/L) throughout most of the OU and is collocated with the high-concentration portion of the carbon tetrachloride plume. The TCE contamination is found from the water table to the bottom of the aquifer. Table 4-3 compares the TCE concentrations in 2019 and 2012. The maximum TCE concentration reported during 2019 was 10.8 µg/L in well 299-W14-71 (Table 4-4). TCE concentrations decreased in most of the 200-ZP-1 OU and 200-UP-1 OU monitoring wells between 2012 and 2019 (Table 4-3). TCE exceeded the 1 µg/L cleanup standard in 26 of 96 monitoring wells in the 200 West Area in 2019, which is a decrease of 11 wells from the 37 wells above the cleanup level in 2012. In 2019, TCE concentrations in 200-ZP-1 OU wells declined an average of 44% since 2012 due to 200 West P&T remediation activities. The TCE contaminant plume extent increased since 2012 based on sample data from the entire aquifer and sample data collected during drilling of new wells in the eastern portion of the 200-ZP-1 OU that were used to delineate the plume.

4.4.1.2.7 Tritium

In 2019, tritium concentrations did not exceed the cleanup standard of 20,000 pCi/L in the 200-ZP-1 OU, except in well 699-48-77C (58,100 pCi/L), which is a monitoring well adjacent to the State-Approved Land Disposal Site (SALDS). Active permitted discharges at the SALDS are an ongoing source of tritium to groundwater in the 200-ZP-1 OU. As a result, concentrations in the wells are expected to remain >20,000 pCi/L as long as permitted discharges continue. Previous sources of contamination included liquid waste from plutonium processing to disposal facilities (including the 216-T-25 Trench) and past leaks from tanks and pipelines adjacent to WMA TX-TY. Excluding the wells near the SALDS, the maximum tritium concentration reported for 2019 in the 200-ZP-1 OU was 6,850 pCi/L at well 299-W11-13 (a monitoring well located downgradient of WMA TX-TY). Tritium concentrations at wells in the 200-ZP-1 OU are declining, from a maximum of 2,940,000 pCi/L in 2000 to 6,850 pCi/L in 2019, which is a 99% decrease over 18 years. The plume area northeast of WMA T has decreased

based on declining concentrations in wells downgradient of WMA T. The decline in tritium concentrations is due to migration, dispersion, and radioactive decay.

4.4.1.3 Natural Attenuation Degradation Byproducts and Field Parameters

Natural attenuation processes are part of the cleanup remedy (along with P&T) to reduce COC concentrations to below cleanup levels. Natural attenuation processes relied upon to reduce COC concentrations include abiotic and biotic degradation, dispersion, dilution, sorption, and radioactive decay (for tritium). As presented in the 200-ZP-1 OU ROD (EPA et al., 2008), natural attenuation processes are relied upon to reduce COC concentrations to acceptable levels within about 100 years following cessation of P&T operations.

Chloroform, dichloromethane, and chloromethane are monitored as degradation byproducts of carbon tetrachloride; vinyl chloride and cis-1,2-dichloroethene are monitored as degradation byproducts of TCE; chloride is monitored as a general degradation byproduct of all chlorinated solvents; and nitrite is monitored to evaluate for evidence of nitrate reduction. Table 4-5 lists the average values for these products of attenuation processes, as well as the measured field parameters in the contaminant monitoring well network during 2019. These sample results, combined with results from previous years' monitoring, are used to establish a data set that can be analyzed to describe the baseline concentrations and trends in MNA indicator parameters. In 2019, an evaluation of biotic degradation rates for carbon tetrachloride was completed (PNNL-28846), which suggested that there is abundant site-specific evidence that supports conditions suitable for abiotic and biotic degradation in the 200 West Area aquifer. Biological degradation byproducts of carbon tetrachloride are present in 200-ZP-1 OU groundwater, suggesting that biotic processes do occur (in addition to abiotic hydrolysis) under conditions prevalent within 200-ZP-1 OU groundwater. However, the study found that the net sum of abiotic and biotic processes likely results in a half-life for carbon tetrachloride that is <400 years but not likely <100 years.

As the data set comprising degradation byproducts and other natural attenuation indicators increases, future reports will include trend-based analyses of parent contaminant data (e.g., carbon tetrachloride and TCE), as well as degradation product data and other groundwater geochemical and hydraulic conditions, to support evaluations of the likely contribution of natural attenuation processes to plume reduction, thereby providing a basis for the ultimate transition from P&T operations to MNA.

4.4.2 Hydraulic Monitoring

This section describes data obtained from the hydraulic monitoring network to evaluate conditions for the 200-ZP-1 OU during 2019. Initial baseline data for the 200-ZP-1 OU (collected in 2012, prior to startup of the 200 West P&T) are used for comparison to data obtained during later years to understand changes in groundwater levels, drawdown, saturated thickness, hydraulic containment extent, and patterns in contaminant distribution and movement within the aquifer beneath the 200-ZP-1 OU. In particular, potential impacts to the remedy from changing (primarily declining) groundwater elevations are discussed in Section 4.4.2.2.4.

Table 4-5. Average Concentrations of Natural Attenuation Degradation Byproducts and Field Parameters in the Contaminant Monitoring Well Network, 2019

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	cis-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (µg/L)	Oxidation-Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Vinyl Chloride (µg/L)
299-W10-1	23,650	2	<1	<1	<1	9,350	<77	244.3	8.07	442	17.35	10.76	<1
299-W10-14	10,500	<0.24	<0.2	<0.1	<0.27	4,060	<108	53.7	8	358	19.6	2.25	<0.19
299-W10-27	28,300	6.45	<0.3	<0.3	<1.6	6,062	<114.75	207.05	8.15	723.8	18.2	20.82	<0.3
299-W10-29*	17,000	—	—	—	—	9,980	<46	347.54	7.99	402.7	19.91	1.55	—
299-W10-30	16,750	0.75	<0.3	<0.3	<1.6	9,721.25	<108	366.91	7.96	381.65	19.99	1.79	<0.3
299-W10-31	26,000	0.57	<0.2	<0.1	<0.27	9,766.88	<46	367.87	7.93	487.3	18.69	1.61	<0.19
299-W10-33	6,900 (2017)	<0.3 (2017)	<0.3 (2017)	<0.3 (2017)	<1.6 (2017)	240 (2017)	181 (2017)	153.1 (2017)	8.01 (2017)	341 (2017)	19.7 (2017)	0.35 (2017)	<0.3 (2017)
299-W11-13	38,600	8.47	<0.3	<0.3	<1.6	8,920	<108	167.8	8.01	895	18.9	163.6	<0.3
299-W11-18	45,000	0.81	<0.3	<0.3	<1.6	8,160	<125	155.4	7.89	604	17.5	30.5	<0.3
299-W11-33Q	36,000 (2018)	1.7 (2018)	<0.2 (2018)	<0.1 (2018)	<0.27 (2018)	9,410 (2018)	<125 (2018)	364.5 (2018)	7.9 (2018)	559 (2018)	20.4 (2018)	4.23 (2018)	<0.19 (2018)
299-W11-43	28,000	2.27	<0.3	<0.3	<1.6	7,770	<125	143.4	7.42	782	17.3	1.45	<0.3
299-W11-45	17,500	7.4	<1	<1	<1	9,350	<72.25	338.2	7.94	540	18.25	1.38	<1
299-W11-47	23,650	4.76	<0.3	<0.3	<1.6	9,265	<77	199.2	7.99	708.5	20.65	6.18	<0.3
299-W11-48	17,100	8.14	<0.3	<0.3	<1.6	10,420	<108	200.4	8.05	554	18	0.23	<0.3
299-W11-87	35,700	9.02	<0.3	<0.3	<1.6	9,860	<108	197.7	7.74	690	19.7	1.66	<0.3
299-W11-88	11,000	1.42	<0.3	<0.3	<1.6	4,010	<125	129.1	7.79	757	17.6	0.92	<0.3
299-W13-1	35,000	7.99	<0.3	<0.3	<1.6	9,690	<125	205	7.8	500	11.8	2.19	<0.3
299-W13-2P	19,500	3.2	<0.32	<0.23	<0.27	9,990	<108	299.5	8.12	482	17.5	0.77	<0.19

Table 4-5. Average Concentrations of Natural Attenuation Degradation Byproducts and Field Parameters in the Contaminant Monitoring Well Network, 2019

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	cis-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (µg/L)	Oxidation-Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Vinyl Chloride (µg/L)
299-W13-2Q	20,000	2.6	<0.32	<0.23	<0.27	9,620	<46	351.6	7.88	484	18.3	0.2	<0.19
299-W14-11	23,450	3.3	<1.6	<1.2	<1.4	9,215	<61.5	232.77	7.65	727	20.95	2.18	<0.97
299-W14-13	27,325	4.3	<0.64	<0.47	<0.54	9,024	1,253.25	186.4	7.94	745	18.06	26.48	<0.39
299-W14-14	19,550	1.85	<0.3	<0.3	<1.6	9,127.5	<92.5	408.85	8.07	534.75	17.3	2.68	<0.3
299-W14-71	—	12.6	<0.3	<0.3	<1.6	8,820	—	326.6	7.83	350	20.7	16.2	<0.3
299-W14-72	14,000	10.6	<0.3	<0.3	<1.6	8,320	<108	165.7	7.87	410	18.8	0.54	<0.3
299-W15-11	26,700	0.98	<0.3	<0.3	<1.6	10,170	<108	190.2	7.89	516	19.3	0.4	<0.3
299-W15-152	32,633.33	0.35	<0.3	<0.3	<1.6	8,058.75	<108	364.1	7.81	553.13	19.64	0.74	<0.3
299-W15-17	37,000	0.36	<0.3	<0.3	<1.6	7,885	<46	415.6	8.01	388	18.5	1.84	<0.3
299-W15-224*	28,400	—	—	—	—	9,034.17	<77	—	7.9	555.75	19.1	2.14	—
299-W15-30*	32,100	—	—	—	—	6,915	1,080	—	8.06	534.75	19.84	2.51	—
299-W15-33	31,900	0.77	<0.33	<0.33	<1.67	9,540	<108	265.3	8.21	550	18.5	0.86	<0.33
299-W15-37	15,000 (2016)	5.25 (2016)	<0.3 (2016)	<0.3 (2016)	<1.6 (2016)	7,640 (2016)	<125 (2016)	177.4 (2016)	8.31 (2016)	436 (2016)	21.5 (2016)	1.21 (2016)	<0.3 (2016)
299-W15-42	52,000 (2016)	3.9 (2016)	<0.08 (2016)	<0.09 (2016)	<0.27 (2016)	8,670 (2016)	<125 (2016)	288.4 (2016)	7.74 (2016)	672 (2016)	21.4 (2016)	0.35 (2016)	<0.08 (2016)
299-W15-46	20,200 (2017)	0.38 (2017)	<0.1 (2017)	<0.1 (2017)	<0.27 (2017)	8,080 (2017)	<108 (2017)	135.1 (2017)	7.81 (2017)	515 (2017)	20 (2017)	2.62 (2017)	<0.19 (2017)
299-W15-49	30,700	0.57 (2018)	<0.3 (2018)	<0.3 (2018)	<1.6 (2018)	10,900	<108	269	7.98	575	18.6	2.47	<0.3 (2018)
299-W15-50	22,300 (2017)	1.8 (2017)	<0.1 (2017)	<0.1 (2017)	<0.27 (2017)	8,340 (2017)	<108 (2017)	37.8 (2017)	7.83 (2017)	596 (2017)	19.8 (2017)	0.73 (2017)	<0.19 (2017)

Table 4-5. Average Concentrations of Natural Attenuation Degradation Byproducts and Field Parameters in the Contaminant Monitoring Well Network, 2019

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	cis-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (µg/L)	Oxidation-Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Vinyl Chloride (µg/L)
299-W15-7	20,000	1	<0.32	<0.23	<0.27	9,900	<46	156.6	7.77	464	21.5	9.26	<0.19
299-W15-763	20,350	0.58	<1	<1	<1	8,965	<77	290.45	8.01	600.5	19.4	1.1	<1
299-W15-765	38,275	0.79	<0.32	<0.23	<0.27	9,502.5	<77	351.8	7.94	577.25	18.78	0.88	<0.19
299-W15-83	28,450	0.47	<0.32	<0.23	<0.27	8,024.17	<108	275.63	7.84	572.08	19.78	2.09	<0.19
299-W15-94	35,650	<1	<1	<1	<1	7,202.5	<77	315.88	7.81	571.75	19.46	0.51	<1
299-W18-1	31,400 (2017)	0.26 (2017)	<0.1 (2017)	<0.1 (2017)	<0.27 (2017)	7,990 (2017)	<108 (2017)	267.7 (2017)	7.84 (2017)	593 (2017)	19.2 (2017)	0.39 (2017)	<0.19 (2017)
299-W18-15	26,900 (2018)	0.46 (2017)	<0.3 (2017)	<0.3 (2017)	<1.6 (2017)	5,350 (2017)	<108 (2018)	205.5 (2017)	8.2 (2018)	458 (2018)	16.1 (2018)	18 (2018)	<0.3 (2017)
299-W18-16	23,600 (2017)	1.1 (2017)	<0.1 (2017)	<0.1 (2017)	<0.27 (2017)	9,660 (2017)	<108 (2017)	225.3 (2017)	7.88 (2017)	1,255 (2017)	20.1 (2017)	506 (2017)	<0.19 (2017)
299-W18-21	36,450	<0.3	<0.3	<0.3	<1.6	5,601.54	<77	170.92	8.19	621.38	18.52	106.52	<0.3
299-W18-22	21,350	0.42	<0.32	<0.23	<0.27	7,614.62	<108	191.34	7.99	436.15	21.02	1.76	<0.19
299-W18-40	24,000	1.58	<0.3	<0.3	<1.6	11,414.5	<112.25	64.98	7.9	471.52	20.75	3.45	<0.3
299-W19-105	4,400 (2017)	1.55	<0.3	<0.3	<1.6	8,930	223 (2017)	178.7	7.81	307	18.9	4.5	<0.3
299-W19-107	17,900	5.74	<0.3	<0.3	<1.6	10,030	<108	43.7	7.72	456	18.5	0.95	<0.3
299-W19-115	6,580	3.3	<0.32	<0.23	<0.27	8,725	<87.33	280.9	7.84	337.33	19.2	2.32	<0.19
299-W19-34A	7,900	1.95	<0.3	<0.3	<1.6	7,950	<125	281.9	7.83	328	19.9	6.91	<0.3
299-W19-34B	9,500 (2018)	5.69	<0.3	<0.3	<1.6	5,750	204 (2018)	425.3	7.76	349	19.5	0.99	<0.3
299-W19-36	10,533.33	9.3	0.76	<0.23	<0.27	7,450	<72.33	81.4	7.79	721	20.2	1.51	<0.19

Table 4-5. Average Concentrations of Natural Attenuation Degradation Byproducts and Field Parameters in the Contaminant Monitoring Well Network, 2019

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	cis-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (µg/L)	Oxidation-Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Vinyl Chloride (µg/L)
299-W19-4	25,000	3.6	<0.32	<0.23	<0.27	6,710	<46	306	7.97	567	21.1	3.83	<0.19
299-W19-41	30,375	3.35	<0.3	<0.3	<1.6	8,240	<81.25	133.5	8.26	483.75	17.93	2.91	<0.3
299-W19-47	17,150	2.77	<0.3	<0 (0)	<1.6	8,790	<96.75	375.2	7.78	505.75	18.43	2.06	<0.3
299-W19-48	6,270	0.6	<0.32	<0.23	<0.27	8,250	<108	211.3	7.87	288	21.1	3.67	<0.19
299-W19-49	6,500	1.14	<0.3	<0.3	<1.6	8,780	<46	213.5	7.9	311	22.6	3.83	<0.3
299-W19-6	5,110	3.08	<0.3	<0.3	<1.6	6,330	<108	244.8	7.84	281	19.4	4.59	<0.3
299-W21-2	11,800	1.13	<0.3	<0.3	<1.6	7,860	<108	296.8	7.7	384	22.3	12.9	<0.3
299-W22-47	6,690	1.6	<1	<1	<1	7,990	<108	216.8	7.74	255.5	17.3	1.15	<1
299-W22-72	9,580	2.43	<0.3	<0.3	<1.6	7,160	<108	320.4	7.8	335.5	21.45	30.25	<0.3
299-W22-86	5,620	1.38	<0.3	<0.3	<1.6	6,950	<594	288.4	7.8	293	22.9	1.7	<0.3
299-W22-87	5,180	0.51	<0.32	<0.23	<0.27	8,760	<108	228.4	7.97	283.5	19.35	2.45	<0.19
299-W22-88	20,000 (2016)	0.89	<1	<1	<1	7,280	<125 (2016)	241.8	7.85	397	21.2	3.59	<1
299-W23-19	15,060	1.35	<0.32	<0.23	<0.27	8,610	<118.8	481.4	7.74	517.5	19.05	4.4	<0.19
299-W23-4	12,100	1.07	<0.3	<0.3	<1.6	8,610	<66.67	210.2	7.94	328.5	16.9	5.15	<0.3
299-W26-13	6,293.33	<0.3	<0.3	<0.3	<1.6	8,647.5	<108	251.14	7.81	325.5	18.48	2.13	<0.3
299-W27-2	20,300	0.45	<0.3	<0.3	<1.6	7,760	<108	226.1	7.7	368	17.9	7.84	<0.3
299-W5-2P	21,800	3.24	<0.3	<0.3	<1.6	8,320	<108	165.9	7.39	1221	17.1	0.22	<0.3
299-W5-2Q	15,000	4	<0.8	<0.59	<0.68	7,980	<46	196.8	7.45	1189	17.4	0.17	<0.49

Table 4-5. Average Concentrations of Natural Attenuation Degradation Byproducts and Field Parameters in the Contaminant Monitoring Well Network, 2019

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	cis-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (µg/L)	Oxidation-Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Vinyl Chloride (µg/L)
299-W6-11*	6,100 (2018)	—	—	—	—	10,660 (2018)	<125 (2018)	10.31 (2018)	8.08 (2018)	373.5 (2018)	16.1 (2018)	3.56 (2018)	—
299-W6-12*	—	—	—	—	—	9,810 (2018)	—	—	8.33 (2018)	314 (2018)	14.4 (2018)	18.8 (2018)	—
299-W6-3	10,600	1.2	<0.2	<0.1	<0.27	5,705	<108	173.6	7.93	828.5	18.65	4.38	<0.19
299-W6-6	45,000	<0.3	<0.3	<0.3	<1.6	13,225	<125	299.2	7.65	665.5	14.1	4.58	<0.3
299-W7-3	4,800	0.7	<0.32	<0.23	<0.27	3,556.67	<108	150.2	8.13	310.75	17.15	1.57	<0.19
699-30-66	9,690 (2015)	0.37	<1	<1	<1	6,990	<125 (2015)	366.3	7.54	391	20.3	0.31	<1
699-32-62	8,320	0.83	<0.3	<0.3	<1.6	9,900	<108	245.9	8.06	362	18.9	4.09	<0.3
699-32-72A	10,600	0.61	<0.3	<0.3	<1.6	5,840	<108	214.6	8.02	344	20.6	3.64	<0.3
699-33-75	11,500	0.39	<0.3	<0.3	<1.6	8,497.5	<46	380.76	7.71	290.63	18	2.1	<0.3
699-34-61	10,800	0.99	<0.3	<0.3	<1.6	9,640	<108	241.5	7.92	391	19.6	18.2	<0.3
699-35-66A	12,133.33	1.1	<0.2	<0.1	<0.64	6,860	226.67	214.2	7.97	386	21.35	5.01	<0.6
699-35-78A	12,300 (2015)	0.7	<0.3	<0.3	<1.6	5,340	<125 (2015)	402.9	8	318	16.3	3.63	<0.3
699-36-61A	24,400	0.34	<0.32	<0.23	<0.27	8,030	<108	439.1	7.72	500	20.4	18.5	<0.19
699-36-66B	23,500	0.73	<1	<1	<1.3	7,690	<46	221.3	7.84	475	21.45	1.55	<0.65
699-36-70A	13,400	0.52	<0.3	<0.3	<1.6	7,780	311.2	346.1	7.95	370	20.8	1.03	<0.3
699-36-70B	14,600	1.7	<0.32	<0.23	<0.27	10,810	<108	84.4	7.84	527	23.2	28.9	<0.19
699-37-66	17,766.67	0.68	<0.2	<0.1	<0.51	9,500	<108	222.4	7.73	613	21.35	3.18	<0.46

Table 4-5. Average Concentrations of Natural Attenuation Degradation Byproducts and Field Parameters in the Contaminant Monitoring Well Network, 2019

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	cis-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (µg/L)	Oxidation-Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Vinyl Chloride (µg/L)
699-38-61	33,000	<0.3	<0.3	<0.3	<1.6	7,900	<125	395.6	7.87	560	19.6	1.19	<0.3
699-38-65	16,400	0.41	<1	<1	<1	7,120	<108	272.7	7.97	685	21.2	4.86	<1
699-38-68A	29,000 (2018)	1.5 (2018)	<0.1 (2018)	<0.1 (2018)	<0.27 (2018)	10,500 (2018)	427 (2018)	330.3 (2018)	8.04 (2018)	707 (2018)	17.5 (2018)	121 (2018)	<0.19 (2018)
699-38-70B	22,000	4.89	<0.3	<0.3	<1.6	9,740 (2018)	<46	367.6	7.69	535	20.4	2.02	<0.3
699-38-70C	20,300	1.9	<0.32	<0.23	<0.27	11,710	<108	161.5 (2018)	7.6	632	21.1	3.1	<0.19
699-40-62	26,000	<0.24	<0.2	<0.1	<0.27	8,200	<125	374.1	7.89	660	20.4	2.61	<0.19
699-40-65	21,400	2.63	<0.3	<0.3	<1.6	9,580	<108	371.5	7.63	723	20.9	0.42	<0.3
699-43-69	31,000	4	<0.4	<0.2	<0.54	10,170	<46	252.3	7.88	507	20.8	4.91	<0.39
699-44-64	23,000	1.3	<0.32	<0.23	<0.27	6,510	<46	227.4	7.91	484	21	4.39	<0.19
699-45-69A	16,500	<0.24	<0.32	<0.23	<0.27	6,100	<108	125.6	7.11	305	17.7	243	<0.19
699-45-69C	20,000	1.5	<0.32	<0.23	<0.27	10,500	<46	181.4	7.81	763	20.5	2.94	<0.19
699-47-60	9,910	<0.65	<0.3	<0.3	<1.3	7,240	<108	127.5	8.22	401	17.7	2.99	<0.65
699-48-71	210,000	7.47	<0.3	<0.3	<1.6	1,560	<125	180.8	5.92	2287	18.3	23.7	<0.3
699-50-74	1,860	0.61	<0.32	<0.23	<0.27	9,180	<108	207.8	8.22	277	20.6	3.23	<0.19
699-51-63	14,000	<1	<1	<1	<1	7,600	<46	342.8	7.96	366	19	5.4	<1

Table 4-5. Average Concentrations of Natural Attenuation Degradation Byproducts and Field Parameters in the Contaminant Monitoring Well Network, 2019

Well	Chloride (µg/L)	Chloroform (µg/L)	Chloromethane (µg/L)	cis-1,2-Dichloroethylene (µg/L)	Dichloromethane (µg/L)	Dissolved Oxygen (µg/L)	Nitrite (µg/L)	Oxidation-Reduction Potential (mV)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Vinyl Chloride (µg/L)

Notes:

The less than symbol (<) indicates that the sample result was below the listed detection limit.

Concentrations are averaged for all sample results collected throughout the year from each monitoring well for each contaminant.

If sample data were not available for 2019, the year applicable to the sample data is provided in parenthesis following the value.

*Well added for sampling in accordance with TPA-CN-0875, *DOE/RL-2009-115, Tri-Party Agreement Change Notice Form: DOE/RL-2009-115, Performance Monitoring Plan for the 200-ZP-1 Groundwater Operable Unit Remedial Action, Revision 2*. The change notice was approved in November 2019, so sampling was not performed as part of routine 2019 sampling.

— = analyses not required

4.4.2.1 Hydraulic Monitoring Network

The hydraulic monitoring network for the 200-ZP-1 OU groundwater remedy incorporates water levels obtained as follows (Figure 4-6):

- From monitoring wells using manual (depth-to-water) measurements
- From monitoring wells using pressure transducers with data loggers, with records stored on the data logger and retrieved using telemetry (referred to as the automated water-level network [AWLN])
- From extraction and injection wells using pressure transducers, with records stored in the central treatment system supervisory control and data acquisition system

Groundwater-level data obtained during 2019 include water levels obtained during both synoptic water-level campaigns (i.e., over a short time period from a defined group of wells covering a wide area throughout the 200-ZP-1 OU). Data are obtained continuously from the AWLN, which incorporates a smaller number of wells than measured during synoptic surveys but provides continuous data at those locations.

A synoptic water-level event occurred in March 2019 at which time water levels were obtained from over 100 monitoring wells in the 200-ZP-1 OU and additional wells in the 200-UP-1 OU and 200 East Area. In addition to this synoptic event, water levels were recorded throughout 2019 using pressure transducers and data loggers from select monitoring wells in the 200-ZP-1 OU, plus additional monitoring wells instrumented with pressure transducers and data loggers within the adjacent 200-UP-1 OU P&T remedy areas. To prepare the water-level maps and related analyses in this report, a combination of manual water-level data and records from the AWLN were used for water table mapping and related mapping-based analyses, with the number of wells providing data varying each month depending on data availability.

Water levels were also recorded in extraction and injection wells that were instrumented with pressure transducers and actively operated during 2019, which varied in number throughout the year.

4.4.2.2 Hydraulic Monitoring Data

This section presents the water-level data obtained during 2019 and provides initial depictions of the data. Section 4.5 provides more detailed data interpretation.

When reviewing and interpreting water-level data, flow rates recorded at extraction and injection wells are also reviewed to help understand probable causes of changing groundwater levels. Analyses of water-level data generally focus on conditions during the month of December, representing the cumulative effect of sustained pumping achieved by the end of the year. Figure 4-1 shows extraction and injection rates typical of operations during December 2019. The 200 West P&T average total throughput for December 2019 was 9,369 L/min (2,475 gal/min), which combines groundwater extracted from the 200-ZP-1, 200-UP-1, and 200-BP-5 OUs and 200-DV-1 OU perched water.

4.4.2.2.1 Water-Level Hydrographs

Figures 4-7 through 4-9 present water-level hydrographs for selected monitoring wells within the AWLN that are located near 200-ZP-1 OU groundwater extraction wells. These figures show changes in groundwater elevations (shown using continuous lines) in response to changing pumping rates at the closest remedy well (shown as gray-shaded “top-down” columns).

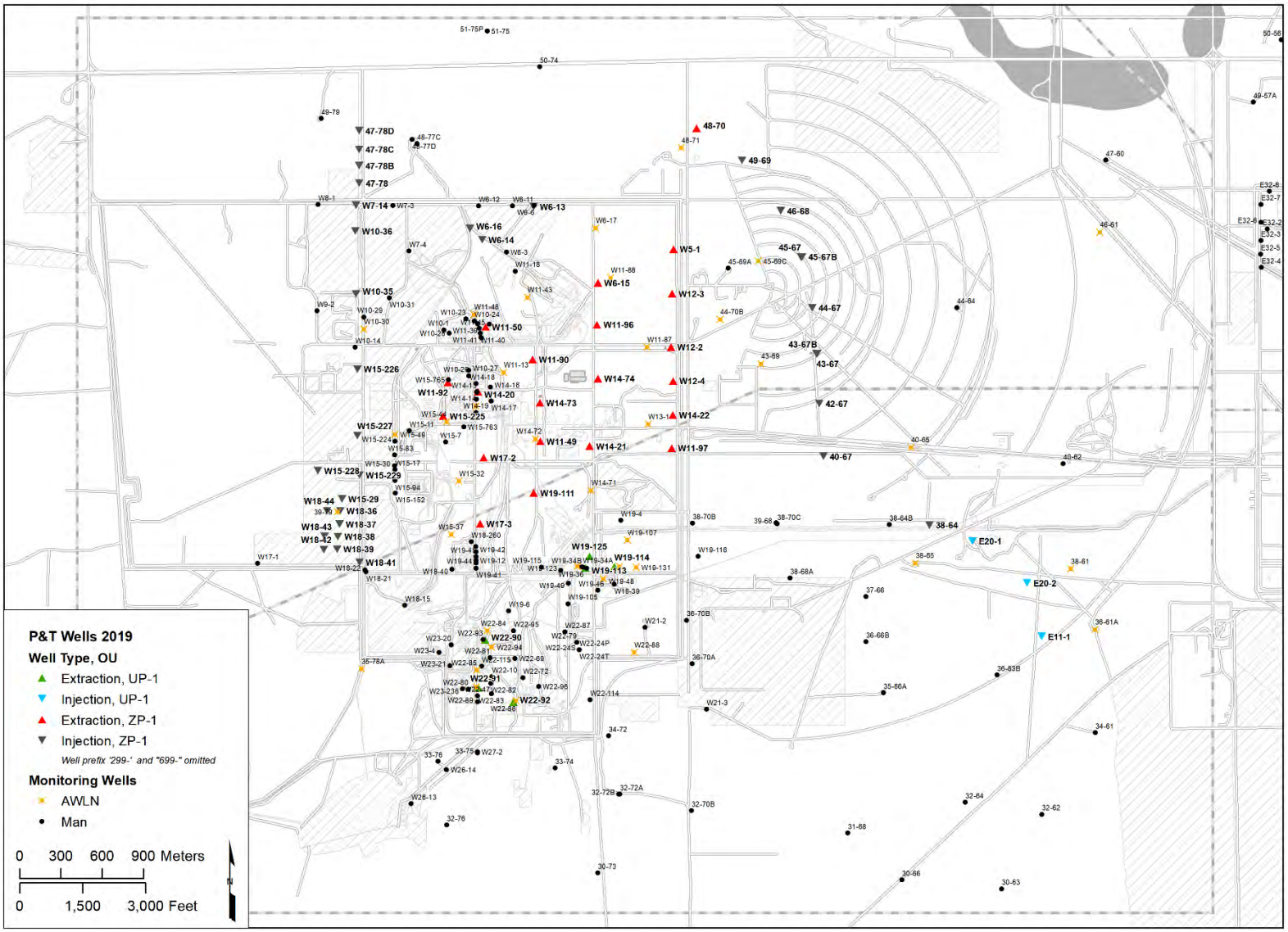

Figure 4-6. Location of Monitoring Wells with Groundwater Elevation Data During 2019

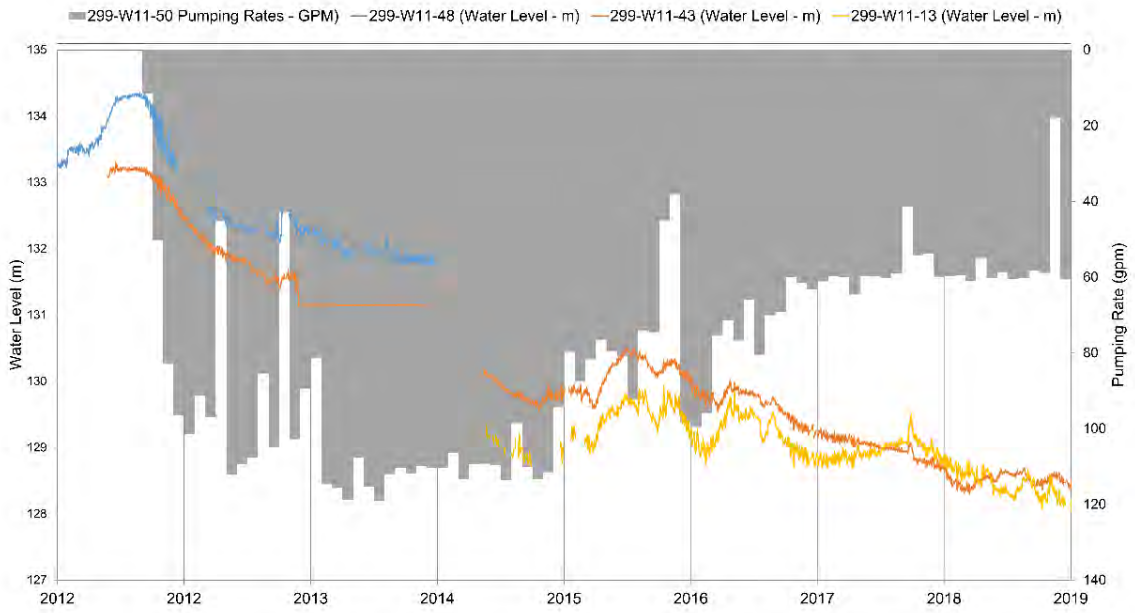

Figure 4-7. Water-Level Hydrographs for Selected Monitoring Wells Located Near Groundwater Extraction Well 299-W11-50

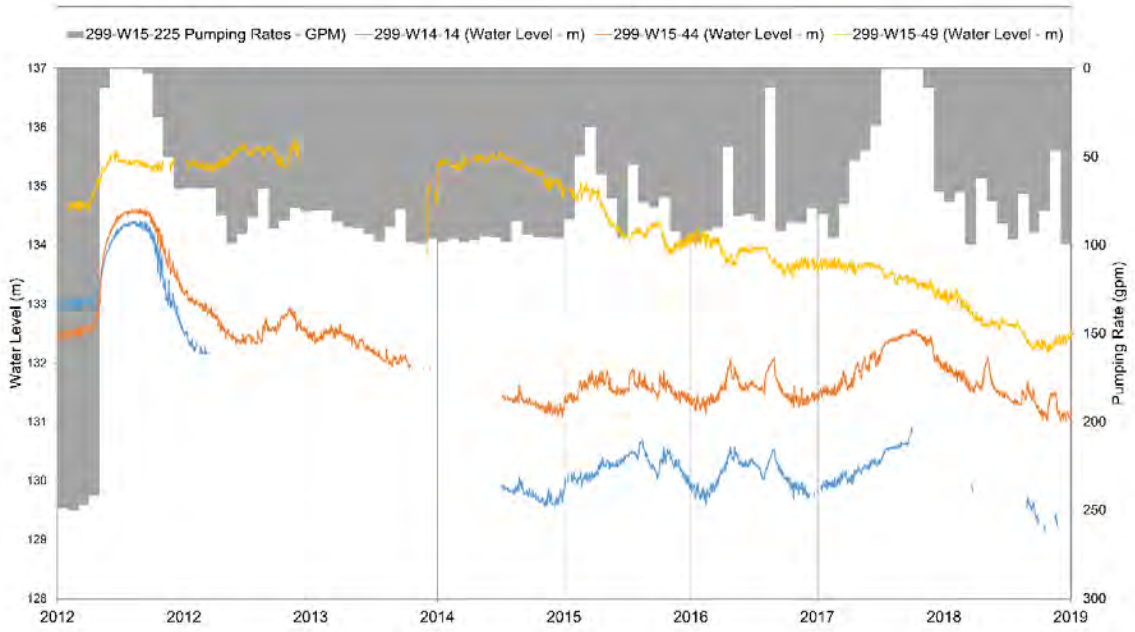

Figure 4-8. Water-Level Hydrographs for Selected Monitoring Wells Located Near Groundwater Extraction Well 299-W15-225

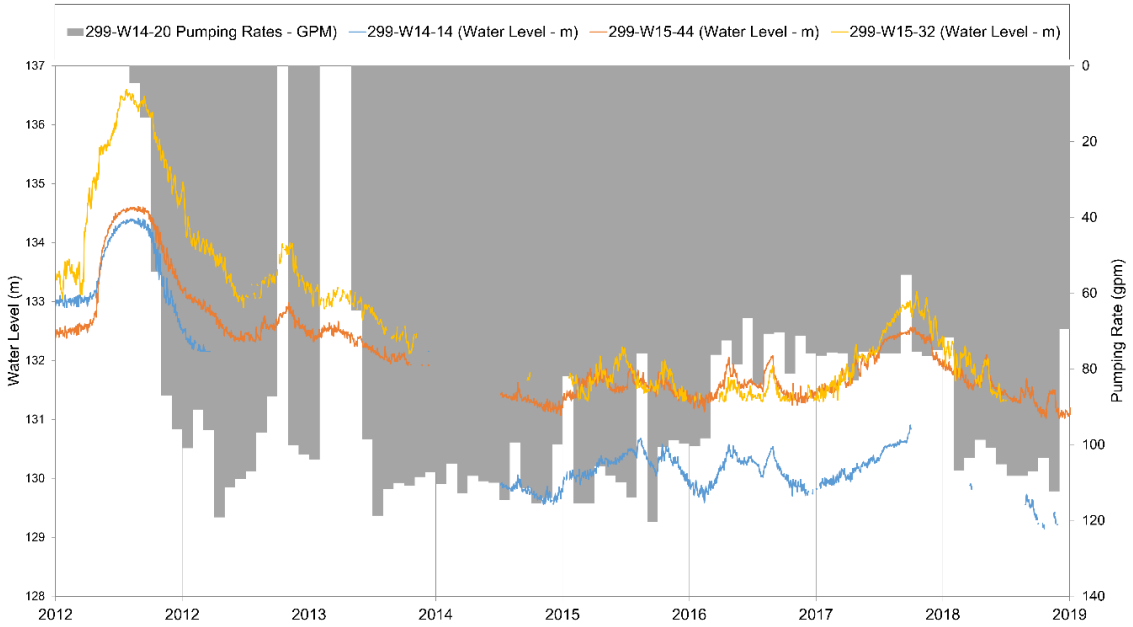

Figure 4-9. Water-Level Hydrographs for Selected Monitoring Wells Located Near Groundwater Extraction Well 299-W14-20

4.4.2.2.2 Mapped Water Levels

Figure 4-10 (panels a and b) shows the contoured groundwater elevations during June 2012 (prior to startup of the final 200-ZP-1 P&T remedy [top panel]) and during December 2019 (when the 200 West P&T was operating [bottom panel]) prepared by interpolating data obtained from monitoring wells screened above the Rlm within the Rwie. The contours that depict the water table during June 2012 (top panel in Figure 4-10) show general patterns when a P&T remedy was not operating in the 200 West Area (DOE/RL-2013-14 provides details on the original preparation of these contours). The December 2019 map was constructed using the method described in SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*, with a combination of manual water-level data, AWLN data, and concurrent groundwater extraction and injection pumping data at operating P&T remedy wells. As described in SGW-42305, kriging incorporates (in an approximate manner) drawdown and mounding resulting from groundwater extraction and injection above the Rlm. Differences between the contoured water levels using data from December 2019 (bottom panel in Figure 4-10) and June 2012 show the pattern of groundwater-level changes due to extraction and injection since the 200-ZP-1 OU (and to a lesser extent, the neighboring 200-UP-1 OU) P&T remedy began operating.

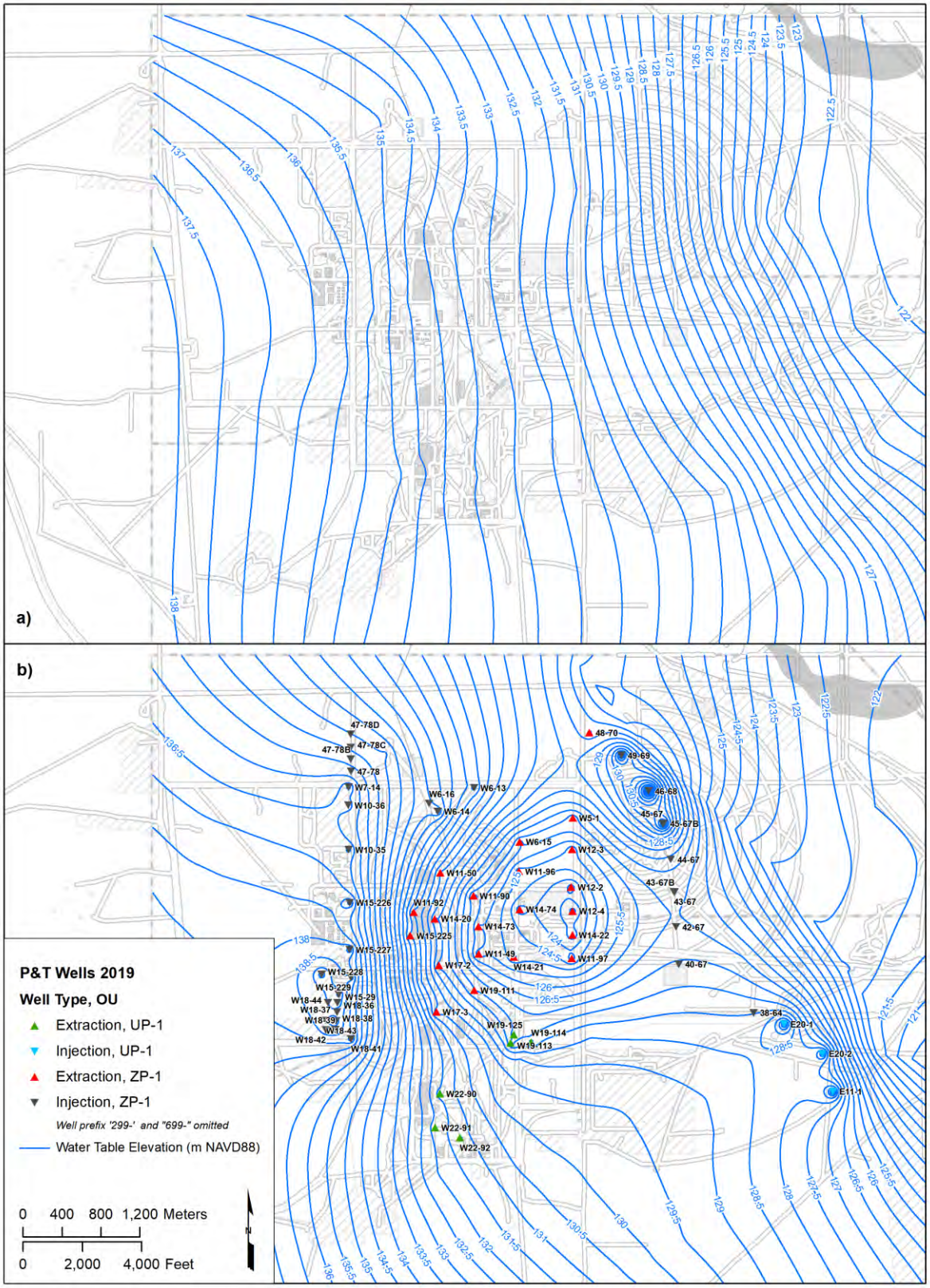

Figure 4-10. Groundwater Elevation Contours Computed Using Water-Level Mapping: (a) Above the Rlm in June 2012 and (b) Above the Rlm in December 2019

4.4.2.2.3 Mapped Drawdown and Mounding

Comparison of panels a and b in Figure 4-10 identifies areas of groundwater mounding in response to injection and drawdown in response to extraction at wells screened partially or entirely above the Rlm. Because most groundwater extraction occurs above the Rlm, drawdown and mounding are clearly shown in the contours, and Figure 4-10 (panel b) shows a well-defined area of convergent hydraulic gradients centered on the extraction wells. Figure 4-11 shows two depictions of groundwater-level changes, calculated using the same water-level mapping method for data above the Rlm between June 2012 and December 2019. Noting that the water table in the Central Plateau is still declining in many areas due to cessation of historical operational water discharges to the subsurface (in 2014, the decline rate was estimated to be about 0.22 to 0.27 m/yr [0.72 to 0.89 ft/yr]), Figure 4-11 (panel a) shows the simple difference between the June 2012 and December 2019 water-level contours (i.e., unadjusted change). Figure 4-11 (panel b) shows the difference between the June 2012 and December 2019 water-level contours when incorporating the background decline of about 1.858 m (about 6.09 ft) from June 2012 to December 2019 that is not due to P&T operations (i.e., adjusted change). Therefore, Figure 4-11 (panel b) approximates the change in groundwater levels that are solely due to operation of the P&T systems in the 200 West Area. In both figures, the region of mounding on the east side of the 200-ZP-1 P&T remedy is shown to continue to the east-southeast, toward the line of injection wells designed to slow the migration of iodine from the 200-UP-1 OU.

It is important to note that the extent of drawdown is not the same as the extent of hydraulic containment, which is discussed in Section 4.4. The water-level maps, drawdown maps, and derived hydraulic containment maps (Section 4.4) are interpreted as reasonable approximations of groundwater conditions that help interpret directions and rates of groundwater movement and the likely extent of convergent hydraulic gradients that combine to develop hydraulic containment. Water-level, drawdown, and hydraulic containment depictions computed using the P2R Model are presented in this report for comparison with the interpolated water-level, drawdown, and hydraulic containment maps.

4.4.2.2.4 Potential Impacts to the Remedy from Changing Groundwater Elevations

Groundwater elevation changes computed from water-level data are generally consistent with expectations based on the 200-ZP-1 OU remedy design, as described in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE). Two particular potential impacts to the remedy are considered from changing groundwater elevations: (1) impacts to the monitoring network (discussed in this section); and (2) impacts to groundwater extraction and injection effectiveness and, therefore, hydraulic containment and contaminant mass recovery (discussed in Section 4.5).

As noted in SGW-50907, *Predicted Impact of Future Water-Level Declines on Groundwater Well Longevity within the 200 West Area, Hanford Site*, water-level declines due to a combination of background regional decline, plus groundwater extraction associated with remediation, will cause some monitoring wells to go dry. This will prevent groundwater samples and water levels from being obtained at those locations, which is expected to be the most pronounced in areas near extraction wells. SGW-50907 projected that 29 wells would become sample dry (i.e., exhibit <0.9 m [3 ft] of water above the bottom of the screened interval and, therefore, insufficient water depth to allow sampling pump operation) soon after startup of the 200 West P&T. During 2019, the remaining wells that were predicted to go dry but had not yet gone sample dry were wells 299-W7-4, 699-48-77D, and 299-W18-21. In addition to these wells, well 299-W19-18 was not sampled in 2019 due to insufficient water (i.e., sample dry). SGW-50907 also projected that some wells may recover over time due to nearby injection of treated water from the 200 West P&T central treatment facility. For example, well 299-W8-1, which was sample dry during 2012, now contains sufficient water for sampling and has been undergoing routine sampling.

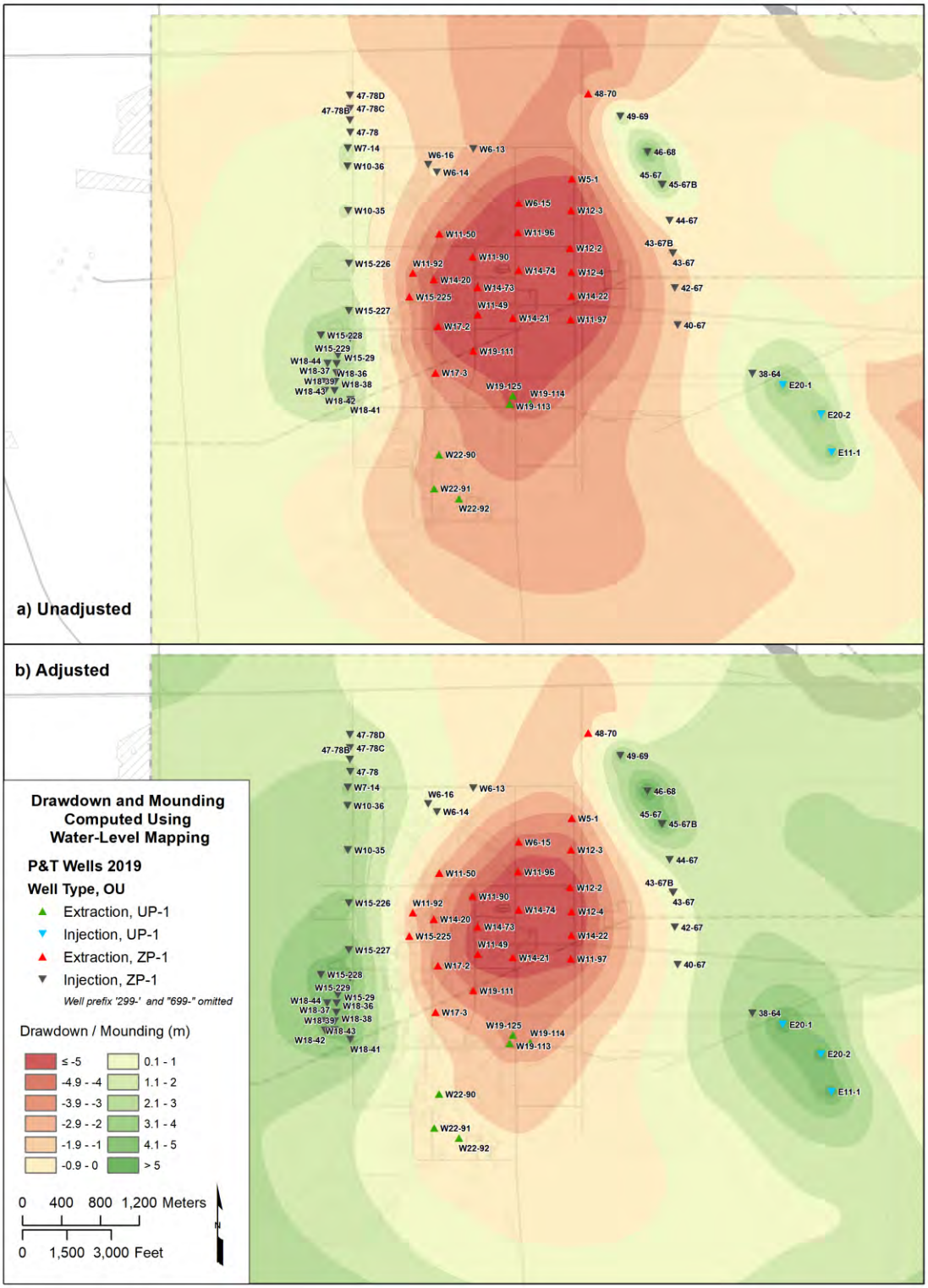

Figure 4-11. Drawdown and Mounding Computed Using Water-Level Mapping Above the Rlm Between June 2012 and December 2019: (a) Unadjusted and (b) Adjusted Calculation

The analysis presented in SGW-50907 (which includes estimates of the time remaining until monitoring wells are "sample dry) is currently being updated. This evaluation will be used to support modeling studies conducted as part of the optimization study. The modeling calculations completed during the optimization study will also be processed to indicate the extent to which remedy alternatives may exacerbate the need for monitoring well replacements due to sample-dry conditions.

An additional potential consequence of changing groundwater elevations is the residualization of sorbing contaminants within the vadose zone as water levels decline. The potential for this occurrence is best evaluated through planned rebound (i.e., shutdown and startup) activities.

4.4.3 Performance Data Evaluation Methods and Tools

This section summarizes the methods and tools used to evaluate the performance monitoring data.

4.4.3.1 Data Evaluation

Monitoring data are initially evaluated by plotting time series (including water-level and sample concentration time series) to assess data reliability, to assess consistency with or changes from prior data, and to compare with regulatory standards (or other target concentrations) to qualitatively assess progress toward attaining intermediate goals or final RAOs. Emphasis is placed on water-level and sample data obtained from wells listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2); however, this is supplemented with data from other wells within the 200-ZP-1 OU and adjacent 200-UP-1 OU when available. Data obtained from extraction and injection wells, including pumping rates and water levels, are also plotted as time series for review and for use in evaluating changes in well capacity over time. Monitoring data are also evaluated by preparing maps and other graphics (e.g., histograms) to compare recent results with baseline values.

The initial plots, maps, and graphs are then combined with the use of more interpretative methods for data processing and depiction (e.g., spatial or temporal trends); to combine data to prepare maps; to compute descriptive statistics; and to prepare inputs for, or help interpret the outputs from, groundwater modeling calculations. These calculations form the basis for interpreting the monitoring data in the context of the targets, goals, and RAOs presented in this report.

Outputs from the foregoing calculations include the following:

- Two-dimensional maps of groundwater elevations, drawdown, saturated thickness, and hydraulic containment
- Three-dimensional estimates of the extent of contamination
- Statistical analysis of contaminant concentrations over time (i.e., trends) for individual wells and for the entire 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) monitoring network

Projections of anticipated remedy performance in terms of attaining the RAOs are then completed using the P2R Model.

4.4.3.2 Analysis Using the Plateau to River Model

Toward the end of 2019, a process began to retire the CPGWM and transition to the P2R Model to provide both near-field and far-field simulation capability integrated between 200 West and 200 East Areas (CP-57037). As was the case for the CPGWM, the P2R Model was constructed using MODFLOW to simulate groundwater flow and MT3DMS to simulate contaminant transport. The model transition began late in 2019 and was completed in March 2020, which was in sufficient time for modeling-based analyses presented in this P&T report to be completed using the P2R Model. In doing so, the P2R Model

was updated with inputs through the end of 2019, providing a basis for the use of the P2R Model to support future P&T reports.

In this report, the P2R Model is used for the following purposes: (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 progress toward attaining short-term targets, intermediate-term goals, and the RAOs. The P2R Model will be updated each year to incorporate actual (monthly averaged) extraction and injection rates to minimize differences between actual and simulated flows. Application of the P2R Model for remedy evaluation purposes for this report for 2019 is described in ECF-HANFORD-20-0049, which also provides the calculation methods used to evaluate hydraulic containment and mass recovery for 2019.

4.5 Performance Data Evaluation

This section presents evaluations of the contaminant sampling data (Section 4.4.1) and hydraulic data (Section 4.4.2).

4.5.1 Evaluation of Contaminant Data

This section presents evaluations of the contaminant data obtained from wells throughout the 200-ZP-1 OU and, where appropriate, the adjacent 200-UP-1 OU. Most of the analyses focus on data obtained from wells included in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2). The data and associated analyses provide information on the extent of groundwater contamination, concentration trends at individual wells and throughout the OU, and the impact of groundwater extraction on concentration trends for 200-ZP-1 OU COCs. These assessments are critical to understanding how the remedy is performing to meet near-term targets and goals. However, because the remedy is anticipated to operate for decades to allow the groundwater P&T and natural attenuation processes to reduce concentrations, it is difficult to accurately predict the rate of progress toward attaining groundwater cleanup levels.

4.5.1.1 Two-Dimensional and Three-Dimensional Plume Maps

Two- and three-dimensional estimates of the extent of groundwater contaminated above cleanup levels (as presented in the 200-ZP-1 OU ROD [EPA et al., 2008] and the 200-ZP-1 P&T RD/RAWP [DOE/RL-2008-78 Rev. 0 REISSUE]) are used to help design, evaluate, and optimize the groundwater remedy. Two-dimensional depictions of contamination for all 200-ZP-1 OU COCs are used to illustrate the general contamination extent, whereas three-dimensional plume shells are constructed for some COCs for use in F&T calculations and to provide a comprehensive depiction of contamination to evaluate remedy performance. The plume shells provide mass estimates for carbon tetrachloride and other COCs to evaluate the attainment of mass removal goals, to project the likely effectiveness of the 200 West P&T remedy in achieving RAOs, and to identify changes to extraction and injection rates that should accelerate attainment of these goals and RAOs. Details on the preparation of the two-dimensional plume maps are provided in ECF-HANFORD-20-0018. Details on the preparation of the three-dimensional plume shells and figures presented for carbon tetrachloride and nitrate are provided in ECF-200W-20-0052 and are summarized in the following discussion.

4.5.1.2 Overview of Plume Mapping Methods

This section summarizes various efforts made over time to depict the three-dimensional extent of carbon tetrachloride and, from time to time other COCs, before presenting the most recently prepared three-dimensional depictions of contamination extents.

During 2007 and 2008, to support the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE), three-dimensional depictions of carbon tetrachloride and other COCs were prepared using ordinary kriging, uniform-score transform (quantile) kriging, and sequential Gaussian simulation (SGSIM) (DOE/RL-2009-38, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial Design/ Remedial Action Work Plan*). The extent and mass of groundwater contamination estimated using these techniques varied, reflecting uncertainties in contamination extent and differences between the methods. In particular, extents and masses estimated using SGSIM were higher than when estimated using other methods.

Since 2009, drilling of new wells revealed a greater presence of carbon tetrachloride beneath the Rlm and within the lower portion of the Rwie (in areas where the Rlm is absent). Extraction wells have since been constructed to the top of the basalt where the Rlm is absent to provide for flow-path control, containment, and capture of contamination in these deeper parts of the aquifer. During 2012, carbon tetrachloride and other COCs were mapped in three dimensions (ECF-200ZP1-13-0006, *Description of Groundwater Modeling Calculations for the Calendar Year 2012 (CY2012) 200 Areas Pump-and-Treat Report*) using quantile kriging. The three-dimensional estimates were again updated using the same method for the 2015 P&T report (DOE/RL-2016-20) with data obtained through 2015, providing initial conditions for F&T modeling (ECF-200ZP1-16-0076, *Description of Groundwater Calculations and Assessments for the Calendar Year 2015 (CY 2015) 200 Areas Pump and Treat Report*).

During 2017 and 2018, the three-dimensional extents of carbon tetrachloride and nitrate were re-evaluated using both quantile kriging and SGSIM, as used during preparation of the P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE). ECF-200W-18-0028, *Evaluation of Three-Dimensional Extent of Carbon Tetrachloride and Nitrate in Groundwater for 200-West for Calendar Years (CY) 2015 and 2017*, details the calculations, indicating that the extents were estimated using data obtained for two periods: (1) sample results from 2014 through 2015, and (2) sample results from 2017. Plume shells estimated using data from 2014 through 2015 were used as initial conditions for contaminant F&T modeling (using the approach described in Section 4.5), enabling simulated and measured concentrations and mass recovery in wells and for the 200 West P&T treatment system as a whole to be compared from 2015 through 2018. The three-dimensional extents estimated using 2017 data were used to prepare depictions of current conditions presented in ECF-HANFORD-18-0013, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2017 Hanford Site Groundwater Monitoring Report*. The process used to prepare plume shells using data from 2014 through 2015 for use as initial conditions in F&T simulations is summarized below and detailed in ECF-HANFORD-18-0013.

As detailed in ECF-200W-18-0028 and ECF-HANFORD-18-0013, quantile kriging provides a single plume shell, whereas SGSIM provides multiple realizations (in this case, 100 alternate realizations of the extent of carbon tetrachloride and nitrate). When multiple realizations were generated to prepare the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE), the mass present in the arithmetic or expected (i.e., E-type) average was substantially larger than that generated using ordinary kriging and was interpreted as likely overstating the mass of carbon tetrachloride present. Since that time, data obtained from individual extraction wells and for the entire P&T system help constrain the likely mass of carbon tetrachloride and nitrate present in groundwater. This information was used (as described in ECF-200W-18-0028 and ECF-HANFORD-18-0013) to develop a weighted-average plume from the 100 SGSIM realizations, which (combined with the plume derived from quantile kriging) assists in characterizing the carbon tetrachloride extent in groundwater.

For the 2018 annual P&T report (DOE/RL-2018-68), the three-dimensional extents of carbon tetrachloride and nitrate were updated using only the quantile kriging approach (as documented in ECF-HANFORD-19-0010, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2018 Hanford Site Groundwater Monitoring Report*) using 2018 data. The previous analyses completed in 2017 using the SGSIM method were not revisited using 2018 data.

For this 2019 P&T report, three-dimensional extents of contamination were prepared as follows:

- **Method 1:** For carbon tetrachloride only, three-dimensional extents representing current conditions were estimated using quantile kriging with data through 2019 to provide a current depiction of carbon tetrachloride extents in figures.
- **Method 2:** For all COCs (including carbon tetrachloride), three dimensional extents representing conditions during 2015 were estimated using quantile kriging as follows (detailed in ECF-200W-20-0052):
  - Sample data from 2014 and 2015 without modification
  - Sample data from 2016 through 2019, backtracked in time and space using the P2R Model, to their estimated locations during 2015
  - Scaling of the resulting three-dimensional plume based on comparison of simulated with measured mass recovery at extraction wells over the period from 2015 through 2019

Because of the mass constraint that is applied, the three-dimensional extents prepared using Method 2 are the most suitable for use with the P2R Model to make predictions of the future F&T of the COCs in the 200-ZP-1 OU. The extents prepared using Method 1 can be used as an (alternative) representation of the current extents for carbon tetrachloride. Figures and discussions presented in the following sections regarding the three-dimensional extent of carbon tetrachloride emphasize and contrast the newly constructed depiction prepared using Method 1 with that prepared using SGSIM with 2017 data. For the remaining COCs, two-dimensional depictions are used in most maps and comparisons.

Although the previous analyses completed in 2017 using the SGSIM method were not updated or revised using more recent data, the plumes that were generated in 2017 using the SGSIM method for use with the CPGWM were translated to the three-dimensional grid structure of the P2R Model so the SGSIM plumes could be used for comparison with the plumes prepared using the quantile kriging method (ECF-200W-20-0052).

4.5.1.3 Carbon Tetrachloride Summary

DOE/RL-2013-14 provides historical carbon tetrachloride plume maps showing the gradual reduction and elimination (between 1995 and 2004) of the high-concentration area around the PFP. During 2019, none of the monitoring locations exhibited carbon tetrachloride concentrations >2,000 µg/L. However, as sample data were obtained throughout the entire aquifer thickness since issuance of the 200-ZP-1 OU ROD (EPA et al., 2008), the estimated carbon tetrachloride plume extent above the 100 µg/L level targeted for hydraulic containment and the 3.4 µg/L cleanup level RAO has increased.

Figure 4-12 shows the current estimated carbon tetrachloride footprint above the Rlm (panel a) and below the Rlm (panel b) as derived from three-dimensional quantile kriging using data obtained through 2019. To produce the figures shown in panels a and b of Figure 4-12, outputs from three-dimensional quantile kriging were post-processed to identify and contour the maximum concentration in any layer in the three-dimensional grid above and below the Rlm, respectively. The resulting maps show carbon tetrachloride extending east, north, and south of documented source areas. The area of the carbon

tetrachloride plume is estimated from these maps to be >20 km^2 (7.9 mi^2). Because carbon tetrachloride in the 200-UP-1 OU is attributed to contamination migrating from the 200-ZP-1 OU, carbon tetrachloride concentrations are monitored in numerous wells in the 200-UP-1 OU (DOE/RL-2009-115, Rev. 2).

For comparison, Figure 4-13 shows the carbon tetrachloride footprint above the Rlm (panel a) and below the Rlm (panel b), as estimated using the weighted-average plume derived from the 100 SGSIM realizations (ECF-200W-18-0028) with data obtained during 2017. These figures remain unchanged from those presented in the 2017 annual P&T report. Although the general extent and geometry are similar to those shown from quantile kriging, the core area of the plume derived from quantile kriging is more focused and highly concentrated than that derived from SGSIM, and the plume footprint is (in most places) larger for the plume prepared using SGSIM. Figures 4-14 and 4-15 provide cross-sectional views through the three-dimensional interpolated carbon tetrachloride plume prepared using quantile kriging with data through 2019) and SGSIM (using data through 2017), respectively. Figures 4-14 and 4-15 show the carbon tetrachloride plume extending to the east and vertically downward from documented source areas, entering Rwia beneath the Rlm where the Rlm appears to be absent. Section 4.5 further discusses differences between the quantile and SGSIM representations for carbon tetrachloride.

Figures 4-16 through 4-18 compare the 2012 and 2019 carbon tetrachloride concentrations for 200-ZP-1 and 200-UP-1 OU monitoring wells. Sample data obtained during 2019 from most monitoring and extraction wells indicate that overall concentrations are declining. Exceptions include some monitoring wells near operating extraction wells. Figure 4-18 shows the locations of the monitoring wells in relationship to the 200-ZP-1 and 200-UP-1 OU extraction wells. Comparing the 2019 sample results to baseline data indicates that, in most cases, concentrations were lower in 2019 than in 2012, although a small number of wells exhibited higher concentrations in 2019 than in 2012.

4.5.1.4 Chromium Summary

Figure 4-19 shows the inferred extent of the dissolved chromium plume in the unconfined aquifer. The dissolved chromium plume is migrating eastward in the 200-ZP-1 OU and is within the capture zone of the 200 West P&T extraction wells. A comparison of the 2012 and 2019 sampling results for dissolved chromium indicates that concentrations are declining at most locations (Figure 4-20). Figure 4-21 presents the dissolved chromium concentrations in relationship to the extraction wells. Work for 2020 will assess the likelihood and location of potential continuing sources at locations in the Central Plateau. This will include the preparation and analysis of detailed three-dimensional depictions of contamination.

