Play Area Interim Action Monitoring Report

Gas Works Park Site
Seattle, Washington

for
Puget Sound Energy and the City of Seattle

August 13, 2021

GeoEngineers
Earth Science + Technology

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ACRONYMS AND ABBREVIATIONS

Acronym/ Abbreviation	Description
City	City of Seattle
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
FS	Feasibility Study
GPM	gallons per minute
IAWP	Interim Action Work Plan
LNAPL	light nonaqueous phase liquids
µ/L	micrograms per liter
mg/L	milligrams per liter
MTCA	Model Toxics Control Act
PSE	Puget Sound Energy
QAPP	Quality Assurance Project Plan
RI	Remedial Investigation
SAP	Sampling and Analysis Plan
SI	Supplemental Investigation
SPR	Seattle Parks and Recreation
UIC	Underground Injection Control
WAC	Washington Administrative Code

1.0 INTERIM ACTION BACKGROUND

1.1. Site Background

The Play Area is within Gas Works Park, a 20-acre park located at 1801 North Northlake Way, in Seattle, Washington. The park is part of the Gas Works Park cleanup site (GWPS; Figure 1). The Play Area is near the shoreline of Lake Union (Figure 2).

Formerly, the Play Area portion of the GWPS was the location of a manufactured gas treatment operation that used a Thylox process to remove hydrogen sulfide. The former treatment facilities, including the Kelly Filter, are shown on Figure 2. The Thylox process used a sodium thioarsenate solution to remove hydrogen sulfide from the manufactured gas. The detection of elevated arsenic in soil and groundwater in this area likely reflects past releases of sodium thioarsenate, which migrated downward through soil and groundwater because it was denser than water. Local geology and geochemistry controlled how and where it moved.

1.2. Interim Action Objectives

The primary objectives of the Play Area Groundwater Treatment Interim Action (Interim Action) were to install remediation infrastructure that would allow in-situ treatment of arsenic in groundwater beneath the Play Area following renovation of the Play Area and to perform in situ treatment using the remediation infrastructure to reduce dissolved arsenic concentrations in groundwater in the vicinity of the Play Area. No screening level or concentration goal was established for the interim action. The cleanup standard for dissolved arsenic is being developed as part of the FS.

1.3. Regulatory Process

The Interim Action was authorized under the Second and Third Amendments to the 2005 Agreed Order (No. DE 2008) between Puget Sound Energy (PSE), City of Seattle (City), and Washington State Department of Ecology (Ecology) for the Gas Works Park Sediment Site. The April 2017 Second Amendment authorized installation of the groundwater treatment infrastructure and associated groundwater monitoring wells (Ecology 2017a). Following treatment and monitoring infrastructure installation, the Play Area Groundwater Treatment Interim Action Work Plan (Work Plan) (GeoEngineers 2017a) was prepared to support the August 2017 Third Amendment (Ecology 2017b). The Third Amendment authorized the in-situ treatment and monitoring described in the Work Plan.

Injection wells are part of the groundwater treatment infrastructure that was installed at the Play Area and are regulated by Ecology under the requirements of Washington Administrative Code (WAC) 173-218 (Underground Injection Control [UIC] Program). The Interim Action injection wells are considered Class V injection wells per WAC 173-218-040(5)(a)(x) and were registered with the Ecology UIC program prior to being used for injection to meet the regulatory requirements for Model Toxics Control Act (MTCA) cleanup actions completed under Ecology supervision.

1.4. Purpose and Contents of Monitoring Report

This Play Area Interim Action Monitoring Report (Monitoring Report) documents the groundwater treatment performed and presents monitoring results. Ecology’s January 6, 2021 letter to PSE and the City requested a groundwater monitoring report summarizing monitoring results, including conclusions and recommendations, and an Interim Action Completion Report. Ecology will use these reports to determine if the interim action work conducted in accordance with Agreed Order No. DE 2008 is complete.

The primary purpose of this Monitoring Report is to present the results of the Interim Action. Section 2 includes a description of the Interim Action infrastructure installation and the treatment performed. The results of the baseline, short-term, performance, and confirmation monitoring are presented in Sections 3 to 6. Section 7 provides conclusions and recommendations.

2.0 INTERIM ACTION TREATMENT

This section provides an overview of the Interim Action infrastructure and treatment. Details regarding the construction of the infrastructure will be presented in a separate Play Area Interim Action Completion Report.

2.1. Interim Action Infrastructure

The Interim Action infrastructure was designed to treat groundwater within both the fill and outwash units below the Play Area. Figure 3 presents a cross-sectional view showing the fill and outwash units at the Play Area. The footprint of the injection infrastructure was designed to allow treatment within the limits of the Play Area. The layout of the injection infrastructure and groundwater monitoring well network was based on hydrogeologic conditions and pretreatment arsenic concentrations in fill and outwash groundwater presented on Figures 4 and 5, respectively. Infrastructure design is documented in the August 2016 memorandum titled “Supplemental Play Area Investigation and Treatment Infrastructure Construction” (GeoEngineers 2016a). The basis for the monitoring well layout is described in the December 2016 memorandum titled “Play Area Injection Infrastructure Groundwater Monitoring Well Network” (GeoEngineers 2016b). Both of these documents will be appendices to a separate Play Area Interim Action Completion Report.

The Interim Action treatment infrastructure includes injection wells, underground conveyance piping connected to each injection well, and below ground utility vaults located outside the Play Area where the conveyance piping terminates. The Interim Action monitoring well network consists of existing and new monitoring wells located within and outside the fill and outwash treatment areas. The Interim Action was designed to treat arsenic in fill unit and outwash unit groundwater within the Play Area. To achieve this, the injection infrastructure and monitoring network includes wells screened in the fill unit and wells screened in the outwash unit. The injection wells consist of 22 wells screened in the fill unit and 13 wells screened in the outwash unit. Injection wells are located in rows with individual wells generally spaced 20 feet on center in the cross-gradient direction (north to south). The rows of injection wells are generally spaced 30 feet apart. However, specific injection well locations were constrained by the presence of surface and subsurface obstructions. Figure 6 presents the layout of the Interim Action injection infrastructure, including injection wells and conveyance piping and vaults

Following installation of the treatment infrastructure in 2017, the Interim Action monitoring well network was installed to allow sampling to evaluate the performance of the in-situ treatment. In addition, several monitoring wells were installed along the shoreline to evaluate long-distance effects of the treatment on groundwater quality and to evaluate groundwater quality along the shoreline. The monitoring well installation included 15 new monitoring wells to supplement the two existing monitoring wells (MW-36S and MW-36D), resulting in nine wells screened in the fill unit and eight wells screened in the outwash unit, as shown on Figure 7. The Interim Action monitoring network consists of:

- Nine monitoring wells located within the expected area of influence of treatment (six fill unit wells and three outwash unit wells),

- Two upgradient monitoring wells (one fill unit well and one outwash unit well), and
- Six downgradient monitoring wells near the shoreline (two fill unit wells and four outwash unit wells).

2.2. Interim Action Treatment

Based on treatability testing the Interim Action used an in-situ arsenic treatment technology for reducing dissolved concentrations of arsenic in Play Area groundwater. Treatability testing showed that elevated arsenic concentrations in Play Area groundwater can be reduced by applying iron-containing amendments that act to decrease the soluble arsenic fraction in groundwater. The tested iron-containing amendments work by reducing groundwater pH and sulfide concentrations, which results in arsenic sequestration within the soil matrix. The treatability testing results are summarized in the Arsenic Treatability Study Report (Anchor QEA 2016). The report shows that a dilute solution of ferrous sulfate ($FeSO4$) is compatible with site conditions and is capable of significant reduction of dissolved arsenic in groundwater. This report will be an appendix to a separate Play Area Interim Action Completion Report.

The general treatment approach for the Interim Action neutralizes high pH and increases iron concentrations to sequester dissolved arsenic by precipitation as well as creating conditions favorable for adsorption. The ferrous sulfate reagent was selected to form iron oxyhydroxides and sulfide phases over time, which will remove arsenic from groundwater by precipitation and enhance the long-term arsenic adsorption capacity of the aquifer solids.

A total of approximately 100,000 gallons of ferrous sulfate reagent at 5 percent concentration (21 tons of solid ferrous sulfate) were injected into the 22 fill unit and 13 outwash unit injection wells. The reagent injections occurred over three injection events. Reagent was handled and mixed in accordance with the Work Plan (GeoEngineers 2017a) utilizing a mobile injection system positioned outside the Play Area footprint. The injection system connected to multiple injection wells simultaneously and allowed monitoring of injection pressure and flow rate for each well to monitor injected reagent at each injection well. Table 1 presents a summary of the injection quantities and flow rates for each injection well over the three injection events. Figure 6 presents the location of the injection wells, grouped in four parallel rows (A, B, C, and D).

As presented in Table 1, flow rates used for injection varied from less than 0.5 gallons per minute (GPM) to over 3 GPM. As expected, the lowest flow rates were used for fill wells in the A and B lines (Figure 6). The fill treatment zone in this area is shallow, thin, and consists of fine-grained soils underlain by a silt confining layer, requiring injection using low pressure and flow rates over longer periods. Fill soil in the vicinity of the C and D injection wells consists of coarser agglomerate that is more permeable, allowing higher flow rates of up to 3.2 GPM. The outwash unit has an intermediate permeability compared to the overlying fill unit. The thicker outwash saturated zone and the corresponding longer-screened injection wells allowed a moderate flow rate of 1.2 to 1.9 GPM.

The first two rounds of injections, conducted in 2017 and 2018 respectively, included all 35 injection wells. The third round conducted in 2019, focused on the downgradient areas, injecting 20 wells within the C and D lines. The total volume of reagent injected in each set of injection wells is listed below:

UNIT TOTAL VOLUME OF REAGENT

Unit	Wells	Gallons
A line Fill	A1, A2, A3, A4, and A5	4,500
B line Fill	B1, B2, B4, B6, B7, and B8	7,600
B line Outwash	B4 and B5	3,200
C line Fill	C1, C2, C4, C6, C8, and C9	22,200
C line Outwash	C3, C5, C7, C10, C11, and C12	21,500
D line Fill	D1, D3, D5, D7, and D10	18,800
D line Outwash	D2, D4, D6, D8, and D9	21,600

3.0 INTERIM ACTION MONITORING

This section describes the monitoring completed during the Interim Action.

3.1. Monitoring Scope and Schedule

Monitoring evaluated the effectiveness of the ferrous sulfate reagent injection at generating the desired geochemical conditions for treatment (i.e., reduced pH and increased iron and sulfate concentrations) and at reducing dissolved arsenic concentrations within the footprint of the treatment layout. In addition, the monitoring evaluated downgradient effects of the treatment in the form of reduced dissolved arsenic as well as direct chemical influence from the injected reagent. The monitoring well network for the Interim Action, in relation to the injection well locations, is shown on Figure 7. The objectives for each monitoring event are described in the following paragraphs.

Generally, the Interim Action monitoring consisted of performing baseline sampling to evaluate pre-treatment conditions, short-term monitoring to collect groundwater data during and immediately following the reagent injection to evaluate the short-term influence of reagent injection, and performance monitoring to collect post-injection samples to evaluate treatment performance following treatment. Confirmation monitoring was conducted to evaluate longer-term performance and stability of the arsenic treatment and characterize final conditions to be considered during completion of the feasibility study for the GWPS.

Groundwater samples collected throughout the Interim Action monitoring were collected using low-flow methods in accordance with the Sampling and Analysis Plan (GeoEngineers 2017b). Prior to sampling, groundwater elevation measurements were collected from each of the Interim Action monitoring wells. Field parameters were measured during purging with a multi-parameter water quality meter, including dissolved oxygen, pH, specific conductivity, turbidity, temperature, and oxidation-reduction potential.

Baseline monitoring was conducted after installation of treatment and monitoring infrastructure to measure conditions prior to initiating treatment. Baseline monitoring involved measurement of groundwater elevations and collecting groundwater samples from all 17 Interim Action monitoring wells for field parameters and chemical analytical testing to document arsenic concentrations and geochemical conditions before in-situ treatment.

Short-term monitoring was conducted to evaluate the conditions during and immediately following reagent injection, including injection flow conditions and the conditions at monitoring wells located near the injection wells. Injection well flow conditions (pressure and flow rate) were monitored during injection to manage the injection process. Short-term monitoring included groundwater sampling at eight monitoring wells within the immediate vicinity of the injection wells: fill unit wells MW-42S, MW-43S, MW-44S, MW-45S, and MW-47S and outwash unit wells MW-45D, MW-46D, and MW-48D. The effect of reagent injection on nearby groundwater elevation and chemistry were measured at monitoring wells near the injection wells during and for a short period immediately following injection to evaluate the immediate influence of reagent injection at various distances away from the injection wells.

Performance monitoring events were conducted following completion of each injection event and consisted of sampling all 17 wells in the monitoring well network, including shoreline monitoring wells outside the targeted treatment area. These shoreline wells were monitored to evaluate the potential for downgradient effects of injected reagent as well as the potential for reduction of arsenic concentrations beyond the expected treatment area. The performance monitoring events were conducted approximately one month after injection to evaluate conditions after the immediate hydraulic effects of injection had subsided and the injected reagent had affected groundwater geochemistry enough to result in reduced dissolved arsenic. In addition to the planned one-month performance monitoring event, additional performance monitoring was conducted to evaluate longer-term results and provide a new baseline for the subsequent injection events in 2018 and 2019. Prior to each of the two subsequent rounds of injection, pre-treatment conditions were reestablished by conducting a performance sampling event prior to injection. These events were referred to as Baseline 2 and Baseline 3 (Tables 2, 3, and 4), as they also served to evaluate conditions immediately prior to injection to inform treatment.

Confirmation monitoring was intended to evaluate conditions following completion of treatment activities, including an extended period after which any rebound of arsenic concentrations would be observed to evaluate the sustained performance of the treatment. Confirmation monitoring was performed 13 months after completing the third and final treatment event and included sampling of all 17 wells in the monitoring well network.

3.2. Modifications to Original Monitoring Plan

Several changes were made to the monitoring program that was outlined in the Work Plan, as documented in the Sampling and Analysis Plan and Quality Assurance Project Plan Addendum No. 4 (GeoEngineers 2017b). These changes included:

- Modify the analytical method for arsenic by eliminating acid preservation and switching from United States Environmental Protection Agency (EPA) Method 200.8 to EPA Method 6010.
- Add well MW-46D to the short-term monitoring network.
- Add arsenic field kit testing to the short-term monitoring program.
- Replace the field test kit methods used during the fourth short-term monitoring event with laboratory analysis for total and dissolved arsenic, total and dissolved iron, and sulfate.

4.0 BASELINE MONITORING RESULTS

The baseline conditions are representative of the groundwater conditions after the installation of the injection and monitoring wells within the Play Area in Spring 2017 and before the first round of injection treatment in December 2017. The initial baseline groundwater monitoring event was conducted in

September 2017 to measure groundwater elevations and obtain chemical analytical data to document geochemical conditions before in-situ treatment. Groundwater elevations and depth to light nonaqueous phase liquids (LNAPL) and LNAPL thicknesses are presented in Table 2. Groundwater monitoring was conducted at all 17 wells in the monitoring well network. The wells were measured for field parameters and field tested for arsenic (Table 2). Samples were collected from the wells for laboratory analysis of total and dissolved arsenic, total and dissolved iron, sulfide and sulfate concentrations (Table 3).

4.1. Initial Baseline Arsenic Conditions

4.1.1. Total Arsenic and Dissolved Arsenic Analysis Methods

Arsenic was measured in the field using colorimetric field tests, a Hach EZ Arsenic High Range (range: 0 to 4,000 micrograms per liter [µg/L]). The field test kits were intended to determine approximate arsenic concentrations during the first baseline monitoring event and field methods are described in the Interim Action Work Plan (IAWP; GeoEngineers 2017a). Field test kit results for baseline conditions are presented in Table 3. Generally, the field test kits for arsenic were determined to be of limited use due to complexities associated with the groundwater geochemistry and high arsenic concentrations.

The September 2017 baseline total and dissolved arsenic samples were analyzed by EPA method 200.8. As noted in the Data Validation Report dated January 9, 2018 (Appendix C), groundwater samples were found to be incongruous and noticeable amounts of particulates were observed in the field-filtered and preserved sample containers upon receipt at the laboratory. The particulates observed were likely precipitated arsenic, iron, and sulfide minerals as a result of shifting from alkaline conditions to acidic conditions due to the nitric acid preservative. The total and dissolved arsenic results from the EPA 200.8 analyses were qualified as estimated (J).

Note that subsequent monitoring events used analytical method EPA 6061C and samples were not filtered or preserved in the field to avoid the precipitation loss of dissolved arsenic with the acidic preservation method. This modification of the sampling plan was documented in the Sampling and Analysis Plan and Quality Assurance Project Plan Addendum No. 4 (GeoEngineers 2017b).

4.1.2. Total Arsenic and Dissolved Arsenic

Chemical analytical results for baseline conditions are presented in Table 3. The initial baseline range of total arsenic concentrations in fill wells ranged from 10.3 to 38,800 µg/L. Dissolved arsenic concentrations in fill wells ranged from 4.07 to 36,600 µg/L. The highest values of both total and dissolved arsenic were located in the central portion of the Play Area Renovation Boundary. The highest concentration of dissolved arsenic was measured at monitoring well MW-45S (36,600 µg/L). Dissolved arsenic in the fill unit shoreline monitoring wells were below 120 µg/L (MW-36S and MW-51S).

The initial baseline range of total arsenic concentrations in outwash wells was 37.9 to 293,000 µg/L. Baseline dissolved arsenic concentrations in outwash wells ranged 61.8 to 98,600 µg/L. The highest values of both total and dissolved arsenic were located east of the Play Area Renovation Boundary in outwash unit shoreline wells as shown in Figure 5. The highest baseline concentration of dissolved arsenic in outwash groundwater was measured at shoreline monitoring well MW-52D (98,600 µg/L). Dissolved arsenic in the upgradient outwash well was below 150 µg /L (MW-41D).

As described in Section 4.1.1 above, the sample preservation and analytical method used for the baseline sampling event likely resulted in precipitation of dissolved arsenic between sampling and analysis for some samples. This appeared to affect samples of alkaline groundwater with higher concentrations of dissolved arsenic with remaining thioarsenates. The use of an acid preservative for dissolved arsenic samples during the baseline sampling event likely had the effect of neutralizing pH and causing some dissolved arsenic to precipitate. This appeared to result in under-estimated dissolved arsenic baseline conditions at some locations, including fill well MW-45S located at the Kelly Filter and outwash wells MW-36D, MW-49D, MW-50D, and MW-52D located along the shoreline, where groundwater has high pH and substantial fractions of arsenic as thioarsenates.

Baseline dissolved arsenic concentrations observed at the wells described above were followed by substantially increased dissolved arsenic concentrations in the following monitoring event using the modified sampling procedures without acid preservation. For example, dissolved arsenic increased from the baseline concentration of 36,600 µg/L at fill well MW-45S to 48,300 µg/L at the first short-term monitoring event. This increase was more pronounced at outwash shoreline wells where pH was much higher, in the vicinity of pH 9.0, such as at well MW-52D where dissolved arsenic results increased from 98,600 µg/L during the baseline event to 326,000 µg/L during the next sampling event (December 2017 performance event). For these wells that appeared to be impacted most significantly by the preservation method used during the baseline sampling event, the baseline results were not used for comparison to later dissolved arsenic results, as they underestimate pre-treatment concentrations. For the purpose of presenting pre-treatment conditions and evaluating treatment performance, these baseline results were replaced by the dissolved arsenic result from the subsequent event to serve as surrogate baseline results. Because these surrogate baseline results are from after the first injection round, it is possible that these values underestimate actual pre-treatment conditions, particularly for well MW-45S located within the fill unit treatment area. The pre-treatment conditions of dissolved arsenic, including the surrogate baseline values for fill well MW-45S and outwash wells MW-36D, -49D, -50D, and -52D, are presented on Figures 4 and 5.

4.1.3. Arsenic Speciation

Samples from selected monitoring wells were collected for arsenic speciation analysis using the anoxic sampling methodology described in the SAP-QAPP (GeoEngineers 2017a). Arsenic speciation analysis had been performed on six samples during the supplemental Investigation (SI) event in December 2014 prior to the Interim Action. Arsenic was speciated for seven samples collected during the baseline monitoring event in September 2017, as shown in Table 5. Arsenic speciation analyses were performed again on seven samples during the second repeat baseline event in June 2018.

Arsenic speciation determines which oxidation state is present and at what concentrations. Baseline samples taken in September 2017 yielded two inorganic forms as oxyanions of trivalent arsenite (As(III)) and pentavalent arsenate (As(V)) and a third category of unknown arsenic species further broken down into four subcategories. This third category was interpreted as likely being representative of the group of thioarsenate compounds associated with releases of Thylox solution. The speciation results of the 2014 and 2017 sampling events indicated that As(III) is more dominant than As(V). However, the speciation results indicated that some locations have a significant percentage of the dissolved arsenic present as thioarsenates, up to 52 percent in 2014 (MW-36D) and 48 percent in 2017 (MW-42D). The highest concentrations of thioarsenates were measured in outwash unit groundwater, although relatively high concentrations of thioarsenates were also observed at fill unit well MW-45S, which is located in the immediate vicinity of the Kelly Filter.

4.2. Initial Baseline Iron, Sulfate, and Sulfide Conditions

Iron, sulfate, and sulfide are indicator analytes for the Interim Action that are monitored to evaluate geochemical conditions, as well as the presence and influence of injected reagent. Iron is naturally present in soluble and insoluble forms in Play Area groundwater and is influenced by the precipitation processes with arsenic. Iron concentrations across the Play Area are also expected to be influenced by the injected ferrous sulfate reagent solution. Sulfate in groundwater is also monitored to evaluate the influence of injected ferrous sulfate. Sulfide is present in Play Area groundwater because of the breakdown of thioarsenates and is expected to be influenced by the precipitation of arsenic-iron-sulfide minerals from the treatment.

Iron and sulfate concentrations were measured in the field using colorimetric field tests (Hach IR-18 for iron and Hach SF-1 for sulfate). Field test kits were used to determine approximate concentrations of total iron and sulfate during the first baseline monitoring event and field methods are described in the IAWP (GeoEngineers 2017). Field test kit results for baseline conditions are presented in Table 3.

Groundwater samples were collected from all 17 wells in the monitoring well network to determine total iron, dissolved iron, sulfide, and sulfate concentrations prior to in-situ treatment. Total and dissolved iron were analyzed by EPA method 6061C. Sulfide was analyzed by method SM 4500-S2 and sulfate by EPA method 300.0. Laboratory analytical data for baseline conditions are presented in Table 4.

4.2.1. Total and Dissolved Iron

The initial baseline concentrations of total and dissolved iron were generally below 5,000 µg/L for most fill and outwash wells. However, total and dissolved iron are affected by the complex geochemistry of soil and groundwater at the Play Area. Upgradient iron conditions observed at wells MW-41S and MW-41D indicated that iron is present in groundwater flowing toward the Play Area at concentrations from 3,550 µg/L (MW-41S) to greater than 16,000 µg/L (MW-41D). The iron concentration observed at MW-41S is not the highest concentration observed in fill groundwater during the baseline sampling, indicating that background iron conditions in fill groundwater are likely higher than what was observed at well MW-41S. Iron present in soil and groundwater at the Play Area before the Interim Action contributed to the attenuation of arsenic by precipitation, which has resulted in reduced equilibrium concentrations of iron, particularly in the fill unit, where soil samples evaluated during the Play Area Geochemistry Evaluation (Appendix 2B-2 of the RI [GeoEngineers 2020]) indicated the presence of iron-arsenic precipitates in the soil matrix. The high concentration of dissolved iron in MW-41D is likely representative of equilibrium conditions outside the influence of arsenic attenuation. Primarily, the baseline iron conditions are intended to provide a comparison to post-treatment conditions influenced by the injection of an iron-based reagent and the subsequent precipitation of iron-arsenic minerals following treatment.

4.2.1. Sulfide

Sulfide concentrations were greater than 250 milligrams per liter (mg/L) in two shoreline wells (MW-50D, MW-52D) and were less than 100 mg/L in remaining locations. Sulfide is a breakdown product of the decomposition of thioarsenates (“thio” refers to the presence of a sulfur ion in a compound) and is expected to be found at higher concentrations in locations where thioarsenates are present. The baseline results confirmed this, showing highest sulfide concentrations correspond to wells with the highest baseline arsenic concentrations. Sulfide conditions directly affect the breakdown of thioarsenates and precipitation of arsenic; sulfide is generated by the breakdown of thioarsenates and the presence of excess sulfide prevents further breakdown of thioarsenates. The precipitation of sulfide with iron promotes the breakdown of thioarsenates and creates conditions favorable for precipitation of arsenic as arsenic-iron-sulfide minerals.

4.2.1. Sulfate

Sulfate concentrations varied widely across the site (2.74 to 2,460 mg/L) and similar to sulfide, sulfate also appears to vary with respect to baseline arsenic concentrations and the likely presence of arsenic as thioarsenate.

4.2.2. General Chemistry Conditions

General chemistry conditions observed during the baseline monitoring event are reported in Table 3. The general chemistry condition of greatest importance during the Interim Action was pH; the geochemical conditions associated with the released Thylox solution as well as the reagent used for treatment are highly acid/base reaction dependent. Generally, the most basic (high pH) groundwater was associated with the highest baseline arsenic concentrations. These basic conditions are the result of remaining Thylox solution and the preservation of thioarsenates in some areas such as in outwash groundwater along the shoreline and isolated areas of fill groundwater near the center of the Thylox process area (e.g., MW-45S).

In fill unit groundwater, baseline conditions were generally neutral to slightly acidic (approximately 5.5 to 7.5), with the exception of two wells located in the heart of the Thylox process area (MW-42S and MW-45S). Outwash groundwater in the Interim Action area, particularly downgradient areas with higher arsenic, is typically more basic, with pH at or above 9 observed in several monitoring wells. Upgradient conditions, represented by outwash well MW-41D, are neutral pH.

4.3. Repeated Baseline Conditions

The Interim Action treatment was conducted over three rounds between December 2017 and December 2019. Prior to each subsequent round of treatment, pre-treatment conditions were reestablished by conducting new “baseline” sampling events, referred to as Baseline 2 and Baseline 3 in this Monitoring Report. These subsequent baseline monitoring events were completed to evaluate conditions immediately prior to injection to inform planning for the injection and to provide a snapshot of conditions against which to compare post-injection short-term and performance monitoring results. The initial baseline event described in this section was used in determining percent of arsenic removed as discussed in Section 6.

5.0 SHORT-TERM MONITORING RESULTS

Short-term monitoring was conducted to document groundwater conditions during and shortly after reagent injection, including the effect of reagent injection on nearby groundwater elevation and chemistry. Short-term monitoring was conducted using the eight monitoring wells within the Interim Action area (MW-42S, MW-43S, MW-44S, MW-45S, MW-47S, MW-45D, MW-46D, and MW-48D). Short-term monitoring included collecting groundwater elevation data before, during, and after reagent injection and monitoring of field parameters, arsenic, iron, and sulfate approximately twice per week for two weeks following the reagent injection (Table 3). Two weeks following injection, groundwater samples were collected and submitted to the analytical laboratory for arsenic, iron, and sulfate analyses (Table 4).

5.1. Injection Physical Response Monitoring

Short-term injection monitoring evaluated the conditions during reagent injection, including injection flow conditions and conditions at monitoring wells near the injection wells. Injection well flow conditions (pressure and flow rate) were monitored during injection to ensure proper flow at the wells being injected and to track and record the volume of reagent being injected at each well. Table 1 presents average flow rates and total volumes injected for each injection well during the three injection events.

