



Yakima Railroad Area PCE Contamination

Groundwater Quality Monitoring Data Summary, 2022 – 2023

By

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For the

Environmental Assessment Program

Washington State Department of Ecology
Southwest Regional Office

Olympia, Washington

March 2026, Publication 26-03-003

Publication Information

This report is available on the Department of Ecology's website at:

<https://apps.ecology.wa.gov/publications/SummaryPages/2603003.html>.

Data for this project are available in Ecology's [EIM Database](#).¹ Search Study ID: YRRA.

The Activity Tracker Code for this study is 12-049.

Suggested Citation

Mohr, M. 2026. Yakima Railroad Area PCE Contamination: Groundwater Quality Monitoring 2022 – 2023. Publication 26-03-003. Washington State Department of Ecology, Olympia.

<https://apps.ecology.wa.gov/publications/SummaryPages/2603003.html>.

Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

- WRIAs: 37
- HUC Numbers: 17030003

Any use of product or firm names in this publication is for descriptive purposes only and does not imply endorsement by the author or the Department of Ecology.

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ECOLOGY
State of Washington

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Abstract

The Washington State Department of Ecology (Ecology) conducted four sampling events at the Yakima Railroad Area (YRRA) groundwater monitoring network between 2022 and 2023 as part of an ongoing semi-annual sampling program. The YRRA is located along a railroad corridor encompassing approximately six-square-miles in the cities of Yakima and Union Gap. Groundwater in the YRRA is impacted by tetrachloroethene (PCE) contamination, originating from multiple sources. Cleanup activities in the project area began following site definition in 1991, and sampling results indicate effective reductions in PCE concentrations at select source area sites.

Of the 41 wells sampled in 2022 and 2023, 19 had PCE concentrations above (not meeting) the Model Toxics Control Act cleanup level of 5 µg/L. PCE concentrations above the cleanup level at individual sites within the YRRA ranged from 5.03 µg/L to 22,000 µg/L.

Elevated PCE concentrations primarily occurred in shallow wells at three of the source areas: Cameron Yakima, Washington Central Railroad, and Frank Wear Cleaners. Two shallow remedial investigation wells located in the western portion of the YRRA also had elevated PCE concentrations. The source of contamination for the remedial investigation wells has not been identified.

PCE concentrations higher than the 5 µg/L cleanup level were also detected in the deeper Washington Central Railroad Roundhouse wells. PCE concentrations ranged from 9.3 µg/L in WDOE-3D, the deepest well in the cluster, to 15.4 µg/L in WDOE-3S. PCE concentrations in these wells indicate the contaminant plume has a vertical extent that reaches the lower confined water-bearing zone in this portion of the YRRA.

The 2022 – 2023 groundwater data confirm continued impact from PCE and associated contaminants in groundwater throughout the YRRA project area. While concentrations have decreased at some identified source areas, high PCE concentrations remain in the central portion of the YRRA.

Introduction

Background

Tetrachloroethene (PCE) contaminated soil and groundwater were discovered in the Yakima Railroad Area (YRRA) following routine inspections of industrial facilities in the 1980s (Secor 1998). These findings were referred to the Washington State Department of Ecology (Ecology) by the U.S. Environmental Protection Agency (EPA). The definition of the YRRA was established in 1991 following numerous soil and groundwater investigations.

The YRRA spans approximately 6 square miles of mixed industrial/commercial and residential property along the railroad corridor in the cities of Yakima and Union Gap (Figure 1). Within the project area, Ecology has identified 13 commercial and industrial facilities as potential PCE sources. These sources include machine shops, dry cleaners, a carbon regeneration facility, and a former pesticide formulation plant.

Cleanup activities in the YRRA were conducted at many of the source facilities in the 1990's, including a remedial investigation (RI) conducted in 1998 (Secor 1998). Between 1999 and 2012, routine groundwater sampling occurred at 59 monitoring wells to characterize PCE in the YRRA groundwater. Groundwater analytical results from this period indicated that PCE concentrations are highest near known sources; however, PCE was also detected in the shallow aquifer, where no known sources are present.

Ecology's Environmental Assessment Program (EAP) assumed responsibility for the area-wide monitoring program in 2013. Initial monitoring activities conducted by Ecology included regular monitoring at a subset of 36 wells in the YRRA. Ten monitoring wells from the Frank Wear Cleaners site were added to the YRRA in 2017, and two wells in the northern extent of the project area were removed.

The goal of the 2022 – 2023 monitoring activities is to provide Ecology's Toxics Cleanup Program (TCP) with groundwater analytical data for evaluation of remedial actions taken at the YRRA under the Model Toxics Control Act (MTCA). These data may also help identify additional impacted areas within YRRA that require further source investigation and remedial action.

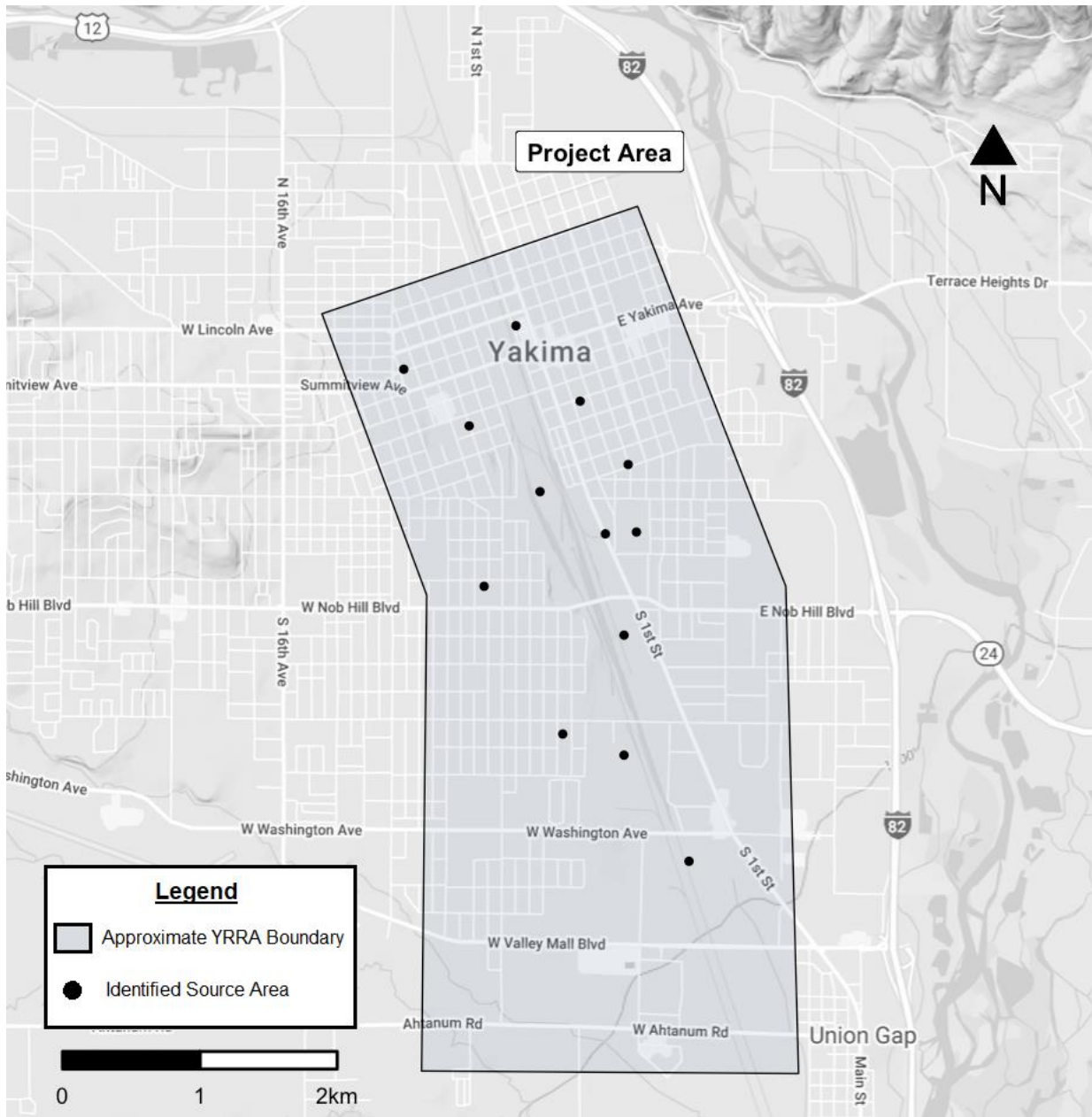


Figure 1. Yakima Railroad Area (YRRA) project location map, Yakima, WA.

Physical setting

The YRRA is located within the Yakima River floodplain and is mostly underlain by unconsolidated terrace deposits and Quaternary-age alluvium. The terrace deposits generally occur at the surface away from the Yakima River and beneath alluvium near the river. The terrace deposits consist of coarse gravels interspersed with discontinuous layers of silt, clay, sand, and cemented gravel. This unit averages 90 feet (ft) in thickness and ranges up to 350 ft (USGS 2009). The alluvium consists of unconsolidated silt, sand, gravel, and cobble, and averages 20 ft in thickness, ranging up to 120 ft (USGS 2009). In some areas of the YRRA, these unconsolidated Quaternary deposits are overlain by up to 20 ft of artificial fill material. Underlying these deposits are the consolidated Tertiary-age continental sediments of the Upper Ellensburg Formation.

Groundwater monitoring activities in the YRRA focus on the upper portion of the shallow, unconfined aquifer located within the unconsolidated sands and gravels. Near the Yakima River, this portion of the aquifer is highly permeable. However, the prevalence of fine-grained material and cemented gravels in the northern and western portions of the project area led to an area of reduced permeability. The RI/Feasibility Study identified both shallow and deep water-bearing zones of the aquifer because of the variable permeability within the YRRA (Secor 1998). There appears to be hydraulic connectivity between the shallow and deep zones in the southern portion of the project area. Near the northern extent of the study area, the shallow and deep zones appear to be hydraulically separated.

Groundwater depths within the YRRA range from approximately 3 ft to 30 ft below ground surface (bgs), depending on local topography, precipitation, and seasonal irrigation. Groundwater depths are greater to the north and lesser to the south. The Yakima Valley is an agricultural area that is heavily irrigated using surface water from nearby rivers between late March and early October. This irrigation results in a water table that fluctuates between 1 ft and 12 ft seasonally, with a deeper water table in the spring and a shallower water table in the fall.

Groundwater flow in the shallow water-bearing zone was characterized as flow towards the southeast, with an approximate horizontal gradient of 0.005 ft/ft throughout the YRRA. The deep water-bearing zone is estimated to flow primarily to the southeast, with an approximate gradient of 0.004ft/ft. The vertical gradient across the YRRA is generally downward, ranging from -0.278 ft/ft in the northern portion of the project area to -0.005 ft/ft in the southern extent (Secor 1998).

Methods

Groundwater sampling

Ecology's Environmental Assessment Program conducts groundwater sampling activities twice a year in the YRRA, typically in April and October. This sampling recurrence is chosen to assess variability in contamination of the site groundwater due to seasonal groundwater level fluctuations.

Beginning in 2013, Ecology's sampling focused on a subset of 36 wells in the project area. Ecology excluded wells within the YRRA that reported either low concentrations or no detection of chlorinated volatile organic compounds (cVOCs) during prior sampling events. The cVOC compounds in the project area include PCE and its metabolic breakdown products, trichloroethene (TCE), cis-1-2-dichloroethene (DCE), and vinyl chloride (VC).

In 2015, the monitoring intervals of the 36 selected wells were adjusted to improve cost-effectiveness. The frequency of sampling at each well was determined by PCE concentration, seasonal pattern, and temporal trend. Seven wells reported higher PCE concentrations in the spring, 13 wells had higher PCE concentrations in the fall, and there was no apparent seasonal pattern in the remaining wells.

In 2017, 10 wells were added to the monitoring network at the north end of the project area when the Frank Wear Cleaners site was added to the project area. Currently, these 10 wells are being sampled semi-annually. Monitoring frequency for the Frank Wear Cleaners wells may be adjusted if seasonal patterns or trends can be established. Two wells were also removed from the monitoring program: NMW-2 at the Nu-Way Cleaners site, which was decommissioned in 2016, and ATMW-4 at the Agri-Tech site, which has not been sampled since 2017 due to difficulty locating the well. The relative locations of the 44 remaining wells in the monitoring program are shown in Figure 2.

Between 2022 and 2023, Ecology sampled 41 of the 44 wells in the monitoring network. Of the wells sampled, 32 are associated with seven known source areas for contamination, including the following: Goodwill — City of Yakima (Goodwill), Nu-Way Cleaners (Nu-Way), Southgate Laundry (Southgate), Fifth Wheel Truck Repair (Fifth Wheel), Cameron Yakima (Cameron), the Washington Central Railroad Roundhouse (WCRR), and Frank Wear Cleaners (Frank Wear). Wells at these seven locations are monitored to evaluate the long-term effectiveness of site-specific remedial activities.