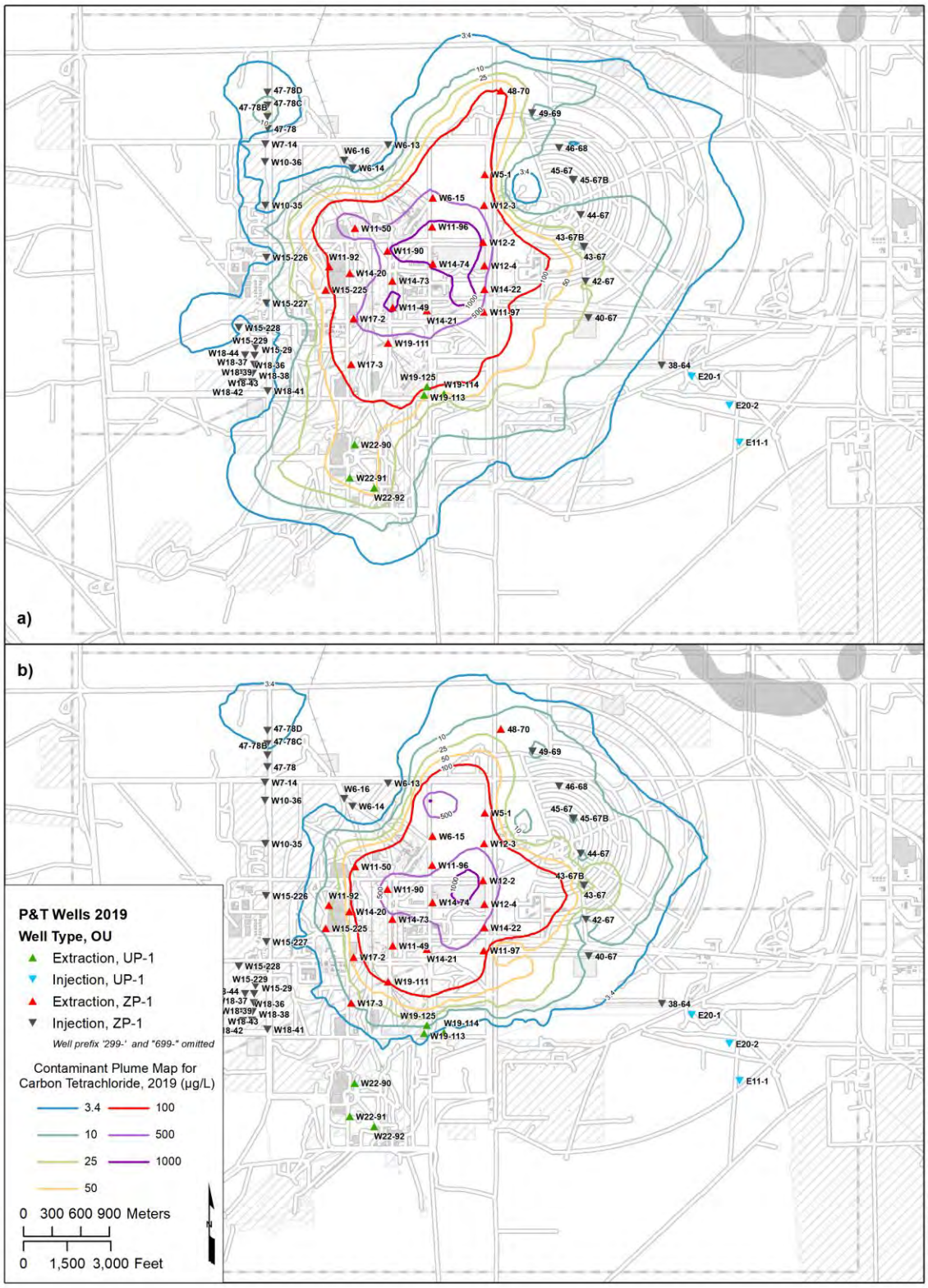

Figure 4-12. Contaminant Plume Map for Carbon Tetrachloride for 2019: (a) Above the RIm and (b) Below the RIm (Quantile Method)

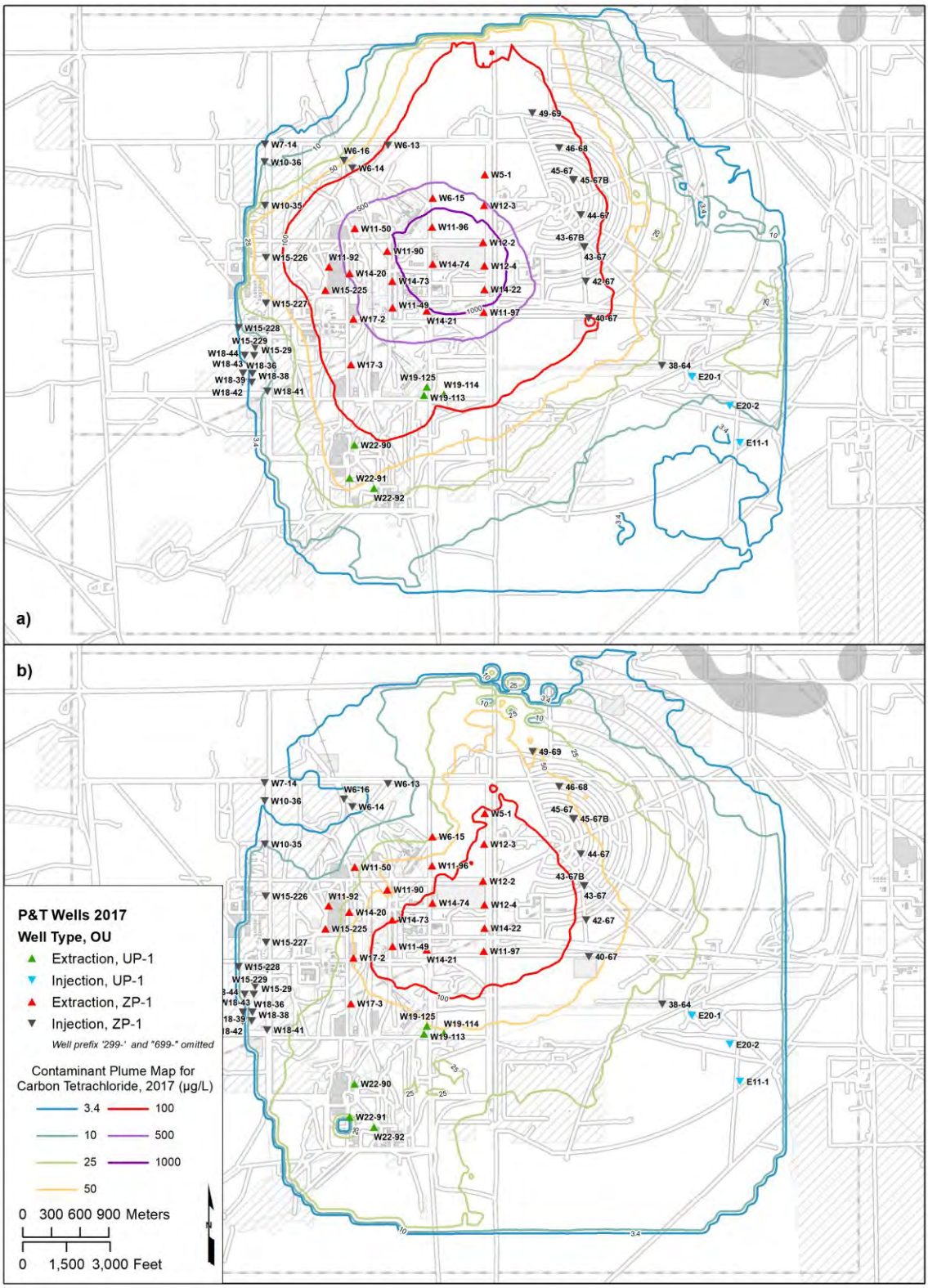

Figure 4-13. Contaminant Plume Map for Carbon Tetrachloride, 2017:
(a) Above the Rim and (b) Below the Rim (SGSIM Method)

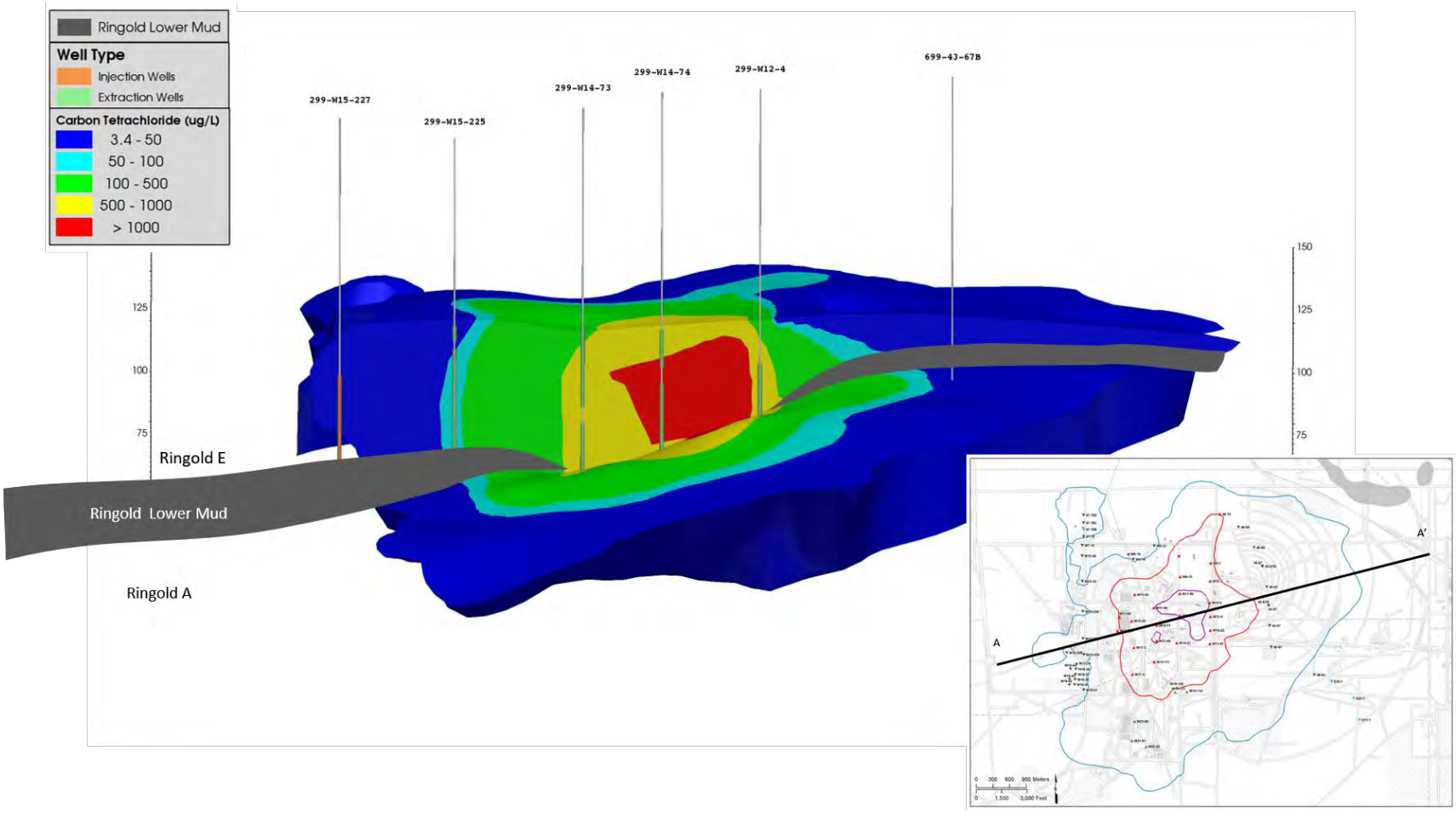

Figure 4-14. 200-ZP-1 OU Carbon Tetrachloride Plume Cross-**Section A to A' (Quantile Method**, 2019 Data)

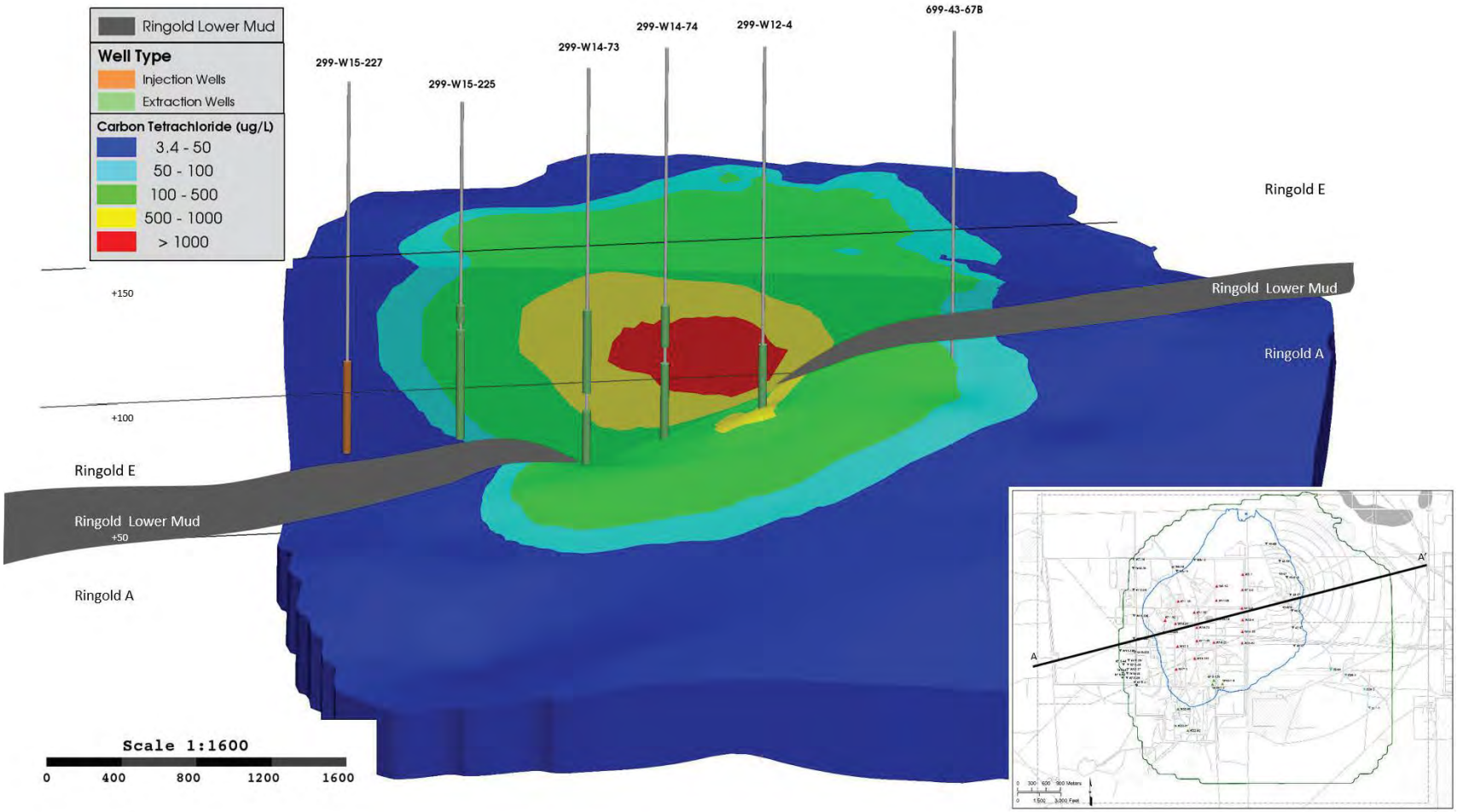

Figure 4-15. 200-ZP-1 OU Carbon Tetrachloride Plume Cross-**Section A to A' (SGSIM Method**, 2017 Data)

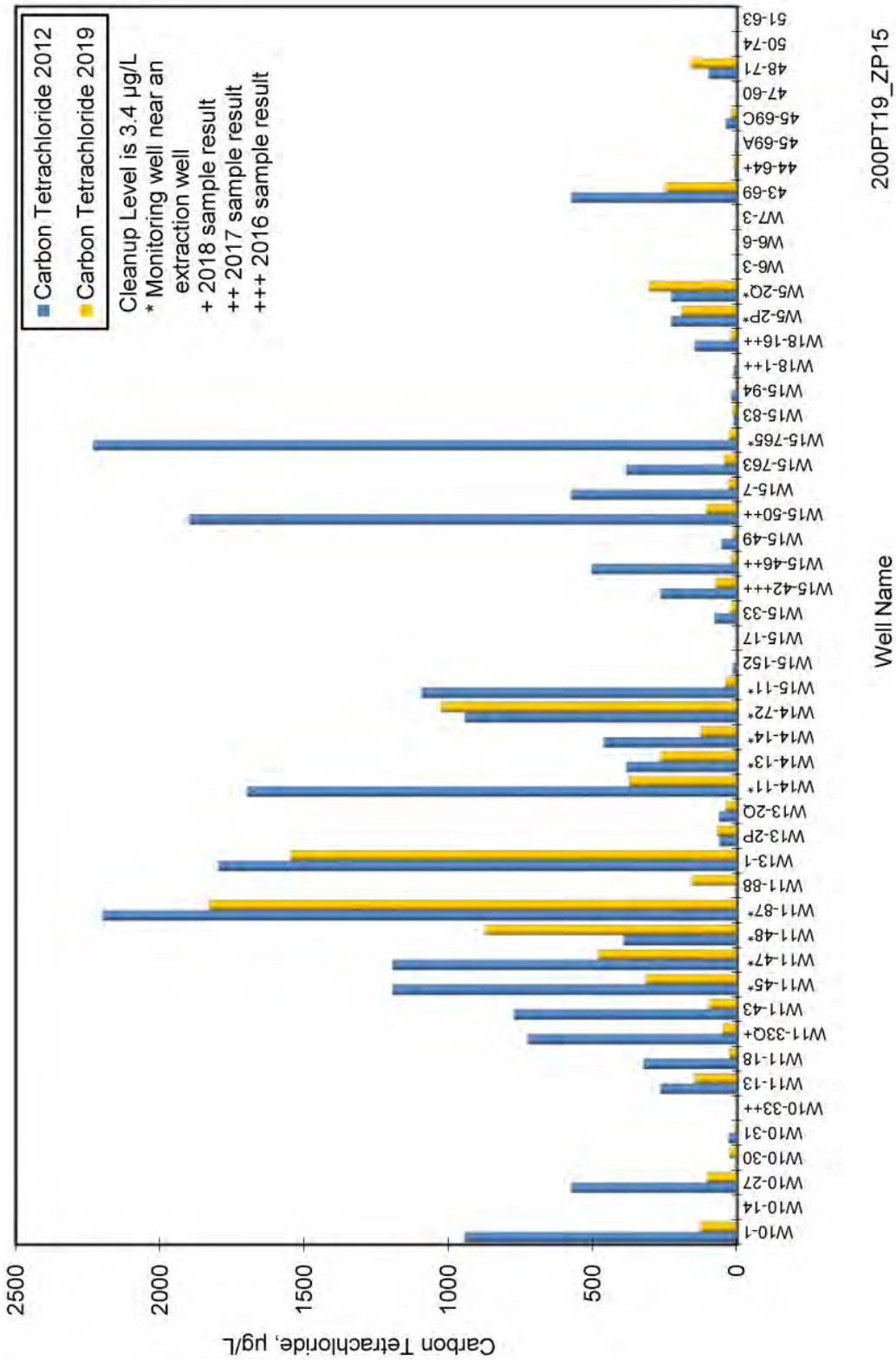

Figure 4-16. Comparison Chart of Carbon Tetrachloride Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

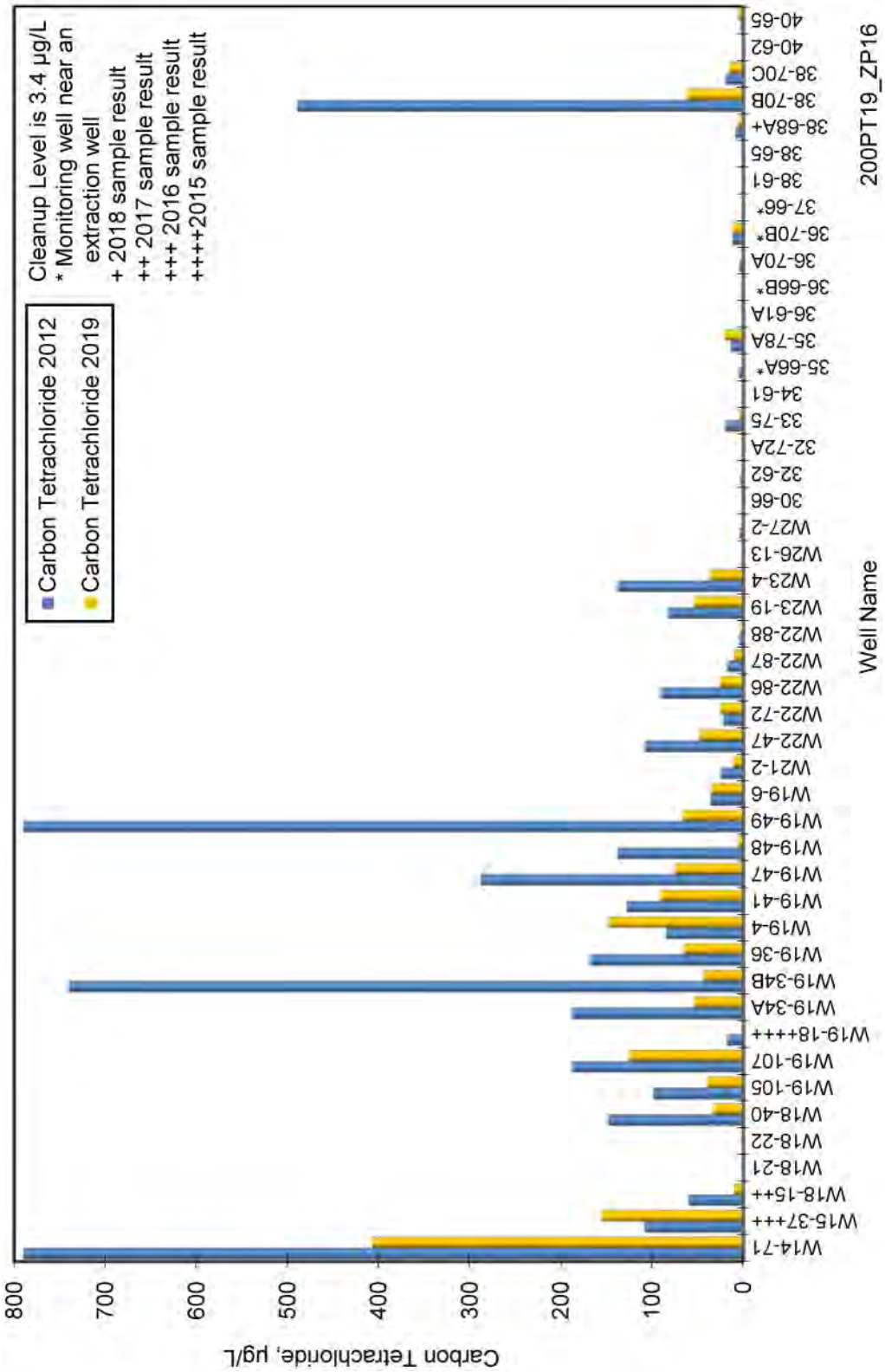

Figure 4-17. Comparison Chart of Carbon Tetrachloride Concentrations in 200-UP-1 OU Monitoring Wells in 2012 and 2019

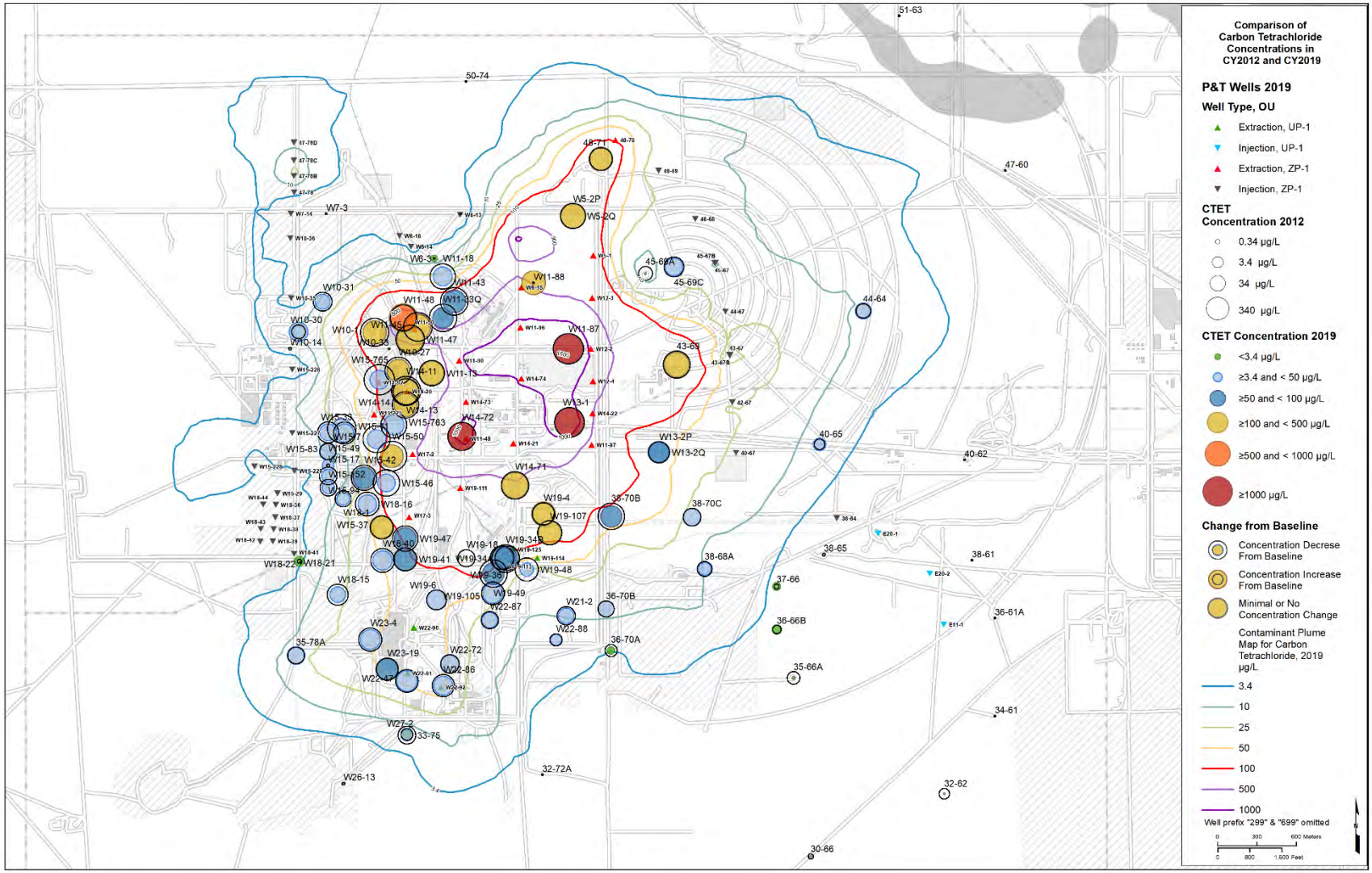

Figure 4-18. Comparison Map of Carbon Tetrachloride Concentrations in 200-ZP-1 and 200-UP-1 OU Monitoring Wells in 2012 and 2019

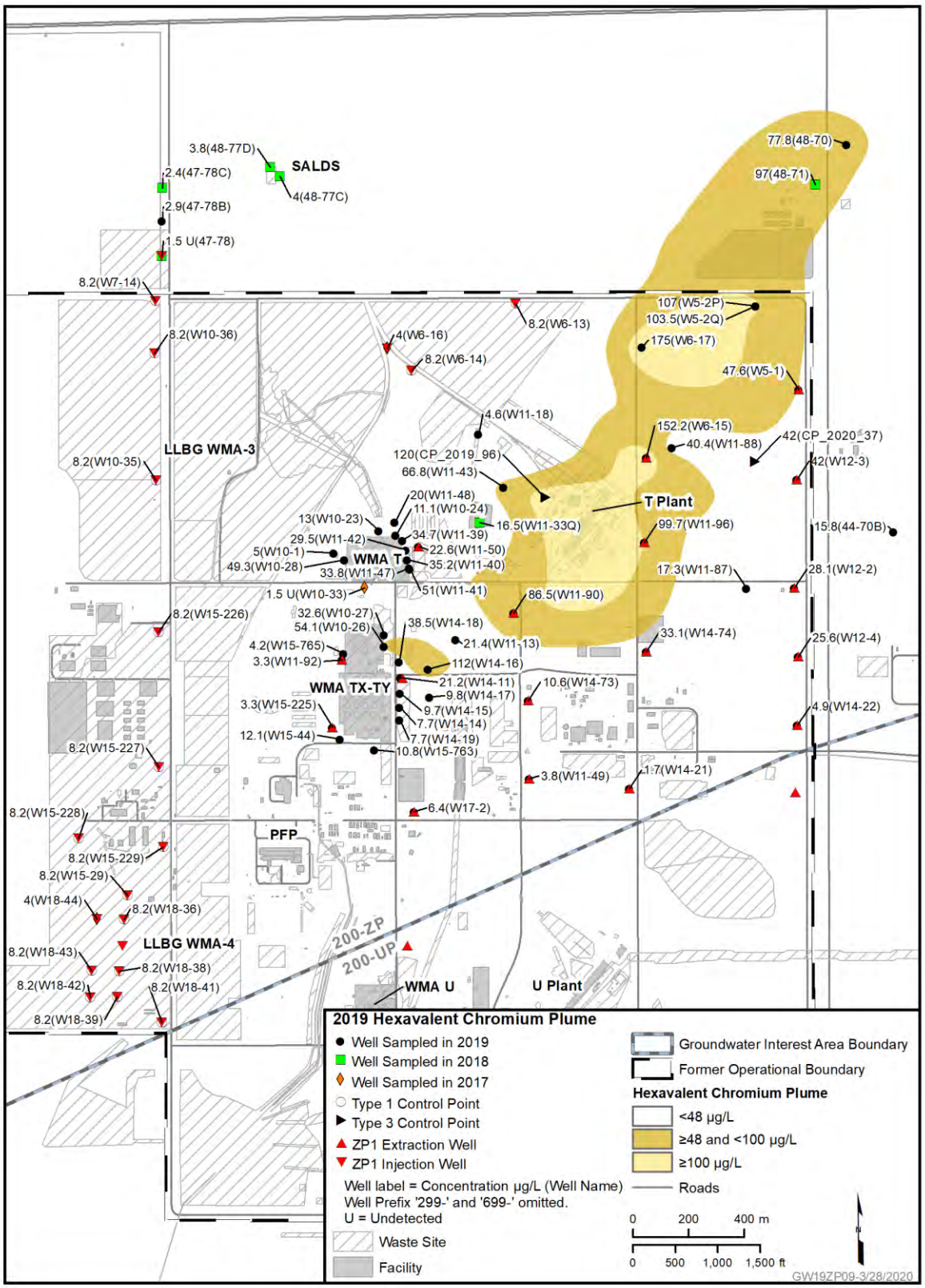

Figure 4-19. Contaminant Plume Map for Dissolved Chromium, 2019

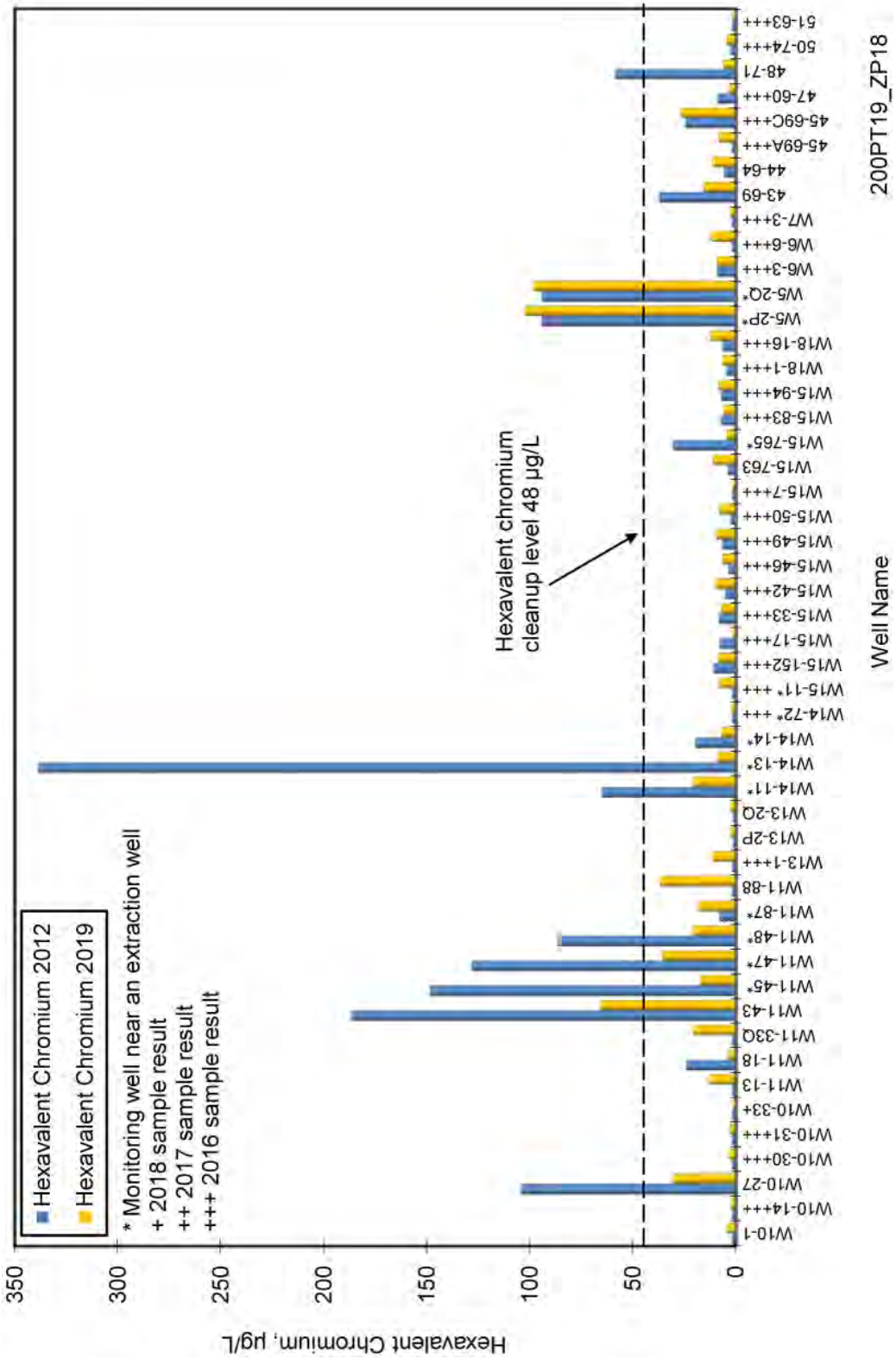

Figure 4-20. Comparison Chart of Dissolved Chromium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

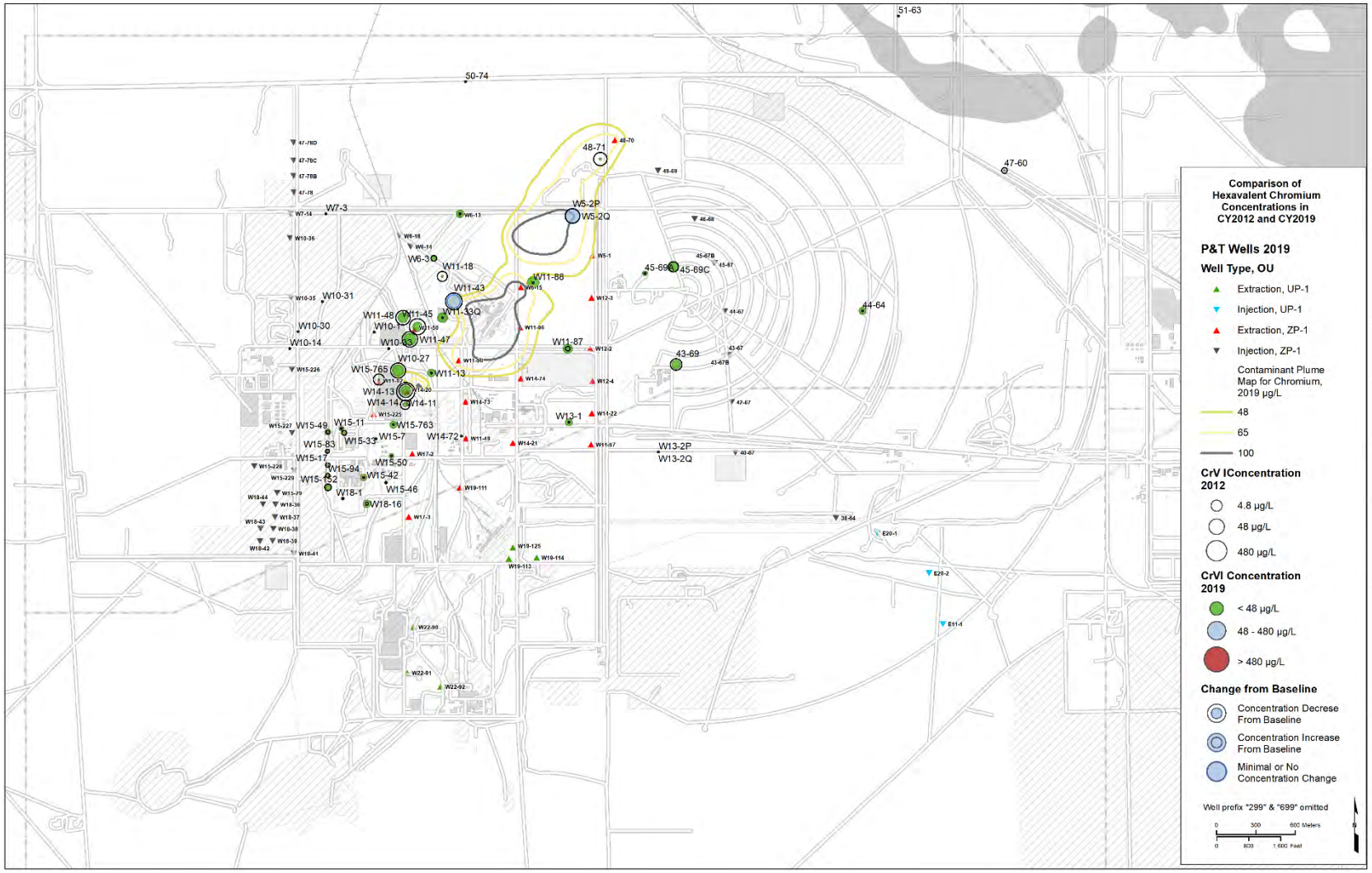

Figure 4-21. Comparison Map of Dissolved Chromium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

4.5.1.5 Iodine Summary

Figure 4-22 shows the extent of the iodine-129 plume in the unconfined aquifer. The iodine-129 plume is migrating toward the east (as with other contaminant plumes in the 200-ZP-1 OU) and northeast and is within the capture zone of the 200 West P&T extraction wells. Concentrations declined in many monitoring wells sampled in 2012 and 2019 (Figure 4-23). Figure 4-24 presents the iodine-129 concentrations in relationship to the extraction wells.

4.5.1.6 Nitrate Summary

The results of two-dimensional interpolation suggest little change from 2018 to 2019 in the interpreted extent and area of the nitrate plume at concentrations >45 mg/L for the 200-ZP-1 OU (Figure 4-25). The region exhibiting nitrate substantially >100 mg/L beneath WMA T, WMA TX-TY, and the 216-Z Cribs and Trenches is located within the extent of hydraulic containment of the 200 West P&T extraction wells. Figure 4-26 shows changes in nitrate concentrations from 2012 to 2019 in 200-ZP-1 OU monitoring wells. Figure 4-27 presents nitrate concentrations in relationship to the extraction wells.

4.5.1.7 Technetium-99 Summary

Figure 4-28 shows two distinct technetium-99 plumes above the 900 pCi/L standard, centered at the northern end of WMA TX-TY and beneath WMA T. The technetium-99 plumes are migrating eastward (as are other contaminant plumes in the OU) and are within the capture zone of the 200 West P&T extraction wells. Figure 4-29 shows changes in the 2012 and 2019 concentrations in 200-ZP-1 OU monitoring wells. Figure 4-30 presents technetium-99 concentrations in relationship to the extraction wells. As previously discussed, an assessment of the potential for continuing sources of technetium-99 to groundwater is planned for 2020 in response to observed trends in monitoring well activity concentrations and extraction well activity mass recovery rates.

4.5.1.8 Trichloroethene Summary

Figure 4-31 shows the extent of the TCE plume in the unconfined aquifer. Although the plume is fairly extensive, most concentrations are within a factor of 10 of the cleanup level of 1 µg/L. Figure 4-32 shows the changes in the 2012 and 2019 concentrations in 200-ZP-1 OU monitoring wells. Most locations exhibited decreases, but other locations exhibited increases resulting from the changing flow field induced by groundwater pumping. Figure 4-33 compares concentrations from 2012 and 2019 in 200-UP-1 OU monitoring wells; similarly, the changes are mixed. Figure 4-34 presents the concentrations in relationship to the extraction wells.

4.5.1.9 Tritium Summary

Figure 4-35 shows the extent of the tritium plume in the unconfined aquifer. Tritium is migrating eastward in the 200-ZP-1 OU and is within the capture zone of the 200 West P&T extraction wells. The only distinct area where tritium exceeds the cleanup standard established in the 200-ZP-1 OU ROD (EPA et al., 2008) is near the permitted SALDS, where it is anticipated that concentration exceedances will continue at least for the duration of the facility's operation. Comparison of sampling results for 2012 and 2019 indicates that concentrations are declining in most locations (Figure 4-36). Figure 4-37 presents these concentrations in relationship to the extraction wells.

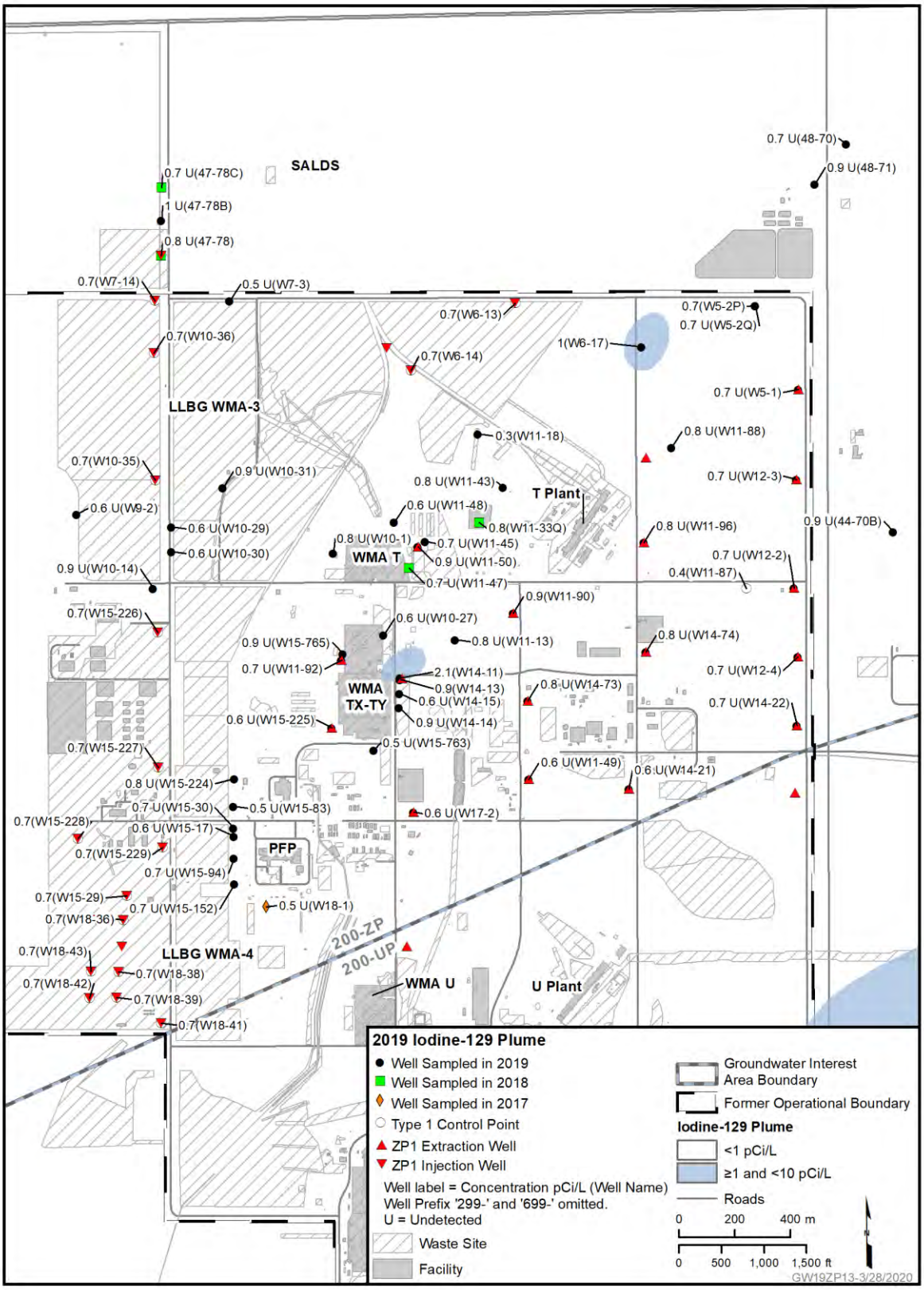

Figure 4-22. Contaminant Plume Map for Iodine-129, 2019

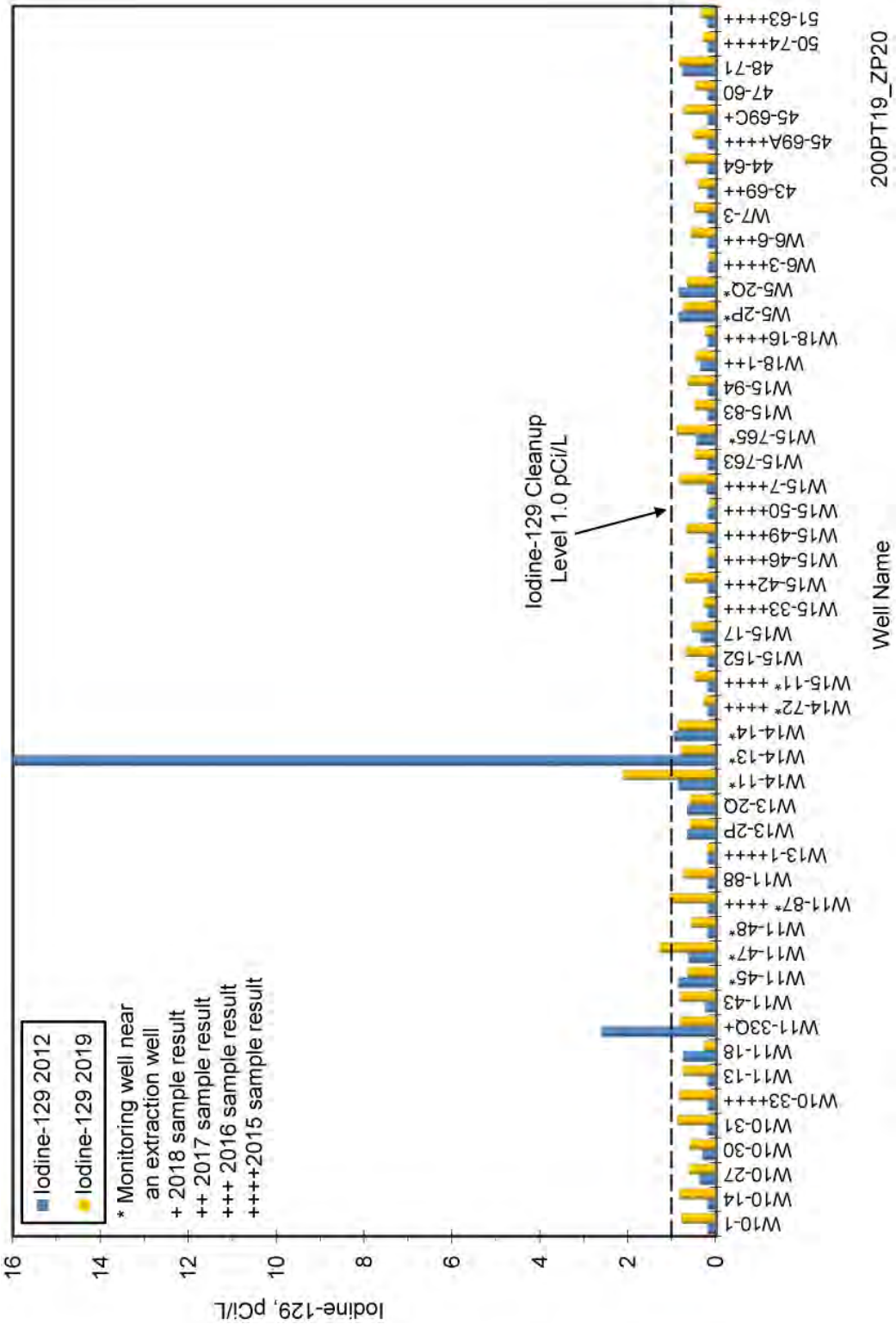

Figure 4-23. Comparison Chart of Iodine-129 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

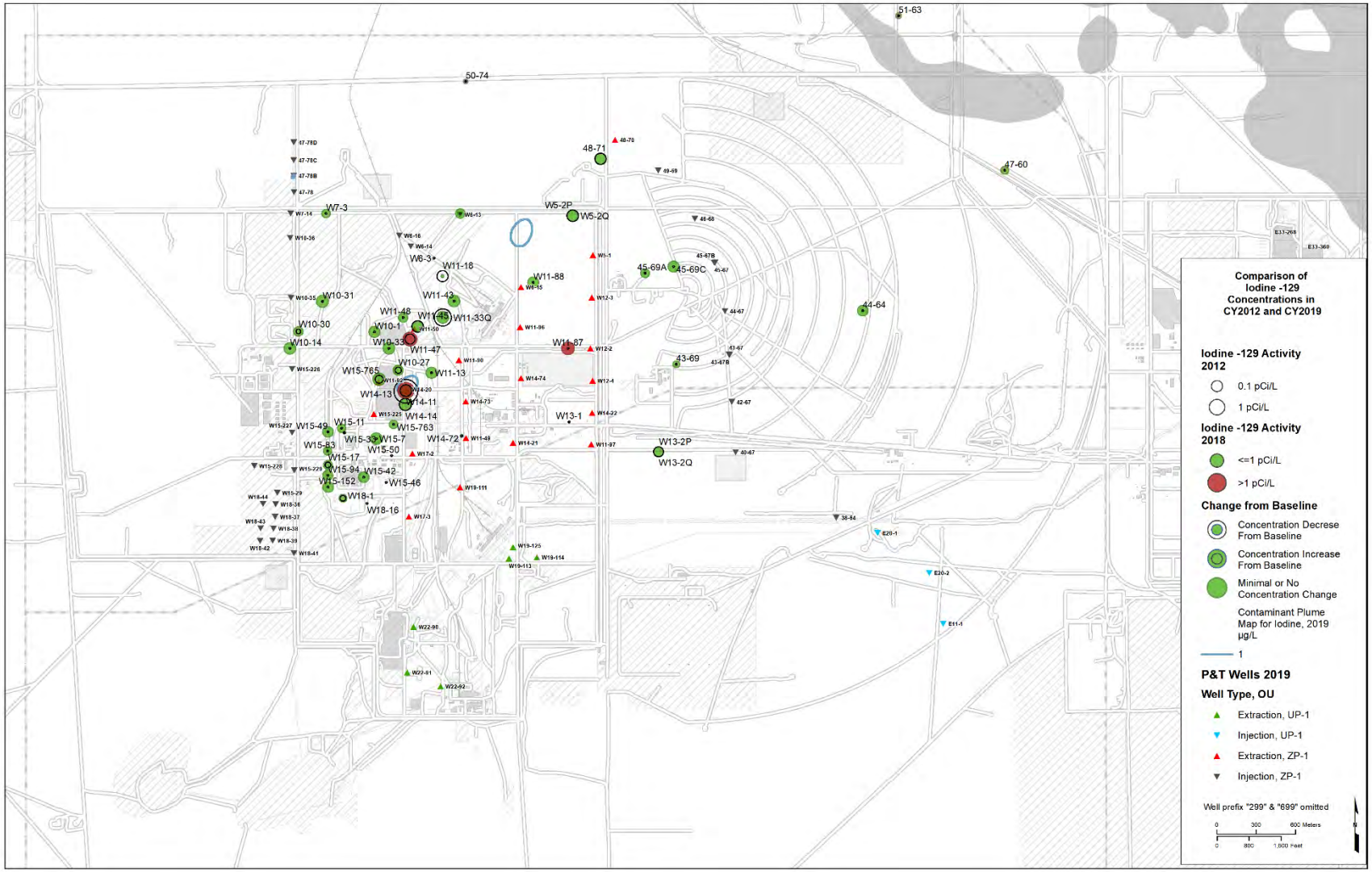

Figure 4-24. Comparison Map of Iodine-129 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

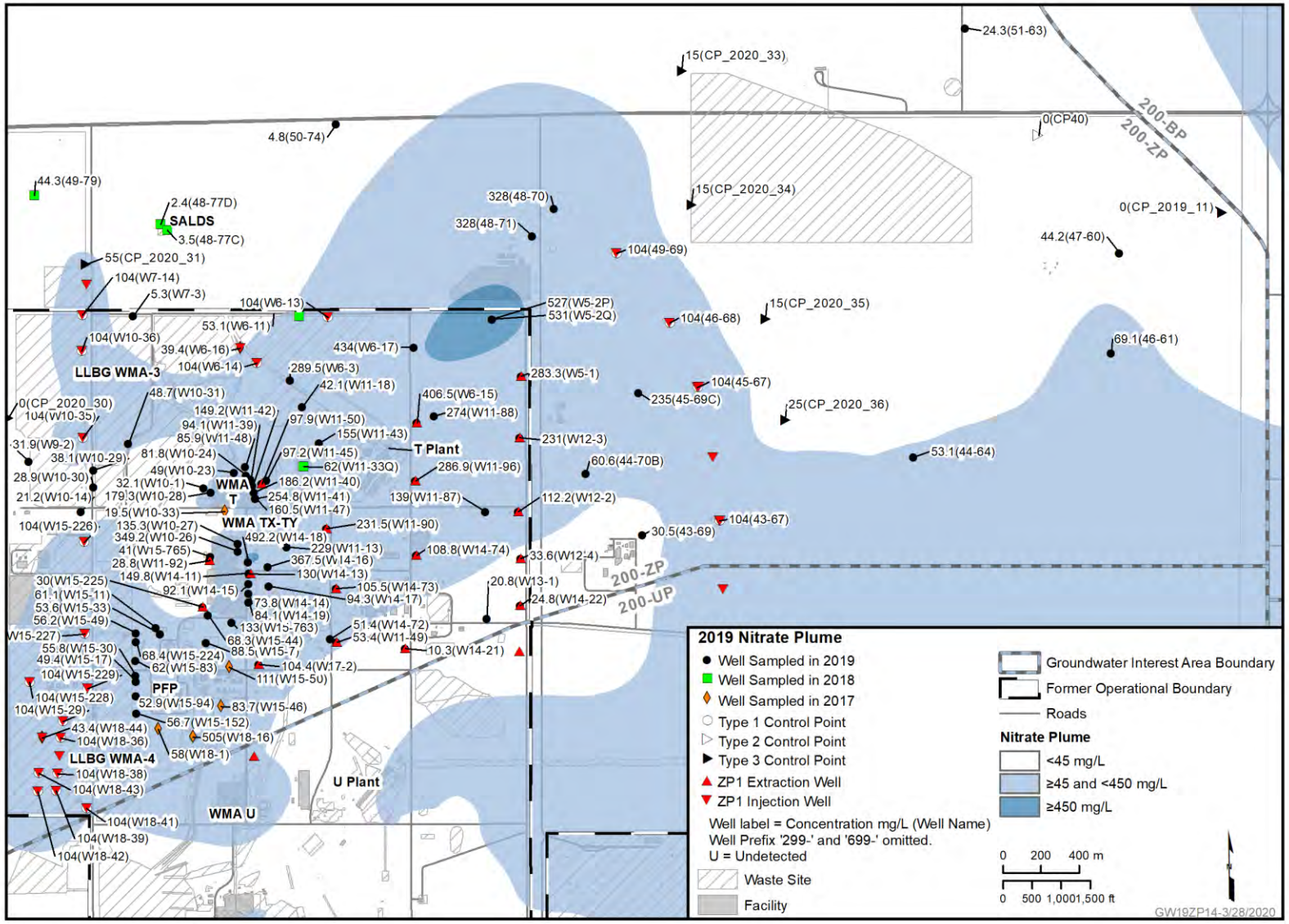

Figure 4-25. Contaminant Plume Map for Nitrate, 2019

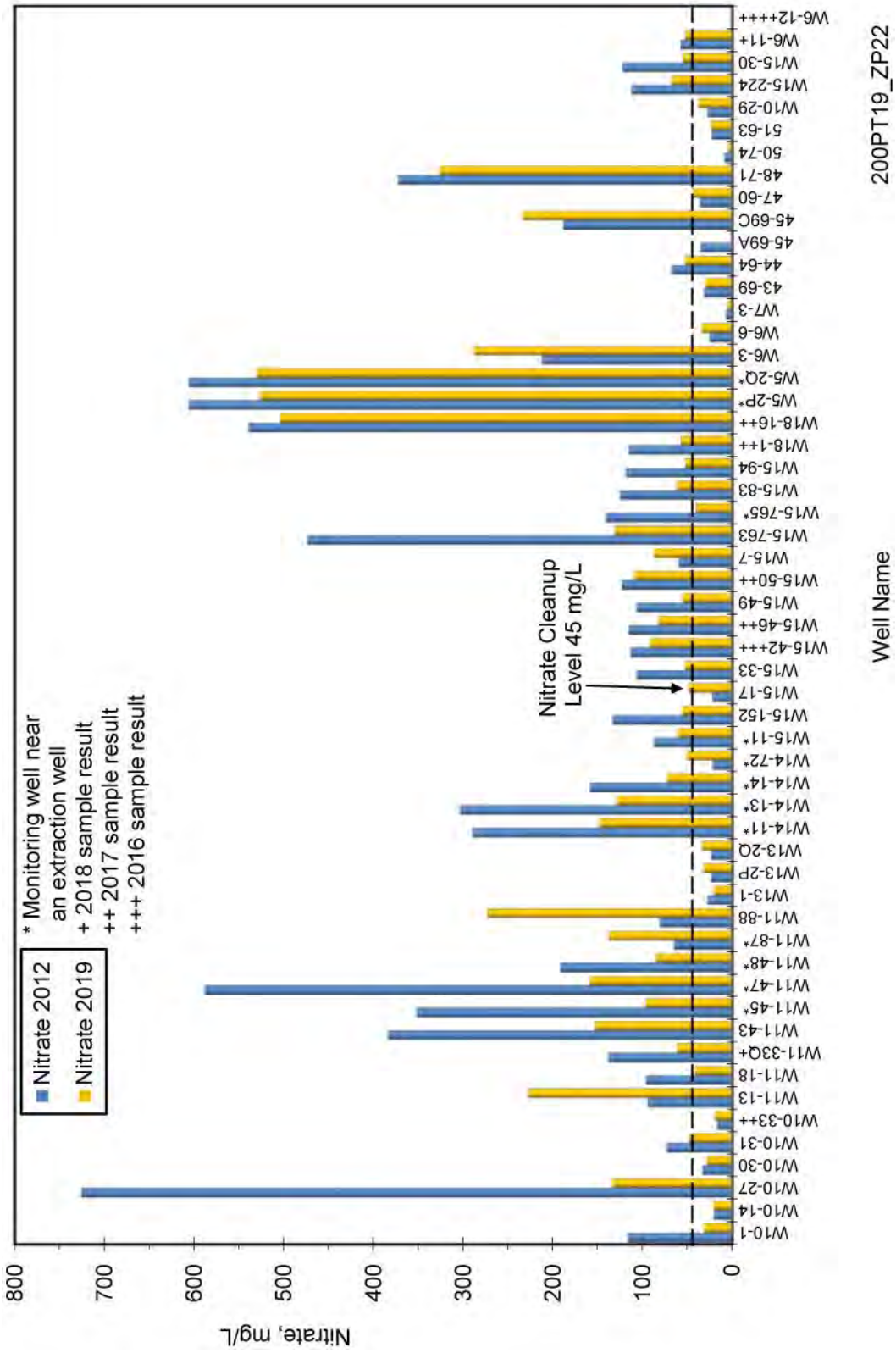

Figure 4-26. Comparison Chart of Nitrate Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

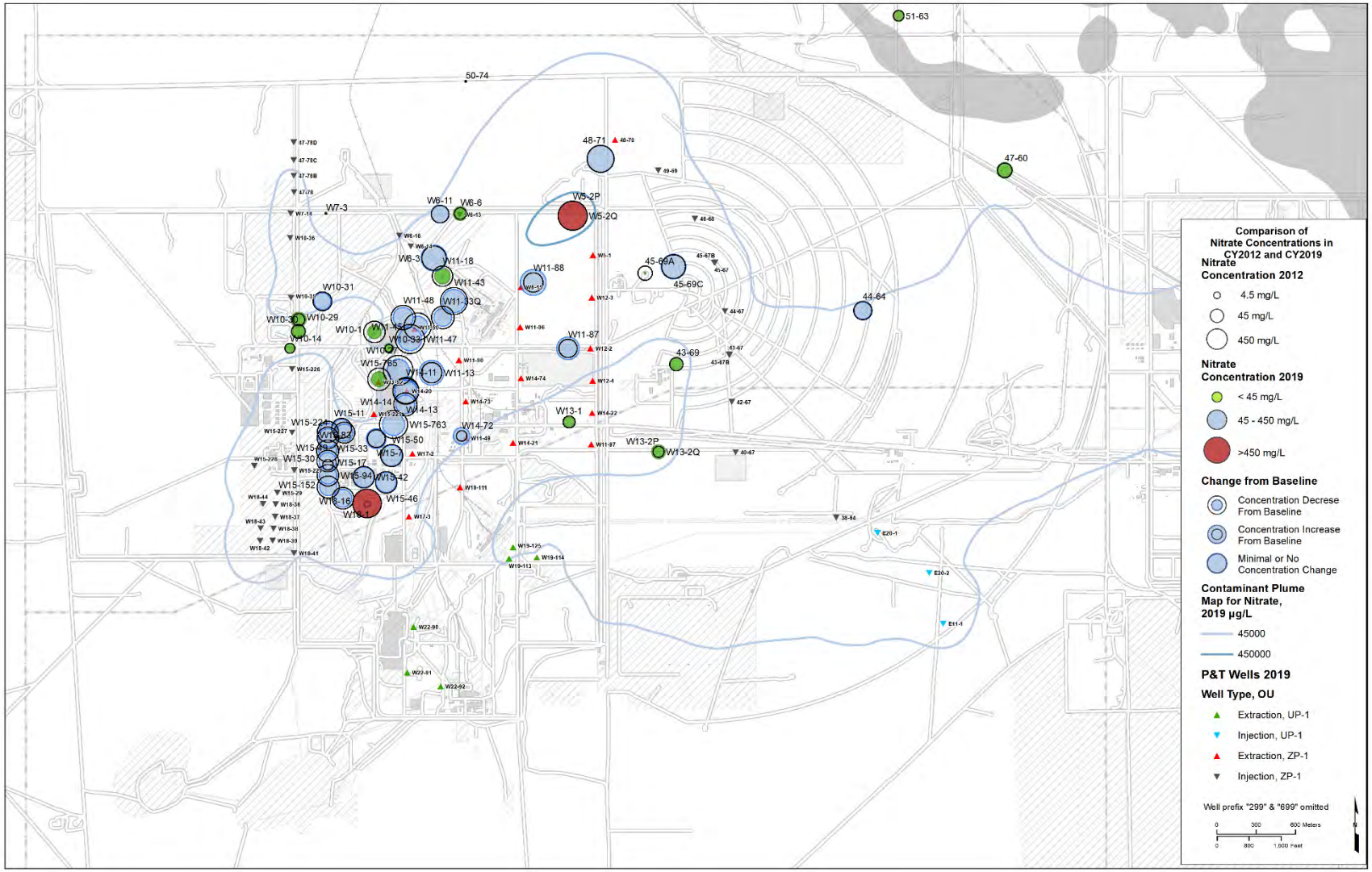

Figure 4-27. Comparison Map of Nitrate Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