Transducers were installed in seven monitoring wells (fill wells MW-42S, MW-43S, MW-44S, MW-45S, and MW-47S and outwash wells MW-45D and MW-48D) to measure groundwater elevation (calculated based on pressure measured by the transducer) at regular intervals during and after injection periods and evaluate changes in groundwater elevation resulting from nearby injection. Periods of reagent injection at individual injection wells were recorded to allow correlation between injection at specific wells and changes in groundwater elevation at nearby monitoring wells. Graphs of the relationship between injection and groundwater elevations at fill and outwash unit injection wells and nearby fill and outwash unit monitoring wells are presented in Appendix A.

Figure A-1 in Appendix A shows the groundwater elevation response at fill unit monitoring well MW-42S during injection at nearby fill unit injection wells A1, A2, B1, B2, and B4. The response at well MW-42S to nearby injection was significant (up to approximately 3 feet of head) and the increase was gradual and long lasting. In contrast, groundwater elevations measured at other fill unit monitoring wells such as MW-43S (Figure A-2), MW-44S (Figure A-3), increased quickly in response to nearby injection, and decreased quickly afterward. In the downgradient portion of the Play Area, where fill soil is larger grained and highly permeable, the increase in groundwater elevation because of nearby injection was insignificant. This behavior is shown on Figure A-5, which presents the stable groundwater elevation observed at fill well MW-47S.

The relationship between injection at outwash wells and increased head at nearby outwash monitoring wells was more substantial than that observed in the fill unit. The ability to inject at higher flow rates within the outwash unit results in significant head generated at nearby outwash monitoring wells. In addition, the outwash unit in the vicinity of the B injection wells, represented by well MW-45D as shown on Figure A-4 of Appendix A, is confined by the silt layer between the fill and outwash units. The over 10 feet of head generated at well MW-45D (Figure A-4) from nearby injection is consistent with confined conditions. Downgradient of the Kelly Filter, the silt layer confining the outwash unit farther upgradient is not present and the highly permeable fill soil (described above in the vicinity of fill well MW-47S) directly overlies the outwash soil. As a result, the hydraulic influence of outwash injection on nearby outwash groundwater is less pronounced in the downgradient area, as shown for downgradient outwash well MW-48D on Figure A-6.

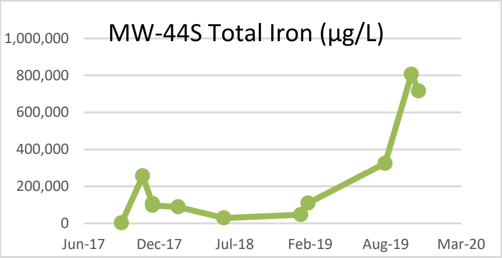
5.2. Injection Chemical Response Monitoring

Short-term monitoring also evaluated chemical conditions for a two-week period following each reagent injection event, which involved measuring field parameters (pH, specific conductivity, turbidity, dissolved oxygen, temperature and oxidation/reduction potential) and performing field test kits for arsenic, iron, and sulfate biweekly over the two weeks following the injection. As a result of inconclusive field kit results during initial short-term events, the sampling and analysis plan was modified (GeoEngineers 2017b) to include laboratory analysis of short-term groundwater samples for total and dissolved arsenic and iron, and sulfate.

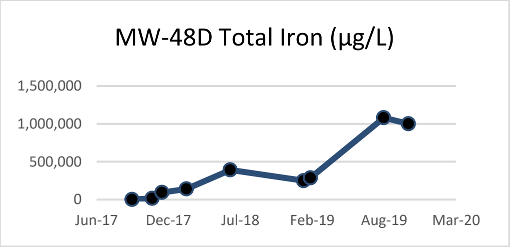
Short term groundwater sampling used low-flow sampling techniques. Methods outlined for each field test kit were followed once groundwater parameters had stabilized and at least one well volume was purged. Lab methods for total arsenic, sulfate, and total iron were EPA 6010C, 300.3, and 6061C, respectively. The field test kit results for the four short-term events associated with each injection event are presented in Table 2. The corresponding lab analysis of samples collected from the fourth short-term event associated with each injection event are presented in Table 3. Appendix B includes graphs of short-term results at various fill and outwash monitoring wells for iron, sulfate, pH and arsenic data.

5.2.1. Short-Term Iron Results

Iron field test kits followed the same general trend of laboratory analysis but the limiting range of the test kit did not allow evaluation of reagent presence due to the wide span of iron concentrations. Iron test kits utilized a visual color disc comparison method that is completed in approximately 15 minutes. Field kit detection results range from 0.1 to 10 mg/L with an increment of 2 mg/L. Laboratory analytical results for iron offered greater precision and accuracy and allowed distinction between total and dissolved iron. The laboratory analyses were conducted during the fourth short-term event, two weeks following each injection event, and are represented in Table 4 as the "Short-term 4" events. Figure B-1 in Appendix B presents total iron results for multiple fill and outwash wells. Figures B-4 and B-5 present the relationship between total iron and dissolved arsenic at fill and outwash wells during the Interim Action.

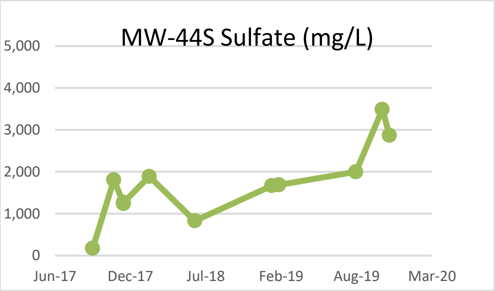


Following the first injection event, the short-term monitoring indicated that injected ferrous sulfate was observed at several monitoring wells in the form of increased iron concentrations at the two-week mark following injection, represented by the November 2017 "Short Term 4" results in Table 4. Fill unit monitoring wells MW-42S, -43S, -44S, and -47S all had significant increases of total iron, with the strongest increase observed at well MW-44S, as shown in the inset graph. However, the short-term results indicated that the increase in total iron can occur with a decrease of dissolved iron, as observed in some wells during the short-term events. This reduction of dissolved iron is the result of precipitation in a short timeframe following injection. The total iron results appear to be a better indicator of the distribution of ferrous sulfate. The immediate increase of iron at the short-term event following the first injection event was limited to the fill unit wells listed above. Increased total iron indicating influence from injected ferrous sulfate was delayed at outwash wells, as shown on the inset graph of MW-48D. The short-term sampling performed after the second and third injection events indicated progressively stronger response from injection, in the form of significant increased iron observed at wells MW-45D and MW-48D.

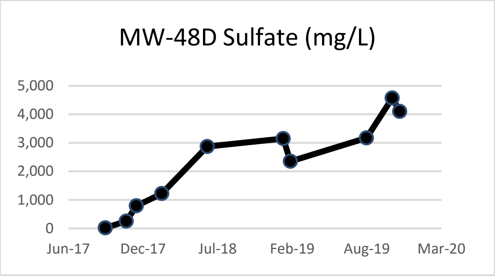


5.2.2. Short-Term Sulfate Results

Sulfate field test kits results were generally in agreement with laboratory analysis but were limited by the detection range of the kit. Sulfate field test kits utilize a turbidimetric method to detect concentrations from 50 to 200 mg/L with measurement increments of 50 mg/L. Laboratory analytical results offered greater precision and accuracy. The laboratory analyses were conducted during the fourth short-term event, two weeks following each injection event, and are represented in Table 4 as the “Short-term 4” events. Figure B-2 in Appendix B presents sulfate results for multiple fill and outwash wells. Figures B-8 and B-9 present the relationship between sulfate and dissolved arsenic at fill and outwash wells during the Interim Action.



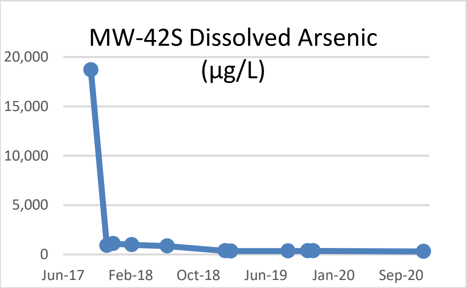
Like what was observed for iron, sulfate concentrations increased primarily at fill unit monitoring wells near injection wells, including MW-42S, -43S, -44S, and -47S, with the strongest increase observed at well MW-44S. Sulfate and total iron concentrations at well MW-44S appeared to follow the same trend, as shown on Figure B-10 in Appendix B.



A strong increase in sulfate was observed immediately at outwash well MW-48D, following the first injection event, which differs from the iron concentration response at this well. The inset graph shows how sulfate increased immediately and continued to rise through most of the interim action. Sulfate appears to be a better indicator of immediate distribution of ferrous sulfate reagent as it appears to be less susceptible to immediate geochemical transformation relative to iron, which has the potential to immediately precipitate and become part of the soil matrix.

5.2.3. Short-Term Arsenic Results

Arsenic field test kits gave variable results that were considered inconclusive, warranting the addition of laboratory analysis at the two-week point of the short-term monitoring. The laboratory analytical results offered greater precision and accuracy and provided differentiation between total and dissolved arsenic.



The first short-term laboratory analysis at two-weeks following the injection event indicated that significant reduction of arsenic was occurring at two wells within that short timeframe, although most wells showed limited effect. Wells MW-42S and MW-44S showed immediate arsenic reduction of greater than 85 percent at the two-week mark of the short-term monitoring. The immediate, and permanent, reduction of dissolved arsenic at well MW-42S is shown in the inset graph. Short-term monitoring more commonly showed little immediate reduction of dissolved arsenic, with reductions observed over a longer timeframe as indicated during performance monitoring.

6.0 PERFORMANCE AND CONFIRMATION MONITORING RESULTS

Performance monitoring was conducted to document groundwater conditions after an extended period following reagent injection. Performance monitoring events were conducted at approximately one month after completion of each injection event. Additional sampling events at longer intervals following injection (e.g., repeated baseline) were conducted and were considered performance monitoring events for the purpose of evaluating conditions at longer periods following injection. At approximately 13 months following completion of the third injection event, a confirmation monitoring event was performed to evaluate long-term performance and characterize groundwater conditions to be considered during completion of the feasibility study for the GWPS.

Performance and confirmation monitoring was conducted using all 17 Interim Action monitoring wells and included manual measurements of depth-to-groundwater (Table 2) and field parameters (Table 3). Groundwater samples were collected for laboratory analysis for arsenic (performance and confirmation events) and iron and sulfate (performance events (Table 4).

6.1. Performance Monitoring Results

Results from each performance monitoring event were evaluated to determine effectiveness of the in-situ treatment and to adjust proposed treatment volumes for future subsequent injection rounds. In addition to the planned one-month sampling after each injection event, performance monitoring was conducted to evaluate longer-term results and provide a new baseline for following injection events. Prior to each of the two subsequent rounds of injection, pre-treatment conditions were reestablished by conducting a performance sampling event prior to injection. These events were referred to as Baseline 2 and Baseline 3 (Tables 2 and 3). These subsequent baseline monitoring events were completed to evaluate conditions immediately prior to injection to inform planning for the following injection, but also provide a longer-term evaluation of conditions following the previous injection event.

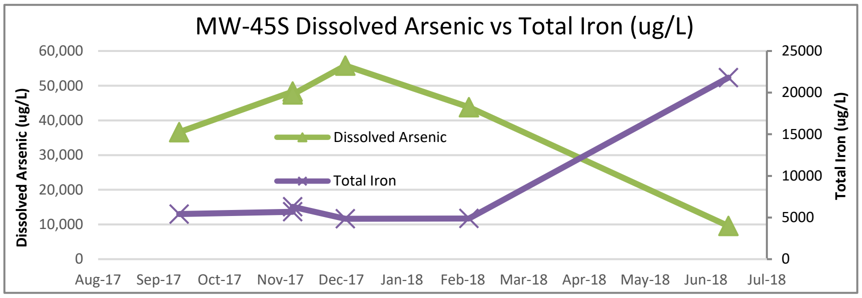
Results for performance monitoring events are tabulated in Table 4. Performance data trend plots are presented in Appendix B.

6.1.1. Round 1 Performance Monitoring Results

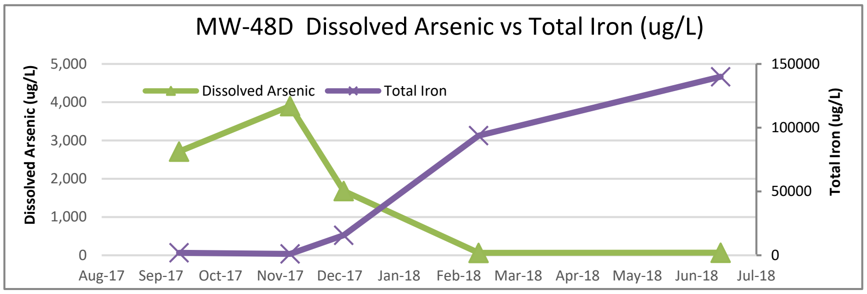
The first post-treatment performance monitoring was conducted in mid-December 2017, approximately six weeks following the completion of Injection Round No. 1 on October 31, 2017. Additional performance monitoring was conducted in mid-February 2018 (Supplemental Performance event in Tables 2 and 3) and mid-June 2018 (Baseline 2 in Tables 2 and 3). These supplemental events were added to evaluate longer-term performance prior to the second injection event that began in late June 2018.

Performance monitoring data indicated three fill wells (MW-41S, MW-42S, and MW-44S) achieved reduction of dissolved arsenic by greater than 90 percent relative to baseline conditions. These fill wells decreased in concentrations of dissolved arsenic by up to 17,700 µg/L approximately six weeks after in-situ treatment. The three other fill wells within the immediate vicinity of the injection wells (MW-43S, MW-45S, and MW-47S) displayed an increase of dissolved arsenic.

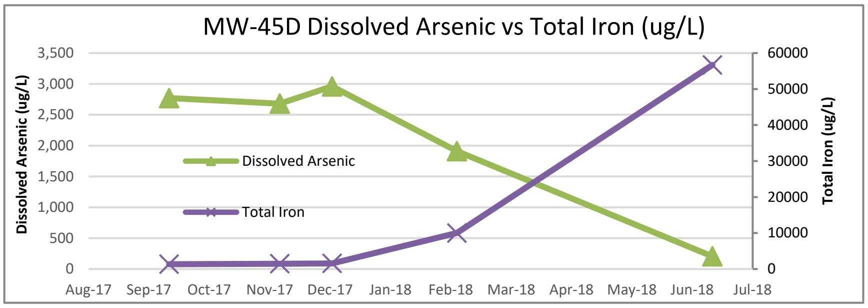
The increased dissolved arsenic concentration between the baseline event and the first performance event at well MW-45S is likely the result of underestimated baseline conditions associated with the original sample preservation method used during the baseline event, as described in Section 4.1.1. Treatment performance at well MW-45S appears to be slow relative to other fill wells. The inset trend plot shows how response from the injected ferrous sulfate was delayed for several months following the late-October injection event. By June 2018, the dissolved arsenic had reduced by over 80 percent relative to the peak concentration observed in December 2017. Figure B-12 in Appendix B presents concentration trend plots for dissolved arsenic at fill unit monitoring wells.



After the first round of treatment injections, the first performance monitoring event in December 2017 indicated that outwash groundwater in the immediate vicinity of the injection wells (e.g., wells MW-45D and MW-48D) had dissolved arsenic reduction up to 57 percent, as observed at well MW-48D. Other indicators of influence from injected ferrous sulfate, iron and sulfate, were observed to increase during the first performance monitoring event, including increased total iron and increased sulfate. The inset graph shows the progression of dissolved arsenic and total iron at well MW-48D through the performance monitoring conducted between the first and second injection events. Additional chemical trend plots for MW-48D and other wells are presented in Appendix B.



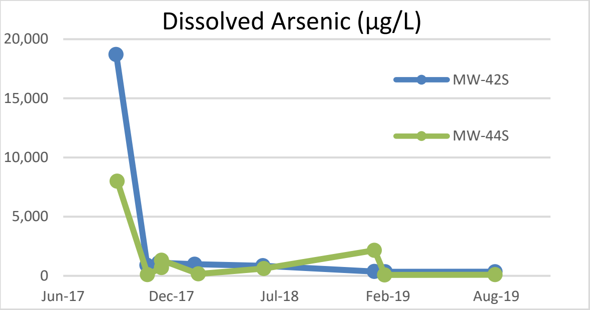
Monitoring well MW-45D near the Kelly Filter did not show reduction at the first performance monitoring event in December 2017 but was followed by significant dissolved arsenic reduction in the two later events prior to the second treatment injection event. The reduced arsenic concentrations correlated with delayed increase in total iron, which indicates a slower distribution of reagent in some outwash areas relative to other outwash areas. The inset trend plot shows the arsenic and iron behavior between baseline conditions and the end of performance monitoring associated with the first injection event. This conclusion is supported by the iron and sulfate analyses at MW-45D, which indicated stable conditions during the December 2017 performance event, but significant increases during later monitoring events.



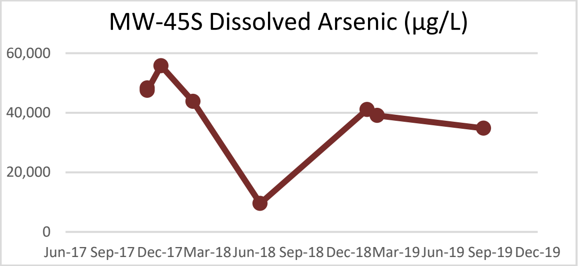
During the performance monitoring event, shoreline wells located outside the expected immediate influence of injected reagent were sampled to evaluate the potential for long-distance migration of reagent and to further characterize groundwater at the shoreline downgradient of the Play Area. Minimal influence from injected ferrous sulfate in the form of acidic conditions or increased iron or sulfate was observed at either fill or outwash shoreline monitoring wells during the period of performance monitoring (Table 4).

6.1.2. Round 2 Performance Monitoring Results

Performance monitoring was conducted approximately five weeks following the completion of the second treatment injection on December 21, 2018. In addition, a second monitoring event was conducted in August 2019, approximately 8 months following completion of the second treatment injection event. This event served as a baseline prior to the third injection event, as well as an additional post-treatment performance event. The performance monitoring data indicates that the three fill wells within the immediate vicinity of the injection wells (MW-42S, and MW-44S) generally maintained the initial reductions that were observed following the first injection event, as shown in the inset trend plot.



The second baseline monitoring event conducted prior to the second injection event indicated that dissolved arsenic at well MW-45S had decreased by over 80 percent relative to the highest concentrations. However, following this decline, dissolved arsenic concentrations had rebounded to 74 percent of the peak concentration of 55,800 µg/L by the short-term monitoring event (mid-January) following the second injection event.



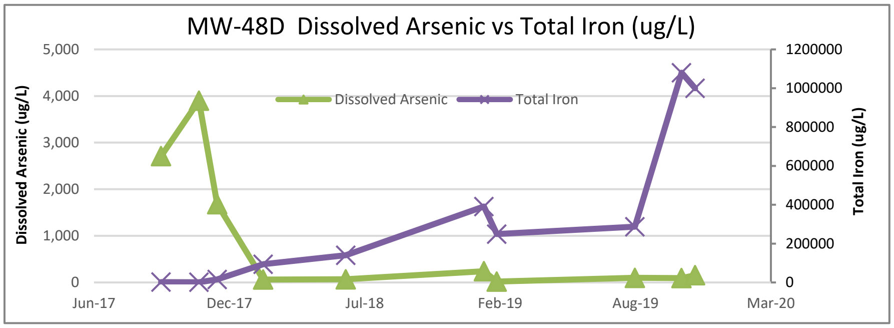
The second performance monitoring event suggested that the conditions in the vicinity of well MW-43S are resistant to treatment by the ferrous sulfate reagent. This is discussed further in Section 6.3.1 below.

After the second round of treatment injection, performance monitoring indicated that the two outwash wells within the vicinity of the injection wells, MW-45D and MW-48D achieved greater than 97 percent reduction of dissolved arsenic and maintained this reduction consistently through the monitoring period. Monitoring well MW-46D located at the edge of the expected treatment zone displayed a slight increase of dissolved arsenic relative to the short-term event following the completion of the second injection event. However, this was followed by a gradual decrease. Figure B-13 of Appendix B presents dissolved arsenic trend plots for all outwash monitoring wells. The performance monitoring indicated that MW-46D was on the edge of downgradient treatment in the outwash unit. This well is a designated performance well as outlined in the 2017 IAWP (GeoEngineers 2017a) but was positioned to test the extent of treatment delivered downgradient of the D-line injection wells.

6.1.3. Round 3 Performance Monitoring Results

The third round of treatment injections performed in October 2019 focused on the downgradient fill and outwash groundwater and only injected at C and D injection wells, as shown in Table 1. However, the performance monitoring conducted following the injection event included sampling all 17 Interim Action monitoring wells. The November 2019 performance monitoring indicated that fill groundwater in the upgradient area near the A and B injection wells that were not used during the third injection event, maintained the reduction that had been achieved during earlier treatment, with some locations showing additional reduction. Specifically, performance monitoring data indicated five fill wells (MW-41S, MW-42S, MW-43S, MW-44S, and MW-47S) had achieved 80 percent or greater reduction of dissolved arsenic, with up to an additional 6,820 µg/L of decreased dissolved arsenic from the previous performance monitoring event. Fill well MW-45S indicated a decrease of dissolved arsenic by 25 percent. Figure B-12 of Appendix B presents dissolved arsenic trend plots for all fill unit monitoring wells.

After the third round of treatment injections, reduced arsenic and increased indicators of injected ferrous sulfate (i.e., increased iron and sulfate) were observed at outwash wells MW-45D and MW-48D. The inset plot shows total iron versus dissolved arsenic for well MW-48D through the final performance monitoring event in November 2018. Figures B-1 and B-2 in Appendix B present concentration trends for iron and sulfate. These two wells maintained strong arsenic reduction of over 90 percent but indicated a slight rebound relative to samples collected during the pre-injection baseline sampling in August 2019.



6.1.4. Confirmation Monitoring Results

Approximately one year after the third round of treatment injections, confirmation groundwater monitoring was conducted to evaluate the long-term performance of arsenic treatment and provide information on conditions after the direct influence from injected reagent had dissipated. The confirmation groundwater monitoring results were also collected for use in the feasibility study for the GWPS. Confirmation monitoring was conducted using all the Interim Action monitoring wells and focused only on arsenic conditions. Iron, sulfate, and sulfide analyses were not conducted during the confirmation monitoring.

Confirmation monitoring data indicated that arsenic concentrations at four of the fill wells (MW-41S, MW-42S, MW-44S, and MW-45S) were stable or reduced relative to the conditions during the third performance monitoring. Figure B-12 in Appendix B presents dissolved arsenic trend plots for the full duration of the Interim Action, including the confirmation monitoring event. Three of these fill wells (MW-41S, MW-42S, and MW-44S) maintained an overall percent reduction of 83 percent or greater. Well MW-45S, the fill well with the highest initial arsenic concentration, showed continued reduction of dissolved arsenic between the third performance monitoring event and the confirmation monitoring event—an overall percent reduction of 49 percent relative to initial conditions. Figure 8 presents the data trends and the final percent reduction of dissolved arsenic in fill unit monitoring wells across the Play Area.

Significant rebound of arsenic concentration was observed at wells MW-43S and MW-47S over the 13 months prior to the confirmation monitoring event. The rebound of dissolved arsenic at MW-43S is further discussed in Section 6.3. The conditions at these wells fluctuated significantly over the course of the interim action. Dissolved arsenic concentrations at well MW-47S were generally at or below 1,150 µg/L but ranged to as low as 30.4 µg/L in November 2019 following the third injection event. The confirmation monitoring event indicated that dissolved arsenic concentration at MW-47 rebounded significantly relative to the final performance monitoring event but was still over 50 percent lower than the highest concentration observed at that location and is still significantly lower than fill unit groundwater observed at other wells within the treatment area. Final fill unit dissolved arsenic concentrations from the confirmation monitoring event are presented on Figure 10.

Conditions in outwash groundwater generally improved over the 13-month period prior to the confirmation monitoring event. Final outwash unit dissolved arsenic concentrations from the confirmation monitoring event are presented on Figure 11. Outwash monitoring wells MW-45D and MW-48D improved on the previous reductions of dissolved arsenic observed during performance monitoring; both achieving final dissolved arsenic concentrations below 100 µg/L and up to 99 percent reduction relative to baseline conditions. In addition to continued reduction observed in outwash groundwater within the immediate vicinity of the outwash injection wells, reduction of dissolved arsenic was observed at locations downgradient of the treatment system, including wells MW-46D downgradient of outwash injection well D4 and shoreline wells MW-36D and MW-49D downgradient of outwash injection wells C10, C11, and C12 (Figure 11). Dissolved arsenic decreased by more than 20 percent at MW-46D between the third performance monitoring event and the confirmation monitoring event. More significantly, the dissolved arsenic concentrations at wells MW-36D and MW-49D reduced by 87 to 97 percent relative to initial conditions at these wells[1]. Figure B-13 in Appendix B presents dissolved arsenic concentration trend plots for select outwash monitoring wells, including MW-36D, MW-46D, and MW-49D.

6.2. Progressive Indication of Treatment

Groundwater chemistry and hydraulic response were assessed throughout the treatment process to determine baseline, immediate performance, and post-performance conditions in the fill and outwash units. In addition to total and dissolved arsenic, groundwater samples were tested for indicator analytes representative of the injected reagent. Transducers installed in seven performance monitoring wells near injection wells evaluated the hydraulic response to injection and groundwater gradients that might influence reagent distribution.

6.2.1. Groundwater Chemical Indicators

Geochemical indicators for the ferrous sulfate treatment reagent include total iron, dissolved iron, sulfide, sulfate, and pH. Groundwater parameter field measurements and chemical analyte data were collected during the baseline, short term performance, performance, and confirmation monitoring events. Graphical representations of dissolved arsenic, total iron, sulfate, and pH over the duration of the Interim Action are presented in Appendix B.

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[1] Pre-treatment conditions at wells MW-36D and MW-49D are represented by the December 2017 performance monitoring concentrations due to under estimated baseline conditions at high pH wells, as described in Section 4.1.1.

Dissolved arsenic concentration trends are plotted for fill and outwash wells and included in Appendix B. Figures B-12 and B-13 present arsenic concentration trend plots for select fill and outwash monitoring wells. Figure B-12 shows that, with some exceptions, dissolved arsenic concentrations were significantly reduced because of the ferrous sulfate treatment. Figure B-12 also shows fluctuations of dissolved arsenic concentrations in most wells. Figure B-13 shows that outwash groundwater was more consistently treated by the injected ferrous sulfate relative to the fill treatment area. Outwash treatment during the Interim Action included treatment of shoreline groundwater at wells MW-36D and MW-49D where dissolved arsenic was significantly higher than areas targeted for treatment in the Play Area.

Figures B-1 through B-3 present trend plots for total iron, sulfate, and pH. Figures B-4 and B-5 show the relationship between total iron (an indicator of reagent influence) and dissolved arsenic concentrations. Figures B-6 and B-7 provide the same comparison for pH and Figures B-8 and B-9 provide the same comparison for sulfate.

Total iron levels in the fill wells generally increased during the Interim Action. Sharp increases of total iron in fill wells correlate to decreases of dissolved arsenic and is likely a diagnostic indicator for the presence of ferrous sulfate reagent. As described earlier, iron is an indicator of short-term influence from injected iron-based reagent, but the treatment process used in the Interim Action relies on the iron precipitating. The fluctuations observed at some wells, particularly well MW-42S, shows the increase of iron after reagent injection, followed by a decrease as treatment progresses (i.e., precipitation of iron-arsenic minerals).

Outwash wells within the immediate vicinity of injection wells, MW-45D and MW-48D, showed a strong influence from injected iron (Figure B-5), resulting in extremely high iron concentrations, upward of 0.1 percent iron at well MW-48D. This strong increase in total and dissolved iron following strong reduction of dissolved arsenic indicates excess iron after treatment.