The nine remaining sampled wells were installed during the YRRA Remedial Investigation (RI) and are in the western and southern extent of the YRRA. Analytical data collected from these wells may help to identify areas of further groundwater contamination within the project area that require additional source investigation and remedial action.

Construction details for the sampled wells are provided in Appendix A, Table 1.

Ecology sampled these wells in accordance with Ecology’s Standard Operating Procedures (SOPs) EAP052 (Ecology 2023) and EAP078 (Ecology 2024), and the site-specific Quality Assurance Project Plan (Marti 2013).



Figure 2. YRRA groundwater monitoring locations.

Analysis

Groundwater samples were submitted to Ecology's Manchester Environmental Laboratory (MEL) for analysis of volatile organic compounds (VOCs) by a modification of EPA SW-846 Method 8260C. Samples collected during October 2022 were submitted to Onsite Environmental Inc. (Onsite) in Redmond, Washington, following initial submittal to MEL. An equipment failure at MEL required shipment of the samples to Onsite.

Field observations

Prior to purging groundwater, Ecology measured depth-to-water in each of the 41 monitoring wells. Groundwater field parameters were recorded during purging, and samples were collected following parameter stabilization. Final temperature, pH, dissolved oxygen, oxidation-reduction potential (ORP), and specific conductance measurements are listed in Table 2 in Appendix A.

In 2022 and 2023, depth-to-water measurements in the spring ranged from about 40.33 ft bgs at the northern end of the YRRA project area to about 9.8 ft bgs at the southern end of the area, and from about 27.97 ft to 4.37 ft bgs in the fall. This seasonal increase in groundwater levels from spring to fall primarily occurs due to irrigation over the summer months.

The overall flow directions for the shallow groundwater appear to be southeast towards the Yakima River. The flow direction in the deep water-bearing zone is difficult to determine due to the limited number of measurements during both sampling events. However, previous investigations (Kane Environmental 2011) have described the flow direction as towards the southeast.

Table 1 summarizes field measurement data for 2022 and 2023, which were within expected ranges. Dissolved oxygen concentrations in most of the sampled wells had measurements that ranged from about 2 mg/L to 11 mg/L, indicating aerobic conditions in both the shallow and deep wells. Dissolved oxygen concentrations in three of the Frank Wear wells (FWMW-10, FWMW-16, and FWMW-20) and two Washington Central Railroad Roundhouse wells (WDOE-3D, WDOE-3I) were below 1 mg/L during 2022 and 2023. Dissolved oxygen concentrations below 1 mg/L indicate an anaerobic environment in groundwater.

Table 1. Summary of Yakima Railroad Area stable field measurements, 2022 – 2023.

Parameter	Number of Observations	Minimum	Maximum	25th Percentile	Median	75th Percentile
Temperature (°C)	105	9.2	19.8	16.0	16.6	17.4
pH (Std Units)	105	6.4	8.00	6.6	6.8	7.1
Conductivity (uS/cm@25°C)	105	86	1659	298	332	392
Dissolved Oxygen (mg/L)	105	0	11.4	4.4	6.8	7.3
Oxidation Reduction Potential (mV)	105	-117	388	128	186	295

Analytical Results

PCE was detected at least once in all 41 sampled monitoring wells throughout the 2022 and 2023 monitoring period (Table 2). Detected concentrations of PCE ranged from an estimated 0.17NJ µg/L to 22,000J µg/L throughout the 2022 and 2023 monitoring period.

During April 2022, seven monitoring wells reported PCE concentrations exceeding the 5 µg/L cleanup level. These samples were collected at five Frank Wear wells (FWMW-4, FWMW-10, FWMW-16, FWMW-20, FWMW-24), one Cameron well (CYIMW103S), and one Remedial Investigation well (RI-4S). Concentrations ranged from an estimated 7.45J µg/L to 3,060 µg/L.

In October 2022, 10 monitoring wells reported PCE concentrations exceeding the 5 µg/L cleanup level. These samples were collected at four Frank Wear wells (FWMW-10, FWMW-16, FWMW-20, FWMW-24), three Roundhouse wells (WDOE-3D, WDOE-3I, WDOE-3S), two Cameron wells (CYIMW102S, CYIMW103S), and one Remedial Investigation well (RI-6S). PCE concentrations in these wells ranged from an estimated 5.2J µg/L to 20,000J µg/L.

The 2022 analytical results for PCE and the metabolic breakdown products TCE, DCE, and VC are presented in Table 2.

During April 2023, 11 monitoring wells reported PCE concentrations exceeding the 5 µg/L cleanup level. These samples were collected at five Frank Wear wells (FWMW-4, FWMW-10, FWMW-16, FWMW-20, FWMW-24), three Cameron well (CYIMW103S, CYIMW107S, CYIMW113S), two Goodwill wells (GMW-1, GMW-2) and one Remedial Investigation well (RI-4S). Concentrations ranged from 5.03 µg/L to 10,400 µg/L.

In October 2023, 14 monitoring wells reported PCE concentrations exceeding the 5 µg/L cleanup level. These samples were collected at five Frank Wear wells (FWMW-6, FWMW-10, FWMW-16, FWMW-20, FWMW-24), three Roundhouse wells (WDOE-3D, WDOE-3I, WDOE-3S), four Cameron wells (CYIMW102S, CYIMW103S, CYIMW106S, CYIMW114S), one Goodwill well (GMW-2), and one Remedial Investigation well (RI-6S). Concentrations ranged from 5.1 µg/L to an estimated 22,000J µg/L.

The 2023 analytical results for PCE and the metabolic breakdown products TCE, DCE, and VC are presented in Table 3.

Sample collection bias and overall analytical precision were assessed by collecting field quality control samples consisting of field duplicates, equipment blanks, and transport blank samples. Appendix B presents the Quality Assurance data for the 2022 – 2023 monitoring period (Appendix B, Tables 3 to 6).

In 2022, all duplicate samples collected met the acceptance criteria for all analytes of concern. In 2023, the duplicate sample collected from GMW-2 reported a relative percentage difference (RPD) of 99.15% for PCE, exceeding the acceptance criteria value of 30% for parent and duplicate sample concentrations. The sample result at GMW-2 represents the average between the parent and duplicate sample concentration and is qualified with a “J” flag accordingly.

During April 2022, PCE was detected in an equipment blank sample at an estimated 0.34J µg/L. The equipment blank was collected on 4/20/2022, following sample collection from the Frank Wear wells with the highest PCE concentrations (FWMW-10, FWMW-20). Non-detect results from an equipment blank collected earlier on 4/20/2022 indicate that contamination was not occurring prior to sampling the high concentration wells at Frank Wear; therefore, no results are qualified due to the equipment blank contamination. The transport blank collected on 4/18/2022 reported a detected PCE concentration of 0.24J µg/L, and as a result, all samples with concentrations less than 5 times the detected blank concentration are qualified with a “B” flag.

The reporting limit for VC during April 2022 was higher than the typical 0.2 µg/L reporting limit due to calibration issues at MEL, resulting in a 5 µg/L reporting limit for this event, above the 0.2 µg/L cleanup level for VC.

During October 2022, PCE was detected in the second equipment blank sample at an estimated 0.37J µg/L. The equipment blank was collected on 11/13/2022, following sample collection from well FWMW-10. Analytical results from the equipment blank taken prior to sampling FWMW-10 did not contain reportable concentrations of PCE; therefore, no results are qualified due to the equipment blank concentration. All results from October 2022 are qualified as estimates with a “J” flag due to holding time exceedances.

There were no detections in any blank samples submitted in April 2023, and therefore, no samples are qualified. The equipment blank sample collected on 10/18/2023 reported a PCE concentration of 0.77J µg/L. This equipment blank was collected following sample collection at the highest concentration Frank Wear wells (FWMW-4, FWMW-10, and FWMW-20). This detection does not warrant any data qualification, as the equipment blank collected prior to sampling FWMW-4, FWMW-10, and FWMW-20 did not contain reportable PCE concentrations.

Data from April and October 2022 are considered usable as qualified, and data from April and October 2023 are of good quality and are usable as presented here without further qualification. Appendix B contains additional details about project quality assurance.

Historical groundwater data for the YRRA monitoring program wells are available in Appendix C (Tables 9 to 54). Historical project data are also presented in the Appendix C time series plots (Figures 1 to 51), which depict contaminant concentrations in individual wells throughout the monitoring program.

The following section, Discussion by Source Area, presents a summary of the 2022 and 2023 results by the seven contaminant source areas.

Table 2. Analytical results for 2022.

Well	April PCE	April TCE	April DCE	April VC	October PCE	October TCE	October DCE	October VC
5WMW-2	—	—	—	—	2.8J	0.2UJ	0.2UJ	0.2UJ
CYIMW102S	—	—	—	—	5.2J	0.23J	0.2UJ	0.2UJ
CYIMW103D	1.93J	0.55J	1U	5UJ	—	—	—	—
CYIMW103S	7.45J	0.99J	0.2J	5UJ	6J	0.38J	0.2UJ	0.2UJ
CYIMW106S	—	—	—	—	4J	0.2UJ	0.2UJ	0.2UJ
CYIMW107S	3.39J	0.66J	1U	5UJ	0.91J	0.2UJ	0.2UJ	0.2UJ
CYIMW108S	—	—	—	—	2J	0.2UJ	0.2UJ	0.2UJ
CYIMW111S	—	—	—	—	1.3J	0.2UJ	0.2UJ	0.2UJ
CYIMW112S	—	—	—	—	3.9J	0.2UJ	0.2UJ	0.2UJ
CYIMW113D	2.44J	0.54J	1U	5UJ	—	—	—	—
CYIMW113S	4.6J	0.76J	1U	5UJ	—	—	—	—
FWMW-10	3060	103	60.9	22.6	4500J	97J	42J	20UJ
FWMW-16	29.6J	16.5	44.5	5UJ	44J	5.1J	51J	6.1J
FWMW-17	0.39B	1U	1U	5UJ	0.2UJ	0.2UJ	0.2UJ	0.2UJ
FWMW-18	1.17B	0.67J	1U	5UJ	0.9J	0.2UJ	0.2UJ	0.2UJ
FWMW-19	0.33B	1U	1U	5UJ	0.2UJ	0.2UJ	0.2UJ	0.2UJ
FWMW-20	1880	511	334	56.5	20000J	640J	300J	100UJ
FWMW-24	23.4J	2.36	1.7	5UJ	50J	1.1J	0.66J	0.4UJ
FWMW-4	127J	31.3	71.9	57.6J	—	—	—	—
FWMW-5	1.5J	0.86J	0.61J	5UJ	1.5J	0.2UJ	0.2UJ	0.2UJ
FWMW-6	1.22J	0.54J	1U	5UJ	4.6J	1.1J	2.3J	0.2UJ
GMW-1	0.85B	1U	1U	5UJ	—	—	—	—
GMW-2	0.91B	1U	1U	5UJ	4.6J	0.2UJ	0.2UJ	0.2UJ
GMW-4	0.29B	1U	1U	5UJ	—	—	—	—
NMW-1	1.16B	0.49J	1U	5UJ	—	—	—	—
RMW-3D	—	—	—	—	9.3J	2.7J	1.6J	0.2UJ
RMW-3I	—	—	—	—	9.3J	1.5J	1.8J	0.78J
RMW-3S	—	—	—	—	9.2J	0.24J	0.2UJ	0.2UJ
SGMW-1	—	—	—	—	0.2UJ	0.2UJ	0.2UJ	0.2UJ
SGMW-2	—	—	—	—	1.4J	0.2UJ	0.2UJ	0.2UJ
SGMW-3	—	—	—	—	1.2J	0.2UJ	0.2UJ	0.2UJ
RI-3S	0.3B	1U	1U	5U	—	—	—	—
RI-4D	2.17	1U	1U	5UJ	—	—	—	—
RI-4S	12	1U	1U	5UJ	—	—	—	—
RI-5D	1.31	1U	1U	5UJ	—	—	—	—
RI-5S	2.73	1U	1U	5UJ	—	—	—	—
RI-6S	—	—	—	—	7J	0.2UJ	0.2UJ	0.2UJ
RI-9S	—	—	—	—	1.1J	0.2UJ	0.2UJ	0.2UJ
RI-10S	1.22	0.52J	1U	5UJ	—	—	—	—
RI-11S	—	—	—	—	0.68J	0.2UJ	0.2UJ	0.2UJ

PCE: Tetrachloroethene; TCE: Trichloroethene; DCE: cis-1,2-dichloroethene; VC: Vinyl chloride;
 Results in µg/L; —: Not sampled; **Bold**: Analyte was detected; **Bold and Underlined**: Analyte was detected at a concentration above the cleanup level; U: Analyte was not detected at or above the reported value;
 J: Analyte was positively identified (the associated numerical result is an estimate); B: Analyte detected in sample and transport blank.