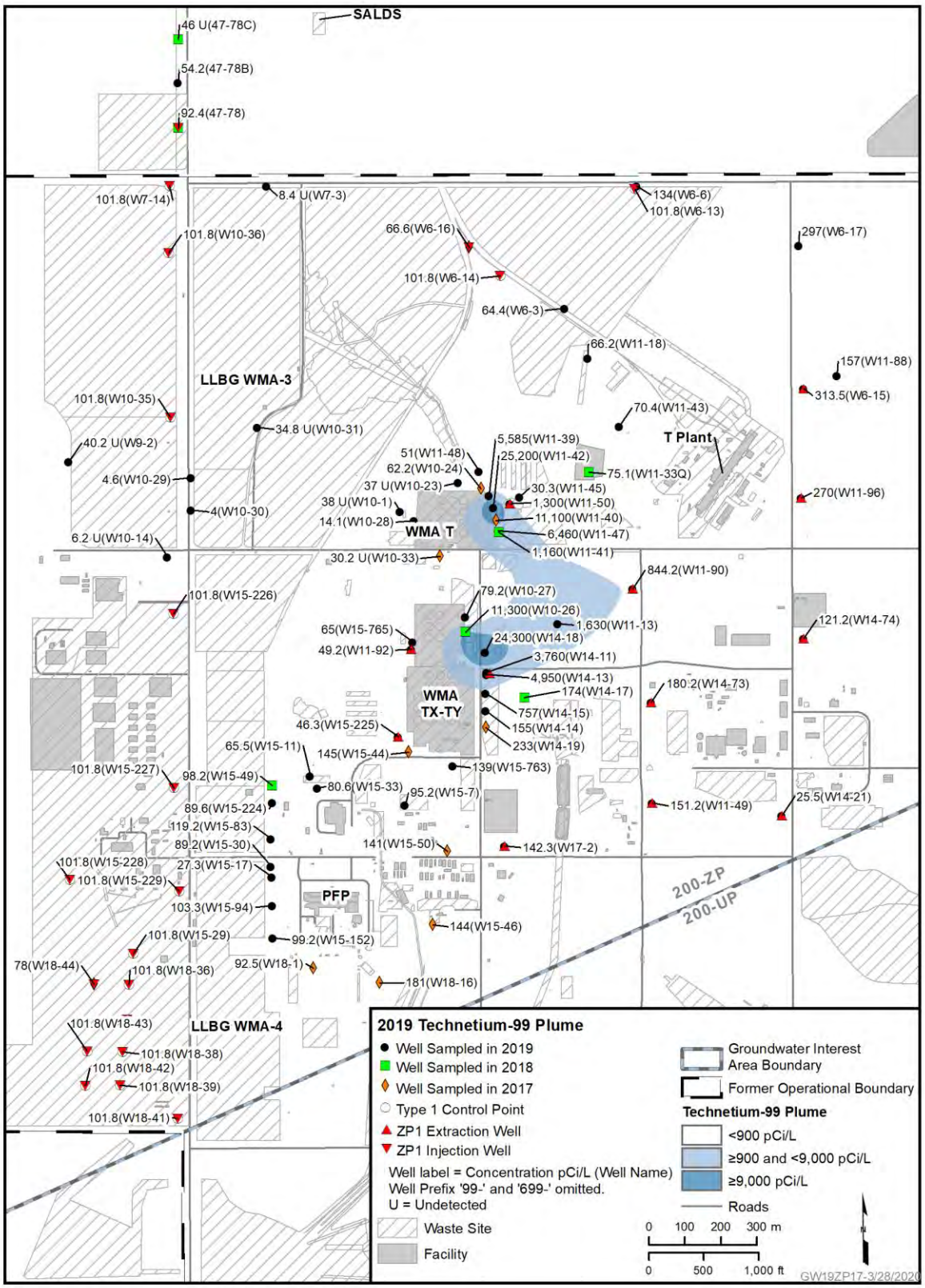

Figure 4-28. Contaminant Plume Map for Technetium-99, 2019

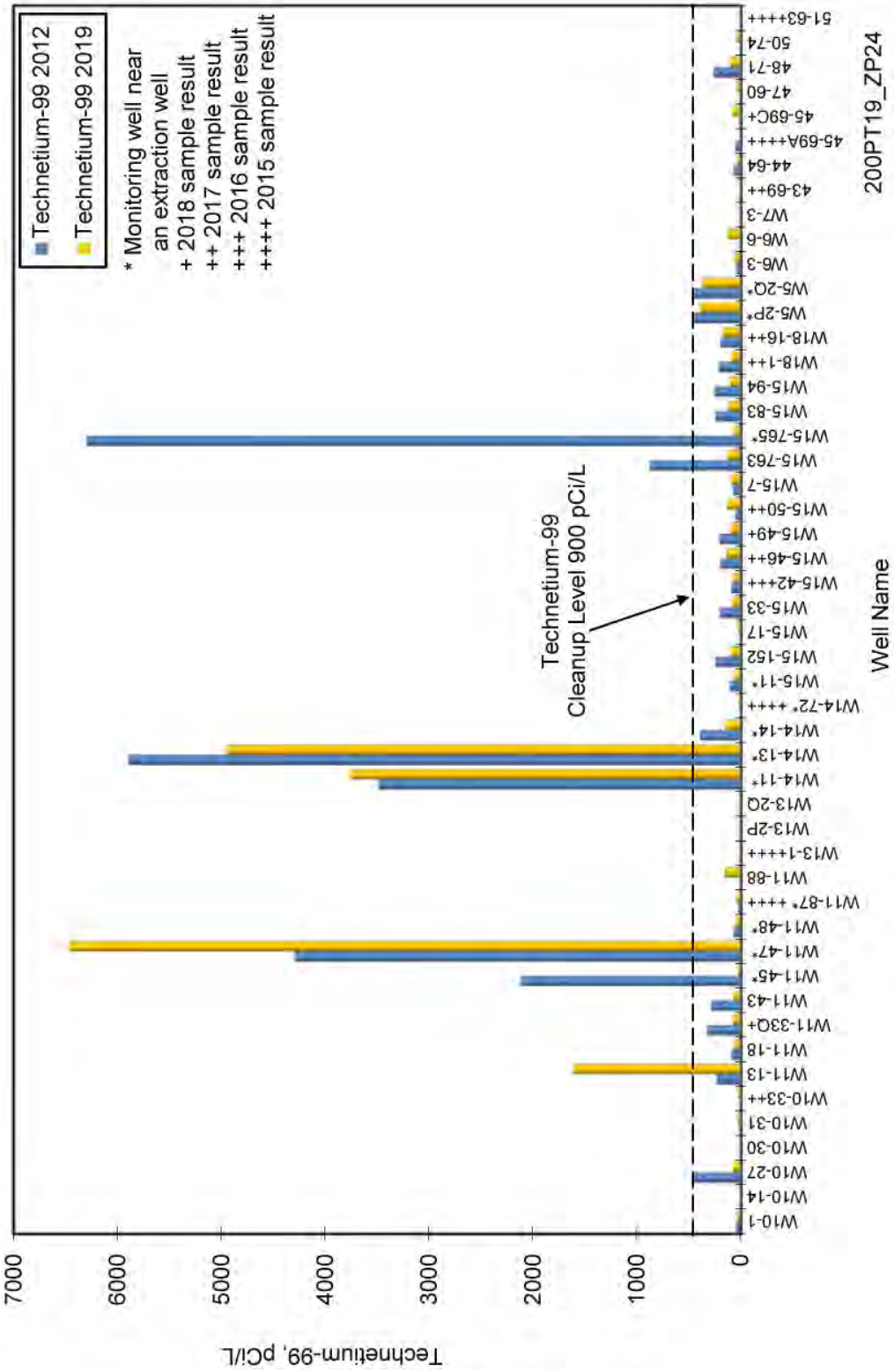

Figure 4-29. Comparison Chart of Technetium-99 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

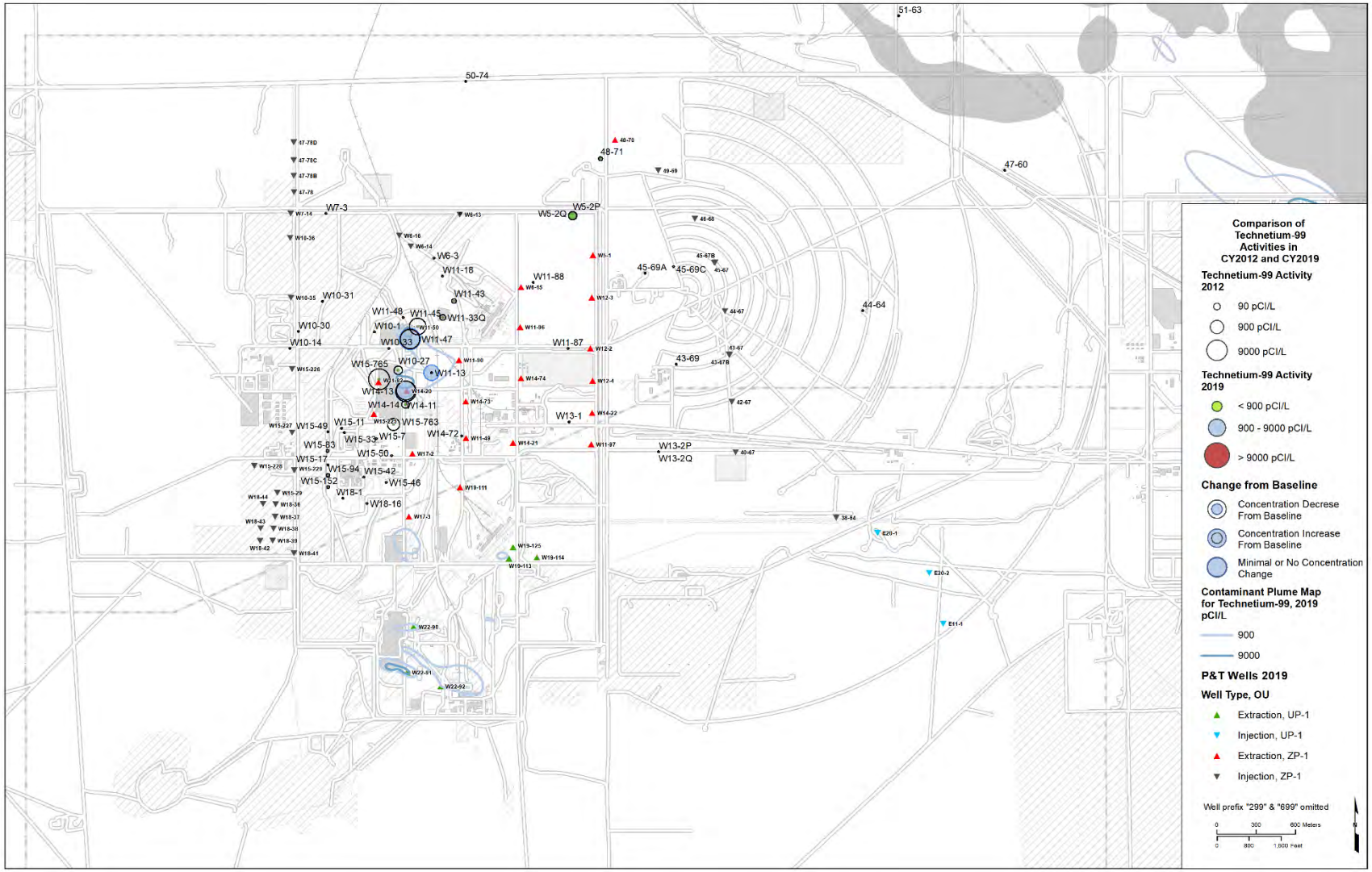

Figure 4-30. Comparison Map of Technetium-99 Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

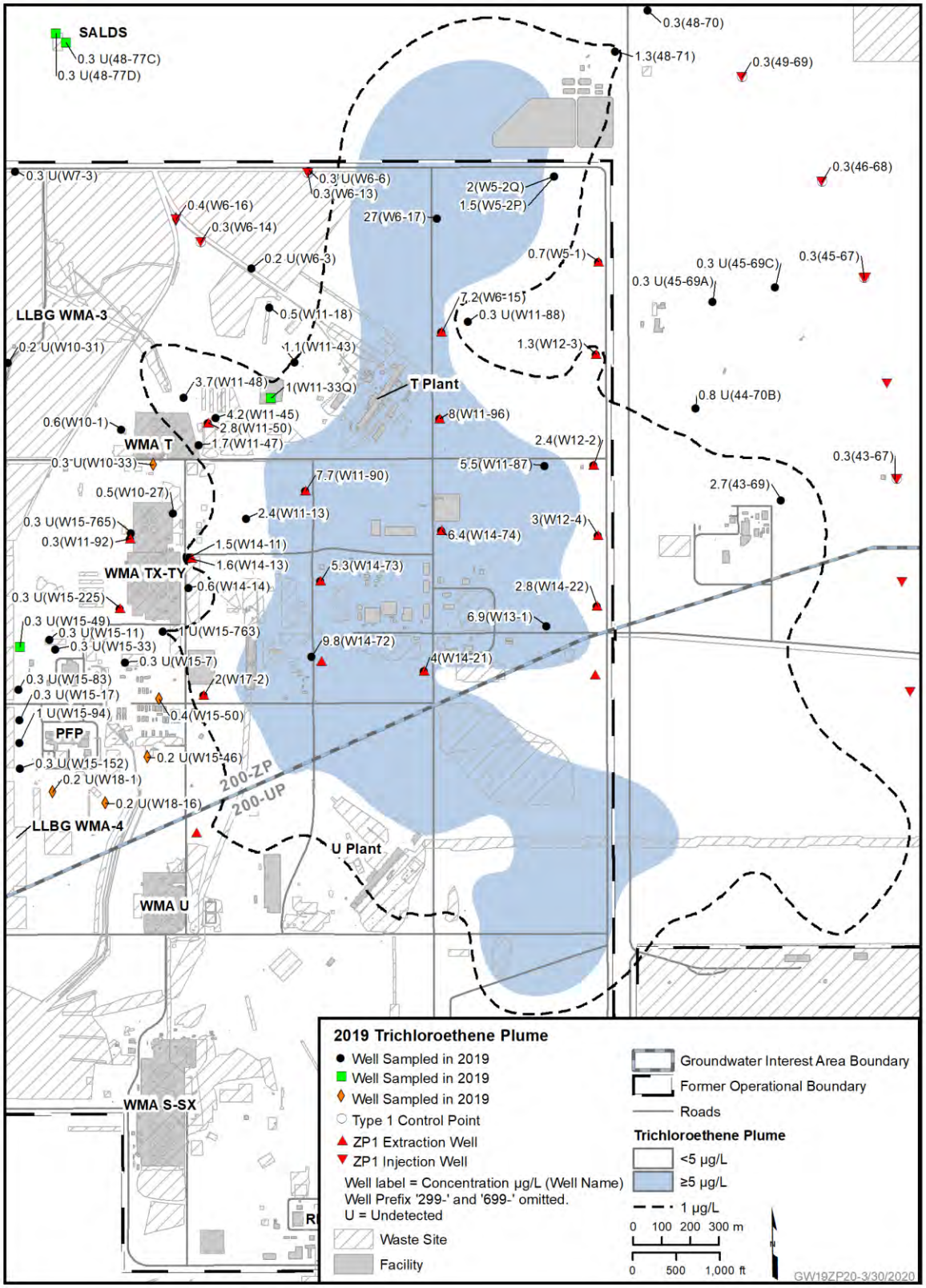

Figure 4-31. Contaminant Plume Map for TCE, 2019

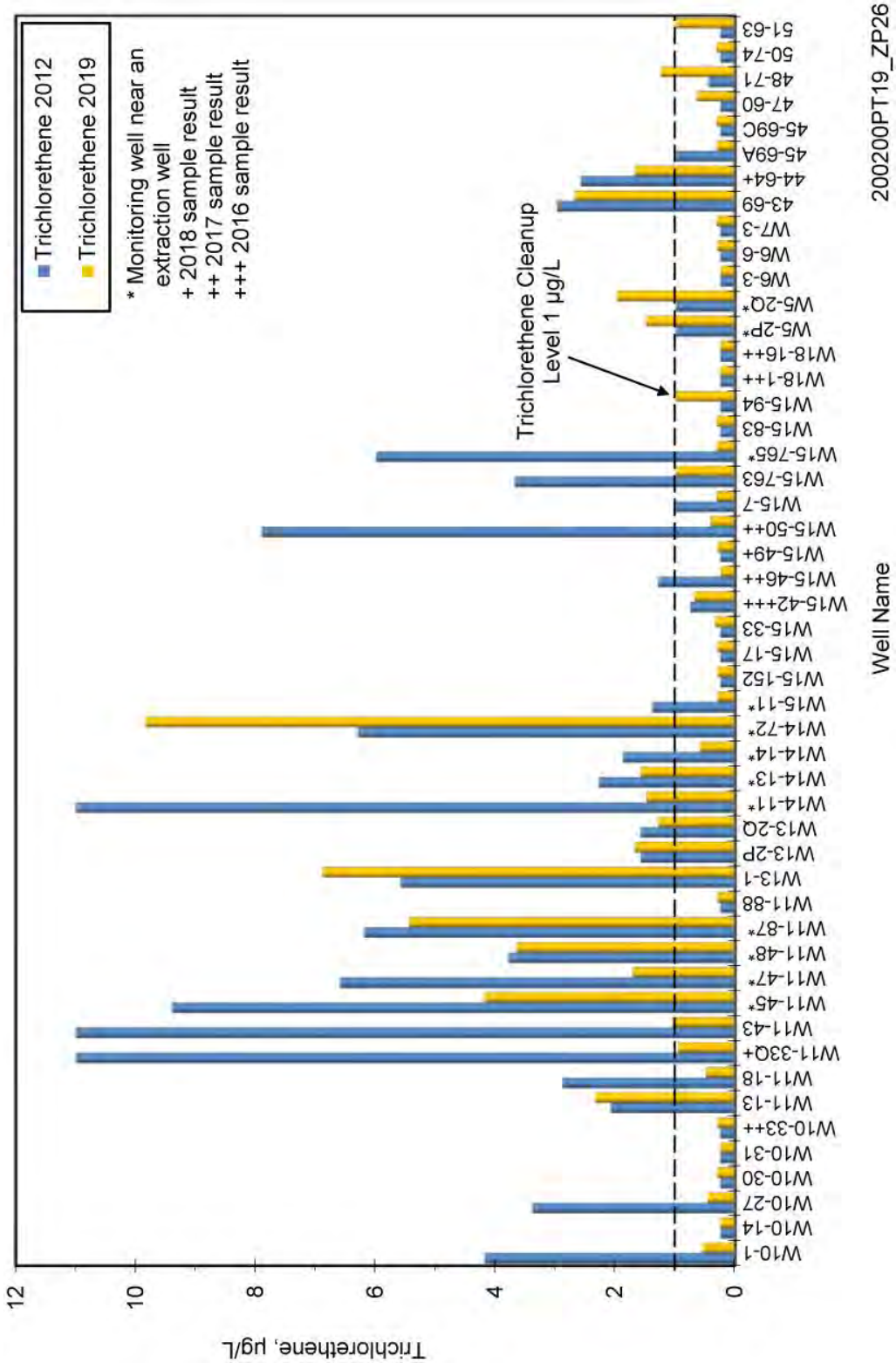

Figure 4-32. Comparison Chart of TCE Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

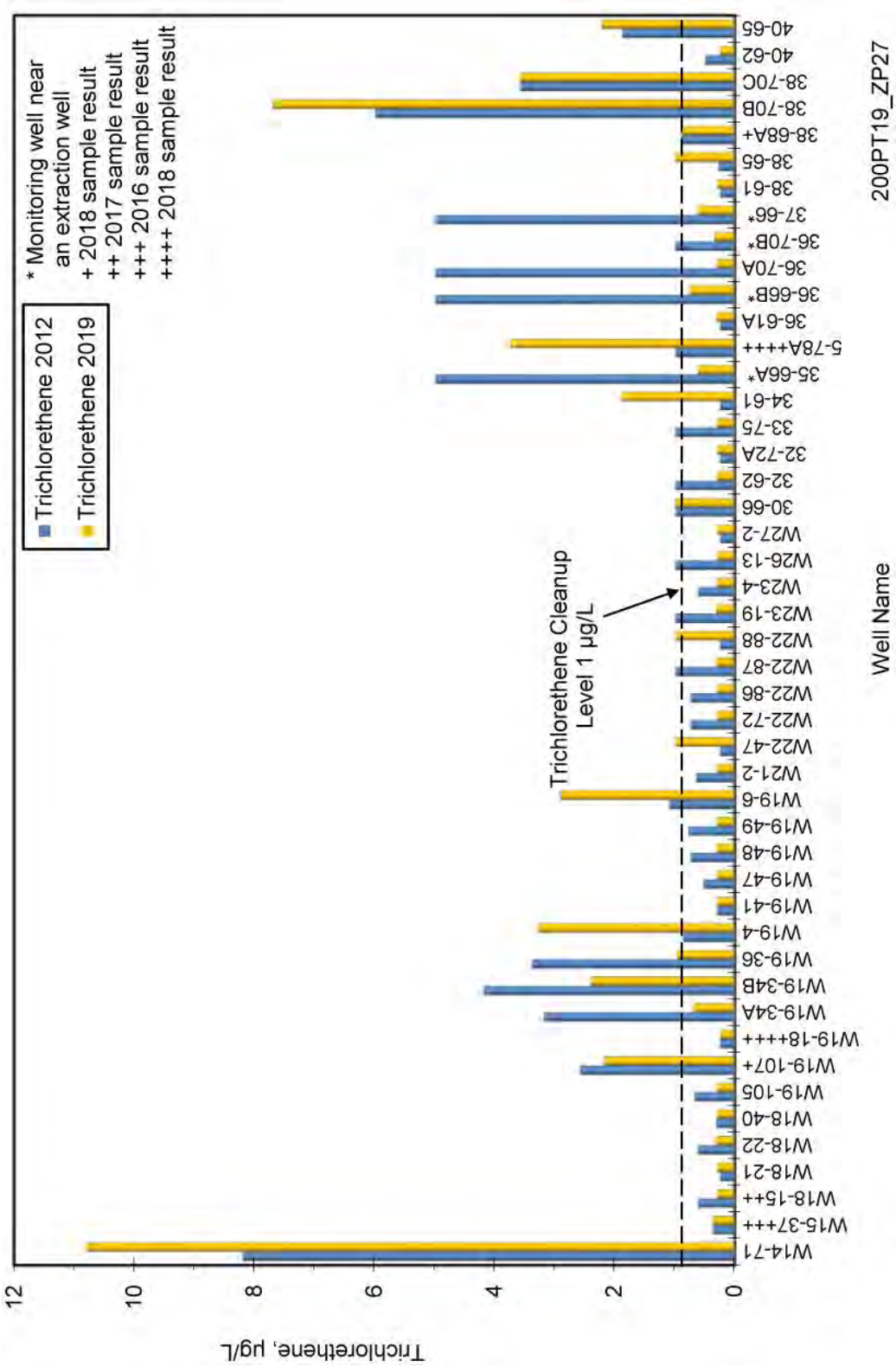

Figure 4-33. Comparison Chart of TCE Concentrations in 200-UP-1 OU Monitoring Wells in 2012 and 2019

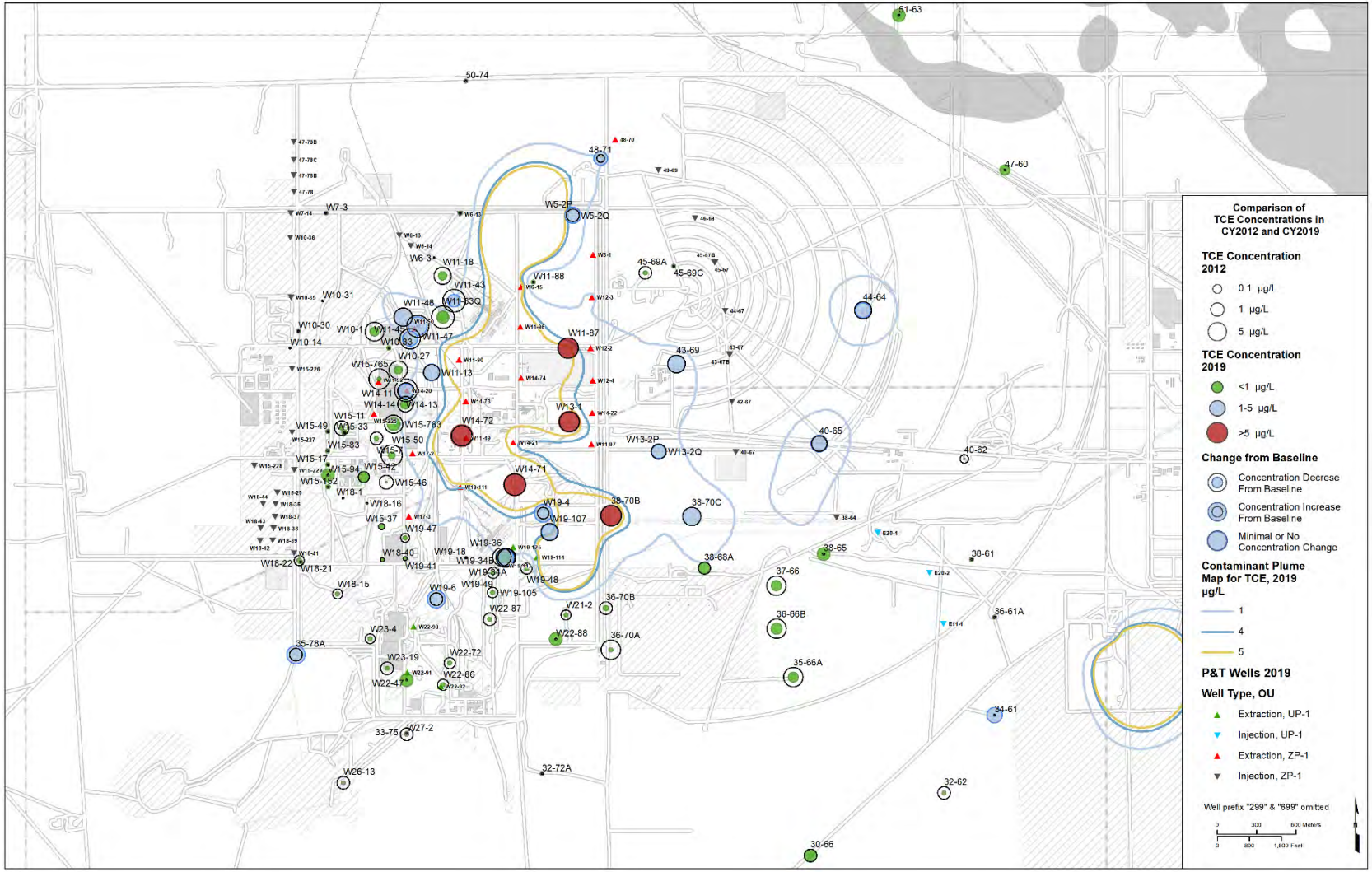

Figure 4-34. Comparison Map of TCE Concentrations in 200-ZP-1 and 200-UP-1 OU Monitoring Wells in 2012 and 2019

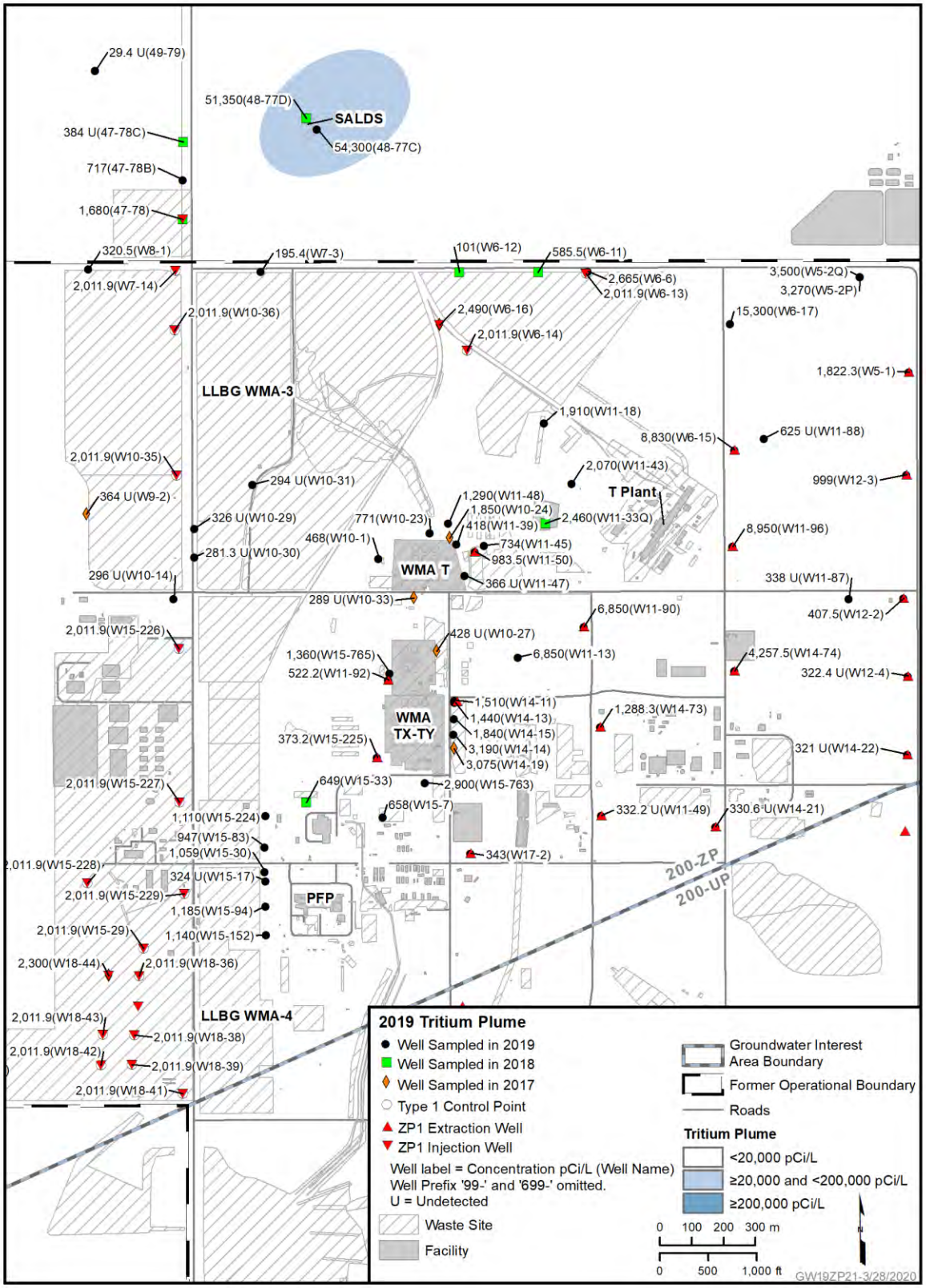

Figure 4-35. Contaminant Plume Map for Tritium, 2019

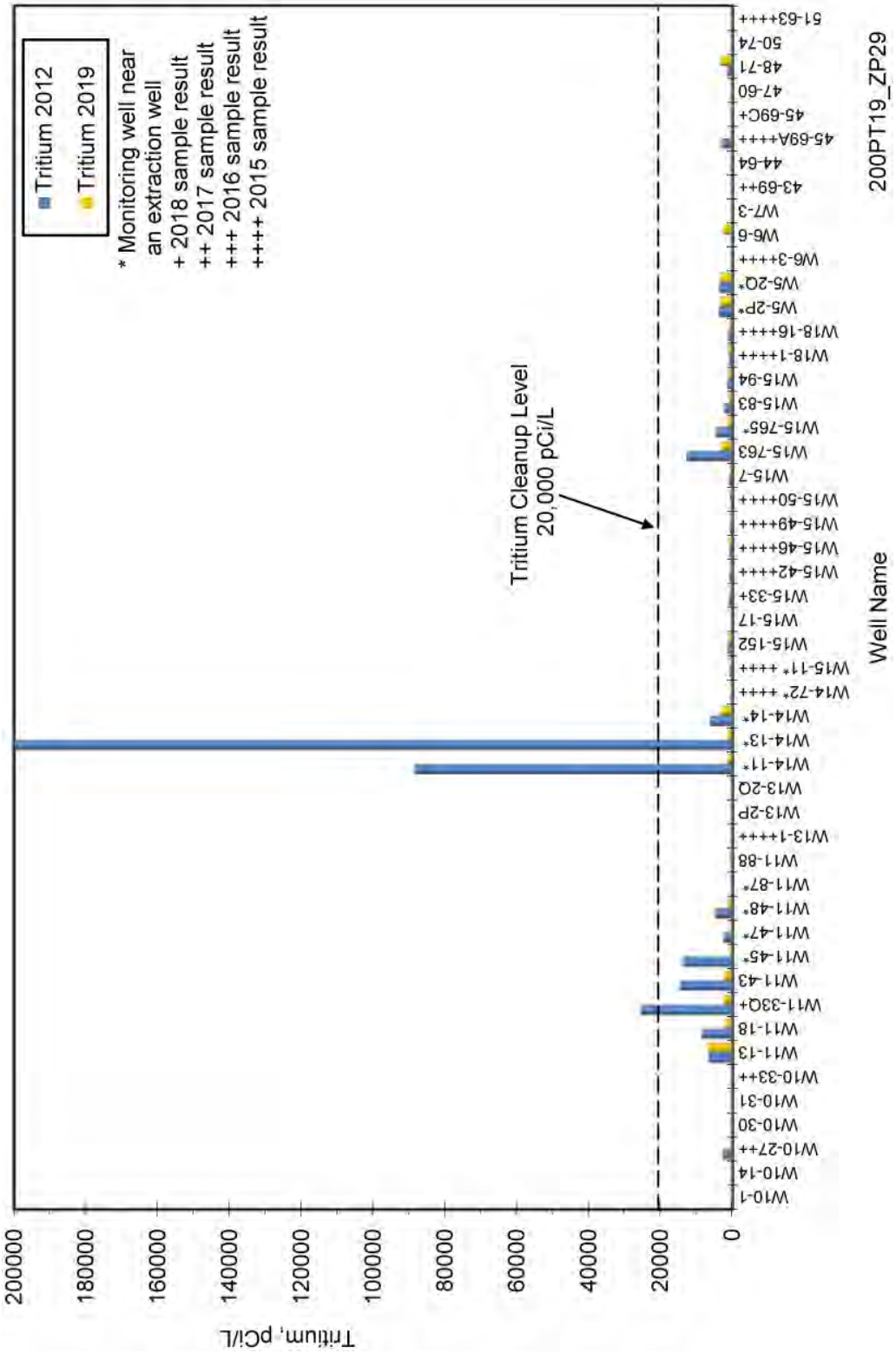

Figure 4-36. Comparison Chart of Tritium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

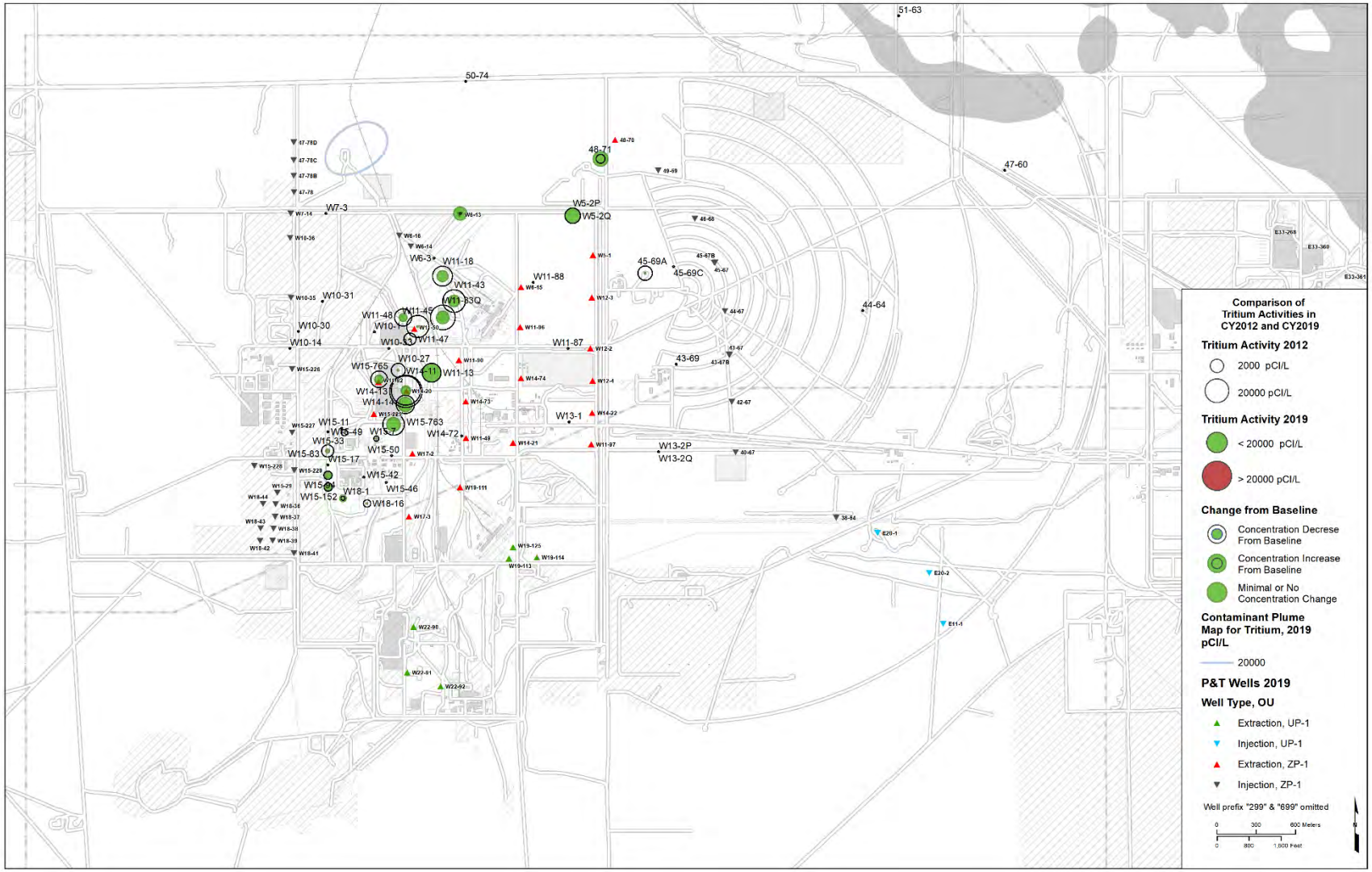

Figure 4-37. Comparison Map of Tritium Concentrations in 200-ZP-1 OU Monitoring Wells in 2012 and 2019

4.5.1.10 Contaminant of Concern Trends and Summary Statistics

To further the qualitative summaries of concentration changes for the 200-ZP-1 OU COCs from initiation of the P&T remedy presented in the previous section, this section presents the results of quantitative analyses of concentration data over time using two complementary techniques.

The first method evaluates concentration changes at individual monitoring wells independently of other wells to estimate trends and summary statistics, including UCLs on the mean for the previous year. These are referred to as intrawell trends and summary statistics. For this evaluation, emphasis is placed on the monitoring wells listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2). This evaluation enables location-specific assessment of progress but does not provide an overall depiction of remedy progress. Intrawell trends are calculated prior to and following the startup of the 200-ZP-1 OU P&T remedy as detailed in ECF-200ZP1-20-0050, *Calculation of Concentration Trends, Means, and Confidence Limits for the 200-ZP-1 Operable Unit Contaminants of Concern Before and After 200 West Pump and Treat Startup for the Calendar Year 2019 (CY 2019*).

The second method evaluates concentrations at multiple monitoring wells together within a year (but independently year to year) to estimate summary statistics (including UCLs on the mean) and changes in those summary statistics over time. For this evaluation, emphasis is placed on the most regularly sampled wells listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2). In contrast to the intrawell calculations, this evaluation provides an overall depiction of progress throughout the entire extent of contamination but does not enable location-specific progress evaluations. These summary statistics are calculated for the year immediately preceding startup of the P&T (in 2011) and for the years including and following startup of the P&T remedy (2012 and onward), as detailed in ECF-200ZP1-20-0051, *Calculation of Concentration Summary Statistics for Monitoring Wells of the 200-ZP-1 Performance Monitoring Plan (PMP) for the Calendar Year 2019 (CY 2019*).

ECF-200ZP1-20-0050 presents detailed time-series plots of concentrations for every COC at each monitoring well listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2). In addition to these plots, ECF-200ZP1-20-0050 describes the methods used to calculate concentration trends using the Tobit maximum likelihood technique. The Tobit method estimates linear trends when there are left- or right-censored data (nondetects are left-censored data) in the dependent variable. When all data are quantified (i.e., no nondetects), the Tobit method yields the same trend coefficients as ordinary least-squares regression. ECF-200ZP1-20-0050 and SGW-58883, *Methodology for the Calculation of Concentration Trends, Means, and Confidence Limits for Performance and Attainment Monitoring*, provide further details on the Tobit method for estimating trends. Results from intrawell trend calculations are summarized in figures using symbols to show the trend result (i.e., up, down, indeterminate, or insignificant, as described in ECF-200ZP1-20-0050) and comparison of the intrawell UCLs to groundwater cleanup levels established in the 200-ZP-1 OU ROD (EPA et al., 2008). In these figures, an inverted triangle symbol indicates a downward trend, and a green-colored symbol indicates a concentration that is below the threshold concentration value used in the figure (which, in most cases, is the final cleanup level).

Figure 4-38 presents a map of trend calculation results for carbon tetrachloride using the concentration of 100 µg/L (which is targeted for hydraulic containment) as the threshold concentration value for visualization purposes. Figure 4-39 presents a map of trend calculation results for carbon tetrachloride using the final cleanup concentration of 3.4 µg/L as the threshold concentration value. These figures suggest that while most contaminants are decreasing in concentration, many wells continue to exceed 100 µg/L, and a much larger number of wells continue to exceed 3.4 µg/L, which is expected at this stage in the remedy lifecycle. All wells that show a concentration >100 µg/L and an upward or insignificant

trend (red upward triangles and squares, respectively) are within the capture zone of the combined 200-ZP-1 and 200-UP-1 OU P&T systems. Although most wells listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) are sampled for carbon tetrachloride, trends could not be determined for a fairly large number of wells at this time in the monitoring program due to a combination of either (1) insufficient data, (2) a preponderance of censored (i.e., nondetected result) data, or (3) the presence of a sample data that presents indiscernible trend results.

The number of wells listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) network sampled for the other COCs varies depending upon the specific COC. At this time, trends could not be determined in several wells, but the number of wells for which calculations could be made has increased since 2018 and will continue to increase over time as additional sample results are obtained. Summary figures presenting the results of trend calculations for the other 200-ZP-1 COCs are as follows:

- Figure 4-40 provides a map of Cr(VI) trend calculation results using the final cleanup concentration of 48 µg/L as the threshold concentration value for visualization purposes.
- Figure 4-41 provides a map of nitrate trend calculation results using the final cleanup concentration of 45,000 µg/L as NO_3 as the threshold concentration value for visualization purposes.
- Figure 4-42 provides a map of TCE trend calculation results using the final cleanup concentration of 1 µg/L as a threshold concentration value for visualization purposes.
- Figure 4-43 provides a map of iodine-129 trend calculation results using the final cleanup concentration of 1 pCi/L as a threshold concentration value for visualization purposes.
- Figure 4-44 provides a map of technetium-99 trend calculation results using the final cleanup concentration of 900 pCi/L as a threshold concentration value for visualization purposes.
- Figure 4-45 provides a map of tritium trend calculation results using the final cleanup concentration of 20,000 pCi/L as a threshold concentration value for visualization purposes.

Figures 4-38 through 4-45 show the results of the intrawell trend calculations completed for individual COCs to support detailed analysis of P&T system performance at the local scale (e.g., well-specific or small groups of wells). Over time, these trend calculations and results will help support P&T remedy optimization (including modifications to pumping rates and locations). This will be combined with the transition to and evaluation of MNA as attainment of final cleanup levels occurs on a well-by-well basis following guidance established by EPA for demonstrating cleanup.

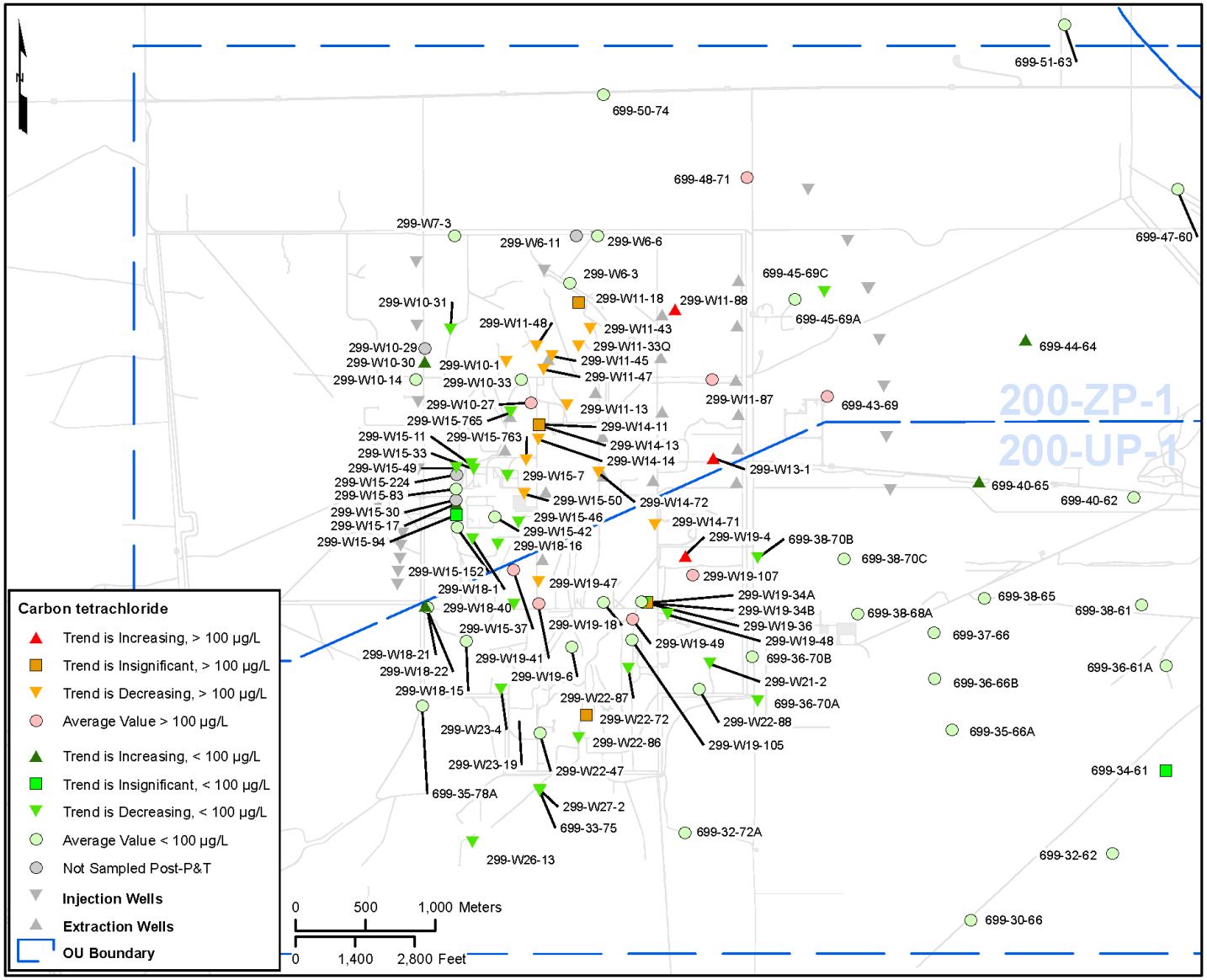

Figure 4-38. Map of Trend Calculation Results: Carbon Tetrachloride Using 100 µg/L Target Concentration

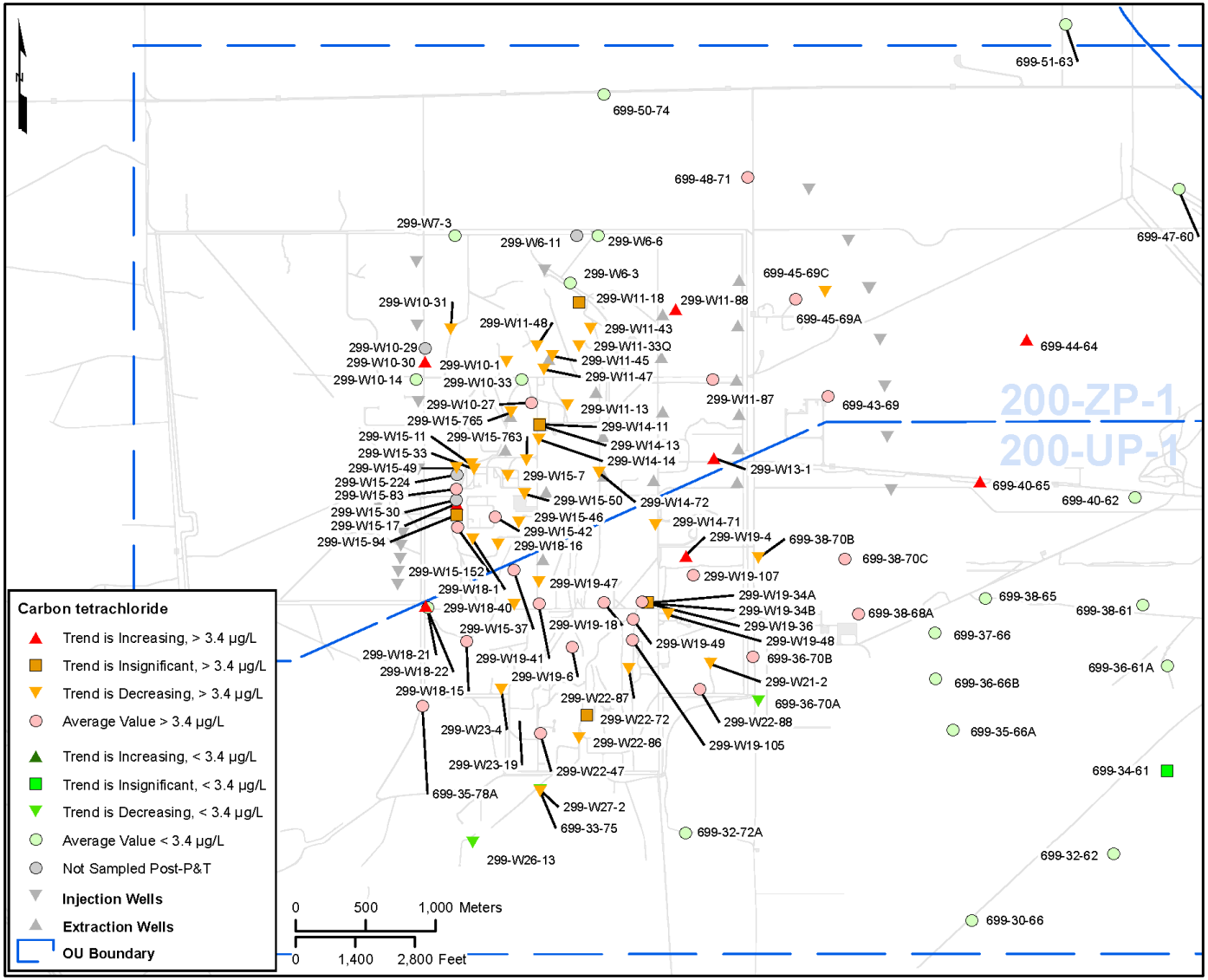

Figure 4-39. Map of Trend Calculation Results: Carbon Tetrachloride Using 3.4 µg/L Target Concentration

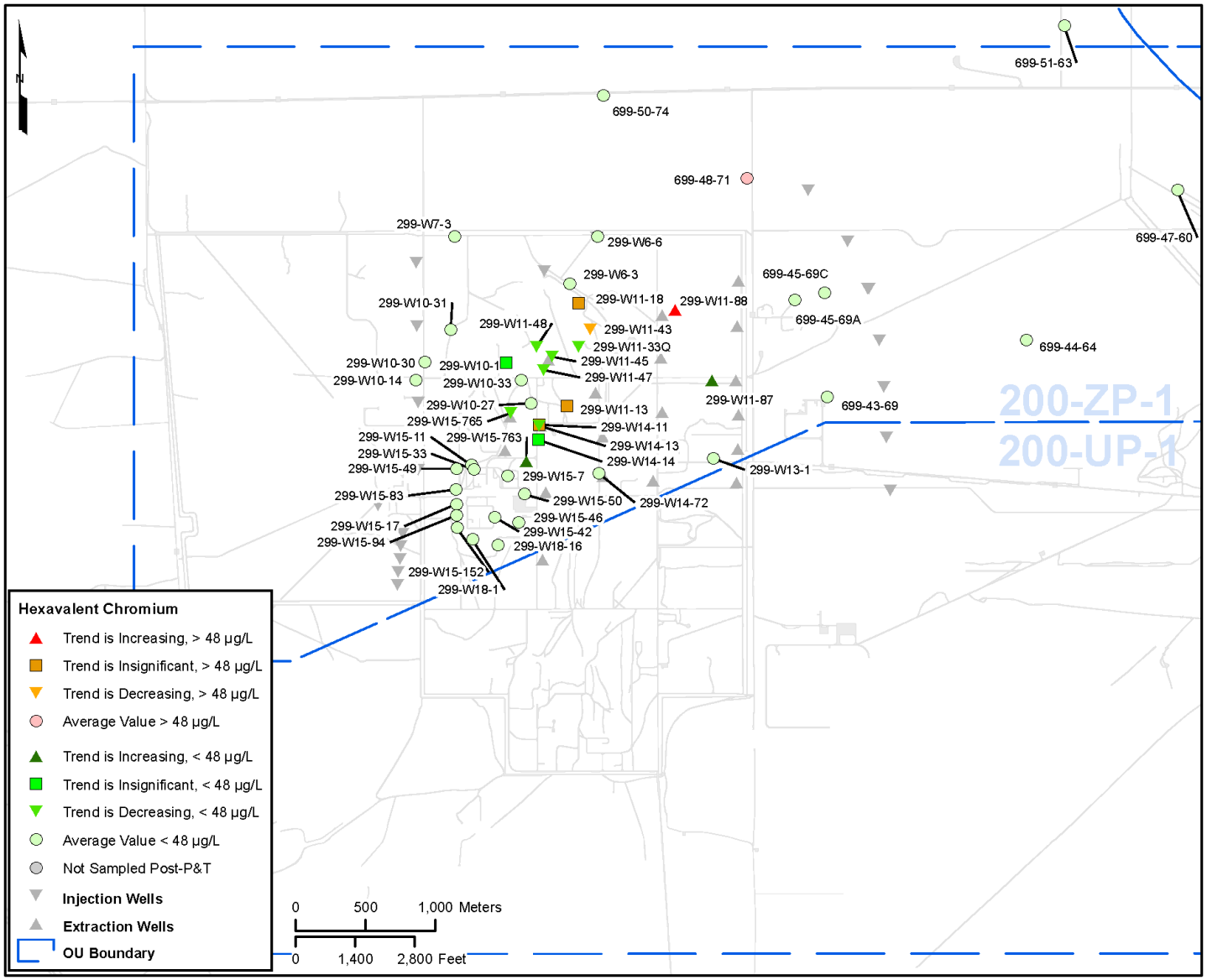

Figure 4-40. Map of Trend Calculation Results for Cr(VI)