Groundwater acidity, represented by pH, was a primary indicator of treatment due to the role that acidity plays in the geochemistry of thioarsenate-impacted groundwater and the use of an acidic reagent for treatment. pH would be expected to reduce as a result of the injection of acidic ferrous sulfate solution. pH response to injection appeared to be strong at fill well MW-42S, which had high pH baseline conditions. More gradual reduction of pH was observed at outwash wells MW-36D, MW-45D, and MW-48D. The most significant outlier for pH behavior was MW-45S, where pH fluctuated significantly over the course of the interim action. MW-45S appeared to exhibit a strong influence from injected ferrous sulfate at the second baseline event in the form of significantly lower pH, as well as elevated iron and reduced arsenic. The observations for MW-45S are further discussed in Section 6.3.1.

6.2.2. Hydraulic Influences on Groundwater Chemistry

Interim Action monitoring included measuring groundwater elevation and head within the fill and outwash treatment areas as well as reviewing lake elevation data for Lake Union. Water levels and gradients can influence groundwater chemistry and in-situ treatment effectiveness, particularly in shallow unconfined groundwater, such as in the fill unit. The primary hydraulic factors applicable to the Interim Action are:

- Unconfined water levels affect the soil that groundwater contacts. When water levels are high, groundwater is in contact with soil at a higher elevation which could either be a source of contaminants or remove contaminants via adsorption.

- The saturated thickness, which changes with the water level, affects injection performance and the vertical distribution of injected reagent for treatment.
- Seasonal gradient reversal in nearshore areas because of the rise and fall of Lake Union. The Army Corps of Engineers increases the lake level in late winter/early spring and reduces the lake level by approximately 2 feet in summer. During high lake level periods, the groundwater gradient is inward and lake water could affect nearshore groundwater quality, especially where the hydraulic conductivity is higher (e.g., where the fill consists of agglomerate).
- Gradients toward the lake are highest in later spring/early summer after seasonal rainfall and when the lake level is lowered by the Corps of Engineers.

Figure 12 presents lake levels throughout the duration of the Interim Action and shows the timing of injection and sampling events. Although determination of hydraulic influences on arsenic concentrations is outside the scope of the Interim Action, water levels and gradients influence the distribution and movement of reagent and contribute to fluctuating arsenic concentrations in the fill unit. Performance monitoring wells on site reflect the rising and falling lake levels that correspond to the engineered control of the lake groundwater elevation.

6.3. Monitoring Anomalies

Shallow wells screened within the fill unit MW-43S and MW-45S displayed anomalous responses that are discussed in the following sections.

6.3.1. Arsenic and Geochemical Conditions at MW-43S

The results of arsenic speciation analyses and other data collected during the interim action were evaluated to examine the geochemical conditions in the vicinity of performance well MW-43S (Anchor 2016). The baseline conditions at well MW-43S differ significantly from other areas in the Play Area; slightly acidic groundwater (pH of 5.65), high total and dissolved iron, and low sulfide, with moderately high total and dissolved arsenic. The speciation results for MW-43S from the baseline event indicated that thioarsenates are not present in groundwater at this well (Table 5). Despite hydraulic response to the injection activities and elevated levels of total iron, the concentration of dissolved arsenic was not as responsive to treatment as other areas. Dissolved arsenic levels reached the lowest concentration (1,090 µg/L) during the third performance monitoring event but conditions rebound during the following confirmation monitoring event in December 2020.

The baseline low pH of groundwater at MW-43S was the lowest of all wells on site, although fill groundwater outside the influence of thioarsenate is generally slightly acidic. Due to these acidic conditions, combined with the high iron at MW-43S and low sulfide relative to other portions of the Play Area, the addition of ferrous sulfate did not result in as substantial reduction of dissolved arsenic when compared to other areas. However, the conditions at well MW-43S appear isolated, as indicated by significantly lower arsenic concentrations downgradient, as represented by baseline conditions at wells MW-47S and MW-36S (Figure 4).

6.3.2. Dissolved Arsenic Rebound at Monitoring well MW-45S

Dissolved arsenic was treated to a lower degree during the Interim Action in the vicinity of MW-45S, when compared to the percent reductions observed at other fill wells such as MW-44S and MW-42S.

Considerations focus on the physical conditions to complement the geochemical evaluation. The MW-45S monitoring well is completed in agglomerate (GP), a high permeability and relatively thick unit suggesting relatively high transmissivity, which makes it difficult to fully flood during injection treatment. Transducer records show short-lived, half-foot pulses that do not appear to be related to injection into the fill unit (Figure A-4) suggesting that there is not direct immediate influence from injection. However, water levels gradually increased during injection periods suggesting a possible longer-term response.

The upgradient C-line injection wells were completed in heterogeneous fill overlying a concrete rubble base that could potentially serve as a preferential pathway for injection reagent. The downgradient D-line wells were installed at a lower elevation and in soil with a higher degree of larger-grain agglomerate. As described in Section 2.2, the injection flow rate at the D-line fill injection wells was the highest observed during the injection activities. Fill unit injection wells in the C line, upgradient of MW-45S, were injected at a lower flow rate than the D-line wells due to higher pressure and thus, lower permeability. Longer-term performance data, such as the June 2018 "Baseline 2" event performed approximately 8 months after completing the first injection event, and the August 2019 "Baseline 3" event performed approximately 8 months after completing the second injection event (Table 4) suggests that reagent eventually reached the area surrounding MW-45S, but at lower concentrations due to time and distance. Both of these sampling events coincide with falling water levels in Lake Union (Figure 12) when the gradient toward the lake is highest and reagent from upgradient injection would most likely flow through this area. These two events had significantly reduced pH and increased total iron, both indicators of influence from ferrous sulfate, which are shown on trend plots on Figure B-4 (total iron) and B-6 (pH).

Arsenic sources near MW-45S in the soil flanking the Kelly Filter were not removed during demolition. The heterogeneous nature of the fill soil in this area, particularly the layers of highly permeable agglomerate soil and lower permeability sand and silt layers, likely have trapped small amounts of released Thylox solution. However, the difficulty achieving immediate influence from injection is likely also preventing downgradient migration of the high-concentration arsenic. Fill unit groundwater immediately downgradient of MW-45S, represented by results from well MW-46S, has significantly lower dissolved arsenic, in the 100 µg/L range. This indicates that conditions at MW-45S are isolated and attenuate quickly downgradient.

7.0 CONCLUSIONS AND RECOMENDATIONS

This section provides a summary of the conclusions gathered during the Interim Action and provides recommendations for further action to address arsenic impacts associated with the former Thylox process in the Play Area portion of the GWPS. In particular, the results of the Interim Action will be used during the Feasibility Study to evaluate treatment methods for arsenic in groundwater downgradient of the Play Area footprint.

7.1. Monitoring and Treatment Effectiveness Conclusions

The monitoring performed during the Interim Action provided short-term (days to weeks), medium-term (months), and long-term (over a year) data to evaluate performance of both the injection process and the chemical treatment process used for the Interim Action. The nine fill wells and eight outwash wells used for monitoring, including transducers deployed at seven wells, resulted in an integrated view of the hydraulic units and the physical and chemical response from treatment across the Play Area.

Pre-treatment conditions in the fill unit indicated concentrations of dissolved arsenic up to 48,300 µg/L. As described in Section 4.1.1, pre-treatment conditions at some wells are based on monitoring events completed after the baseline monitoring event due to issues with the sampling and analytical methods used during the baseline monitoring event. For fill groundwater, the pre-treatment concentration of 48,300 µg/L at well MW-45S is from the short-term monitoring event rather than the baseline monitoring event. The pre-treatment geochemical conditions at the Interim Action monitoring wells varied significantly, from initially acidic with very high dissolved iron (MW-43S) to generally neutral acidity with elevated (greater than 1,000 µg/L) residual dissolved arsenic (MW-44S) and areas of high baseline pH and high dissolved arsenic indicative of residual Thylox solution (MW-42S and MW-45S). Sustained dissolved arsenic removal of up to 98 percent relative to baseline concentrations was achieved within the fill treatment zone, indicating adequate delivery of reagent and successful treatment of arsenic (Figure 8). At fill well MW-45S, which had the highest initial arsenic concentration and where treatment seemed less effective, an overall reduction of 49 percent was achieved after one year following treatment. On a mass basis, this was the greatest reduction of dissolved arsenic in the fill unit. Dissolved arsenic in fill groundwater immediately downgradient and within the same general elevation interval as fill groundwater in the original Thylox process area is significantly lower than within the Thylox area, as represented by dissolved arsenic concentrations at wells MW-46S and MW-51S on Figure 10. However, in the area immediately downgradient of the Play Area, the thickness of the fill unit increases as the underlying outwash unit slopes toward Lake Union. The deeper portions of the fill in this area, represented by sample locations PAI-2B and PAI-10 on Figure 10, likely remain impacted by relatively high concentrations of dissolved arsenic. Recommendations for this area are discussed in Section 7.2 below.

The thicker, more homogeneous outwash unit was consistently treated beneath the Play Area. The treatment resulted in reduction of dissolved arsenic within the footprint of the Play Area to below 100 µg/L (below the 100 µg/L detection limit in the case of well MW-48D), which corresponds to a percent reduction of 97 percent or higher. After one year following completion of the interim action treatment, the effectiveness of the treatment appeared to extend to downgradient shoreline wells MW-36D and MW-49D in the southern portion of the treatment area where the outwash injection wells (C10, C11, and C12 on Figure 6) are closest to the shoreline. These three injection wells are spaced close together in the direction of groundwater flow toward Lake Union. Significant reduction of dissolved arsenic was not observed at downgradient outwash well MW-46D (Figures 9 and 11) during the Interim Action. However, the confirmation sampling conducted 13 months following treatment indicated a reduction of total arsenic to the lowest concentration observed during the Interim Action (Table 4).

Confirmation monitoring documented treatment was effective in both the fill and outwash wells. The dissolved arsenic concentration was reduced to levels below 1,000 µg/L across a significant portion of the Play Area, both in fill and outwash groundwater, diminishing the source of dissolved arsenic available to migrate from the original source below the Play Area. These results indicate that the ferrous sulfate treatment used in the interim action was successful for conditions within the Play Area and are expected to be effective if used as a treatment method to reduce arsenic concentrations remaining in groundwater along the groundwater pathway between the Play Area and surface water.

7.2. Recommendations

7.2.1. Discontinue the Play Area Interim Action

Generally, the goals and expectations of the Interim Action have been met by successfully installing and operating the in-situ treatment system beneath the Play Area. The Interim Action treatment achieved significant reduction of dissolved arsenic concentrations across most of the treatment area. The exceptions where lesser reduction of dissolved arsenic occurred within the treatment area were isolated to the fill unit in the vicinities of MW-43S and MW-45S.

Groundwater geochemistry in the area represented by well MW-43S on the south side of the Play Area includes low sulfide concentrations, low pH and high iron conditions. These conditions are likely to result in limited additional effectiveness from further treatment with ferrous sulfate. In addition, monitoring downgradient of MW-43S indicates that this area is not acting as a substantial source of dissolved arsenic to downgradient areas.

The other area where lower degree of arsenic reduction was observed in fill groundwater is at well MW-45S. Substantial mass reduction was observed at MW-45S but the final percent reduction of dissolved arsenic was less than observed elsewhere. Although geochemical conditions at MW-45S are favorable for treatment, the limited saturated thickness and heterogeneous subsurface conditions appear to limit reagent delivery to this isolated area near the Kelly Filter. Additional treatment of arsenic in fill groundwater in the vicinity of MW-45S is expected to be considered in the FS.

Dissolved arsenic in outwash groundwater beneath the footprint of the Play Area targeted by the interim action was successfully treated by greater than 95% relative to baseline conditions. However, dissolved arsenic in groundwater downgradient of the interim action treatment area remains elevated. Additional treatment of arsenic in this area is expected to be considered in the FS.

These results support the recommendation that the Play Area Interim Action be discontinued. However, additional treatment should be considered in the FS to further reduce arsenic concentrations in groundwater in the fill near MW-45S and in the outwash downgradient of the Play Area. See Section 7.2.2 below.

7.2.2. Consider Further Application of Treatment Method in the Feasibility Study

The Interim Action results indicate that the in situ chemical treatment method used would be applicable for treatment of remaining high dissolved arsenic concentrations in fill and outwash groundwater along the groundwater flow path between the former Thylox process area and Lake Union.

Focused treatment of remaining elevated dissolved arsenic in the fill unit surrounding and immediately downgradient of monitoring well MW-45S, as shown in Figure 10, is expected to be effective for addressing the remaining areas of thioarsenate impacts in the fill unit groundwater at and downgradient of the Kelly Filter. Treatment of deeper fill unit groundwater along the original downward flow path of Thylox solution from the fill to outwash unit immediately downgradient of the Play Area, represented by sample location PAI-2B, would further reduce a source of dissolved arsenic to the flow path to sediment (e.g., lower fill at PAI- 10). Arsenic in fill groundwater in this zone is expected to be treatable using the same chemical treatment method used for the Interim Action. The fill unit groundwater in this area is neutral to slightly acidic with low dissolved iron and moderate dissolved sulfide (order of magnitude higher than iron) concentrations. These conditions indicate past precipitation has neutralized alkaline conditions and utilized dissolved iron but moderately high dissolved sulfide remains (GeoEngineers 2020). Adding ferrous sulfate to increase dissolved iron would be expected to promote precipitation of iron sulfide minerals and further reduce dissolved arsenic. In addition, the deeper, thicker saturated fill unit in the area downgradient of the Play Area is also expected to be amenable to more efficient reagent injection relative to the shallow, thin fill interval within the Play Area. The potential area for additional treatment is presented on Figure 10.

Treatment of high concentrations of dissolved arsenic in outwash groundwater in the area downgradient of the Interim Action treatment area, as shown on Figure 11, is expected to be effective based on the results of outwash groundwater treatment observed during the Interim Action. The outwash groundwater conditions (i.e., alkaline conditions, thioarsenate forms of arsenic, very high dissolved sulfide concentrations, and low dissolved iron concentrations) between the Play Area and the shoreline observed at several wells monitored during the Interim Action are ideal for the chemical treatment process used during the Interim Action. Ferrous sulfate chemical treatment is expected to reduce pH, degrade thioarsenates and increase dissolved iron resulting in precipitation of iron sulfide minerals and reduction of dissolved arsenic. The potential area for additional treatment is presented on Figure 11, where downgradient monitoring conducted during the Interim Action indicate that dissolved arsenic and alkaline conditions remain in outwash groundwater along the shoreline downgradient of the Play Area.

Additional treatment of remaining high dissolved arsenic concentrations in fill and outwash groundwater along the groundwater flow path between the former Thylox process area and Lake Union should be considered in the FS.

8.0 REFERENCES

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Table 1

Interim Action Reagent Injection Summary

Play Area Interim Action

Gas Works Park Site

Seattle, Washington

Injection Well Information						Injection Flow Data					
						1st Round (October 2017)		2nd Round (June/December 2018)		3rd Round (October 2019)	
Well ID	**Well Screen Geologic Unit**	**Depth to Top of Slotted Screen (ft bgs)**	**Depth to Bottom of Slotted Screen (ft bgs)**	**Depth to Bottom of Casing (end cap) (ft bgs)**	**Anticipated Flow Rate (GPM)**	**Total Injection Volume (gallons)**	**Average Flow Rate (GPM)**	**Total Injection Volume (gallons)**	**Average Flow Rate (GPM)**	**Total Injection Volume (gallons)**	**Average Flow Rate (GPM)**
A1	Fill	10.2	15.7	15.8	0.5	456	0.4	448	0.5		
A2	Fill	7.0	12.5	12.5	0.5	466	0.5	540	0.7		
A3	Fill	10.2	15.2	15.3	0.5	435	0.5	393	0.4		
A4	Fill	10.2	13.7	13.8	0.5	316	0.5	314	0.7		
A5	Fill	5.2	10.2	10.2	0.5	463	0.6	657	0.7		
A Fill						2136	-	2351	-		
B1	Fill	10.3	19.8	19.8	0.5	712	0.5	642	0.4		
B2	Fill	10.2	19.2	19.3	0.5	627	0.5	918	0.6		
B3	Outwash	20.3	26.8	27.9	1.0	690	1.4	923	1.0		
B4	Fill	10.2	16.7	16.8	0.5	429	0.5	700	0.6		
B5	Outwash	19.8	26.8	27.9	1.0	576	1.3	969	1.0		
B6	Fill	10.3	16.8	16.8	0.5	492	0.5	704	0.6		
B7	Fill	10.3	15.3	15.3	0.5	374	0.5	840	0.7		
B8	Fill	7.2	12.7	12.7	0.5	403	0.5	740	0.7		
B Fill						3037	-	4544	-		
B Outwash						1266	-	1891	-		
C1	Fill	10.2	17.7	17.8	2.0	1518	1.8	1448	1.8		
C2	Fill	10.2	18.2	18.3	2.0	1510	1.6	2041	1.7	2193	1.9
C3	Outwash	25.3	33.3	34.4	1.0	921	1.4	1398	1.2	1108	1.5
C4	Fill	8.7	14.2	14.3	2.0	1040	2.0	1699	1.9	1565	1.9
C5	Outwash	22.8	29.8	30.8	1.0	776	1.5	982	1.2	979	1.5
C6	Fill	10.3	13.3	13.3	2.0	570	1.4	960	1.7	860	1.9
C7	Outwash	19.9	26.9	28.0	1.0	671	1.6	981	1.4	979	1.5
C8	Fill	8.7	14.2	14.3	2.0	1070	2.1	1693	1.9	1565	1.9
C9	Fill	7.8	12.8	12.8	2.0	940	2.3	1510	1.7		
C10	Outwash	16.3	27.3	28.4	1.0	956	1.7	1863	1.3	1552	1.9
C11	Outwash	18.1	30.1	31.2	1.0	1160	1.6	1347	1.1	1684	1.7
C12	Outwash	23.8	32.8	33.9	1.0	865	1.6	1658	1.3	1663	1.7
C Fill						6648	-	9351	-	6183	-
C Outwash						5349	-	8227	-	7965	-
D1	Fill	15.1	21.1	21.2	5.0	1137	2.3	1139	2.6	1108	2.3
D2	Outwash	19.5	29.0	30.1	1.0	909	1.7	1748	1.2	1546	1.9
D3	Fill	15.0	22.0	22.1	5.0	1357	2.3	1180	2.6	1313	2.3
D4	Outwash	25.3	34.3	35.4	1.0	1139	1.6	1653	1.2	1663	1.9
D5	Fill	14.6	24.6	24.7	5.0	1695	2.2	1680	3.2	1867	2.3
D6	Outwash	25.3	35.3	36.4	1.0	1248	1.6	1488	1.2	1867	1.9
D7	Fill	9.9	16.9	17.0	5.0	1147	2.3	1180	2.6	1108	2.3
D8	Outwash	20.4	32.4	33.4	1.0	1155	1.8	1671	1.3	1896	1.9
D9	Outwash	20.3	32.3	33.4	1.0	909	1.7	1442	1.4	1313	1.9
D10	Fill	10.0	15.0	15.1	5.0	940	2.9	939	2.6	963	2.3
D Fill						6276	-	6118	-	6359	-
D Outwash						5360	-	8001	-	8285	-
TOTAL						30072		40483		28792	

Notes:

bgs = below the ground surface

ft = feet

GPM = gallons per minute

Table 2

Summary of Groundwater Elevation Measurements

Play Area Interim Action Monitoring Report
Gas Works Park Site
Seattle, Washington

Sample Location[1]	Injection Round[2]	Event	Date	Top of Casing Elevation[3] (feet)	Depth to Water from Top of Casing (feet)	Groundwater Elevation[3] (feet)	Depth to LNAPL (feet)	LNAPL thickness (feet)
Fill Unit Groundwater Monitoring Wells								
MW-41S	1	Pre Development	4/24/2017	32.27	4.38	27.89	-	-
		Snapshot	9/18/2017	32.27	7.94	24.33	-	-
		Baseline	09/25/17	32.27	7.55	24.72	-	-
		Performance	12/11/17	32.27	4.49	27.78	-	-
		Supplemental Performance	02/16/18	32.27	4.47	27.80	-	-
	2	Baseline 2	06/18/18	32.86	5.57	27.29	-	-
		Performance	01/31/19	32.86	5.32	27.54	-	-
	3	Baseline 3	08/20/19	32.86	5.78	27.08	-	-
		Performance	11/18/19	32.86	5.75	27.11	-	-
		Confirmation	12/15/20	32.86	5.32	27.54	-	-
MW-42S	1	Pre Development	4/24/2017	26.07	4.66	21.41	-	-
		Snapshot	9/18/2017	36.10	12.97	23.13	-	-
		Baseline	09/20/17	36.10	12.99	23.11	-	-
		Short-term 1	11/06/17	36.10	10.92	25.18	-	-
		Short-term 2	11/14/17	36.10	10.42	25.68	-	-
		Short-term 3	11/14/17	36.10	10.42	25.68	-	-
		Short-term 4	11/16/17	36.10	10.32	25.78	-	-
		Performance	12/08/17	36.10	10.35	25.75	-	-
		Supplemental Performance	02/12/18	36.10	9.96	26.14	-	-
	2	Baseline 2	06/18/18	32.70	6.66	26.04	-	-
		Short-term 1	12/27/18	32.70	7.02	25.68	-	-
		Short-term 2	01/02/19	32.70	7.21	25.49	-	-
		Short-term 3	01/07/19	32.70	7.04	25.66	-	-
		Short-term 4	01/10/19	32.70	6.94	25.76	-	-
		Performance	01/30/19	32.70	7.03	25.67	-	-
	3	Baseline 3	08/20/19	32.72	7.18	25.54	-	-
		Short-term 1	10/21/19	32.72	7.28	25.44	-	-
		Short-term 2	10/23/19	32.72	7.50	25.22	-	-
		Short-term 3	10/28/19	32.72	7.19	25.53	-	-
		Short-term 4	10/30/19	32.72	7.47	25.25	-	-
		Performance	11/18/19	32.72	7.61	25.11	-	-
		Confirmation	12/14/20	32.72	7.20	25.52	-	-

Sample Location[1]	Injection Round[2]	Event	Date	Top of Casing Elevation[3] (feet)	Depth to Water from Top of Casing (feet)	Groundwater Elevation[3] (feet)	Depth to LNAPL (feet)	LNAPL thickness (feet)
MW-43S	1	Pre Development	4/24/2017	32.28	8.45	23.83	-	-
		Snapshot	9/18/2017	32.28	10.92	21.36	-	-
		Baseline	09/21/17	32.28	10.98	21.30	-	-
		Short-term 1	11/07/17	32.28	10.15	22.13	-	-
		Short-term 2	11/10/17	32.28	10.31	21.97	-	-
		Short-term 3	11/14/17	32.28	10.43	21.85	-	-
		Short-term 4	11/16/17	32.28	10.17	22.11	-	-
		Performance	12/12/17	32.28	10.25	22.03	-	-
		Supplemental Performance	02/19/18	32.28	10.18	22.10	-	-
	2	Baseline 2	06/20/18	32.28	9.14	23.14	-	-
		Short-term 1	12/27/18	32.28	10.32	21.96	-	-
		Short-term 2	01/02/19	32.28	10.00	22.28	-	-
		Short-term 3	01/07/19	32.28	10.34	21.94	-	-
		Short-term 4	01/11/19	32.28	10.14	22.14	-	-
		Performance	01/31/19	32.28	10.19	22.09	-	-
	3	Baseline 3	08/20/19	32.28	10.17	22.11	-	-
		Short-term 1	10/21/19	32.28	10.12	22.16	-	-
		Short-term 2	10/23/19	32.28	10.13	22.15	-	-
		Short-term 3	10/28/19	32.28	10.09	22.19	-	-
		Short-term 4	10/30/19	32.28	10.21	22.07	-	-
		Performance	11/18/19	32.28	10.53	21.75	-	-
		Confirmation	12/15/20	32.28	10.11	22.17	-	-
MW-44S	1	Pre Development	4/24/2017	33.54	11.67	21.87	-	-
		Snapshot	9/18/2017	33.54	13.45	20.41	13.11	0.34
		Baseline	09/22/17	33.54	13.40	20.47	13.05	0.35
		Short-term 1	11/07/17	33.54	12.76	20.82	12.72	0.04
		Short-term 2	11/10/17	33.54	12.80	20.76	12.78	0.02
		Short-term 3	11/14/17	33.54	12.79	20.76	12.78	0.01
		Short-term 4	11/17/17	33.54	12.95	20.59	12.95	trace
		Performance	12/13/17	33.54	13.25	20.48	13.05	0.20
		Supplemental Performance	02/19/18	33.54	13.10	20.58	12.95	0.15
	2	Baseline 2	06/20/18	33.54	11.79	21.90	11.63	0.16
		Short-term 1	12/27/18	33.54	13.09	20.54	13.00	0.09
		Short-term 2	01/02/19	33.54	12.84	20.70	-	-
		Short-term 3	01/07/19	33.54	12.99	20.56	12.98	0.01
		Short-term 4	01/10/19	33.54	13.08	20.49	13.05	0.03
		Performance	01/29/19	33.54	13.18	20.52	13.01	0.17
	3	Baseline 3	08/20/19	33.61	12.57	21.04	12.42	0.15
		Short-term 1	10/21/19	33.61	12.45	21.16	12.43	0.02
		Short-term 2	10/23/19	33.61	12.53	21.08	12.48	0.05
		Short-term 3	10/28/19	33.61	12.62	20.99	12.6	0.02
		Short-term 4	10/30/19	33.61	12.65	20.96	12.64	0.01
		Performance	11/18/19	33.61	13.03	20.58	13.02	0.01
		Confirmation	12/14/20	33.61	13.12	20.49	13.11	0.01

Sample Location[1]	Injection Round[2]	Event	Date	Top of Casing Elevation[3] (feet)	Depth to Water from Top of Casing (feet)	Groundwater Elevation[3] (feet)	Depth to LNAPL (feet)	LNAPL thickness (feet)
MW-45S	1	Pre Development	4/24/2017	33.99	12.13	21.90	12.09	0.04
		Snapshot	9/18/2017	33.99	13.79	20.31	13.67	0.12
		Baseline	09/22/17	33.99	13.63	20.36	trace	trace
		Short-term 1	11/07/17	33.99	13.46	20.58	13.41	0.05
		Short-term 2	11/10/17	33.99	13.46	20.53	-	-
		Short-term 3	11/14/17	33.99	13.51	20.48	-	-
		Short-term 4	11/17/17	33.99	13.60	20.39	-	-
		Performance	12/12/17	33.99	13.83	20.16	trace	trace
		Supplemental Performance	02/19/18	33.99	13.70	20.29	trace	trace
	2	Baseline 2	06/20/18	33.92	11.81	22.11	-	-
		Short-term 1	12/28/18	33.92	13.40	20.53	13.39	0.01
		Short-term 2	01/02/19	33.92	13.41	20.52	13.40	0.01
		Short-term 3	01/07/19	33.92	13.40	20.52	trace	trace
		Short-term 4	01/10/19	33.92	13.46	20.47	13.45	0.01
		Performance	01/29/19	33.92	13.47	20.45	-	-
	3	Baseline 3	08/20/19	33.75	12.70	21.05	-	-
		Short-term 1	10/21/19	33.75	12.72	21.03	-	-
		Short-term 2	10/23/19	33.75	12.75	21.00	-	-
		Short-term 3	10/28/19	33.75	12.88	20.87	-	-
		Short-term 4	10/30/19	33.75	12.95	20.80	-	-
		Performance	11/18/19	33.75	13.30	20.45	13.29	0.01
		Confirmation	12/14/20	33.75	13.48	20.27	13.47	0.01
MW-46S	1	Pre Development	4/24/2017	28.09	6.18	21.91	-	-
		Snapshot	9/18/2017	28.09	7.80	20.29	-	-
		Baseline	09/21/17	28.09	7.74	20.35	-	-
		Performance	12/07/17	28.09	7.91	20.18	-	-
		Supplemental Performance	02/13/18	28.09	7.92	20.17	-	-
	2	Baseline 2	06/20/18	28.09	6.27	21.82	-	-
		Performance	01/30/19	28.09	7.94	21.82	-	-
	3	Baseline 3	08/20/19	28.10	7.18	20.92	-	-
		Performance	11/18/19	28.10	7.75	20.35	-	-
		Confirmation	12/16/20	28.10	7.92	20.18	-	-
MW-47S	1	Pre Development	4/24/2017	33.05	-	-	-	-
		Snapshot	9/18/2017	33.05	12.75	20.30	-	-
		Baseline	09/19/17	33.05	12.74	20.31	-	-
		Short-term 1	11/06/17	33.05	12.50	20.55	-	-
		Short-term 2	11/09/17	33.05	12.51	20.54	-	-
		Short-term 3	11/14/17	33.05	12.59	20.46	-	-
		Short-term 4	11/16/17	33.05	12.65	20.40	-	-
		Performance	12/08/17	33.05	12.95	20.10	-	-
		Supplemental Performance	02/12/18	33.05	12.92	20.13	-	-
	2	Baseline 2	06/19/18	33.05	11.25	21.80	-	-
		Short-term 1	12/27/18	33.05	13.92	19.13	-	-
		Short-term 2	01/02/19	33.05	13.91	19.14	-	-
		Short-term 3	01/07/19	33.05	12.94	20.11	-	-
		Short-term 4	01/10/19	33.05	12.95	20.10	-	-
		Performance	01/30/19	33.05	15.70	17.35	-	-
	3	Baseline 3	08/20/19	33.05	12.18	20.87	-	-
		Short-term 1	10/21/19	33.05	12.18	20.87	-	-
		Short-term 2	10/23/19	33.05	12.21	20.84	-	-
		Short-term 3	10/28/19	33.05	12.33	20.72	-	-
		Short-term 4	10/30/19	33.05	12.38	20.67	-	-
		Performance	11/18/19	33.05	12.73	20.32	-	-
		Confirmation	12/14/20	33.05	12.94	20.11	-	-