Table 3. Analytical results for 2023.

Well	April PCE	April TCE	April DCE	April VC	October PCE	October TCE	October DCE	October VC
5WMW-2	—	—	—	—	3.97	0.1NJ	1U	0.2U
CYIMW102S	—	—	—	—	6.61	0.27J	0.47J	0.2U
CYIMW103D	2.74	1U	1U	1U	—	—	—	—
CYIMW103S	11.4	0.72J	0.26J	0.2U	5.84	0.34J	0.47J	0.2U
CYIMW106S	—	—	—	—	5.19	0.16J	0.42NJ	0.2U
CYIMW107S	5.03	0.23J	1U	0.2U	4.9	0.22J	0.43J	0.2U
CYIMW108S	—	—	—	—	3.14	1U	0.43NJ	0.2U
CYIMW111S	—	—	—	—	3.78	0.13NJ	0.42J	0.2U
CYIMW113D	3.32	1U	1U	0.2U	—	—	—	—
CYIMW113S	10.3	0.55J	0.18J	0.2U	—	—	—	—
CYIMW114S	—	—	—	—	9.25	0.5J	0.51J	0.2U
FWMW-10	10400	162	84.3	28.5	4610J	87.2	35.5	15.6
FWMW-16	61.3	7.88	62.7	12.6	53.8	5.56	67.9	14.9J
FWMW-17	1U	1U	1U	0.2U	0.17NJ	1U	1U	0.2U
FWMW-18	0.92J	1U	1U	0.2U	1.6	0.21J	1U	0.2U
FWMW-19	1U	1U	1U	0.2U	0.19J	1U	1U	0.2U
FWMW-20	7410	564	301	50	22000J	407	207	51.4
FWMW-24	28.4	1.32	0.77J	0.2U	53.3	1.15	1.14J	0.2U
FWMW-4	414	19	56.7	0.42	4.24	1U	0.42NJ	0.2U
FWMW-5	4.91	1.36	1.4	0.2U	1.49	1U	0.41NJ	0.2U
FWMW-6	1.96	1U	1U	0.2U	5.1	1.22	2.23J	0.2U
GMW-1	8.8	1U	1U	0.2U	—	—	—	—
GMW-2	14.8J	1U	1U	0.2U	13.8	1U	1U	0.2U
GMW-4	0.8J	1U	1U	0.2U	—	—	—	—
NMW-1	1.69	1U	1U	0.2U	—	—	—	—
RMW-3D	—	—	—	—	11.6	3.45	1.86J	0.2NJ
RMW-3I	—	—	—	—	12.1	2.25	2.2J	1.38J
RMW-3S	—	—	—	—	15.4	0.47J	0.66NJ	0.2U
SGMW-1	—	—	—	—	0.36J	1U	1U	0.2U
SGMW-2	—	—	—	—	1.66	1U	1U	0.2U
SGMW-3	—	—	—	—	1.6	1U	1U	0.2U
RI-3S	1U	1U	1U	0.2U	—	—	—	—
RI-4D	3.41	1U	1U	0.2U	—	—	—	—
RI-4S	19.1	1U	1U	0.2U	—	—	—	—
RI-5D	1.9	1U	1U	0.2U	—	—	—	—
RI-5S	3.99	1U	1U	0.2UJ	—	—	—	—
RI-6S	—	—	—	—	9.38	1U	1U	0.2U
RI-9S	—	—	—	—	1.19	1U	1U	0.2U
RI-10S	1.53	1U	1U	0.2U	—	—	—	—

PCE: Tetrachloroethene; TCE: Trichloroethene; DCE: cis-1,2-dichloroethene; VC: Vinyl chloride; Results in µg/L; —: Not sampled; **Bold**: Analyte was detected; **Bold and Underlined**: Analyte was detected at a concentration above the cleanup level; U: Analyte was not detected at or above the reported value; J: Analyte was positively identified (the associated numerical result is an estimate); NJ: Analyte was tentatively identified (the associated numerical result is an estimate).

Discussion by source area

During 2022 and 2023, four of the seven source areas sampled in the YRRA had PCE concentrations higher than the 5 µg/L cleanup level in at least one well. The source areas were Cameron, Frank Wear, Goodwill, and the WCRR. Groundwater samples collected at the three remaining source areas, Fifth Wheel, Nu-Way, and Southgate Laundry, have not reported concentrations of PCE above the 5 µg/L cleanup level in many years. The two RI wells (RI-4S and RI-6S) with PCE concentrations above the cleanup level are in the western extent of the study area and currently have no known source area.

Goodwill — City of Yakima

The Goodwill — City of Yakima site is located in the northern portion of the YRRA. This site is the present location of the City of Yakima Police Station and Justice Center (Figure 3). Cleanup activities at this site consisted of contaminated soil removal conducted in 1995 (Huntingdon Engineering 1995).

During the 2022 and 2023 monitoring period, PCE was the only chlorinated solvent detected in groundwater samples collected at this site (Figure 3). The PCE metabolic breakdown products – TCE, DCE, and VC – were not detected above the reporting limits. The April 2022 PCE results are “B” qualified due to a PCE detection in the transport blank of 0.24 µg/L.

During both monitoring events in 2022 and 2023, PCE was detected in the downgradient well GMW-2. In April 2022, PCE was detected at an estimated concentration of 0.91B µg/L, below the laboratory reporting limit of 1 µg/L. In October 2022, the PCE concentration in GMW-2 was 4.6J µg/L, below the 5 µg/L cleanup level. PCE concentrations generally increased in samples collected during 2023, with a maximum reported concentration of an estimated 14.8J µg/L in April 2023 at GMW-2. The April 2023 sample collected from GWM-2 was submitted to the laboratory with a duplicate sample for quality control purposes. The relative percentage difference (RPD) of this parent and duplicate sample failed the data quality objectives (DQOs) of a 30% RPD limit; therefore, the results from this sample are reported as an average of the parent and duplicate sample and are “J” qualified. The parent and duplicate samples reported PCE concentrations of 22.1 µg/L and 7.45 µg/L, respectively. The reported concentration of an estimated 14.8J µg/L is the average of the parent and duplicate samples collected from GMW-2 during April 2023.

Wells GMW-1 and GMW-4 are sampled annually during the spring. During April 2022, PCE was detected in both wells below the 1 µg/L reporting limit. PCE concentrations during this event were 0.85B µg/L and 0.29B µg/L at wells GMW-1 and GWM-4, respectively. The April 2023 PCE concentration at GMW-1 increased an order of magnitude to 8.8 µg/L, while the sample collected from GMW-4 remained below the reporting limit with an estimated concentration of 0.8J µg/L.

PCE concentrations in GMW-2 have generally decreased since 2018, when PCE was detected at an estimated 24J µg/L. However, the samples collected during the 2022 and 2023 reporting

periods suggest a slight increase in PCE concentrations. With the exception of the October 2023 sampling event, PCE in GMW-2 has been near or below the 5 µg/L cleanup level. PCE concentrations in GMW-1 and GMW-4 have generally been below the 5 µg/L cleanup level, with the exception of outlier detections in GMW-1 during 2018 and April 2023 (Appendix C Tables 9 to 11, Figures 1 to 3).

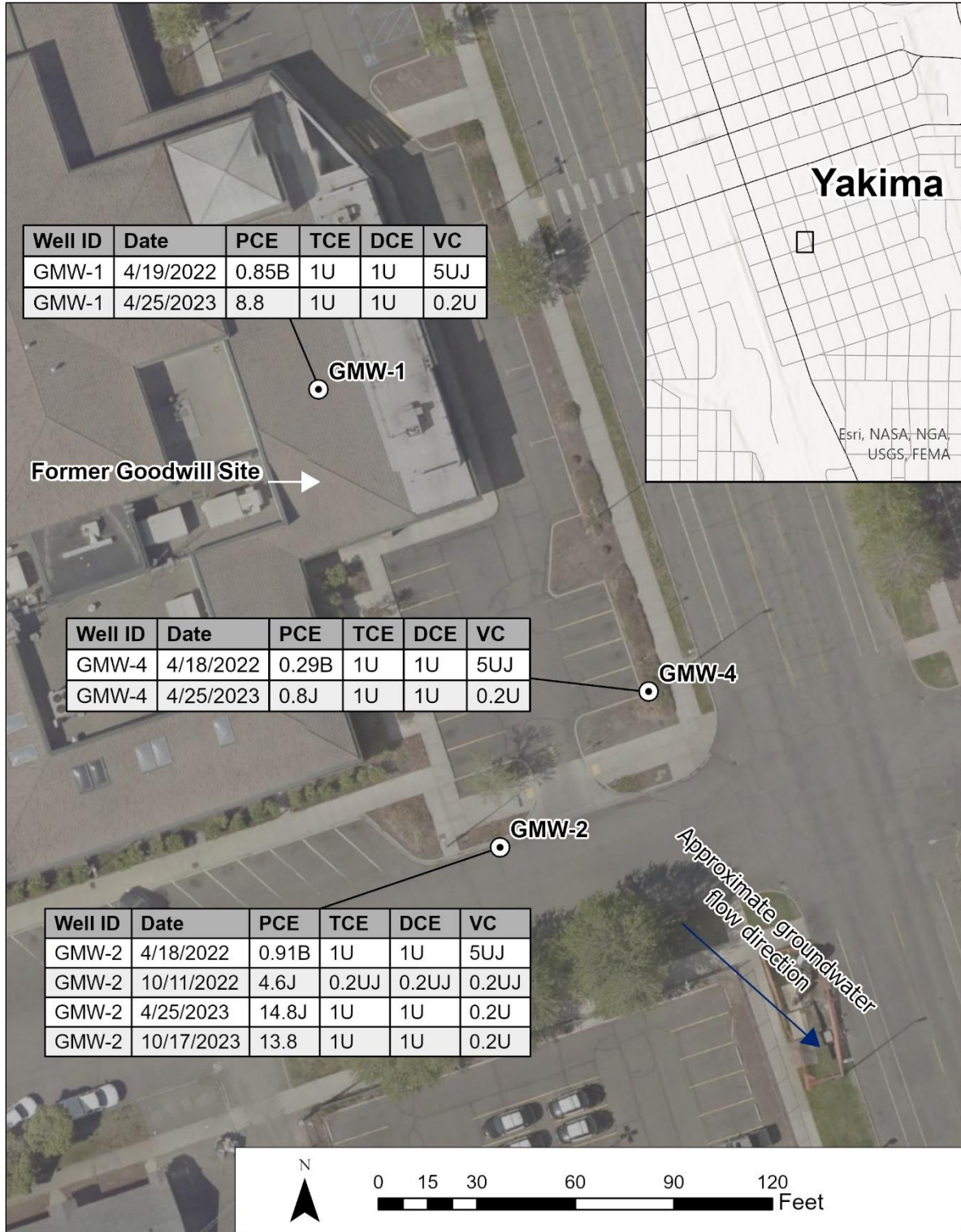


Figure 3. Goodwill — City of Yakima well locations and cVOC results ($\mu\text{g/L}$), 2022 – 2023.

Nu-Way Cleaners

The Nu-Way Cleaners site sits approximately 0.5 miles southeast of the Goodwill site (Figure 2). PCE source removal activities occurred at this site in 1996 (Enviros 1996).

During spring 2022 and 2023, samples were collected from NMW-1. PCE was detected below the 5 µg/L cleanup level at concentrations of 1.16B µg/L and 1.69 µg/L, during 2022 and 2023, respectively (Figure 4). In 2022, TCE was detected in this well below the 1 µg/L reporting limit. The remaining target analytes were not detected above reporting limits in these samples.

Monitoring well NMW-3 is in a parking lot and was consistently inaccessible throughout 2022 and 2023 due to a parked vehicle. Monitoring well NMW-2 was decommissioned in 2016 and is no longer part of the YRRA monitoring program.

Since regular monitoring began at this site in 1997, PCE concentrations in samples collected from the three monitoring wells have generally been below the 5 µg/L cleanup levels (Appendix C Tables 12 to 14, Figures 4 to 6). PCE concentrations have ranged below reporting limits of 1 µg/L to 5.5 µg/L. Downgradient PCE concentrations at this site have been consistent with upgradient concentrations of PCE, indicating that this site no longer represents a significant source of PCE to the YRRA plume.



Figure 4. Nu-Way Cleaners well locations and cVOC results ($\mu\text{g/L}$), 2022 – 2023.