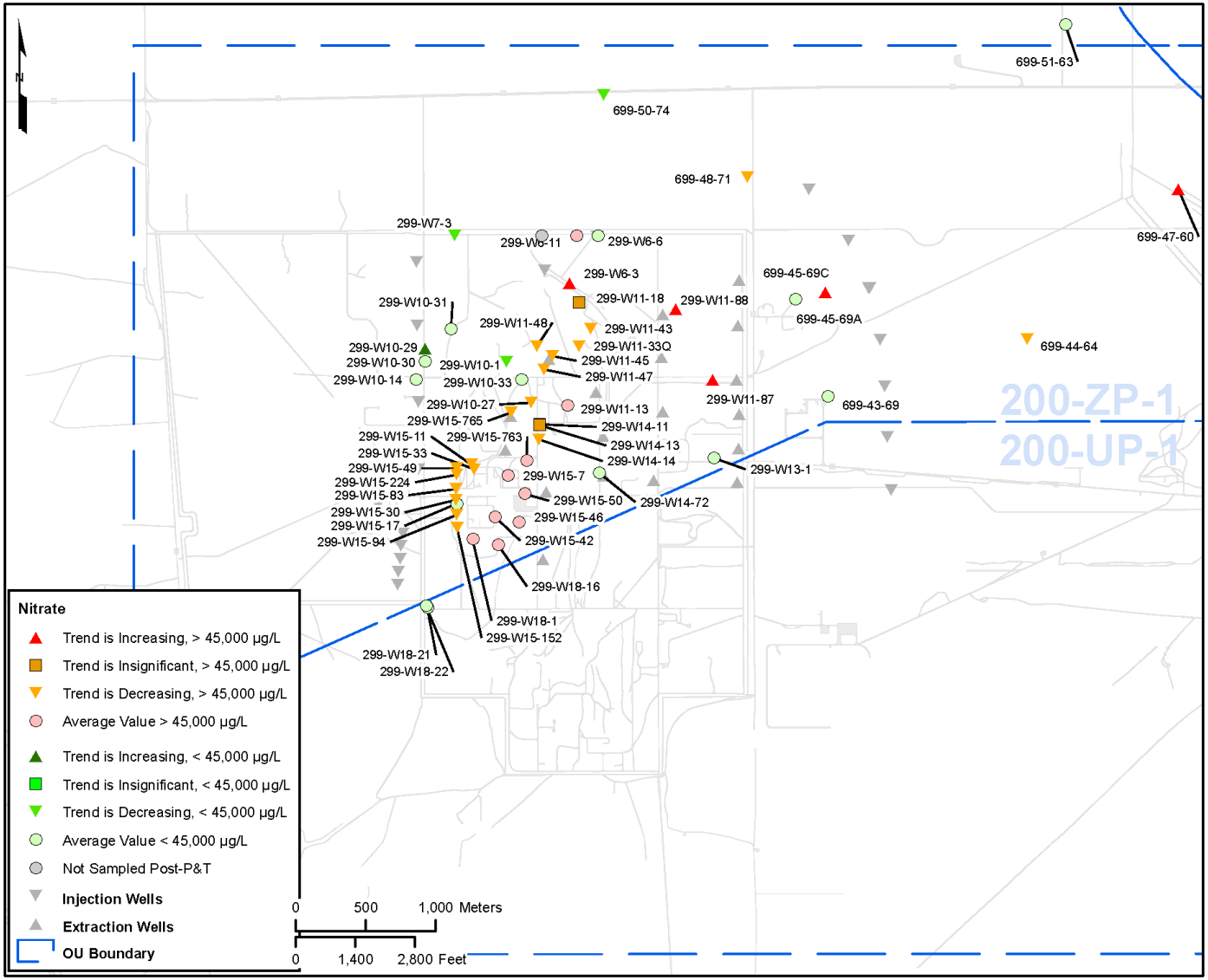

Figure 4-41. Map of Trend Calculation Results for Nitrate

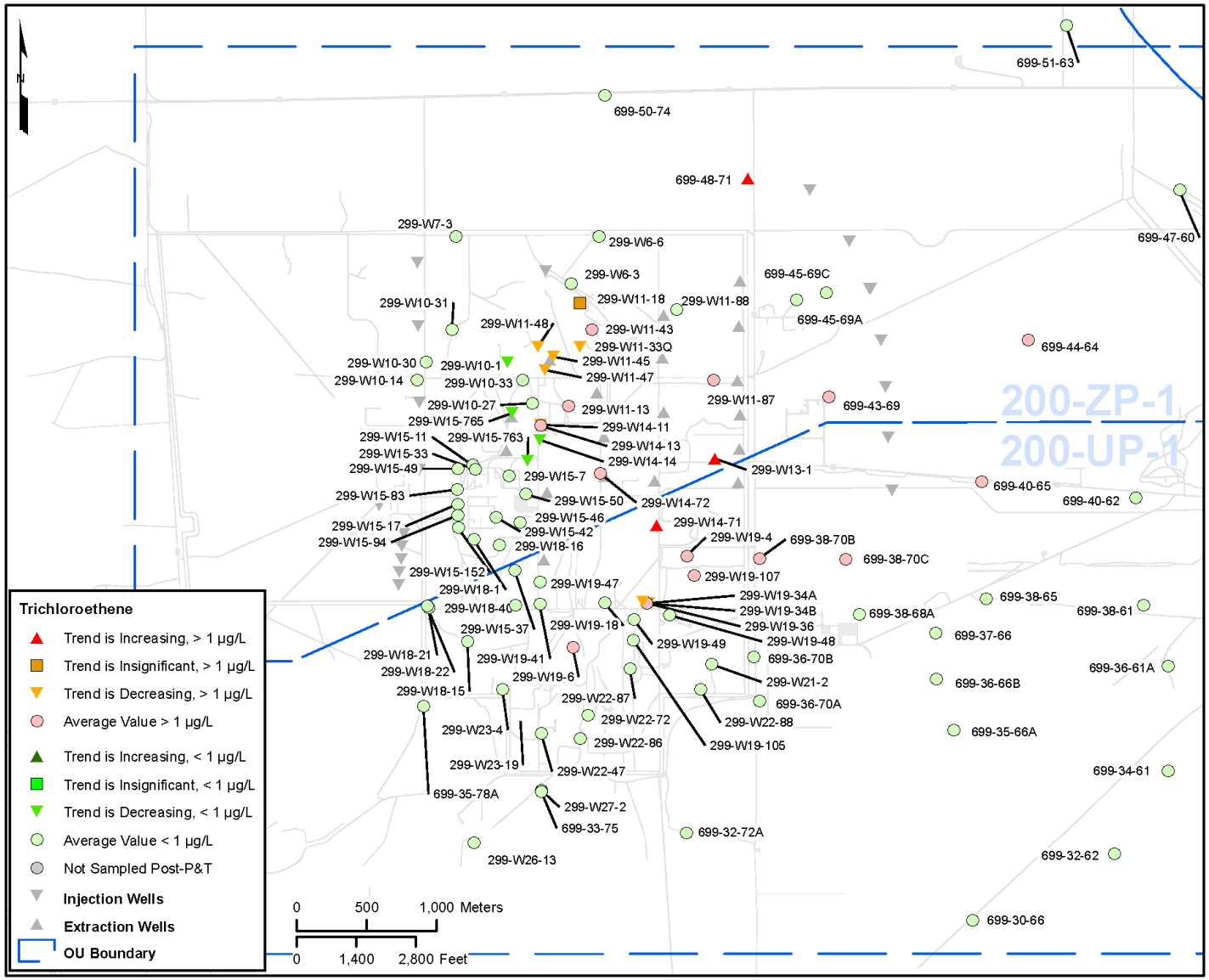

Figure 4-42. Map of Trend Calculation Results for TCE

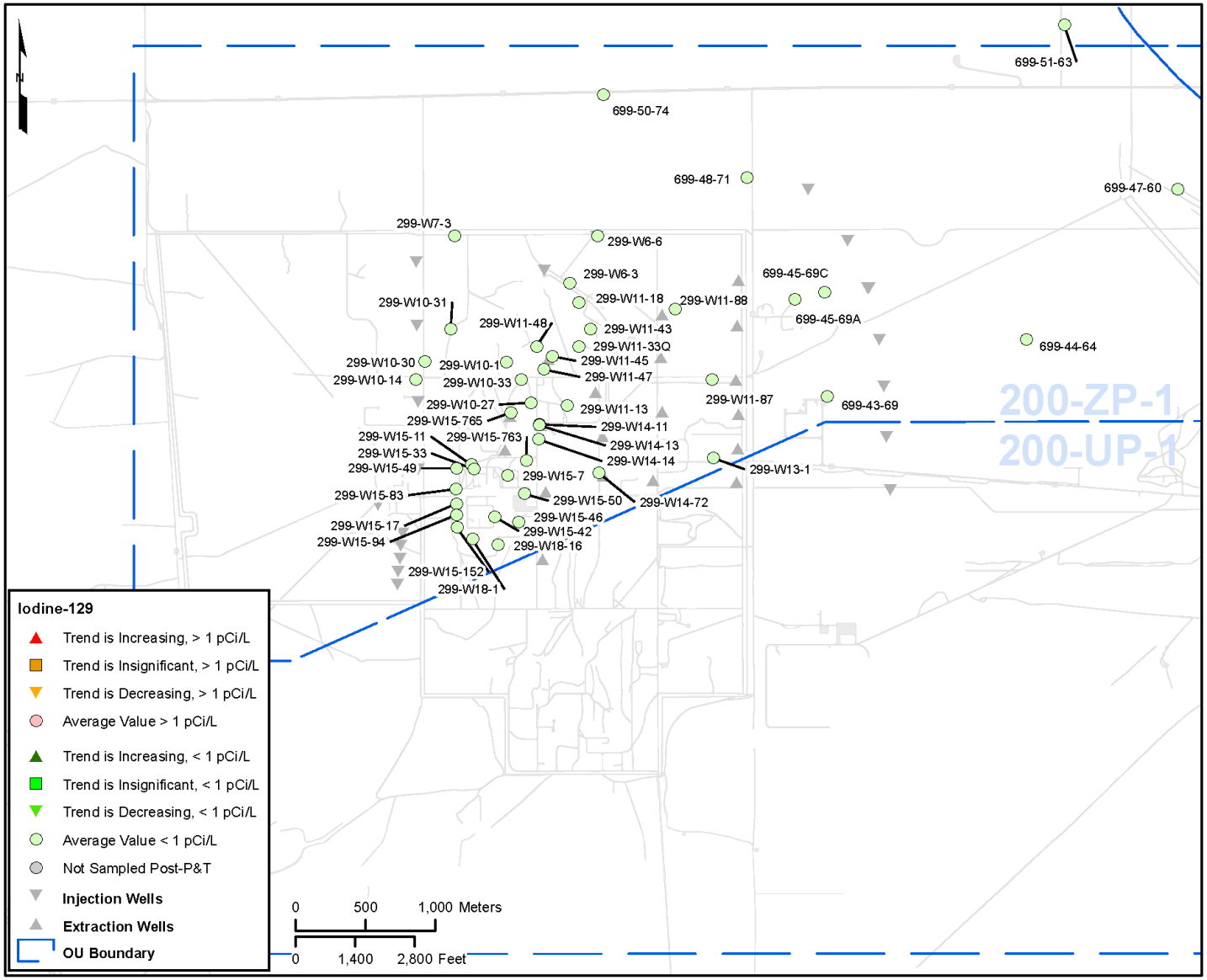

Figure 4-43. Map of Trend Calculation Results for Iodine-129

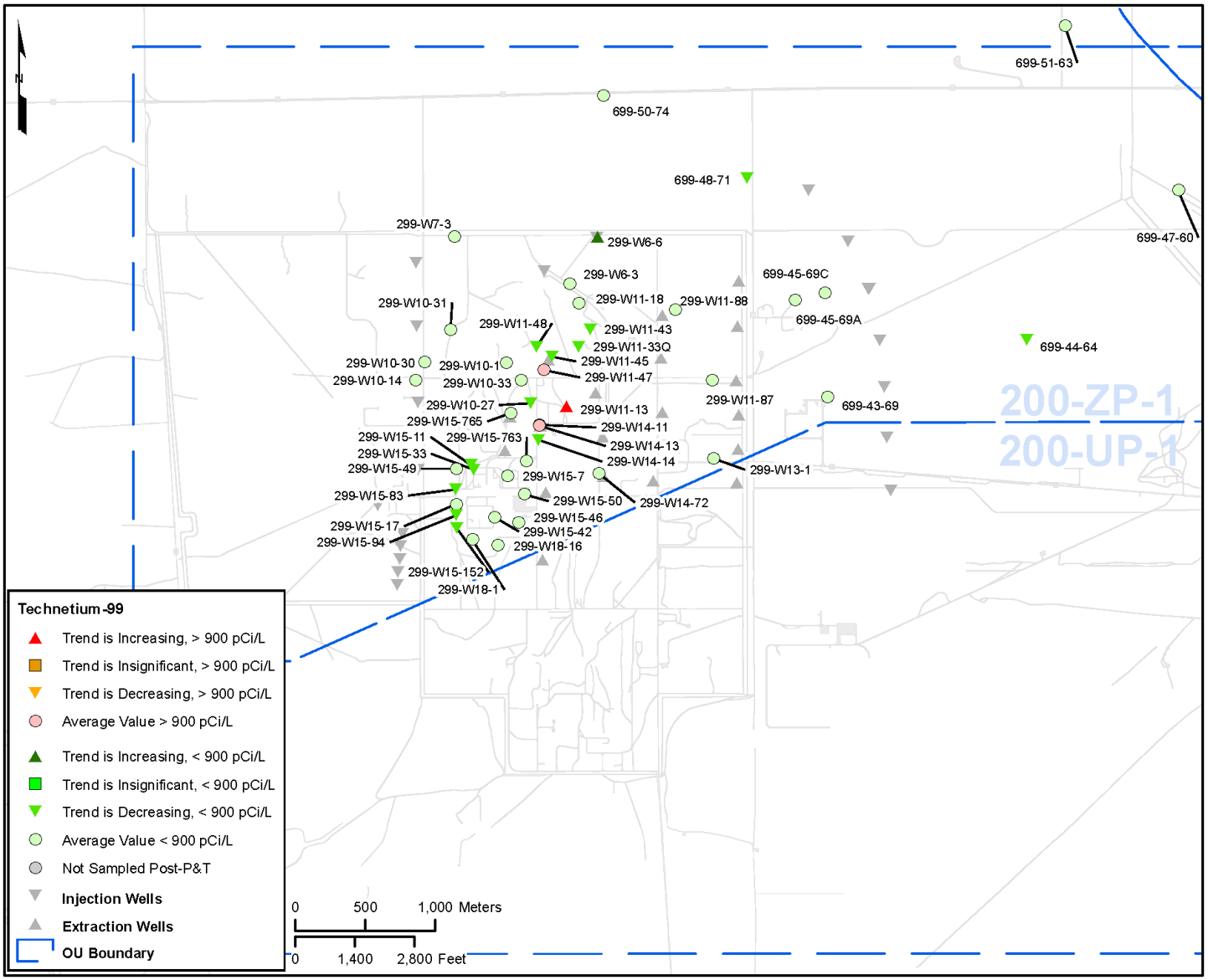

Figure 4-44. Map of Trend Calculation Results for Technetium-99

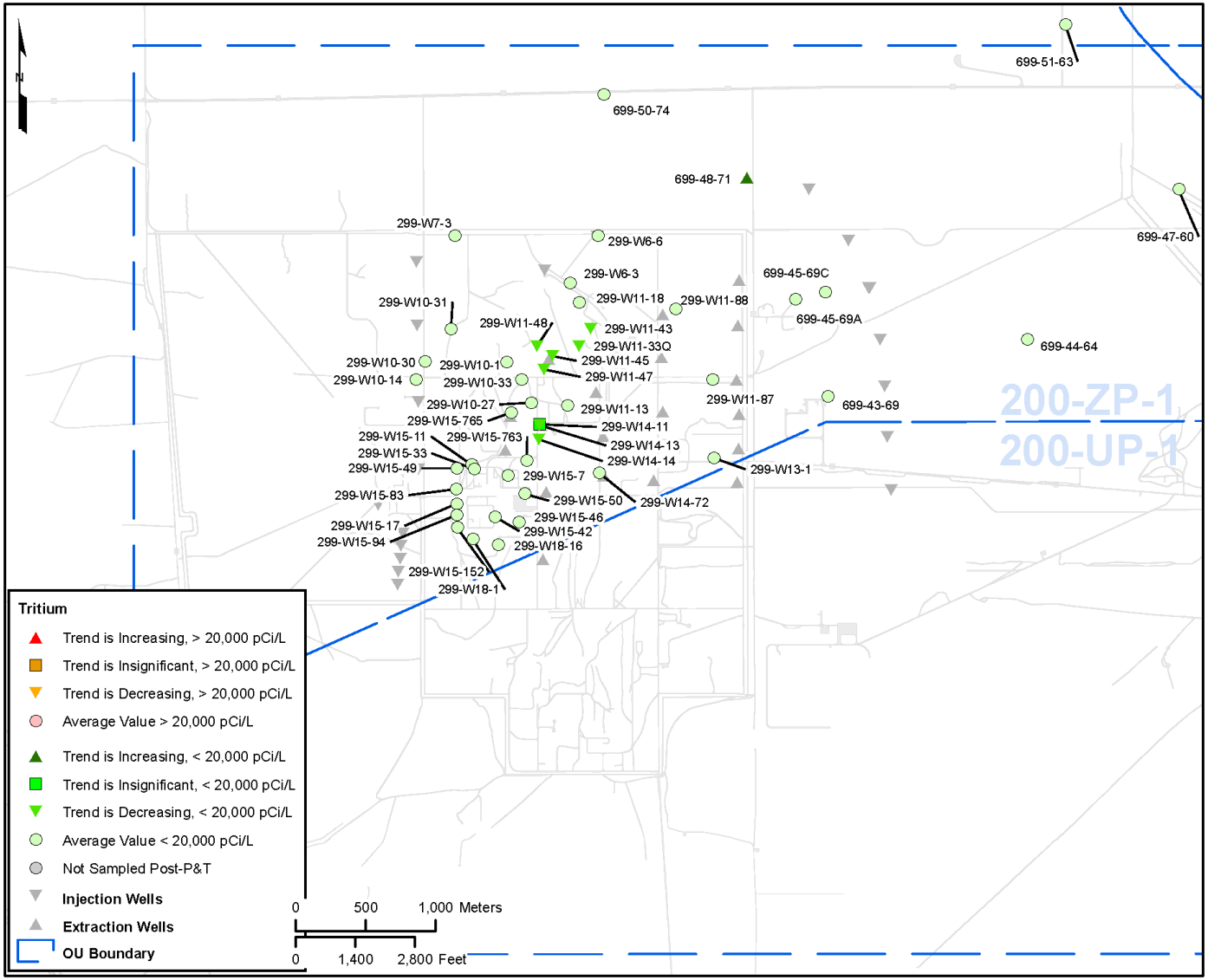

Figure 4-45. Map of Trend Calculation Results for Tritium

To provide plume and OU-wide assessments of concentration changes over time, summary statistics were calculated for each year since 2011 (the last full year prior to the year that the P&T system began operating) using two sets of wells:

- Wells listed as members of the network specifically designated in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) for sampling and evaluating the 200-ZP-1 OU remedy performance, regardless of whether each well was sampled during all years (thereby resulting in a different number of wells used to calculate statistics each year)
- Wells listed as members of the network specifically designated in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) for sampling and evaluating the 200-ZP-1 OU remedy performance, and for which sampling has occurred every year (thereby providing a consistent number of wells each year for statistical calculations, but resulting in fewer wells included in the calculations each year)

Note that well 299-W19-18 is listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2). Well 299-W19-115 was installed in 2016 adjacent to well 299-W19-18 as a replacement for well 299-W19-18. ECF-200ZP1-20-0051 details the summary statistic calculations for each of the 200-ZP-1 OU COCs that are summarized below. The calculations completed for this report use data from wells 299-W19-18 and 299-W19-115.

Sample summary statistics calculated for carbon tetrachloride were used to prepare Figures 4-46 and 4-47. For each graph for each year, the number of samples considered (*#S*), the number of sampled locations (*n*), the number of nondetect results (*ND*), and the number of detected samples (*D*) are listed. The graphs are presented as “box-and-whisker”-style plots that show the maximum and minimum values (top and bottom of the “whiskers”), 25th and 75th percentile values (top and bottom of the box), median (horizontal line within the box and blue dashed line), average, and UCL on the average as calculated using a Student’s t-test distribution. The graphs use concentration axes that emphasize the bulk of the calculation results, which for some COCs for some years means that the maximum value (i.e., the single value at the top of the whisker) extends off the chart.

Figure 4-46 presents summary statistics calculated for carbon tetrachloride using all wells with sample results obtained that particular year, regardless of whether the well yielded sample results in every year. The top panel (panel a) presents the results on a linear concentration axis, and the bottom panel (panel b) presents the results on a logarithmic concentration axis. Figure 4-47 presents the same suite of summary statistics for carbon tetrachloride, again using linear and logarithmic concentration axes, but computed only for the subset of wells listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) that had samples available each year. Figures 4-46 and 4-47 show that carbon tetrachloride concentrations have exhibited a general decline since startup of the 200 West P&T.

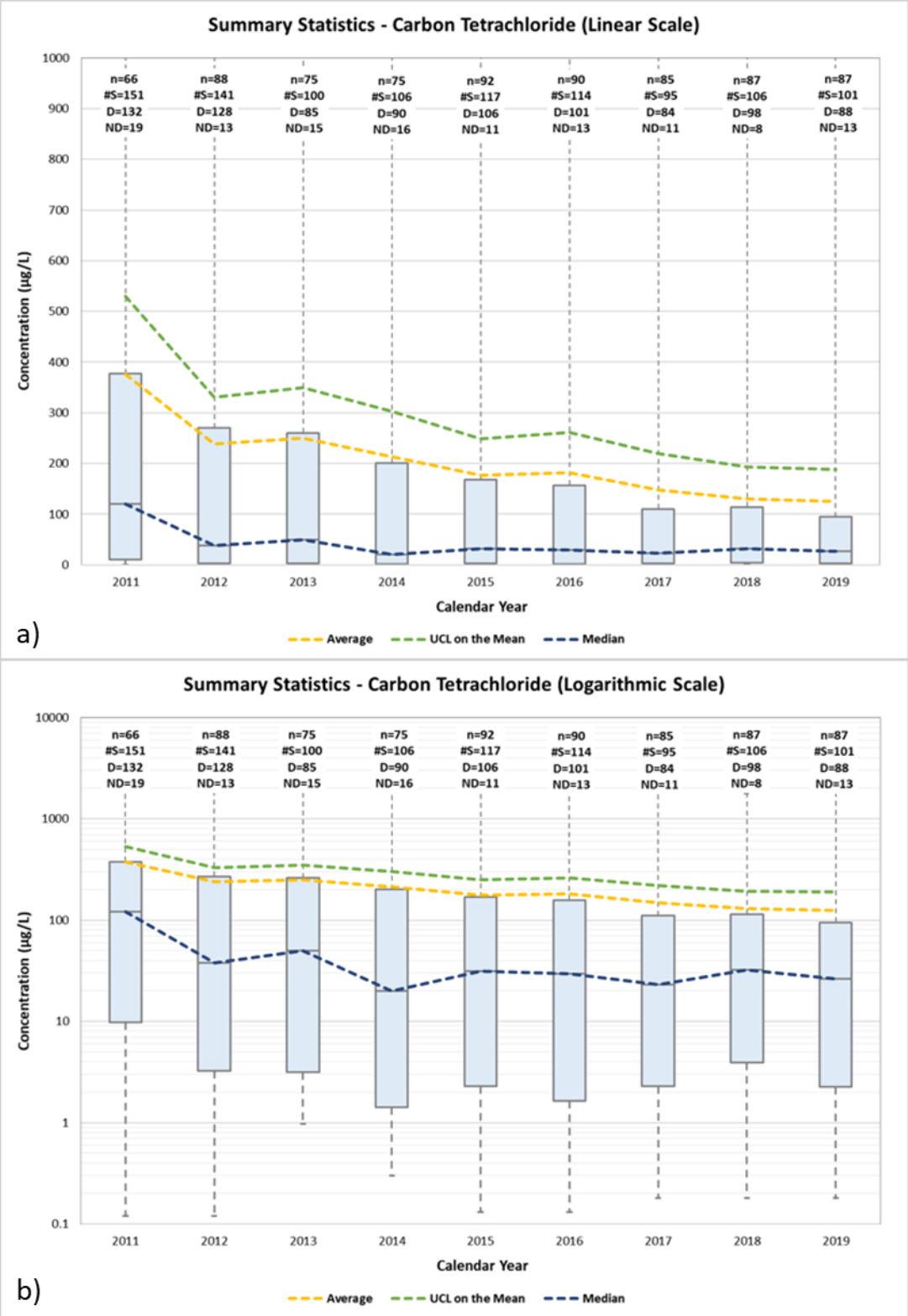

Figure 4-46. Summary Statistics for Carbon Tetrachloride for All Wells: (a) Linear Scale and (b) Logarithmic Scale

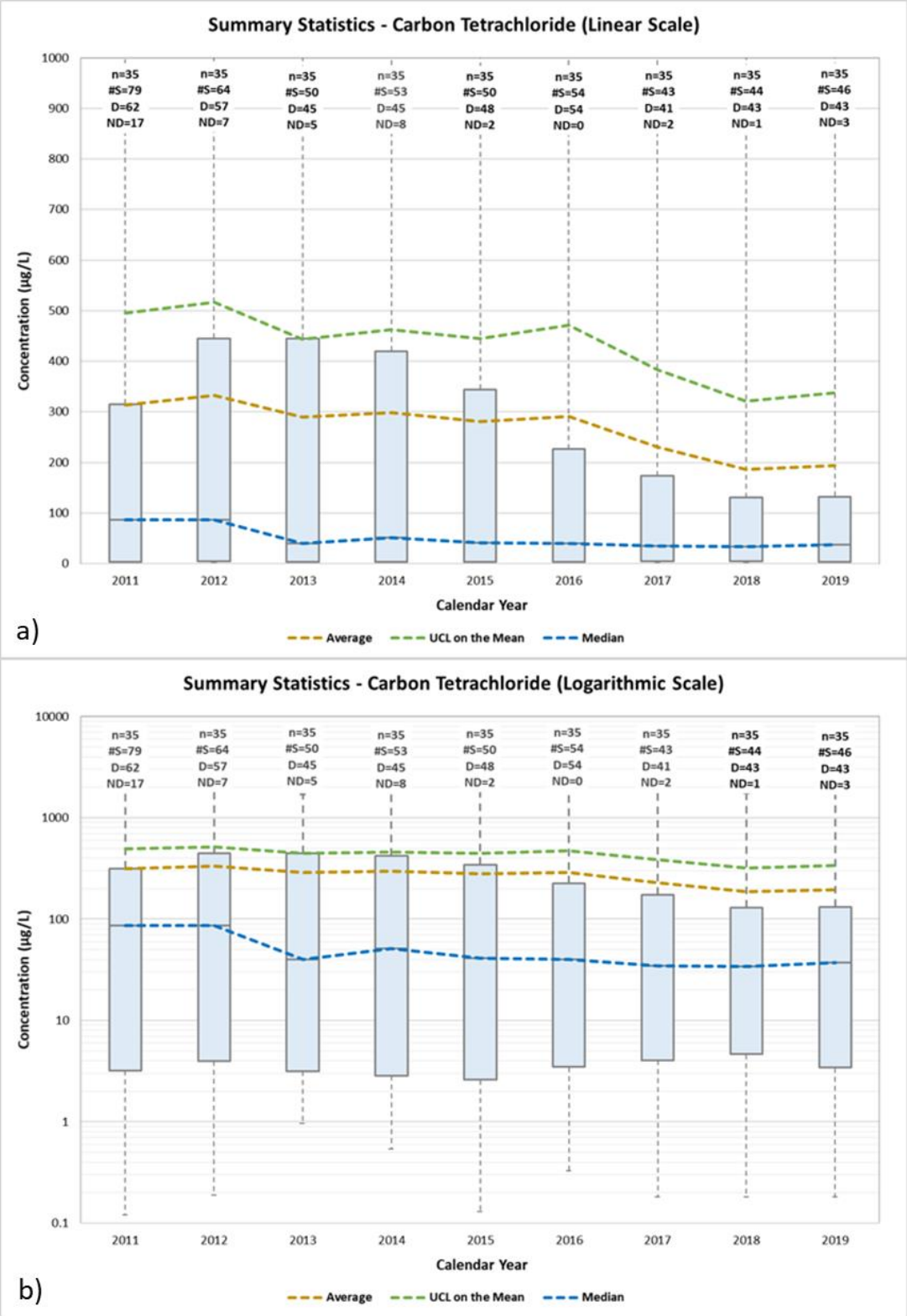

Figure 4-47. Summary Statistics for Carbon Tetrachloride for PMP Wells: (a) Linear Scale and (b) Logarithmic Scale

4.5.2 Evaluation of Hydraulic Data

This section evaluates hydraulic data obtained from wells throughout the 200-ZP-1 OU and the adjacent 200-UP-1 OU. Changes in groundwater levels and gradients are discussed, followed by an evaluation of the extent of hydraulic containment developed by the P&T system and the degree to which the primary COC (carbon tetrachloride) is contained. This section also presents groundwater elevation depictions and the extent of hydraulic containment as simulated using the P2R Model for comparison with the depictions and inferences obtained from the mapped groundwater elevation data. These data and associated analyses (when combined with the COC sample results and interpretation discussed in Section 4.4.1) provide information on the ability of the P&T remedy to establish flow-path control, to achieve hydraulic control of the area targeted for containment, and to recover these contaminants via extraction. This information is critical to understanding how the remedy is performing to meet interim targets and goals. However, because the P&T component of the remedy is anticipated to operate for decades to reduce concentrations to levels amenable to natural attenuation processes, it is difficult to accurately predict the rate of progress toward attaining final cleanup levels for groundwater.

4.5.2.1 Groundwater Elevations and Drawdown

Water-level hydrographs in Figures 4-7 through 4-9 show the changes in groundwater elevations (e.g., decreasing water levels in response to pumping, with some increases in response to periods of pumping cessation). Patterns of groundwater levels, and of drawdown and mounding, resulting from operation of the 200-ZP-1 and 200-UP-1 OU P&T remedies are shown in Figures 4-10 and 4-11, respectively, on the basis of groundwater-level mapping. For comparison with the mapped water levels shown in Figure 4-10, groundwater elevation contours computed using the P2R Model are shown in Figure 4-48 for the following aquifer intervals and periods:

- Figure 4-48 (panel a) depicts above the Rlm at the end of 2019.
- Figure 4-48 (panel b) depicts below the Rlm at the end of 2019.

The simulated water table elevations and spacing of equipotential contours compare favorably with those obtained using water-level mapping (Figure 4-10), particularly within the area of the extraction and injection wells where water-level monitoring is abundant. Outside of these areas, where the effects of injection and extraction are more subtle and there is less monitoring density, the mapped and modeled water levels show differences that primarily result from differences in the methods used to construct the contours (i.e., deterministic groundwater modeling versus geostatistical interpolation).

For comparison with the drawdown and mounding maps presented in Figure 4-11, unadjusted and adjusted drawdown and mounding estimated using the P2R Model are shown in Figures 4-49 and 4-50 for the following aquifer intervals (note: calculation of the adjustment applied is detailed in Section 4.3.2.2):

- Figure 4-49 (panel a) depicts above the Rlm at the end of 2019 (not adjusted for regional declines).
- Figure 4-49 (panel b) depicts below the Rlm at the end of 2019 (not adjusted for regional declines).
- Figure 4-50 (panel a) depicts above the Rlm at the end of 2019 (adjusted for regional declines).
- Figure 4-50 (panel b) depicts below the Rlm at the end of 2019 (adjusted for regional declines).

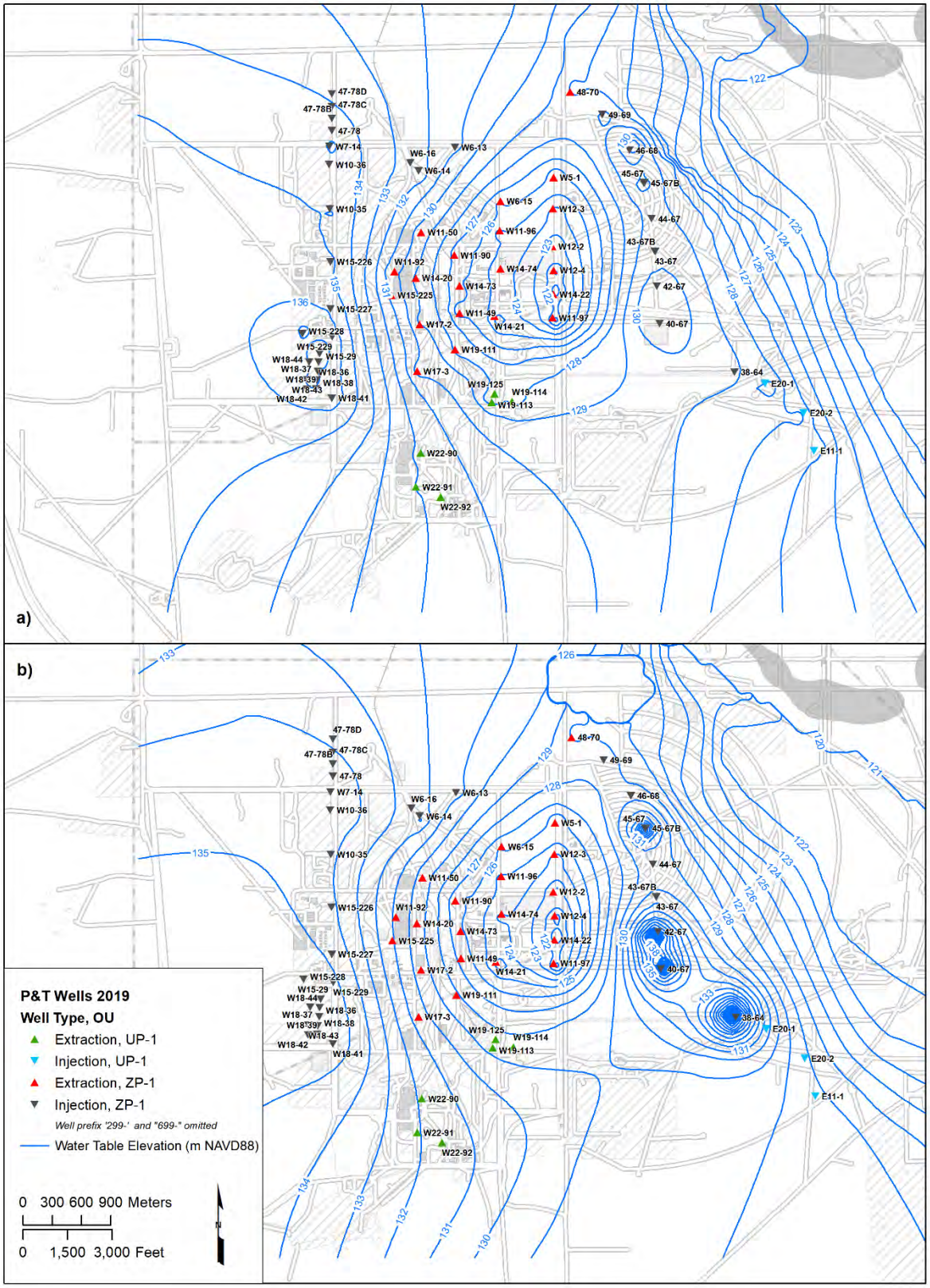

Figure 4-48. Groundwater Elevation Contours Computed Using the P2R Model: (a) Above the Rlm at the End of 2019 and (b) Below the Rlm at the End of 2019

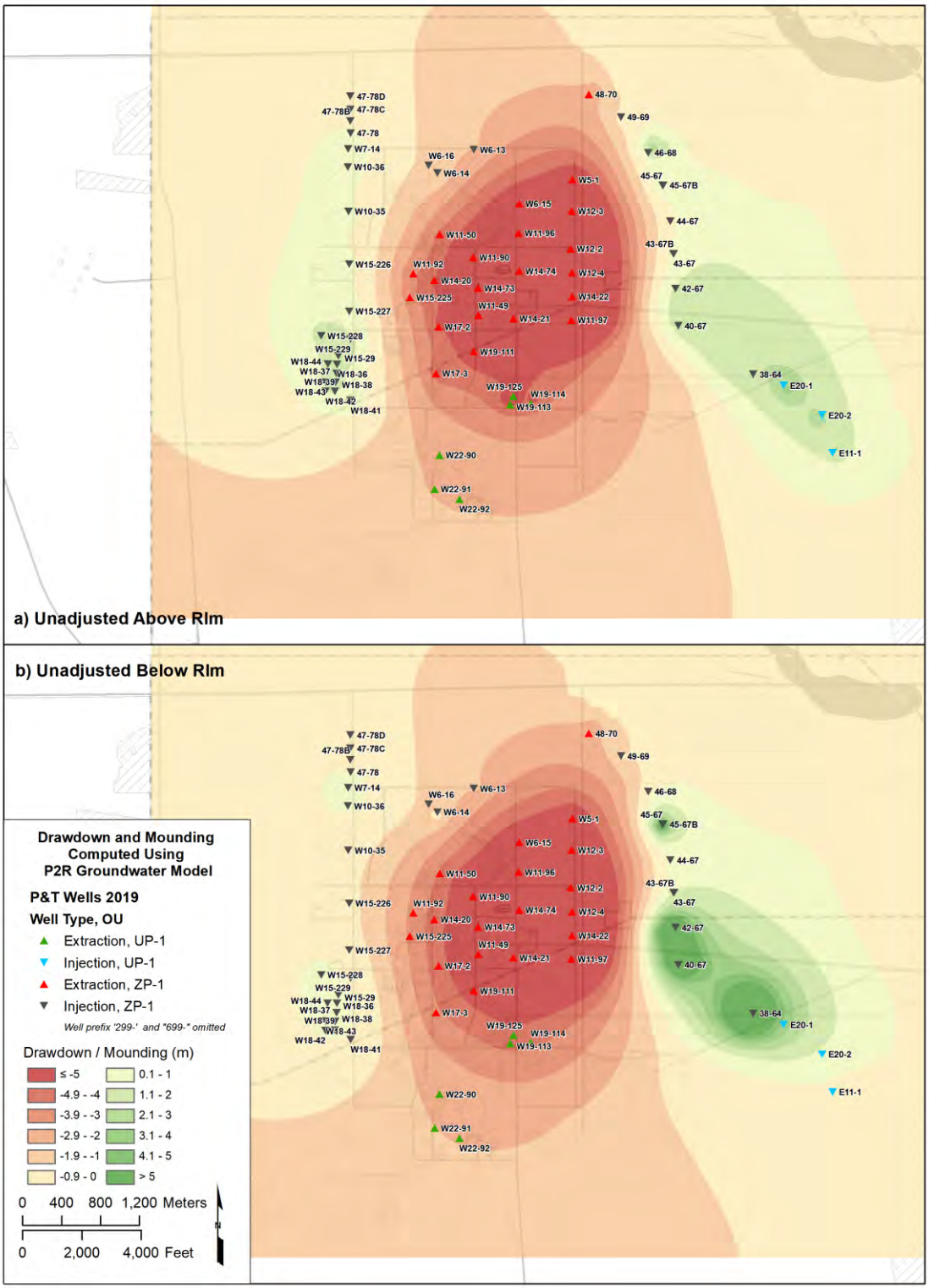

Figure 4-49. Unadjusted Drawdown and Mounding Estimated Using the P2R Model: (a) Unadjusted Drawdown Above the Rlm at the End of 2019 and (b) Unadjusted Drawdown Below the Rlm at the End of 2019

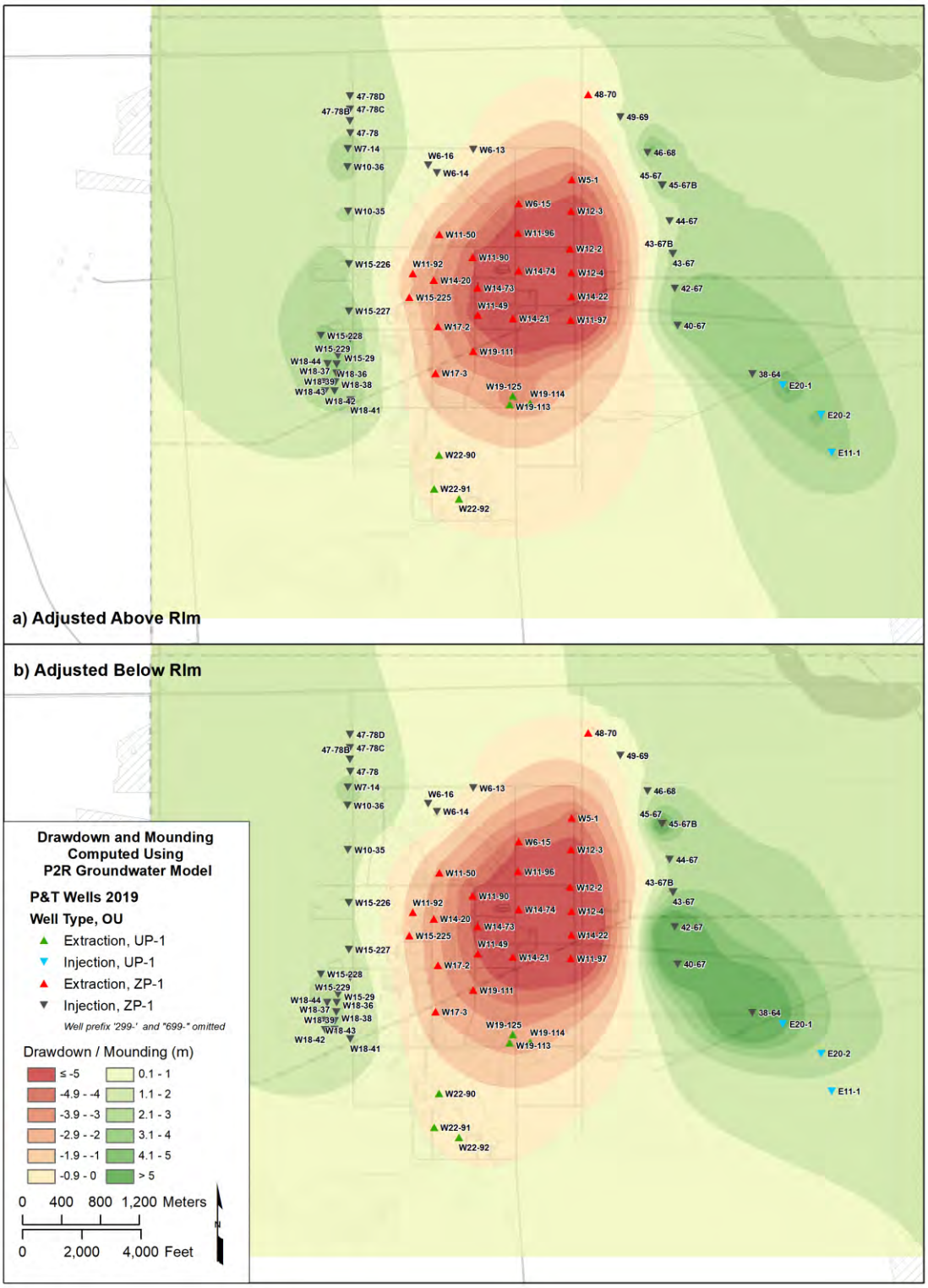

Figure 4-50. Adjusted Drawdown and Mounding Estimated Using the P2R Model:
(a) Adjusted Drawdown Above the Rlm at the End of 2019 and
(b) Adjusted Drawdown Below the Rlm at the End of 2019

The pattern of simulated groundwater mounding and drawdown (and spacing of contours) above the Rlm compares favorably with that obtained using water-level mapping (Figure 4-11). Both maps identify focused areas of drawdown and mounding near the extraction and injection wells, respectively. Encircling the 200-ZP-1 OU groundwater extraction wells that pump primarily above the Rlm is a large area exhibiting drawdown >1 m (3.3 ft), with a limited region in the center of the extraction wellfield exhibiting drawdown >5 m (16.5 ft). Two distinct aquifer regions that exhibit mounding >1 m (3.3 ft) occur around the injection wells screened above the Rlm on the west side of the 200-ZP-1 OU and around the injection wells screened beneath the Rlm on the east side of the OU.

These simulation results are consistent with findings from the water-level interpolation. This suggests that the P2R Model reasonably reflects the actual impacts of extraction and injection on the aquifer and provides some confidence that depictions of the extent of drawdown and capture calculated with the P2R Model are reasonably reflective of actual conditions.

4.5.2.2 Saturated Thickness of the Unconfined Aquifer

Declining groundwater levels can compromise the ability of extraction wells to recover contaminated groundwater through reduced well capacity. Extraction wells installed as part of the 200 West P&T were constructed with long screen intervals to provide high capacity and to mitigate impacts to well performance from the lowering of groundwater elevations. In most cases, the drawdown expected in the aquifer adjacent to each extraction well is a few meters, whereas the screened interval for most extraction wells is tens of meters long. During 2019, notable impacts to extraction well performance were not found as a result of declining water levels. However, the likelihood for reductions to extraction well performance as a result of water-level declines and other factors (e.g., well screen or filter pack fouling) will increase over time, reducing well efficiency and productivity. The potential effects of well fouling can be mitigated through testing, maintaining, and redeveloping extraction wells as part of the O&M program.

Figure 4-51 shows the estimated saturated thickness of the unconfined aquifer in 2012 and 2019 as calculated by subtracting the mapped elevation of the base of the unconfined aquifer from the mapped groundwater elevations for those 2 years. For purposes of this calculation, the base of the unconfined aquifer is considered to be either (1) the top of the Rlm, where present; or (2) for consistency of interpretation, the top of the Rwia where the Rlm is absent. This results in an estimate of the saturated thickness of the unconfined aquifer that lies within the Rwie, which is the upper aquifer unit. The thickness contours terminate to the northeast where less water-level data are available to constrain the mapping and where the saturated thickness appears to diminish.

Figure 4-52 shows the estimated saturated thickness of the unconfined aquifer in 2012 and 2019 as calculated by subtracting the mapped elevation of the base of the unconfined aquifer from the groundwater elevations simulated for those 2 years using the P2R Model. As with Figure 4-51, the contours terminate the northeast where fewer water-level data are available to constrain the mapping and where the saturated thickness appears to quickly diminish.

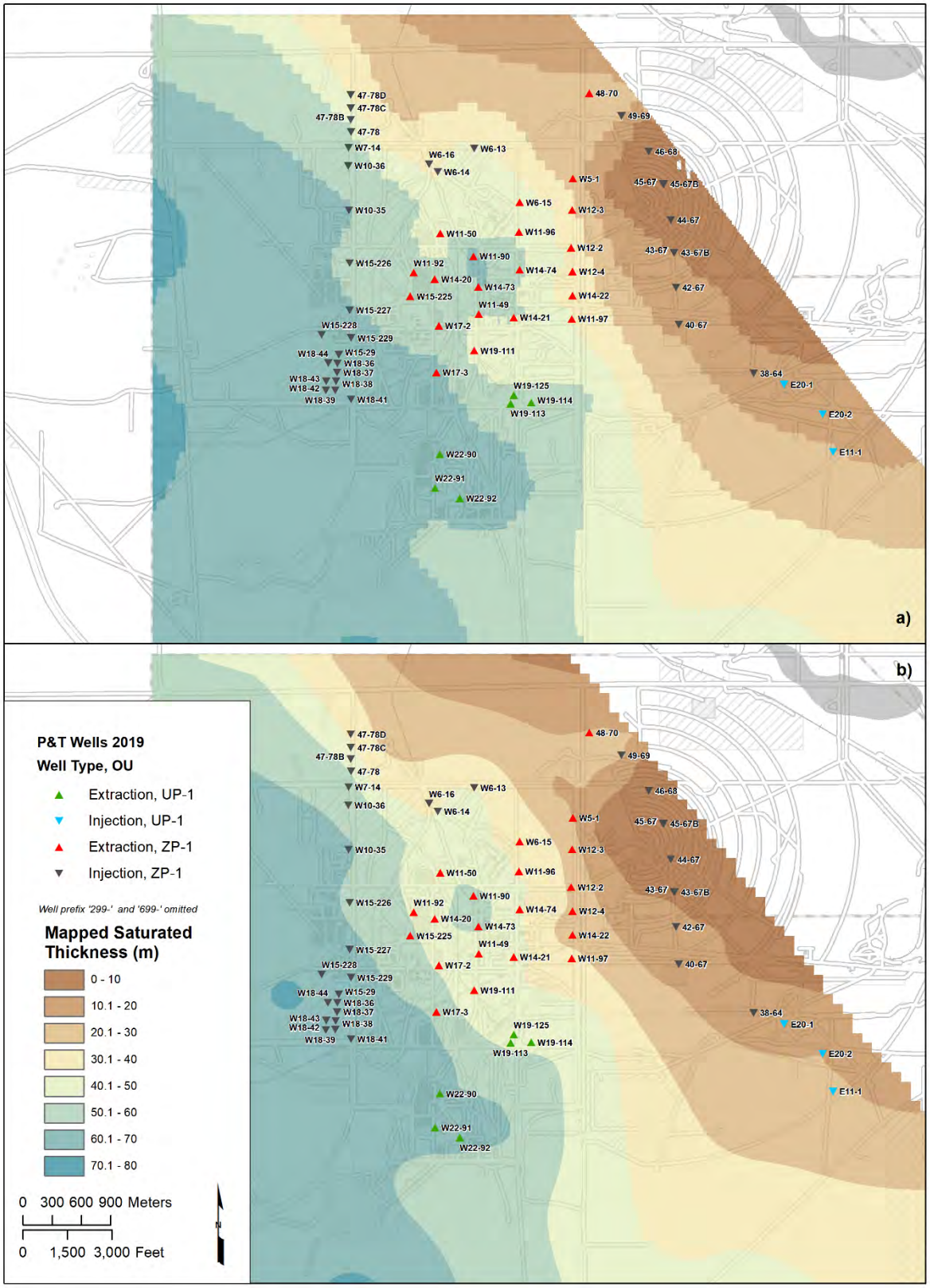

Figure 4-51. Mapped Saturated Thickness in (a) 2012 and (b) 2019

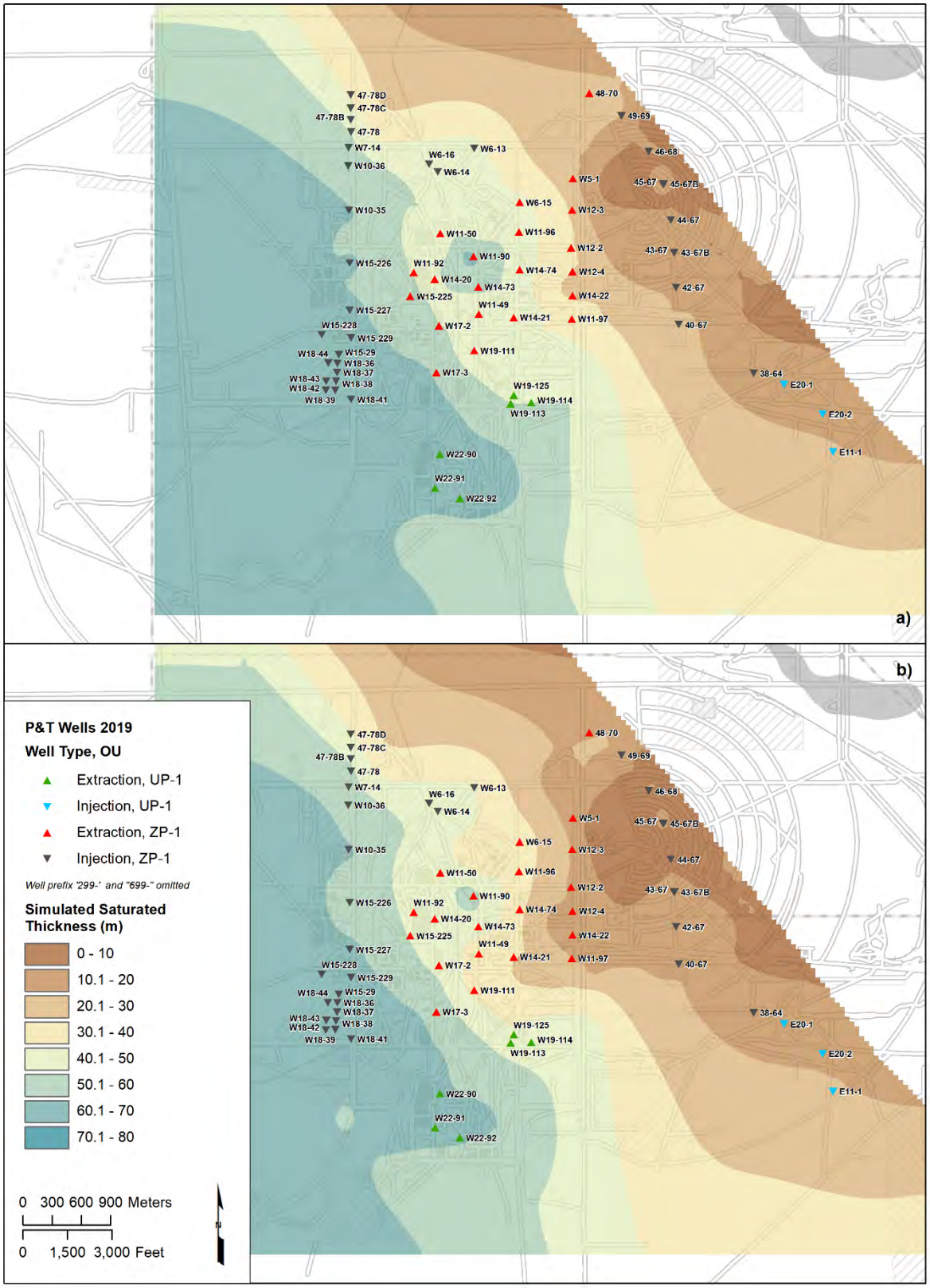

Figure 4-52. Simulated Saturated Thickness in (a) 2012 and (b) 2019

Figures 4-53 and 4-54 compare the saturated thickness estimated in 2019 with that estimated in 2012 using the mapped groundwater levels and simulated groundwater levels, respectively. The comparison is shown as a percentage. A value of 100% represents equivalency between the two periods, where values <100% represent a reduced saturated thickness, and values >100% represent increased saturated thickness (in 2019 versus 2012 conditions). The pattern and magnitude of increased and reduced areas of saturated thickness are generally consistent between the methods. Both methods suggest that in some areas on the northeast side of the concentrated area of extraction wells, the saturated thickness may have reduced below half of the initial saturated thickness. Reductions of saturated thickness of this proportion already have the potential to compromise extraction well performance.

It was recommended in the 2018 groundwater P&T report (DOE/RL-2018-68) that further attention be given to evaluating water-level decline rates in response to both pumping and ongoing recession following the end of Hanford Site production operations to ensure that sufficient saturated thickness is maintained to efficiently operate the 200 West P&T. The potential effects of the groundwater-level declines and reductions of saturated thickness on extraction well performance can be mitigated by re-routing a greater proportion of the treated water to be injected on the upgradient (i.e., west) side of the extraction wells to maintain the aquifer saturated thickness. This also has the added benefit of increasing the rate of flushing of groundwater and contaminants toward the extraction wells. In recognition of the likely benefits of such wellfield reconfiguration, modifications to the distribution of injected water will be evaluated during remedy optimization analyses conducted in 2020.

Although the general representation of saturated thickness declines agrees between the simulated and mapped estimates, differences may become operationally significant in areas where extraction wells are operating and where continued water-level declines may lead to greater diminishment of saturated thickness, which could further affect extraction well performance.

4.5.2.3 Particle Paths and Hydraulic Containment

Estimates of the extent of hydraulic containment developed for the 200 West P&T are based on water-level mapping and groundwater modeling using the P2R Model. Hydraulic containment estimates are obtained by tracing particle paths using the results of water-level mapping and groundwater modeling, and then differentiating particles that are captured from those particles that are not captured under the given conditions. Particle paths calculated using the groundwater elevation maps are also provided to illustrate general patterns of flow under recent conditions.

Figure 4-55 shows the particle paths calculated for December 2019 using the groundwater elevations mapped above the Rlm (panel b of Figure 4-10). The particle paths represent an instantaneous calculation of the likely path that hypothetical water parcels would take if conditions mapped during December 2019 were to persist indefinitely. These particle paths show general patterns of groundwater and contaminant migration under these conditions but do not readily lend themselves to estimating the contiguous hydraulic containment extent developed by the P&T systems.

Figure 4-56 shows the extent of hydraulic containment calculated when a sufficiently large number of particles is tracked on the mapped water-level surface above the Rlm (panel b in Figure 4-10) to encompass the entire extent of hydraulic containment. In Figure 4-56, the light-gray shading indicates regions of the aquifer above the Rlm that are likely to be contained and ultimately captured by 200-ZP-1 OU extraction wells under current operating conditions, whereas the darker gray shading indicates regions of the aquifer (above the Rlm) that are likely to be contained and ultimately captured by 200-UP-1 OU extraction wells. Figure 4-56 also shows the estimated carbon tetrachloride plume extent at concentrations >100 µg/L and 3.4 µg/L, as determined using quantile kriging.

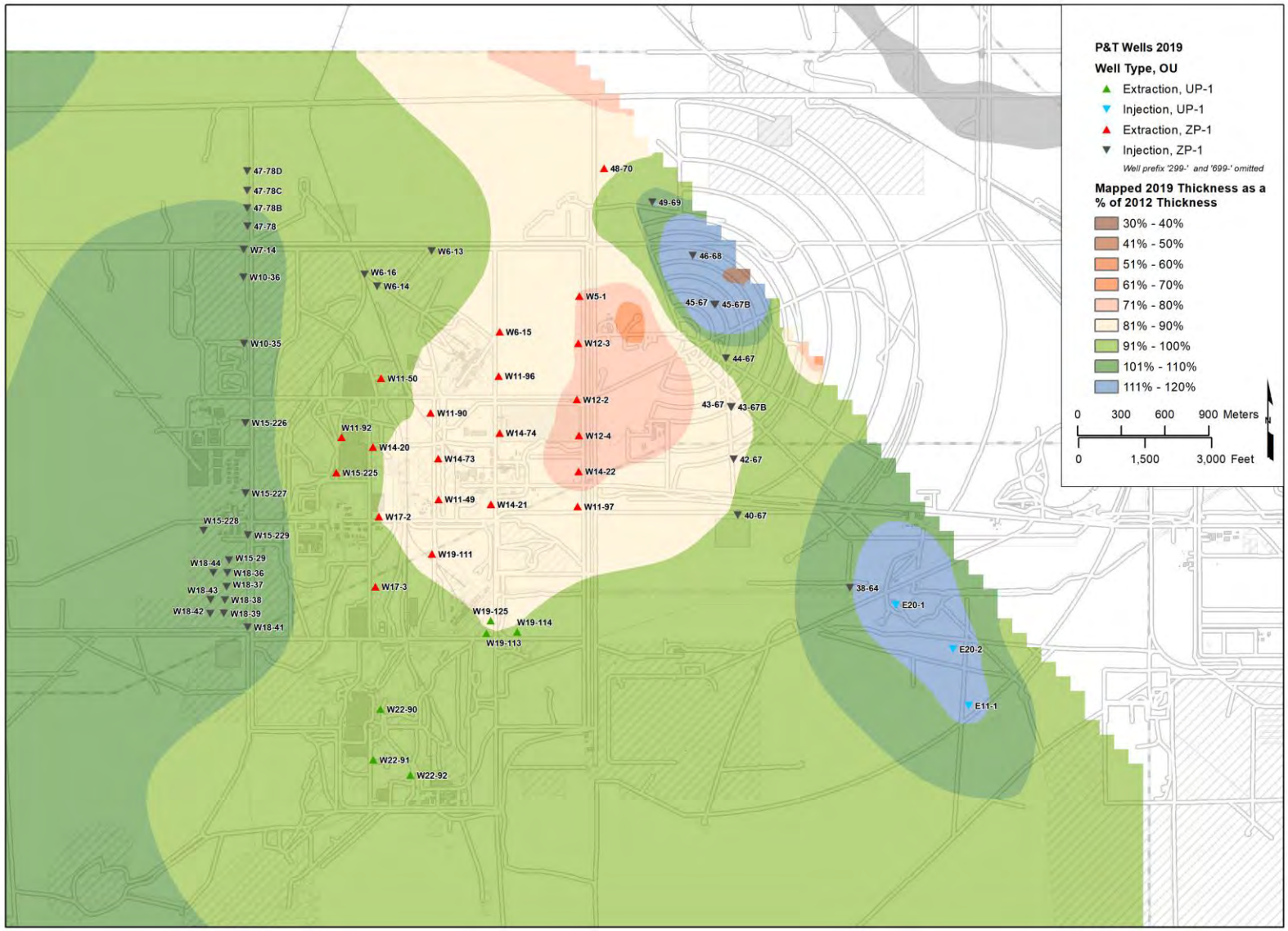

Figure 4-53. Mapped Saturated Thickness in 2019 Compared to 2012

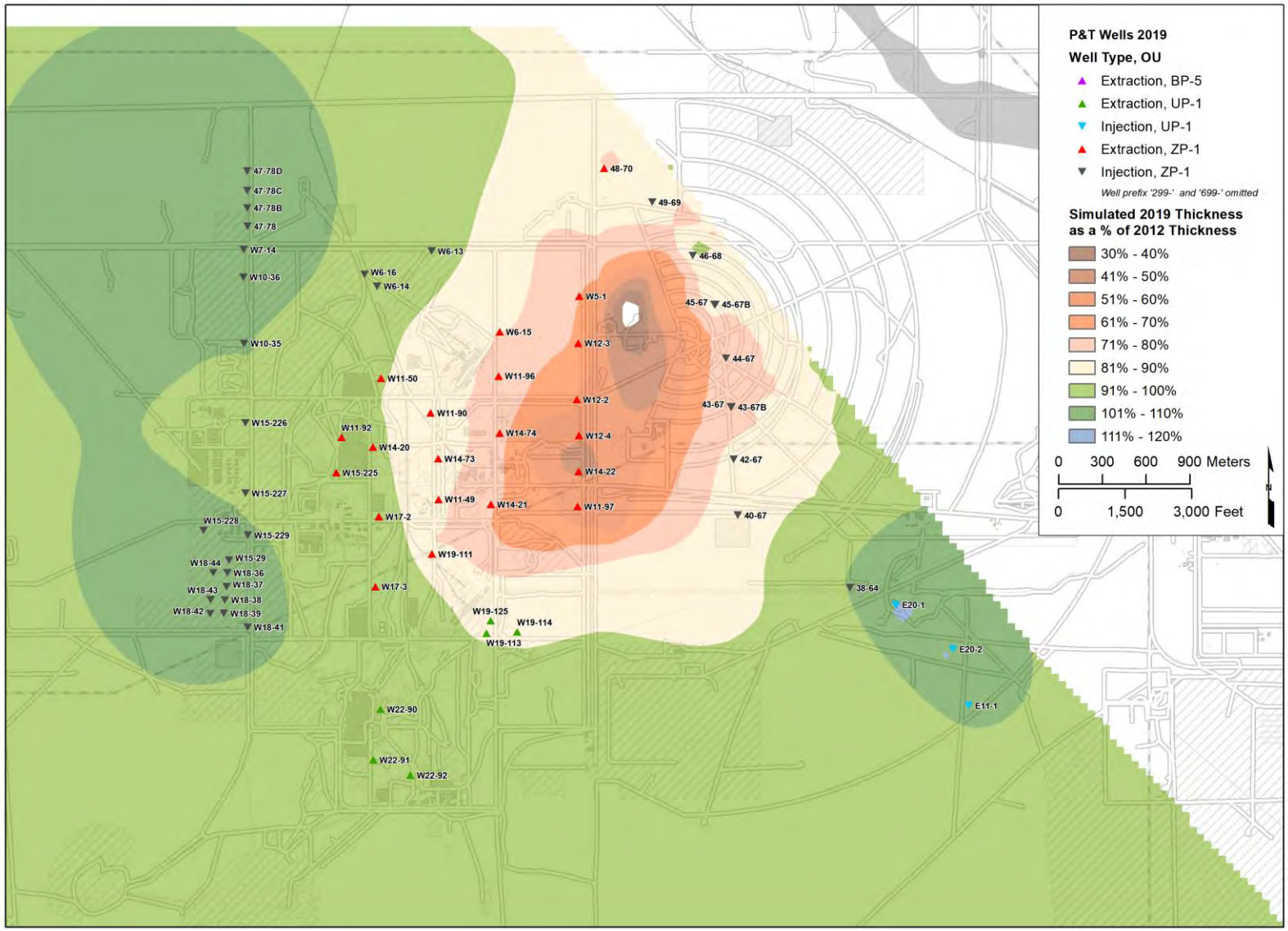

Figure 4-54. Simulated Saturated Thickness in 2019 Compared to 2012

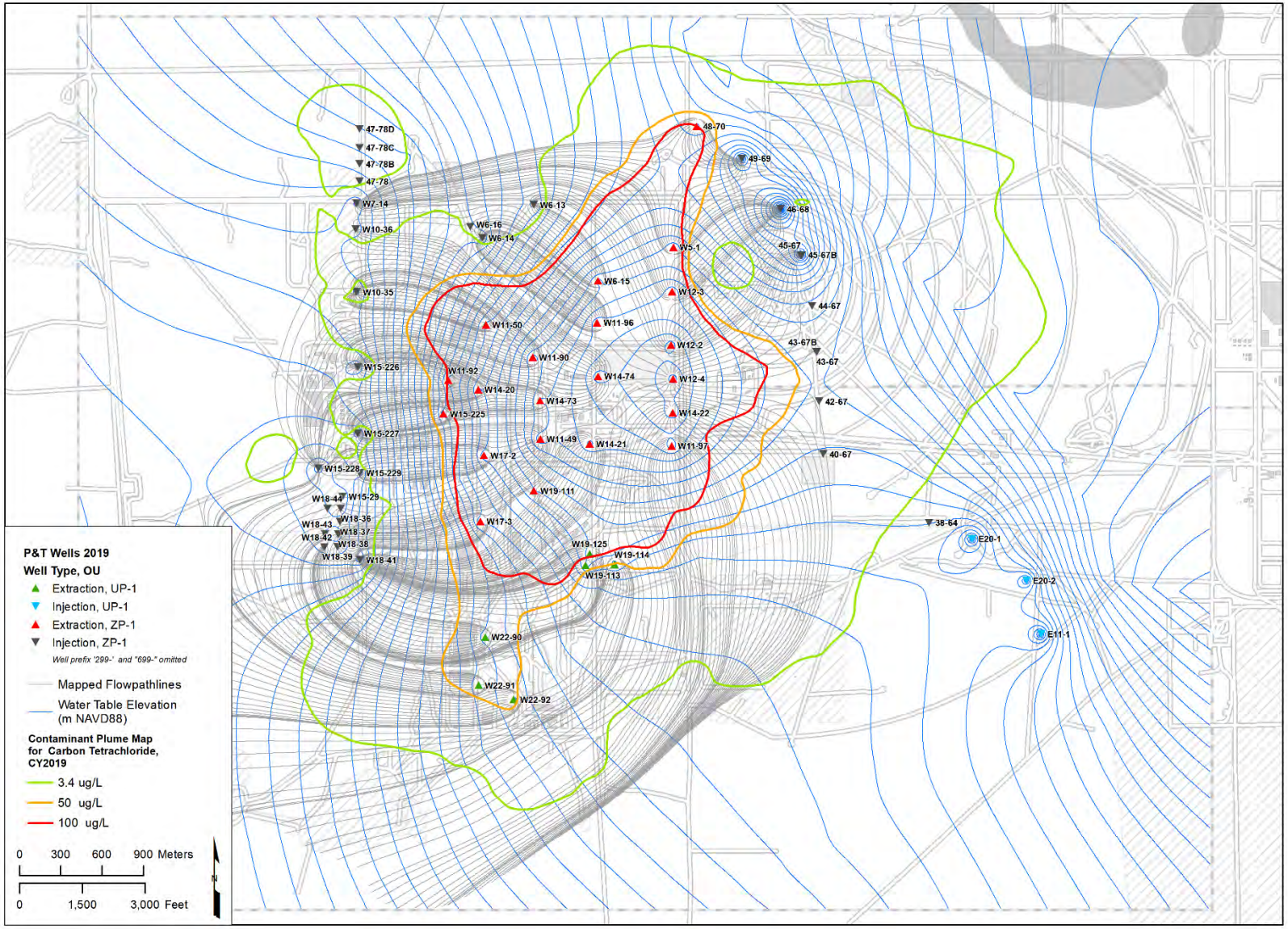

Figure 4-55. Particle Paths Computed for December 2019 Using Water-Level Mapping Above the RIm

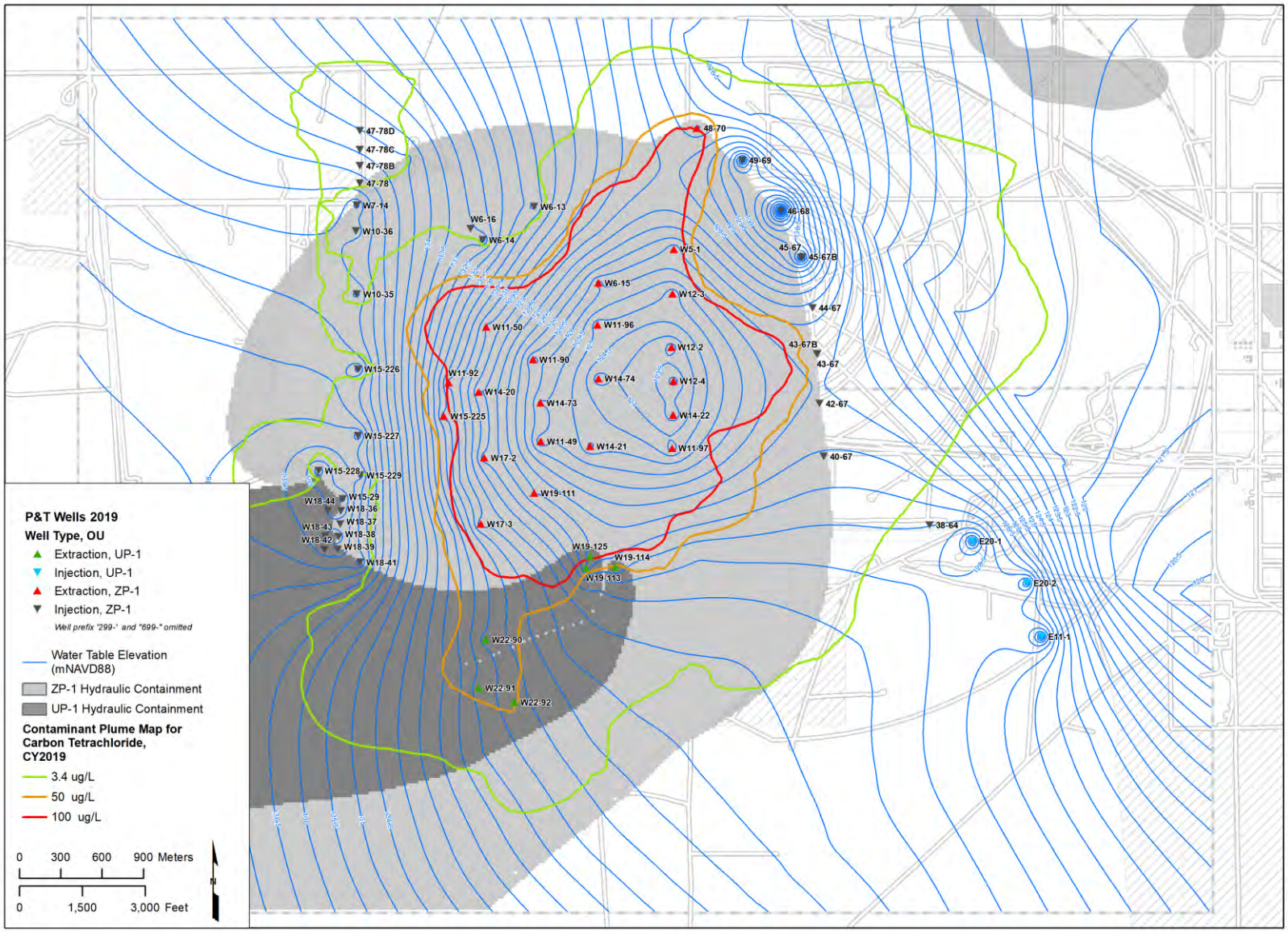

Figure 4-56. Extent of Hydraulic Containment Computed for December 2019 Using Water-Level Mapping Above the RIm

Figure 4-57 shows the extent of hydraulic containment calculated when a sufficiently large number of particles is tracked using the P2R Model (which produced the simulated water-level surface shown in Figures 4-48). In Figure 4-57, the upper panel shows the extent of capture simulated above the Rlm, and the lower panel shows the extent of capture simulated below the Rlm. The light-gray shading indicates regions of the aquifer (above and below the Rlm) that are likely to be contained and ultimately captured by 200-ZP-1 OU extraction wells, whereas the darker gray shading indicates regions of the aquifer (above the Rlm) that are likely to be contained and captured by 200-UP-1 OU extraction wells. Figure 4-57 also shows the estimated carbon tetrachloride plume extent at concentrations >100 µg/L and 3.4 µg/L (as determined using quantile kriging) above and below the Rlm.