Sample Location[1]	Injection Round[2]	Event	Date	Top of Casing Elevation[3] (feet)	Depth to Water from Top of Casing (feet)	Groundwater Elevation[3] (feet)	Depth to LNAPL (feet)	LNAPL thickness (feet)
MW-51S	1	Pre Development	4/24/2017	28.62	6.70	21.92	-	-
		Snapshot	9/18/2017	28.62	8.33	20.29	-	-
		Baseline	09/21/17	28.62	9.25	19.37	-	-
		Performance	12/08/17	28.62	8.46	20.16	-	-
		Supplemental Performance	02/15/18	28.62	8.49	20.13	-	-
	2	Baseline 2	06/22/18	28.62	6.84	21.78	-	-
		Performance	01/29/19	28.62	8.43	21.78	-	-
	3	Baseline 3	08/20/19	28.62	7.72	20.90	-	-
		Performance	11/18/19	28.62	8.22	20.40	-	-
		Confirmation	12/16/20	28.62	8.46	20.16	-	-
MW-36S	1	Pre Development	4/24/2017	29.62	7.70	21.92	-	-
		Snapshot	9/18/2017	29.62	9.33	20.29	-	-
		Baseline	09/21/17	29.62	9.26	20.36	-	-
		Performance	12/13/17	29.62	9.46	20.16	-	-
		Supplemental Performance	02/14/18	29.62	9.42	20.20	-	-
	2	Baseline 2	06/21/18	29.62	7.84	21.78	-	-
		Performance	01/30/19	29.62	9.48	21.78	-	-
	3	Baseline 3	08/20/19	29.62	8.72	20.90	-	-
		Performance	11/18/19	29.62	9.20	20.42	-	-
		Confirmation	12/15/20	29.62	9.47	20.15	-	-
Outwash Unit Groundwater Monitoring Wells								
MW-41D	1	Pre Development	4/24/2017	32.44	7.78	24.66	-	-
		Snapshot	9/18/2017	32.44	10.48	21.96	-	-
		Baseline	09/19/17	32.44	10.53	21.91	-	-
		Performance	12/11/17	32.44	9.01	23.43	-	-
		Supplemental Performance	02/16/18	32.44	9.22	23.22	-	-
	2	Baseline 2	06/18/18	32.44	9.48	22.96	-	-
		Performance	01/31/19	32.44	9.13	22.96	-	-
	3	Baseline 3	08/20/19	32.44	8.99	23.45	-	-
		Performance	11/18/19	32.44	9.89	22.55	-	-
		Confirmation	12/15/230	32.44	9.28	23.16	-	-
MW-45D	1	Pre Development	4/24/2017	33.25	10.86	22.39	-	-
		Snapshot	9/18/2017	33.25	12.65	20.60	-	-
		Baseline	09/22/17	33.25	13.63	19.62	-	-
		Short-term 1	11/07/17	33.25	12.25	21.00	-	-
		Short-term 2	11/10/17	33.25	12.20	21.05	-	-
		Short-term 3	11/14/17	33.25	12.31	20.94	-	-
		Short-term 4	11/16/17	33.25	12.34	20.91	-	-
		Performance	12/12/17	33.25	12.50	20.75	-	-
		Supplemental Performance	02/12/18	33.25	12.93	20.32	-	-
	2	Baseline 2	06/19/18	33.25	11.15	22.10	-	-
		Short-term 1	12/28/18	33.25	12.99	20.26	-	-
		Short-term 2	01/02/19	33.25	13.39	19.86	-	-
		Short-term 3	01/07/19	33.25	12.60	20.65	-	-
		Short-term 4	01/10/19	33.25	12.64	20.61	-	-
		Performance	01/30/19	33.25	12.67	20.58	-	-
	3	Baseline 3	08/20/19	33.40	12.04	21.36	-	-
		Short-term 1	10/21/19	33.40	12.18	21.22	-	-
		Short-term 2	10/23/19	33.40	12.05	21.35	-	-
		Short-term 3	10/28/19	33.40	12.18	21.22	-	-
		Short-term 4	10/30/19	33.40	12.45	20.95	-	-
		Performance	11/18/19	33.40	12.62	20.78	-	-
		Confirmation	12/14/20	33.40	12.64	20.76	-	-

Sample Location[1]	Injection Round[2]	Event	Date	Top of Casing Elevation[3] (feet)	Depth to Water from Top of Casing (feet)	Groundwater Elevation[3] (feet)	Depth to LNAPL (feet)	LNAPL thickness (feet)
MW-46D	1	Pre Development	4/24/2017	28.17	5.88	22.29	-	-
		Snapshot	9/18/2017	28.17	7.25	20.92	-	-
		Baseline	09/20/17	28.17	7.47	20.70	-	-
		Short-term 1	-	28.17	-	-	-	-
		Short-term 2	11/10/17	28.17	7.24	20.93	-	-
		Short-term 3	11/14/17	28.17	7.56	20.61	-	-
		Short-term 4	11/17/17	28.17	7.64	20.53	-	-
		Performance	12/07/17	28.17	7.86	20.31	-	-
		Supplemental Performance	02/13/18	28.17	7.84	20.33	-	-
	2	Baseline 2	06/20/18	28.17	6.64	21.53	-	-
		Short-term 1	12/28/18	28.17	9.65	18.52	-	-
		Short-term 2	01/02/19	28.17	7.89	20.28	-	-
		Short-term 3	01/07/19	28.17	7.90	20.27	-	-
		Short-term 4	01/11/19	28.17	7.89	20.28	-	-
		Performance	01/30/19	28.17	7.92	20.25	-	-
	3	Baseline 3	08/20/19	28.17	6.69	21.48	-	-
		Short-term 1	10/21/19	28.17	7.11	21.06	-	-
		Short-term 2	10/23/19	28.17	7.21	20.96	-	-
		Short-term 3	10/28/19	28.17	7.34	20.83	-	-
		Short-term 4	10/30/19	28.17	7.41	20.76	-	-
		Performance	11/18/19	28.17	7.92	20.25	-	-
		Confirmation	12/16/20	28.17	7.95	20.22	-	-
MW-48D	1	Pre Development	4/24/2017	30.05	8.11	21.95	8.10	0.01
		Snapshot	9/18/2017	30.05	9.69	20.37	9.68	0.01
		Baseline	09/21/17	30.05	9.66	20.39	-	-
		Short-term 1	11/07/17	30.05	9.34	20.71	-	-
		Short-term 2	11/10/17	30.05	9.41	20.64	-	-
		Short-term 3	11/14/17	30.05	9.50	20.55	-	-
		Short-term 4	11/16/17	30.05	9.53	20.52	-	-
		Performance	12/13/17	30.05	9.80	20.25	-	-
		Supplemental Performance	02/16/18	30.05	9.92	20.13	-	-
	2	Baseline 2	06/21/18	30.05	8.25	21.80	-	-
		Short-term 1	12/28/18	30.05	9.84	20.21	-	-
		Short-term 2	01/02/19	30.05	9.79	20.26	-	-
		Short-term 3	01/07/19	30.05	9.85	20.20	-	-
		Short-term 4	01/11/19	30.05	9.81	20.24	-	-
		Performance	01/30/19	30.05	10.04	20.01	-	-
	3	Baseline 3	08/20/19	30.05	9.14	20.91	-	-
		Short-term 1	10/21/19	30.05	9.10	20.95	-	-
		Short-term 2	10/23/19	30.05	9.07	20.98	-	-
		Short-term 3	10/28/19	30.05	9.57	20.48	-	-
		Short-term 4	10/30/19	30.05	9.32	20.73	-	-
		Performance	11/18/19	30.05	9.61	20.44	-	-
		Confirmation	12/16/20	30.05	9.80	20.25	-	-

Sample Location[1]	Injection Round[2]	Event	Date	Top of Casing Elevation[3] (feet)	Depth to Water from Top of Casing (feet)	Groundwater Elevation[3] (feet)	Depth to LNAPL (feet)	LNAPL thickness (feet)
MW-49D	1	Pre Development	4/24/2017	29.40	7.51	21.89	-	-
		Snapshot	9/18/2017	29.40	9.09	20.31	-	-
		Baseline	09/20/17	29.40	9.12	20.28	-	-
		Performance	12/14/17	29.40	9.24	20.16	-	-
		Supplemental Performance	02/14/18	29.40	9.02	20.38	-	-
	2	Baseline 2	06/21/18	29.40	7.55	21.85	-	-
		Performance	01/30/19	29.40	9.00	21.85	-	-
	3	Baseline 3	08/20/19	29.40	8.52	20.88	-	-
		Performance	11/18/19	29.40	9.10	20.30	-	-
		Confirmation	12/15/20	29.40	9.27	20.13	-	-
MW-36D	1	Pre Development	4/24/2017	29.55	7.76	21.79	-	-
		Snapshot	9/18/2017	29.55	9.28	20.27	-	-
		Baseline	09/22/17	29.55	9.21	20.34	-	-
		Performance	12/14/17	29.55	9.56	19.99	-	-
		Supplemental Performance	02/13/18	29.55	9.69	19.86	-	-
	2	Baseline 2	06/21/18	29.55	7.91	21.64	-	-
		Performance	01/30/19	29.55	8.90	21.64	-	-
	3	Baseline 3	08/20/19	29.55	9.87	19.68	-	-
		Performance	11/18/19	29.55	9.60	19.95	-	-
		Confirmation	12/14/20	29.55	9.41	20.14	-	-
MW-50D	1	Pre Development	4/24/2017	28.31	6.42	21.89	-	-
		Snapshot	9/18/2017	28.31	8.04	20.27	-	-
		Baseline	09/20/17	28.31	8.15	20.16	-	-
		Performance	12/07/17	28.31	7.51	20.80	-	-
		Supplemental Performance	02/15/18	28.31	8.12	20.19	-	-
	2	Baseline 2	06/21/18	28.31	7.24	21.07	-	-
		Performance	01/29/19	28.31	7.84	21.07	-	-
	3	Baseline 3	08/20/19	25.06	9.60	15.46	-	-
		Performance	11/18/19	25.06	9.73	15.33	-	-
		Confirmation	12/16/20	25.06	8.19	16.87	-	-
MW-52D	1	Pre Development	4/24/2017	28.56	6.70	21.87	6.69	0.01
		Snapshot	9/18/2017	28.56	8.35	20.21	trace	trace
		Baseline	09/21/17	28.56	8.31	20.25	-	-
		Performance	12/08/17	28.56	8.23	20.33	-	-
		Supplemental Performance	02/15/18	28.56	8.32	20.24	-	-
	2	Baseline 2	06/22/18	28.56	5.47	23.09	-	-
		Performance	01/30/19	28.56	8.45	23.09	-	-
	3	Baseline 3	08/20/19	28.56	7.83	20.73	-	-
		Performance	11/18/19	28.56	8.17	20.39	-	-
		Confirmation	12/14/20	28.56	8.44	20.12	-	-

Notes:

[1] Monitoring well locations are shown on Figure 7.

[2] Three mobilizations of injection treatment were conducted between December 2017 and December 2019.

[3] Elevation is referenced to United States Army Corp of Engineers Vertical Datum

- = not measured

trace = residual product identified on probe

Error = Equipment error

LNAPL specific gravity, PTS result for MW09-130415-LNAPL. 0.921153346

Table 3

Groundwater Quality Field Parameters

Play Area Interim Action Monitoring Report
Gas Works Park Site
Seattle, Washington

Sample Location[2]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Top of Casing Elevation[3] (feet)	Groundwater Elevation (ft USACE)	Field Measurements[1]						Field Test Kit Analyses			Tubing Intake	Volume Purged (gal)
							pH	SC (µS/cm)	Turbidity (NTU)	DO (mg/L)	Temp (°F)	ORP (mV)	Sulfate (mg/L)	Iron (mg/L)	Arsenic (ppb)		
Fill Unit Monitoring Wells																	
MW-41S	1	Baseline	09/25/17	7.55	32.27	24.72	7.37	719	83.6	4.6	65.30	115.5	100	0	50	-	-
		Performance	12/11/17	4.49	32.27	27.78	7.26	482	1.9	1.0	52.40	51.0	-	-	-	-	-
		Supplemental Performance	02/16/18	-	32.27	-	7.16	423	1.6	0.9	49.30	76.5	-	-	-	9.4	3
	2	Baseline 2	06/19/18	5.57	32.27	26.70	7.21	627	1.52	0.36	62.3	26.0	-	-	-	-	-
		Performance	01/31/19	5.32	32.27	26.95	7.09	611	3.91	0.94	50.1	20.2	-	-	-	8	1.8
	3	Baseline 3	08/20/19	5.78	32.27	26.49	7.12	751	4.53	0.18	67.3	-127.0	175	0.85	-	8	2.1
		Performance	11/18/19	5.75	32.27	26.52	7.47	656	9.64	1.65	57.6	-35.4	125	0.80	-	8	4.5
		Confirmation	12/15/20	5.32	32.27	26.95	7.24	511	4.72	2.10	54.3	177.5	-	-	-	8	1.5
MW-42S	1	Baseline	09/20/17	12.99	31.07	18.08	9.26	1,295	-	2.74	62.0	-114.1	-	-	-	14.18	1.7
		Short-term 1	11/06/17	10.92	31.07	20.15	6.22	1,633	2.32	1.15	58.5	85.5	>200	3.0	50-500	14.18	2.5
		Short-term 2	11/09/17	10.72	31.07	20.35	6.76	1,776	4.60	0.17	56.6	-8.50	>200	4.0	500	14.18	2.5
		Short-term 3	11/14/17	10.42	31.07	20.65	6.48	1,486	2.66	0.28	56.2	94.0	>200	5.5	250	14.18	2.5
		Short-term 4	11/16/17	10.32	31.07	20.75	6.46	1,268	2.70	0.37	54.0	105.5	>200	6.0	500	14.18	2.5
		Performance	12/08/17	10.35	31.07	20.72	6.61	800	2.38	0.29	51.4	-23.8	-	-	-	14.18	1.15
		Supplemental Performance	02/12/18	-	31.07	-	6.55	615	1.52	0.17	48.8	-49.8	-	-	-	14.18	2.8
	2	Baseline 2	06/18/18	6.66	31.07	24.41	6.62	770	2.98	0.38	65.5	-18.8	-	-	-	--	--
		Short-term 1	12/27/18	7.02	31.07	24.05	7.51	1,050	3.73	11.42[3]	55.2	-43.0	175	7	-	12	1.42
		Short-term 2	01/02/19	7.21	31.07	23.86	7.86	1,240	4.32	12.2[3]	54.0	-107.0	>200	>7	-	12	2
		Short-term 3	01/07/19	7.04	31.07	24.03	6.64	1,169	0.02	0.33	53.2	-27.7	>200	>7	-	12	1.7
		Short-term 4	01/10/19	6.94	31.07	24.13	6.79	1,169	4.27	0.49	54.5	64.6	>200	>7	-	12	1.4
		Performance	01/30/19	7.03	31.07	24.04	6.52	1,209	4.39	0.66	49.4	50.8	--	--	-	12	1.5
	3	Baseline 3	08/21/19	7.18	31.07	23.89	6.46	1,868	9.46	0.59	61.2	30.3	>200	3.5	-	12	2.1
		Short-term 1	10/21/19	7.28	31.07	23.79	6.55	1,064	-	0.62	15.4	-150.3	150	7.5	-	12	1.8
		Short-term 2	10/23/19	7.50	31.07	23.57	6.75	1,086	-	0.16	60.0	-313.50	>200	1.5	-	11	4.8
		Short-term 3	10/28/19	7.19	31.07	23.88	6.96	1,153	7.62	0.24	58.2	-113.3	>200	0 - 0.5	-	12	1.8
		Short-term 4	10/30/19	7.47	31.07	23.60	6.93	1,180	9.21	0.21	58.1	-91.5	>200	>10	-	12	1.8
		Performance	11/18/19	7.61	31.07	23.46	6.91	1,160	1.48	0.19	58.8	-132.8	>200	8.0		9	3.5
		Confirmation	12/14/20	7.20	31.07	23.87	6.78	998	1.88	0.42	56.8	-96.2	-	-	-	9	3

Sample Location[2]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Top of Casing Elevation[3] (feet)	Groundwater Elevation (ft USACE)	Field Measurements[1]						Field Test Kit Analyses			Tubing Intake	Volume Purged (gal)
							pH	SC (μS/cm)	Turbidity (NTU)	DO (mg/L)	Temp (°F)	ORP (mV)	Sulfate (mg/L)	Iron (mg/L)	Arsenic (ppb)		
MW-43S	1	Baseline	09/21/17	10.98	32.28	21.30	5.65	189	8.31	1.32	62.2	-122.6	55	7.0	100	12.04	1.9
		Short-term 1	11/07/17	10.15	32.28	22.13	5.37	281	5.37	0.30	60.4	41.1	80	3.0	400	12.04	1.9
		Short-term 2	11/10/17	10.31	32.28	21.97	5.3	307	4.60	0.30	61.1	68.1	90	3.5	1,500	12.04	1.9
		Short-term 3	11/14/17	10.43	32.28	21.85	5.22	273	2.44	0.14	59.7	103.1	80	4.0	1,500	12.04	1.9
		Short-term 4	11/16/17	10.17	32.28	22.11	5.25	272	2.15	0.16	58.3	100.7	80	5.0	1,500	12.04	1.9
		Performance	12/12/17	10.25	32.28	22.03	5.26	267	2.91	0.62	56.6	57.4	-	-	-	12.04	-
		Supplemental Performance	02/19/18	-	32.28	-	5.33	298	1.16	0.17	52.9	197.5	-	-	-	12.04	1.2
	2	Baseline 2	06/20/18	9.14	32.28	23.14	5.05	267	0.84	0.25	16.5	23.8	-	-	-	--	-
		Short-term 1	12/27/18	10.32	32.28	21.96	7.41	398	4.47	10.68[3]	56.2	110.0	200	7.0	-	12	3
		Short-term 2	01/02/19	10.00	32.28	22.28	7.61	394	3.01	10.04[3]	56.4	41.0	160	>7.0	-	12	2
		Short-term 3	01/07/19	10.34	32.28	21.94	5.21	468	3.27	3.12	53.2	13.7	>200	5	-	12	1.5
		Short-term 4	01/11/19	10.14	32.28	22.14	5.87	428	4.63	1.14	55.0	42.4	150	7	-	12	2.2
		Performance	01/31/19	10.19	32.28	22.09	5.22	382	3.57	2.43	53.7	41.3	--	--	-	12	1.25
	3	Baseline 3	08/22/19	10.17	32.28	22.11	5.52	324	8.62	0.45	63.1	69.3	150	>>10	-	12	1.6
		Short-term 1	10/21/19	10.12	32.28	22.16	5.71	356		0.15	62.1	-130.8	200	>10	-	11	2
		Short-term 2	10/23/19	10.13	32.28	22.15	5.67	313	5.39	0.28	62.2	-16.10	125	3.5	-	11	3.5
		Short-term 3	10/28/19	10.09	32.28	22.19	5.6	309	4.93	0.20	61.5	25.9	150	2.0	-	11	1.25
		Short-term 4	10/30/19	10.21	32.28	22.07	5.58	303	3.89	0.20	60.4	29.3	125	>10	-	11	1.25
		Performance	11/18/19	10.53	32.28	21.75	5.81	316	3.59	0.20	59.9	24.2	125	>10	-	11	2.75
		Confirmation	12/15/20	10.11	32.28	22.17	5.65	280	2.99	0.62	57.6	39.7	-	-	-	11	1
MW-44S	1	Baseline	09/22/17	13.40	33.54	20.14	6.60	1,359	4.60	0.21	60.8	-303.7	125	1.0	100	15.15	1.65
		Short-term 1	11/07/17	12.76	33.54	20.78	6.16	3,086	5.26	0.26	58.7	-9.80	>200	6.0	400	15.15	1.65
		Short-term 2	11/10/17	12.80	33.54	20.74	6.07	3,367	16.1	0.22	58.5	35.0	>200	4.0	500	15.15	1.65
		Short-term 3	11/14/17	12.79	33.54	20.75	6.06	3,384	10.7	0.25	58.3	128	>200	4.5	1,500	15.15	1.65
		Short-term 4	11/17/17	12.95	33.54	20.59	6.07	3,250	10.5	0.15	58.1	60.0	>200	4.5	1,500	15.15	1.65
		Performance	12/13/17	13.25	33.54	20.29	6.12	2,788	46.9	0.14	56.7	-150.0	-	-	-	15.15	2.2
		Supplemental Performance	02/19/18	-	33.54	-	6.07	3,647	8.3	0.18	54.1	63.3	-	-	-	15.15	2.4
	2	Baseline 2	06/20/18	11.79	33.54	-G65	5.92	1,614	3.25	0.17	59.7	34.9	--	--	-	-	-
		Short-term 1	12/27/18	13.09	33.54	20.45	8.18	2,400	5.04	8.47[3]	53.2	-99.0	>200	7.0	-	15	3.9
		Short-term 2	01/02/19	12.84	33.54	20.70	7.75	2,450	17.50	9.92[3]	54.0	-112.0	>200	>7.0	-	15	2
		Short-term 3	01/07/19	12.98	33.54	20.56	6.03	2,402	5.47	0.28	53.4	-33.2	>200	>7.0	-	15	1.4
		Short-term 4	01/10/19	13.08	33.54	20.46	6.33	2,435	4.89	0.18	55.4	40.2	>200	7.0	-	15	1.6
		Performance	01/29/19	13.18	33.54	20.36	5.97	2,639	4.92	1.52	52.8	63.9	--	--	-	15	2.7
	3	Baseline 3	08/21/19	12.57	33.54	20.97	5.84	5,790	12.7	3.03	59.7	14.4	>>200	>>10	-	18.5	2.5
		Short-term 1	10/21/19	12.45	33.54	21.09	5.96	3,492	-	0.43	15.0	-116.3	>200	>10	-	15	1.2
		Short-term 2	10/23/19	12.53	33.54	21.01	5.92	4,174	5.39	0.25	58.9	-232.30	>200	>10	-	15	2.5
		Short-term 3	10/28/19	12.62	33.54	20.92	5.92	4,573	5.45	0.24	58.5	-154.1	>200	0.5-1	-	15	2.4
		Short-term 4	10/30/19	12.65	33.54	20.89	5.90	4,867	0.02	0.19	58.8	-118.4	>200	>10	-	15	2.4
		Performance	11/18/19	13.03	33.54	20.51	5.94	4,295	4.63	0.34	57.0	-157.8	>200	>10	-	15.5	1.75
		Confirmation	12/14/20	13.12	33.54	20.42	6.37	2,349	11.10	0.30	57.7	-136.2	-	-	-	15.5	2

Sample Location[2]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Top of Casing Elevation[3] (feet)	Groundwater Elevation (ft USACE)	Field Measurements[1]						Field Test Kit Analyses			Tubing Intake	Volume Purged (gal)
							pH	SC (µS/cm)	Turbidity (NTU)	DO (mg/L)	Temp (°F)	ORP (mV)	Sulfate (mg/L)	Iron (mg/L)	Arsenic (ppb)		
MW-45S	1	Baseline	09/22/17	13.63	33.99	20.36	7.50	1,381	2.65	0.19	58.0	-37.8	50	1.0	--	16.2	1.7
		Short-term 1	11/07/17	13.46	33.99	20.53	7.40	2,780	48.2	0.31	58.4	63.3	>200	1.0	250	16.2	1.7
		Short-term 2	11/10/17	13.46	33.99	20.53	7.27	2,524	25.2	0.18	58.6	66.0	200	0.5	500	16.2	1.7
		Short-term 3	11/14/17	13.51	33.99	20.48	6.84	2,232	14.8	0.23	59.1	182.8	>200	3.0	500	16.2	1.7
		Short-term 4	11/17/17	13.60	33.99	20.39	8.37	2,482	21.7	0.14	57.5	129.3	>200	1.0	1,500	16.2	1.7
		Performance	12/12/17	13.83	33.99	20.16	9.18	2,719	26.8	0.10	55.1	-16.5	-	-	-	-	-
		Supplemental Performance	02/19/18	-	33.99	-	9.25	2,703	60.0	0.37	50.0	72.6	-	-	-	16.2	1.05
	2	Baseline 2	06/20/18	11.81	33.99	22.18	6.56	2,031	11.10	0.07	63.9	-43.8	-	-	-	-	-
		Short-term 1	12/28/18	13.40	33.99	20.90	8.40	2,740	97.30	11.04[3]	56.3	-371.0	>200	1.0	-	16	4.75
		Short-term 2	01/02/19	13.41	33.99	21.15	7.81	2,830	6.45	10.59[3]	53.9	-249.0	>200	1.5	-	16	2.3
		Short-term 3	01/07/19	13.40	33.99	21.01	8.91	2,708	2.68	0.11	54.3	-74.8	>200	0.5	-	16	2.9
		Short-term 4	01/10/19	13.46	33.99	20.91	9.45	2,663	4.27	0.10	56.3	-91.0	>200	0.1	-	16	2.2
		Performance	01/29/19	13.47	33.99	20.52	8.33	2,580	14.90	1.11	53.9	-178.0	-	-	-	15	2.2
	3	Baseline 3	08/20/19	12.70	33.99	21.29	6.92	4,119	70.70	0.21	64.0	-210.7	>200	-	-	15	2.1
		Short-term 1	10/21/19	12.72	33.99	21.27	8.78	2,472	-	0.23	15.3	-353.4	>200	>10	-	15	1.8
		Short-term 2	10/23/19	12.75	33.99	21.24	8.86	2,613	2.51	0.02	59.5	-403.80	>200	7.0	-	15	2
		Short-term 3	10/28/19	12.88	33.99	21.11	7.79	2,594	0.02	0.14	58.1	-333.5	>200	0.5	-	15	1.5
		Short-term 4	10/30/19	12.95	33.99	21.04	8.17	2,592	0.02	0.28	56.2	-349.5	>200	-	-	15	1.5
		Performance	11/18/19	13.30	33.99	20.69	8.17	2,521	4.04	0.13	57.8	-408.0	>200	6	-	15	1
		Confirmation	12/14/20	13.48	33.99	20.51	9.52	2,570	9.58	0.17	57.6	-380.7	-	-	-	15	2
MW-46S	1	Baseline	09/21/17	7.74	28.09	20.35	5.94	350	0.31	0.21	59.8	-15.2	50	2.0	25	-	-
		Performance	12/07/17	7.91	28.09	20.18	5.69	293	0.35	0.17	59.0	14.9	-	-	-	-	-
		Supplemental Performance	02/13/18	-	28.09	-	5.63	353	0.16	0.16	55.0	100.3	-	-	-	12.3	3.25
	2	Baseline 2	06/20/18	6.27	28.09	21.82	6.04	436	2.31	0.12	59.8	17.8	-	-	-	-	-
		Performance	01/30/19	7.94	28.09	20.15	5.88	364	3.92	0.30	56.3	25.7	-	-	-	14	1.7
	3	Baseline 3	08/21/19	7.18	28.09	20.91	6.06	350	1.82	0.20	60.6	-134.9	<50	0.5	-	14	2.5
		Performance	11/18/19	7.75	28.09	20.34	6.29	324	3.18	0.30	59.0	172.9	<50	2.0	-	13	1.75
		Confirmation	12/16/20	7.92	28.09	20.17	6.44	302	4.52	0.15	59.1	-79.3	-	-	-	13	1.75