Southgate Laundry

The Southgate Laundry site sits approximately 0.5 miles west of the railroad tracks along Nob Hill Road (Figure 2). Interim remedial activities at this site took place in 1997 and consisted of contaminated soil removal (Maxim Technologies 1998).

During 2022 and 2023, PCE was the only contaminant detected at this site (Figure 5). PCE concentrations were below the cleanup level of 5 µg/L in all samples collected from wells SGMW-1, SGMW-2, and SGMW-3. The reported PCE concentrations at upgradient well SGMW-1 ranged from non-detect to an estimated 0.36J µg/L. Downgradient wells SGMW-2 and SGMW-3 reported PCE concentrations ranging from an estimated 1.2J µg/L to 1.66 µg/L throughout the monitoring period.

The historic results for upgradient well SGMW-1 indicate PCE concentrations consistently below the cleanup level of 5 µg/L (Appendix C Figure 7). From the beginning of monitoring activities at this site until 2005, PCE concentrations in downgradient wells SGMW-2 and SGMW-3 were often higher than the cleanup level (Appendix C Figures 8 to 9), ranging from 2 µg/L to 29 µg/L (Appendix C Tables 7 to 9). Samples collected from 2006 onward reported concentrations of PCE below the cleanup level, ranging from below 1 µg/L to 4.5 µg/L, indicating successful PCE reduction from source-removal activities.



Figure 5. Southgate Laundry well locations and cVOC results ($\mu\text{g/L}$), 2022 – 2023.

Washington Central Railroad Roundhouse (WCRR)

The WCRR site is in the central portion of the YRRA study area along the railroad tracks (Figure 2). There is no record of remedial activities conducted at this site to reduce PCE contamination. The three WCRR wells are installed in a cluster with completion depths of approximately 30 ft bgs (WDOE-3S), 58 ft bgs (WDOE-3I), and 100 ft bgs (WDOE-3D) (Figure 6). Analytical results from these wells indicate continued elevation of PCE concentrations and associated metabolic breakdown products (Appendix C Tables 10 to 13), demonstrating that the WCRR site represents a significant source of groundwater contamination.

Shallow Well WDOE-3S

During October 2022 and 2023, PCE was detected above the cleanup level in WDOE-3S at an estimated concentration of 9.2J $\mu\text{g/L}$ and 15.4 $\mu\text{g/L}$, respectively. TCE was detected below the cleanup level during 2022 and 2023. DCE and VC were not detected in this well, except for the October 2023 sample, in which DCE was tentatively identified below the 1 $\mu\text{g/L}$ reporting limit. Except for October 2006, PCE concentrations in WDOE-3S have consistently been above the 5 $\mu\text{g/L}$ cleanup level since monitoring began in 1999 (Appendix C Figure 10).

Deep Wells WDOE-3I and WDOE-3D

During October 2022, PCE was detected in wells WDOE-3I and WDOE-3D at an estimated concentration of 9.3J $\mu\text{g/L}$ in both wells. During October 2023, PCE was detected in wells WDOE-3I and WDOE-3D at concentrations of 12.1 $\mu\text{g/L}$ and 11.6 $\mu\text{g/L}$, respectively. PCE concentrations were higher than (exceeded) the 5 $\mu\text{g/L}$ cleanup level in both wells.

TCE was detected in WDOE-3I at an estimated concentration of 1.5J $\mu\text{g/L}$ and 2.25 $\mu\text{g/L}$ in 2022 and 2023, respectively. The estimated TCE concentration in WDOE-3D was 2.7J $\mu\text{g/L}$ and 3.45 $\mu\text{g/L}$ in 2022 and 2023, respectively. In both wells, the TCE concentrations were below the 5 $\mu\text{g/L}$ cleanup level. Increasing TCE concentrations in WDOE-3I were observed during 2009 – 2014, reaching a local maximum of 15 $\mu\text{g/L}$ in October 2014 (Appendix C Figure 11). From 2014 through 2023, TCE concentrations in wells WDOE-3I and WDOE-3D have not been detected at concentrations above the 5 $\mu\text{g/L}$ cleanup level (Appendix C Table 19).

DCE was detected in WDOE-3I and WDOE-3D at estimated concentrations ranging between 1.6J $\mu\text{g/L}$ and 2.2J $\mu\text{g/L}$ during October 2022 and 2023, respectively, below the 70 $\mu\text{g/L}$ cleanup level. VC was detected in WDOE-3I at an estimated concentration of 0.78J $\mu\text{g/L}$ and 1.38J $\mu\text{g/L}$ in 2022 and 2023, respectively, higher than the 0.2 $\mu\text{g/L}$ cleanup level.

PCE concentrations at WDOE-3I have been above the 5 $\mu\text{g/L}$ cleanup level during fall sampling events but have consistently been below the cleanup level during spring sampling since March 2001 (Appendix C Figure 11). PCE concentrations in WDOE-3D have consistently been above the 5 $\mu\text{g/L}$ cleanup level during both spring and fall sampling events since monitoring began, with the exception of June 2000 (Appendix C Figure 12).

Contaminant concentrations in wells WDOE-3I and WDOE-3D indicate that the vertical extent of the plume reaches the deep-water-bearing zone in this portion of the YRRA. The data indicate

that the WCRR facility continues to represent a significant source of groundwater contamination, including both the shallow and deeper portions of the aquifer system.

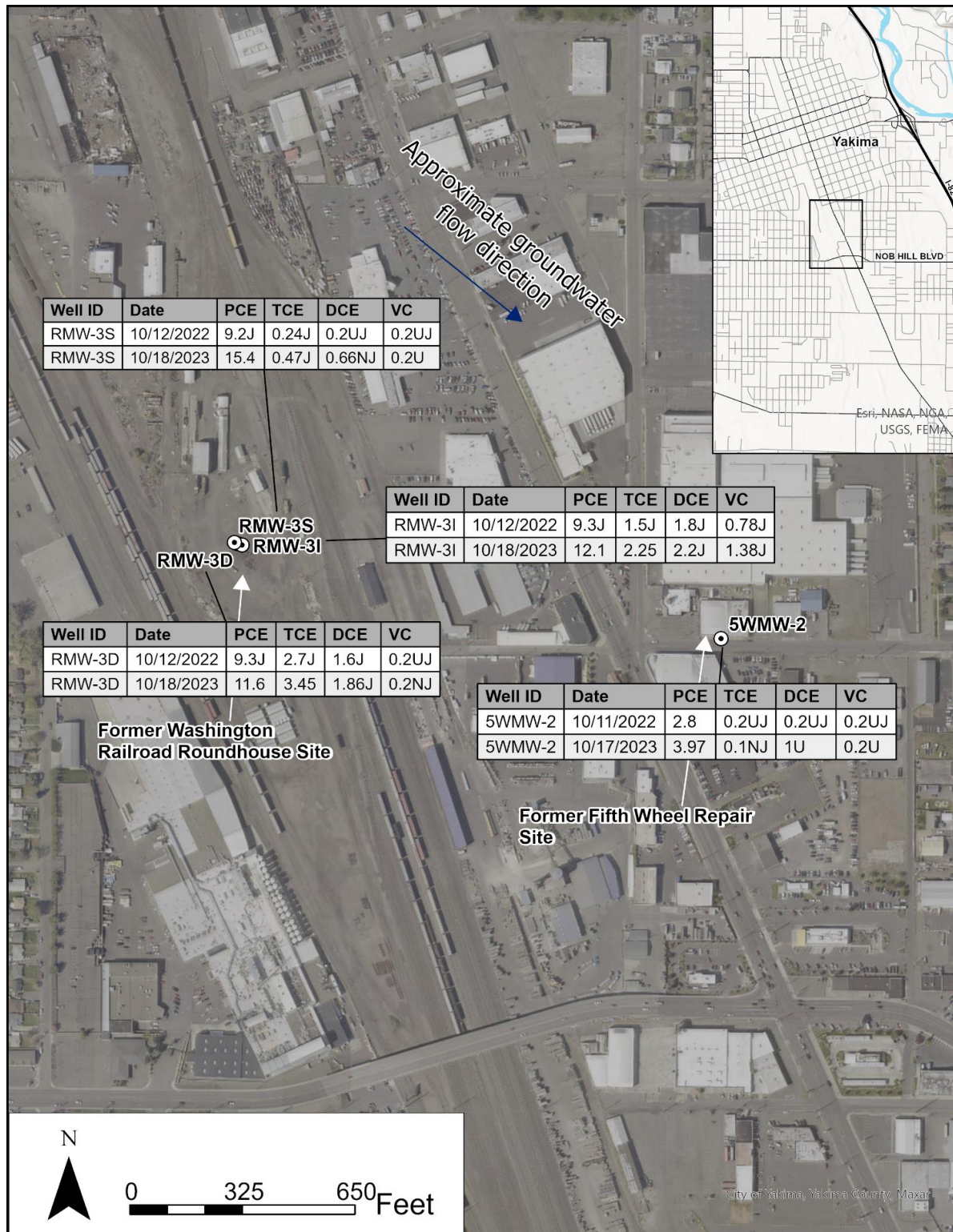


Figure 6. Washington Central Railroad Roundhouse and Fifth Wheel Truck Repair Well locations and cVOC results (µg/L), 2022 – 2023.

Fifth Wheel Truck Repair

Fifth Wheel Truck Repair is approximately 0.3 miles east (cross-gradient) of the WCRR wells, along the east side of the railroad tracks (Figure 2). Cleanup activities occurred onsite between 1991 and 2001 (Maxim Technologies 1996).

During 2022 and 2023, Ecology sampled downgradient well 5WMW-2. PCE was detected at concentrations of an estimated 2.8J $\mu\text{g/L}$ and 3.97 $\mu\text{g/L}$ during 2022 and 2023, respectively, below the 5 $\mu\text{g/L}$ cleanup level. DCE, TCE, and VC concentrations were reported as non-detect, with the exception of the sample collected during October 2023, in which TCE was tentatively identified below the reporting limit (Figure 4).

The PCE concentrations from 1999 through the present for well 5WMW-2 range from less than 1 $\mu\text{g/L}$ to 11 $\mu\text{g/L}$, with higher concentrations occurring in the fall. PCE concentrations suggest a gradual decrease following cleanup activities and have not been greater than the 5 $\mu\text{g/L}$ cleanup level since October 2016 (Appendix C Figure 14).

Cameron Yakima

The Cameron Yakima site occupies the central portion of the YRRA, approximately 0.5 miles southeast (downgradient) of the WCRR wells along the west side of the railroad tracks (Figure 2). Site remedial activities consisting of soil excavation occurred at this site between 1998 and 1999 (Creative Environmental Technologies, Inc. 2000).

Between 2022 and 2023, Ecology collected groundwater samples from 11 wells on the Cameron site. PCE was detected in all 11 wells at concentrations ranging from an estimated 0.91J $\mu\text{g/L}$ in CYIMW107S during October 2022 to 11.4J $\mu\text{g/L}$ in CYIMW103S during April 2023 (Figure 7). Historical groundwater analytical results for the Cameron monitoring wells are presented in Appendix C, Tables 23 – 35 and Figures 16 – 28.

TCE was detected in 10 of the 11 wells, and DCE was detected in seven wells. These PCE degradation products were detected below the applicable reporting limits and fall within the range of historical data collected at the Cameron site since 1997.

VC has not been detected in groundwater samples collected at the Cameron site since sampling began in 1997.

Wells CYIMW106S and CYIMW107S

Upgradient wells CYIMW106S and CYIMW107S are in the northern portion of the Cameron site (Figure 6).

PCE concentrations in CYIMW106S ranged from 4J $\mu\text{g/L}$ to 5.19 $\mu\text{g/L}$ during October 2022 and 2023, respectively. Estimated TCE concentrations in CYIMW106S ranged from non-detect during October 2022 to an estimated concentration below the reporting limit during October 2023. DCE concentrations in CYIMW106S were below the reporting limit. VC was not detected in CYIMW106S during both 2022 and 2023.

PCE concentrations in CYIMW107S ranged from an estimated 0.91J µg/L during October 2022 to 5.03 µg/L during April 2023. TCE concentrations in CYIMW107S ranged from non-detected during October 2022 to an estimated concentration below the reporting limit during April 2022. DCE concentrations in CYIMW107S were reported as non-detected during all sampling events, except for October 2023, which reported an estimated concentration below the reporting limit. VC was not detected in CYIMW107S during both 2022 and 2023.

PCE concentrations have been decreasing in these wells following the cleanup actions, but have not consistently decreased below the cleanup level (Appendix C Figures 19 to 20). PCE concentrations are consistently higher in the fall than in the spring for CYIMW106S. However, this well was only sampled in the fall throughout this reporting period. No apparent seasonal trend is indicated by analytical results from CYIMW107S. Continued elevation in PCE concentrations in these upgradient wells may indicate continued groundwater contamination at the Cameron site from upgradient sources.