The estimated hydraulic containment extents shown in Figures 4-56 and 4-57 (panel a) (i.e., above the Rlm) throughout the 200-ZP-1 OU and for the 200-ZP-1 OU extraction wells located within the 200-UP-1 OU are very similar (particularly over the area encompassing the 100 µg/L), suggesting that groundwater extraction is effectively containing the majority of the area exhibiting carbon tetrachloride concentrations >100 µg/L. Figures 4-56 and 4-57 (panel a) also suggest that the northeastern region that was identified as not contained in 2017 and 2018 was addressed by installing new extraction well 699-48-70, which appears to effectively contain carbon tetrachloride contamination above the 100 µg/L target. The extent of this uncontained area is largely defined by sample data obtained from a single monitoring well (699-48-71). Carbon tetrachloride concentrations were steadily increasing in well 699-48-71 prior to installing and operating extraction well 699-48-70. An additional injection well (699-50-71) was also planned for the area to help hydraulically contain this region of the plume. Installation and operation of proposed injection well 699-50-71 will be contingent upon the performance of well 699-48-70.

The data presented in this chapter are collected to evaluate performance of the 200-ZP-1 OU remedy, to depict initial plots and maps of those data, and to present various analyses and interpretations of the data to provide a basis for remedy performance evaluation. The following sections interpret the performance monitoring data in the context of the remedy targets, goals, and RAOs for the 200-ZP-1 OU remedy.

4.6 Predictive Modeling Calculations Using the Plateau to River Model

As of 2019, the 200 West P&T has been operating for over 7 years, which is nearly one quarter of the operating lifecycle that was originally proposed for the P&T component of the remedy in the 200-ZP-1 OU ROD (EPA et al., 2008). Progress toward attaining short-term targets and intermediate-term goals for this remedial action can, to a large extent, be assessed by directly evaluating and interpreting the performance monitoring data, supplemented where appropriate using simulations completed with the P2R Model. However, because assessing the progress toward attaining the intermediate mass recovery goal and the ultimate cleanup levels in groundwater require predictions of future conditions, those particular evaluations require using the P2R Model to make reasonable projections. For this reason, the projections of likely future performance discussed in Section 4.7 were completed using the P2R Model.

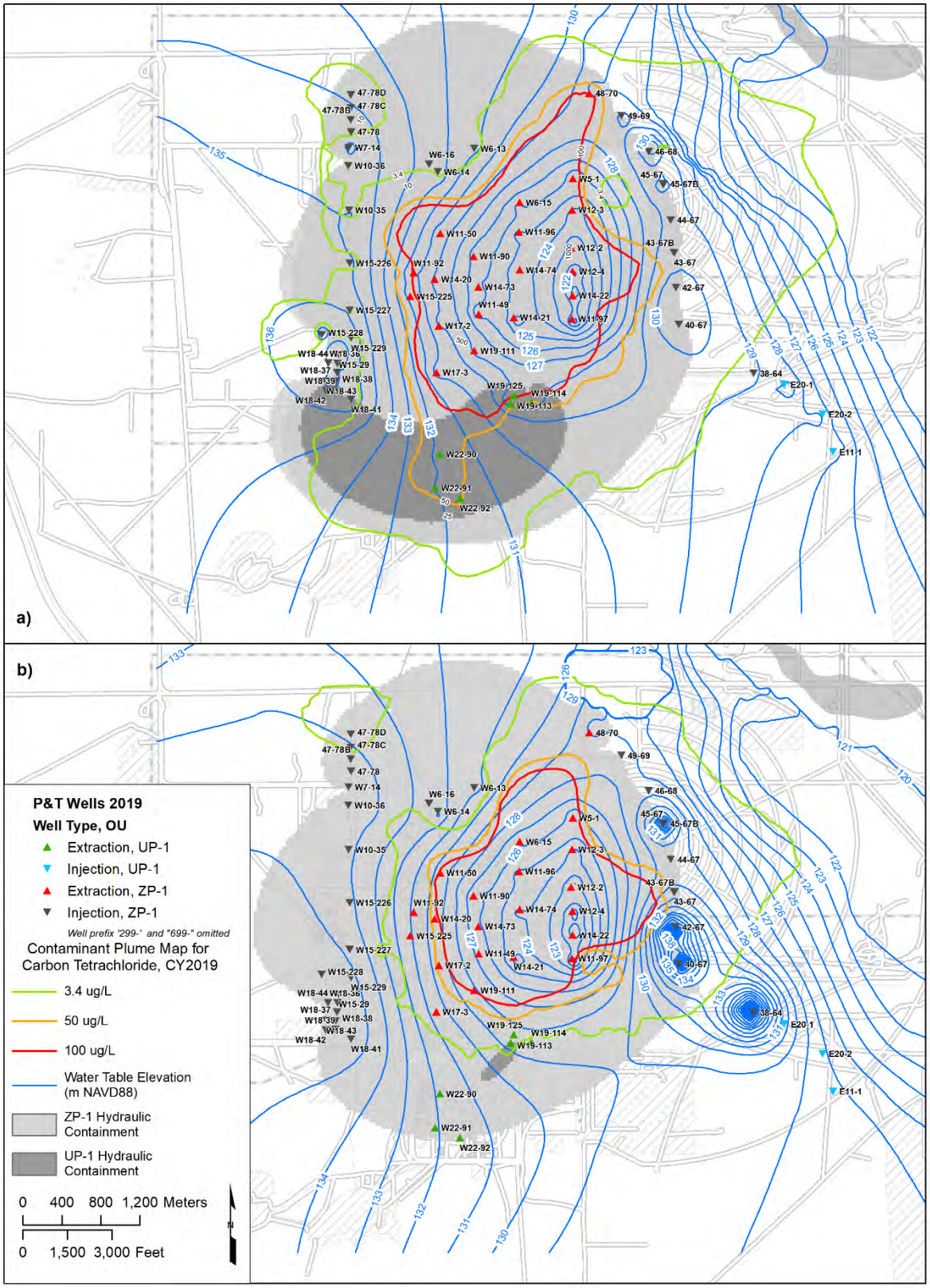

Figure 4-57. Extent of Hydraulic Containment Computed for December 2019 Using the P2R Model: (a) Above the RIm and (b) Below the RIm

ECF-HANFORD-20-0049 discusses the calculation methods using the P2R Model that were developed to predict the likely future performance of the 200-ZP-1 OU remedy and presents the results of the calculations in greater detail than provided herein. The predictions focus on (1) likely mass recovery rates at individual extraction wells, (2) the P&T remedy in its entirety, and (3) the proportion that the projected mass recovery represents of the initial contaminant mass present at startup of the remedy and progress toward attaining groundwater cleanup levels. Simulated historical rates for extraction and injection wells are based on monthly operational rates observed from startup of the P&T remedies through December 2019 (discussed in Chapter 2), while simulated projections generally assume that operating rates are similar to those during 2019 (i.e., have not been subject to formal optimization to maximize mass recovery, and unanticipated difficulty is not encountered maintaining these rates).

Projections also assume that the P2R Model reasonably represents conditions in the subsurface and the operations of the remedy, that the initial conditions (i.e., starting plumes) reasonably represent the actual distribution of contamination at the beginning of the model predictions, and that the simulations using the groundwater model and the initial conditions reasonably represent actual conditions. For purposes of this report, the most recent release of the P2R Model was used as the basis for predicting future conditions. A single set of initial conditions was used as the basis for predicting future conditions, which is constructed using quantile kriging. The initial conditions are assumed to represent contaminant distributions around late 2015. These initial conditions are used with the P2R Model to provide information for 4 years (2016 through 2019) prior to the period of prediction (e.g., 2020 through 2037), for which simulated concentrations versus time and mass recovery versus time can be compared with measurements to indicate how well the combination of the groundwater model and assumed initial conditions represent actual conditions. The calculations performed for carbon tetrachloride used two values for the degradation half-life, which are based upon recent analyses of degradation rates via abiotic processes alone (630 years) and via combined abiotic and biotic processes (300 years) (as discussed in Section 4.2.2.2).

Figures 4-58 and 4-59 present simulated carbon tetrachloride concentrations at extraction wells when assuming 300-year and 630-year half-lives for carbon tetrachloride, respectively (similar plots are presented for the other 200-ZP-1 OU COCs in ECF-HANFORD-20-0049). In these figures, simulated values are presented using the initial conditions constructed using quantile kriging. The comparison between simulated and measured concentrations is fairly good at most wells, which is encouraging because the contaminant transport parameters used in the P2R Model have not been subjected to or estimated using formal calibration to water quality data obtained from monitoring and extraction wells since the P&T system began operation. After operating for 7 years, calculated concentration changes are barely distinguishable between degradation half-lives of 300 and 630 years. As anticipated, the most significant factor altering concentrations over the period shown in these figures is the action of the groundwater P&T system. Following shutdown of the 200 West P&T, natural attenuation will be the dominant process controlling changes in concentration over time; under those conditions, the relative difference between 300-year and 630-year half-lives will be more significant. As additional data are collected, it is anticipated that contaminant transport parameters will be calibrated to improve correspondence between the actual and simulated mass recovery, improving the reliability of longer-term mass recovery projections. New information (when available) regarding both biotic and abiotic degradation rate constants for carbon tetrachloride will be incorporated into projections.

The same P2R Model predictive modeling simulations presented in this section provided outputs used to assess the likely progress of the remedy toward achieving the groundwater standards established as RAOs in the 200-ZP-1 OU ROD (EPA et al., 2008). Detailed documentation of predicted concentrations for each COC is provided in the ECF-HANFORD-20-0049 and is summarized in Section 4.7.

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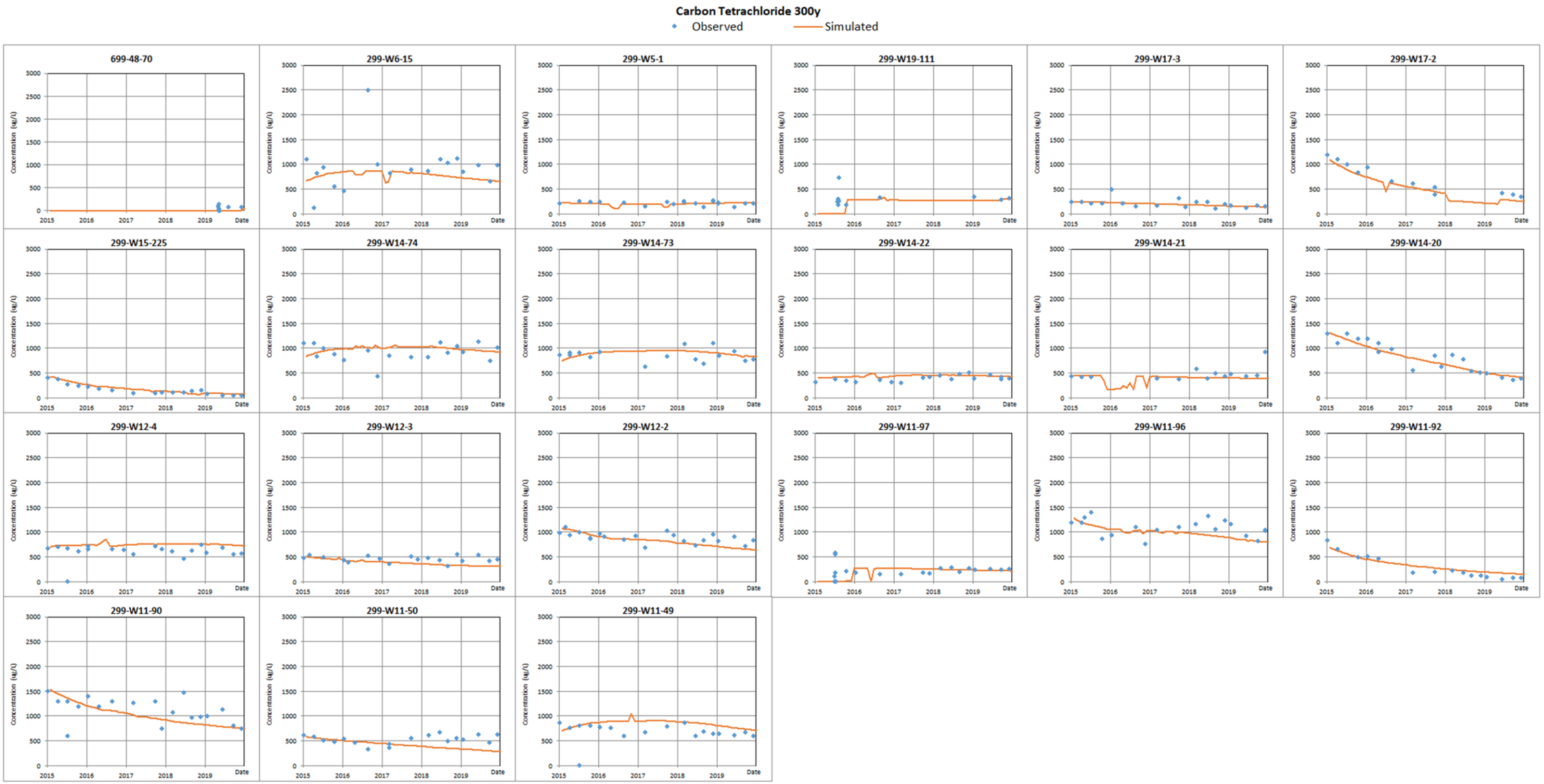


Figure 4-58. Simulated and Measured Carbon Tetrachloride Concentrations at Extraction Wells Assuming a 300-Year Half-Life

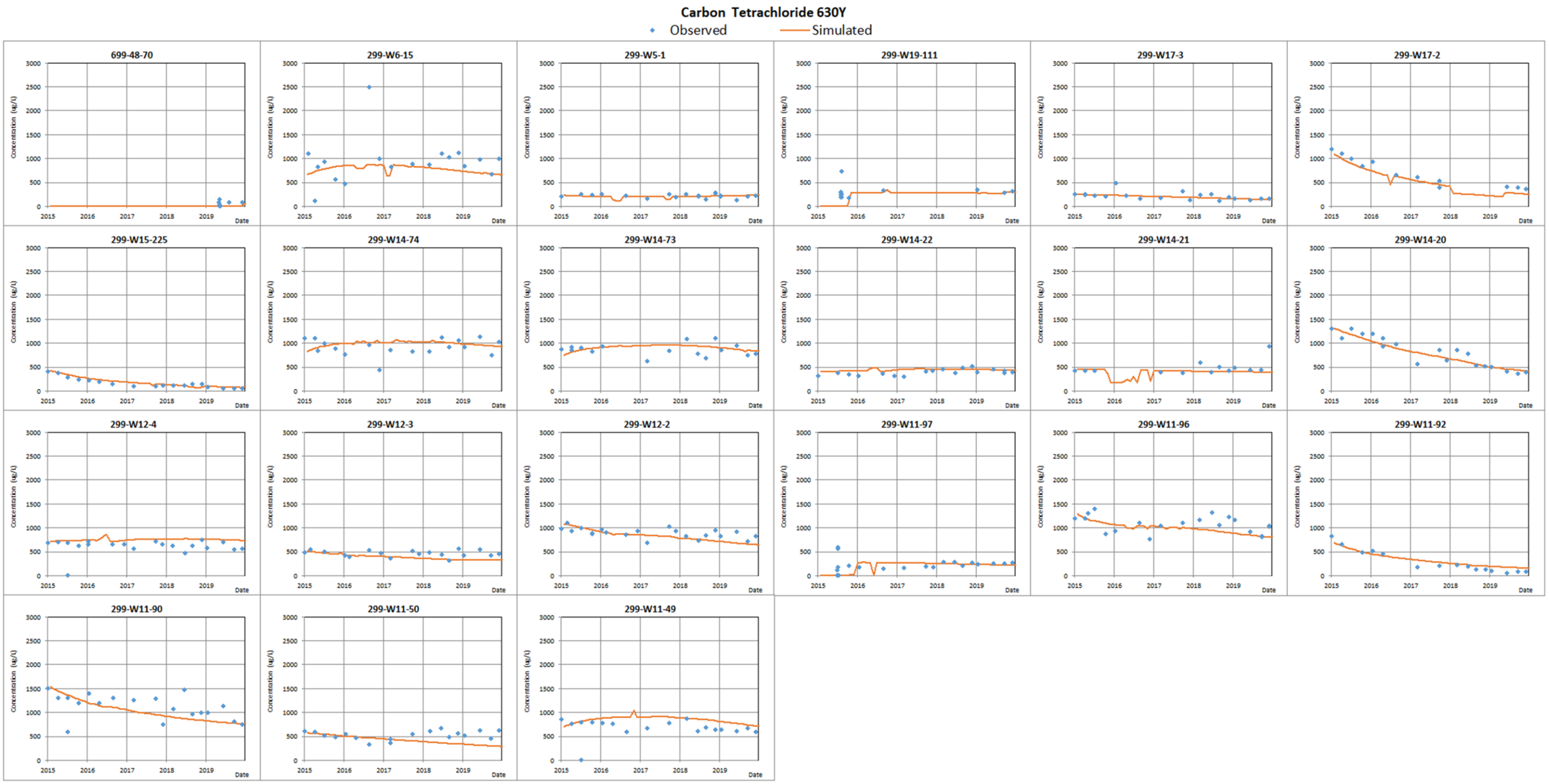


Figure 4-59. Simulated and Measured Carbon Tetrachloride Concentrations at Extraction Wells Assuming a 630-Year Half-Life

4.7 Progress Toward Meeting Targets, Goals, and Remedial Action Objectives

This section evaluates the progress toward attaining the remedy targets, goals, and the final RAOs discussed in this chapter and presented in the 200-ZP-1 OU ROD (EPA et al., 2008) and the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE).

4.7.1 Targets

Near-term targets for the P&T component of the 200-ZP-1 OU remedy (DOE/RL-2008-78, Rev. 0 REISSUE) are as follows:

- Attain specified (i.e., target) total system-wide operating rates and specified rates at individual extraction and injection wells. This target is evaluated in this section.
- Achieve desirable reinjected treated water quality. This specific target is discussed and evaluated in Chapter 2.

Target system-wide operating rates and rates at individual extraction and injection wells were developed from groundwater flow modeling to meet flow-path control and hydraulic containment goals. To achieve the mass removal goal identified in the 200-ZP-1 OU ROD (EPA et al., 2008), a phased implementation approach was planned, which included an initial 3-year phase with the P&T system operating at a nominal rate of 3,785 L/min (1,000 gal/min), followed by 22 years of operating at a nominal rate of 7,600 L/min (2,000 gal/min). The design also included treating contaminated groundwater from the S-SX Tank Farms in the 200-UP-1 OU. The 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 1) includes provisions for 200 West P&T expansion to increase maximum flow capacity to 14,200 L/min (3,750 gal/min), which will allow an increase in flow capacity for 200-ZP-1 OU extraction wells to approximately 11,600 L/min (3,070 gal/min) to enhance performance of carbon tetrachloride plume remediation.

Figure 4-60 shows the actual cumulative groundwater volume that has been extracted and treated through 2019 compared to the design basis expectation for groundwater extraction and treatment, as well as the projected volume to be treated through 2025, assuming that the 200 West P&T continues to operate at average 2019 flow rates until that time. Most of the treated volume is groundwater extracted from the 200-ZP-1 OU. The 200 West P&T central treatment facility also treats contaminated groundwater from other OUs (e.g., 200-UP-1 and 200-BP-5, and perched water from 200-DV-1), as discussed in Chapter 2. The actual total of 200-ZP-1 OU and S-SX Tank Farm extracted groundwater treated was below the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) design throughput in April 2019. However, with suspension of active biological treatment and facility modifications made as part of the optimization study (DOE/RL-2019-38) beginning in October 2019, treatment flow rates have increased to 90% of system capacity. Figure 4-60 shows that the cumulative volume treated from the 200-ZP-1 OU and S-SX Tank Farms extraction wells (at fourth quarter of 2019 flow rates) is projected to increase above the cumulative design throughput volume in February 2021.

As discussed in Section 2.5, recommendations to minimize biofouling issues to improve injection well capacity were implemented in 2019, including suspending active biological treatment as one aspect of implementing the 200-ZP-1 OU optimization study. These actions, as well as ongoing 200 West P&T optimization activities, are being conducted to improve the likelihood of achieving cleanup of carbon tetrachloride in the timeframe specified in the 200-ZP-1 OU ROD (EPA et al., 2008). Other actions described in Section 4.3.2 are being implemented to achieve operating at the facility design throughput identified in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 1) to increase total overall operating capacity and to meet the treatment targets for the 200-ZP-1 OU and treatment needs for the other OUs.

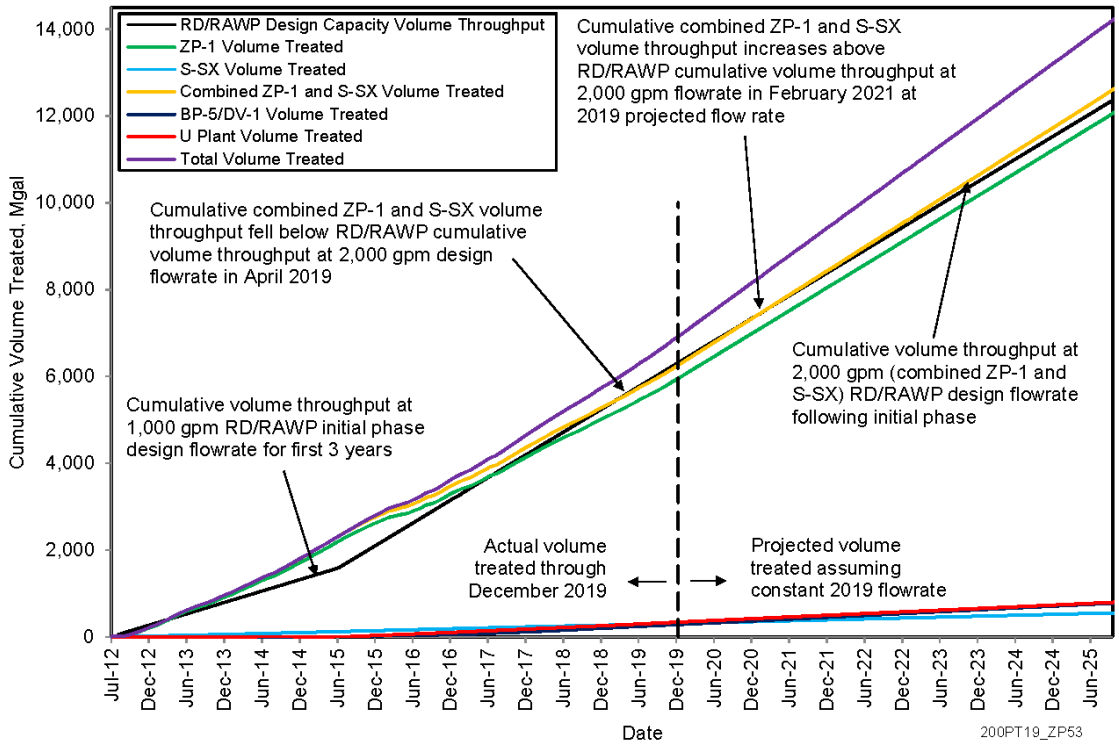


Figure 4-60. 200 West P&T Actual Cumulative Volume Treated Compared to Design Capacity Throughput

4.7.2 Goals

The intermediate-term goals for the P&T component of the 200-ZP-1 OU remedy are as follows:

- Achieve hydraulic containment of the carbon tetrachloride plume at concentrations >100 µg/L.
- Achieve flow-path control.
- Reduce the mass of contaminants throughout the 200-ZP-1 OU by 95%. This goal is designed to be achieved after 25 years of P&T operations

Progress toward attaining these goals is evaluated in the following discussion.

4.7.2.1 Evaluation of Hydraulic Containment of the Inferred 100 µg/L Carbon Tetrachloride Plume Extent

The 200 West P&T extraction and injection wells were positioned to develop an extent of containment encompassing the area defined by carbon tetrachloride concentrations >100 µg/L. Because most contaminant mass lies within this isoconcentration line, focusing hydraulic containment on this area maximizes the mass recovery efficiency. Figures 4-56 and 4-57 provide maps of estimated hydraulic containment, providing snapshots (or instantaneous extents) representing conditions for December 2019. Similar instantaneous depictions can be prepared for each month of the year, resulting in 12 depictions that reflect variation in the capture extent during the year in response to changes in pumping rates and other conditions. The 12 monthly instantaneous depictions of the estimated extent of capture can be combined to prepare a capture frequency map (CFM) (Karanovic et al., 2009, "KT3D_H2O: A Program for Kriging Water Level Data Using Hydrologic Drift Terms"), which is discussed in ECF-HANFORD-20-0049. The resulting CFM shows the frequency (valued between zero and one) during which groundwater in a region is hydraulically contained by the groundwater P&T remedy

(as indicated by movement of groundwater toward extraction wells) over 12 months during the year. A value of 1 indicates that the region was contained during all 12 months, and a value of <1 indicates that for at least some months, the region was not hydraulically contained (i.e., groundwater was not always moving toward extraction wells).

Figures 4-61 and 4-62 show the extent of hydraulic containment above and below the Rlm, respectively, using a simulated CFM computed using the P2R Model. In each case, the CFM is overlain with the estimated carbon tetrachloride extent in groundwater at concentrations >3.4 µg/L (the cleanup level) and 100 µg/L (the level targeted for hydraulic containment and focused mass recovery). Figure 4-63 shows the estimated extent of hydraulic containment above the Rlm as determined using a CFM obtained through water-level mapping, overlain with the same 3.4 and 100 µg/L isoconcentration lines. The hydraulic containment extents shown in these figures reflect groundwater extraction at the range of rates for the 200-ZP-1 and 200-UP-1 OU extraction wells during 2019. In these figures, green coloring indicates a frequency of capture of 1 (equating to all monthly events), red coloring indicates a frequency of capture of about 0.5 (equating to half of the monthly events), and intermediate shades of orange and blue indicate intermediate values of capture frequency. Frequencies <0.5 are not colored.

During 2019, the entire carbon tetrachloride area >100 µg/L beneath the Rlm appears to be hydraulically contained (Figure 4-62). For 2019, the simulated extent of hydraulic containment shown above the Rlm compares well to the extent derived from water-level mapping. Differences are limited to areas to the north and to the west-southwest beyond the region exhibiting concentrations for carbon tetrachloride of >100 µg/L. With a single exception, the region defined by the 100 µg/L concentration was largely contained by pumping during 2019. The single exception was above the Rlm and is located in the area northeast of focused groundwater extraction, where concentrations >100 µg/L appear to extend beyond the hydraulic containment zone as depicted using the CFM. However, as previously noted, Figures 4-56 and 4-57 (panel a) suggest that after new extraction well 699-48-70 was installed and operating (in the last quarter of 2019), the P&T effectively contained carbon tetrachloride contamination above the 100 µg/L target. Therefore, it is anticipated that if extraction rates similar to those achieved in December 2019 could be maintained, then a CFM prepared on the basis of multiple months of data would demonstrate containment of the northeastern region of the plume >100 µg/L.

Figures 4-64 and 4-65 provide an alternate way of interpreting the degree to which carbon tetrachloride concentrations are hydraulically contained by the groundwater P&T using color-coded stacked bar charts for a range of concentration thresholds. Figure 4-64 compares the simulated extent of hydraulic containment above the Rlm (using the CFM approach) to the extent of carbon tetrachloride across a range of concentrations including 3.4 and 100 µg/L. In this figure, green coloring indicates a frequency of capture of 1, red coloring indicates a frequency of capture of zero, and intermediate shades of orange and blue indicate intermediate values of capture frequency. Using the same color scheme, Figure 4-65 compares the simulated extent of hydraulic containment below the Rlm (using the CFM approach) to the extent of carbon tetrachloride across a range of concentrations including 3.4 and 100 µg/L.

Figures 4-64 and 4-65 suggest that >99% of the plume at concentrations >100 µg/L is being hydraulically contained. These figures also indicate that the 200 West P&T is hydraulically containing about 99% of the area exceeding concentrations of 50 µg/L and >95% of the area exceeding concentrations of 25 µg/L. Hydraulic containment of the regions that are <100 µg/L (while not specifically an objective under the 200-ZP-1 OU ROD [EPA et al., 2008]) will likely prove beneficial to long-term remedy effectiveness since the carbon tetrachloride half-life is likely to be substantially longer than anticipated at the time of ROD issuance, and natural attenuation processes will be less effective than anticipated for concentrations <100 µg/L.

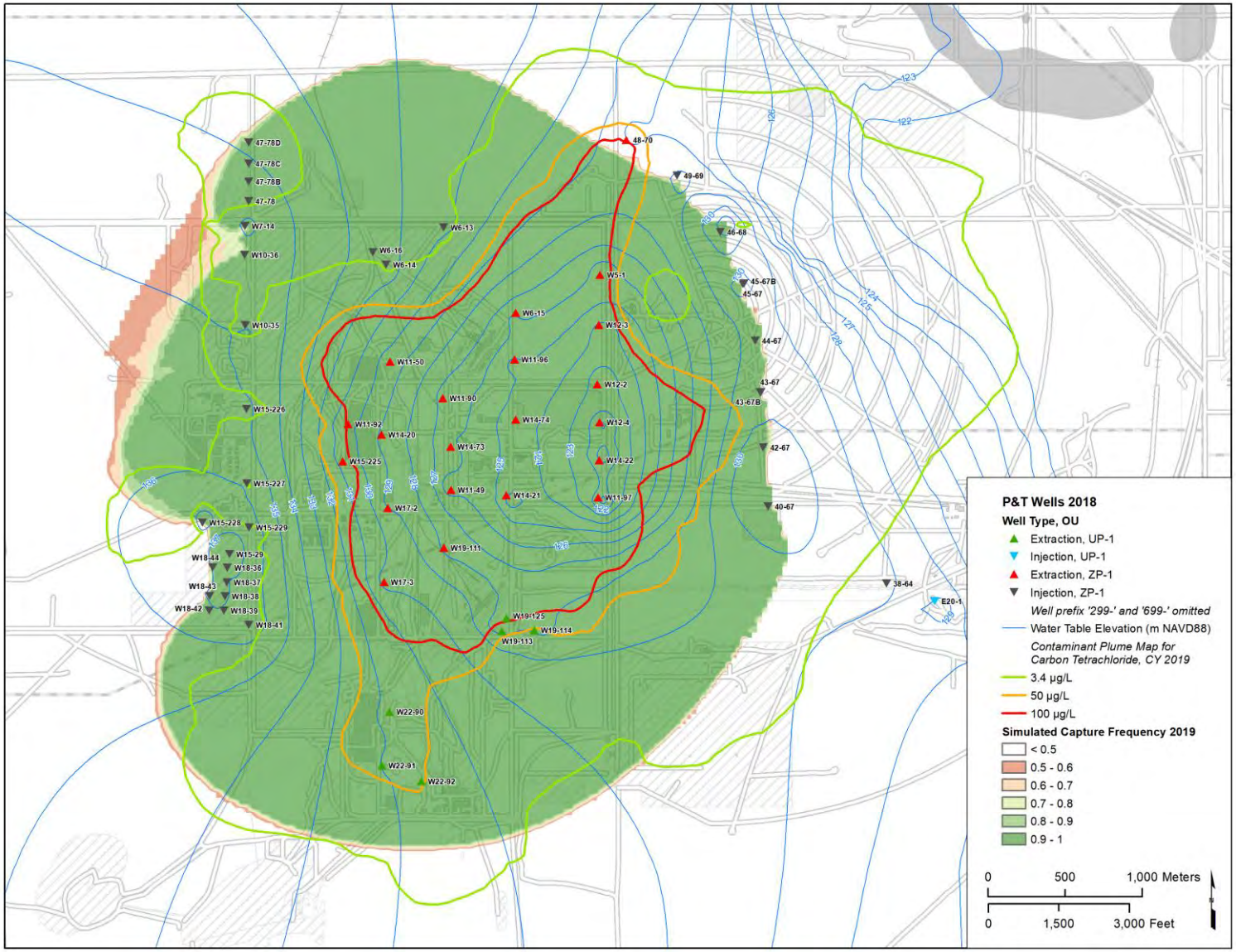


Figure 4-61. Simulated CFM Above the Rlm, 2019

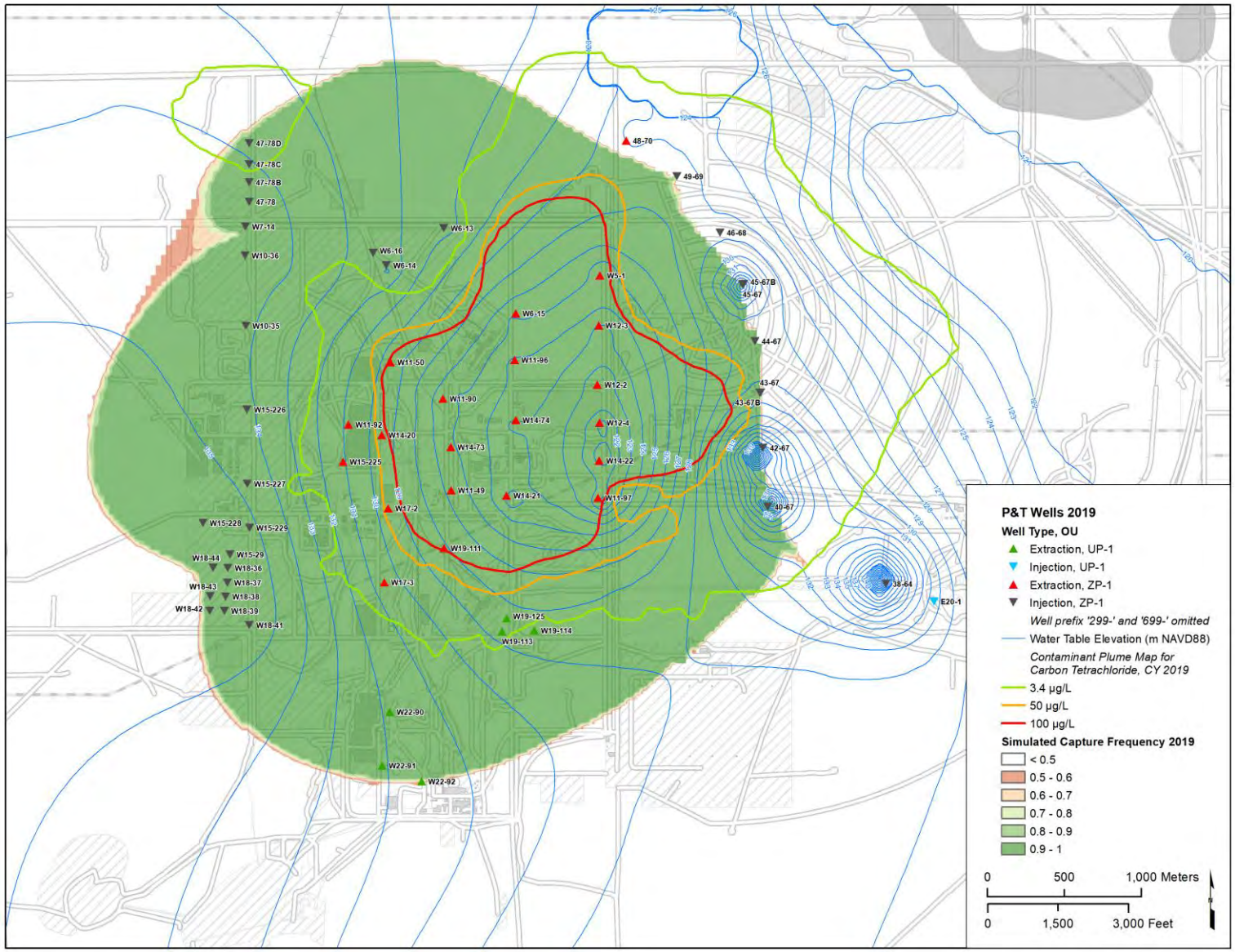


Figure 4-62. Simulated CFM Below the RIm, 2019

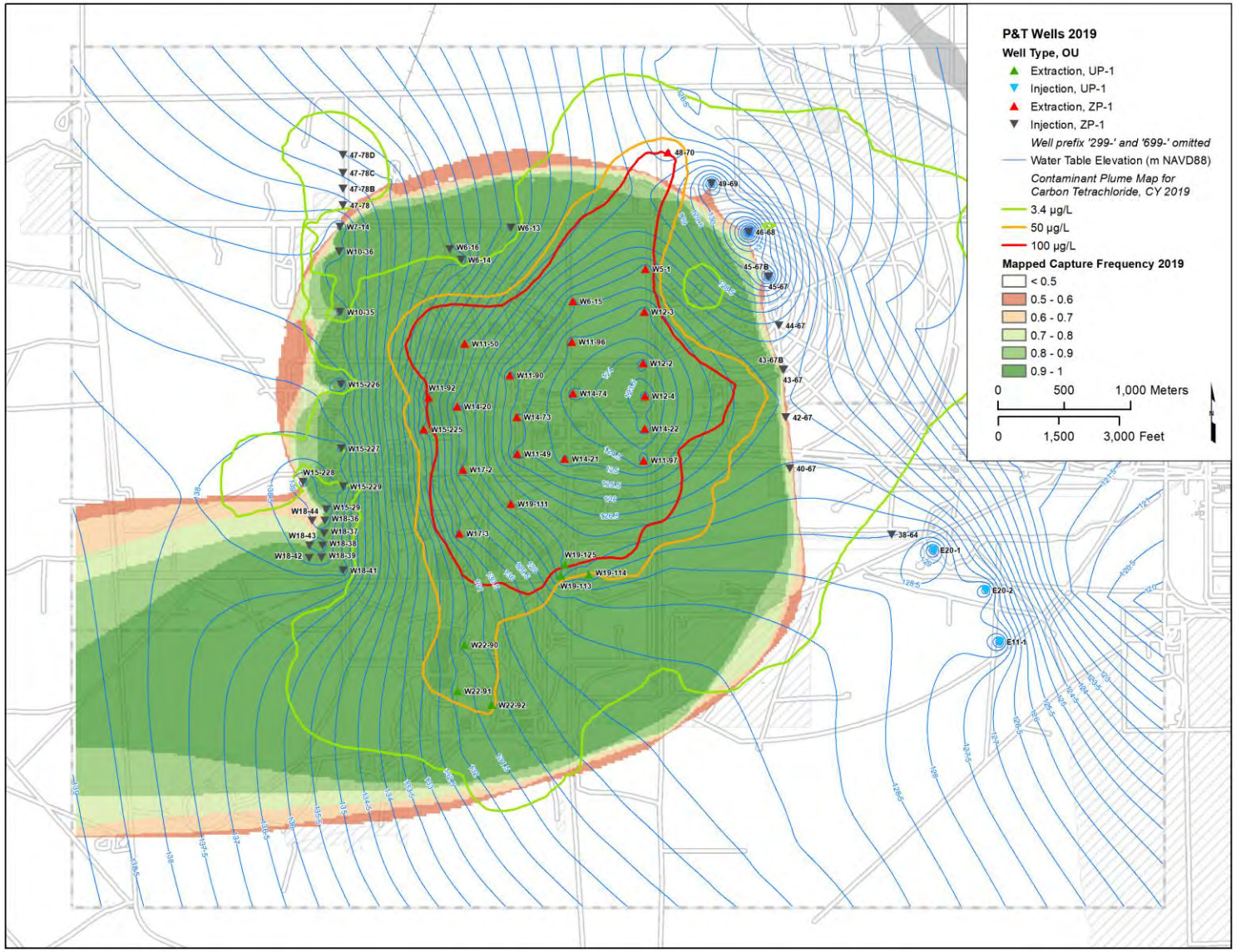


Figure 4-63. Mapped CFM Above the RIm, 2019

Concentration Cut-off (µg/l)	3.4	10	25	50	100	500	1000
Percent of Plume area	100%	62%	43%	32%	23%	8%	2%
Capture Frequency	Percent of Plume Area Contained						
0.00	100%	100%	100%	100%	100%	100%	100%
0.10	70.7%	88.4%	98.0%	99.1%	99.8%	100.0%	100.0%
0.20	70.6%	88.4%	98.0%	99.1%	99.8%	100.0%	100.0%
0.30	70.5%	88.4%	98.0%	99.1%	99.8%	100.0%	100.0%
0.40	70.3%	88.4%	98.0%	99.1%	99.8%	100.0%	100.0%
0.50	70.1%	88.3%	98.0%	99.1%	99.8%	100.0%	100.0%
0.60	69.8%	88.2%	97.9%	99.0%	99.7%	100.0%	100.0%
0.70	69.3%	88.2%	97.8%	99.0%	99.7%	100.0%	100.0%
0.80	69.1%	88.0%	97.7%	98.9%	99.6%	100.0%	100.0%
0.90	69.0%	88.0%	97.7%	98.9%	99.6%	100.0%	100.0%
1.00	68.4%	87.8%	97.5%	98.7%	99.6%	100.0%	100.0%

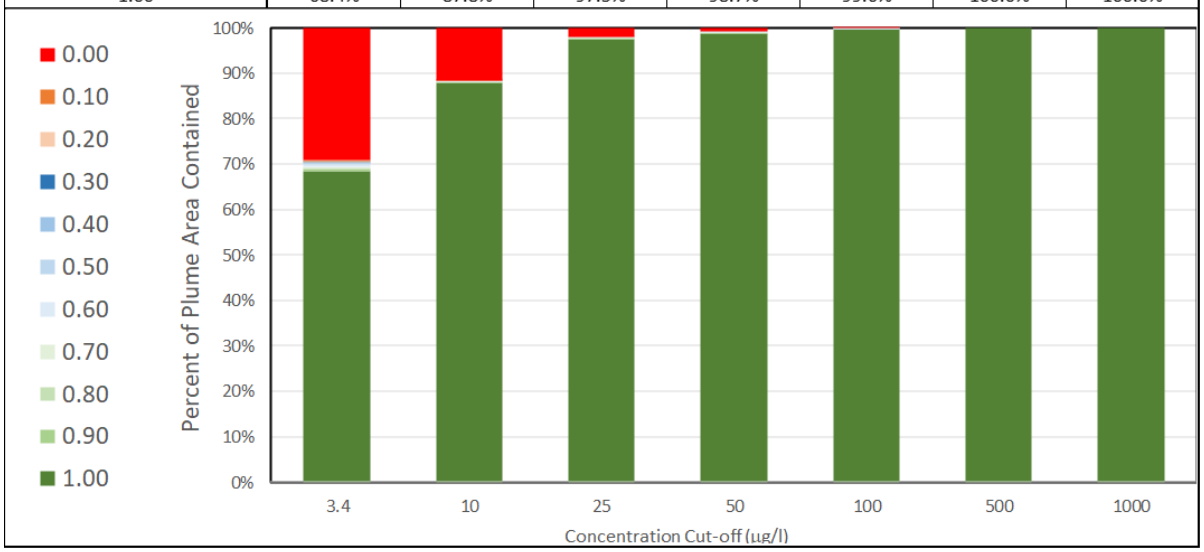


Figure 4-64. Percent Containment of Targeted Concentrations of Carbon Tetrachloride Above the Rlm Computed Using the CPGWM

These comparisons of hydraulic containment extent with the carbon tetrachloride contamination extent suggest that if the 200 West P&T can sustain rates near or exceeding the 2019 rates, then the P&T system can hydraulically contain an area equal to or larger than the area mapped at concentrations >100 µg/L and would also contain the vast majority of groundwater exhibiting concentrations >25 µg/L.

Concentration Cut-off (µg/l)	3.4	10	25	50	100	500	1000
Percent of Plume area	100%	73%	47%	37%	30%	7%	1%
Capture Frequency	Percent of Plume Area Contained						
0.00	100%	100%	100%	100%	100%	100%	100%
0.10	70.5%	80.4%	97.4%	100.0%	100.0%	100.0%	100.0%
0.20	70.3%	80.2%	97.3%	100.0%	100.0%	100.0%	100.0%
0.30	70.2%	80.2%	97.3%	100.0%	100.0%	100.0%	100.0%
0.40	70.1%	80.2%	97.3%	100.0%	100.0%	100.0%	100.0%
0.50	70.0%	80.2%	97.3%	100.0%	100.0%	100.0%	100.0%
0.60	69.9%	80.2%	97.3%	100.0%	100.0%	100.0%	100.0%
0.70	69.9%	80.2%	97.3%	100.0%	100.0%	100.0%	100.0%
0.80	69.7%	80.1%	97.3%	100.0%	100.0%	100.0%	100.0%
0.90	69.5%	79.9%	97.3%	100.0%	100.0%	100.0%	100.0%
1.00	69.0%	79.8%	97.3%	100.0%	100.0%	100.0%	100.0%

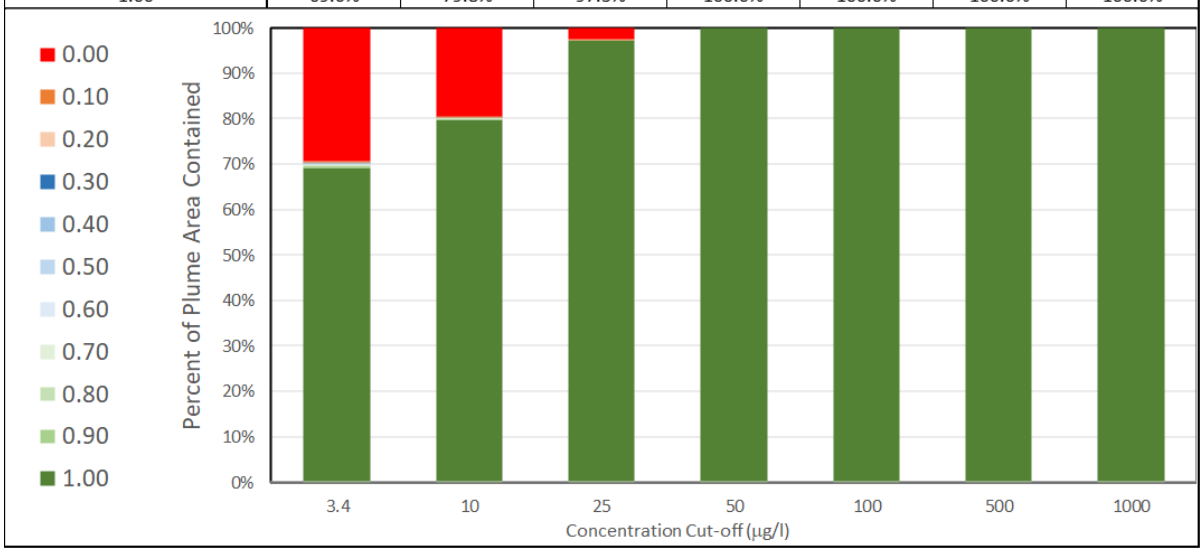


Figure 4-65. Percent Containment of Targeted Concentrations of Carbon Tetrachloride Below the Rlm Computed Using the CPGWM

4.7.2.2 Evaluation of Flow-Path Control

Flow-path control considers the extent of hydraulic containment, in addition to developing reduced hydraulic gradients in downgradient directions to the northeast and southeast of the 200-ZP-1 OU. Evaluation of flow-path control integrates assessments of contamination extent (emphasizing carbon tetrachloride), the extent of hydraulic containment, and the region over which hydraulic gradients are reduced by 200 West P&T operations. Methods used to evaluate and depict the status of flow-path control were first presented in ECF-200ZP1-15-0002, *Description of Groundwater Calculations and Assessments for the Calendar Year 2014 (CY2014) 200 Areas Pump-and-Treat Report*. The methods were later revised to provide visual depictions that are more intuitive. ECF-HANFORD-20-0049 discusses the methods used to prepare this report.

Figures 4-66 and 4-67 show estimated mapped and simulated hydraulic gradients above the Rlm, respectively. Figure 4-68 shows estimated hydraulic gradients below the Rlm. In Figures 4-66 through 4-68, the gradient arrows are depicted along a general line of control that is used to help interpret flow-path control. The orientation of the arrows indicates the gradient direction, and the arrow length indicates gradient magnitude. Natural gradients without influence of groundwater P&T produce arrows pointing toward the east (as shown in left panel [panel a] in Figures 4-66 through 4-68). The gradient direction and magnitude under current conditions are shown by arrow orientation and length in the right panel (panel b) in each of the three figures. Larger changes in gradient direction and magnitude due to

P&T operations are shown by larger differences in the arrow direction and length between figure panels a and b.

In Figures 4-66 through 4-68, the greatest gradient magnitude and direction changes are observed between the extraction and injection wells, as anticipated. Gradient magnitude changes are shown in the right panel in each figure by coloring. A decrease in the gradient magnitude from west to east is colored red, whereas an increase in gradient magnitude in the same direction is colored green. Gradient changes are less evident moving farther away from the extraction and injection wells to the northeast and southeast of the 200-ZP-1 OU, as expected (i.e., to the north and to the south of the eastern [downgradient] line of injection wells).

The combination of color-coded gradient change and the outline of the simulated extent of hydraulic containment above the Rlm suggest that flow-path control is maintained in the core of the region contaminated by carbon tetrachloride at concentrations >100 µg/L, leading to hydraulic containment and greatly reducing eastward migration. In particular, the pattern of gradient reduction and reversal has improved northeast of the focused groundwater extraction following installation and operation of new extraction well 699-48-70. Conditions are somewhat similar in the Rwia (below the Rlm); however, the contamination extent >100 µg/L is inferred as smaller and not extending as far to the north and flow-path control appears to be more effective. However, the number of wells present to characterize the contamination extent below the Rlm is substantially smaller than the number of wells above the Rlm.

A comprehensive data gap study (SGW-61350, *Data Gaps Evaluation in Groundwater Monitoring at the Hanford 200-ZP-1 Groundwater Operable Unit*) also identified an area along the northern end of the eastern (downgradient) injection well line as a particular focus for additional investigation. This was due, in part, to the relatively low density of monitoring locations in this area and because modeling predictions suggest that contamination could escape capture in this area and migrate eastward (Figure 4-69; a high score in this figure identifies an area that is prioritized for new well installations). This area was also previously a location where the hydraulic containment did not encompass the region of carbon tetrachloride at concentrations >100 µg/L (red line). This area was addressed with installation of new extraction well 699-48-70.

4.7.2.3 Evaluation of Contaminant of Concern Mass Removal

As described in the 200-ZP-1 OU ROD (EPA et al., 2008), carbon tetrachloride concentrations in groundwater >100 µg/L were estimated to correspond to about 95% of the dissolved carbon tetrachloride mass in the aquifer at startup of the 200 West P&T. Therefore, the carbon tetrachloride plume area >100 µg/L is the focus for mass removal.

As detailed in ECF-200W-20-0052, the three-dimensional carbon tetrachloride plume was recently updated so it could be incorporated into predictive simulations completed using the P2R Model. The three-dimensional depictions of contamination extent are used to prepare figures in this report and also to evaluate the performance of the remedy in recovering contaminant mass. The updated three-dimensional carbon tetrachloride plume (calculated using 2015 data) is used for comparison and prediction purposes because the simulated rate of mass recovered from 2016 through 2019 can be compared with the actual rate of mass recovery, which is not possible using plumes constructed with more recent (e.g., 2019) data.

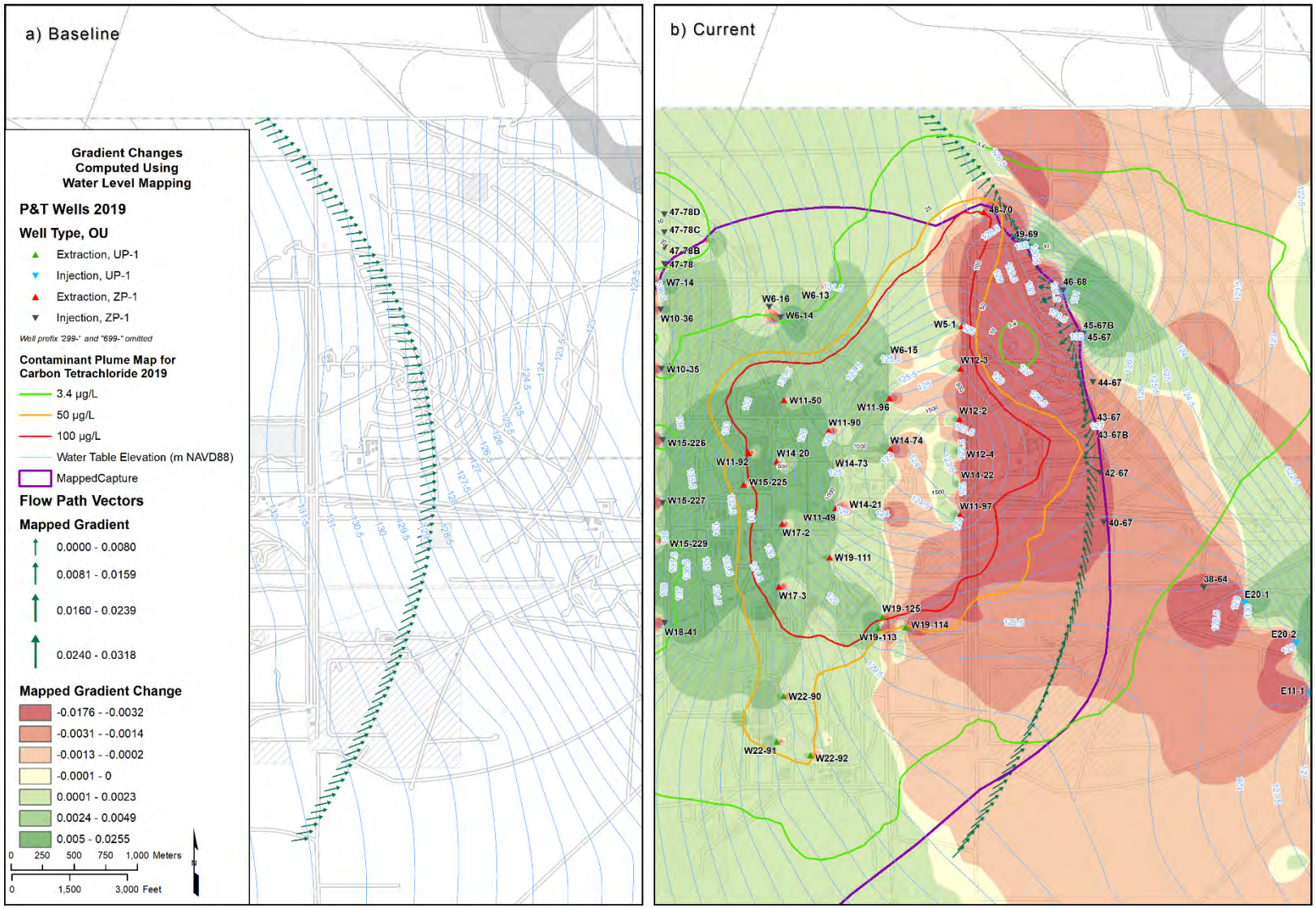


Figure 4-66. Mapped Gradient Changes Along Line of Control Above the Rlm: (a) Baseline and (b) Current

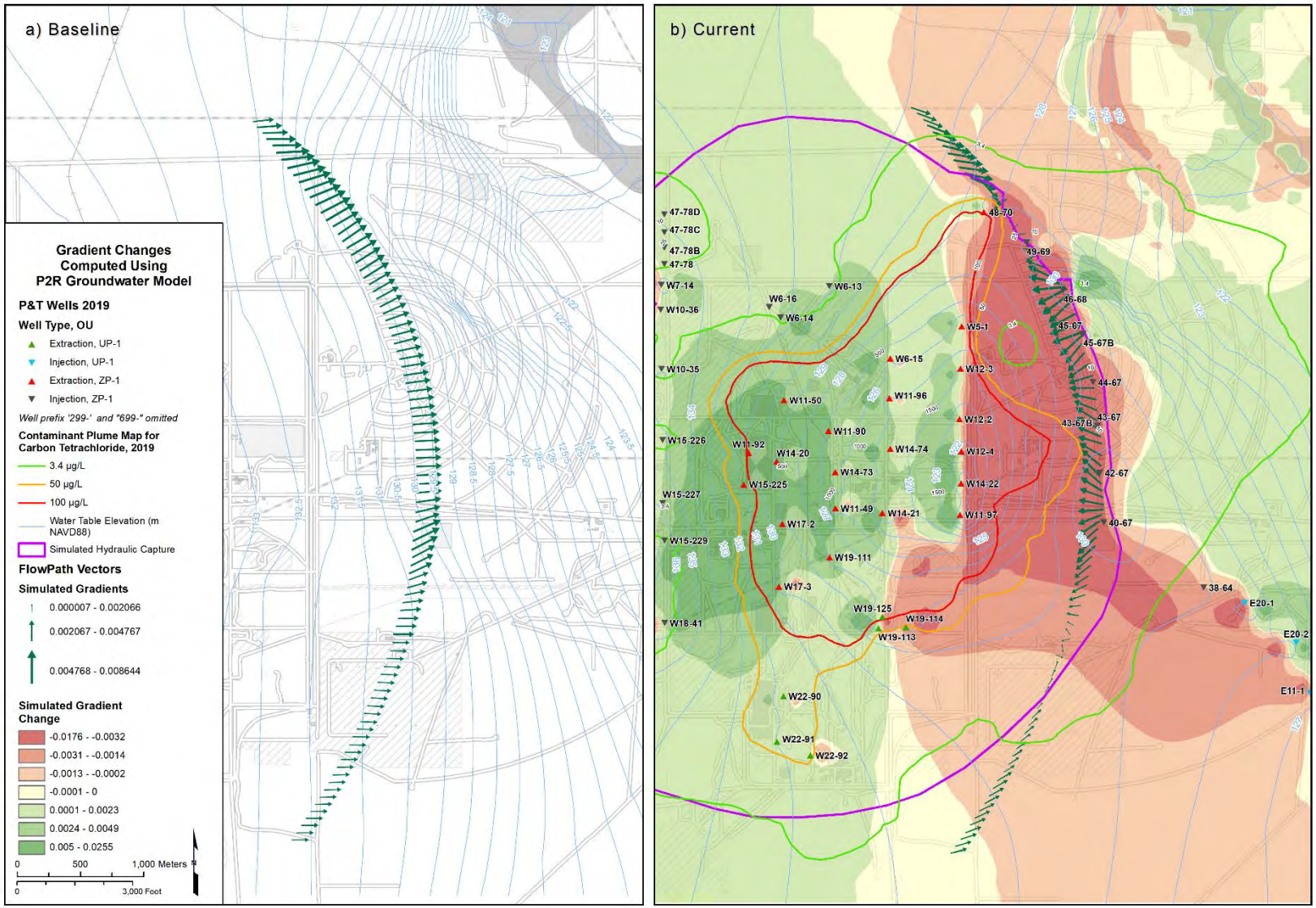


Figure 4-67. Simulated Gradient Changes Along Line of Control Above the Rlm: (a) Baseline and (b) Current

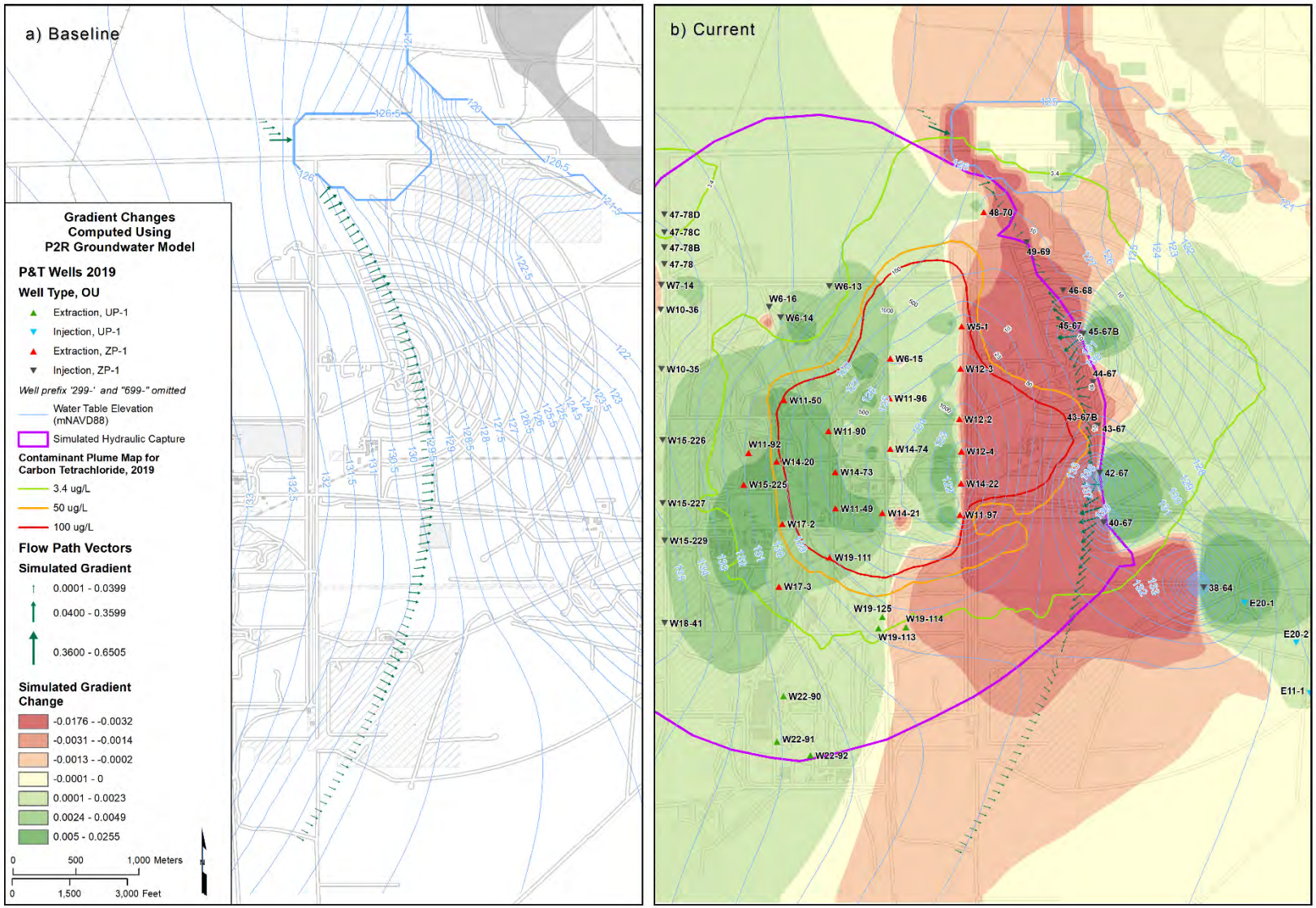
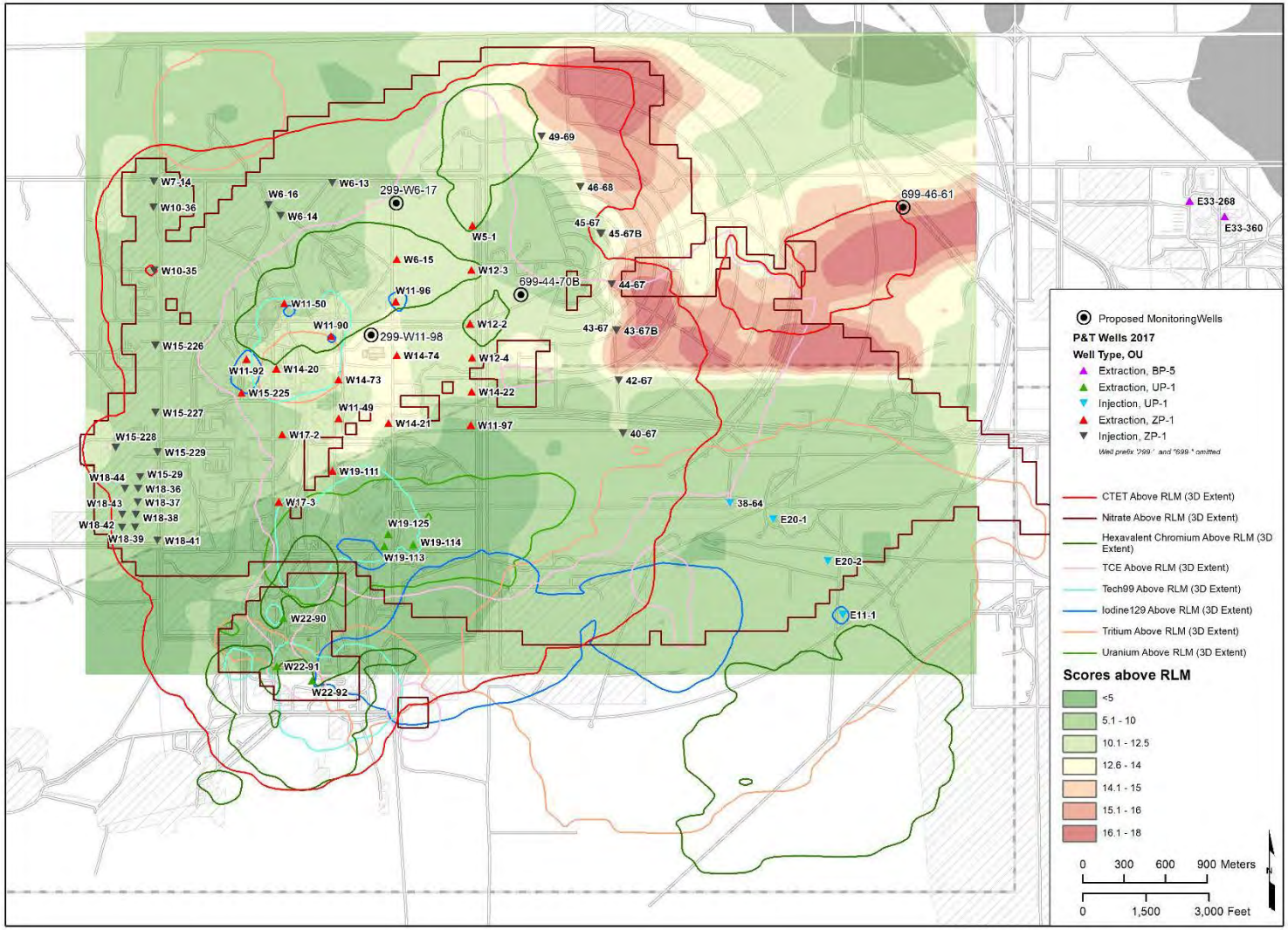


Figure 4-68. Simulated Gradient Changes Along Line of Control Below the Rlm: (a) Baseline and (b) Current



Note: Figure modified from SGW-61350, *Data Gaps Evaluation in Groundwater Monitoring at the Hanford 200-ZP-1 Groundwater Operable Unit*.