							Field Measurements[1]						Field Test Kit Analyses				
Sample Location[2]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Top of Casing Elevation[3] (feet)	Groundwater Elevation (ft USACE)	pH	SC (µS/cm)	Turbidity (NTU)	DO (mg/L)	Temp (°F)	ORP (mV)	Sulfate (mg/L)	Iron (mg/L)	Arsenic (ppb)	Tubing Intake	Volume Purged (gal)
MW-47S	1	Baseline	09/19/17	12.74	33.05	20.31	6.18	531	1.95	0.18	59.8	3.80	50	3.5	15	16.6	3.6
		Short-term 1	11/06/17	12.50	33.05	20.55	6.06	569	1.35	0.22	59.2	5.00	90	6.5	75	16.6	3.6
		Short-term 2	11/09/17	12.51	33.05	20.54	6.05	567	1.68	0.24	59.4	130.3	100	4.0	75	16.6	3.6
		Short-term 3	11/14/17	12.59	33.05	20.46	6.04	540	2.07	0.14	59.8	108.2	90	6.5	85	16.6	3.6
		Short-term 4	11/16/17	12.65	33.05	20.40	5.95	563	0.83	0.65	58.5	165.6	90	4.0	100	16.6	3.6
		Performance	12/08/17	12.95	33.05	20.10	6.09	518	0.85	0.24	57.4	-13.6	-	-	-	16.6	-
		Supplemental Performance	02/12/18	-	33.05	-	6.05	490	0.75	0.12	53.4	-10.4	-	-	-	16.6	3.25
	2	Baseline 2	06/19/18	11.25	33.05	21.80	6.14	610	0.75	0.20	57.9	-15.3	-	-	-	-	-
		Short-term 1	12/27/18	13.92	33.05	19.13	7.83	468	2.25	9.92[3]	56.0	-73.0	65	7.0	-	16	2.5
		Short-term 2	01/02/19	13.91	33.05	19.14	7.81	318	3.27	11.47[3]	53.2	-84.0	0	7.0	-	16	2
		Short-term 3	01/07/19	12.94	33.05	20.11	5.83	313	0.02	0.27	56.0	-42.7	<50	7.0	-	16	1.5
		Short-term 4	01/10/19	12.95	33.05	20.10	6.50	471	2.93	0.43	57.5	-64.2	55	4.0	-	16	1.8
		Performance	01/30/19	15.70	33.05	17.35	5.95	419	2.66	0.40	55.2	-1.2	-	-	-	17	1.7
	3	Baseline 3	08/21/19	12.18	33.05	20.87	5.76	414	8.40	0.26	61.4	55.1	<50	3.5	-	17	2.8
		Short-term 1	10/21/19	12.18	33.05	20.87	6.21	1,016	--	0.27	15.7	-182.4	>200	>10	-	15	1.8
		Short-term 2	10/23/19	12.21	33.05	20.84	6.14	839	--	0.11	60.6	-82.80	>200	7.0	-	16.5	2
		Short-term 3	10/28/19	12.33	33.05	20.72	6.06	602	3.10	0.10	61.1	1.5	>200	3.0	-	16.5	1.5
		Short-term 4	10/30/19	12.38	33.05	20.67	6.06	563	1.93	0.11	61.1	3.7	200	>10	-	16	3
		Performance	11/18/19	12.73	33.05	20.32	6.28	400	2.94	0.15	60.6	-34.3	60	>10	-	17	2
		Confirmation	12/14/20	12.94	33.05	20.11	6.08	350	1.63	0.25	59.4	-91.7	-	-	-	17	4
MW-51S	1	Baseline	09/21/17	9.25	28.62	19.37	6.08	339	0.88	0.21	61.2	15.4	50	3.0	50	-	-
		Performance	12/08/17	8.46	28.62	20.16	5.81	234	0.72	0.20	55.8	-1.00	-	-	-	-	-
		Supplemental Performance	02/15/18	-	28.62	-	5.70	247	1.52	0.14	53.2	10.10	-	-	-	12.5	1.75
	2	Baseline 2	06/22/18	6.84	28.62	21.78	5.96	206	1.15	0.16	59.5	19.0	-	-	-	-	-
		Performance	01/29/19	8.43	28.62	20.19	6.19	238	4.43	0.27	55.6	34.7	-	-	-	13	3.5
	3	Baseline 3	08/22/19	7.72	28.62	20.90	6.26	333	7.58	0.10	59.8	-161.0	<<50	2.5	-	13	1.5
		Performance	11/18/19	8.22	28.62	20.40	6.38	231	2.41	0.26	58.4	-137.3	<50	2.0	-	13	1.75
		Confirmation	12/16/20	8.46	28.62	20.16	6.60	257	4.28	0.29	57.8	-76.0	-	-	-	13	2
MW-36S	1	Baseline	09/21/17	9.26	29.62	20.36	6.45	363	2.43	0.90	60.2	-131.5	50	2.5	15	-	-
		Performance	12/13/17	9.46	29.62	20.16	6.08	414	2.90	0.30	57.8	-55.9	-	-	-	14.9	3.65
		Supplemental Performance	02/13/18	-	29.62	-	6.05	520	1.86	0.11	54.7	-31.4	-	-	-	14.9	5.1
	2	Baseline 2	06/21/18	7.84	29.62	21.78	5.92	345	4.10	0.20	57.1	38.6	-	-	-	-	-
		Performance	01/30/19	9.48	29.62	20.14	6.32	414	7.50	0.52	54.5	7.8	-	-	-	19	2
	3	Baseline 3	08/22/19	8.72	29.62	20.90	6.05	383	4.85	0.08	60.6	-171.2	<<50	>10	-	19	1.43
		Performance	11/18/19	9.20	29.62	20.42	6.22	320	3.81	0.20	59.2	-38.3	<59	>10	-	17	3.5
		Confirmation	12/15/20	9.47	29.62	20.15	6.55	405	5.02	0.15	56.6	-228.0	-	-	-	17	3

							Field Measurements[1]						Field Test Kit Analyses				
Sample Location[2]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Top of Casing Elevation[3] (feet)	Groundwater Elevation (ft USACE)	pH	SC (µS/cm)	Turbidity (NTU)	DO (mg/L)	Temp (°F)	ORP (mV)	Sulfate (mg/L)	Iron (mg/L)	Arsenic (ppb)	Tubing Intake	Volume Purged (gal)
Outwash Unit Monitoring Wells																	
MW-41D	1	Baseline	09/19/17	10.53	32.44	21.91	6.86	728	3.95	0.28	59.4	-20.4	50	7.0	10	-	-
		Performance	12/11/17	9.01	32.44	23.43	6.54	713	3.35	0.20	56.6	66.1	-	-	-	-	-
		Supplemental Performance	02/16/18	-	32.44	-	6.40	719	3.95	0.16	53.3	44.2	-	-	-	23.5	3.4
	2	Baseline 2	06/18/18	9.48	32.44	22.96	6.52	732	0.62	0.17	65.2	-36.9	-	-	-	-	-
		Performance	01/31/19	9.13	32.44	23.31	6.29	692	4.66	0.39	53.1	-11.7	-	-	-	23.5	1.6
	3	Baseline 3	08/20/19	8.99	32.44	23.45	6.46	740	27.50	0.11	60.4	-212.9	<<50	>>10	-	23.5	4.1
		Performance	11/18/19	9.89	32.44	22.55	6.80	767	10.60	0.15	57.4	-86.2	<50	>10	-	27	6
		Confirmation	12/15/20	9.28	32.44	23.16	6.61	736	8.53	0.36	57.0	-69.3	-	-	-	27	8.5
MW-45D	1	Baseline	9/22/17	13.63	33.25	19.62	7.50	1,381	-	0.19	58.0	-37.8	50	1.0	-	27.3	3.5
		Short-term 1	11/07/17	12.25	33.25	21.00	7.50	1,376	2.68	0.27	55.4	12.3	50	1.0	200	27.3	3.5
		Short-term 2	11/10/17	12.20	33.25	21.05	7.46	1,404	3.06	0.24	56.1	17.6	<50	1.5	500	27.3	3.5
		Short-term 3	11/14/17	12.31	33.25	20.94	7.51	1,429	2.41	0.19	56.1	99.2	60	1.5	500	27.3	3.5
		Short-term 4	11/16/17	12.34	33.25	20.91	7.43	1,419	2.46	0.17	55.1	126.2	<50	1.0	500	27.3	3.5
		Performance	12/12/17	12.50	33.25	20.75	7.45	1,403	1.7	0.15	54.6	59.8	-	-	-	-	-
		Supplemental Performance	02/12/18	-	33.25	-	7.25	2,229	1.6	0.12	54.5	-67.1	-	-	-	27.3	2.6
	2	Baseline 2	06/19/18	11.15	33.25	22.10	7.27	2,807	2.31	0.10	61.2	-139.9	-	-	-	-	-
		Short-term 1	12/28/18	12.99	33.25	20.26	7.70	1,250	4.63	9.02[3]	55.1	-97.0	135	1.0	-	25	3.4
		Short-term 2	01/02/19	13.39	33.25	19.86	7.80	1,790	4.03	10.98[3]	53.2	-131.0	>200	>7.0	-	25	2
		Short-term 3	01/07/19	12.60	33.25	20.65	6.92	2,573	1.57	0.30	53.1	-52.0	>200	7.0	-	25	1.7
		Short-term 4	01/10/19	12.64	33.25	20.61	7.27	2,655	1.60	0.32	56.0	-122.1	>200	7.0	-	25	2
		Performance	01/30/19	12.67	33.25	20.58	6.88	2,530	4.70	0.44	52.4	-42.5	--	--	-	27.3	1.7
	3	Baseline 3	08/20/19	12.04	33.25	21.21	6.85	2,460	4.43	0.09	58.5	-175.4	>200	>10	-	27.3	3.1
		Short-term 1	10/21/19	12.18	33.25	21.07	6.84	2,036	-	0.49	14.3	-133.2	>200	>10	-	27	2.7
		Short-term 2	10/23/19	12.05	33.25	21.20	6.89	2,371	-	0.08	57.1	-159.00	>200	7.0	-	27	4.25
		Short-term 3	10/28/19	12.18	33.25	21.07	6.91	2,444	7.22	0.28	56.3	-152.1	>200	0.5	-	27	3
		Short-term 4	10/30/19	12.45	33.25	20.80	6.89	2,521	7.80	0.52	56.8	-160.3	>200	>10	-	27	2.7
		Performance	11/18/19	12.62	33.25	20.63	6.87	2,908	2.00	0.24	56.9	-148.4	>200	>10	-	27	3
		Confirmation	12/14/20	12.64	33.25	20.61	6.78	2,409	2.38	0.56	57.0	-119.1	-	-	-	27	3

							Field Measurements[1]						Field Test Kit Analyses				
Sample Location[2]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Top of Casing Elevation[3] (feet)	Groundwater Elevation (ft USACE)	pH	SC (µS/cm)	Turbidity (NTU)	DO (mg/L)	Temp (°F)	ORP (mV)	Sulfate (mg/L)	Iron (mg/L)	Arsenic (ppb)	Tubing Intake	Volume Purged (gal)
MW-46D	1	Baseline	09/20/17	7.47	28.17	20.70	9.24	2,455	204.0	3.12	57.6	132.5	200	0.5	10	26.5	10
		Short-term 1	-	-	28.17	-	-	-	-	-	-	-	-	-	-	26.5	10
		Short-term 2	11/10/17	7.24	28.17	20.93	9.16	3,506	8.27	0.40	56.4	56.9	>200	0.5	500	26.5	10
		Short-term 3	11/14/17	7.56	28.17	20.61	8.64	2,113	35.0	0.55	56.7	229.2	200	0.5	500	26.5	10
		Short-term 4	11/17/17	7.64	28.17	20.53	9.04	2,575	9.83	0.14	55.8	198.0	200	0.5	500	26.5	10
		Performance	12/07/17	7.86	28.17	20.31	9.03	2,553	11.7	0.14	55.2	14.3	-	-	-	-	-
		Supplemental Performance	02/13/18	-	28.17	-	9.09	2,621	3.6	0.06	55.5	93.0	-	-	-	26.5	3.7
	2	Baseline 2	06/20/18	6.77	28.17	21.40	8.75	2,519	2.77	0.10	18.5	44.5	-	-	-	-	-
		Short-term 1	12/28/18	9.65	28.17	18.52	8.23	2,840	0.19	8.29[3]	54.5	-210.0	>200	<1.0	-	25	3
		Short-term 2	01/02/19	7.89	28.17	20.28	7.77	2,850	4.71	9.40[3]	55.2	-265.0	>200	1.0	-	25	2.9
		Short-term 3	01/07/19	7.90	28.17	20.27	9.11	3,099	4.14	0.24	56.0	-27.9	>200	4.25	-	25	1.4
		Short-term 4	01/11/19	7.89	28.17	20.28	9.41	2,823	4.12	0.25	57.1	5.3	>200	0.5	-	25	1.9
		Performance	01/30/19	7.92	28.17	20.25	9.20	3,091	2.40	0.30	55.4	49.7	-	-	-	26.5	1.8
	3	Baseline 3	08/21/19	6.69	28.17	21.48	9.00	2,895	15.70	0.04	58.7	-260.1	>200	1	-	26.5	5
		Short-term 1	10/21/19	7.11	28.17	21.06	9.06	3,499	-	0.50	57.5	-292.8	>200	1.0	-	27	5
		Short-term 2	10/23/19	7.21	28.17	20.96	8.88	3,579	5.62	0.24	57.7	-304.70	>200	0.5	-	27	4.6
		Short-term 3	10/28/19	7.34	28.17	20.83	8.75	3,600	3.17	0.24	57.0	-193.9	>200	0.8	-	27	4.25
		Short-term 4	10/30/19	7.41	28.17	20.76	8.79	4,400	2.22	0.10	57.2	-264.8	>200	3.0	-	27	4
		Performance	11/18/19	7.92	28.17	20.25	8.83	4,596	1.42	0.37	56.7	-268.8	>200	1.5	-	27	3.75
		Confirmation	12/16/20	7.95	28.17	20.22	8.11	4,496	1.37	0.20	56.7	-252.3	-	-	-	27	4
MW-48D	1	Baseline	09/21/17	9.66	30.05	20.39	7.79	1,022	12.60	0.35	60.5	-108.4	0	1.0	75	27.1	7.3
		Short-term 1	11/07/17	9.34	30.05	20.71	7.67	1,119	3.36	0.23	56.8	40.2	<50	1.0	500	27.1	7.3
		Short-term 2	11/10/17	9.41	30.05	20.64	7.60	1,157	3.57	0.22	57.8	19.4	55	0.5	1,500	27.1	7.3
		Short-term 3	11/14/17	9.50	30.05	20.55	7.51	1,298	0.93	1.62	56.8	137.8	150	1.0	500	27.1	7.3
		Short-term 4	11/16/17	9.53	30.05	20.52	7.40	1,442	0.71	0.12	56.4	56.4	200	1.0	500	27.1	7.3
		Performance	12/13/17	9.80	30.05	20.25	7.26	2,308	0.6	0.10	56.8	-7.5	-	-	-	27.1	3.9
		Supplemental Performance	02/16/18	-	30.05	-	6.86	2,722	0.6	0.12	56.6	-78.4	-	-	-	27.1	4.2
	2	Baseline 2	06/21/18	8.25	30.05	21.80	6.92	4,251	3.01	0.21	57.8	72.2	-	-	-	-	-
		Short-term 1	12/28/18	9.84	30.05	20.21	9.09	215	25.10	10.79[3]	57.5	-136.0	<50	0.5	-	15	4
		Short-term 2	01/02/19	9.79	30.05	20.26	7.53	4,500	4.88	8.90[3]	56.4	-102.0	>200	>7.0	-	15	2.4
		Short-term 3	01/07/19	9.85	30.05	20.20	6.30	4,998	3.22	0.24	56.6	-47.3	>200	4.5	-	15	2.3
		Short-term 4	01/11/19	9.81	30.05	20.24	6.79	3,522	3.68	0.40	57.3	-58.3	>200	>7.0	-	15	1.9
		Performance	01/30/19	10.04	30.05	20.01	6.67	2,971	4.51	0.55	56.2	-52.6	-	-	-	27.1	1.25
	3	Baseline 3	08/22/19	9.14	30.05	20.91	6.46	4,807	4.32	0.22	60.3	-89.7	>200	>>10	-	27.1	4.2
		Short-term 1	10/21/19	9.10	30.05	20.95	6.38	5,150	-	0.22	57.7	-105.1	>200	>10	-	30	5
		Short-term 2	10/23/19	9.07	30.05	20.98	6.36	5,318	6.15	0.21	58.1	-108.20	>200	>7	-	25	4.5
		Short-term 3	10/28/19	9.57	30.05	20.48	6.37	4,641	2.79	0.21	58.3	-66.2	>200	7.0	-	28	4.25
		Short-term 4	10/30/19	9.32	30.05	20.73	6.34	5,047	2.28	0.11	57.6	-60.2	>200	>10	-	32	4
		Performance	11/18/19	9.61	30.05	20.44	6.50	5,230	4.90	0.12	57.6	-86.8	>200	>10	-	28	5
		Confirmation	12/16/20	9.80	30.05	20.25	6.64	529	2.78	0.63	57.4	-71.2	-	-	-	28	5.2

							Field Measurements[1]						Field Test Kit Analyses				
Sample Location[2]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Top of Casing Elevation[3] (feet)	Groundwater Elevation (ft USACE)	pH	SC (μS/cm)	Turbidity (NTU)	DO (mg/L)	Temp (°F)	ORP (mV)	Sulfate (mg/L)	Iron (mg/L)	Arsenic (ppb)	Tubing Intake	Volume Purged (gal)
MW-49D	1	Baseline	09/20/17	9.12	29.40	20.28	9.12	4,394	37.5	4.14	58.9	-266.8	200	0.0	10	-	-
		Performance	12/14/17	9.24	29.40	20.16	8.91	4,484	20.20	0.30	57.0	37.2	-	-	-	-	5.6
		Supplemental Performance	02/14/18	-	29.40	-	8.89	4,622	14.00	0.05	54.6	25.1	-	-	-	29.1	7
	2	Baseline 2	06/21/18	7.55	29.40	21.85	8.94	4,130	7.73	0.13	15.2	-72.5	-	-	-	-	-
		Performance	01/30/19	9.00	29.40	20.40	8.95	4,694	4.92	0.44	56.5	-2.1	-	-	-	26	2.5
	3	Baseline 3	08/22/19	8.52	29.40	20.88	9.04	3,947	4.20	0.09	58.8	-38.4	>200	3	-	26	4.1
		Performance	11/18/19	9.10	29.40	20.30	8.88	7,496	1.06	0.09	57.0	-264.7	>200	<10	<1.0	-	5
		Confirmation	12/15/20	9.27	29.40	20.13	8.64	8,256	3.87	0.15	56.3	-519.2	-	-	-	29	5.5
MW-36D	1	Baseline	09/22/17	9.21	29.55	20.34	8.95	3,573	1.58	0.53	60.7	-233.5	200	0.0	700	31.15	-
		Performance	12/14/17	9.56	29.55	19.99	8.88	3,622	1.52	0.29	56.4	52.0	-	-	-	31.15	3
		Supplemental Performance	02/13/18	-	29.55	-	8.93	3,641	0.95	0.05	55.0	40.0	-	-	-	31.15	3.3
	2	Baseline 2	06/21/18	7.91	29.55	21.64	9.03	3,644	0.44	0.08	59.7	-22.1	-	-	-	-	-
		Performance	01/30/19	8.90	29.55	20.65	7.91	2,943	3.72	0.61	52.1	-21.8	-	-	-	29.5	1.25
	3	Baseline 3	08/22/19	9.87	29.55	19.68	8.97	6,280	4.60	0.04	58.7	-325.7	-	-	-	29.5	4.2
		Performance	11/18/19	9.60	29.55	19.95	8.74	6,716	4.16	0.10	57.2	-230.1	>200	-	-	30	4.3
		Confirmation	12/15/20	9.41	29.55	20.14	7.14	8,970	3.71	0.20	56.2	-316.1	-	-	-	30	4.25
MW-50D	1	Baseline	09/20/17	8.15	28.31	20.16	9.62	8,522	4.99	0.15	58.0	19.4	200	1.8	75	-	-
		Performance	12/07/17	7.51	28.31	20.80	9.42	7,019	3.66	0.09	53.5	12.5	-	-	-	-	-
		Supplemental Performance	02/15/18	-	28.31	-	9.35	-	5.22	0.05	54.7	-22.1	-	-	-	31.6	7.4
	2	Baseline 2	06/21/18	7.24	28.31	21.07	9.38	7,065	3.06	0.06	14.5	-94.4	-	-	-	-	-
		Performance	01/29/19	7.84	28.31	20.47	9.41	6,950	4.52	0.47	55.6	-38.4	-	-	-	31	2.5
	3	Baseline 3	08/22/19	9.60	28.31	18.71	9.62	7,738	3.96	0.05	57.4	-305.3	>>200	1	-	32	4.5
		Performance	11/18/19	9.73	28.31	18.58	9.41	7,614	4.92	0.09	56.7	-333.0	>>200	-	-	31	4.5
		Confirmation	12/16/20	9.73	28.31	18.58	9.55	7,444	3.24	0.46	56.4	-316.3	-	-	-	31	4.5
MW-52D	1	Baseline	09/21/17	8.31	28.56	20.25	8.98	9,825	4.86	0.22	59.8	-360.3	200	3.0	200	-	-
		Performance	12/08/17	8.23	28.56	20.33	8.62	9,662	2.01	0.10	56.1	30.0	-	-	-	-	-
		Supplemental Performance	02/15/18	-	28.56	-	8.71	9,603	1.95	0.03	54.1	-15.6	-	-	-	31.9	7.5
	2	Baseline 2	06/22/18	5.47	28.56	23.09	8.91	9,830	0.63	0.05	57.7	-23.3	-	-	-	-	-
		Performance	01/30/19	8.45	28.56	20.11	8.90	5,103	3.14	0.17	55.3	47.5	-	-	-	31.9	2
	3	Baseline 3	08/21/19	7.83	28.56	20.73	8.80	9,584	4.36	0.05	58.3	-300.0	>>200	1	-	31.9	4.6
		Performance	11/18/19	8.17	28.56	20.39	8.66	10,570	3.64	0.07	56.7	-304.8	>200	-	-	31	4.6
		Confirmation	12/14/20	8.44	28.56	20.12	8.16	11,330	0.69	0.68	56.5	-365.5	-	-	-	31	4.8

Notes:

1. Water quality parameters measured using YSI Multi-Probe Field Meters with flow through cells.
2. Monitoring well locations are shown on Figure 7.
3. DO equipement error for injection round 2 short-term 1 and 2 events

°F = degrees Fahrenheit
SC = Specific Conductance
DO = Dissolved Oxygen
mV = millivolts
mg/L - miligram per liter
uS/cm = microsiemens per centimeter
NTU = nephelometric turbidity unit
-- = not measured

Table 4

Groundwater Analytical Results

Play Area Interim Action
Gas Works Park Site
Seattle, Washington

Sample Location[1]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Field Measurements	Laboratory Chemical Analyses						Calculations
						Total Arsenic	Dissolved Arsenic	Total Iron	Dissolved Iron	Sulfate	Sulfide	Dissolved Arsenic Removed
						Unpreserved	Unpreserved (lab-filtered)	Preserved	Preserved (lab-filtered)	Unpreserved	Preserved	
						EPA 6010C	EPA 6010C	EPA 6010C	EPA 6010C	EPA 300.0	SM 4500-S2	% Removal[2]
					pH	(µg/L)				(mg/L)		
Fill Unit Monitoring Wells												
MW-41S	1	Baseline	09/25/17	7.55	7.37	8,650	10,600[3]	3,850	3,550	92.1	1.72	-
		Performance	12/11/17	4.49	7.26	2,350	2,540	345	275	87.2	<0.050	76%
		Supplemental Performance	02/16/18	-	7.16	2,550	2,280	324	330	50.1	<0.050	78%
	2	Baseline 2	06/18/18	5.57	7.21	4,360	4,760	706	418	83.2	0.053	55%
		Performance	01/31/19	5.32	7.09	2,980	1,960	284	150	111	0.050	82%
	3	Baseline 3	08/20/19	5.78	7.12	4,730	6,280	1,610	422	88.7	0.167	41%
		Performance	11/19/19	5.75	7.47	2,580	1,670	1,530	410	97.8	0.111	84%
		Confirmation	12/15/20	5.32	7.24	1,920	1,830	-	-	-	-	83%
MW-42S	1	Baseline	09/20/17	12.99	9.26	19,000[3]	18,700[3]	3,390	2,840	500	8.32	-
		Short-term 4	11/16/2017	10.32	6.46	1,090	897	10,900	326	568	-	95%
		Performance	12/08/17	10.35	6.61	1,460	1,100	15,200	202	115	1.2	94%
		Supplemental Performance	02/12/18	-	6.55	1,070	979	2,950	920	66	6.55	95%
	2	Baseline 2	06/18/18	6.66	6.62	905	852	1,350	234	66.6	4.59	95%
		Short-term 4	01/10/19	6.94	6.79	68.2	362	14,100	12,800	301	-	98%
		Performance	01/30/19	7.03	6.52	605	340	13,300	6,010	277	0.112	98%
	3	Baseline 3	08/21/19	7.18	6.46	326	345	3,120	1,010	120	1.91	98%
		Short-term 4	10/30/19	7.47	6.93	1,050	361	21,000	18,000	281	-	98%
		Performance	11/18/19	7.61	6.91	340	360	6,840	2,240	144	0.736	98%
		Confirmation	12/14/20	7.20	6.78	307	303	-	-	-	-	98%
MW-43S	1	Baseline	09/21/17	10.98	5.65	8,120	8,230[3]	20,400	18,700	32.5	0.349	-
		Short-term 4	11/16/2017	10.17	5.25	8,410	7,110	25,800	23,000	62.6	-	14%
		Performance	12/12/17	10.25	5.26	11,800	12,000	25,300	25,700	56.6	0.241	-46%
		Supplemental Performance	02/19/18	-	5.33	13,700	5,530	31,900	26,700	75.9	0.228	33%
	2	Baseline 2	06/20/18	9.14	5.05	14,000	7,750	26,700	24,500	71.9	0.250	6%
		Short-term 4	01/11/19	10.14	5.87	12,900	12,000	58,400	56,200	207	-	-46%
		Performance	01/31/19	10.19	5.22	10,800	7,910	43,600	44,200	151	0.050	4%
	3	Baseline 3	08/22/19	10.17	5.52	8,500	6,100	32,200	33,000	105	0.580	26%
		Short-term 4	10/30/19	10.21	5.58	7,730	5,690	28,600	26,600	312	-	31%
		Performance	11/19/19	10.53	5.81	5,120	1,090	25,500	27,500	80.6	0.866	87%
		Confirmation	12/15/20	10.11	5.65	5,860	5,340	-	-	-	-	35%