Wells CYIMW102S, CYIMW103S, and CYIMW103D

Upgradient wells CYIMW102S, CYIMW103S, and CYIMW103D occupy the northwest portion of the Cameron site (downgradient of CYIMW106S and CYIMW107S) and include two shallow wells (CYIMW102S, CYIMW103S) and one deeper well (CYIMW103D) (Figure 6).

Between 2022 and 2023, PCE concentrations in the two shallow wells ranged from an estimated 5.2J µg/L in CYIMW102S during October 2022 to 11.4 µg/L in CYIMW103S during April 2023. PCE in both wells is consistently above the 5 µg/L cleanup level but has decreased substantially in the years following soil removal activities (Appendix C Figures 16 to 17). In September 1999, prior to soil removal, these wells had some of the highest PCE concentrations in the pre-Frank Wear Cleaners period of YRRA, at approximately 72 µg/L (CYIMW102S) and 139 µg/L (CYIMW103S). Although PCE concentrations continue to exceed the cleanup level in these two shallow wells, PCE in groundwater has decreased substantially since 2006 and is often below 10 µg/L.

PCE was detected at an estimated concentration of 1.93J µg/L and at 2.74 µg/L in the deep well CYIMW103D during April 2022 and 2023, respectively. PCE concentrations from this well have consistently been below the 5 µg/L cleanup level (Appendix C Figure 18).

Concentrations of metabolites TCE and DCE in these wells ranged from non-detects to estimated concentrations below reporting limits throughout the monitoring period. These estimated detections are below the reporting limit of 1 µg/L. There were no detections of DCE for monitoring well CYIMW103D throughout the reporting period. VC was not detected above reporting limits in samples collected between 2022 and 2023.

Wells CYIMW108S and CYIMW111S

Upgradient wells CYIMW108S and CYIMW111S occupy the northeast corner of the site, downgradient from CYIMW106S and CYIMW107S (Figure 6). PCE concentrations in these wells were below the 5 µg/L cleanup level during October 2022 and 2023. PCE detections ranged

from an estimated concentration of 1.3J µg/L to 3.78 µg/L at CYIW111S during 2022 and 2023, respectively.

These two wells typically contain lower PCE concentrations than other Cameron monitoring wells. The maximum PCE concentration in these wells was reported as 7.8J µg/L during August 1998 (Appendix C Figure 21) and has ranged from 0.13J µg/L to 5.9 µg/L following source removal. Only two detections of PCE in these wells have exceeded the cleanup level since source removal activities were completed in 2000.

PCE concentrations in CYIMW111S (Appendix C Figure 24) reached a maximum of 9.4J µg/L prior to the 1998 – 1999 cleanup and have since typically been below the 5 µg/L cleanup level. Occasional exceedances of the cleanup level have occurred, with the most recent exceedance concentration of 5.5 µg/L reported from October 2009.

Wells CYIMW112S, CYIMW113S, and CYIMW114S

Downgradient wells CYIMW112S, CYIMW113S, and CYIMW114S (Appendix C Figures 25 to 28) are located in the southeast corner of the property (Figure 6). Samples were collected at CYIMW112S and CYIMW113S in 2022 and from CYIMW113S and CYIMW114S during 2023. PCE concentrations during 2022 ranged from an estimated 3.9J µg/L at CYIMW112S to 4.6J µg/L at CYIMW113S, below the 5 µg/L cleanup level. PCE concentrations during 2023 exceeded the 5 µg/L cleanup level, ranging from 9.25 µg/L at CYIMW114S to 10.3 µg/L at CYIMW113S. TCE was detected at estimated concentrations below the reporting limit in well CYIMW113S. The sample collected at CYIMW112S during October 2022 did not contain TCE above the reporting limit of 1 µg/L. DCE was detected only in samples collected during 2023, with estimated concentrations below the reporting limit at wells CYIMW113S and CYIMW114S. VC was not detected in samples collected from these wells during the reporting period.

Historical exceedances of the PCE cleanup levels in these wells occurred during December 2000 and March 2001. The PCE concentrations ranged from 8 µg/L to 11.6 µg/L in CYIMW112S, from 9.8 µg/L to 10.3 µg/L in CYIMW113S, and from 15 µg/L to 19.1 µg/L in CYIMW114S.

PCE concentrations in these wells decreased gradually following the cleanup activities in 2000, but increased in 2009 and have since remained near or above the 5 µg/L cleanup level. The elevated PCE concentrations along the downgradient extent of the site indicate possible off-site migration further downgradient.

Deep well CYIMW113D

Downgradient well CYIMW113D is a deep well paired with shallow well CYIMW113S. PCE concentrations in this well were an estimated 2.44J µg/L and 3.32 µg/L during 2022 and 2023, respectively, below the 5 µg/L cleanup level. The only historical PCE detection exceeding the cleanup level occurred during June 2011, with a concentration of 6.1 µg/L (Appendix C Figure 27).



Figure 7. Cameron Yakima well locations and cVOC results ($\mu\text{g/L}$), 2022 – 2023.

Frank Wear Cleaners

The Frank Wear Cleaners site is located at the northern end of the YRRA project area, approximately 0.7 miles upgradient from the WCRR wells (Figure 2). In 2017, the Frank Wear site was added to the YRRA monitoring program.

This site was formerly occupied by a dry-cleaning facility, which historically violated dangerous waste regulations and was identified as a PCE source to the YRRA in 1991. Site soils and groundwater were discovered to be highly contaminated with PCE in 1995 (Maxim 1996). Initial cleanup activities began in 1995 following this discovery and consisted of the following: (1) contaminated soil removal, (2) removal of the Frank Wear building in 2001, (3) soil vapor extraction (SVE) system installation in 2012, and (4) installation of a groundwater recirculation system (GRS) in 2014. The GRS was shut down in 2016 due to financial constraints. The SVE unit remains operational.

Ecology collected groundwater samples from 10 of the 24 wells at the Frank Wear site in 2022 and 2023. Seven of these wells are shallow and are completed to depths of 35 ft bgs, and three wells are deep with completion depths of 92 – 93 ft bgs (Figure 8, Figure 9).

PCE was detected in samples collected from each well sampled throughout the reporting period. PCE concentrations ranged from an estimated 0.17NJ µg/L to 22,000 µg/L. TCE was detected in eight wells at estimated concentrations ranging from 0.21J µg/L to 640J µg/L. DCE was also detected in eight wells at concentrations ranging from an estimated 0.41NJ µg/L to 334 µg/L. VC was detected in four wells at concentrations ranging from 0.42 µg/L to an estimated 57.6J µg/L.

Shallow well FWMW-16 and deep well FWMW-17

Shallow well FWMW-16 and deep well FWMW-17 are in the northwest corner of the Frank Wear site (Figure 8).

PCE and the metabolic breakdown products TCE, DCE, and VC were detected in samples collected from FWMW-16 throughout the reporting period. PCE concentrations ranged from an estimated 29.6J µg/L to 61.3 µg/L during April 2022 and April 2023, respectively, far above the 5 µg/L cleanup level. TCE concentrations ranged from an estimated 5.1J µg/L to 16.5 µg/L during October 2022 and April 2022, respectively, exceeding the cleanup level of 5 µg/L. DCE concentrations ranged from 44.5 µg/L to 67.9 µg/L, below the 70 µg/L cleanup level. VC ranged from estimated concentrations of 6.1J µg/L to 14.9J µg/L during October 2022 and October 2023, respectively, far exceeding the 0.2 µg/L cleanup level.

PCE concentrations in FWMW-17 were low, ranging from a non-detect to an estimated concentration of 0.39B µg/L during April 2023 and April 2022, respectively, below the 5 µg/L cleanup level. PCE breakdown products TCE, DCE, and VC were not detected above reporting limits in samples collected at this well throughout the reporting period.

PCE concentrations in FWMW-16 reached a maximum of 100 µg/L during SVE and GRS operation and had declined significantly until the 2022 – 2023 sampling period (Appendix C

Figure 37). TCE and VC concentrations in FWMW-16 have typically been above their respective cleanup levels since 2016 (Appendix C Figure 38). DCE has not been detected in FWMW-16 above the 70 µg/L cleanup limit, but concentrations indicate increases since 2016.

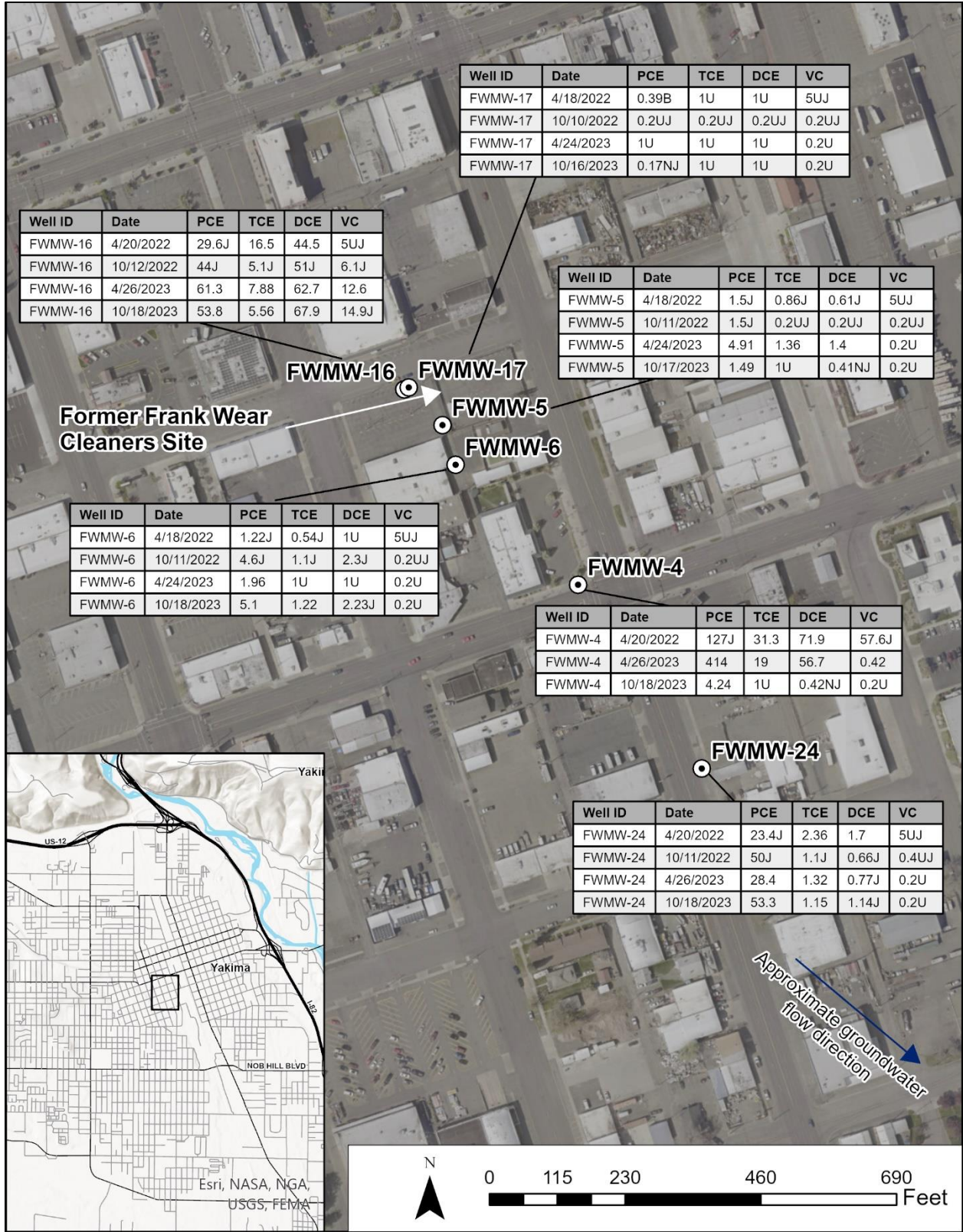


Figure 8. Frank Wear Cleaners well locations and cVOC results ($\mu\text{g/L}$), 2022 – 2023, 1 of 2.