Figure 4-69. Example of Results from Data Gap Study Highlighting Areas Prioritized for Investigation (Red-Shaded Areas)

Figure 4-70 presents a combination of measured and simulated mass recovery since the 200 West P&T began operating. For the period from 2012 through 2015, the figure depicts the measured recovery of carbon tetrachloride mass. From 2016 onward, Figure 4-70 shows the mass recovery simulated using the P2R Model, with initial conditions obtained as detailed in ECF-200W-20-0052. A half-life of 300 years is assumed, and the mass recovery is projected over the 25-year target P&T operational period (through 2037). Figure 4-71 provides a similar plot, showing measured mass recovery from 2012 through 2015, with simulated mass recovery plotted from 2016 and projected into the future but assuming a half-life of 630 years. The future projections assume operating rates similar to the 2019 rates through to the end of 2021, followed by a gradual increase in groundwater pumping that is consistent with the scheduled increase in capacity of the 200 West P&T system from the current total capacity (9,500 L/min [2,500 gal/min]) to a nominal capacity approaching 14,200 L/min (3,750 gal/min). Full details of the simulated future rates are provided in ECF-HANFORD-20-0049.

Figures 4-70 and 4-71 show that a change in the half-life from 300 to 630 years reduces the contribution that degradation makes to mass reduction and related reductions in concentrations over the lifecycle of the P&T remedy. The projected fraction of the initial mass remaining in groundwater when assuming a 630-year half-life is larger than when assuming a 300-year half-life. In either scenario, the projected initial mass proportion that will be recovered or degraded by 2037 (without optimization of the remedy to maximize mass recovery) is ≤90% (i.e., about 90% for a 300-year half-life, and about 88% for a 630-year half-life). To understand this difference, Figure 4-72 shows the effect of the assumed degradation half-life alone on changes in concentrations over time. In this figure, changes in concentration from an initial value (starting at 1.0) are calculated over a period of 100 years using three half-lives: 41.3 years (which was the lower value assumed in the 200-ZP-1 OU FS [DOE/RL-2007-28] and the 200-ZP-1 OU ROD [EPA et al., 2008] for carbon tetrachloride); 300 years, and 630 years (which is the best currently available estimate for solely abiotic degradation of carbon tetrachloride).

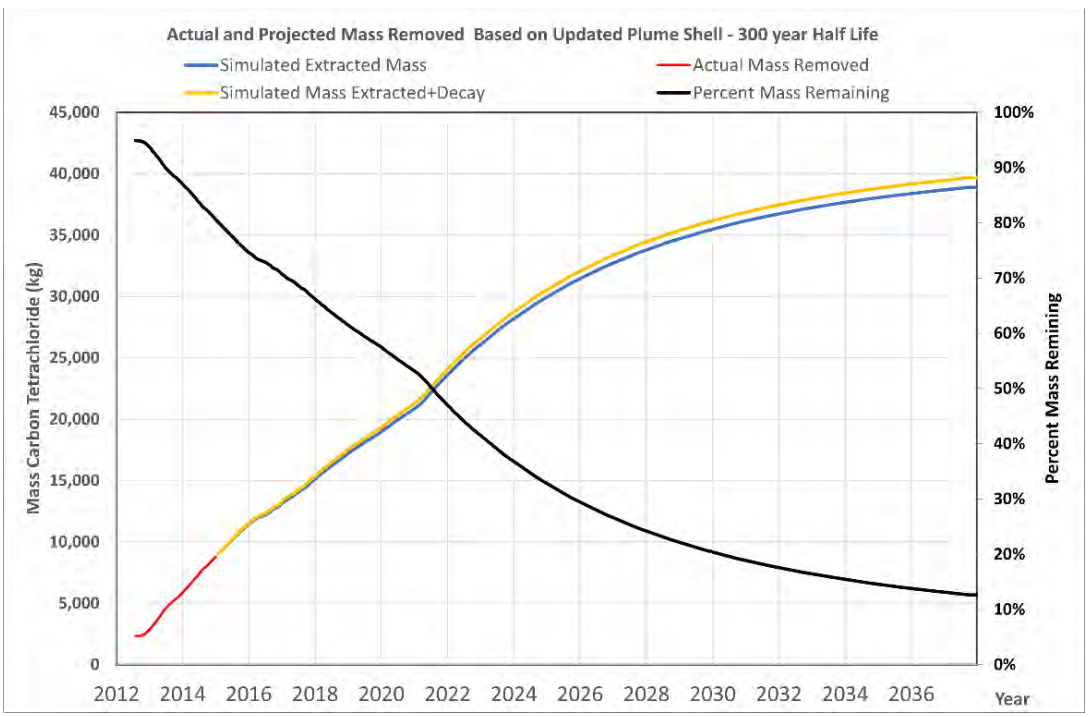


Figure 4-70. Actual Carbon Tetrachloride Mass Recovery Compared to Projected Mass Recovery: 300-Year Half-Life, Initial Plume from Quantile Kriging

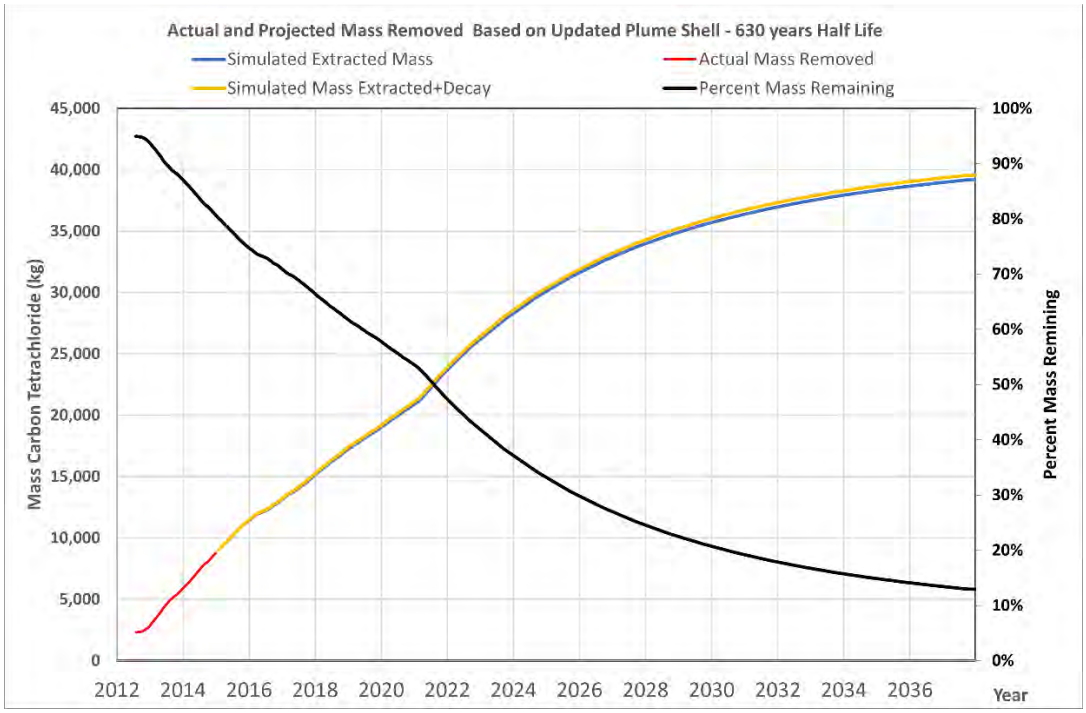


Figure 4-71. Actual Carbon Tetrachloride Mass Recovery Compared to Projected Mass Recovery: 630-Year Half-Life, Initial Plume from Quantile Kriging

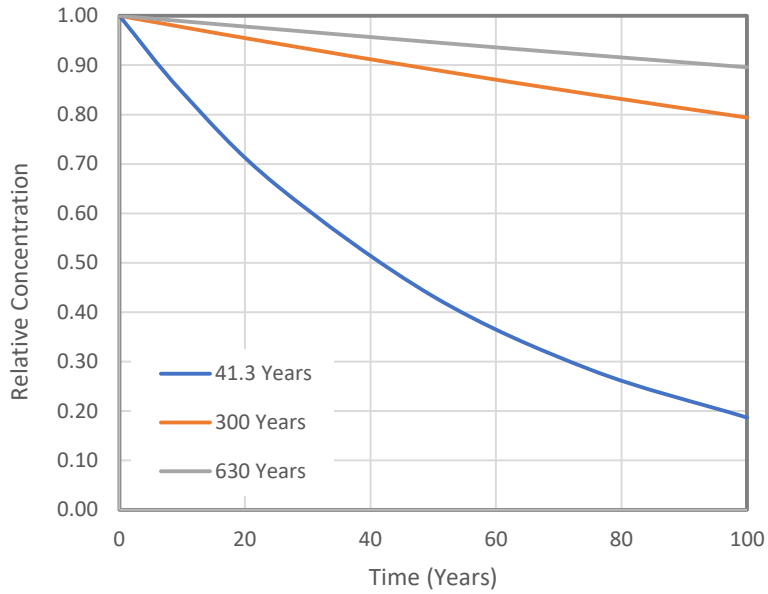


Figure 4-72. Illustration of Effect of Degradation Half-Life on Cleanup Time

Figures 4-73 and 4-74 present the estimated cumulative fraction of the initial carbon tetrachloride mass projected to be remediated (i.e., recovered and treated, or degraded in the subsurface) assuming 300-year and 630-year half-lives, respectively, using three alternate initial conditions (Section 4.2.2.3):

- Initial conditions obtained using quantile kriging. This initial condition is considered, for the current time, to represent the base case for predictive purposes.
- Weighted-average initial conditions obtained from the SGSIM calculations. This initial condition is considered, for the current time, to represent a reasonable alternate case for predictive purposes.
- E-type average initial conditions obtained from SGSIM calculations. This initial condition is included only for comparison with projections provided in DOE/RL-2009-38.

As noted in Section 4.2.2.3, although the E-type average was used in the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) as a best estimate from SGSIM, the analyses previously presented in ECF-200W-18-0028 suggest that the E-type likely overestimates the dissolved mass present in groundwater. The weighted average of the SGSIM realizations is more likely to accurately represent the dissolved mass present within the convex hull of the sample data and region from which the groundwater extraction wells have recovered contaminants since 2012.

Setting aside the results obtained using the E-type average plume, the simulated mass remediated over the 25-year P&T period is about 89% (quantile kriging) and 83% (weighted-average SGSIM) of the calculated initial mass for the 300-year half-life (Figure 4-73). For the 630-year half-life (which, based on PNNL-22062, is considered to be the most likely value for the half-life of carbon tetrachloride), the simulated mass remediated over the 25-year P&T period is about 87% (quantile kriging) and 81% (weighted-average SGSIM) of the calculated initial mass (Figure 4-74).

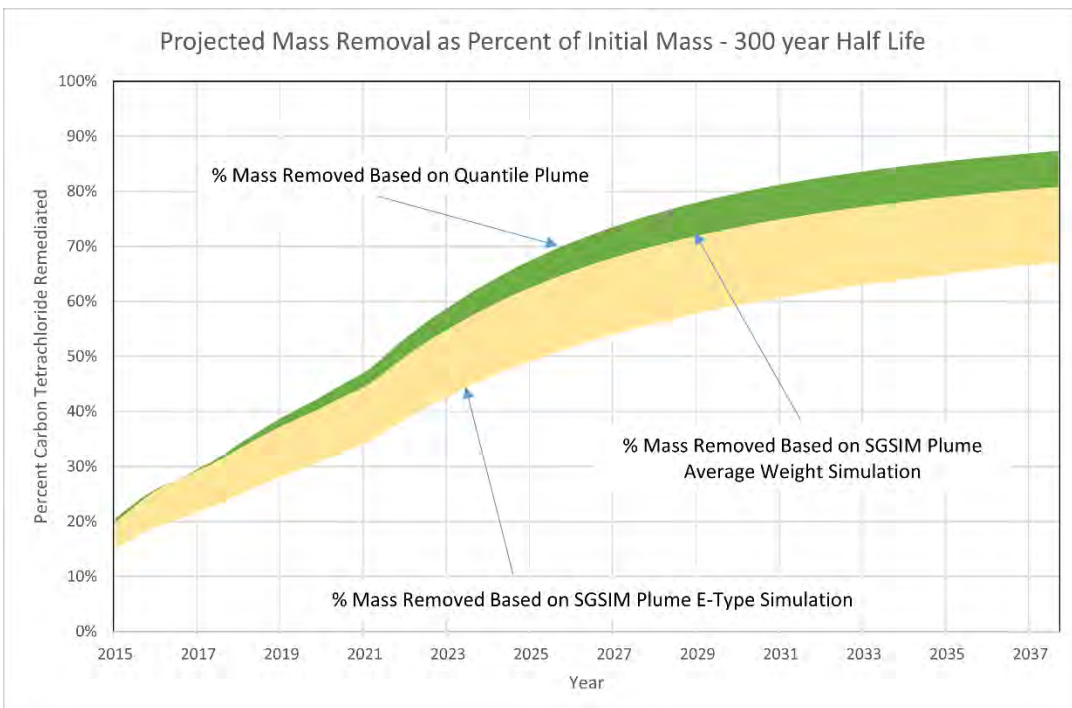


Figure 4-73. Percent Carbon Tetrachloride Mass Removal Range: 300-Year Half-Life for Alternate Initial Plumes

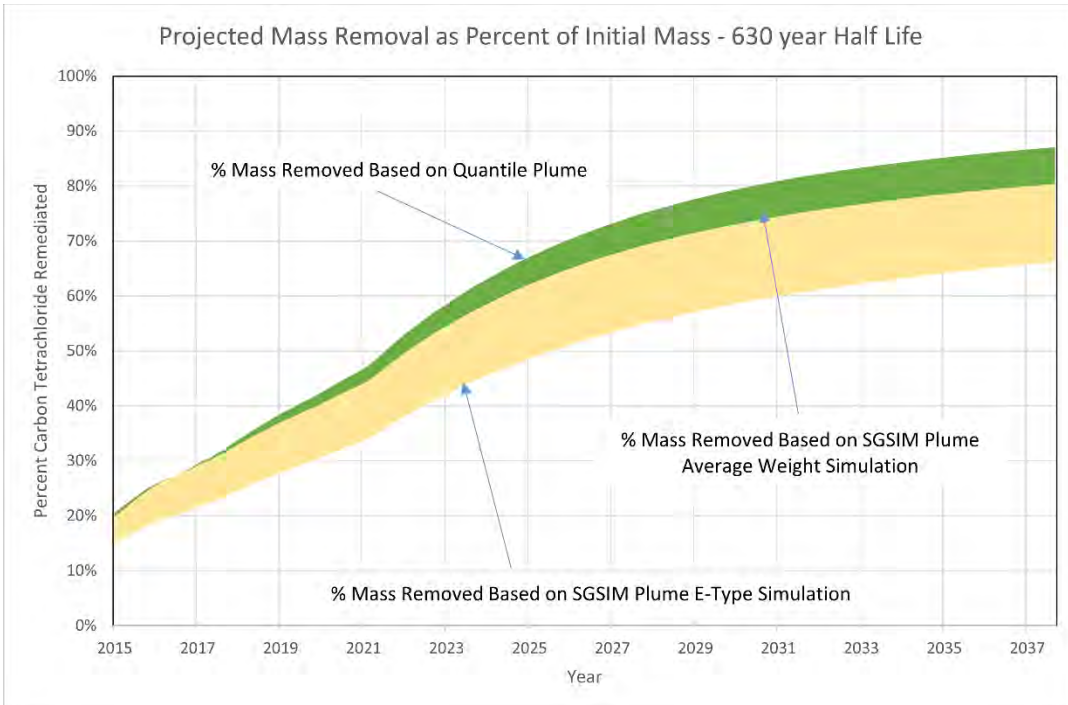


Figure 4-74. Percent Carbon Tetrachloride Mass Removal Range:
630-Year Half-Life for Alternate Initial Plumes

Although the projections for mass recovery presented in Figures 4-70, 4-71, 4-73, and 4-74 appear visually similar to the projections presented in the 2018 annual P&T report (DOE/RL-2018-68), the percentages presented for 2019 are actually substantially higher due to the planned increase in capacity to 14,200 L/min (3,750 gal/min) for the 200 West P&T system as a whole and for the extraction and injection wells of the 200-ZP-1 OU wellfield specifically. In addition, mass recovery is continuing to increase at a greater rate with the increased capacity assumed in the projections made for this report than was evident in the 2018 annual P&T report when assuming current system capacity limitations. Nonetheless, review of the actual mass removed by P&T through 2019 and the projections presented in this chapter indicates that although operating flow rates, hydraulic containment, and mass removal targets appear close to being achieved over the near term, overall mass removal within the proposed 25-year timeframe is projected to be below the 95% target.

Table 4-6 summarizes the estimated range of fractions of the initial mass that is projected to be remediated over 25 years of operation using the three alternate initial plumes (note that the E-type average plume is considered to give the least likely initial mass estimates). The projected mass removal using the most current best estimate of the abiotic-only half-life of 630 years suggests that the 95% mass remediation goal will not be achieved within the 25-year operating period with the current wellfield and operational parameters (i.e., without optimization of the remedy to maximize mass recovery).

The extraction and injection rates detailed in ECF-HANFORD-20-0049 that were used to prepare Figures 4-70, 4-71, 4-73, and 4-74 have not (at this time) been subject to formal optimization to maximize mass recovery. Focused optimization is currently taking place and will continue for a period of at least 6 years as part of the 200-ZP-1 OU OSP (DOE/RL-2019-38) and will be reported separately from this P&T report.

Table 4-6. Estimated Range of Fractions of Initial Mass Remediated over 25 Years of Operation Based on Quantile Kriging, Weighted Stochastic Average, and Stochastic E-Type

Run	Initial Condition	Half-Life (years)	Distribution Coefficient	Porosity	Calculated R	Initial Mass in 2015 (kg)			Mass Extracted (kg)	Mass Decayed (kg)	Mass Remediated (kg)	Mass Removed Prior to 2015	% Total Mass Remediated in 2037	% Dissolved Mass Remediated in 2037
						Dissolved	Sorbed	Total						
1	Quantile kriging	300	0.011	0.15	1.1404	32,141	4,514	36,655	30,110	789	30,899	9,314	87%	96%
2	Stochastic average weighted	300	0.011	0.15	1.1404	30,676	4,308	34,985	25,730	856	26,586		81%	87%
3	Stochastic E-type	300	0.011	0.15	1.1404	45,310	6,363	51,673	30,178	1,583	31,761		67%	70%
1	Quantile kriging	630	0.011	0.15	1.1404	32,141	4,514	36,655	30,396	379	30,775	9,314	87%	96%
2	Stochastic average weighted	630	0.011	0.15	1.1404	30,676	4,308	34,985	25,978	411	26,389		81%	86%
3	Stochastic E-type	630	0.011	0.15	1.1404	45,310	6,363	51,673	30,487	762	31,249		67%	69%

Source: Table 7-1 in ECF-HANFORD-20-0049, *Description of Groundwater Calculations and Assessments for the Calendar Year 2019 (CY2019) 200 Areas Pump-and-Treat Report*.

Groundwater extraction to contain and remove carbon tetrachloride (the primary COC for the 200-ZP-1 OU) at concentrations above 100 µg/L also removes other 200-ZP-1 OU COCs. Table 4-7 summarizes the projected mass of contamination, and the estimated fraction of the initial contaminant mass that is estimated to be recovered by the 200 West P&T remedy over 25 years of operation. The projection estimates are based upon initial conditions (i.e., three-dimensional plumes) for each COC obtained using quantile kriging. There is uncertainty accompanying the contaminant masses and distributions associated with all of these initial conditions; the uncertainty is greater for some COCs than for others due, for example, to their distribution and relatively small number of monitoring wells with sampling results compared to that which was available to develop the carbon tetrachloride initial condition. In addition, for some COCs, a substantial proportion of their estimated mass is actually present at concentrations below their groundwater cleanup level identified in the ROD. Further evaluation of the extent of COCs besides carbon tetrachloride and nitrate is planned during FY 2021. Full details of the calculations used to obtain the projected contaminant mass removal estimates are provided in ECF-HANFORD-20-0049.

4.7.3 Remedial Action Objectives

The RAOs identified in the 200-ZP-1 OU ROD (EPA et al., 2008) are site-specific goals that define the cleanup extent necessary to achieve the specific level of remediation at the site. Measurable progress was made during the reporting period to meet specific RAOs:

- **RAO #1:** Return the 200-ZP-1 OU groundwater to beneficial use (restore groundwater to achieve domestic drinking water levels) by achieving the cleanup levels (Table 4-1). This objective is to be achieved within the entire 200-ZP-1 OU groundwater plumes. The estimated period to achieve cleanup levels is within 150 years.

  Conclusions: The interim 200-ZP-1 P&T and the 200 West P&T have made progress toward this objective. The interim remedy system removed 13,718 kg of carbon tetrachloride from groundwater and, since startup in July 2012, the 200 West P&T central treatment facility has successfully removed about 17,225 kg of carbon tetrachloride; 2,186,276 kg of nitrate (as nitrate); 506 kg of chromium; 76 kg of TCE; and 774 g (13.2 Ci) of technetium-99. Concentration trends indicate reductions for most COCs at most wells over time. However, improved knowledge of the increased extent of carbon tetrachloride contamination and greatly reduced role of degradation in attenuating concentrations versus that assumed in the 200-ZP-1 OU FS (DOE/RL 2007-28) and the 200-ZP-1 P&T RD/RAWP (DOE/RL-2008-78, Rev. 0 REISSUE) demonstrated that conditions are unfavorable for attaining the carbon tetrachloride cleanup level RAO in the timeframe anticipated in the 200-ZP-1 OU ROD (EPA et al., 2008). As detailed in the 2018 annual P&T report (DOE/RL-2018-68) and further substantiated by the calculations detailed in ECF-HANFORD-20-0049, the rate of mass recovery with the current well configuration and system capacity will not be sufficient to achieve the 95% mass removal goal for carbon tetrachloride (as shown, for example, in Table 4-6), nor to achieve the groundwater cleanup level RAOs (as illustrated for all COCs in ECF-HANFORD-20-0049). These findings initiated the remedy optimization study and the Ringold A SAP (DOE/RL-2019-23) to better characterize conditions within the Rwia. Information from these efforts will be combined to evaluate and optimize overall remedy performance, which it is anticipated will lead to revised goals and corresponding operational targets designed to achieve the RAOs within a reasonable timeframe. As detailed in DOE/RL-2019-38 and in Section 4.3 of this report, the system capacity is planned for progressive expansion from the current nominal value of 9,500 L/min (2,500 gal/min) to a maximum capacity of 14,200 L/min (3,750 gal/min) beginning in October 2021 (FY 2022).

- **RAO #2:** Apply ICs to prevent the use of groundwater until cleanup levels (Table 4-1) have been achieved. Within the entire OU groundwater plumes, ICs must be maintained and enforced until the cleanup levels are achieved, which is estimated to be within 150 years.

  Conclusions: 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 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 the 200-ZP-1 OU contaminants must continue until cleanup levels are achieved, which is estimated to be within 150 years.

  Conclusions: 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 central treatment facility, the treated water is injected into the aquifer to the west to direct groundwater flow eastward, toward the extraction wells. Treated water is also injected to the northeast and east of groundwater contamination to slow the natural eastward flow of most of the groundwater and to maintain the contaminants within the hydraulic capture zone of the extraction wells. Slowing groundwater flow eastward also increases the time available for natural attenuation processes to reduce the contaminant concentrations not captured by the extraction wells. The focused optimization study (detailed in DOE/RL-2019-38 and in Section 4.3 of this report) will be evaluating to determine whether flow-path control can be maintained if injection on the east side is reduced or ceases, with the intention of reinjecting water instead (1) on the west side of the extraction wells, or (2) within the extraction wellfield, in order to enhance flushing and accelerate remediation.

Table 4-7. Estimated Contaminant Mass Recovered and Fraction of Initial Mass over 25 Years of Operation

Contaminant of Concern	Half-Life (years)	Distribution Coefficient	Porosity	Calculated R	Initial Mass in 2015 (kg)			Mass Remediated by P&T (kg)	Mass Decayed (kg)	Total Mass Removed (kg)	Mass Removed Prior to 2015	% Total Mass Remediated in 2037	% Dissolved Mass Remediated in 2037
					Dissolved	Sorbed	Total						
Carbon Tetrachloride 300y Half life	300	0.011	0.15	1.1404	32,141	4,514	36,655	30,110	789	30,899	8,783	87%	97%
Carbon Tetrachloride 630y Half life	630	0.011	0.15	1.1404	32,141	4,514	36,655	30,396	379	30,775	8,783	87%	97%
Chromium	NA	0	0.15	1.0000	3,893	-	3,893	1,325	-	1,325	181	37%	37%
Iodine-129 (Ci)	1.57E+07	0.1000	0.15	2.2767	3	4	6.7	0.01	6.63E-06	0.01	0	0%	0%
Nitrate (as NO3)	NA	0	0.15	1.0000	12,201,500	-	12,201,500	1,275,850	-	1,275,850	580,375	15%	15%
Technetium (Ci)	211000	0	0.15	1.0000	15	-	15	20	0	20	3	125%	125%
Trichloroethene	NA	0.025	0.15	1.3192	210	67	276	185	-	185	32	70%	90%
Uranium	4.47E+09	0.40	0.15	6.1067	788	4,024	4,812	497	0	497	-	10%	63%
Tritium	12.3	0	0.15	1.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = not applicable

P&T = pump and treat

4.8 Quality Assurance/Quality Control

Appendix E of DOE/RL-2019-66 discusses the QA and QC for sampling and analysis of applicable wells.

4.9 Conclusions

The following conclusions are made regarding the 200-ZP-1 OU:

- Data from the 200 West P&T demonstrate that the system is capable of operating at or beyond its nominal design capacity of 7,600 L/min (2,000 gal/min). For example, the 200 West P&T average total throughput for December 2019 was 8,126 L/min (2,145 gal/min), with the majority of this extraction taking place at 200-ZP-1 extraction wells. When the 200 West P&T is operating at close to nominal capacity, the combination of 200-ZP-1 extraction and injection wells appears able to hydraulically contain the majority of carbon tetrachloride present in groundwater at concentrations >100 µg/L, as targeted to achieve the desired recovery of carbon tetrachloride mass. Installation of a new extraction well in the northeastern region of the plume (>100 µg/L) appears to have successfully achieved containment in this area. However, a small area of carbon tetrachloride at concentrations >100 µg/L may be present east of the eastern line of injection wells.

- Summary statistics calculated using contaminant sampling results throughout the monitoring wells listed in the 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 2) indicate that overall carbon tetrachloride concentrations are reducing each year. This is consistent with expectations and reflects an area-wide reduction in dissolved contaminant mass throughout the area encompassed by the groundwater P&T remedy. Contaminant monitoring at individual monitoring wells also indicates decreasing contaminant concentrations for most COCs when compared to baseline concentrations established in 2012.

- Despite the progress made establishing hydraulic containment, recovering mass, and reducing concentrations, groundwater modeling suggests that the current remedy will not recover 95% of the initial carbon tetrachloride mass. In particular, simulations using more recent estimates of the extent of contamination, and assuming a carbon tetrachloride half-life on the order of 300 to 630 years (rather than the values of 41.3 and 100 years assumed in the 200-ZP-1 OU ROD [EPA et al., 2008]), the remedy is unlikely to achieve final groundwater cleanup levels for carbon tetrachloride. Furthermore, the contamination beneath the Rlm (within the Rwia) will require substantially longer to recover than will be required for the Rwie. Based on this groundwater modeling and empirical data analyses, the optimization study was initiated, and several optimization activities were completed to evaluate modification options for the 200 West P&T to accelerate contaminant mass removal and achieve groundwater cleanup levels for carbon tetrachloride.

- The regulatory path forward for the Rwie to implement the identified improvements resulted in commencement of a 200-ZP-1 OU optimization study that was approved on September 30, 2019, and implementation began in October 2019. This work resulted in the following:

  - Suspension in October 2019 of active biological treatment for nitrate to focus on increasing carbon tetrachloride treatment capacity and mass removal. Suspension of the active biological treatment system eliminates addition of well-foulant constituents in facility effluent, although injection wells may continue to require disinfection and rehabilitation to sustain injection capacity.
  - A plan to expand the 200 West P&T in 2022 to achieve a peak capacity of 14,200 L/min (3,750 gal/min), with about 11,600 L/min (3,070 gal/min) of this capacity devoted to groundwater extraction within the 200-ZP-1 OU.

- To address conditions in the Rwia, the revised 200-ZP-1 OU PMP (DOE/RL-2009-115, Rev. 3) and the Ringold A SAP (DOE/RL-2019-23) were issued in early 2020. Section 4.3 in the PMP summarizes the DQOs and describes the multi-stage decision-making process to resolve the decision statements and address the decision rules. The Ringold A SAP addresses the phased installation of monitoring wells in and around the 200-ZP-1 OU to obtain data to further characterize the nature and extent of contaminants, to refine the geologic framework for the Rwia, and to provide hydraulic properties for contaminant F&T modeling.
- Further modeling is planned to locate additional extraction and/or injection wells to expand the region of containment, to locate monitoring wells within the Rwie and Rwia, and to identify further F&T modeling efforts necessary to support 200-ZP-1 OU optimization study decision making for the near-term and for ultimate RAO attainment or ROD modification.

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5 200-DV-1 Operable Unit Perched Water Removal Action

This chapter discusses the removal action activities performed for contaminated perched water in the 200-DV-1 OU during 2019.

Highlights

- The removal action for perched water extraction continued to successfully operate during 2019.
- Development of a three-dimensional, site-specific geoframework model of the 200-DV-1 OU perched zone was completed in 2019 to support F&T evaluations, future extraction and monitoring well placement, and optimized pumping operations.
- A hydraulic analysis was completed in 2019 that examined well configuration options for increasing the perched water extraction rate.
- The installation of 12 vertical perched water wells (8 extraction and 4 monitoring) was planned in 2019. The first two extraction wells are scheduled to be drilled in 2020.
- A SAP was drafted in 2019 for implementing increases in perched water extraction capacity and mass removal.
- Five Tri-Party Agreement changes notices were approved in 2019 to add the new extraction and monitoring wells to the perched water extraction authorizing documents.

Extraction of contaminated perched water using well 299-E33-344 began in August 2011 to collect information on the perched zone and to reduce contaminant migration to the unconfined aquifer. Two additional 200-DV-1 OU perched water extraction wells (299-E33-350 and 299-E33-351) were drilled in 2014 in accordance with the characterization SAP issued in 2014 (DOE/RL-2013-52, *Sampling and Analysis Plan for Perched Water Wells C8914 and C8915 in the 200-DV-1 Operable Unit*). Extraction of perched water using all three wells began in 2016 as a CERCLA NTCRA in accordance with the action memorandum issued in December 2014 (DOE/RL-2014-34). The removal action work plan (DOE/RL-2014-37, *Removal Action Work Plan for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction*) and associated removal action SAP (DOE/RL-2014-51, *Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction*) for the NTCRA were issued in November 2015. DOE/RL-2016-22, *Waste Management Plan for Perched Water Pumping/Pore Water Extraction, 200-DV-1 Operable Unit*, was issued in March 2016. These five documents were modified in December 2019 to incorporate planned new perched water extraction and monitoring wells:

- TPA-CN-0878, *Tri-Party Agreement Change Notice Form: DOE/RL-2014-51, Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction, Revision 0*, modified DOE/RL-2014-51 by updating the sampling requirements for perched water extraction and monitoring wells.
- TPA-CN-0879, *Tri-Party Agreement Change Notice Form: DOE/RL-2013-52, Sampling and Analysis Plan for Perched Water Wells C8914 and C8915 in the 200-DV-1 Operable Unit, Rev. 0*, modified DOE/RL-2013-52 by adding soil and perched water characterization for planned new extraction and monitoring wells.
- TPA-CN-0880, *Tri-Party Agreement Change Notice Form: DOE/RL-2014-34, Action Memorandum for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction, Rev. 0*, modified DOE/RL-2014-34 by expanding the scope of the perched water removal action to include additional extraction and monitoring wells.
- TPA-CN-0881, *Tri-Party Agreement Change Notice Form: DOE/RL-2014-37, Removal Action Work Plan for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction*, Rev. 0, modified DOE/RL-2014-37 by expanding the scope of the perched water removal action to include additional extraction and monitoring wells.

- TPA-CN-0882, *Tri-Party Agreement Change Notice Form: DOE/RL-2016-22, Waste Management Plan for Perched Water Pumping/Pore Water Extraction, 200-DV-1 Operable Unit*, *Rev. 0*, modified DOE/RL-2016-22 by adding planned new extraction and monitoring wells.

The removal action work plan (DOE/RL-2014-37) was modified in March 2016 by adding the waste management plan (TPA-CN-0719, *Tri-Party Agreement Change Notice Form: DOE/RL-2014-37, Removal Action Work Plan for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction*, Rev. 0) and in December 2017 by allowing injection of potable water for development of extraction wells (TPA-CN-0809, *Tri-Party Agreement Change Notice Form: DOE/RL-2014-37, Removal Action Work Plan for 200-DV-1 Operable Unit Perched Water Pumping / Pore Water Extraction*, Rev. 0). The removal action SAP (DOE/RL-2014-51) was modified in March 2016 by adding the waste management plan (TPA-CN-0720, *Tri-Party Agreement Change Notice Form: DOE/RL-2014-51, Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction, Revision 0*,) and in January 2018 by removing the requirement for continuous field monitoring of conductivity in extraction wells (TPA-CN-0796, *Tri-Party Agreement Change Notice Form: DOE/RL-2014-51, Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction, Revision 0*).

Contaminated perched water is present in the deep vadose zone at the B Complex area, located in the Hanford Central Plateau Inner Area (Figure 5-1). The B Complex includes waste sites in the 200-DV-1 OU and the SST farms in WMA B-BX-BY (Figure 5-2). Perched water was discovered in this area in 1991 during drilling of wells to characterize groundwater contamination in the underlying unconfined aquifer in the 200-BP-5 OU. In 2008, perched water was encountered during the drilling of wells 299-E33-343, 299-E33-344, and 299-E33-345 as part of the CERCLA RI for the 200-BP-5 OU. The perched water contains high concentrations of uranium, technetium-99, and nitrate. The contaminated water in the perched zone likely originated from unplanned releases to the vadose zone from the SSTs in the B Complex and engineered releases to associated liquid waste discharge facilities.

The perched water is contained within a very fine sand and silt layer overlying a low-permeability perching silt. Perched water, which is a continuing contamination source to the underlying unconfined aquifer, is slowly migrating downward through the vadose zone. Characterization and remediation of the contaminated perched water is being conducted for the 200-DV-1 OU, which was created in 2010 to support remedy selection for waste sites with deep vadose zone contamination. The perched water zone is estimated to extend from the central portion of the BX Tank Farm northeast to the 216-B-8 Crib, and it includes the western portion of the B Tank Farm (Figure 5-2). The saturated thickness of the perched zone ranges up to 3.7 m (12 ft) (Figure 5-3). The depth to the perched water varies from 69.1 to 70.1 m (227 to 230 ft) bgs.

Hydraulic testing during startup of the existing three-well extraction system was conducted from February through September 2016. Testing continued in 2017, using one well as an observation point to collect water levels. In 2018, the hydraulic testing results were evaluated in PNNL-27846, *Physical and Hydraulic Properties of Sediments from the 200-DV-1 Operable Unit*. The report concluded that the extent of the perched water hydrologic boundary cannot fully be determined without incorporating additional extraction and monitoring wells that could accelerate dewatering of the perched water zone.

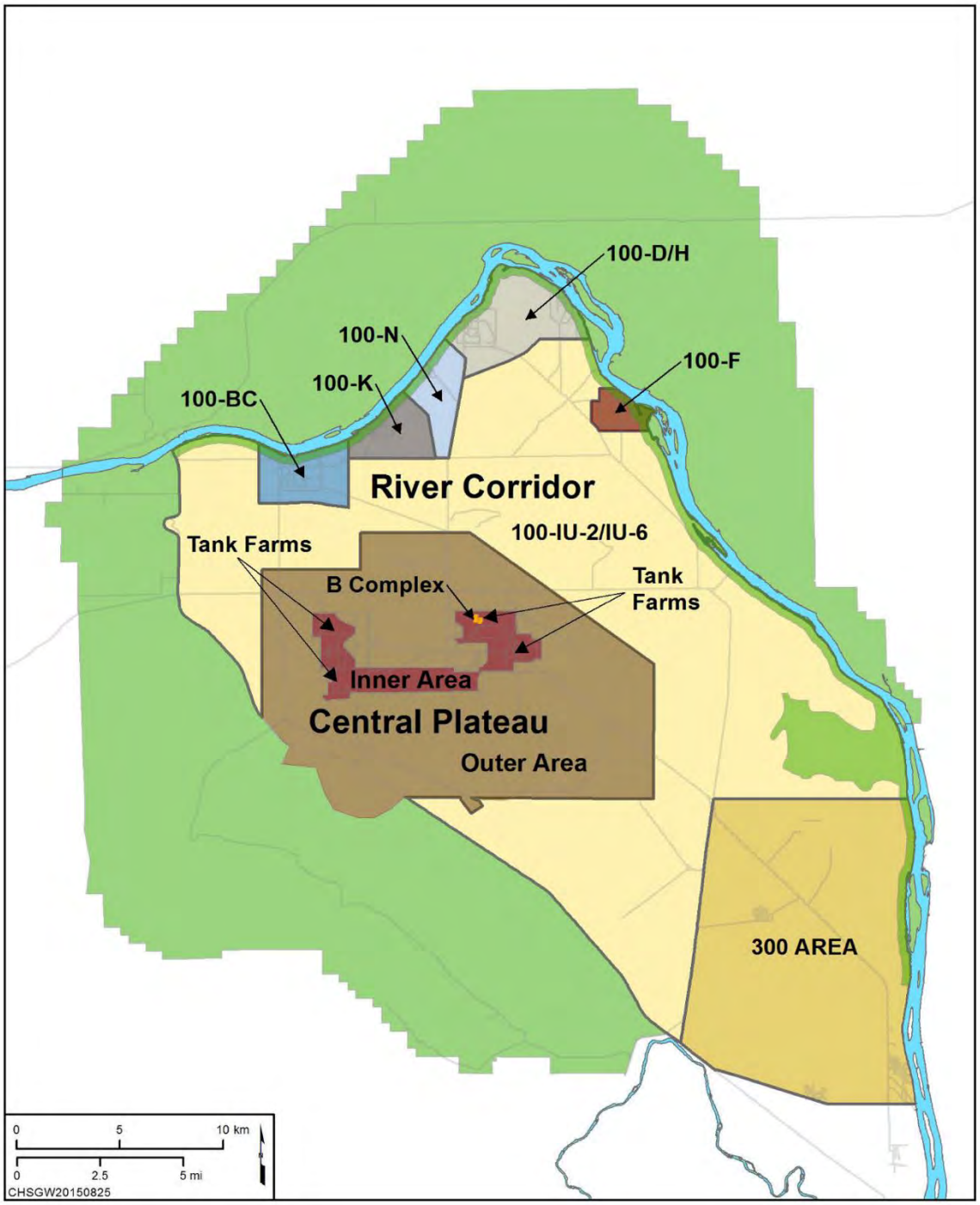


Figure 5-1. Location of the B Complex Area at the Hanford Site

Development of a three-dimensional, site-specific geoframework model of the 200-DV-1 OU perched zone was completed in 2019 to support F&T evaluations, future extraction and monitoring well placement, and optimized pumping operations (ECF-200DV1-18-0036, *B-Complex Perched Zone Geoframework, 200 East, Hanford Site*). The site-specific geoframework model was used to revise the extent of the perched water (Figure 5-2) and estimate the variation in saturated thickness of the perched zone (Figure 5-3).

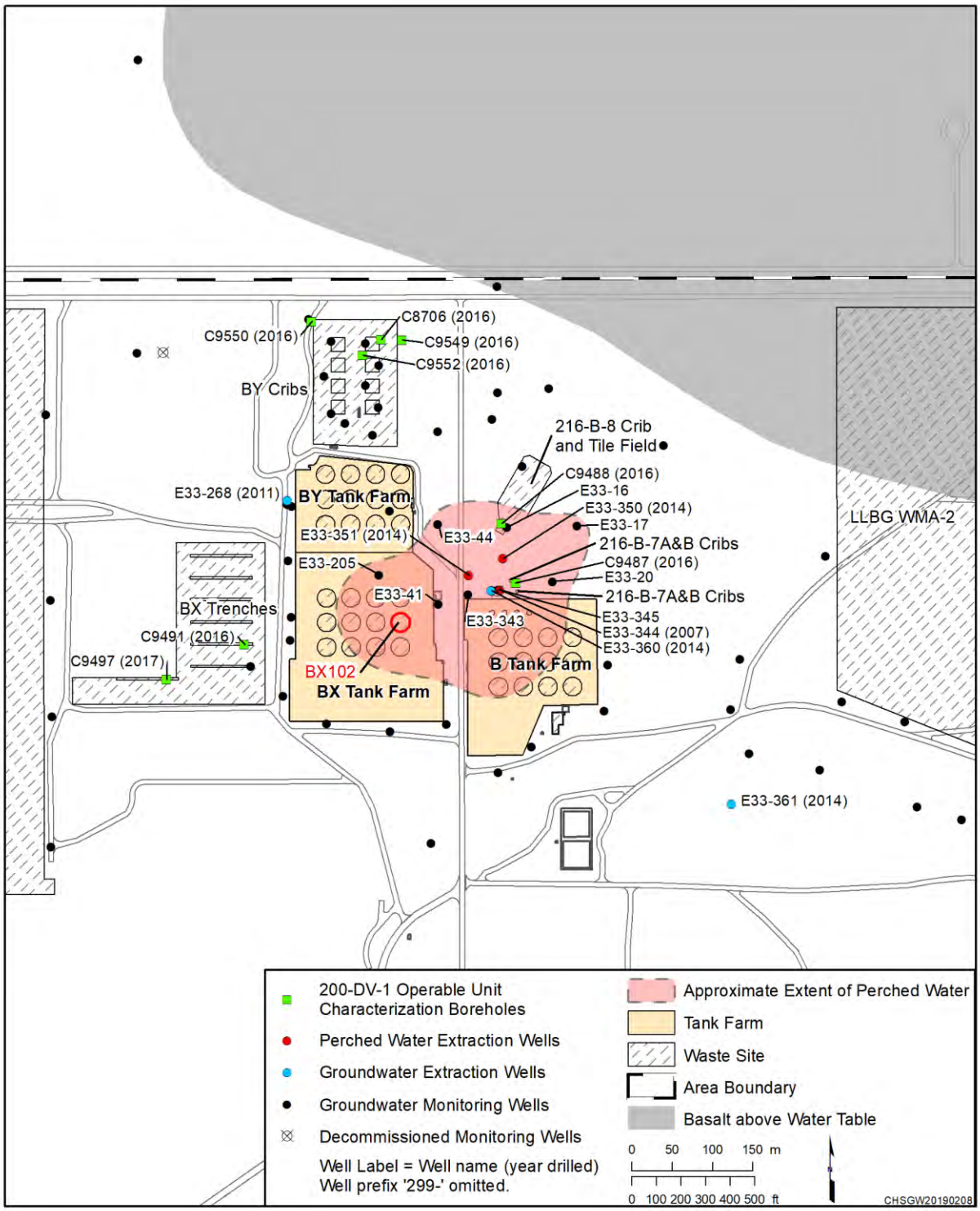


Figure 5-2. Location of Waste Sites, Tank Farms, Wells, and Estimated Extent of Perched Water in the B Complex Area

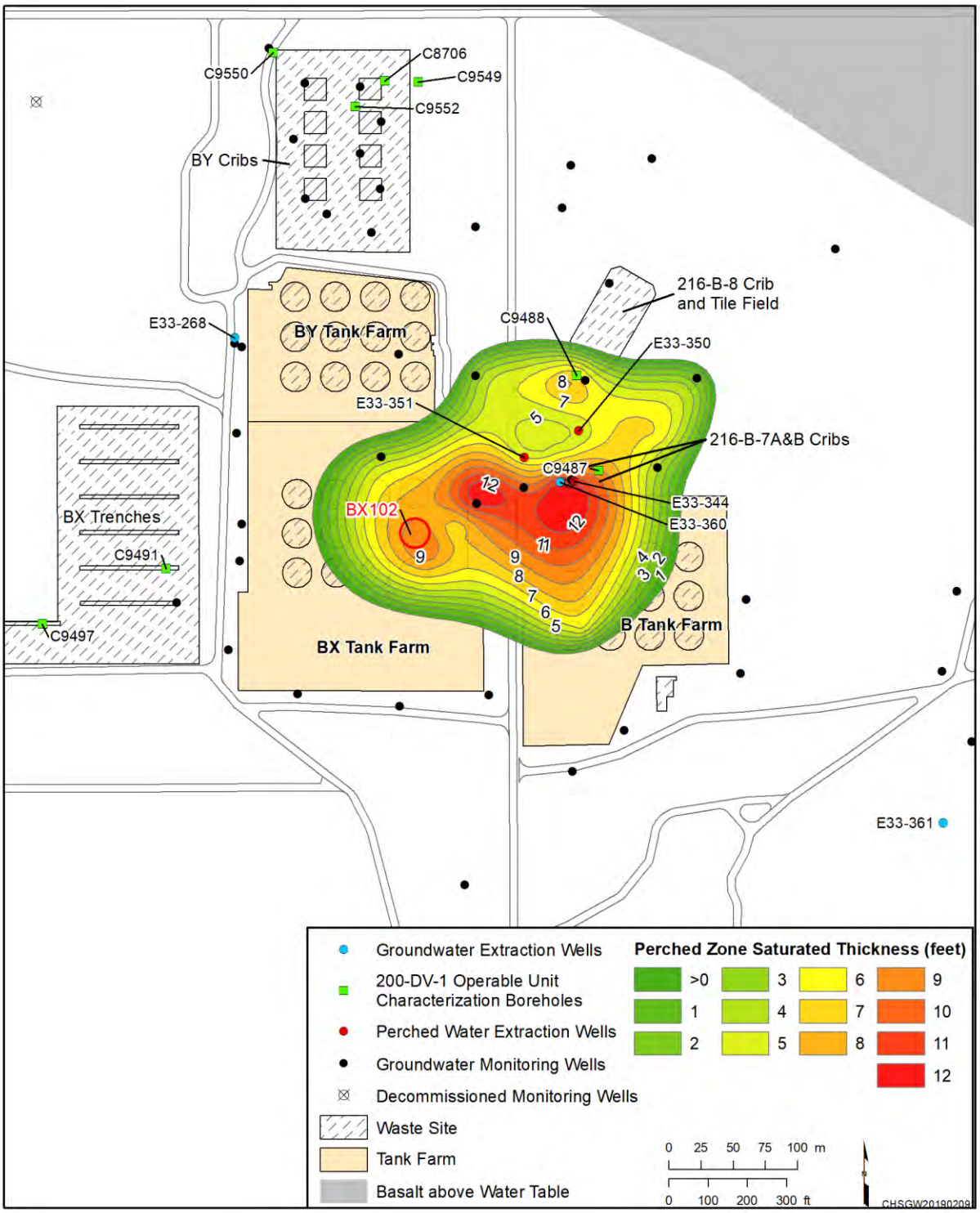


Figure 5-3. Saturated Thickness of the Perched Water Zone

In 2019, a hydraulic analysis examined extraction well configuration options for increasing the rate of contaminated perched water removal (SGW-63236). The results of the analysis concluded that the low hydraulic conductivity and relatively thin saturated thickness of the perched water zone severely limits the flow of perched water into extraction wells. Three different well completions were evaluated in the hydraulic analysis. The analysis and optimization of the vertical well designs did not identify a significant improvement in perched water extraction rates for vertical wells. The horizontal well option shows promise for increasing the extraction rate of perched water. However, installation is dependent on the accuracy of existing boring and geophysical logs and may present health and safety and waste management issues when dealing with drilling fluids and development water. Site-specific conditions will need to be considered in future cost estimates for each of the scenarios presented in SGW-63236 before a decision can be made regarding the most effective option to increase perched water removal in the 200-DV-1 OU.

The 2019 hydraulic analysis and geoframework model, as well as other existing information for the perched water zone and the overall hydrogeological system, were used to guide planning to install additional extraction and monitoring wells within the perched water zone to increase the extraction rate, dewater the perched zone, increase mass removal of uranium, and support refinement of the conceptual model. The locations for 12 vertical perched water wells (8 extraction and 4 monitoring) outside of the B-BX-BY Tank Farms were planned in 2019 (Figure 5-4). The first two extraction wells are scheduled to be installed in 2020. TPA-CN-0879 added the locations and sampling design for the 12 new wells to DOE/RL-2013-52.

A SAP that will supersede DOE/RL-2013-52 is anticipated to be approved by the regulatory agencies by the end of FY 2020. The new SAP outlines the approach for the drilling, construction, and installation of additional vertical extraction and monitoring wells outside of the B-BX-BY Tank Farms. Data will be collected to characterize the subsurface hydrogeology and contamination and to support phased implementation of additional extraction capacity, as well as to provide input to future remedy decisions that may include other remediation approaches and/or control of the hydrogeological system. Planning is anticipated to include a cost-benefit analysis for the feasibility of installing a single horizontal extraction well to dewater the perched zone instead of installing numerous vertical wells inside the B-BX-BY Tank Farms.

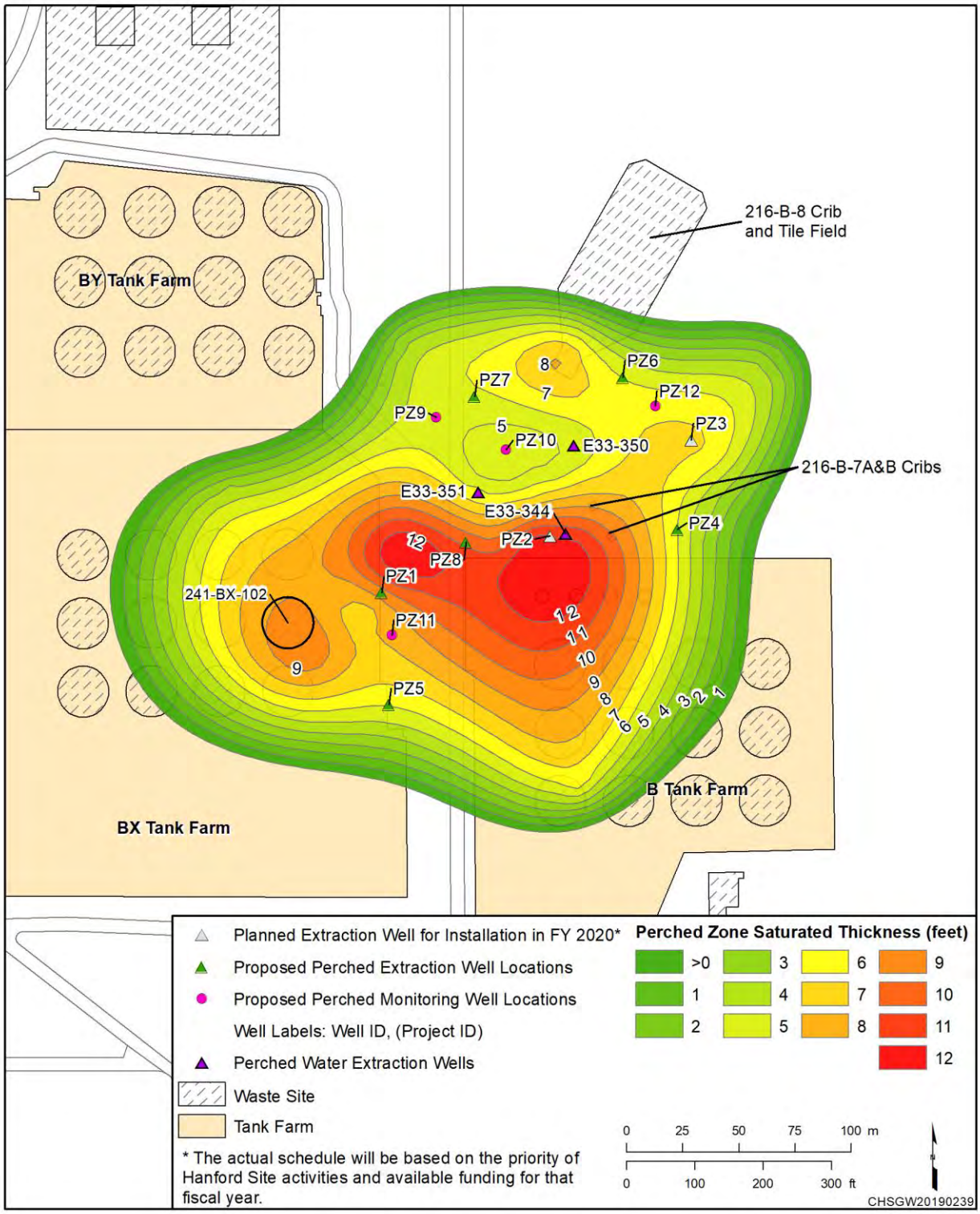


Figure 5-4. Approximate Locations of Proposed Perched Water Extraction and Monitoring Wells

5.1 Removal System Operation

The perched water extraction system operated from January 1 through December 31, 2019. Wells 299-E33-344 and 299-E33-351 were operational 97% of the time during 2019 (Figure 5-5). Following redevelopment in 2018 and subsequent maintenance, extraction from well 299-E33-350 resumed in March 2019 and was operational for the remainder of 2019 (82% of the year).

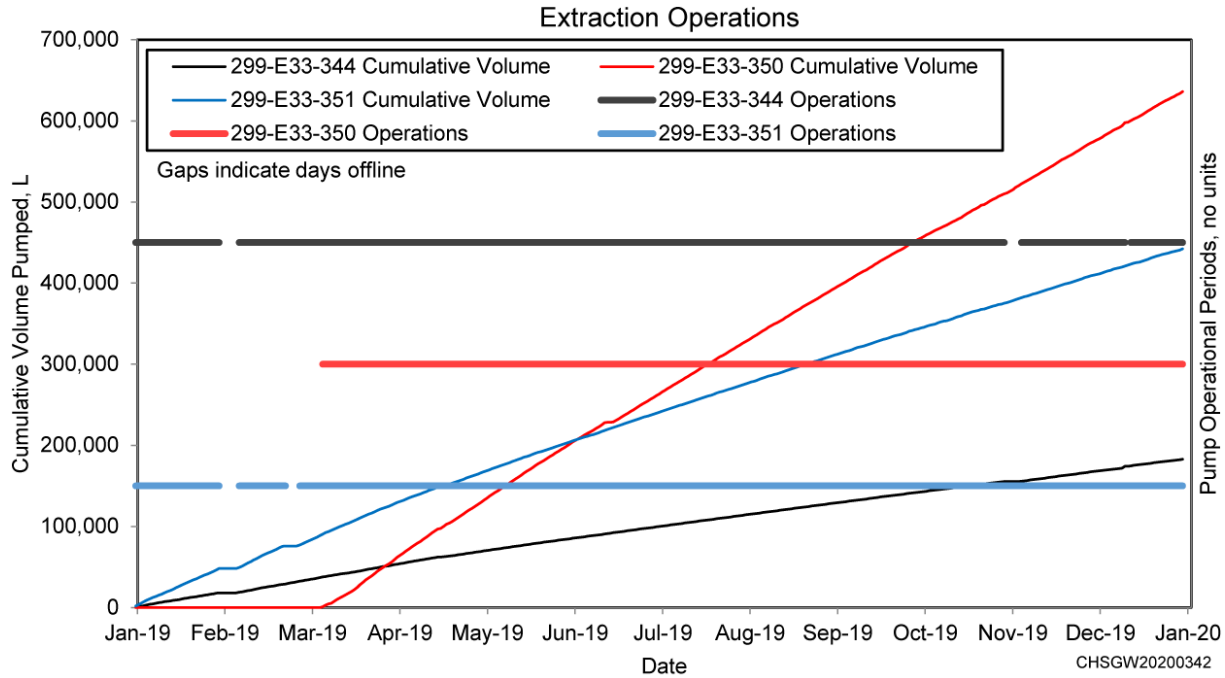


Figure 5-5. Perched Water Extraction Operations Timeline and Cumulative Volumes Extracted, 2019

5.1.1 Overview of Removal System

Perched water is pumped using extraction wells 299-E33-344, 299-E33-350, and 299-E33-351. A dedicated submersible pump is installed in each well with an automatic on/off pump control regulated by a water-level transducer. Each transducer is located 0.3 m (1 ft) above the pump intake. When the perched water level in the well reaches the transducer high-level set point, the pump turns on and the water is pumped into a single, aboveground, 11,000 L (3,000 gal), HDPE, double-wall collection container centrally located near the three wells. When pumping lowers the water level to the transducer low-level set point, the pump shuts off to allow the well to recover.

The high and low set points for each extraction well are periodically optimized to support efficient pumping operations. Table 5-1 lists the typical high and low set points used in 2019, and Table 5-2 lists the extraction well configurations. Table 5-3 summarizes the operational parameters for each extraction well during 2019.

None of the perched water extraction wells were redeveloped in 2019. Well 299-E33-344 was redeveloped in July and November 2018. The pump did not restart after redevelopment and a new, lower flow pump was installed. Well 299-E33-350 was redeveloped in September 2018. The pump also did not restart after redevelopment and required troubleshooting and maintenance. Redevelopment did not lead to an increase in production from either well.

Table 5-1. Typical Perched Water Extraction Well Set Points in 2019

Well	Transducer High Set Point (m [ft] Above the Pump)	Transducer Low Set Point (m [ft] Above the Pump)
299-E33-344	1.5 (5.0)	0.9 (3.0)
299-E33-350	1.4 (4.7)	0.3 (1.1)
299-E33-351	1.4 (4.7)	0.1 (0.4)

Table 5-2. Perched Water Extraction Well Configuration

Well	Top of Screen (m [ft] Below Pad)	Bottom of Screen (m [ft] Below Pad)	Screen Length (m [ft])	Pump Intake (m [ft] Below Pad)	Transducer (m [ft] Below Pad)	Well Casing Diameter (cm [in.])
299-E33-344	66.4 (217.9)	72.3 (237.1)	5.9 (19.2)	72.0 (236.1)	71.7 (235.1)	10.2 (4)
299-E33-350	68.1 (223.5)	71.2 (233.5)	3.0 (10)	70.9 (232.5)	70.6 (231.5)	15.2 (6)
299-E33-351	67.9 (222.8)	71.0 (232.8)	3.0 (10)	70.7 (231.8)	70.3 (230.8)	15.2 (6)

Table 5-3. Perched Water Extraction Well Operations in 2019

Well	Total Volume Pumped [L (gal)]	Typical Pumping Cycle (min)[a]	Typical Recharge Time (min)[a]	Total Operating Time (hr)	Total Pumping Time (hr)[b]	Daily Average Flow Rate When Pumping [L/min (gal/min)]
299-E33-344	181,700 (48,000)	2	21	8,472	737	4.14 (1.09)
299-E33-350	617,022 (163,000)	5	16	7,200	1,714	6.18 (1.63)
299-E33-351	442,893 (117,000)	3	26	8,520	881	8.36 (2.21)

a. Source: SGW-62783-VA, *Perched Well Pumping Status*.

b. The total pumping time does not include the time when the pump has been shut off to allow the well to recover.

Extracted perched water is transferred from the single, aboveground perched water collection container to a nearby larger, aboveground collection container used for groundwater extracted from the underlying 200-BP-5 OU. Perched water and groundwater in the 200-BP-5 OU container are conveyed through a cross-site transfer pipeline to a holding tank at the 200 West P&T. The water is then transferred into the uranium inlet tank where it is mixed with 200-UP-1 OU extracted groundwater and ERDF leachate. The mixed water is sent through the uranium and technetium-99 treatment systems and finally to the central treatment system (Section 2.3.1). The treated water is then injected into the 200 West Area aquifer at or below the MCLs for the respective contaminants.

5.1.2 Contaminant Monitoring

Perched water was monitored during 2019 in accordance with the removal action SAP (Table 3-1 in DOE/RL-2014-51). The constituents in the SAP include six COCs and a list of specific non-COCs. The COCs (technetium-99, tritium, total chromium, Cr(VI), nitrate, and uranium) are monitored during quarterly sampling (in March, June, September, and December). Carbon-14 is analyzed during semiannual sampling (in March and September), and all other constituents required by the SAP are analyzed during annual sampling (in March). Field parameters (dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature, and turbidity) are collected during each sampling event. All required perched water samples and associated field QC samples were obtained quarterly from March through December 2019. All of the required constituents and field parameters were analyzed in the 2019 perched water samples. The analytical data were reviewed by the project scientist and requests for data review were submitted as needed.

Tables 5-4, 5-5, and 5-6 provide the analytical results for uranium, technetium-99, and nitrate (the primary COCs of interest) for samples collected from the three perched water extraction wells in 2019. Table 5-7 provides the maximum concentrations detected during 2017, 2018, and 2019 for the COCs and other constituents required by the 200-DV-1 OU removal action SAP (DOE/RL-2014-51).

Uranium and technetium-99 concentrations in well 299-E33-344 remain higher than before pumping began in 2011 and have continued to fluctuate over time (Figure 5-6). Figures 5-7 through 5-9 show the 2016 through 2019 concentrations of uranium, technetium-99, and nitrate in samples collected from the three perched water extraction wells. The highest uranium concentration in 2019 was 108,000 µg/L in well 299-E33-350 (Figure 5-7; Tables 5-5 and 5-7). The highest technetium-99 concentration was 78,300 pCi/L in well 299-E33-350 (Figure 5-8; Tables 5-5 and 5-7). Nitrate concentrations were the highest in well 299-E33-351 (Figure 5-9; Tables 5-6 and 5-7).