Sample Location[1]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Field Measurements	Laboratory Chemical Analyses						Calculations
						Total Arsenic	Dissolved Arsenic	Total Iron	Dissolved Iron	Sulfate	Sulfide	Dissolved Arsenic Removed
						Unpreserved	Unpreserved (lab-filtered)	Preserved	Preserved (lab-filtered)	Unpreserved	Preserved	
						EPA 6010C	EPA 6010C	EPA 6010C	EPA 6010C	EPA 300.0	SM 4500-S2	% Removal[2]
					pH	(µg/L)				(mg/L)		
MW-44S	1	Baseline	09/22/17	13.40	6.60	29,800	7,990[3]	1,950	1,330	173	81	-
		Short-term 4	11/17/2017	12.95	6.07	4,120	104	256,000	202,000	1,810	-	99%
		Performance	12/13/2017	13.25	6.12	13,900	697	106,000	40,100	1,240	15.5	91%
		Performance	12/13/17	-	6.12	7,270	1,320	96,800	45,900	1,270	15.4	83%
		Supplemental Performance	02/19/18	-	6.07	5,800	163	88,400	76,700	1,890	6.66	98%
	2	Baseline 2	06/20/18	11.79	5.92	3,140	613	28,900	28,300	830	6.34	92%
		Short-term 4	01/10/19	13.08	6.33	3,300	2,160	46,500	27,200	1,670	-	73%
		Performance	01/29/19	13.18	5.97	3,820	77.3	109,000	128,000	1,690	13.5	99%
	3	Baseline 3	08/21/19	12.57	5.84	1,100	93.4	324,000	296,000	2,000	2.69	99%
		Short-term 4	10/30/19	12.65	5.90	1,020	113	806,000	638,000	3,490	-	99%
		Performance	11/18/19	13.03	5.94	794	135 J	716,000	678,000	2,870	0.050	98%
		Confirmation	12/14/20	13.12	6.37	1,830	80.1	-	-	-	-	99%
MW-45S	1	Baseline	09/22/17	13.63	7.50	36,000	36,600[3]	5,420	1,190	475	42.4	-
		Short-term 4	11/17/2017	13.60	8.37	50,000	48,300	5,690	1,930	451	-	-
		Short-term 4	11/17/2017	-	8.37	49,300	47,500	6,290	1,780	447	-	2%
		Performance	12/13/17	13.83	9.18	55,800	55,800	4,850	2,580	417	65	-16%
		Supplemental Performance	02/12/18	-	9.25	42,200	43,800	4,890	2,950	397	52	9%
	2	Baseline 2	06/20/18	11.81	5.92	18,800	9,560	21,800	20,700	687	3.48	80%
		Short-term 4	01/10/19	13.46	9.45	43,600	41,100	4,400	4,380	400	-	15%
		Performance	01/29/19	13.47	8.33	40,100	39,100	4,680	4,230	405	49	19%
	3	Baseline 3	08/20/19	12.70	6.92	30,500	34,800	14,400	2,460	401	35.4	28%
		Short-term 4	10/30/19	12.95	8.17	35,600	30,700	3,190	1,690	478	-	36%
		Performance	11/18/19	13.30	8.17	34,100	36,000	3,280	1,650	456	79.6	25%
		Confirmation	12/14/20	13.48	9.52	26,700	24,700	-	-	-	-	49%
MW-46S	1	Baseline	09/21/17	7.74	5.94	76.7	68.3[3]	2,020	1,940	28.3	2.74	-
		Performance	12/07/17	7.91	5.69	114	110	3,980	2,100	12.6	1.63	-
		Supplemental Performance	02/13/18	-	6.56	53.2	58.7	1,900	1,890	35.6	1.28	47%
	2	Baseline 2	06/20/18	6.27	6.04	133	108	3,430	3,740	34.4	1.46	2%
		Performance	01/30/19	7.94	5.88	90.7	69.5	1,210	1,170	28.3	3.4	37%
	3	Baseline 3	08/21/19	7.18	6.06	80.7	85.5	570	533	8.5	2.22	22%
		Performance	11/19/19	7.75	6.29	110 J	106 J	1,370	1,010	17	2.610	4%
		Confirmation	12/16/20	7.92	6.44	63.0	82.6	-	-	-	-	25%

Sample Location[1]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Field Measurements	Total Arsenic	Dissolved Arsenic	Total Iron	Dissolved Iron	Sulfate	Sulfide	Dissolved Arsenic Removed
						Laboratory Chemical Analyses						Calculations
						Unpreserved	Unpreserved (lab-filtered)	Preserved	Preserved (lab-filtered)	Unpreserved	Preserved	
						EPA 6010C	EPA 6010C	EPA 6010C	EPA 6010C	EPA 300.0	SM 4500-S2	% Removal[2]
					pH	(µg/L)				(mg/L)		
MW-47S	1	Baseline	09/19/17	12.74	6.18	352	207[3]	6,280	5,040	10.2	3.47	-
		Short-term 4	11/16/2017	12.65	5.95	453	469	8,520	1,330	91.3	-	-
		Performance	12/08/17	12.95	6.09	697	631	6,760	845	69.4	2.44	-35%
		Supplemental Performance	02/12/18	-	6.05	1,050	1,150	4,060	3,980	50.4	3.32	-145%
	2	Baseline 2	06/19/18	11.25	6.14	883	898	4,490	1,520	70.6	2.80	-91%
		Short-term 4	01/10/19	12.95	6.50	157	359	8,380	8,190	14.9	-	23%
		Performance	01/30/19	15.70	5.95	817	647	8,330	7,220	27.8	3.08	-38%
	3	Baseline 3	08/21/19	12.18	5.76	233	142	3,320	2,850	20.3	0.567	70%
		Short-term 4	10/30/19	12.38	6.06	226	40.9	58,000	43,900	117	-	91%
		Performance	11/19/19	12.73	6.28	142 J	30.4 J	29,100	27,800	187	0.471	94%
		Confirmation	12/14/20	12.94	6.08	592	488	-	-	-	-	-4%
MW-51S	1	Baseline	09/21/17	9.25	6.08	10.3	4.07 [3]	4,810	4,270	4.46	0.312	-
		Performance	12/08/17	8.46	5.81	8.1	19.5	6,200	5,250	13.4	1.11	-
		Supplemental Performance	02/15/18	-	5.70	5.2	10.4	3,540	3,180	12.7	0.715	47%
	2	Baseline 2	06/22/18	6.84	5.96	14	64	2,650	1,560	2.29	<0.050	-228%
		Performance	01/29/19	8.43	6.19	50	5.7	2,210	2,030	2.17	2.16	71%
	3	Baseline 3	08/22/19	7.72	6.26	<23.5	<23.5	2,110	746	2.19	1.69	-21%
		Performance	11/19/19	8.22	6.38	<250	<250	2,620	2,380	11.3	0.419	-1182%
		Confirmation	12/16/20	8.46	6.60	<100	15.6	-	-	-	-	20%
MW-36S	1	Baseline	09/21/17	9.26	6.45	60.6	117[3]	17,900	17,800	4.12	2.28	-
		Performance	12/12/17	9.46	6.08	163	59	16,500	1,170	13.9	2.35	50%
		Supplemental Performance	02/14/18	-	6.05	318	252	9,500	6,960	39.9	3.81	-115%
	2	Baseline 2	06/21/18	7.84	5.92	30	22	11,800	8,630	13.4	0.15	81%
		Performance	01/30/19	9.48	6.32	83.6	68.8	14,600	11,300	24.8	0.503	41%
	3	Baseline 3	08/22/19	8.72	6.05	34.6	<23.5	28,100	22,400	13.8	1.23	80%
		Performance	11/20/19	9.20	6.22	47 J	41.9 J	18,500	14,400	41.2	0.968	64%
		Confirmation	12/15/20	9.47	6.55	197	54.9	-	-	-	-	53%

Sample Location[1]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Field Measurements	Laboratory Chemical Analyses						Calculations
						Total Arsenic	Dissolved Arsenic	Total Iron	Dissolved Iron	Sulfate	Sulfide	Dissolved Arsenic Removed
						Unpreserved	Unpreserved (lab-filtered)	Preserved	Preserved (lab-filtered)	Unpreserved	Preserved	
						EPA 6010C	EPA 6010C	EPA 6010C	EPA 6010C	EPA 300.0	SM 4500-S2	% Removal[2]
					pH	(µg/L)				(mg/L)		
Outwash Unit Monitoring Wells												
MW-41D	1	Baseline	09/19/17	10.53	6.86	37.9	61.8[3]	16,700	16,300	2.74	0.120	-
		Performance	12/11/17	9.01	6.54	49.2	104	13,700	903	1.51	0.121	-
		Supplemental Performance	02/16/18	-	6.40	37.2	33	14,300	9,460	2.27	0.124	68%
	2	Baseline 2	06/18/18	9.48	6.52	47	24	15,200	3,280	0.484	0.12	77%
		Performance	01/31/19	9.13	6.29	31.5	32.3	14,100	7,660	0.22	0.050	69%
	3	Baseline 3	08/20/19	8.99	6.46	49	48.7	16,400	9,980	0.166	0.308	53%
		Performance	11/18/19	9.89	6.80	60.2 J	<250	15,800	11,400	0.216	0.224	-140%
		Confirmation	12/15/20	9.28	6.61	31.1	21.2	-	-	-	-	80%
MW-45D	1	Baseline	9/22/17	13.63	7.50	2,670	2,770[3]	1,340	1,190	10.4	0.639	-
		Short-term 4	11/16/2017	12.34	7.43	3,060	2,680	1,480	1,320	6.53	-	-
		Performance	12/12/17	12.50	7.45	2,790	2,960	1,570	1,460	16.8	0.702	-7%
		Supplemental Performance	02/12/18	-	7.25	2,010	1,910	10,000	8,280	636	0.333	31%
	2	Baseline 2	06/19/18	11.15	7.27	1,800	205	56,700	31,200	932	<0.050	93%
		Short-term 4	01/10/19	12.64	7.27	1,550	479	61,300	41,100	984	-	83%
		Performance	01/30/19	12.67	6.88	1,520	76.6	60,700	48,600	1,310	0.229	97%
	3	Baseline 3	08/20/19	12.04	6.85	1,260	60.8	97,100	70,800	412	0.430	98%
		Short-term 4	10/30/19	12.45	6.89	1,360	56.6	187,000	150,000	935	-	98%
		Performance	11/18/19	12.62	6.87	1,320	<250	223,000	210,000	1,230	0.050	91%
		Confirmation	12/14/20	12.64	6.78	1,380	32.6	-	-	-	-	99%
MW-46D	1	Baseline	09/20/17	7.47	9.24	46,000	44,300[3]	8,660	1,630	204	13.9	-
		Short-term 4	11/17/2017	7.64	9.04	52,900	37,800	1,800	1,580	161	-	15%
		Performance	12/07/17	7.86	9.03	57,000	56,800	1,680	1,730	222	31.6	-28%
		Supplemental Performance	02/13/18	-	9.09	70,600	68,400	2,330	2,290	228	17.4	-54%
	2	Baseline 2	06/20/18	6.77	8.75	57,700	60,000	1,950	2,190	222	14.1	-35%
		Short-term 4	01/11/19	7.89	9.41	56,400	53,700	1,870	2,130	428	-	-21%
		Performance	01/30/19	7.92	9.20	65,600	62,000	2,140	2,000	601	53.5	-40%
	3	Baseline 3	08/21/19	6.69	9.00	63,100	50,600	2,130	1,680	386	20.7	-14%
		Short-term 4	10/30/19	7.41	8.79	50,100	41,500	4,030	2,290	1,420	-	6%
		Performance	11/19/19	7.92	8.83	50,400	51,000	1,960	1,140	2,050	15.500	-15%
		Confirmation	12/16/20	7.95	8.11	41,000	40,200	-	-	-	-	9%

Sample Location[1]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Field Measurements	Laboratory Chemical Analyses						Calculations
						Total Arsenic	Dissolved Arsenic	Total Iron	Dissolved Iron	Sulfate	Sulfide	Dissolved Arsenic Removed
						Unpreserved	Unpreserved (lab-filtered)	Preserved	Preserved (lab-filtered)	Unpreserved	Preserved	
						EPA 6010C	EPA 6010C	EPA 6010C	EPA 6010C	EPA 300.0	SM 4500-S2	% Removal[2]
					pH	(µg/L)				(mg/L)		
MW-48D	1	Baseline	09/21/17	9.66	7.79	3,290	2,710[3]	1,940	1,180	17.9	0.716	-
		Short-term 4	11/16/2017	9.53	7.40	3,770	3,900	1,070	254	253	-	-
		Performance	12/13/17	9.80	7.26	2,720	1,680	15,700	147	789	0.115	57%
		Supplemental Performance	02/19/18	-	6.86	1,300	18.7	93,800	63,400	1,220	0.057	98%
		Supplemental Performance	02/19/18	-	6.86	1,160	16.3	89,700	82,000	1,340	0.068	98%
	2	Baseline 2	06/21/18	8.25	6.92	839	68	140,000	100,000	2,870	<0.050	98%
		Short-term 4	01/11/19	9.81	6.79	641	242	391,000	58,500	3,150	-	94%
		Performance	01/30/19	10.04	6.67	549	19.2	249,000	222,000	2,350	0.285	100%
	3	Baseline 3	08/22/19	9.14	6.46	419	99.3	287,000	242,000	3,170	<0.050	97%
		Short-term 4	10/30/19	9.32	6.34	1,290	93.2	1,080,000	971,000	4,570	-	98%
		Performance	11/19/19	9.61	6.50	1,220	155 J	1,000,000	903,000	4,100	< 0.05 U	96%
		Confirmation	12/16/20	9.80	6.64	29.4	<100	-	-	-	-	97%
MW-49D	1	Baseline	09/20/17	9.12	9.12	103,000	6,150[3]	6,880	1,240	1,060	79.6	-
		Performance	12/14/17	9.24	8.91	118,000	101,000	3,830	3,280	1,050	82.9	-
		Supplemental Performance	02/14/18	-	8.89	120,000	55,000	3,910	2,740	1,080	75.5	46%
	2	Baseline 2	06/21/18	7.55	8.94	121,000	64,700	3,320	2,970	924	45.5	36%
		Performance	01/30/19	9.00	8.95	147,000	134,000	3,040	2,640	1,220	105	-33%
	3	Baseline 3	08/22/19	8.52	9.04	103,000	88,300	2,550	2,070	1,200	70.7	13%
		Performance	11/18/19	9.10	8.88	107,000	85,100	2,400	1,950	2,800	106	16%
		Confirmation	12/15/20	9.27	8.64	20,900	13,500	-	-	-	-	87%
MW-50D	1	Baseline	09/20/17	9.21	9.62	215,000	82,100[3]	4,430	3,490	620	260	-
		Performance	12/07/17	9.56	9.42	194,000	168,000	3,210	3,440	581	92.1	0%
		Supplemental Performance	02/15/18	-	8.93	185,000	161,000	3,270	3,380	577	102	4%
	2	Baseline 2	06/21/18	7.91	9.38	193,000	199,000	4,020	4,010	645	56.2	-18%
		Performance	01/29/19	8.90	9.41	188,000	158,000	3,070	2,990	682	137	6%
	3	Baseline 3	08/22/19	9.60	9.62	250,000	222,000	5,240	3,930	788	110	-32%
		Performance	11/18/19	9.73	9.41	211,000	173,000	3,560	2,950	892	2.11	-3%
		Confirmation	12/16/20	8.19	9.55	198,000	201,000	-	-	-	-	-20%
MW-52D	1	Baseline	09/21/17	8.15	8.98	293,000	98,600[3]	2,620	1,540	2,460	505	-
		Performance	12/08/17	7.51	8.62	349,000	326,000	2,560	2,380	2,900	121	-
		Supplemental Performance	02/15/18	-	9.35	344,000	176,000	2,630	2,290	2,940	143	46%
	2	Baseline 2	06/22/18	7.24	6.22	345,000	341,000	2,520	2,290	2,800	417	-5%
		Performance	01/30/19	7.84	8.90	201,000	182,000	1,580	1,670	1,620	100	44%
	3	Baseline 3	08/21/19	7.83	8.80	361,000	246,000	2,000	1,840	3,430	115	25%
		Performance	11/18/19	8.17	8.66	283,000	25,500	2,660	1,700	4,190	320	92%
		Confirmation	12/14/20	8.44	8.16	384,000	314,000	-	-	-	-	4%

						Laboratory Chemical Analyses						Calculations
Sample Location[1]	Injection Round	Event	Date	Depth to Water (ft BTOC)	Field Measurements	Total Arsenic	Dissolved Arsenic	Total Iron	Dissolved Iron	Sulfate	Sulfide	Dissolved Arsenic Removed
						Unpreserved	Unpreserved (lab-filtered)	Preserved	Preserved (lab-filtered)	Unpreserved	Preserved	
						EPA 6010C	EPA 6010C	EPA 6010C	EPA 6010C	EPA 300.0	SM 4500-S2	% Removal[2]
					pH	(µg/L)				(mg/L)		
MW-36D	1	Baseline	09/22/17	8.31	8.95	79,700	7,730[3]	1,540	1,350	533	95.3	-
		Performance	12/14/17	8.23	8.88	96,300	77,500	1,520	1,480	577	84.3	-
		Supplemental Performance	02/13/18	-	8.71	93,900	34,900	1,500	1,440	583	77	55%
	2	Baseline 2	06/21/18	5.47	9.03	92,300	80,300	1,590	1,500	544	115	-4%
		Performance	01/30/19	8.45	7.91	65,500	50,700	1,150	1,050	635	37.5	35%
	3	Baseline 3	08/22/19	9.87	8.97	66,000	52,000	1,310	1,380	2,680	69.8	33%
		Performance	11/18/19	9.60	8.74	60,000	49,700	1,390	1,070	2,990	74	36%
		Confirmation	12/15/20	9.41	7.14	14,700	1,940	-	-	-	-	97%

Notes:

[1] Monitoring well locations are shown on Figure 7.

[2] Positive values indicate reduction.

[3] Due to underestimated baseline conditions, the November 2017 Short-term or December 2017 Performance event are used for comparison to later data to evaluate performance.

EPA = Environmental Protection Agency

µg/L = micrograms per liter

mg/L - milligram per liter

- = not measured or calculated

Table 5

Groundwater Arsenic Speciation Results

Play Area Interim Action Monitoring Report
Gas Works Park Site
Seattle, Washington

	Supplemental Investigation 2014 (ug/L) - December 2014					
	MW-36D	**MW-36S**	**PAI-11B**	**PAI-12**	**PAI-2B**	**PAI-10**
As(III)	39,700	37.7	28.9	702	42900	482
As(V)	790 J	6.41	1.74	141	1200	15.4 J
DMAs	230 U	0.46 U	0.23 U	2.3 U	120 U	4.6 U
MMAs	210 U	0.42 U	0.21 U	2.1 U	110 U	4.2 U
Unknown As Species	43,230 J	1.65	77.24	291.3	12,900	2,478.2
% Unknown As Species	52%	4%	71%	26%	23%	83%
Total[1]	83,940	46.2	108	1,137	57,115	2,980

	Interim Action 1st Baseline Results (ug/L) - September 2017						
	MW-42S	**MW-43S**	**MW-45S**	**MW-45D**	**MW-46S**	**MW-46D**	**MW-48D**
As(III)	597 J	7,250	36,000	1,960	200 U	27,400	2,330
As(V)	200 U	1,150	3,660	245 J	297 J	3,260	200 U
DMAs	250 U	250 U	250 U	250 U	250 U	250 U	250 U
MMAs	200 U	200 U	200 U	200 U	200 U	200 U	200 U
Unknown As Species	839	250 U	8,830	574	250 U	16,200	629
% Unknown As Species	48%	1%	18%	19%	17%	34%	19%
Total[1]	1,761	8,750	48,715	3,004	747	47,085	3,284

	Interim Action 2nd Baseline Results (ug/L) - June 2018						
	MW-36D	**MW-42S**	**MW-45S**	**MW-45D**	**MW-46D**	**MW-48D**	**MW-52D**
As(III)	56,300	452	14,500	1,750	37,800	514	197,000
As(V)	1,020	40 U	1,290	394	1,950	426	1,890
DMAs	50 U	50 U	50 U	50 U	50 U	50 U	250 U
MMAs	90 U	90 U	90 U	90 U	90 U	90 U	450 U
Unknown As Species	24,800	781	490	50 U	15,700	154	92,300
% Unknown As Species	30%	59%	3%	1%	28%	13%	32%
Total[1]	82,190	1,323	16,350	2,239	55,520	1,164	291,540

Notes:

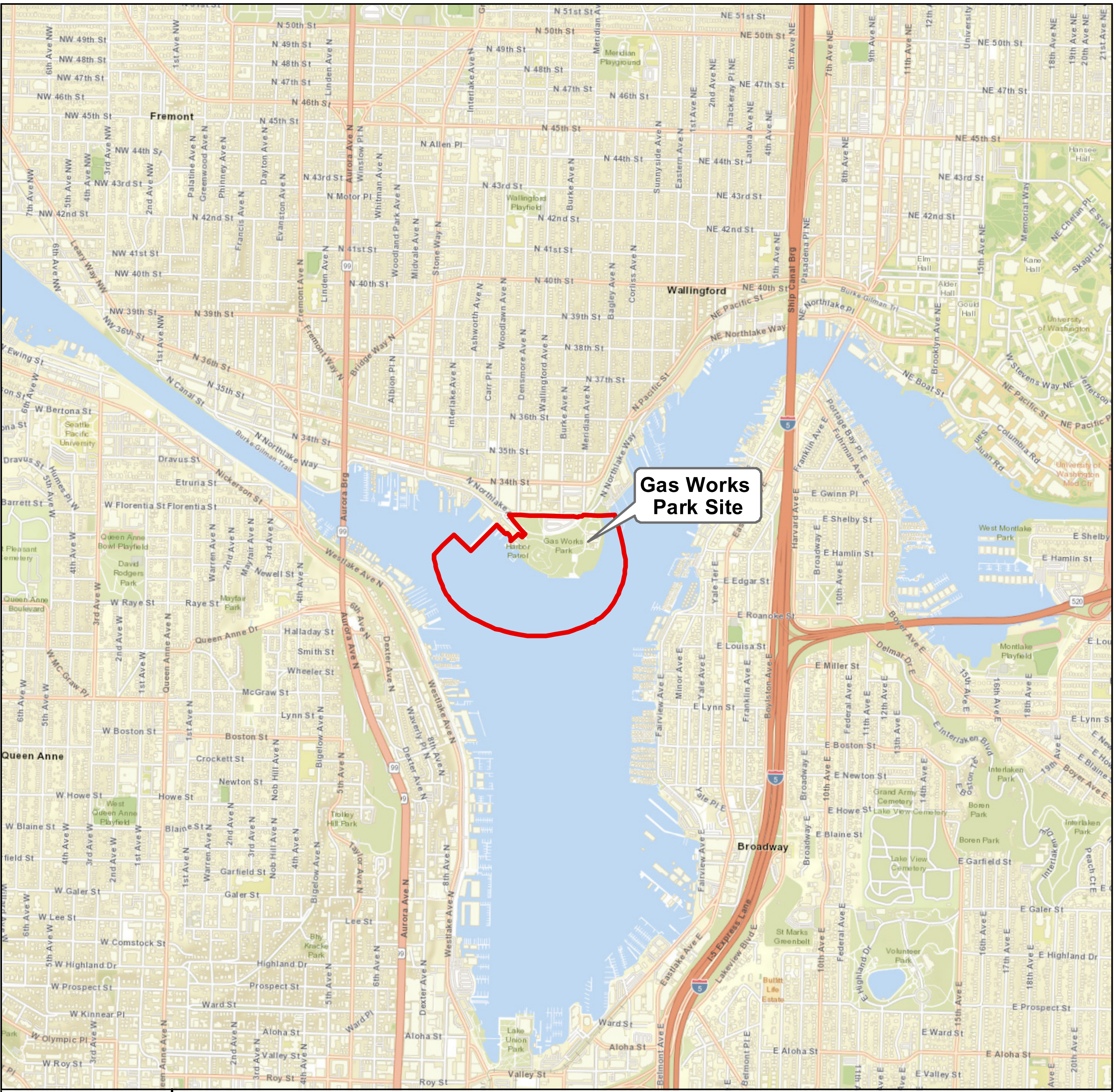
1. Non-detects are treated as half the detection limit.
2. All groundwater samples were field-filtered for analyses presented on this table.
3. Groundwater samples for speciation were collected anoxically.
4. 2014 analysis was conducted by Applied Speciation and Consulting. 2017 and 2018 analysis was conducted by Brooks Applied Labs.

As(III) = Arsenite

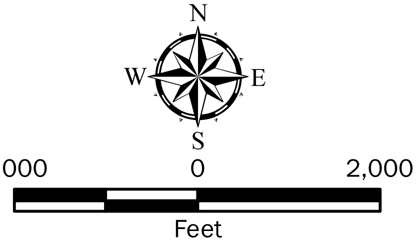
As(V) = Arsenate

DMAs = Dimethylarsinic Acid

MMAs = Monomethylarsonic Acid



🟥 Area of Investigation



Notes:
1. Gas Works Park Site boundary is the Area of Investigation.
2. Basemap - ESRI, 2021.
3. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet.