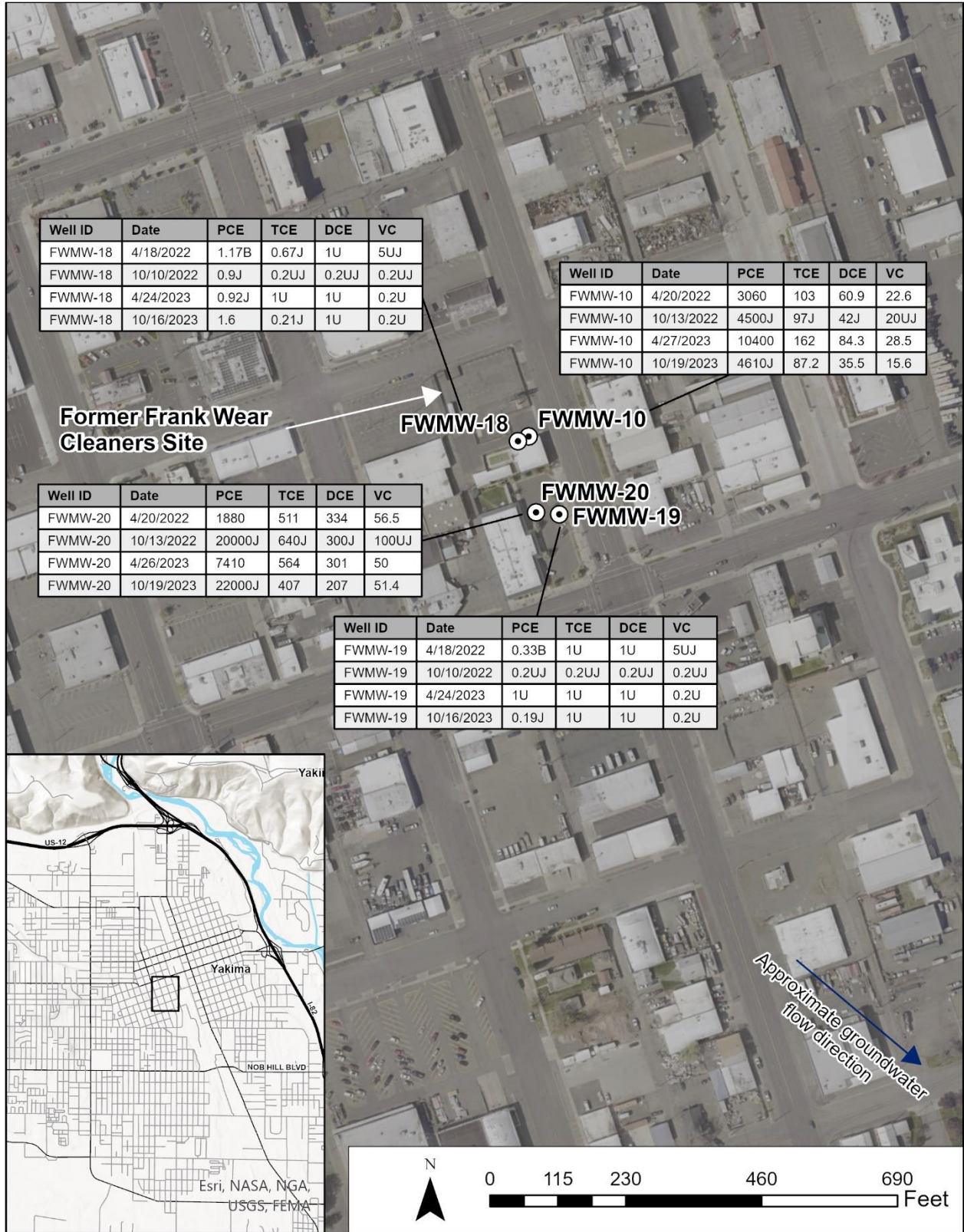


Figure 9. Frank Wear Cleaners well locations and cVOC results ($\mu\text{g/L}$), 2022 – 2023, 2 of 2.

Shallow well FWMW-5 and FWMW-6

Wells FWMW-5 and FWMW-6 are in the northwest edge of the Frank Wear Cleaners site, slightly downgradient from FWMW-16 (Figure 8).

PCE concentrations in FWMW-5 ranged from an estimated 1.5J µg/L to 4.91 µg/L, below the 5 µg/L cleanup level. TCE in FWMW-5 was detected at concentrations ranging from below the reporting limit to below the 5 µg/L cleanup level. DCE was detected at concentrations near the reporting limit of 1 µg/L, below the 70 µg/L cleanup level. VC was not detected in FWMW-5 during the reporting period.

PCE concentrations in FWMW-6 ranged from an estimated 1.22J µg/L to 5.1 µg/L, with the October 2023 sample exceeding the 5 µg/L cleanup level. TCE concentrations were near the 1 µg/L reporting limit, below the 5 µg/L cleanup level. DCE was detected above the reporting limit during October 2022 and October 2023, below the 70 µg/L cleanup level. VC was not detected at this well throughout the 2022 to 2023 sampling period.

Historical exceedances of metabolic breakdown products TCE, DCE, and VC in FWMW-5 and FWMW-6 occurred until 2018 (Appendix C Tables 36 and 37). Results for these metabolites from 2018 onward have been either non-detect or below their respective cleanup levels. Monitoring data show a spike in contaminant concentrations during 2014 in both FWMW-5 (Appendix C Figures 31 and 32) and FWMW-6 (Appendix C Figures 33 and 34), which may have resulted from GRS operation.

Deep Well FWMW-19 and Shallow Well FWMW-20

Deep well FWMW-19 and shallow well FWMW-20 are in the parking lot to the south of the former dry-cleaning facility (Figure 9). FWMW-20 has consistently reported elevated concentrations of PCE and metabolic breakdown products that exceed the applicable cleanup levels (Appendix C Figures 39 and 40). The 2022 and 2023 concentrations were the highest reported in the YRRA and represent a continued increase in PCE concentrations ongoing since 2016.

PCE concentrations in FWMW-20 were far above the 5 µg/L cleanup level through 2022 and 2023, ranging between 1,880 µg/L and an estimated 22,000J µg/L in April 2022 and October 2023, respectively. TCE concentrations ranged from 407 µg/L to an estimated 640J µg/L during October 2023 and October 2022, respectively. DCE concentrations ranged from 207 µg/L to 334 µg/L in October 2023 and April 2022, respectively, exceeding the 70 µg/L cleanup level. VC concentrations ranged from 51.4 µg/L to 56.5 µg/L during October 2023 and April 2022, respectively, far above the 0.2 µg/L cleanup level. Due to the high reporting limit of 100UJ µg/L, VC was reported as non-detect in the sample collected in October 2022.

FWMW-19 is completed in the deeper aquifer and has reported PCE concentrations below the cleanup level since Ecology began sampling the site in 2012 (Appendix C Table 45). PCE concentrations at this well range from non-detects to an estimated 0.33B µg/L. Although the 0.33B µg/L result was associated with a positive detection in an April 2022 transport blank. PCE

was not detected in this well during October 2022. The metabolic breakdown products TCE, DCE, and VC were not detected above reporting limits in samples collected from FWMW-19 during 2022 and 2023.

Wells FWMW-4 and FWMW-24

Wells FWMW-4 and FWMW-24 occupy the southeastern portion of the site and are located approximately 265 ft and 640 ft downgradient from the former dry-cleaning facility, respectively (Figure 8).

PCE concentrations at FWMW-4 ranged from 4.24 µg/L to 414 µg/L during October 2023 and April 2023, respectively, above the 5 µg/L cleanup level during two sampling events (Appendix C Figure 29). TCE concentrations ranged from non-detects to 31.3 µg/L during October 2023 and April 2022, respectively, above the 5 µg/L cleanup level during both spring sampling events. DCE concentrations ranged from a tentatively identified and estimated 0.42NJ µg/L to 71.9 µg/L, above the 70 µg/L cleanup level in April 2022. VC concentrations ranged from non-detects to an estimated 57.6J µg/L during October 2023 and April 2022, respectively, above the 0.2 µg/L cleanup level (Appendix C Figure 30). The October 2022 sample from FWMW-4 was not shipped from MEL to Onsite and was not analyzed.

FWMW-24 is the furthest downgradient well at the Frank Wear site. PCE concentrations at FWMW-24 ranged from an estimated 23.4J µg/L to 53.3 µg/L during April 2022 and October 2023, respectively, above the 5 µg/L cleanup level throughout the reporting period (Appendix C Figure 41). TCE concentrations were slightly above the reporting limit, below the 5 µg/L cleanup level. DCE concentrations were near the reporting limit, below the 70 µg/L cleanup level. VC was not detected during 2022 and 2023 (Appendix C Figure 42).

Wells FWMW-10 and FWMW-18

Wells FWMW-10 and FWMW-18 are situated along the north wall of the former dry-cleaning facility (Figure 9).

PCE and metabolic breakdown products concentrations at FWMW-10 are consistently among the highest at the Frank Wear site (Appendix C Table 39, Figures 35 and 36). PCE concentrations in well FWMW-10 exceeded the 5 µg/L cleanup level during all sampling events, ranging from 3,060 µg/L to 10,400 µg/L during April 2022 and April 2023, respectively. TCE concentrations also exceeded the 5 µg/L cleanup level during all sampling events, ranging from 87.2 µg/L to 162 µg/L during October 2023 and April 2023, respectively. DCE concentrations ranged from an estimated 35.5 µg/L to 84.3 µg/L during October 2023 and April 2023, respectively. The 70 µg/L cleanup level was exceeded only in the April 2023 sample. VC concentrations ranged from 15.6 µg/L to 28.5 µg/L during October 2023 and April 2023, respectively, far exceeding the 0.2 µg/L cleanup level.

FWMW-18 is completed in the deeper water bearing zone and typically contains PCE concentrations below the 5 µg/L cleanup limit (Appendix C Table 44). PCE concentrations in this well ranged from an estimated 0.9J µg/L to 1.6 µg/L during October 2022 and 2023,

respectively. TCE concentrations in this well were reported as estimated detections below the 1 µg/L reporting limit. DCE and VC were not detected above reporting limits in FWMW-18 throughout the reporting period.

Contaminant concentrations have decreased substantially at the Frank Wear site, which appears to be the result of remediation system operation. Prior to Ecology taking over sampling activities at Frank Wear, consultants from Hart Crowser described evidence for PCE mobilization from the soil matrix in addition to reducing conditions in the site groundwater (Hart Crowser 2015). These conditions may enhance reductive dechlorination of cVOCs in groundwater and soil beneath the site.

While groundwater quality has improved significantly at the site following remedial action, high concentrations of PCE, TCE, and VC persist in both the shallow onsite wells and the downgradient off-site wells. Concentrations of cVOCs in site groundwater continue to exceed the applicable cleanup levels. Monitoring data indicate that the PCE plume continues beyond the boundary of the site's monitoring network, suggesting that the full extent of groundwater contamination from the Frank Wear site is not fully delineated.

YRRA Remedial Investigation Wells

The Remedial Investigation monitoring wells are located throughout the entire YRRA. Ecology installed these RI wells across the YRRA to delineate PCE contamination in groundwater away from known source areas. The RI wells were installed as shallow and deep pairs to characterize groundwater in the lower and upper water-bearing zones. Nine wells were selected for continued monitoring and sampled in 2022 and 2023; they are located along the western and southern edges of the YRRA (Figure 2).

PCE was detected in all nine RI wells sampled in 2022 and 2023. PCE concentrations were above the 5 µg/L cleanup level in samples collected from wells RI-4S and RI-6S. Concentrations ranged from an estimated 0.3B µg/L in RI-3S to 19.1 µg/L in RI-4S (Figure 10).

Well RI-3S

RI-3S is the farthest upgradient RI well currently sampled in the YRRA (Figure 10).

PCE was detected in this well at an estimated concentration of 0.3B µg/L during April 2022, below the reporting limit of 1 µg/L. This sample was associated with a PCE detection in a transport blank. PCE was not detected in the April 2023 sample.

PCE concentrations have remained below the 5 µg/L cleanup level in this well since monitoring began in 1999 (Appendix C Figure 43). Since PCE is not naturally occurring, PCE detections at this well indicate that a low-level source of PCE is contaminating the shallow aquifer at the upgradient end of the YRRA study area.

Wells RI-4S and RI-4D

Wells RI-4S and RI-4D are a nested pair located along the western boundary of the YRRA (Figure 10).

PCE concentrations in RI-4S continue to be the highest of the RI wells and are consistently above the 5 µg/L cleanup level (Appendix Table 47, Figure 44). PCE concentration in RI-4S ranged from 12 µg/L to 19.1 µg/L during April 2022 and 2023, respectively.

Well RI-4D contained PCE concentrations ranging from 2.17 µg/L to 3.41 µg/L during April 2022 and 2023, respectively, below the 5 µg/L cleanup levels (Appendix C Figure 45). TCE, DCE, and VC were not detected in samples collected at RI-4S and RI-4D throughout 2022 and 2023.

Concentrations of cVOCs have been relatively stable in RI-4S and RI-4D since 2018, but have increased since 2009. The source responsible for the increased contamination in these wells is uncertain. Data from these wells suggest that the western extent of the YRRA PCE plume is not fully delineated.