The weekly average flow rates when the pumps are extracting perched water are shown in Figure 5-10 for each extraction well from 2017 through 2019. The cumulative volume extracted by all three wells during this time is also shown.

Table 5-4. Extraction Well 299-E33-344 Perched Water Analytical Results, 2019

Sampling Date	Nitrate[a] (mg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
03/27/2019	465	34,700	47,800
05/29/2019	452	25,600	46,200
08/14/2019[b]	496	24,100	39,700
09/19/2019	456	31,700	45,000
12/04/2019	423	32,300	37,300

a. Values in this table are nitrate as NO_3.

b. Sampled for Washington State Department of Health.

Table 5-5. Extraction Well 299-E33-350 Perched Water Analytical Results, 2019

Sampling Date	Nitrate[a] (mg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
03/27/2019	651	29,400	45,500
03/27/2019	651	28,700	42,900
05/29/2019	722	25,600	43,900
08/14/2019[b]	Not analyzed	26,000	46,000
08/14/2019[b]	Not analyzed	27,300	46,000
09/19/2019	1,050	78,300	108,000
09/19/2019	1,020	77,200	105,000
12/04/2019	748	45,800	46,800
12/04/2019	708	48,400	45,600

a. Values in this table are nitrate as NO_3.

b. Sampled for *Atomic Energy Act of 1954* monitoring program; nitrate analysis was not requested.

Table 5-6. Extraction Well 299-E33-351 Perched Water Analytical Results, 2019

Sampling Date	Nitrate[a] (mg/L)	Technetium-99 (pCi/L)	Uranium (µg/L)
03/27/2019	1,330	46,000	35,400
05/29/2019	1,790	32,800	33,900
05/29/2019	2,320	41,300	37,000
08/14/2019[b]	Not analyzed	35,900	31,100
09/19/2019	1,640	35,400	33,100
12/04/2019	1,970	48,800	32,300

a. Values in this table are nitrate as NO_3.

b. Sampled for *Atomic Energy Act of 1954* monitoring program; nitrate analysis was not requested.

Table 5-7. Maximum Contaminant Concentrations Detected During Perched Water Sampling, 2017 and 2018 and 2019

Constituent	Units	Year	Well 299-E33-344[a]	Well 299-E33-350	Well 299-E33-351
			Maximum[b]	Maximum[b]	Maximum[b]
COCs (Sampled Quarterly)					
Uranium	µg/L	2019	47,800	108,000	37,000
		2018	78,200	99,000	42,900
		2017	52,900	105,000	35,900
Technetium-99	pCi/L	2019	34,700	78,300	48,800
		2018	32,900	44,800	37,900
		2017	40,800	45,900	41,300
Nitrate as NO_3	mg/L	2019	496	1,050	2,320
		2018	531	1,110	1,990
		2017	487	1,100	1,810
Total chromium	µg/L	2019	105	95.7	55.6
		2018	126	117	65.3
		2017	71.9	72.3	58.2
Hexavalent chromium	µg/L	2019	104	104	54.5
		2018	118	100	62.1
		2017	71	87	61
Tritium	pCi/L	2019	13,300	21,000	8,990
		2018	17,300	20,100	8,700
		2017	15,800	22,500	7,750
Non-COCs (Sampled Annually or Semiannually)					
Carbon-14	pCi/L	2019	1,200	1,290	929
		2018	1,320	1,320	655
		2017	1,270	1,470	852
Iodine-129	pCi/L	2019	4.11	3.48	11.7
		2018	2.48	4.48	4.58
		2017	0.829 UXR[c]	4.23	17.6 U[c]
Arsenic	µg/L	2019	7.31	22.2	5.83
		2018	11.9	21.7	4.77 B
		2017	8.9	16.0	4.25 B
Calcium	mg/L	2019	133	274	424
		2018	156	275	299
		2017	156	257	461

Table 5-7. Maximum Contaminant Concentrations Detected During Perched Water Sampling, 2017 and 2018 and 2019

Constituent	Units	Year	Well 299-E33-344[a]	Well 299-E33-350	Well 299-E33-351
			Maximum[b]	Maximum[b]	Maximum[b]
Iron	µg/L	2019	81.9 B	94.8 B	30 U
		2018	626	30 U	300 U
		2017	150 U	300 U	300 U
Sodium	mg/L	2019	300	493	524
		2018	295	491	455
		2017	285	425	640
Chloride	mg/L	2019	71.3	87	99.7
		2018	74	120	90
		2017	64	97	91
Fluoride	mg/L	2019	11	7.2	0.48
		2018	13	8.2	0.36
		2017	9.4	6.8	0.28
Nitrite as NO_2	µg/L	2019	108 U	258 B	108 U
		2018	125 U	3,020 Y	1,050 Y
		2017	125 U	2,430 Y	125 U
Sulfate	mg/L	2019	444	613	956
		2018	430	740	830
		2017	410	610	720
Magnesium	mg/L	2019	55.2	118	125
		2018	57.5	115	90
		2017	56.1	101	134
Potassium	mg/L	2019	10.7	17.6	20.7
		2018	11.8	17.5	17.7
		2017	11.1 B	15.9 B	24.7
Bicarbonate alkalinity	mg/L	2019	No data[d]	No data[d]	No data[d]
		2018	302	340	258
		2017	314	362	252
Carbonate alkalinity	µg/L	2019	1,450 U	1,450 U	1,450 U
		2018	15,000 U	1,500 U	1,500 U
		2017	540 U	1,450 U	1,450 U
Total inorganic carbon[e]	mg/L	2019	Not analyzed	Not analyzed	Not analyzed
		2018	Not analyzed	Not analyzed	Not analyzed
		2017	Not analyzed[f]	61.4	49.6

Table 5-7. Maximum Contaminant Concentrations Detected During Perched Water Sampling, 2017 and 2018 and 2019

Constituent	Units	Year	Well 299-E33-344[a]	Well 299-E33-350	Well 299-E33-351
			Maximum[b]	Maximum[b]	Maximum[b]
Total organic carbon[e]	mg/L	2019	Not analyzed	Not analyzed	Not analyzed
		2018	Not analyzed	Not analyzed	Not analyzed
		2017	Not analyzed[f]	2.6	2.8
Total dissolved solids[e]	mg/L	2019	Not analyzed	Not analyzed	Not analyzed
		2018	Not analyzed	Not analyzed	Not analyzed
		2017	Not analyzed[f]	2,490	2,430
Total cyanide[e]	µg/L	2019	1.67 U	1.67 U	2.68 B
		2018	1.67 U	1.81 B	2.97 B
		2017	1.67 U	2.11 B	4.13 B
U-233/234[e]	pCi/L	2019	14,800	26,400	12,800
		2018	18,300	32,000	13,100
		2017	16,800	50,700	12,400
U-235[e]	pCi/L	2019	1,290	1,710	994
		2018	1,080	1,950	976
		2017	1,160	2,530	1,110
U-238[e]	pCi/L	2019	15,800	27,200	13,700
		2018	22,600	32,900	13,500
		2017	15,800	52,600	12,700
Field Parameters (Sampled Quarterly)					
Dissolved oxygen	mg/L	2019	6.78	6.63	8.02
		2018	8.25	6.02	8.53
		2017	7.60	6.91	8.19
Oxidation-reduction potential	RmV	2019	536.7	570.8	594.6
		2018	389.2	402.1	419.5
		2017	401	312.9	308.3
pH	Standard units	2019	7.96	8.18	7.87
		2018	8.01	8.03	8.11
		2017	7.7	8.2	7.87
Specific conductance	µS/cm	2019	2,533	3,330	5,685
		2018	2,430	3,334	4,282
		2017	2,325	3,123	3,629
Temperature	°C	2019	21.0	22.3	21.8
		2018	19.4	20.7	19.9
		2017	18.9	20.0	21.7

Table 5-7. Maximum Contaminant Concentrations Detected During Perched Water Sampling, 2017 and 2018 and 2019

Constituent	Units	Year	Well 299-E33-344[a]	Well 299-E33-350	Well 299-E33-351
			Maximum[b]	Maximum[b]	Maximum[b]
Turbidity	NTU	2019	1.53	15.7	27.2
		2018	1.87	0.83	0.64
		2017	1.19	17.5	5.98

a. The December 2017 sample from well 299-E33-344 was collected in January 2018.

b. Maximum of the multiple samples analyzed for each year.

c. Undetected radionuclide value is the minimum detectable concentration.

d. Alkalinity was analyzed.

e. Not required by DOE/RL-2014-51, *Sampling and Analysis Plan for 200-DV-1 Operable Unit Perched Water Pumping/Pore Water Extraction* when these samples were collected.

f. Analyzed only in the annual (March) sample in 2017. Well 299-E33-344 was offline in March 2017 and could not be sampled.

COC = contaminant of concern

NTU = nephelometric turbidity unit

Data qualifiers:

B = result estimated

R = result rejected

U = constituent not detected at the detection limit shown

X = other specific flags and notes required to properly qualify the result are described in the hardcopy sample data summary package and/or case narrative (for this sample, result is considered a false positive due to no valid peak)

Y = result suspect

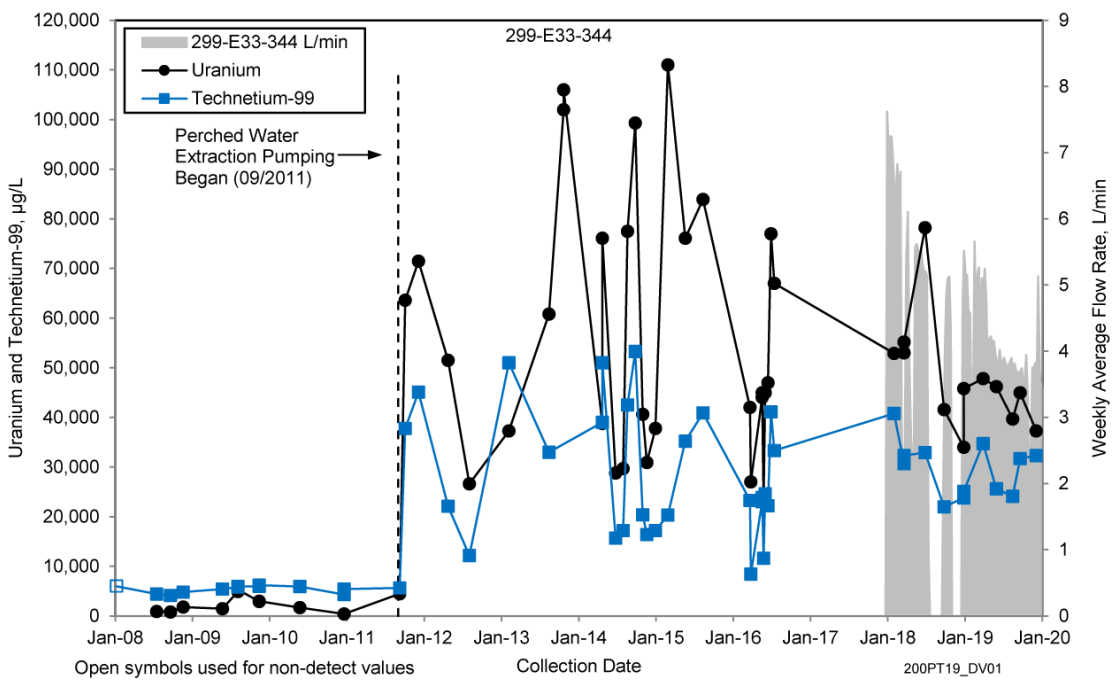


Figure 5-6. Time Series of Uranium and Technetium-99 Concentrations in Perched Water Extraction Well 299-E33-344, 2008–2019

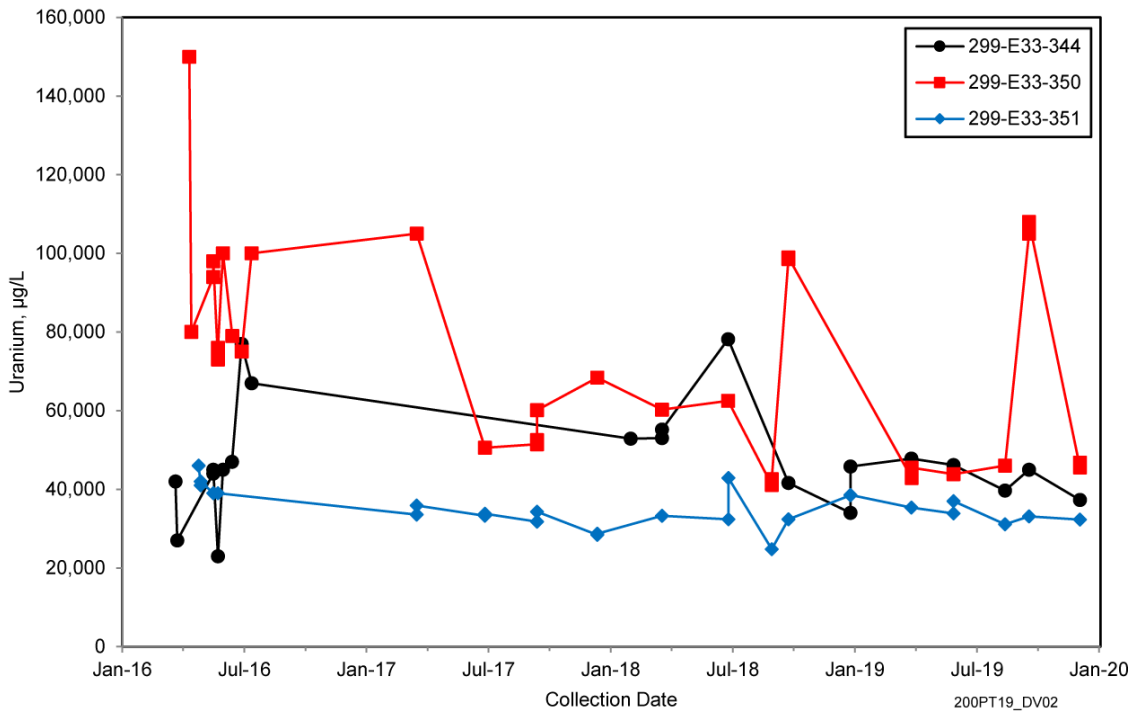


Figure 5-7. Time Series of Uranium Concentrations in Perched Water Extraction Wells 299-E33-344, 299-E33-350, and 299-E33-351, 2016–2019

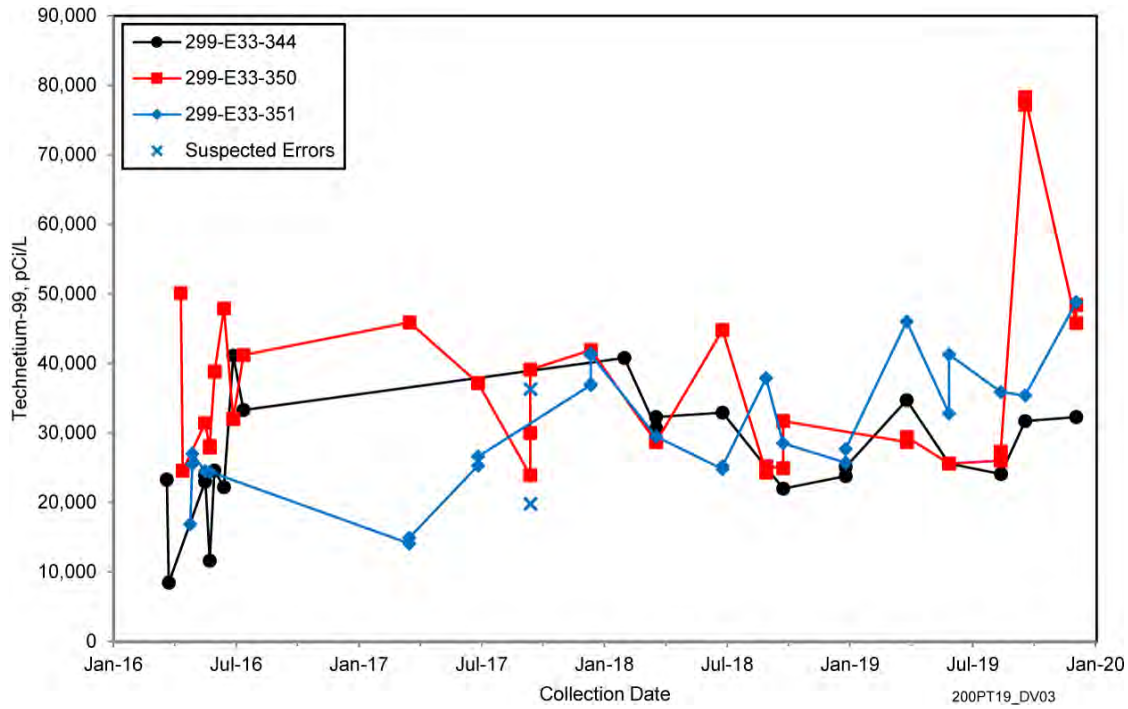


Figure 5-8. Time Series of Technetium-99 Concentrations in Perched Water Extraction Wells 299-E33-344, 299-E33-350, and 299-E33-351, 2016–2019

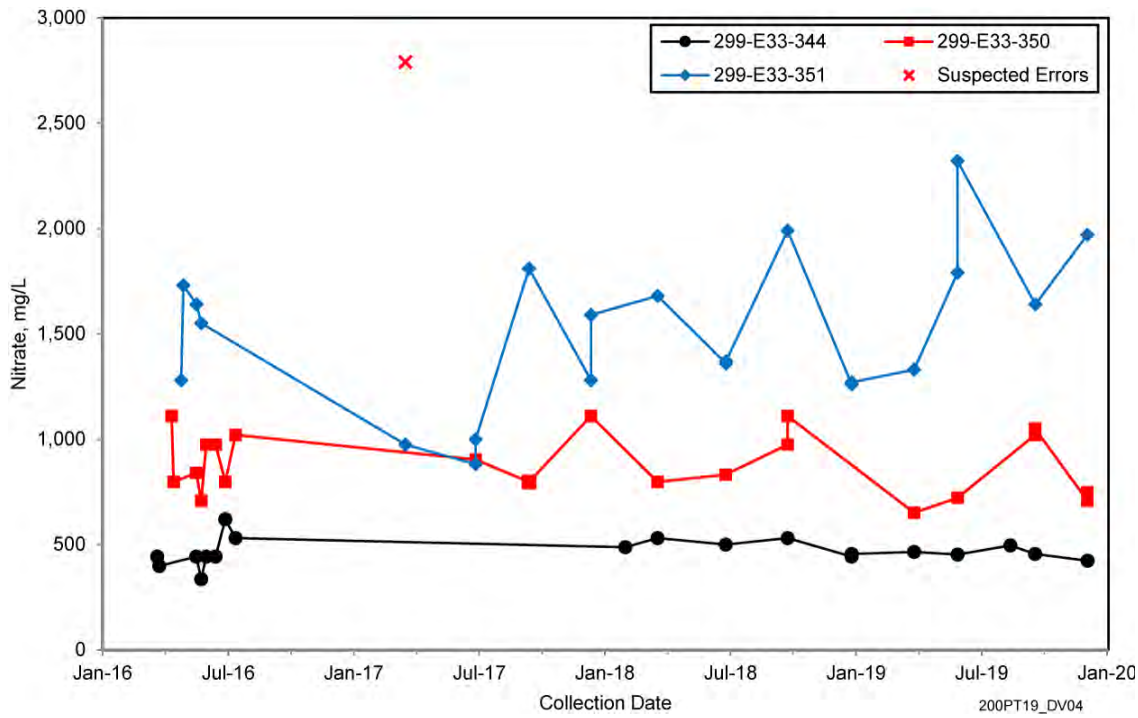


Figure 5-9. Time Series of Nitrate Concentrations in Perched Water Extraction Wells 299-E33-344, 299-E33-350, and 299-E33-351, 2016–2019

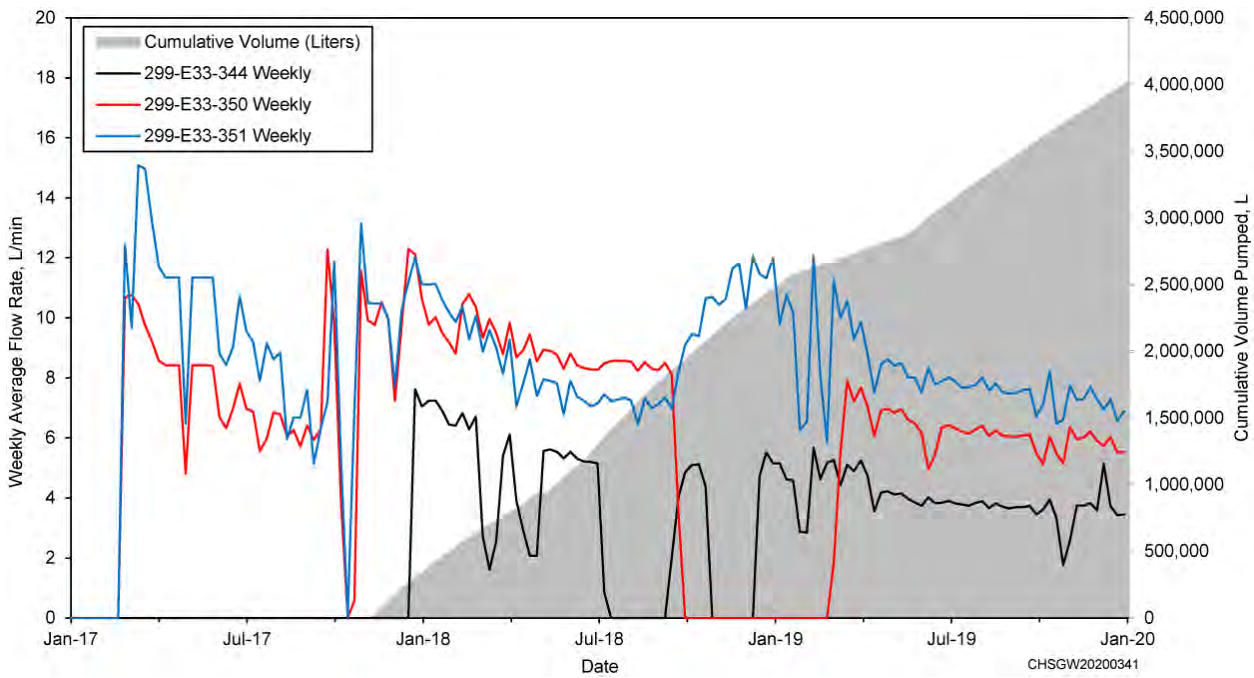


Figure 5-10. Weekly Average Flow Rates for Each Extraction Well and Cumulative Volume Extracted, 2017–2019

5.1.3 Contaminant Mass Removed

Table 5-8 presents the perched water volume and contaminant mass removed since 2011. From 2011 through 2015, only one extraction well (299-E33-344) was operational. Table 5-9 lists the volume and mass removed in 2019 by each of the perched water extraction wells.

In 2019, the perched water extraction wells removed 1,241,615 L (328,000 gal) of water containing 63.3 kg of uranium; 2.72 g (0.046 Ci) of technetium-99; and 1,280 kg of nitrate. Since perched water extraction began in 2011, a total of 5,308,828 L (1,402,444 gal) of perched water containing 293.5 kg of uranium; 10.66 g (0.18 Ci) of technetium-99; and 5,634 kg of nitrate has been removed.

Table 5-8. Perched Water Extracted and Contaminants Removed

Year	Duration	Perched Water Extracted (L [gal])	Uranium Removed (kg)	Technetium-99 Removed (g [Ci])	Nitrate Removed as NO_3 (kg)
2012	08/2011 – 09/2012	246,684 (65,167)	12.0	0.37 (6.3×10^{-3})	131
2013	10/2012 – 09/2013	349,405 (92,303)	13.1	0.74 (1.3×10^{-2})	202.6
2014	10/2013 – 09/2014	286,253 (75,620)	24.1	0.59 (1.0×10^{-2})	137.2
2015	10/2014 – 09/2015	257,654 (68,065)	19.3	0.41 (7.0×10^{-3})	112.2
2016	10/2015 – 12/2016	224,433 (59,289)*	11.2	0.36 (6.1×10^{-3})	195
2017	01/2017 – 12/2017	1,264,328 (334,000)	77.5	2.67 (4.5×10^{-2})	1,970
2018	01/2018 – 12/2018	1,438,456 (380,000)	74.0	2.87 (4.9×10^{-2})	1,606
2019	01/2019 – 12/2019	1,241,615 (328,000)	63.3	2.72 (4.6×10^{-2})	1,280
Totals	**8/2011 – 12/2019**	**5,308,828 (1,402,444)**	**293.5**	**10.66 (1.81×10^{-1})**	**5,634**

*****During 2016, hydraulic testing was conducted when the three-well system started extraction operations. Hydraulic testing included periods of pumping followed by periods of recovery (no pumping) (Table 5-2 in DOE/RL-2016-69, *Calendar Year 2016 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations*). The volume of perched water extracted during 2016 was lower due to the recovery periods.

Table 5-9. Perched Water Extracted and Contaminants Removed in 2019

Well	Duration	Perched Water Extracted (L [gal])	Uranium Removed (kg)	Technetium-99 Removed (g [Ci])	Nitrate Removed as NO_3 (kg)
299-E33-344	1/1/2019 – 12/31/2019	181,700 (48,000)	7.93	0.31 (5.3×10^{-3})	82
299-E33-350	1/1/2019 – 12/31/2019	617,022 (163,000)	40.54	1.47 (2.5×10^{-2})	505
299-E33-351	1/1/2019 – 12/31/2019	442,893 (117,000)	14.81	0.94 (1.6×10^{-2})	693
2019	**1/1/2019 – 12/31/2019**	**1,241,615 (328,000)**	**63.3**	**2.72 (4.6×10^{-2})**	**1,280**

5.2 Removal Action Objectives Progress

Measurable progress was made during 2019 to meet specific removal action objectives for perched water, with the following results:

- Apply ICs to protect human receptors from exposure to contaminants that exceed MCLs in the underlying aquifer.

  Results: The Hanford Sitewide IC plan (DOE/RL-2001-41) has been implemented to prevent the use of groundwater until cleanup levels have been achieved.

- Control sources of groundwater contamination.

  Results: Extraction of perched water controls sources of groundwater contamination by removing contaminant mass from the perched water, minimizing the impact to groundwater. The contaminated water extracted from the perched layer is treated at the 200 West P&T to below MCLs.[3]

- Remove contaminant mass from perched water and support final remedial options for both the 200-DV-1 and 200-BP-5 OUs.

  Results: The 200-DV-1 OU is a source (vadose zone) OU with an RAO to control sources of contamination to the underlying groundwater in the 200-BP-5 OU. The removal action was designed to recover as much perched water as practical while awaiting issuance of the 200-DV-1 OU ROD (Chapter 1 in DOE/RL-2014-34). From 2011 through 2019, substantial quantities of uranium, technetium-99, and nitrate have been removed from perched water in the 200-DV-1 OU, as shown in Tables 5-8 and 5-9. The planned installation of eight additional extraction wells and four monitoring wells in the near-term will augment the recovery of perched water. The information collected from the additional extraction and monitoring wells will enable evaluation of remediation alternatives within and surrounding the perched water zone for the protection of groundwater. The information gathered will also be used to refine the conceptual site model for the perched water zone and the vadose zone above and below the perched water zone with respect to its size, contaminant distribution, and properties related to the effectiveness of perched water extraction and other

[3] As discussed in Section 2.3, nitrate treatment was suspended in October 2019 as part of the 200-ZP-1 OU optimization study (DOE/RL-2019-38).

potential remedies, such as in situ remediation and/or control of the hydrogeological system, for the 200-DV-1 OU and 200-BP-5 OU.

5.3 Quality Assurance/Quality Control

The QC requirements for perched water sampling are specified in the removal action SAP (Table 2-4 in DOE/RL-2014-51). Field QC samples were collected to evaluate cross-contamination potential and provide information relevant to sampling variability. Laboratory QC samples estimate the precision, bias, and matrix effects of analytical data. During 2019, QC samples were collected in accordance with the removal action SAP. Appendix E of DOE/RL-2019-66 provides QA/QC sampling and analysis information for the 200-DV-1 OU perched water wells, including a review of QA/QC issues that may affect data interpretation in this report.

5.4 Removal System Costs

Table 5-10 provides the actual cost breakdown for perched water removal action activities from 2016 through 2019. Sampling activities for routine groundwater monitoring are integrated for all groundwater OUs to reduce overall labor regarding sampling trips and analytical costs. These costs have been pooled in a separate project account and have not been included in the individual project performance monitoring costs. To account for all performance monitoring costs associated with implementation of 200-DV-1 OU perched water removal action, a portion of the pooled costs based on sample trips and analyses performed for the 200-DV-1 OU perched water removal action have been included in the performance reporting costs in this year's report.

Table 5-10. Annual Cost Breakdown for Perched Water Removal Action

Activity	Actual Costs			
	2016	**2017**	**2018**	**2019**
Perched water project management	61,593	510	898	73,568
Design/construct new pipeline[a]	2,104,378	48,882	1,598	0
O&M[b]	327,790	323,410	625,848[c]	636,574[c]
Perched water removal operations	362,020	19,261	47,406	209
Perched water performance reporting[d]	6,722	10,225	8,558	232,387
Install perched water extraction well system	59,321	1,083	0	27,530
Total	**2,921,824**	**403,372**	**684,308**	**970,267**

a. Costs for the cross-site connection to the 200 West P&T were split with the 200-BP-5 OU.

b. The O&M cost is a portion of the overall 200 West P&T O&M cost based on the percentage of mass treated from extracted 200-DV-1 OU perched water to the total mass treated by the 200 West P&T.

c. The higher apportioned 200 West P&T O&M costs in 2018 and 2019 are because the majority of the uranium mass removed is from the perched water extraction wells (60% of the total uranium mass removed).

d. Performance monitoring costs have been adjusted back through 2016 to include pooled sampling costs for groundwater monitoring apportioned to the 200-DV-1 OU perched water removal action.

O&M = operations and maintenance

OU = operable unit

P&T = pump and treat

The costs shown are burdened. Based on a total volume of perched water extracted in 2019 (Table 5-9), the removal system cost in 2019 was $0.78/L ($2.96/gal). The higher O&M costs in 2018 and 2019 reflected in Table 5-10 are because the majority of the uranium mass removed is from the perched water extraction wells (60% of the total uranium mass removed). Performance monitoring costs also increased in 2019 for additional perched water sampling and performance evaluations.

5.5 Summary and Conclusions

The removal action for perched water extraction continued to successfully operate during 2019. Except when a well was offline for maintenance, all three extraction wells were used to remove perched water from January through December. The contaminated perched water extracted was treated at the 200 West P&T.

Perched water samples were collected quarterly for analysis of uranium, technetium-99, nitrate, and other constituents specified in the 200-DV-1 OU removal action SAP (DOE/RL-2014-51).

Development of a three-dimensional, site-specific geoframework model of the 200-DV-1 OU perched zone was completed in 2019 to support F&T evaluations, future extraction and monitoring well placement, and optimized pumping operations (ECF-200DV1-18-0036). The site-specific geoframework model was used to revise the extent of the perched water and estimate the variation in saturated thickness of the perched zone.

The removal action was designed to recover as much perched water as practical while awaiting issuance of the 200-DV-1 OU ROD (Chapter 1 in DOE/RL-2014-34). Due to the hydraulic properties and relatively thin saturated thickness of the perched water zone, flow to the three existing extraction wells has been limited. In 2019, a hydraulic analysis examined extraction well configuration options for increasing the rate of contaminated perched water removal (SGW-63236). The evaluation identified different options that could be used to increase the perched water extraction.

The 2019 hydraulic analysis and geoframework model, as well as other existing information for the perched water zone and the overall hydrogeological system, were used to guide planning to install additional extraction and monitoring wells within the perched water zone to increase the extraction rate, dewater the perched zone, increase mass removal of uranium, and support refinement of the conceptual model. The locations for 12 vertical perched water wells (8 extraction and 4 monitoring) outside of the B-BX-BY Tank Farms were planned in 2019.

In 2019, a SAP was drafted for implementation of increasing perched water extraction. Installation of the initial eight vertical extraction wells and four monitoring wells will enable the evaluation and feasibility of installing one horizontal extraction well instead of numerous additional vertical extraction wells. This evaluation of future perched water wells, as well as other existing information for the perched water zone and the overall hydrogeological system, was used to guide the planning of the SAP for placement and installation of additional extraction and monitoring wells within the perched water zone to increase the extraction rate to dewater the perched zone and remove more mass of uranium. The SAP is anticipated to be approved and issued in late FY 2020.

Five Tri-Party Agreement change notices approved in 2019 that enabled the planning and drilling of the extraction and monitoring wells while awaiting the development and subsequent approval of the SAP:

- TPA-CN-0878 (modifying DOE/RL-2014-51, the perched water removal action SAP)
- TPA-CN-0879 (modifying DOE/RL-2013-52, the perched water drilling SAP)
- TPA-CN-0880 (modifying DOE/RL-2014-34, the perched water action memorandum)
- TPA-CN-0881 (modifying DOE/RL-2014-37, the perched water removal action work plan)
- TPA-CN-0882 (modifying DOE/RL-2016-22, the perched water waste management plan).

During installation of the extraction and monitoring wells, data will be collected to characterize the subsurface and contamination, and the data will be used to support the phased implementation of the additional extraction capacity, as well as provide input to future remedy decisions that may include other remediation approaches such as in situ remediation and/or control of the hydrogeological system. The information gathered will also be used to refine the conceptual site model for the perched water zone and the vadose zone above and below the perched water zone with respect to its size, contaminant distribution, and properties related to the effectiveness of water extraction and other potential remedies.

6 200-BP-5 Operable Unit Removal Action

This chapter discusses the 2019 groundwater removal action activities in the B Complex area (B-BX-BY Tank Farms area) of the 200-BP-5 OU (Figure 6-1). Extraction of B Complex area groundwater began in September 2015 as a treatability test to determine if a 189 L/min (50 gal/min) pumping rate could be sustained within the thin aquifer at the B Complex (DOE/RL-2010-74, *Treatability Test Plan for the 200-BP-5 Groundwater Operable Unit*). The testing demonstrated that groundwater extraction rates up to 567 L/min (150 gal/min) had little effect on the water table, and in 2016 the treatability test transitioned to a NTCRA. The extracted groundwater is conveyed to the 200 West P&T central treatment facility where it is treated to remove uranium and technetium-99 (Chapter 2). The treated groundwater is injected into the unconfined aquifer in the 200 West Area.

Highlights

- Groundwater extraction continues to be an effective method for removing technetium-99 and uranium.
- Technetium-99 activity removed from 2015 through 2019 was approximately 5.33 Ci (314 g).
- B Complex technetium-99 concentrations decreased by an average of 62% from 2015 through 2019.
- Uranium mass removed from 2015 through 2019 was approximately 187 kg.
- B Complex uranium concentrations decreased by an average of 57.4% from 2015 through 2019.
- Extraction well 299-E33-361 began operating in April 2019 to contain the east edge of the B Complex technetium-99 plume.
- The 2019 average flow rate was 609 L/min (161 gal/min).
- The total volume of water extracted from the aquifer during 2019 was 331.2 million L (87.5. million gal).
- The total extracted from startup in September 2015 to the end of 2019 was 1.04 billion L (275 million gal).

The transition from a treatability test to an NTCRA included the completion of DOE/RL-2015-26, *Engineering Evaluation/Cost Analysis for the 200-BP-5 Operable Unit Groundwater Extraction*, and an action memorandum (DOE/RL-2016-41). In February 2018, the removal action work plan for the 200-BP-5 OU was issued (DOE/RL-2017-11). The overall objective of the removal action is to reduce groundwater contamination in the B Complex by capturing and removing uranium and technetium-99. Specific objectives include the following:

- Capture and treat uranium and technetium-99 groundwater contaminant concentrations that exceed 10 times the DWSs.
- Use the 200 West P&T central treatment facility to treat contaminated groundwater. Use an aboveground pipeline to convey water to the 200 West P&T central treatment facility.

As described in the removal action work plan (DOE/RL-2017-11), the removal action will continue until one or more of the following occurs:

- Uranium and technetium-99 concentrations at the B Complex are <10 times their respective DWSs (e.g., measured uranium concentrations are <300 μg/L, and measured technetium-99 concentrations are <9,000 pCi/L).
- DOE, EPA, and Ecology agree to terminate the removal action.
- A remedial action ROD for the 200-BP-5 OU supersedes the removal action.

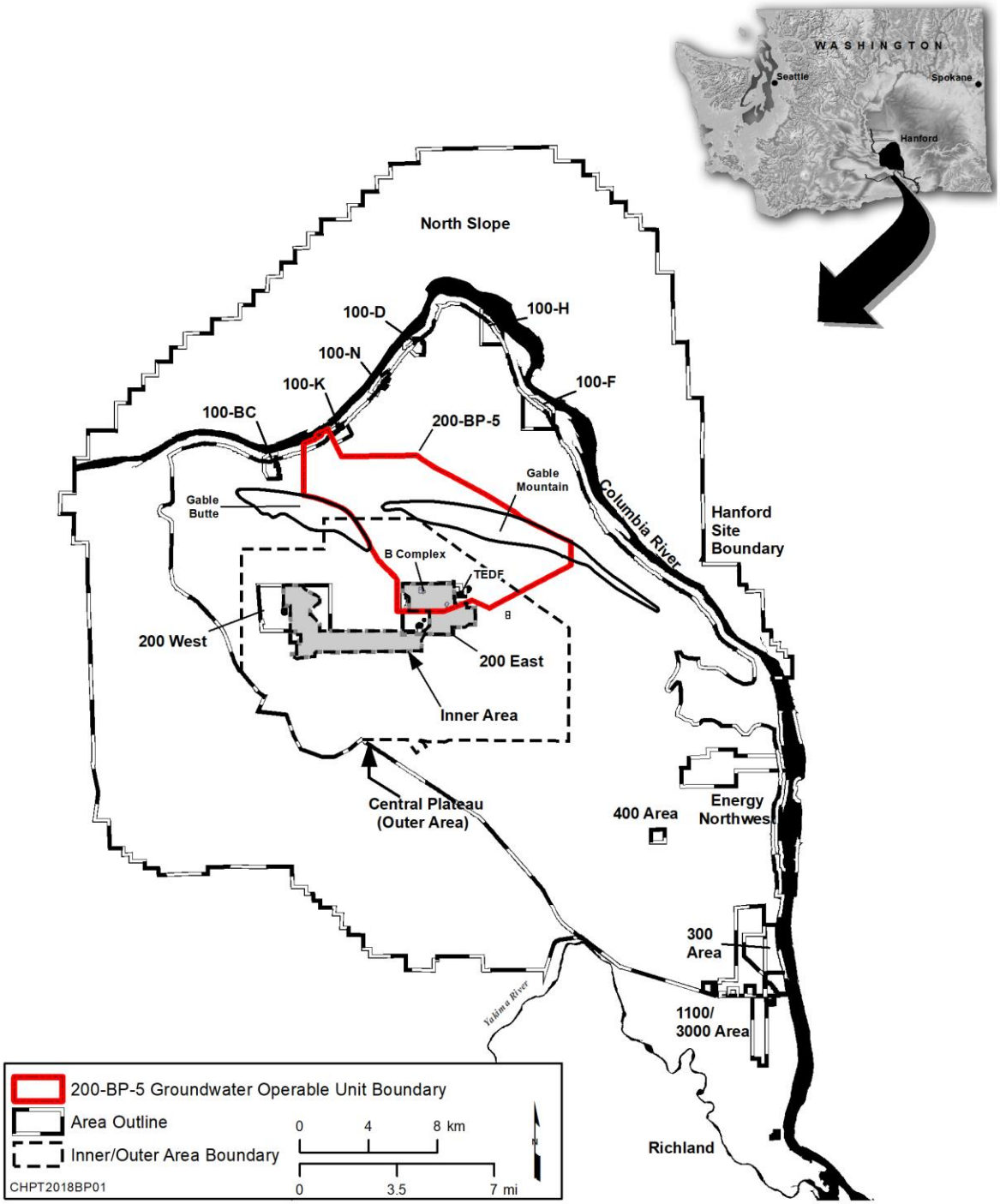
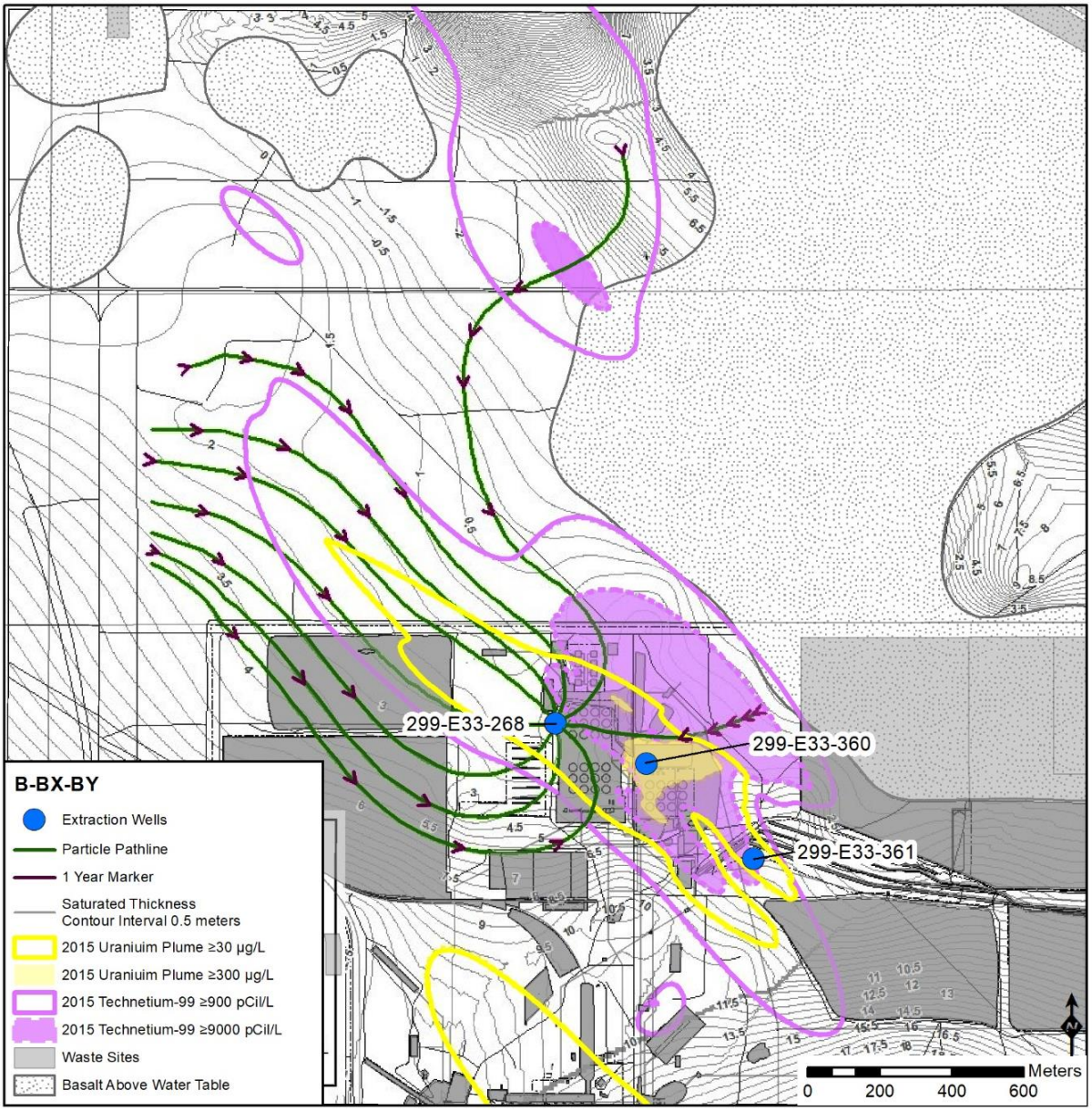


Figure 6-1. Location of the 200-BP-5 OU and 200 East Area Boundaries

Groundwater extraction at the B Complex began at well 299-E33-268 in 2015 and continued at the well through June 15, 2017. Well 299-E33-268, initially planned for drilling prior to the groundwater flow direction change from northwest to southeast in mid-2011, was originally downgradient of the B Complex uranium source. However, after the 2011 groundwater flow direction change, well 299-E33-268 became upgradient of the B Complex uranium source but remained along the west edge of the ≥9,000 pCi/L technetium-99 plume from the BY Cribs. After the 200 West P&T central treatment facility demonstrated the capability for treating extracted groundwater from the B Complex area, planning began for receiving uranium and technetium-99-contaminated groundwater from the central portion of the plume where higher concentrations existed. Concurrently, the removal action recommended extracting contaminated groundwater from up to three additional wells for optimal uranium and technetium-99 removal. One of the locations was well 299-E33-360, located near the uranium source and central to three technetium-99 sources (e.g., BY Cribs, 241-BX-102 unplanned tank release, and unplanned release in B Tank Farm). A modeling evaluation determined that mass removal of technetium-99 and uranium concentrations >10 times the DWS was more effective at well 299-E33-360 than at well 299-E33-268 (ECF-200BP5-16-0145, *Particle Tracking and Transport Modeling in Support of Removal Action Memorandum*) (Figures 6-2 and 6-3). Pumping at well 299-E33-360 began on March 9, 2017, and continued through December 2019. Extraction wells 299-E33-268 and 299-E33-360 operated concurrently from March 2017 through June 2017. In June 2017, pumping at well 299-E33-268 was discontinued because the well is located on the upgradient edge of the target plume and was less effective than well 299-E33-360 for removing technetium-99 and uranium; however, well 299-E33-268 remains configured as an extraction well connected to the 200 West P&T. In 2018, technetium-99 concentrations continued to increase in monitoring wells 299-E34-8, 299-E34-9 and 299-E34-10, east of extraction well 299-E33-360 (Table 6-1 and Figure 6-5 in DOE/RL-2018-66, *Hanford Site Groundwater Monitoring Report for 2018*) and downgradient of the technetium-99 plume, exceeding 10 times the DWS. Planning for connection of well 299-E33-361 began because the cumulative technetium-99 activity removal from wells 299-E33-360 and 299-E33-361 produced the optimum removal of technetium-99 (Figure 6-16 in ECF-200BP5-16-0145). In late April 2019, extraction well 299-E33-361 began extracting groundwater to capture the eastern portion of the B Complex technetium-99 plume. Technetium-99 concentrations continued to decrease at these three wells through the end of 2019.

Since 2015, a total of 1.04 billion L (275 million gal) of contaminated groundwater has been extracted from the B Complex area, of which 331.2 million L (87.5 million gal) were removed in 2019.

Figure 6-4 shows the locations of the four new groundwater wells drilled in 2019 to further investigate the technetium-99 contamination extent within the aquifer outside of the B Complex area. During drilling of the two southern wells (299-E28-34 and 299-E27-137B), depth-discrete groundwater samples were collected to characterize the vertical extent of contamination. Only the deepest depth-discrete samples (collected at the bottom of the unconfined aquifer) returned concentrations exceeding the DWS (Table 6-1). Groundwater pumps were installed at these depths to monitor these contamination zones. Further information obtained during drilling of these wells is provided in SGW-64056, *Borehole Summary Report for the Installation of Two Dual-Purpose Wells in the 200-BP-5 Operable Unit, FY2019.* These wells were installed as dual-purpose wells and can be converted to extraction wells if needed for remedial optimization.



Source: Figure 6-14 in DOE/RL-2016-69, *Calendar Year 2016 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations.*

Figure 6-2. Simulated Capture Zone by Pumping 150 gal/min for 5 Years at Well 299-E33-268 with 2015 Uranium and Technetium-99 Groundwater Plumes

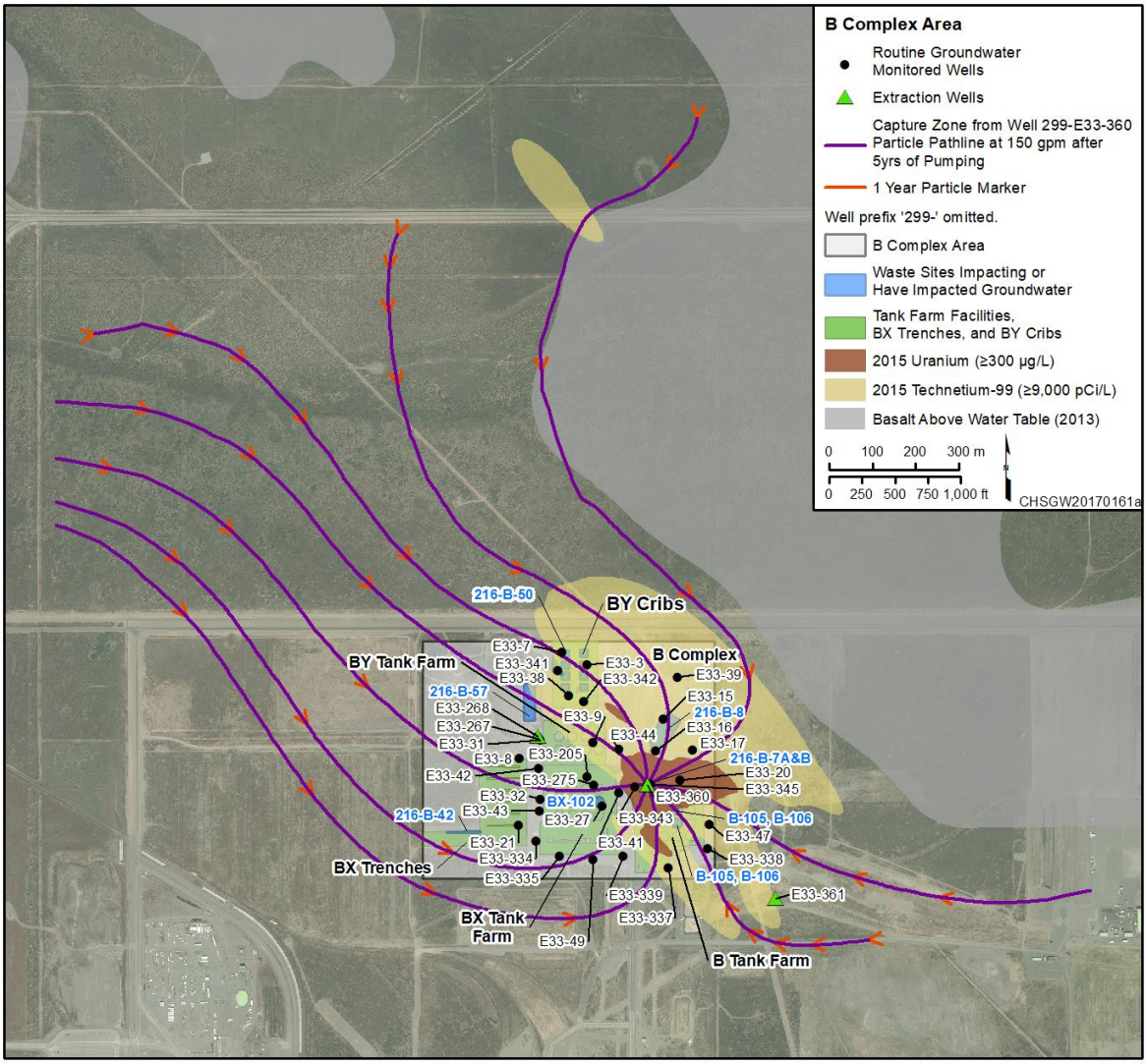


Figure 6-3. Simulated Capture Zone by Pumping 150 gal/min for 5 Years at Well 299-E33-360 with 2015 Uranium and Technetium-99 Groundwater Plumes

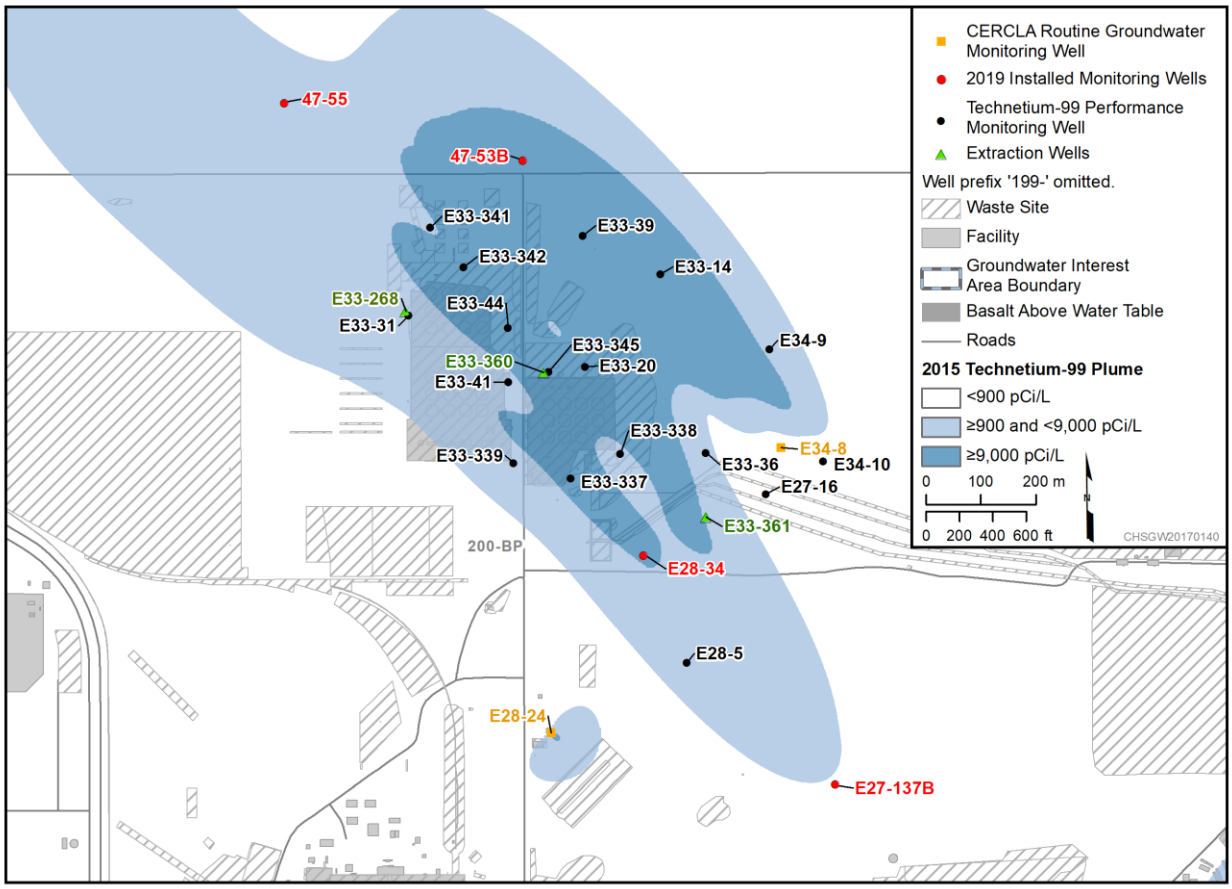


Figure 6-4. 2019 Revised B Complex Removal Action Groundwater Monitoring Well Network Associated with Extraction Well 299-E33-360 and the Interpreted 2015 Technetium-99 Groundwater Plume

The two northern wells (699-47-55 and 699-47-53B) were installed as monitoring wells to define the technetium-99 groundwater extent north of the 200 East Area. The northern wells, as well as an additional transport evaluation for 2019 (ECF-200BP5-19-0035, *Simulation of Focused Feasibility Study Remedy at B Complex*) indicate that technetium-99 plumes to the north and northwest of B Complex were larger than determined by the existing monitoring network in 2015 (Figure 6-5). However, the 2019 technetium-99 concentrations observed at wells 699-47-55 and 699-47-53B (Table 6-1) suggest that technetium-99 groundwater concentrations >9,000 pCi/L have declined from the back-calculated PEST 2015 modeling depiction of technetium-99 shown in Figure 6-5. Further information obtained during drilling of these wells is provided in SGW-64756, *Borehole Summary Report for the Installation of Two Monitoring Wells C9750 and C9751 in the 200-BP-5 Operable Unit, FY2019.* Possible exceptions where technetium-99 may still exceed 9,000 pCi/L north of the 200 East Area include an isolated plume to the northwest of well 699-47-55 and remnants of a plume extending north of wells 299-E33-14 and 299-E33-39. Technetium-99 concentrations at wells 299-E33-14 and 299-E33-39 continue to decline but remain at concentrations >10 times the DWS (Figure 6-6). It is uncertain at this time whether declining technetium-99 concentrations at wells 299-E33-14 and 299-E33-39 are reflective of the northern boundary of the technetium-99 plume exceeding 10 times the DWS or if contaminant flux from the BY Cribs vadose zone could be diminishing. Either way, declining technetium-99 concentrations throughout the B Complex removal action monitoring network suggest that the plume is effectively being captured.

Table 6-1. Depth-Discrete and Post-Development Groundwater Sample Results for Four B Complex Removal Action Monitoring Wells Drilled in 2019

Well Name	Sample Date	Water Table Depth (ft) bgs	Top of Basalt (ft) bgs	Aquifer Thickness (ft)	Sample Depth (ft) bgs	Sample Depth (ft) bwt	Technetium-99 Concentration (pCi/L)	Uranium Concentration (µg/L)	Comment
699-47-55	4/24/2019	219.15	224	4.85	223	3.8	2110	4.73	Groundwater Sample Collected During Drilling
699-47-55	1/27/2020	219.08	224	4.92	222.6	3.5	970	3.69	Post Development Groundwater Sample
[redacted]									
699-47-53B	6/12/2019	216.9	224.16	7.26	222	5.1	2750	3.44	Groundwater Sample Collected During Drilling
699-47-53B	6/12/2019	216.9	224.16	7.26	222	5.1	2890	3.42	Groundwater Sample Collected During Drilling
699-47-53B	1/23/2020	218.9	224.16	5.26	221.6	2.7	2610	3.64	Post Development Groundwater Sample
[redacted]									
299-E28-34	5/7/2019	262.85	285.2	22.35	274.86	12	217	16.5	Groundwater Sample Collected During Drilling
299-E28-34	5/14/2019	262.85	285.2	22.35	283.64	20.8	2030	67.3	Groundwater Sample Collected During Drilling
299-E28-34	7/2/2019	262.5	285.2	22.7	279.12	16.6	441	20.9	Post Development Groundwater Sample
[redacted]									
299-E27-137B	7/12/2019	282	325	43	293	10	302	10	Groundwater Sample Collected During Drilling
299-E27-137B	7/16/2019	282	325	43	302	19	298	19	Groundwater Sample Collected During Drilling
299-E27-137B	7/16/2019	282	325	43	302	19	280	19	Groundwater Sample Collected During Drilling
299-E27-137B	7/18/2019	282	325	43	312	29	354	29	Groundwater Sample Collected During Drilling
299-E27-137B	7/23/2019	282	325	43	322	39	3,570	39	Groundwater Sample Collected During Drilling
299-E27-137B	9/6/2019	282	325	43	298	15	1,370	15	Post Development Groundwater Sample
299-E27-137B	12/2/2019	282	325	43	321	38	416	6.3	Post Development Groundwater Sample

bgs = below ground surface

bwt = below water table

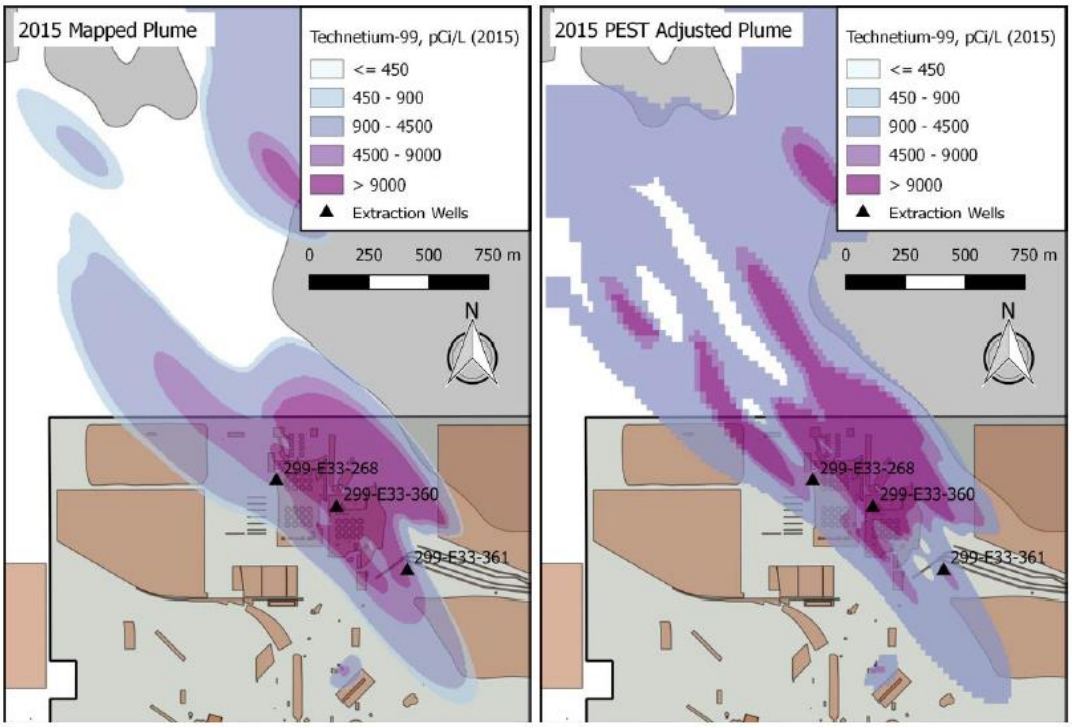


Figure 6-5. Comparison of 2015 Technetium-99 Contour Plume Map (Left) with PEST Transport Evaluation of the Initial Condition Adjustment for the 2015 Technetium-99 Plume Map

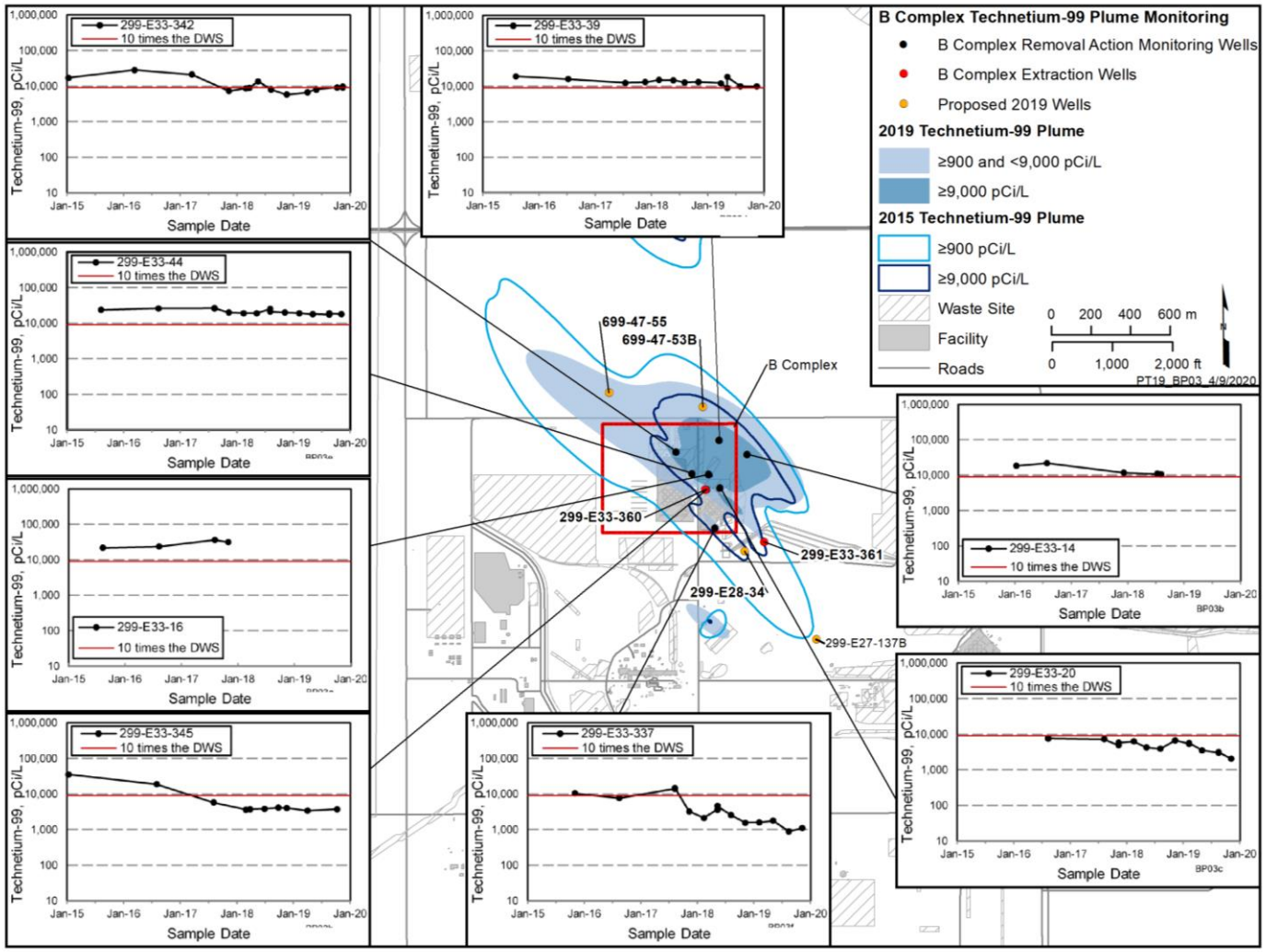


Figure 6-6. Technetium-99 Plume Comparison for 2015 and 2019 and Time-Series Plots for Monitoring Wells with Concentrations >10 Times the DWS

The discussion in this chapter includes the following:

- Section 6.1 provides an overview of the B Complex hydrogeology.
- Section 6.2 describes the 200-BP-5 OU removal system design and monitoring operations.
- Section 6.3 presents the QA/QC for sampling and analysis in the 200-BP-5 OU.
- Section 6.4 summarizes the system costs.
- Section 6.5 summarizes the observations for 2019.