Vicinity Map

Gas Works Park Site
Seattle, Washington

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Figure 1

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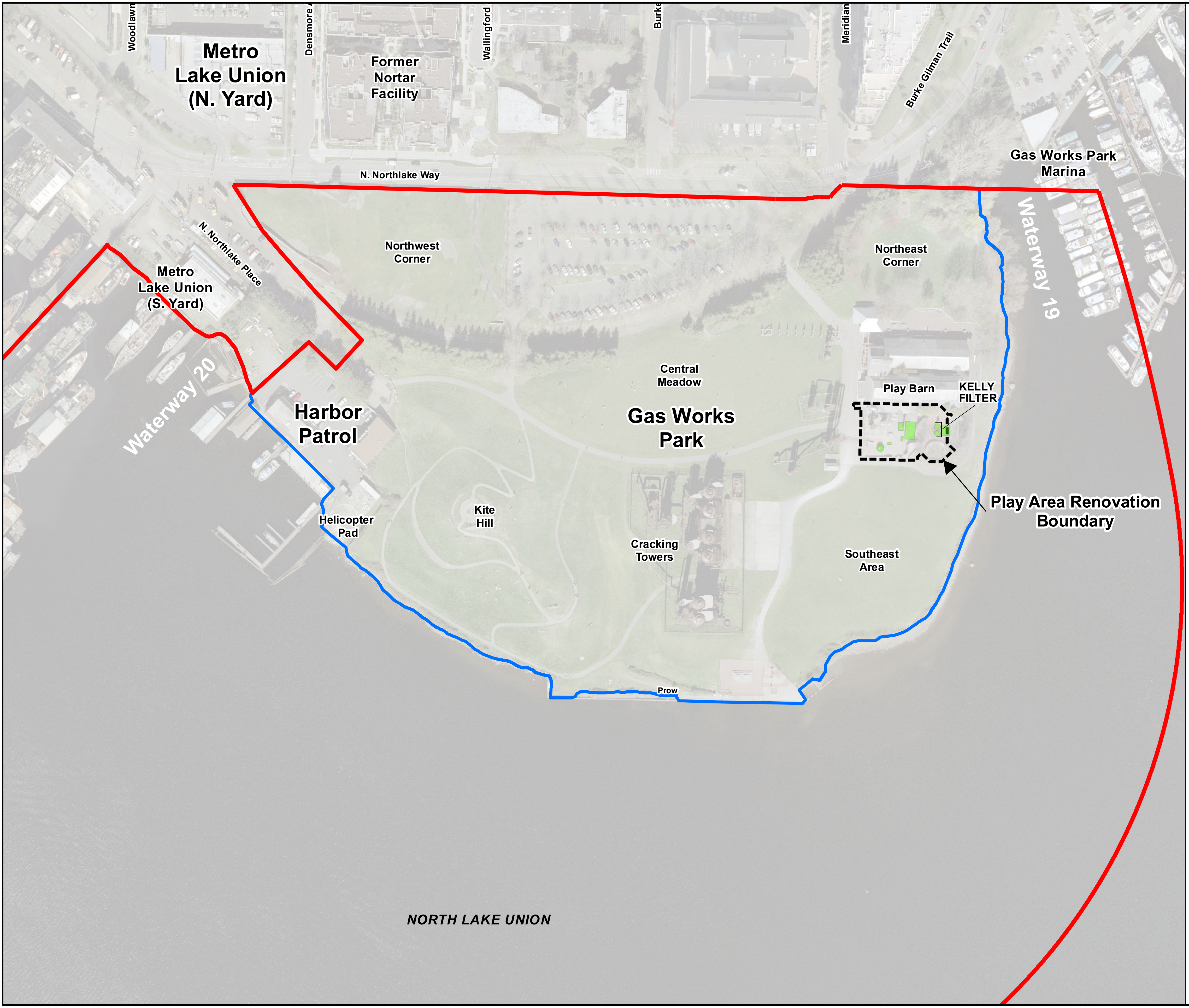

Legend

━	Area of Investigation (AOI) (Ecology 2013)
━	Shoreline (OHWM)
⬚	Play Area Renovation Boundary
🟩	Components of Thylox Process Facility

Notes:

1. The AOI is equivalent to the Gas Works Park Sediment Site boundary documented in the 2013 Amendment of Agreed Order DE 2008 (Ecology 2013).
2. The Uplands Consent Decree boundary is equivalent to the Site boundary documented in Exhibit A of the Final Consent Decree 99-2-52532-9SEA (Ecology 1999).
3. Basemap 2005 USGS aerial photograph. Does not show current conditions.
4. Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet.

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Feet

Site Plan

Gas Works Park Site
Seattle, Washington

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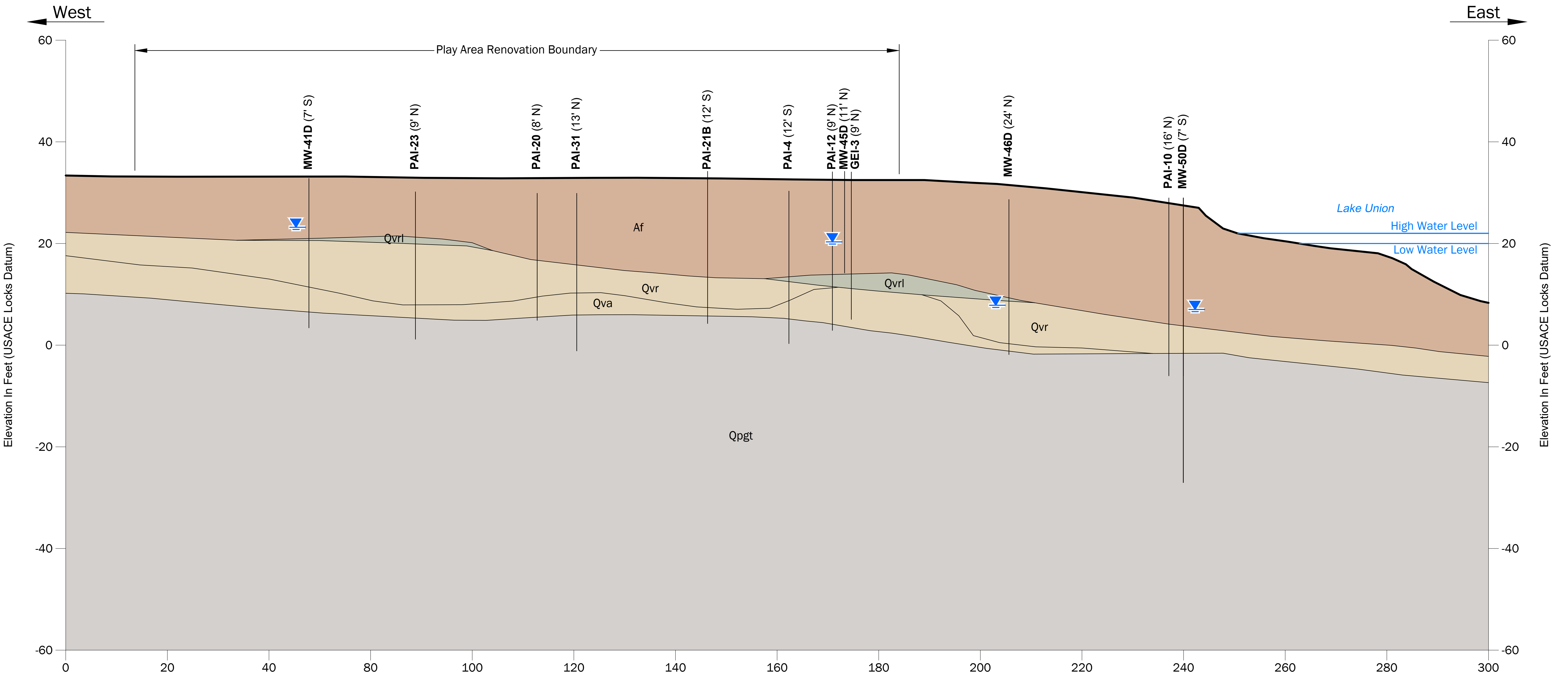
Figure 2

Path: P:\0\0186846\GIS\MXD\Phase01\T1804\0186846\01_T1804S06_F02_Site Plan.mxd Map Revised: 21 June 2021 maugust



Legend

Geologic Units

- ▨ Fill (Af)
- ▨ Lake Sediment (Ql, Qvrl)
- ▨ Outwash (Qvr, Qva)
- ▨ Till (Qpgt)

MW-41D (7' S)
Exploration Offset
Exploration ID
Static Groundwater Level
Soil Contact

20 0 20
Feet

Notes:

1. Groundwater level measured in February 2018 in monitoring wells MW-41D, MW-45D, MW-46D, and MW-50D.
2. Locations of Monitoring Wells and Play Area Renovation Boundary shown in plan view on Figures 4 and 5.

Geologic Cross Section

Gas Works Park Project
Seattle, Washington

GeoEngineers

Figure 3

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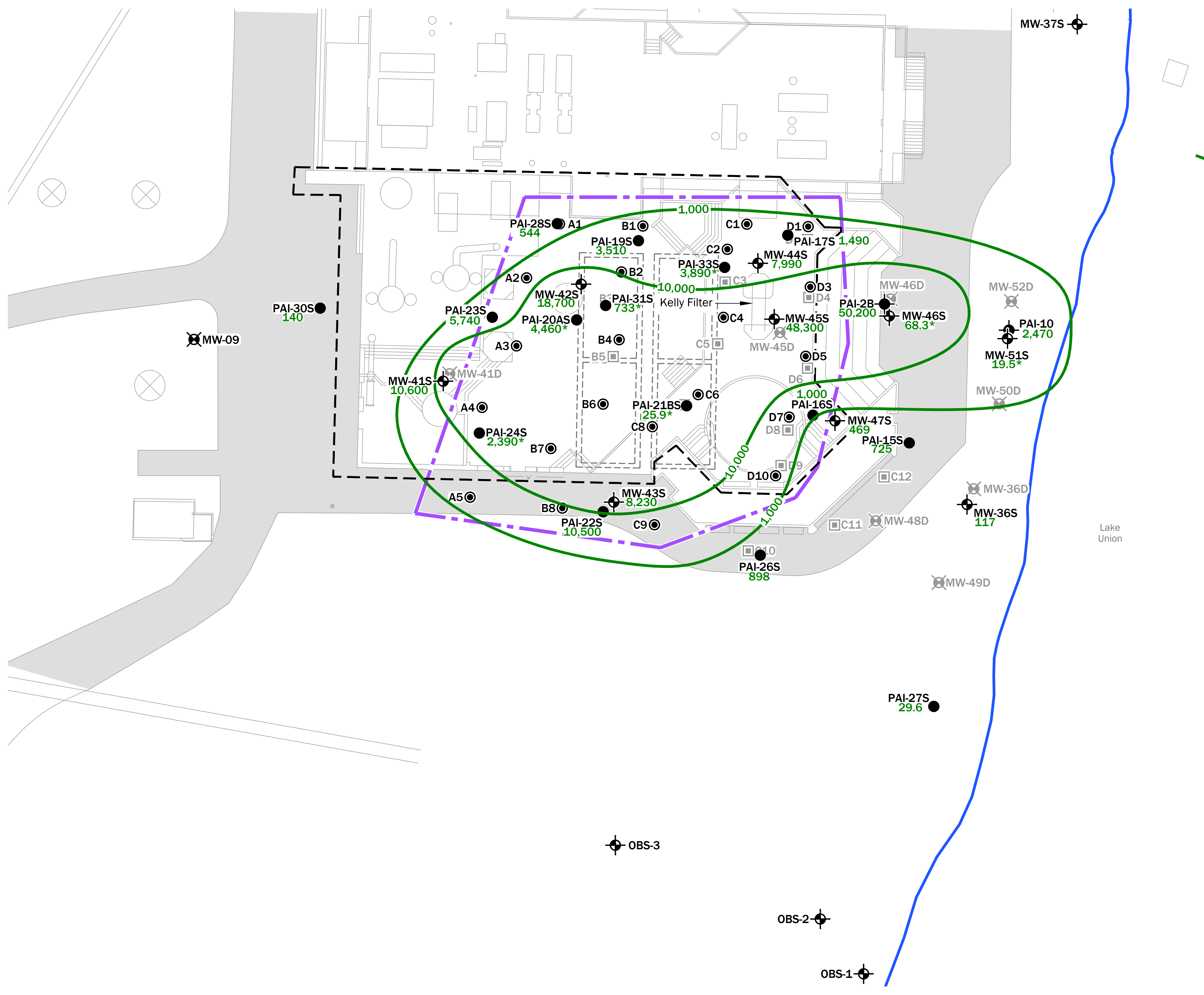

Legend

- Shoreline (OHWM)
- Play Area Renovation Boundary
- D10 ◉ Injection Well - Fill
- MW-46S ⊕ Monitoring Well - Fill
- PAI-2B ⊕ Fill 2014 Subsurface Exploration (Soil and Groundwater)
- PAI-17S ● 2016 Subsurface Exploration (Soil and Groundwater)
- 1,000 Interpolated Fill Dissolved Arsenic Concentration Contour (Dashed Where Inferred) (µg/L)
- 10,500 Fill Dissolved Arsenic Concentration (µg/L)
- * Not Used for Contouring Baseline Conditions
- Fill Area Treatment Boundary

Notes:

1. Fill unit dissolved arsenic concentration contours downgradient of the Play Area are based on samples from PAI locations, collected from a deeper fill unit interval than wells MW-46S and MW-51S.
2. Higher Dissolved Arsenic values selected for wells, MW-45S, MW-47S, and MW-51S due to acid preservation impact on pre-injection measurements.

Data Sources:

- Existing conditions survey by Seattle Parks and Recreation, November 2002
- Construction Completion Report by ThermoRetec, January 2001
- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974
- Agency Review Draft Remedial Investigation by GeoEngineers, June 2020
- Injection system survey information provided by True North Land Surveying INC., August 2017

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Feet

Baseline Dissolved Arsenic, Fill Wells

Gas Works Park Project
Seattle, Washington

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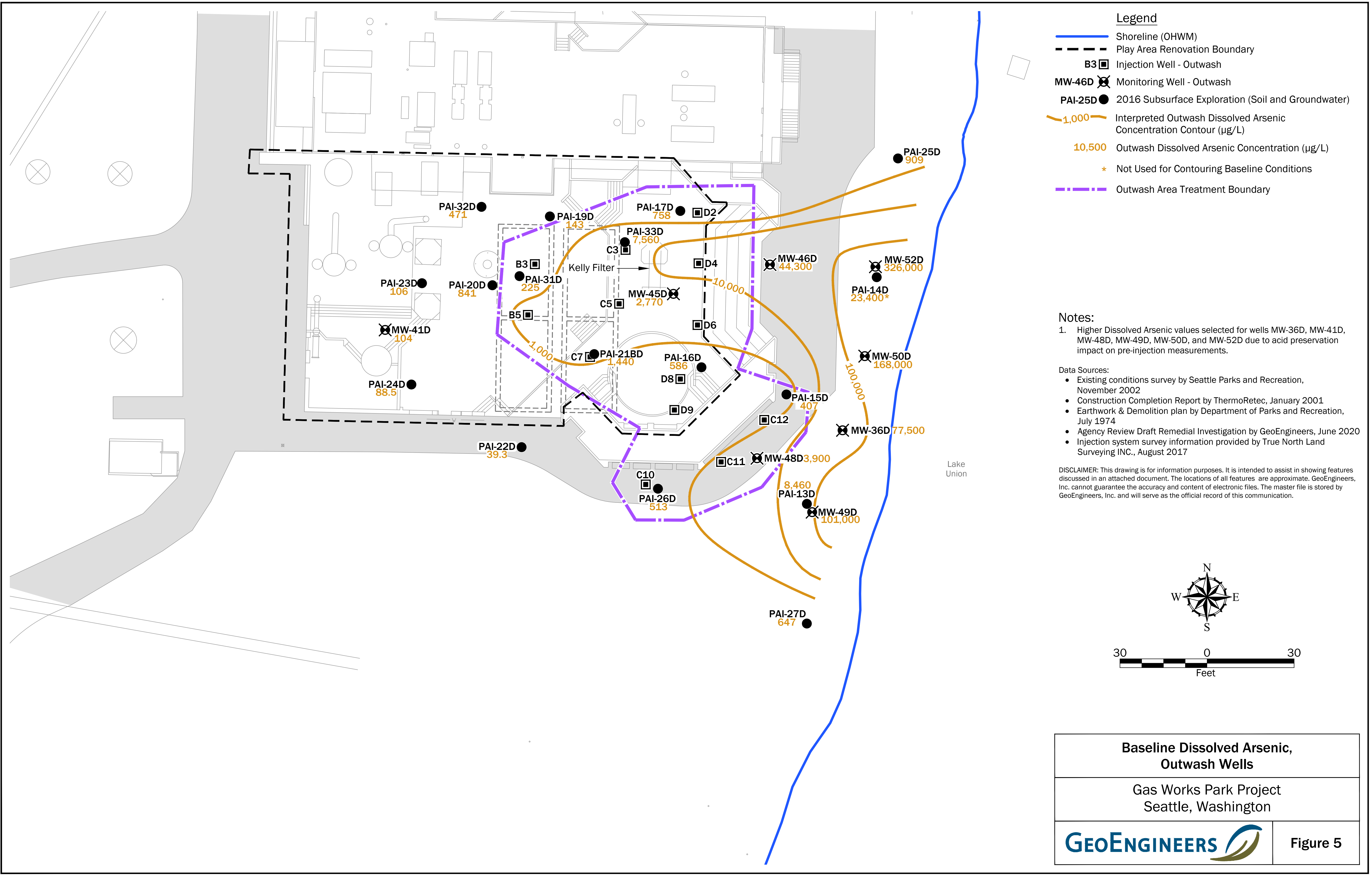
Figure 4

P:\0\0186846\01\CAD\Task 1808 Play Area Action\Monitoring Report\018684601_F04_Baseline Dissolved Arsenic [Fill Wells].dwg TAB:F04_Fill Wells Date Exported: 06/23/21 - 13:48 by hmara



Legend

- Shoreline (OHWM)
- Play Area Renovation Boundary
- B3 ▣ Injection Well - Outwash
- MW-46D ⊗ Monitoring Well - Outwash
- PAI-25D ● 2016 Subsurface Exploration (Soil and Groundwater)
- 1,000 Interpreted Outwash Dissolved Arsenic Concentration Contour (µg/L)
- 10,500 Outwash Dissolved Arsenic Concentration (µg/L)
- * Not Used for Contouring Baseline Conditions
- Outwash Area Treatment Boundary

Notes:

1. Higher Dissolved Arsenic values selected for wells MW-36D, MW-41D, MW-48D, MW-49D, MW-50D, and MW-52D due to acid preservation impact on pre-injection measurements.

Data Sources:

- Existing conditions survey by Seattle Parks and Recreation, November 2002
- Construction Completion Report by ThermoRetec, January 2001
- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974
- Agency Review Draft Remedial Investigation by GeoEngineers, June 2020
- Injection system survey information provided by True North Land Surveying INC., August 2017

Baseline Dissolved Arsenic,
Outwash Wells

Gas Works Park Project
Seattle, Washington

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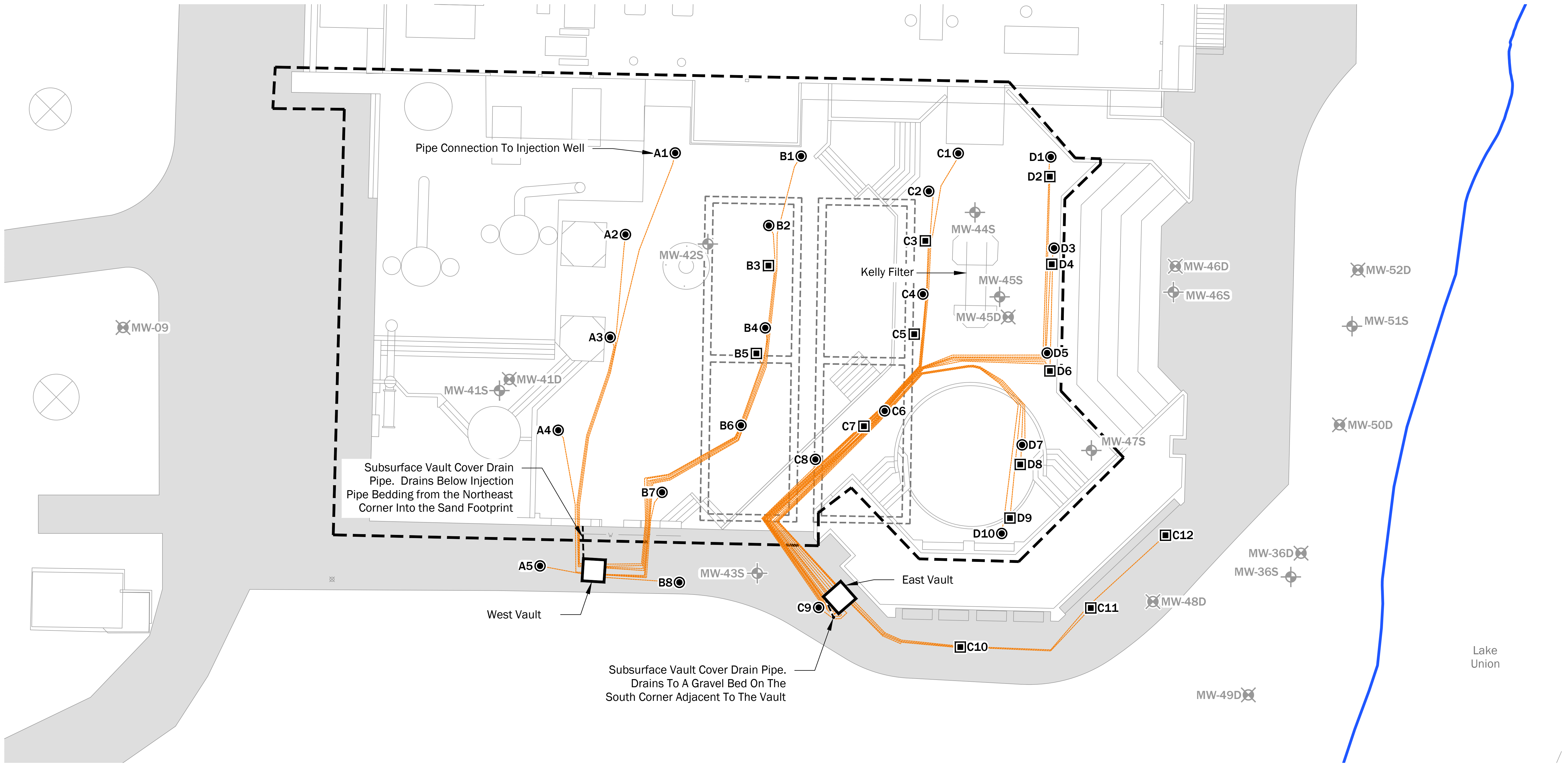
Figure 5



Legend

━	Shoreline (OHWM)
╍	Play Area Renovation Boundary
D10◉	Injection Well - Fill
C7▣	Injection Well - Outwash
MW-46S ⌖	Monitoring Well - Fill
MW-46D ⊗	Monitoring Well - Outwash
┈	Trenched Injection Pipe
☐	System Vault

Projection: WA State Plane, North Zone, NAD83, US Foot.

Data Source:
- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974.
- Existing conditions survey by Seattle Parks and Recreation, November 2002.
- Construction Completion Report by ThermoRetec, January 2001.
- Injection system survey information provided by True North Land Surveying INC., August 2017

Play Area Interim Action
Injection Infrastructure

Gas Works Park Project
Seattle, Washington

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Figure 6

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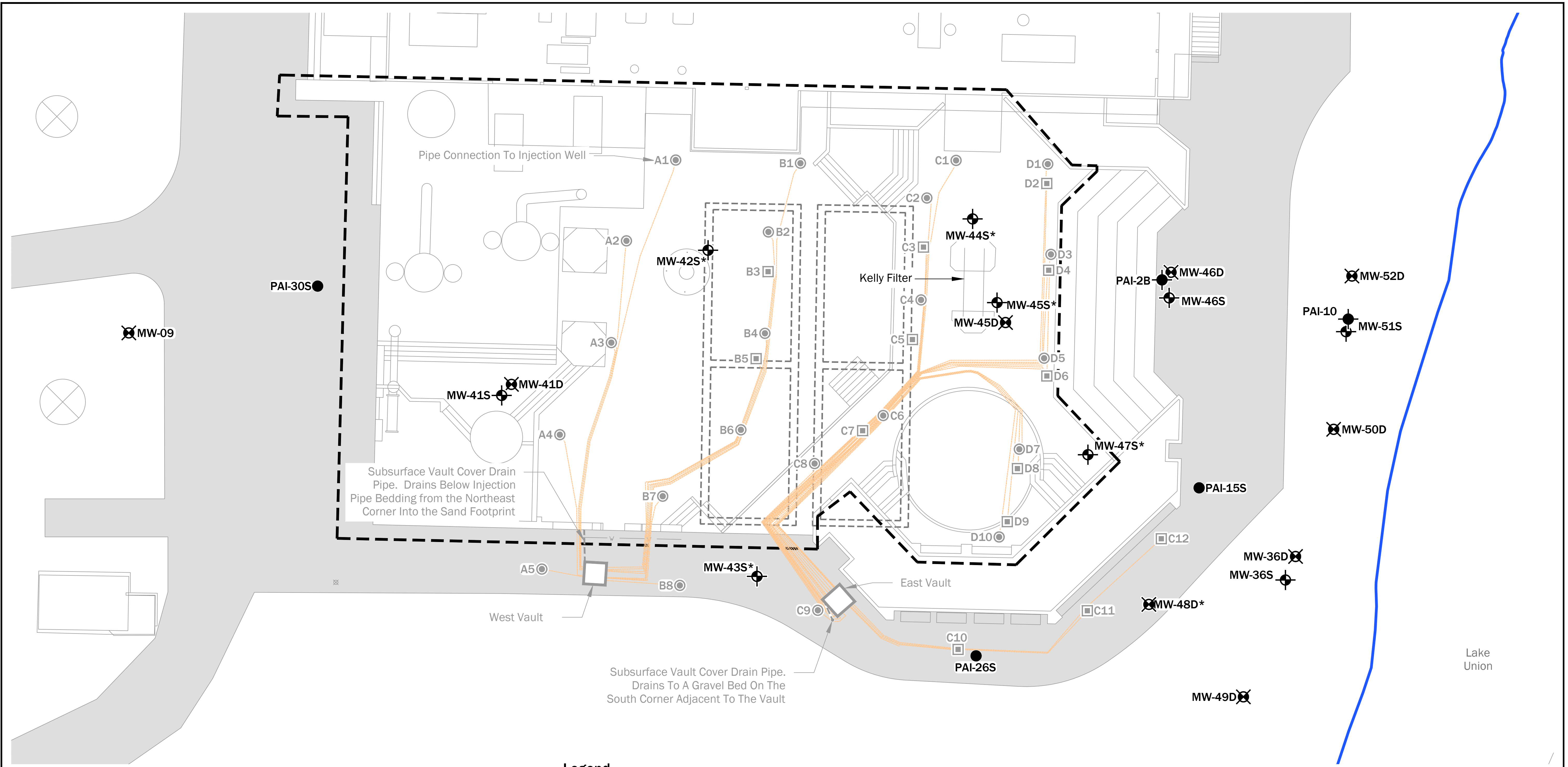

Legend

	Shoreline (OHWM)
	Play Area Renovation Boundary
D10 ◉	Injection Well - Fill
C7 ▣	Injection Well - Outwash
MW-46S	Monitoring Well - Fill
MW-46D	Monitoring Well - Outwash
PAI-2B	Fill 2014 Subsurface Exploration (Soil and Groundwater)
PAI-17S ●	2016 Subsurface Exploration (Soil and Groundwater)
	Trenched Injection Pipe
▭	System Vault

* Monitoring Well with Pressure Transducer Installed During Interim Action

Projection: WA State Plane, North Zone, NAD83, US Foot.