Wells RI-5S and RI-5D

Wells RI-5S and RI-5D are in a residential area, approximately 0.7 miles southeast (downgradient) of RI-4S and RI-4D (Figure 10).

PCE concentrations at these wells ranged from 1.31 µg/L to 1.9 µg/L at RI-5D, and from 2.73 µg/L to 3.99 µg/L at RI-5S during April 2022 and 2023, respectively. There were no detections of TCE, DCE, or VC above reporting limits at these wells throughout the reporting period.

Concentrations in both wells began to increase in 2009 and continued until 2017. From 2017 until the present, PCE concentrations have decreased in RI-5S and remained fairly stable in RI-5D (Appendix C Figures 46 and 47). These wells are in a residential area, which suggests that the low PCE levels likely originate from an upgradient source.

Well RI-6S

RI-6S is in the southeast portion of the YRRA project area (Figure 10).

PCE concentrations at RI-6S ranged from an estimated 7J µg/L to 9.38 µg/L during October 2022 and 2023, respectively, above the 5 µg/L cleanup level. PCE concentrations at this location have a seasonal pattern and are typically higher in the fall (Appendix C Figure 48). TCE, DCE, and VC were not detected above reporting limits in this well throughout the reporting period. There is no known source for the contamination in this well, indicating the need for better groundwater characterization in this portion of the YRRA.

Wells RI-9S, RI-10S, and RI-11S

Wells RI-9S, RI-10S, and RI-11S are located towards the southern boundary of the YRRA study area and are the farthest downgradient wells being sampled (Figure 10).

PCE concentrations in these wells ranged from an estimated 0.68J µg/L in RI-11S to 1.53 µg/L in RI-10S during October 2022 and April 2023, respectively, below the 5 µg/L cleanup level (Appendix C Figures 49 to 51). TCE, DCE, and VC were not detected above reporting limits in these wells during 2022 and 2023.

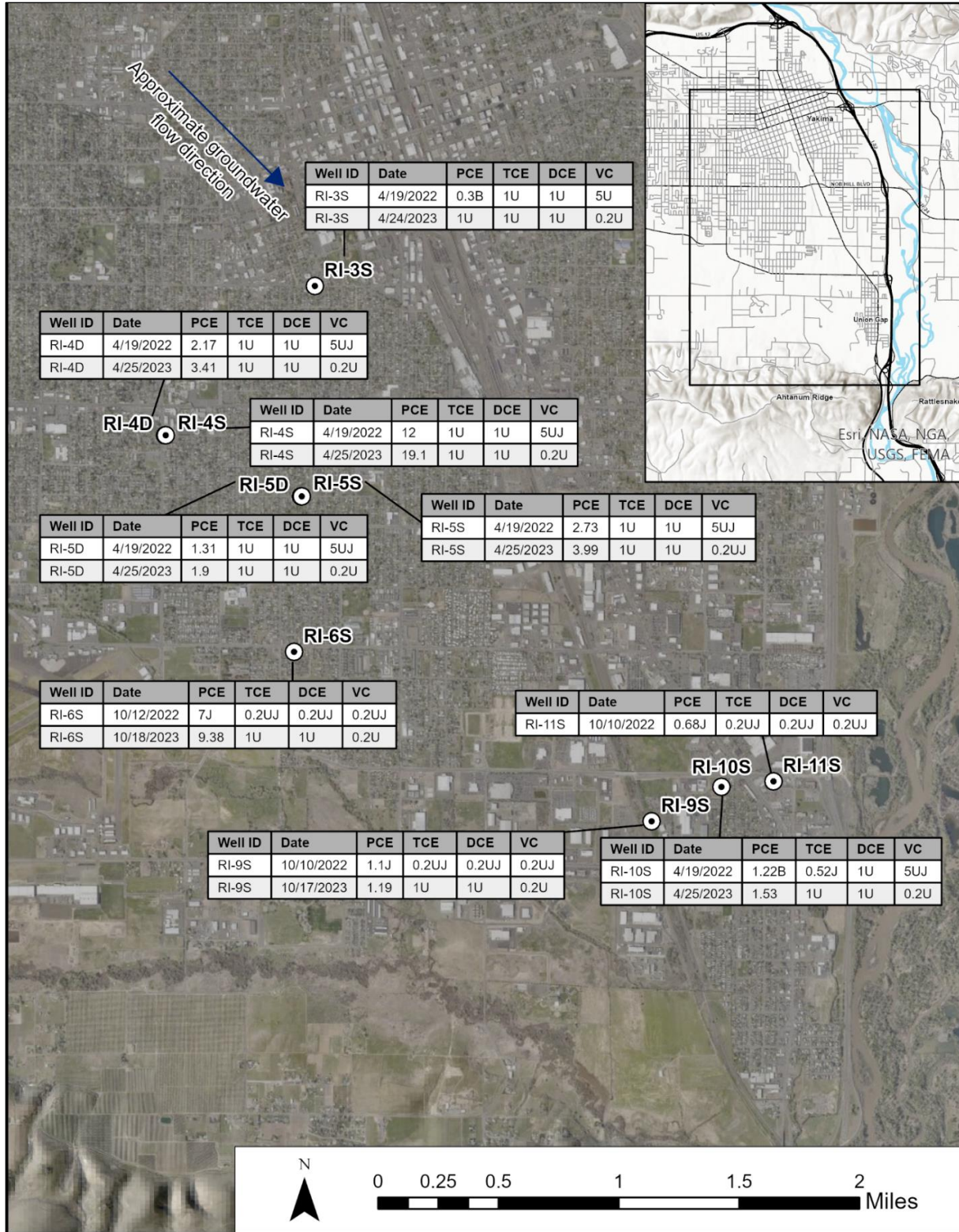


Figure 10. YRRA Remedial Investigation well locations and cVOC results ($\mu\text{g/L}$), 2022 – 2023

Summary

Forty-one wells were sampled within the YRRA in 2022 and 2023; 19 of those sampled (46%) had PCE concentrations above the MTCA Method A cleanup level of 5 µg/L. Wells with PCE concentrations above the cleanup level were located at four established sites: Frank Wear Cleaners, Washington Central Railroad Roundhouse (WCRR), Goodwill-City of Yakima, and Cameron Yakima. Detections of PCE above cleanup levels at two Remedial Investigation wells (RI-4S and RI-6S) represent unknown contaminant sources located along the western edge of the YRRA study area.

Table 4 summarizes the maximum annual PCE concentrations at each site in 2022 and 2023. PCE exceedances generally occur in wells in the shallow water-bearing zone, with completion depths ranging from 26 to 40 ft below ground surface (bgs). The maximum PCE concentrations in these wells ranged from 5.2 µg/L to an estimated 20,000 µg/L during 2022, and from 5.03 µg/L to an estimated 22,000 µg/L during 2023.

The Frank Wear Cleaners site was added to the monitoring program in 2017 and has the highest concentrations of PCE, TCE, DCE, and VC in the YRRA. This site is a significant source of cVOC contamination in groundwater across the study area.

At the WCRR site, PCE, TCE, DCE, and VC have been consistently detected. Contamination is present in all three wells (shallow, intermediate, and deep). PCE concentrations at this site exceeded the cleanup level in all wells sampled during October 2022 and 2023.

At the Cameron Yakima site, PCE concentrations exceeded the cleanup level in six wells. PCE breakdown products were observed at concentrations below the MTCA cleanup levels.

The Goodwill site reported PCE concentrations exceeding the cleanup levels in two wells during 2023. PCE breakdown products were not detected above reporting limits in samples collected during the reporting period. Monitoring data from the Frank Wear, WCRR, Goodwill, and Cameron wells confirm that PCE continues to impact shallow groundwater in the central portion of the YRRA. It is not apparent whether the contaminant plumes are separate or co-mingled.

Table 4. Summary of 2022 and 2023 cleanup level exceedances.

Site	Well	Year	April PCE	April TCE	April DCE	April VC	October PCE	October TCE	October DCE	October VC
Cameron	CYIMW102S	2022	—	—	—	—	<u>5.2J</u>	0.23J	0.2UJ	0.2UJ
	CYIMW102S	2023	—	—	—	—	<u>6.61</u>	0.27J	0.47J	0.2U
	CYIMW103S	2022	<u>7.45J</u>	0.99J	0.2J	5UJ	<u>6J</u>	0.38J	0.2UJ	0.2UJ
	CYIMW103S	2023	<u>11.4</u>	0.72J	0.26J	0.2U	<u>5.84</u>	0.34J	0.47J	0.2U
	CYIMW106S	2023	—	—	—	—	<u>5.19</u>	0.16J	0.42NJ	0.2U
	CYIMW107S	2023	<u>5.03</u>	0.23J	1U	0.2U	—	—	—	—
	CYIMW113S	2023	<u>10.3</u>	0.55J	0.18J	0.2U	—	—	—	—
	CYIMW114S	2023	—	—	—	—	<u>9.25</u>	0.5J	0.51J	0.2UJ
Frank Wear	FWMW-4	2022	<u>127J</u>	31.3	71.9	57.6J	—	—	—	—
	FWMW-4	2023	<u>414</u>	<u>19</u>	56.7	<u>0.42</u>	—	—	—	—
	FWMW-6	2023	—	—	—	—	<u>5.1</u>	1.22	2.23J	0.2U
	FWMW-10	2022	3060	103	60.9	22.6	4500J	97J	42J	20UJ
	FWMW-10	2023	10400	162	84.3	28.5	4610J	87.2	35.5	15.6
	FWMW-16	2022	<u>29.6J</u>	<u>16.5</u>	44.5	5UJ	<u>44J</u>	<u>5.1J</u>	51J	<u>6.1J</u>
	FWMW-16	2023	<u>61.3</u>	<u>7.88</u>	<u>62.7</u>	<u>12.6</u>	<u>53.8</u>	<u>5.56</u>	<u>67.9</u>	<u>14.9J</u>
	FWMW-20	2022	1880	511	334	56.5	20000J	640J	300J	100UJ
	FWMW-20	2023	7410	564	301	50	22000J	407	207	51.4
	FWMW-24	2022	<u>23.4J</u>	2.36	1.7	5UJ	<u>50J</u>	1.1J	0.66J	0.4UJ
FWMW-24	2023	<u>28.4</u>	1.32	0.77J	0.2U	<u>53.3</u>	1.15	1.14J	0.2U	
Goodwill	GMW-1	2023	<u>8.8</u>	1U	1U	0.2U	—	—	—	—
	GMW-2	2023	<u>14.8J</u>	1U	1U	0.2U	<u>13.8</u>	1U	1U	0.2U
WCRR	RMW-3D	2022	—	—	—	—	<u>9.3J</u>	2.7J	1.6J	0.2UJ
	RMW-3D	2023	—	—	—	—	<u>11.6</u>	3.45	1.86J	0.2NJ
	RMW-3I	2022	—	—	—	—	<u>9.3J</u>	1.5J	1.8J	0.78J
	RMW-3I	2023	—	—	—	—	<u>12.1</u>	2.25	2.2J	1.38J
	RMW-3S	2022	—	—	—	—	<u>9.2J</u>	0.24J	0.2UJ	0.2UJ
	RMW-3S	2023	—	—	—	—	<u>15.4</u>	0.47J	0.66NJ	0.2U

Site	Well	Year	April PCE	April TCE	April DCE	April VC	October PCE	October TCE	October DCE	October VC
RI Wells	RI-4S	2022	<u>12</u>	1U	1U	5UJ	—	—	—	—
	RI-4S	2023	<u>19.1</u>	1U	1U	0.2U	—	—	—	—
	RI-6S	2022	—	—	—	—	<u>7.0J</u>	0.2UJ	0.2UJ	0.2UJ
	RI-6S	2023	—	—	—	—	<u>9.38</u>	1U	1U	0.2U
Cleanup Level (µg/L)			5	5	70	0.2	5	5	70	0.2

PCE: Tetrachloroethene; TCE: Trichloroethene; DCE: cis-1,2-dichloroethene; VC: Vinyl chloride;

Results in µg/L; —: Not sampled; **Bold**: Analyte was detected; **Bold and Underlined**: Analyte was detected at a concentration above the cleanup level;

U: Analyte was not detected at or above the reported value;

J: Analyte was positively identified (the associated numerical result is an estimate).