6.1 B Complex Hydrogeology Overview

The B Complex hydrogeology includes a perched water zone and unconfined aquifer. The perched water zone lies approximately 4.6 m (15 ft) above the water table, extending along the northern side of the B Tank Farm (Figure 5-2).

The contaminated unconfined aquifer at B Complex is contained within the Cold Creek unit gravel (Figure 6-7). Depths to the water table from the ground surface range from 66.5 m (218 ft) north of the BY Cribs to 84.5 m (275 ft) south of the B Complex (Figure 6-7). The unconfined aquifer thickness varies from <1 m (3 ft) north of the B Complex to >5 m (16 ft) along the southern B Complex boundary (Figure 6-8). Detailed descriptions of B Complex hydrogeology are provided in PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*; PNNL-19702, *Hydrogeologic Model for the Gable Gap Area, Hanford Site*; and PNNL-19277, *Conceptual Models for Migration of Key Groundwater Contaminants Through the Vadose Zone and Into the Unconfined Aquifer Below the B-Complex*.

The regional B Complex area groundwater gradient is nearly flat (e.g., ranging between 10^{-5} and 10^{-6} m/m) within a transmissive paleochannel. Groundwater flow at the B Complex was previously to the northwest; however, since July 2011, the groundwater flow has been to the south-southeast. The groundwater flow change was associated with continued water table declines in the 200 East Area beginning in the 1980s with the termination of wastewater discharges to waste sites overlying the 200 East Area and vicinity. By July 2011, the 200 East Area water table had declined to an elevation lower than the water table to the north.

Since 2012, Columbia River stages have had varying impacts on the groundwater gradient at the B Complex. Figures 6-2 and 6-3 in ECF-200BP5-19-0036, *Simulations of Focused Feasibility Study Remedy at Waste Management Area C* (2020), show the variability that the southeast groundwater gradient at B Complex can experience from the average (2016) and high (2013) river stages. Figure 6-9 shows the river discharge rate variability through 2019, where high discharge rates are two to three times higher than average and low Columbia River discharge rates, respectively. Sections 2.2, 4.1.5.2, and 4.1.6 in SGW-54165, *Evaluation of the Unconfined Aquifer Hydraulic Gradient Beneath the 200 East Area, Hanford Site* (issued in 2014), discuss the relationship between high Columbia River discharge rates, river stages, and water table fluctuations in the 200 East Area. Order-of-magnitude differences in monthly groundwater gradients have occurred between low and high river stages in the northwestern corner of the 200 East Area (Table 4-11 in SGW-54165). These seasonal differences can significantly affect the groundwater gradient, such as in 2017 and 2018 when river discharge rates were at or near record highs.

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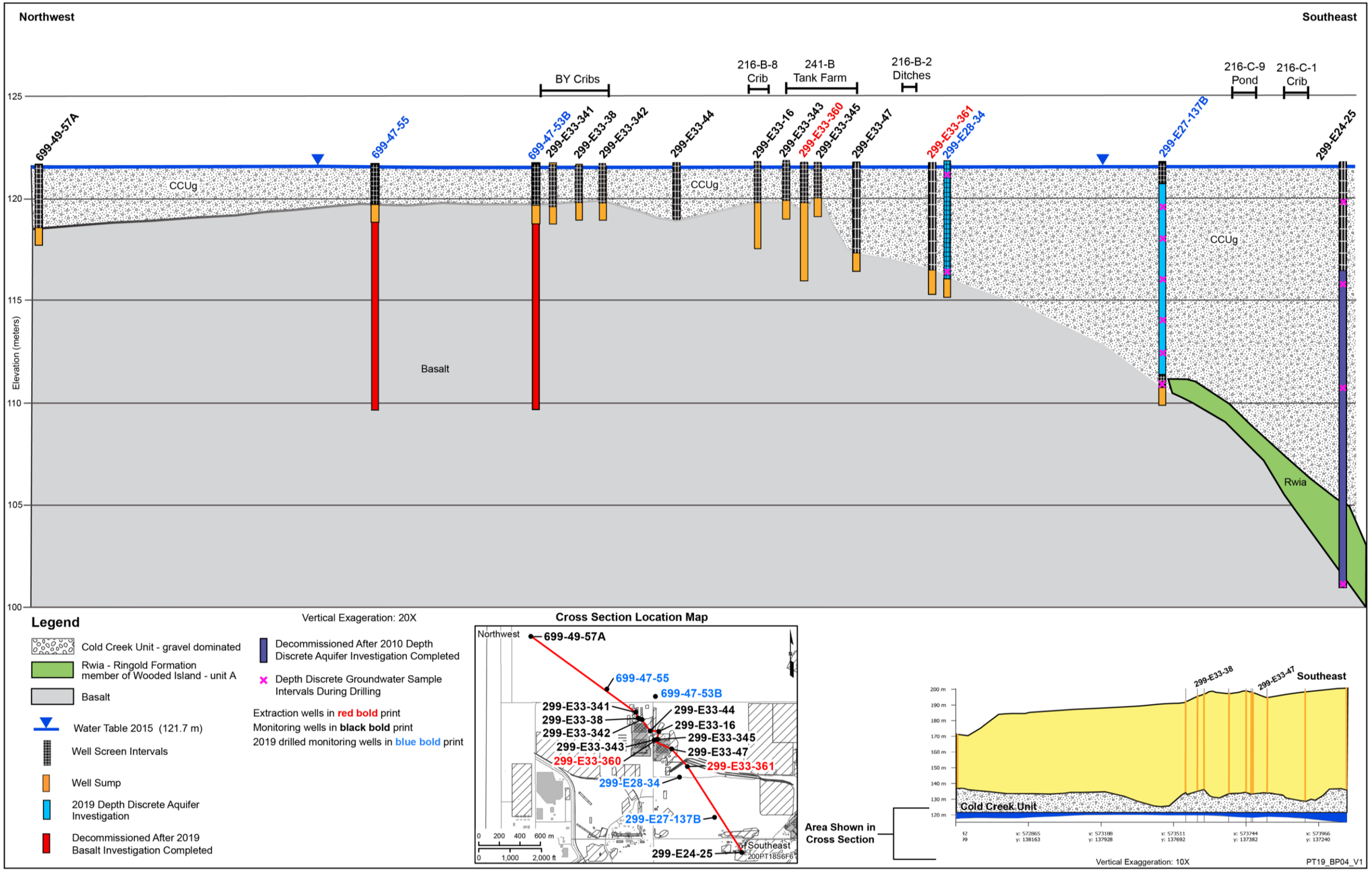

Figure 6-7. Geologic Cross Section of the Saturated Zone Beneath the B Complex and Adjoining Area

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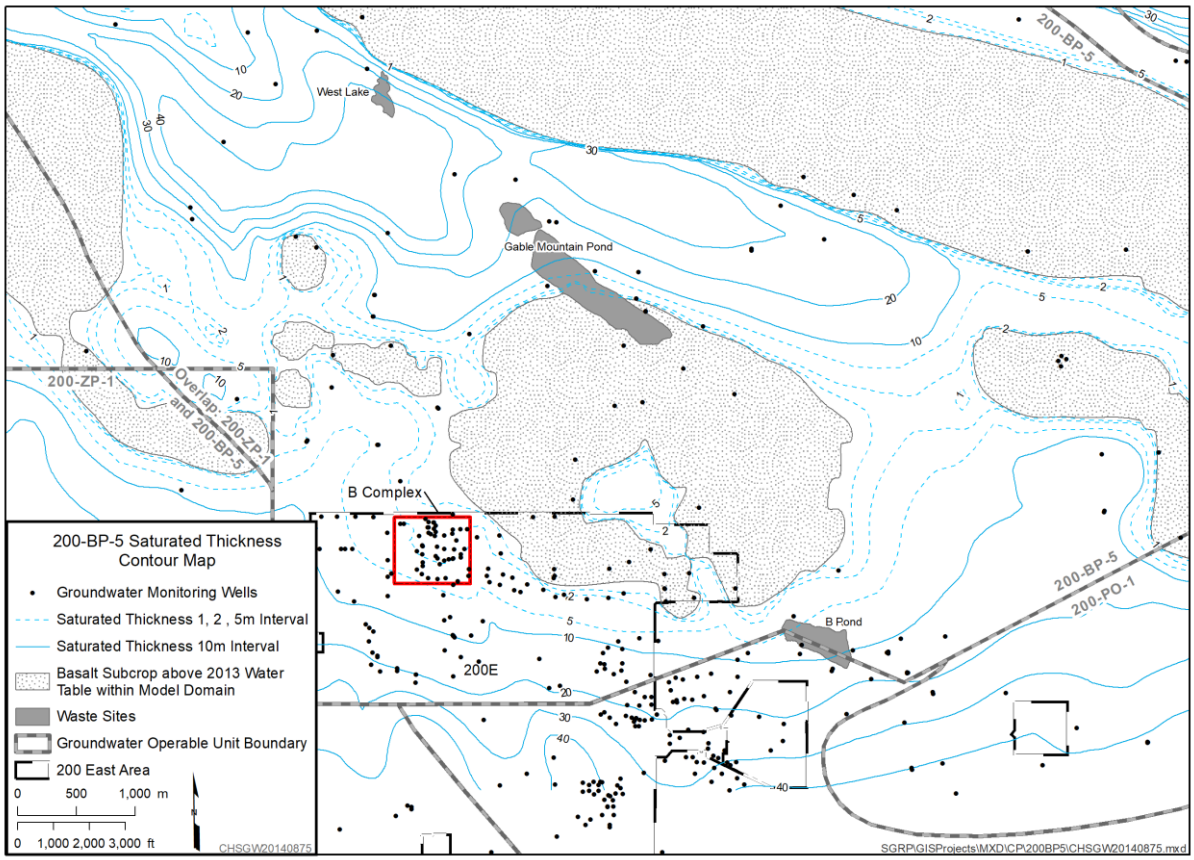

Figure 6-8. Unconfined Aquifer Saturated Thickness Contour Map for B Complex

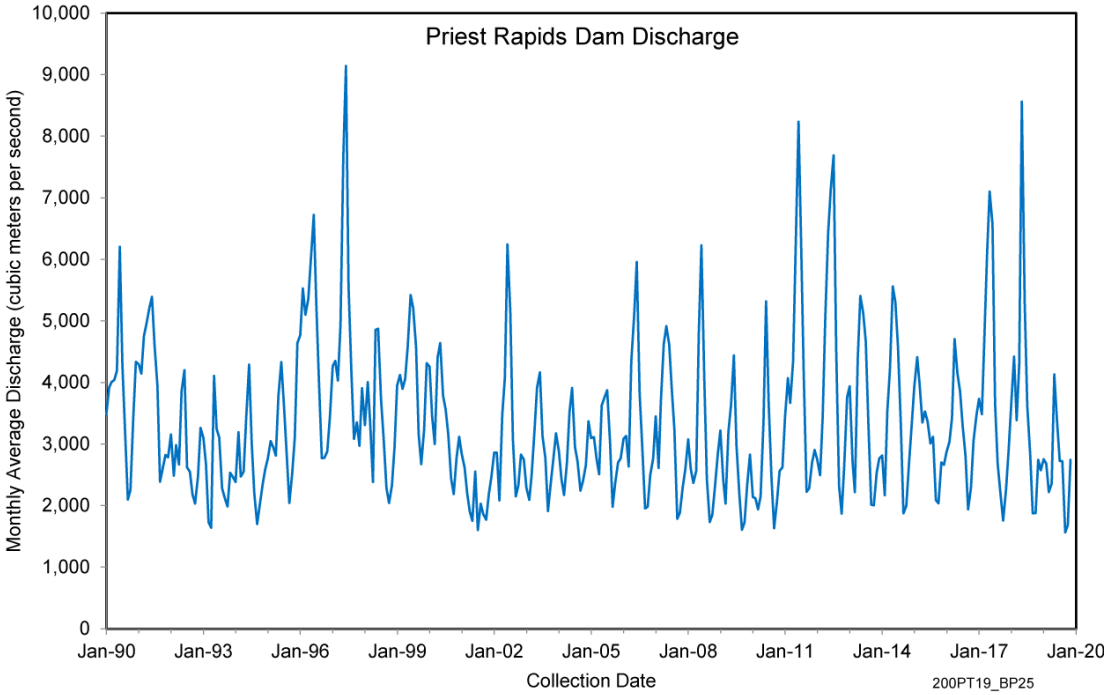

Figure 6-9. Columbia River Monthly Average Discharge Volumes

6.2 200-BP-5 Operable Unit Groundwater Extraction System

The current 200-BP-5 OU groundwater extraction system consists of a transfer tank that combines extracted groundwater from the 200-BP-5 OU with extracted perched water from the 200-DV-1 OU (Chapter 5). In 2019, the B Complex groundwater removal action used groundwater extraction wells 299-E33-360 and 299-E33-361 (Figure 6-3) to recover elevated levels of groundwater contamination. Extraction well 299-E33-360 is screened across the entire unconfined gravel aquifer and is located within 300 m (1,000 ft) of the primary sources of B Complex groundwater contamination. The primary contaminant sources in the B Complex include the BY Cribs and other releases shown in Figure 6-3. Extraction at well 299-E33-361 targets the downgradient portion of the uranium and technetium-99 plumes not captured by well 299-E33-360 (Section 2.1.2 in DOE/RL-2017-11). The system also extracts collocated cyanide, iodine-129, nitrate, and tritium. The B Complex tritium concentrations in 2018 declined below the DWS and remained below the DWS in 2019.

Extracted groundwater in the B Complex transfer tank is transferred to the 200 West P&T central treatment facility via an existing aboveground pipeline (Figure 1-1). The 200 West P&T central treatment facility consists of two main processes, as described in Chapter 2:

- Radiological treatment process using IX resins (primarily to remove uranium and technetium-99, but cyanide is also removed)
- Central treatment process that uses anoxic and aerobic biodegradation[3] for nitrate, metals, and organic contaminants; membrane filtration to remove particulate matter; and air stripping to remove VOCs

Groundwater from the B Complex extraction wells is combined with groundwater from the U Plant area, WMA S-SX, 200-ZP-1 OU, and 200-DV-1 OU extraction wells that require radionuclide treatment, and the combined water is passed through IX resin in the 200 West P&T radiological treatment process. The effluent from this process is then combined with groundwater from the remaining extraction wells (not requiring radionuclide treatment) and is passed through the 200 West P&T central treatment process. The treated water is then returned to the aquifer in the 200 West Area using injection wells, most of which are located within the 200-ZP-1 OU. Chapter 2 provides additional information on the 200 West P&T. Data used to monitor the removal system consist of flow rates from the extraction wells, analytical sample results from the extraction wells, and influent sample results at the 200 West P&T central treatment facility.

6.2.1 Extraction Well Flow Rates

The B Complex groundwater extraction system operated every day during 2019. Figure 6-10 shows the 2019 combined daily average flow rates for extraction wells 299-E33-360 and 299-E33-361. Lower flow rates indicate short-duration maintenance lasting less than a day at one or both of the extraction wells. The average flow rate during 2019 was 609 L/min (161 gal/min). The total volume of water extracted from the aquifer during 2019 was 331.2 million L (87.5. million gal), and the total extracted from startup in September 2015 to the end of 2019 was 1.04 billion L (275 million gal).

[3] As discussed in Section 2.3, biological treatment was suspended in October 2019 as part of the 200-ZP-1 optimization study (DOE/RL-2019-38).

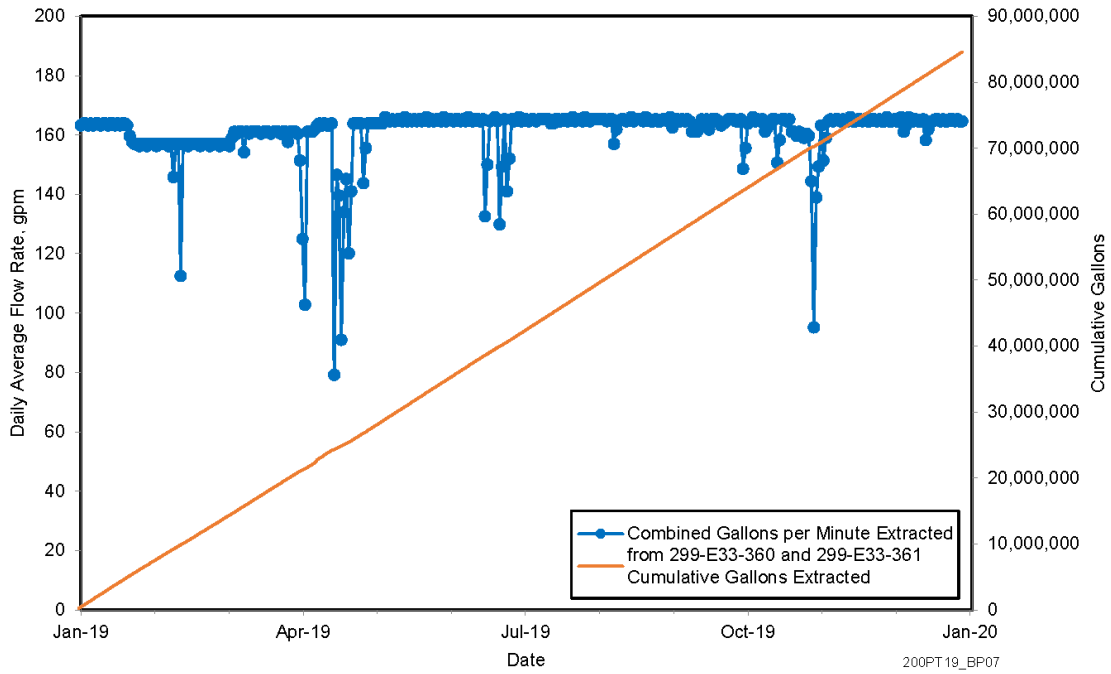

Figure 6-10. Daily Average and Cumulative Groundwater Extraction Volumes, 2019

6.2.2 Extraction Well Mass or Activity Removal

The B Complex groundwater samples were collected quarterly during 2019 from extraction well 299-E33-360 (Table 6-2). Groundwater samples were scheduled monthly during the first 6 months of operation at extraction well 299-E33-361 and quarterly thereafter (Table 6-3). The May 2019 sampling event did not occur. Mass removal calculations use the sample results and the extracted groundwater volume between sampling events to estimate the total mass (or activity) removed from the aquifer. Table 6-4 provides the contaminant removal estimates for 2019. The total uranium mass removed since the start of extraction through the end of 2019 was 187 kg. Total technetium-99 activity removed through 2019 was 5.33 Ci (314 g).

Table 6-2. Analytical Results from Extraction Well 299-E33-360 in 2019

Contaminants	Units	Sample Date and Average Analytical Results			
		1/28/2019	6/12/2019	9/25/2019	12/3/2019
Cyanide	µg/L	187	158	128	133
Free cyanide	µg/L	3.2	1.9	1.4	2.1
Iodine-129	pCi/L	2.72	3.03	1.65	2.52
Nitrate (as NO_3)	µg/L	221,000	210,000	194,000	204,333
Technetium-99	pCi/L	4,160	2,890	3,620	3,650
Uranium	µg/L	73.4	91.4	83.2	76.3
Tritium	pCi/L	3,240	2,750	2,470	2,280

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Table 6-3. Analytical Results from Extraction Well 299-E33-361 in 2019

Contaminants	Units	Sample Date and Analytical Results											
		4/25/2019	4/25/2019	6/18/2019	6/18/2019	7/25/2019	7/25/2019	8/13/2019	9/10/2019	9/10/2019	12/3/2019	12/3/2019	12/3/2019
		Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Unfiltered
Cyanide	µg/L	32.2	32	NS	37.6	42	40.4	43.4	38.7	37.9	NS	40.8	40.2
Free cyanide	µg/L	<1	<1	NS	2.54	1.69	<1	1.62	2.73	<1	NS	<1	NS
Iodine-129	pCi/L	NS	1.91	NS	1.6	NS	2.68	2.46	NS	1.9	NS	1.33	2.64
Nitrate (as NO_3)	µg/L	NS	106,000	111,000	NS	NS	110,000	98,300	96,900	NS	98,700	79,700	NS
Technetium-99	pCi/L	NS	1,160	NS	1,080	NS	1,110	1,150	NS	1,030	NS	913	1,080
Tritium	pCi/L	NS	1,190	NS	1,200	NS	869	1,010	NS	1,150	NS	1,090	680
Uranium	µg/L	36	38.2	NS	31.3	0.9*	27.5	27.2	24.8	25.8	28	27.9	23.8

*Value of 0.9 µg/L was flagged as suspect.

NS = not sampled

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Table 6-4. Analytical Results from Extraction Wells 299-E33-360 and 299-E33-361 in 2019

Contaminant	Units	2019 Estimated Mass/ Activity Removal
Technetium-99	Ci	0.96
Uranium	kg	22.4
Cyanide (total)	kg	47
Nitrate (as NO_3)	kg	63,411
Iodine-129	Ci	2.56E-04
Tritium	Ci	0.19

6.2.3 Water-Level Monitoring

Water-level monitoring is used to evaluate the hydraulic capture effectiveness of the B Complex groundwater extraction system (Section C1.3.1 in Appendix C of DOE/RL-2017-11). Water table elevation differences associated with pumping changes are used to determine the hydraulic capture extent, similar to the process used and reported in DOE/RL-2015-75. Barometrically corrected water levels from three near-field removal action monitoring wells provided observed water-level response to the temporary shutdown of pumping at well 299-E33-360 for maintenance in April 2019. Two other near-field removal action monitoring wells had apparent well construction and/or transducer issues and were not able to be evaluated or did not provide meaningful results. Two other near-field removal action monitoring wells had too much water-level variability to determine a response. More distant B Complex removal action monitoring wells did not register a discernable response. As a result, determining the hydraulic capture zone from observed April 2019 water levels was not possible. The following discussion describes the process used to collect representative water levels, the opportunity to evaluate hydraulic responses from changing pumping rates, and the results of the water-level response.

Water-level monitoring of the local removal action well network started in 2018 using transducers and manual E-tape equipment. The transducers measure pressure changes hourly both above and below the water table so barometric effects on the water table can be removed. In April 2019, extraction at well 299-E33-360 was temporarily shut down for maintenance on four separate occasions, providing the opportunity to establish a baseline water table elevation within the B Complex area. The maintenance shut downs occurred on April 2 (about 1 hour), April 3 through April 4 (about 14 hours), on April 17 (about 11 hours), and on April 19 through April 20 (about 17 hours).

Evaluations of the water table measurements were primarily associated with reviewing hourly transducer water table data. Barometric corrections of the water table measurements were completed as described in Section 3.6 of SGW-54165. The barometrically corrected water table measurements were evaluated for elevation changes during constant pumping over a 3-day period for wells with discernable response to pumping shut downs to determine the following:

- Time duration between changing trends (e.g., from incline to decline or decline to incline)
- Elevation change over an incline or decline interval
- Total number of interval changes (e.g., from increasing to decreasing or decreasing to increasing)
- Maximum elevation change during increasing or decreasing intervals

These observations indicate that, under constant pumping, the water table elevation changes on average every 2 hours. During these changes, the aquifer, on average, changes approximately 1 mm (0.4 in.). These occurrences define the residual noise in the water table measurements after applied barometric corrections. During the constant pumping observation period, nearly all of the wells had a couple of occurrences where the maximum change during an inclining or declining interval ranged between 5 and 10 mm (0.2 and 0.4 in.). However, the change was normally followed by a similar change in the opposite direction in the next recorded water table measurement. Correlations for why these occurrences were observed have not been determined; however, daily pumping records do not show recorded pumping changes.

During the 2019 water table measurement evaluation, two types of temporal water table trends were observed in the barometrically corrected water table measurements in the three wells with most noticeable responses to extraction well 299-E33-360 pumping changes. The first type of temporal change was defined by an increase or decrease of approximately 2.5 to10 mm (0.1 to 0.4 in.) within a 6- to 48-hour period, followed by an opposite trend over a similar time period. The largest water table elevation changes were in well 299-E33-345, which is closest to extraction well 299-E33-360. This temporal change occurred five to seven times at the three wells in May 2019; however, the timing of the increase or decrease between the three wells did not generally correlate. Pumping rates at well 299-E33-360 were assumed constant through May 2019, as daily average pumping rates were constant at 430 L/min (114 gal/min). In addition, the Treated Effluent Disposal Facility discharge rate between April and May 2019 was nearly constant. These short-term changes were also observed in wells farther from the extraction well but were more subtle and periodic. Therefore, the first type of temporal affect in the wells closest to the extraction well is uncertain at this time. The second type of temporal change was a slow, gradual increase starting in June and extending to early July 2019, followed by similar decreasing trend through late July. This temporal change is theorized to be associated with the propagation of Columbia River spring stages as discussed in SGW-54165. Similar changes were observed at wells farther from the extraction well.

The following paragraphs describes the barometrically corrected water-level measurements from five near-field removal action monitoring wells (299-E33-20, 299-E33-41, 299-E33-44, 299-E33-337, and 299-E33-345 [Figure 6-4]). Two other near-field removal action monitoring wells (299-E33-16 [Figure 6-6] and 299-E33-338 [Figure 6-4]) had apparent well construction and/or transducer issues, preventing the collection of meaningful water-level measurements and are, therefore, not discussed further. Removal action monitoring wells beyond these near-field wells did not have discernable water table changes associated with pumping changes and are not discussed. ECF-200BP5-20-0048, *2019 Barometric Water Level Corrections at the B Complex Removal Action Monitoring Network* (in production), provides the B Complex water table measurements, barometric correction methodology, corrected water table elevations, data evaluation, conclusions, and recommendations for 2019.

Three near-field monitoring wells showed various degrees of simultaneous recovery when pumping from well 299-E33-360 was temporarily shut down in April 2019 (Figure 6-11). These three wells showed similar degrees of simultaneous drawdown when pumping from well 299-E33-360 was reactivated. Wells 299-E33-345, 299-E33-41, and 299-E33-44 are 9 m, 80 m, and 100 m (29.5 ft, 262.5 ft, and 328 ft) from extraction well 299-E33-360, respectively (Figure 6-4). Table 6-5 shows the measured water table elevation before and after pumping was temporarily shut down at well 299-E33-360 for wells 299-E33-41, 299-E33-44, and 299-E33-345. Well 299-E33-345, the closest well to extraction well 299-E33-360, had the greatest change in the water table elevation when pumping at well 299-E33-360 was stopped. Wells 299-E33-41 and 299-E33-44 had similar recoveries (Table 6-5). Well 299-E33-44 does not appear to show as great of a water table elevation change because of the higher noise to signal ratio, but examination of the water table elevation increase after pumping stopped

demonstrates similar recovery between wells 299-E33-41 and 299-E33-44. A slight delay in recovery was observed in some of the data at wells 299-E33-41 and 299-E33-44 because of their farther distance from extraction well 299-E33-360. Two other near-field monitoring wells (299-E33-20 and 299-E33-337 [Figure 6-4]) had too much measurement variability to attribute water table elevation changes to recovery or drawdown (Figure 6-12). The water table elevation response in these three wells (299-E33-41, 299-E33-44, and 299-E33-345) provides an indication of capture, which is discussed in Section 6.2.4.

6.2.4 Hydraulic Capture Analysis

Section C3.2.2 in Appendix C of DOE/RL-2017-11 requires evaluation of hydraulic capture based on water-level monitoring. As discussed in Section 6.2.3, barometrically corrected water levels provide a depiction of the drawdown to the northwest and west of extraction well 299-E33-360; however, determining the hydraulic capture zone in other directions from the extraction well was uncertain due to the lack of meaningful water-level measurements. Thus, determining the hydraulic capture zone from barometrically corrected water-level measurements was not possible during 2019. As a result, the release of particles based on 2019 groundwater removal rates was used to determine hydraulic capture at B Complex in 2019.

Particle tracking was used to evaluate hydraulic capture based on 2019 hydraulic conditions and pumping rates. Figure 6-13 shows yearly depictions of 18 particle tracks released from the two operating extraction wells in 2019. General pumping rates in 2019 were 435 L/min (115 gal/min) at well 299-E33-360 and 189 L/min (50 gal/min) at well 299-E33-361. ECF-200BP5-19-0035 describes additional aquifer assumptions and the methodology used to drive particle-tracking movement in B Complex. The particle-tracking depiction indicates capture of the technetium-99 plume at concentrations exceeding 9,000 pCi/L, as required by DOE/RL-2017-11.

6.2.5 Contaminant Monitoring

This section summarizes the groundwater sampling results for technetium-99 and uranium at B Complex. Groundwater monitoring is used to assess performance of the B Complex removal action by comparing the 2019 groundwater samples to sampling results prior to starting groundwater extraction at B Complex. Interpretations of the 2019 plume extent are also compared to the 2015 extent. DOE/RL-2019-66 provides further discussion on the nature and extent of plumes within the 200-BP-5 OU during 2019.

6.2.5.1 Technetium-99 Monitoring Results

Technetium-99 trend plots and areal plume extents between 2015 and 2019 are compared to evaluate the effectiveness of the removal action at B Complex. The 2015 technetium-99 concentrations form the baseline for determining the effectiveness of technetium-99 removal. For the 16 wells in B Complex sampled for technetium-99 in 2015 and 2019, concentrations decreased by an average of 62% (Table 6-6). Figure 6-6 shows the interpreted extent of the 900 and 9,000 pCi/L plumes in 2015 and 2019. The 900 pCi/L plume area decreased from 1,126,000 m^2 (12,115,760 ft^2) in 2015 to 547,700 m^2 (5,893,250 ft^2) in 2019, for a 51% areal reduction. The 9,000 pCi/L plume area decreased from 301,000 m^2 (3,238,760 ft^2) in 2015 to 131,000 m^2 (1,409,560 ft^2) in 2019, for a 56% areal reduction.

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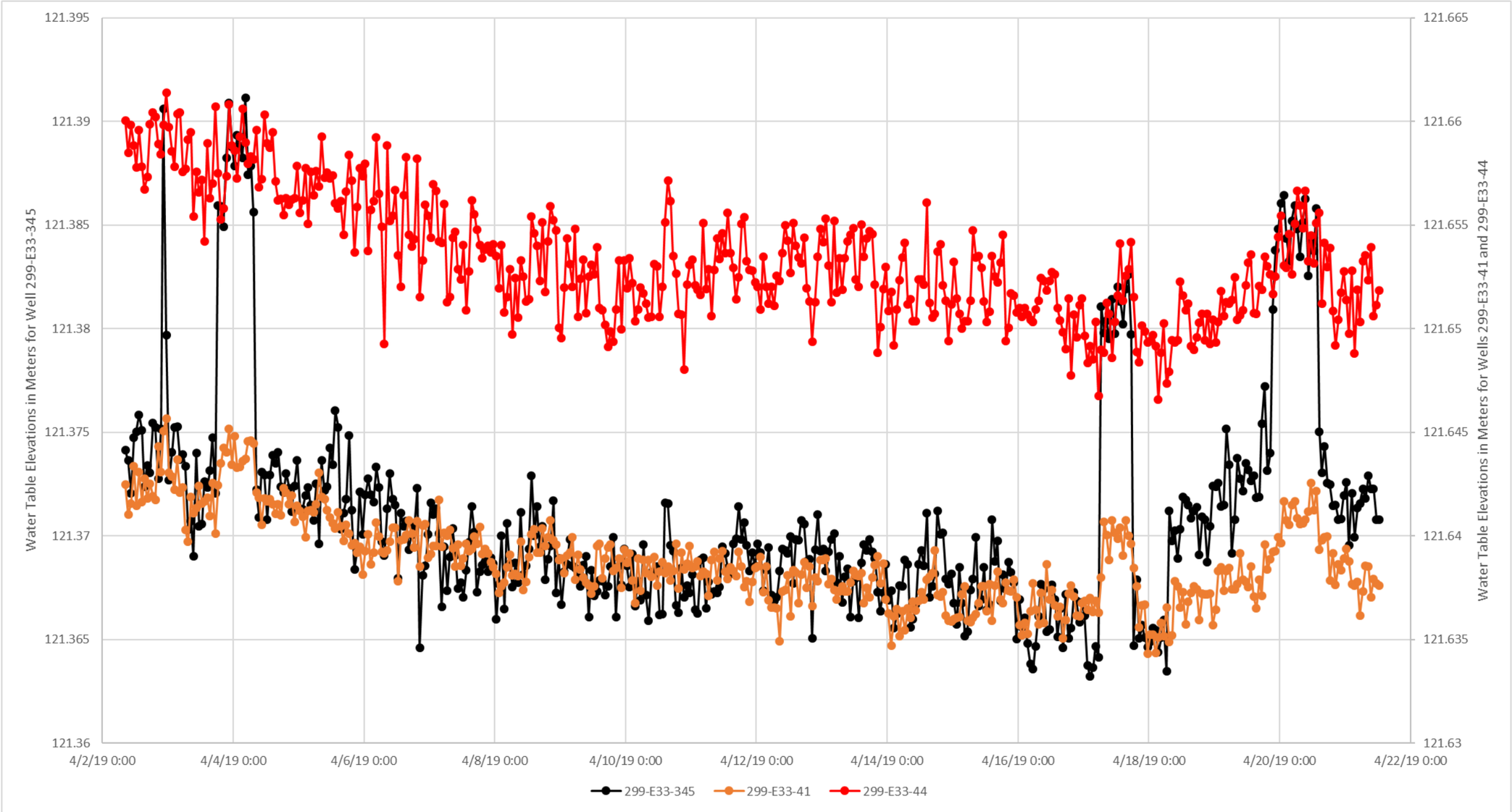

Figure 6-11. Barometric Corrected Water Table Recovery and Drawdown Response at B Complex Removal Action Performance Wells 299-E33-41, 299-E33-44, and 299-E33-345

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Table 6-5. Comparison of Water Table Changes at Wells 299-E33-41, 299-E33-44, and 299-E33-345 Before and After Pumping at Well 299-E33-360 Shutdown

Recovery Period	Date and Time	Evaluation Method	299-E33-345 (m)	299-E33-41 (m)	299-E33-34 (m)
First recovery shown in Figure 6-11	4/2/2019 21:30	Transducer data	121.3752	121.6431	121.6584
	4/2/2019 22:30	Transducer data	121.3906	121.6457[a]	121.6614[a]
	Change in time between 4/2/2019 21:30 and 4/2/2019 22:30	Change in elevation between 4/2/2019 21:30 and 4/2/2019 22:30	0.0154	0.0026	0.0029
	Change in time during pumping from 4/5/2019 to 4/7/2019	Average change in elevation trend during pumping from 4/5/2019 to 4/7/2019	-0.0007	-0.0002	-0.0002
	Change in time during pumping from 4/5/2019 to 4/7/2019	Maximum change in elevation trend during pumping from 4/5/2019 to 4/7/2019	0.0077	0.0029	0.0099
Second recovery shown in Figure 6-11	4/3/2010 17:30	Transducer data	121.3720	121.6401	121.6553[b]
	4/2/2019 22:30	Transducer data	121.3909	121.6452	121.6608
	Change in time between 4/3/2019 17:30 and 4/3/2019 22:30	Change in elevation between 4/3/2019 17:30 and 4/3/2019 22:30	0.0189	0.0051	0.0055
Third recovery shown in Figure 6-11	4/17/2019 5:30	Transducer data	121.3642	121.6363	121.6467
	4/17/2019 6:30	Transducer data	121.3811	121.64067[c]	121.6512[d]
	Change in time between 4/17/2019 5:30 and 4/17/2019 6:30	Change in elevation between 4/17/2019 5:30 and 4/16/2019 6:30	0.0169	0.0043	0.0045
Fourth recovery shown in Figure 6-11	4/19/2019 19:30	Transducer data	121.3732	121.6384	121.6517[e]
	4/20/2019 1:30	Transducer data	121.3864	121.6417	121.6555[f]
	Change in time between 4/19/2019 19:30 and 4/20/2019 1:30	Change in elevation between 4/19/2019 19:30 and 4/20/2019 1:30	0.0132	0.0033	0.0037

a. Water table measurement time is 23:30 on April 2, 2019.
b. Water table measurement time is 19:30 on April 3, 2019.
c. Water table measurement time is 7:30 on April 17, 2019.
d. Water table measurement time is 8:30 on April 17, 2019.
e. Water table measurement time is 21:30 on April 19, 2019.
f. Water table measurement time is 0:30 on April 20, 2019.

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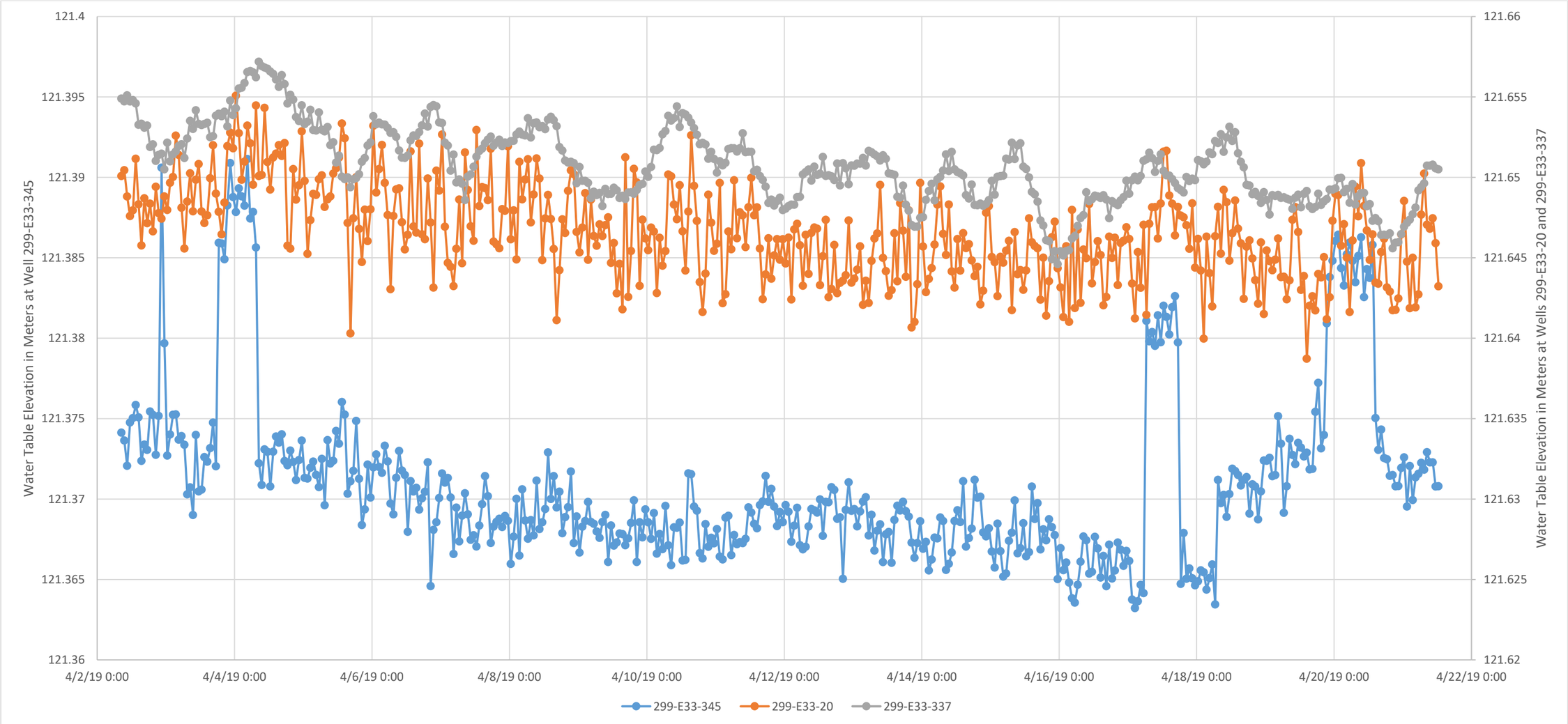

Figure 6-12. Barometric Corrected Water Table Recovery and Drawdown Response at B Complex Removal Action Performance Wells 299-E33-16, 299-E33-20 and 299-E33-345

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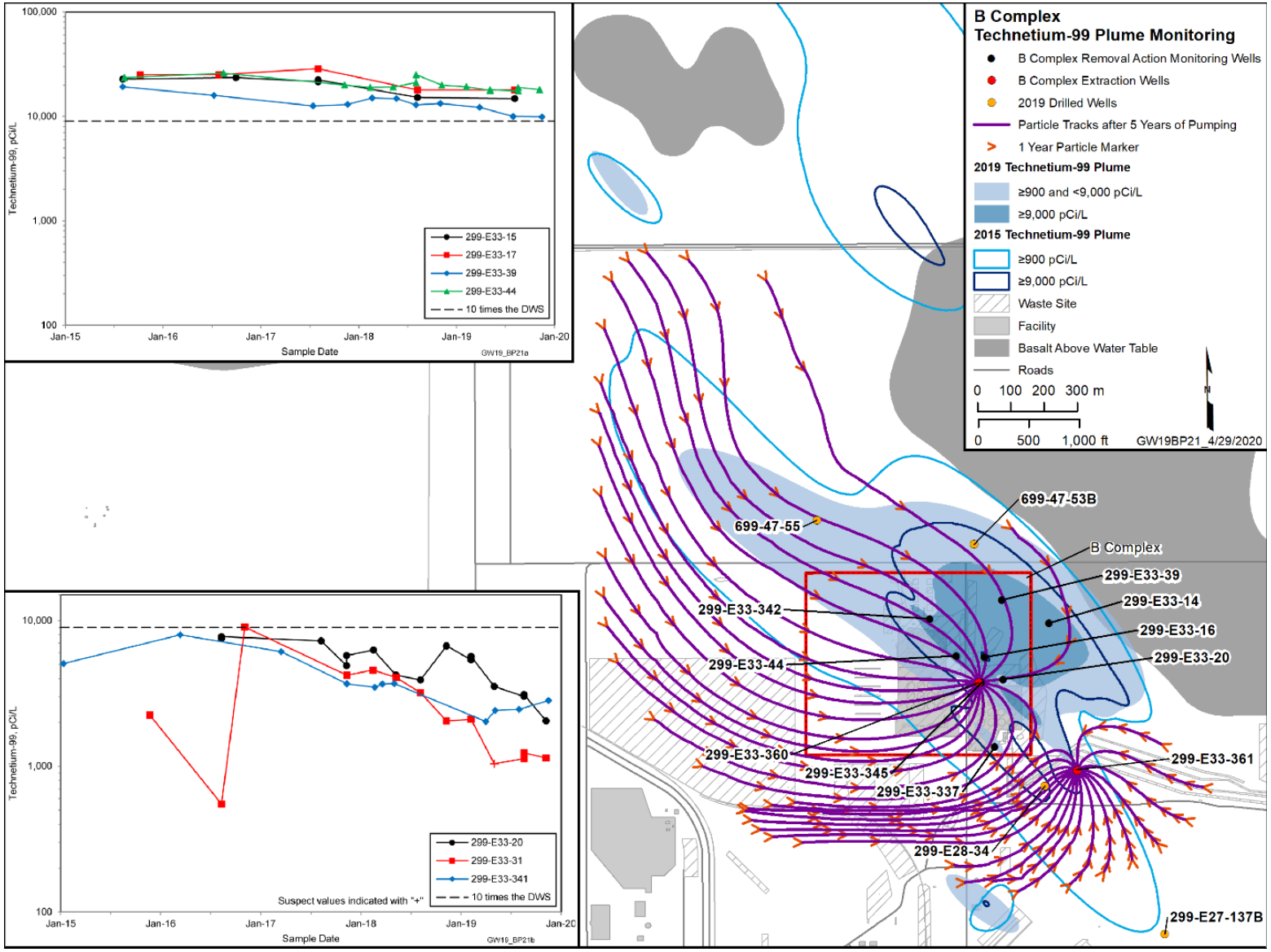

Figure 6-13. Hydraulic Capture for Pumping Rates of 115 gal/min at Well 299-E33-360 and 50 gal/min at Well 299-E33-361

Table 6-6. Changes in Technetium-99 Concentrations in B Complex Wells Between 2015 and 2019

Wells	2015 Technetium-99 Concentration[a]	2019 Technetium-99 Concentration[b]	Percent Change in Technetium-99 Concentration Between 2015 and 2019
299-E33-15	22,700	14,800	-34.8
299-E33-17	25,000	17,900	−28.4
299-E33-342	17,100	8,220	-51.9
299-E33-341	5,070	2,435	-52.0
299-E33-38	16,350	15,550	-4.9
299-E33-31	2,250	1,330	-40.9
299-E33-39	19,200	10,223	-46.8
299-E33-44	23,500	18,217	-22.5
299-E33-343	6,080	722	-88.1
299-E33-41	4,960	965	-80.5
299-E33-42	4,040	731	-81.9
299-E33-334	628	164	-73.9
299-E33-335	562	135	-76.0
299-E33-337	10,550	1,340	-87.3
299-E33-338	2,100	206	-90.2
299-E33-339	3,410	94.3	-97.2
		Average change	**-61.9**[c]

a. Technetium-99 concentration is the average 2015 concentration for each well.

b. Technetium-99 concentration is the average 2019 concentration for each well.

c. Average of all wells.

The November 2019 technetium-99 concentration at well 299-E33-39 declined below 10 times the DWS for the first time since B Complex groundwater extraction began in 2015 (Figure 6-6). Farther north, the December 2019 technetium-99 sample result (3,610 pCi/L), collected from the new well 699-47-53B (Figure 6-4; Table 6-1), confirms that technetium-99 concentrations are below 10 times the DWS north of the 200 East Area. The limited data collected at well 699-47-53B and the 2019 particle-tracking transport simulations (Figure 6-13) indicate that technetium-99 concentrations at well 299-E33-39 should continue to decline, unless contaminant flux from the vadose zone associated with the BY Cribs is contributing to the high technetium-99 groundwater values near well 299-E33-39.

Technetium-99 groundwater concentrations east of the B Complex (e.g., wells 299-E34-8, 299-E34-9, and 299-E34-10) showed decreases in 2019 with the addition of extraction well 299-E33-361 (Figure 6-14). Previous periodic technetium-99 increases at these wells coincide with water-level elevation changes. The increasing water levels are associated with the propagation of high Columbia River spring stages, which creates a groundwater gradient increase. The increased technetium-99 concentrations suggest that these wells were periodically outside of the capture zone of

well 299-E33-360, likely due to the water table gradient increase. Well 299-E33-361, which began operating in April 2019, provides containment of the eastern edge of the B Complex technetium-99 plume (Figure 6-14). Based on the later 2019 declining technetium-99 trends at the three wells, continued pumping at well 299-E33-361 should remove all technetium-99 concentrations from the former eastern edge of the technetium-99 plume.

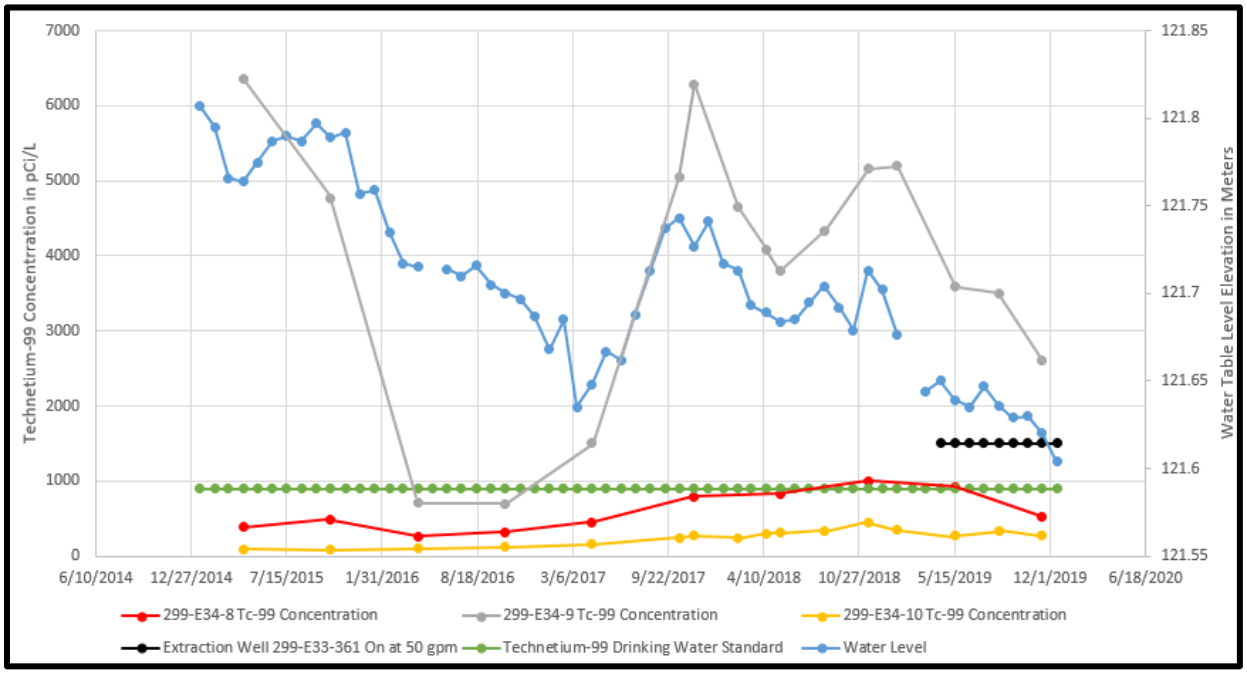

Figure 6-14. Technetium-99 Trend at Wells 299-E34-8, 299-E34-9, and 299-E34-10, East of Extraction Well 299-E33-360

The technetium-99 plume exceeding the DWS southeast of B Complex was determined to extend farther southeast than in 2018. Depth-discrete groundwater samples collected during drilling of new well 299-E27-137B demonstrate a thin, highly concentrated technetium-99 plume within the unconfined aquifer just above the basalt (Table 6-7). The first quarterly sampling results from December 2019 showed a much lower concentration than in the July 2019 depth-discrete sample and the September 2019 post-development sample. The lower December 2019 concentration may potentially be associated with mixing from the upper part of the well screen, although the pump intake is located in the lower screen portion of the well (Table 6-7). Technetium-99 concentrations are anticipated to eventually decline within the aquifer just above the basalt at well 299-E27-137B based on the ongoing success of the B Complex removal action.

Table 6-7. Groundwater Technetium-99 Sampling Results, Geologic Interpretations, Well Construction, and Pump Placement at New B Complex Removal Action Well 299-E27-137B in 2019

Groundwater Sampling Details and Results								
Sample Date	Technetium-99 (pCi/L)	Depth Below Water Table		Depth Below Ground Surface		Type of Sample	Purge Rate (gal/min)	Purge Volume (gal)
		m	ft	m	ft			
7/21/2019	302	3.0	10	89.3	293	Depth discrete	12.5	975
7/16/2019	298	5.8	19	92.0	302	Depth discrete	14	924
7/16/2019	280	5.8	19	92.0	302	Depth discrete	14	924
7/18/2019	354	8.8	29	9531	312	Depth discrete	15	795
7/23/2019	3,570	11.9	39	98.1	322	Depth discrete	14	1,526
9/6/2019	1,370	4.6	15	90.8	298	Post-development	75/60*	2,100/10,100
12/2/2019	416	11.6	38	97.8	321	Quarterly	10	170

Geology							
Lithostratagraphic Facies	Depth Below Ground Surface		Water Table		Geophysical Logging Results During Drilling		
	m	ft	m	ft	Radioactive Nuclides Present	Elevated Moisture Present	Elevated Natural Gamma Present
Hanford upper gravel	0–9.1	0-30	NA	NA	No	No	No
Hanford sand	9.1–74.4	30–244	NA	NA	No	No	No
Hanford lower gravel	74.4–75.0	244–246	NA	NA	No	No	No
Cold Creek fine-grained unit	75.0–77.7	246–255	NA	NA	No	No	No
Cold Creek gravels	77.7–99.1	255–325	86.0	282	No	Groundwater	No
Basalt	99.1	325	NA	NA	No	NA	NA

Table 6-7. Groundwater Technetium-99 Sampling Results, Geologic Interpretations, Well Construction, and Pump Placement at New B Complex Removal Action Well 299-E27-137B in 2019

Saturated Well Construction Details								
	Water Table		Final Upper Screen		Blank		Final Lower Screen	
Material	m	ft	m	ft	m	ft	m	ft
Stainless steel	86.0	282	84.4–92.0	277–302	92.0–95.1	302–312	95.1–98.1	312–322

Note: Pump and placement on November 22, 2019. Installed submersible pump with intake was set at 97.8 m (321 ft) below ground surface.

*Initial development began at 303 L/min (80 gal/min) for the first 3,785 L (1,000 gal), then 227 L/min (60 gal/min) for the remainder of the development.

NA = not applicable

6.2.5.2 Uranium Monitoring Results

Uranium trend plots and areal plume extents between 2015 and 2019 were compared to evaluate the effectiveness of the removal action at the B Complex. The 2015 groundwater uranium concentrations form the baseline for determining the effectiveness of uranium removal. For the seven B Complex wells sampled for uranium in 2015 and 2019, concentrations decreased by an average of 57.4% (Table 6-8). Figure 6-15 compares the uranium extent exceeding the DWS (30 µg/L) and 10 times the DWS (300 µg/L) between 2015 and 2019. The 30 µg/L plume area decreased from 358,000 m^2 in 2015 to 108,300 m^2 in 2019, for a 70% areal reduction. The 300 µg/L plume area decreased from 32,400 m^2 in 2015 to 250 m^2, for a 99% areal reduction. Well 299-E33-20 is the only well where uranium concentrations remain >10 times the DWS; however, if pumping continues under current flow rates, the concentration at well 299-E33-20 is expected to decline below 10 times the DWS in 2020 (Figure 6-15).

Table 6-8. Changes in Uranium Concentrations in B Complex Wells Between 2015 and 2019

Wells	2015 Uranium Concentration[a]	2019 Uranium Concentration[b]	Percent Change in Uranium Between 2015 and 2019
299-E33-20	1,820	464	-74.51%
299-E33-31	73.7	51.4	-30.23%
299-E33-41	56.8	24.2	-57.48%
299-E33-44	91.3	40.5	-55.60%
299-E33-47	80.7	58.9	-27.01%
299-E33-342	75.9	27.9	-63.31%
299-E33-343	1,490	94.1	-93.69%
		Average change	**-57.40%**[c]

a. Uranium concentration is the average 2015 concentration for each well.
b. Uranium concentration is the average 2019 concentration for each well.
c. Average of all wells.

6.3 Quality Assurance/Quality Control

Appendix E of DOE/RL-2019-66 discusses the QA/QC for sampling and analysis of the 200-BP-5 OU wells, including an overall view of QA/QC issues that may affect interpretation of the groundwater data presented in this report.

6.4 Remedial System Costs

Table 6-9 provides the cost breakdown for the 200-BP-5 OU groundwater removal action activities from 2016 through 2019. The costs shown in Table 6-9 are burdened. Based on a total of 324.1 million L (85.6 million gal) of extracted groundwater, the removal system cost in 2019 was $0.0062/L.

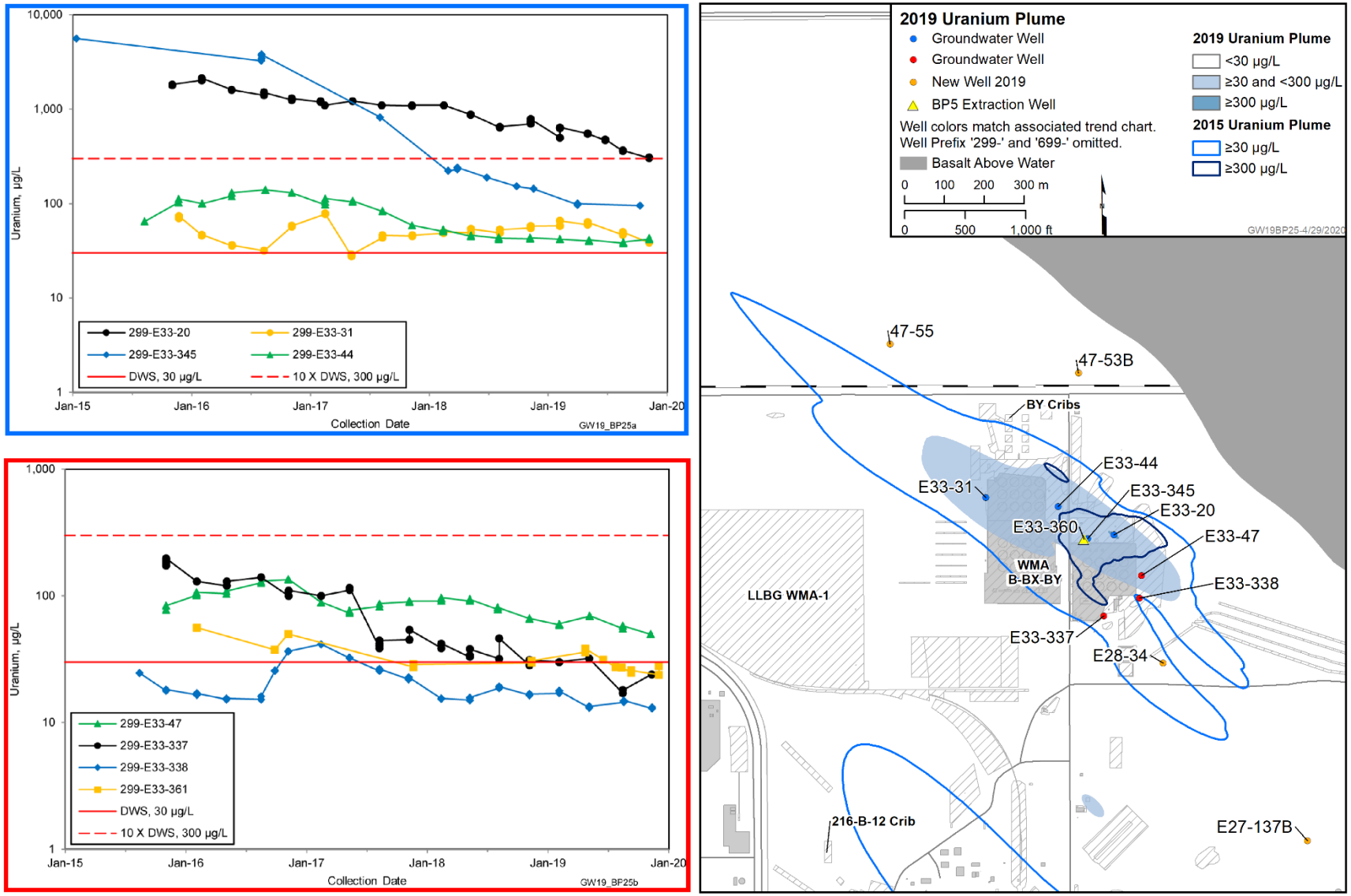

Figure 6-15. Comparison of 2015 and 2018 Uranium Groundwater Plumes Exceeding the DWS and 10 Times the DWS and Associated Trends

Table 6-9. Annual Cost Breakdown for 200-BP-5 OU Groundwater Extraction

Activity	Actual Costs (in $1,000s)			
	2016	2017	2018	2019
Final design of pipeline extension to well 299-E33-360	58.8	—	—	—
Construction of pipeline extension to well 299-E33-360	932.0	13.1	—	756.9
Construction of pipeline extension to well 299-E33-361	—	—	944.1	53.4
Performance monitoring[a]	51.5	108.9	222.3	250.8
Project support	—	134.6	141.8	128.7
O&M[b]	734.1	738.0	725.3	818.5
Totals	**1,776.4**	**994.6**	**2,033.5**	**2,008.2**

a. Performance monitoring costs have been adjusted back through 2016 to include pooled sampling costs for groundwater monitoring proportioned to the 200-BP-5 OU groundwater extraction system.

b. The O&M cost is a portion of the overall 200 West P&T O&M cost based on percentage of mass treated from extracted 200-BP-5 OU groundwater to the total mass treated by the 200 West P&T.

— = no value in this cost rollup OU = operable unit

O&M = operations and maintenance P&T = pump and treat

Remedial costs in 2019 were associated with final design and construction of the pipeline extension, addition of well 299-E33-361 to the B Complex remedial system, and O&M for extraction from well 299-E33-360. Sampling activities for routine groundwater monitoring are integrated for all groundwater OUs to reduce overall labor regarding sampling trips and analytical costs. These costs have been pooled in a separate project account and have not been included in the 200-BP-5 OU performance monitoring costs. To account for all performance monitoring costs associated with implementing remedial actions for the 200-BP-5 OU, a portion of the pooled costs based on sample trips and analyses performed for the OU have been included to the performance monitoring costs in this year's report.

6.5 Summary

Specific accomplishments and observations made for the B Complex removal action during 2019 were as follows:

- Groundwater extraction at the B Complex continues to be an effective method for removing technetium-99 and uranium.
- Technetium-99 activity removed from 2015 through 2019 is approximately 5.33 Ci (314 g).
- B Complex technetium-99 concentrations decreased by an average of 62% from 2015 through 2019.
- Uranium mass removed from 2015 through 2019 was approximately 187 kg.
- B Complex uranium concentrations decreased by an average of 57.4% from 2015 through 2019.
- Extraction well 299-E33-360 (near the tank 241-BX-102 release) has removed nearly all B Complex groundwater with uranium concentrations >10 times the DWS.
- Technetium-99 concentrations at well 299-E33-39 declined below 10 times the DWS for the first time since B Complex groundwater extraction began in 2015.

- December 2019 technetium-99 sample results, collected from newly drilled and installed wells, confirm that technetium-99 concentrations are below 10 times the DWS north of the 200 East Area.
- Extraction well 299-E33-361 began operating in April 2019 for containment of the eastern edge of the B Complex technetium-99 plume.
- Depth-discrete sampling during drilling of new well 299-E27-137B confirmed the conceptual model of a thin, highly concentrated technetium-99 plume located within the unconfined aquifer just above the basalt (Section A2.1 in Appendix A of DOE/RL-2017-11). Technetium-99 concentrations at this location are anticipated to eventually decline within the aquifer based on the ongoing success of the B Complex removal action.
- The total volume of water extracted from the aquifer during 2019 was 331.2 million L (87.5. million gal), and the total extracted from startup in September 2015 through December 2019 was 1.04 billion L (275 million gal).
- ECF-200BP5-20-0048 (in production) provides the B Complex water table measurements, barometric correction methodology, corrected water table elevations, data evaluation, conclusions, and recommendations for 2019. ECF-200BP5-19-0035 was prepared to support this 2019 report, and it documents the F&T modeling performed during FY 2019 for the B Complex P&T system in the 200-BP-5 OU.

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