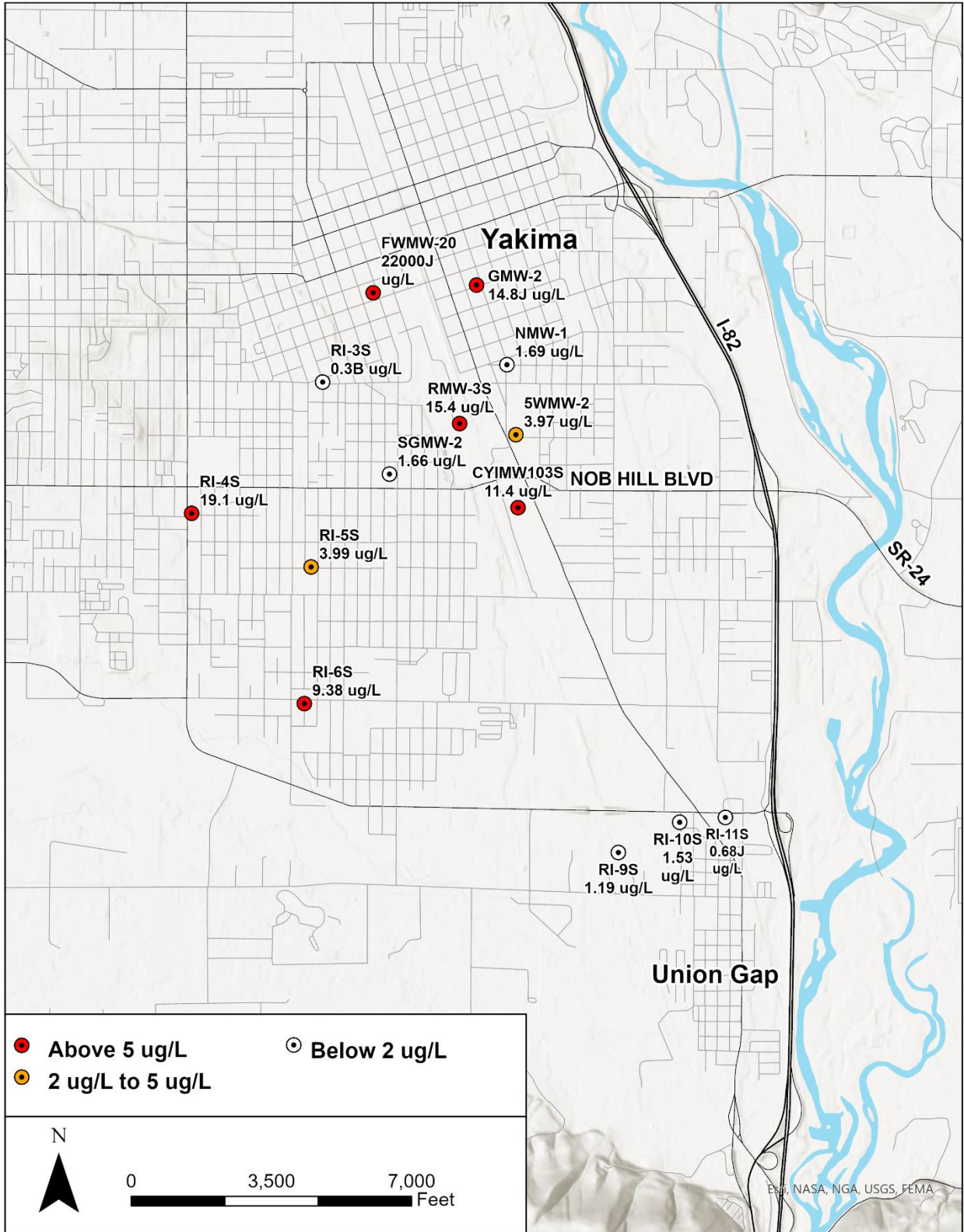


Figure 11. Shallow zone maximum PCE concentrations by site, 2022 – 2023.

Conclusions

Dissolved tetrachloroethene (PCE) continues to exceed cleanup levels in the shallow, unconfined aquifer throughout the Yakima Railroad Area (YRRA) project area. Remediation performed at individual sites appears to have reduced contaminant concentrations in groundwater at many of the identified source areas. However, many areas continue to contain contaminant concentrations higher than (exceed) the established Model Toxics Control Act (MTCA) cleanup levels. Results from 2022 and 2023 indicate an increase in wells exceeding the cleanup levels.

Historically, 59 wells have been sampled throughout this long-term YRRA monitoring program.

- Beginning in 2013, Ecology selected a subset of 36 wells for continued monitoring. Wells were removed from the active monitoring program if they consistently contained low or non-detectable concentrations of cVOC, primarily PCE.
- In 2017, the YRRA well network was augmented through the addition of 10 wells at the Frank Wear site. Two wells were discontinued at this time: (1) a well at the Nu-Way site that was decommissioned in 2016 and (2) a well at Agri-Tech, a former pesticide production facility.

During 2022 and 2023, Ecology collected groundwater samples from 41 of the 44 wells remaining in the monitoring network. The selected subset of wells provides data to evaluate groundwater conditions throughout the YRRA project area.

Existing Cleanup Sites

Thirty-five of the 44 remaining wells in the YRRA monitoring network are associated with seven identified source areas.

- Six of the source areas – Cameron Yakima, Fifth Wheel, Frank Wear Cleaners, Goodwill, Nu-Way Cleaners, and Southgate Laundry – have undergone remedial action to address PCE contamination. Remediation at these sites appears to have reduced the impact of PCE contamination in groundwater or eliminated sources entirely.
- Three of the six source areas – Fifth Wheel, Nu-Way Cleaners, and Southgate Laundry – have consistently reported PCE concentrations below the 5 µg/L cleanup level in recent years. The last instance of PCE concentrations above the cleanup level at Southgate Laundry occurred in 2005. PCE has not been above the cleanup level at Nu-Way since June 2011. The last detection above the cleanup level at the Fifth Wheel site was in October 2016, though the PCE concentration in October 2018 was 5 µg/L, equivalent to the cleanup level.
- The seventh source area – Washington Central Railroad Roundhouse (WCRR) – has no record of any direct remedial action. The three wells at this site are installed as a well cluster with varying depths.

PCE concentrations in the WCRR shallow and deep wells indicate a vertical component to the contaminant plume that extends to the deep water-bearing zone in this portion of the YRRA. PCE metabolic breakdown products, including TCE and DCE, are also typically present in concentrations that exceed the cleanup level. The WCRR site continues to be a significant source of cVOC groundwater contamination, including the deeper portions of the aquifer system.

The Frank Wear Cleaners site was added to the YRRA monitoring program in 2017 and represents the largest source of cVOC contamination to the project area. Ecology sampled groundwater in 10 of the 24 site wells, seven shallow wells, and three deep wells. In-situ remediation activities at the site appear to have reduced contaminant mass. However, this site continues to contain the highest levels of cVOCs in the project area. PCE metabolic breakdown products are detected at concentrations above their respective cleanup levels. Elevated cVOC concentrations in the shallow onsite and downgradient off-site wells indicate that the contaminant plume beyond the monitoring well network is not fully delineated. cVOC concentrations in the deep wells were near or below the reporting limit, suggesting limited vertical migration.

The 2022 and 2023 monitoring data demonstrate that the highest contaminant concentrations continue to occur in the central portion of the YRRA, at Frank Wear Cleaners, WCRR, Goodwill, and Cameron Yakima. While remedial activities have occurred at three of these locations, the full extent of the contaminant plume is still poorly delineated. Further investigation is necessary at these four sites to delineate the full extent of the PCE plumes and to determine whether the plumes have comeled.

Remedial Investigation Wells

The Remedial Investigation site consists of 29 wells installed throughout the YRRA. These wells were installed as shallow and deep pairs at 15 locations spanning the project area to characterize aquifer properties and to determine the lateral and vertical extent of PCE contamination in groundwater throughout the YRRA.

Nine RI wells (RI-3S, RI-4D, RI-4S, RI-5D, RI-5S, RI-6S, RI-9S, RI-10S, and RI-11S) are currently sampled as part of the monitoring program. These wells are located primarily along the southern and western boundaries of the YRRA.

- In seven of the nine wells, PCE was detected at concentrations below the MTCA cleanup level during the 2022 – 2023 reporting period. Because PCE is not naturally occurring, the low concentrations detected in these wells indicate low-level sources of PCE exist and are contributing to the contamination in the YRRA.
- Wells RI-4S and RI-6S, located on the western edge of the YRRA, consistently report PCE concentrations above the 5 µg/L cleanup level. The source of PCE contamination in these wells is still unknown and requires further remedial investigation.

Contaminant Impacts to Deep Water-Bearing Zones

Nine of the 41 wells sampled in the YRRA between 2022 and 2023 are screened in the deeper water-bearing zone (50 – 120 ft bgs). Two deep wells (WDOE-3I and WDOE-3D) contained PCE concentrations that are higher than (exceed) the 5 µg/L MTCA cleanup level.

The remaining seven deep wells consistently report cVOC concentrations below the applicable cleanup levels and have remained relatively stable throughout the 1997 – 2023 monitoring period. Three of these wells are located at the Frank Wear Cleaners site; two are part of the Remedial Investigation network, located along the western extent of the YRRA; and two are located at the Cameron Yakima site.

Recommendations

The continued presence of cVOC concentrations in groundwater throughout the Yakima Railroad Area (YRRA) originates from both identified and unidentified sources. Cleanup activities and investigations continue throughout the project area to address groundwater contamination.

Based on data from the 2022 and 2023 monitoring activities in the YRRA, the following recommendations are provided:

- Further remedial investigation should be conducted at the following sites to fully delineate the lateral and vertical extent of the contaminant plume: (1) Frank Wear Cleaners, (2) Cameron Yakima, and (3) Washington Central Railroad Roundhouse.
- Investigation should be conducted near Remedial Investigation wells RI-4S/D and RI-6S to determine the sources of PCE contamination along the western edge of the project area.
- Conducting a study of water-level data over an entire year may identify seasonal variations in approximate groundwater flow direction over the YRRA. Spatial or temporal variation in the hydrologic gradient may indicate contaminant transport from areas beyond the current project area.
- Removal from the sampling schedule of some or all wells consistently below the cleanup level may improve the cost-effectiveness of this project. These wells are located at the following sites: (1) Nu-Way Cleaners, (2) Southgate Laundry, and (3) Fifth Wheel.
- The Frank Wear Cleaners site should be evaluated for seasonal trends in PCE concentrations. Strong seasonal variation may warrant reducing the sampling frequency to once per year, with samples collected during the highest expected concentrations.
- Continue monitoring of wells within the project area to assess seasonal fluctuations and recent increases of PCE concentrations.

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Glossary, Acronyms, and Abbreviations

Glossary

Analyte: Water quality constituent being measured (parameter).

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Dissolved oxygen: A measure of the amount of oxygen dissolved in water.

Groundwater: Water in the subsurface that saturates the rocks and sediment in which it occurs. The upper surface of groundwater saturation is commonly termed the water table.

Method Detection Limit: This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984).

Oxidation-Reduction Potential: A measure of the oxidizing or reducing potential of water. Values greater than 0 indicate oxidizing conditions. Values less than zero indicate reducing conditions.

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Reporting limit: The minimum value of the calibration range. Analyte detections between the method detection limit and the reporting limit are reported as having estimated concentrations.

Specific conductance: A measure of water's ability to conduct an electrical current. Specific conductance is related to the concentration and charge of dissolved ions in water.

Unconfined aquifer: An aquifer containing water that is not under pressure; the water level in a well is the same as the water table outside the well.

Acronyms and abbreviations

DCE	Cis-1,2-dichloroethene
DO	Dissolved oxygen
Dup	Duplicate
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FS	Feasibility study
GRS	Groundwater recirculation system
LDPE	Low Density Polyethylene
MEL	Manchester Environmental Laboratory
MSL	Mean Sea Level
MTCA	Model Toxics Control Act
MQO	Measurement Quality Objective
MW	Monitoring well
ORP	Oxidation-reduction potential
PCE	Tetrachloroethene
PVC	Polyvinyl chloride
RI	Remedial investigation
RPD	Relative percent difference
SOP	Standard operating procedure
SVE	Soil vapor extraction
TCE	Trichloroethene
TCP	Toxics Cleanup Program
TOC	Top of casing
USGS	U.S. Geological Survey
VC	Vinyl chloride
VOA	Volatile Organic Analysis
cVOC	chlorinated Volatile Organic Compounds
WAC	Washington Administrative Code
WCRR	Washington Central Railroad Roundhouse
YRRA	Yakima Railroad Area (the project area)

Units of Measurement

°C	degrees centigrade
ft	ft
mg/L	milligrams per liter
mV	milli volts
s.u.	standard units
µg/L	micrograms per liter (parts per billion)
uS/cm	microsiemens per centimeter, a unit of conductivity

Appendices

The following Appendices are linked to this report at

<https://apps.ecology.wa.gov/publications/SummaryPages/2603003.html>.

Appendix A. Well Construction Details and Field Measurement Data

Appendix B. Quality Assurance Review

Appendix C. Project Results, December 1997 – October 2023