Data Source:

- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974.
- Existing conditions survey by Seattle Parks and Recreation, November 2002.
- Construction Completion Report by ThermoRetec, January 2001.
- Injection system survey information provided by True North Land Surveying INC., August 2017

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Play Area Interim Action
Monitoring Well Network

Gas Works Park Project
Seattle, Washington

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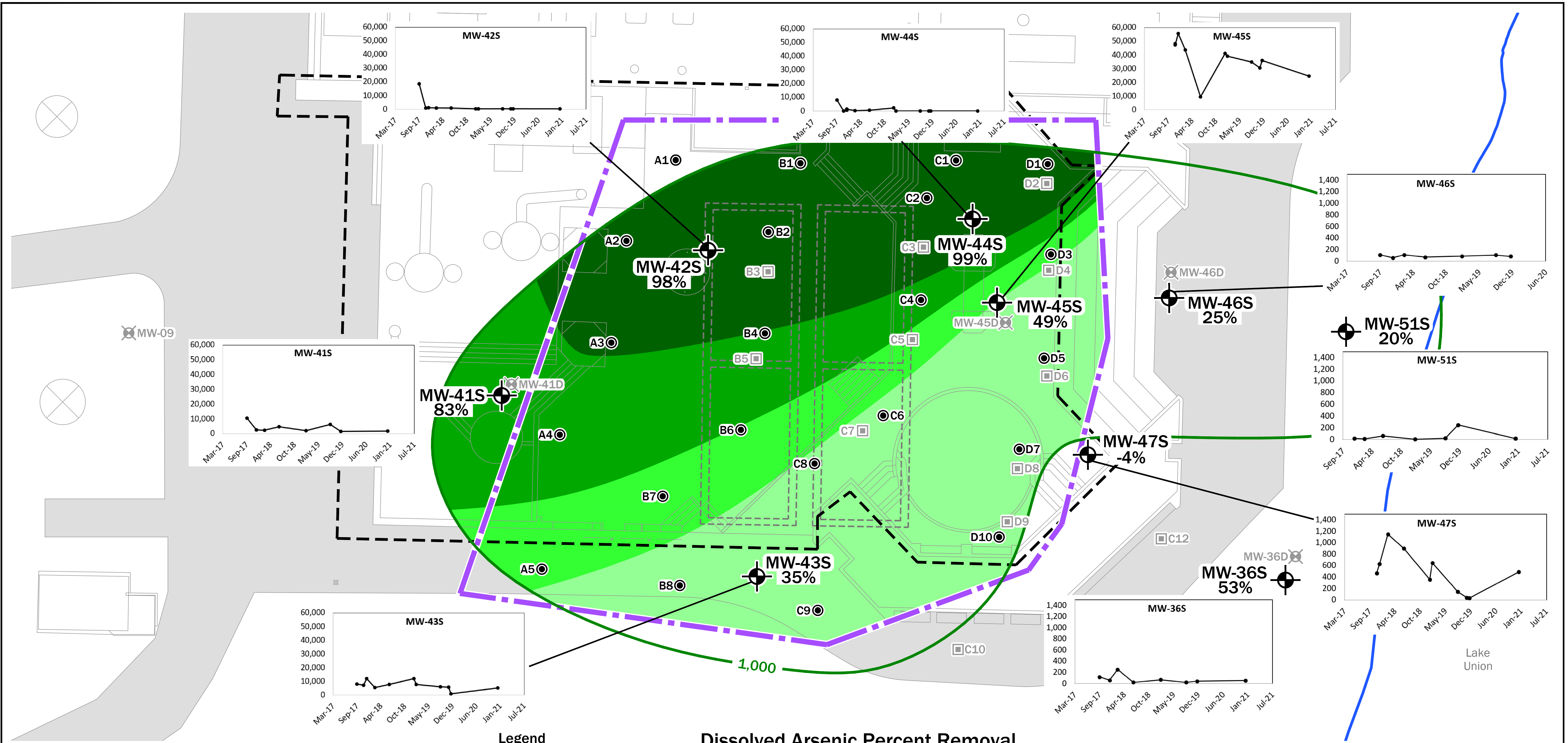
Figure 7

P:\0\0186846\01\CAD\Task 1808 Play Area Action\Monitoring Report\018684601_F07_Monitoring System Infrastructure.dwg TAB:F07 Date Exported: 06/23/21 - 13:48 by hmara



Legend

- Shoreline (OHWM)
- Play Area Renovation Boundary
- D10 ◉ Injection Well - Fill
- C7 ▣ Injection Well - Outwash
- MW-46D ⊗ Monitoring Well - Outwash
- MW-46S ⊕ Monitoring Well - Fill
- 99% % Removed
- Fill Area Treatment Boundary
- 1,000 Baseline 1,000 µg/L Dissolved Arsenic Concentration Contour

Dissolved Arsenic Percent Removal

🟩	>90%
🟩	75 - 90%
🟩	50 - 75%
🟩	25 - 50%

Projection: WA State Plane, North Zone, NAD83, US Foot.

Data Source:
- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974.
- Existing conditions survey by Seattle Parks and Recreation, November 2002.
- Construction Completion Report by ThermoRetec, January 2001.
- Injection system survey information provided by True North Land Surveying INC., August 2017

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Feet

Dissolved Arsenic Percent Removal
Fill Wells

Gas Works Park Project
Seattle, Washington

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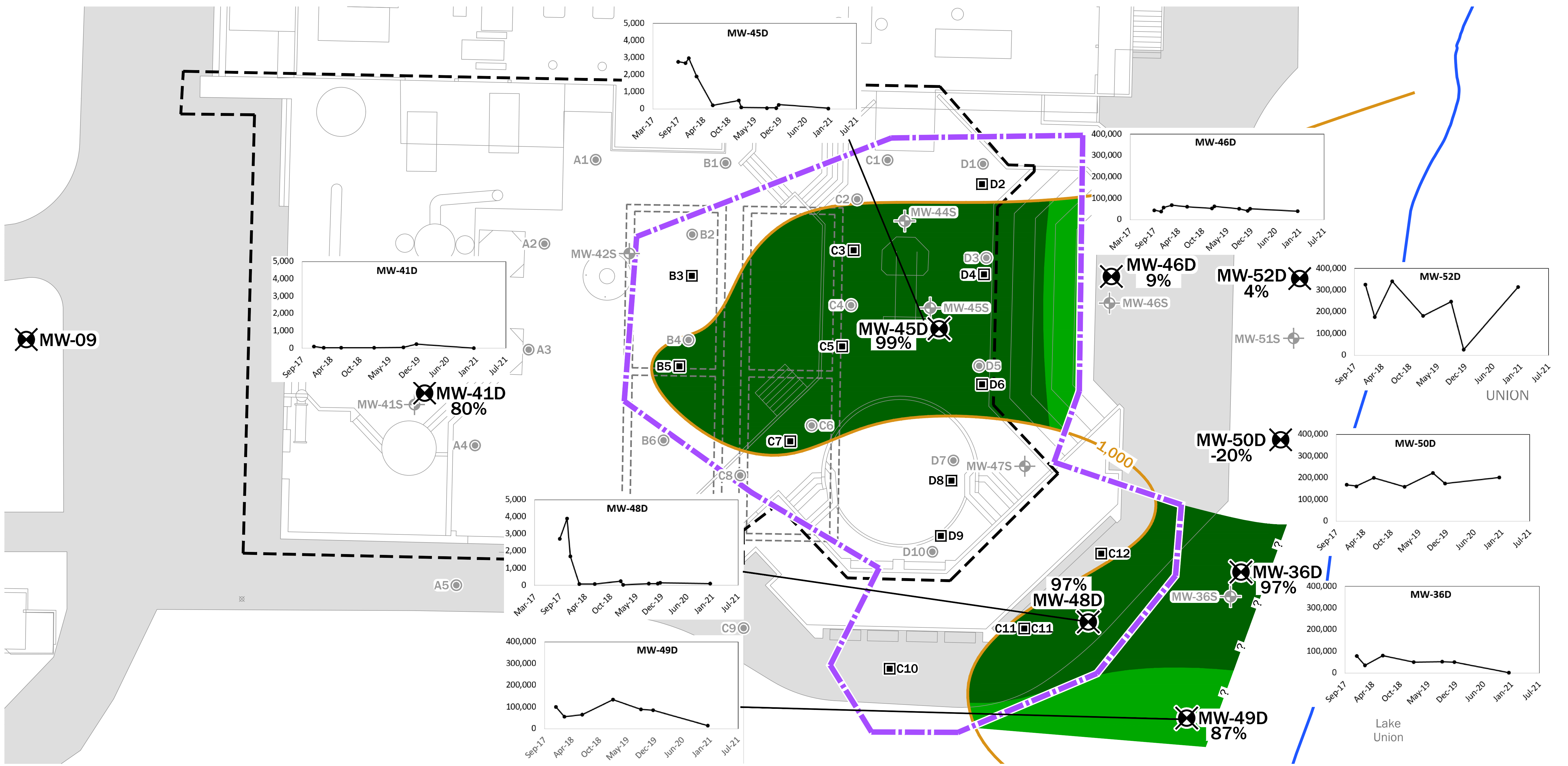
Figure 8

P:\0\0186846\01\CAD\Task 1808 Play Area Action\Monitoring Report\018684601_F08_Arsenic Percent Removal [Fill Wells].dwg TAB:F08 Date Exported: 06/23/21 - 13:48 by hmara



Legend

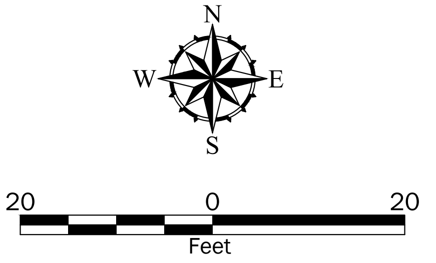
	Shoreline (OHWM)
	Play Area Renovation Boundary
D10 ◉	Injection Well - Fill
C7 ▣	Injection Well - Outwash
MW-46S ⌖	Monitoring Well - Fill
MW-46D ⊗	Monitoring Well - Outwash
99%	% Removed
	Outwash Area Treatment Boundary
1,000	Baseline 1,000 µg/L Dissolved Arsenic Concentration Contour

Dissolved Arsenic Percent Removal

🟩	>90%
🟩	75 - 90%
🟩	50 - 75%
🟩	25 - 50%

Projection: WA State Plane, North Zone, NAD83, US Foot.

Data Source:
- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974.
- Existing conditions survey by Seattle Parks and Recreation, November 2002.
- Construction Completion Report by ThermoRetec, January 2001.
- Injection system survey information provided by True North Land Surveying INC., August 2017

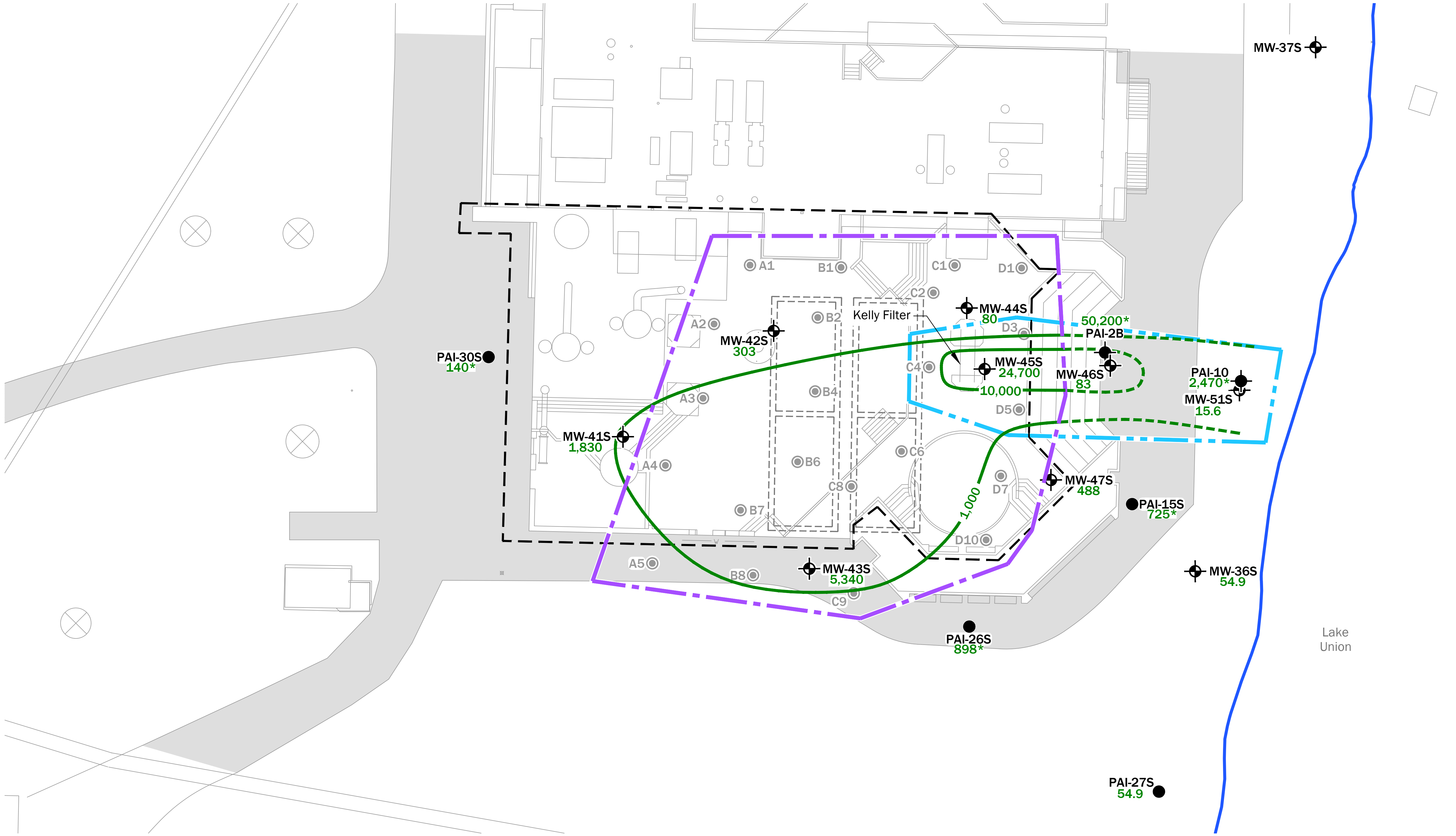


Dissolved Arsenic Percent Removal
Outwash Wells

Gas Works Park Project
Seattle, Washington

GEOENGINEERS

Figure 9



Notes:
1. Fill unit dissolved arsenic concentration contours downgradient of the Play Area are based on samples from PAI locations, collected from a deeper fill unit interval than wells MW-46S and MW-51S.

Projection: WA State Plane, North Zone, NAD83, US Foot.

Data Source:
- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974.
- Existing conditions survey by Seattle Parks and Recreation, November 2002.
- Construction Completion Report by ThermoRetec, January 2001.
- Injection system survey information provided by True North Land Surveying INC., August 2017

Legend

━━	Shoreline (OHWM)
━ ━ ━	Play Area Renovation Boundary
D10 ◎	Injection Well - Fill
MW-46S ⌖	Monitoring Well - Fill
PAI-2B ●	Fill 2014 Subsurface Exploration (Soil and Groundwater)
PAI-17S ●	2016 Subsurface Exploration (Soil and Groundwater)
1,000	Interpolated Fill Dissolved Arsenic Concentration Contour (Dashed Where Inferred) (µg/L)
1,830	Fill Dissolved Arsenic Concentration (µg/L)
*	Pre-treatment Data Used to Contour Data Outside Treatment Boundary
━ · ━	Fill Area Treatment Boundary
━ · ━	Potential Area for Additional Fill Groundwater Treatment in Feasibility Study

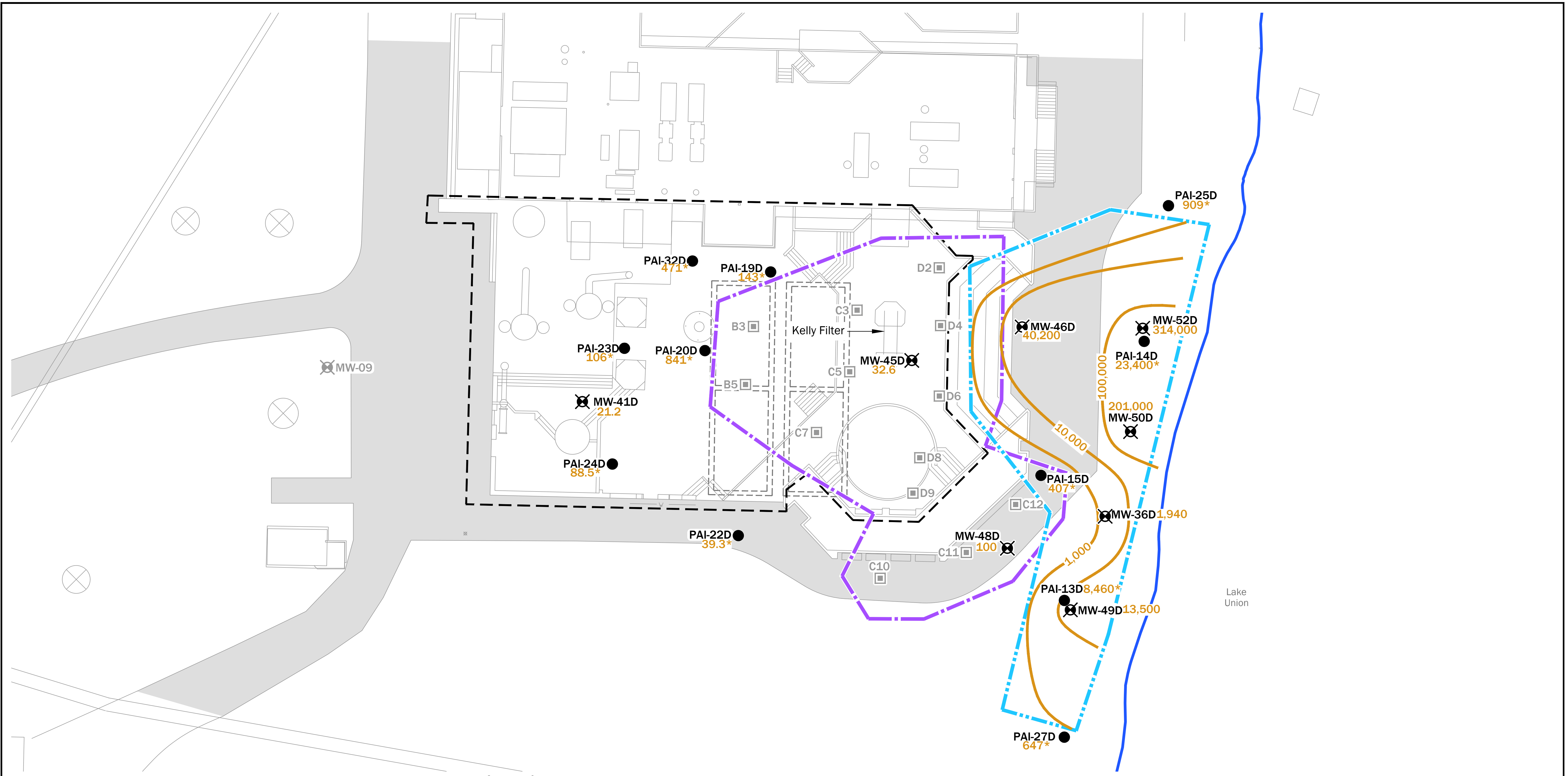
Post-Treatment Conditions
Fill Wells

Gas Works Park Project
Seattle, Washington

GeoEngineers

Figure 10

P:\0\0186846\01\CAD\Task 1808 Play Area Action\Monitoring Report\018684601_F10_Post Treatment [Fill Wells].dwg TAB:F10 Date Exported: 06/23/21 - 13:49 by hmara

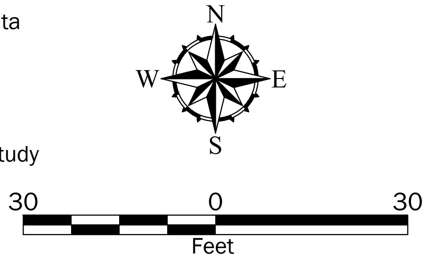


Legend

——	Shoreline (OHWM)
— — —	Play Area Renovation Boundary
C7 ▣	Injection Well - Outwash
MW-46D ⊗	Monitoring Well - Outwash
PAI-17S ●	2016 Subsurface Exploration (Soil and Groundwater)
1,000	Interpolated Outwash Dissolved Arsenic Concentration Contour (Dashed Where Inferred) (µg/L)
1,830	Outwash Dissolved Arsenic Concentration (µg/L)
*	Pre-treatment Data Used to Contour Data Outside Treatment Boundary
-·-·-	Outwash Area Treatment Boundary
-··-··-	Potential Area for Additional Outwash Groundwater Treatment in Feasibility Study

Projection: WA State Plane, North Zone, NAD83, US Foot.

Data Source:
- Earthwork & Demolition plan by Department of Parks and Recreation, July 1974.
- Existing conditions survey by Seattle Parks and Recreation, November 2002.
- Construction Completion Report by ThermoRetec, January 2001.
- Injection system survey information provided by True North Land Surveying INC., August 2017



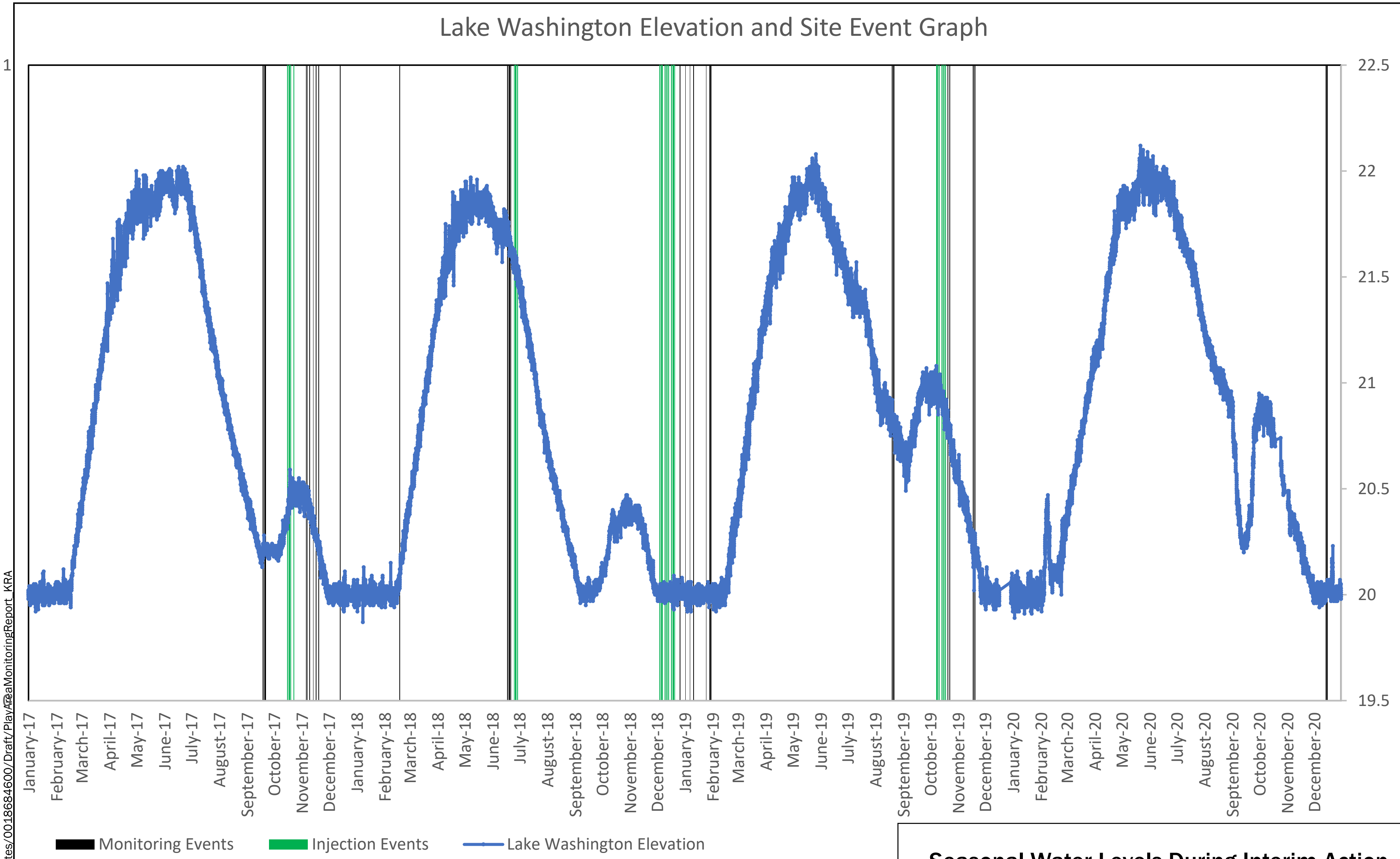
Post-Treatment Conditions
Outwash Wells

Gas Works Park Project
Seattle, Washington

GeoEngineers

Figure 11

P:\0\0186846\01\CAD\Task 1808 Play Area Action\Monitoring Report\018684601_F11_Post Treatment [Outwash Wells].dwg TAB:F09 Date Exported: 06/23/21 - 13:49 by hmara



Seasonal Water Levels During Interim Action

Play Area Interim Action Monitoring Report
Seattle, Washington

GeoEngineers

Figure 12

https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport_KRA

APPENDICES

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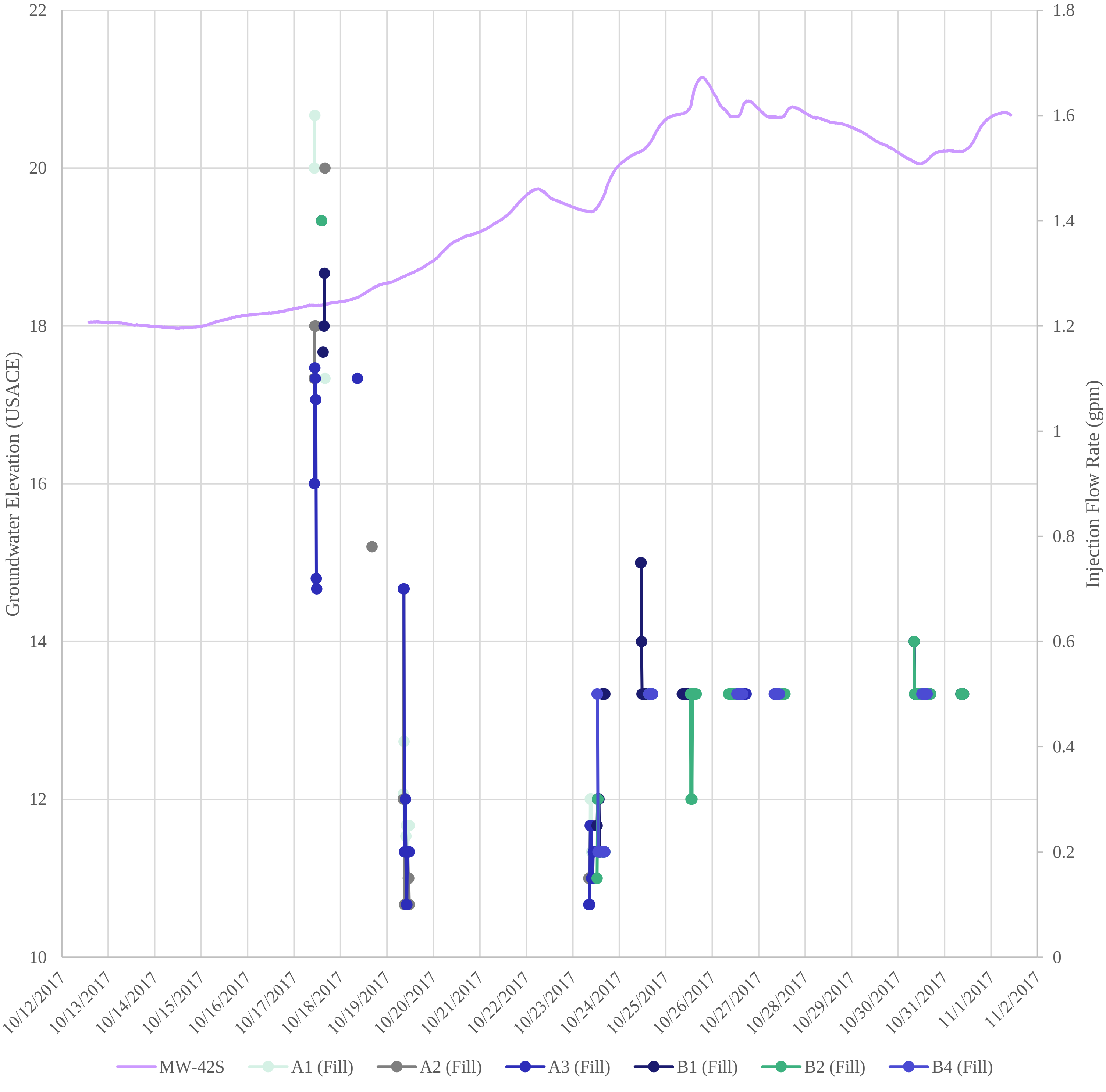
APPENDIX A

Hydraulic Response to Injection – Groundwater Elevation Graphs

Fill Well MW-42S and Nearby Fill Injection Wells
Groundwater Elevations and Injection Rates

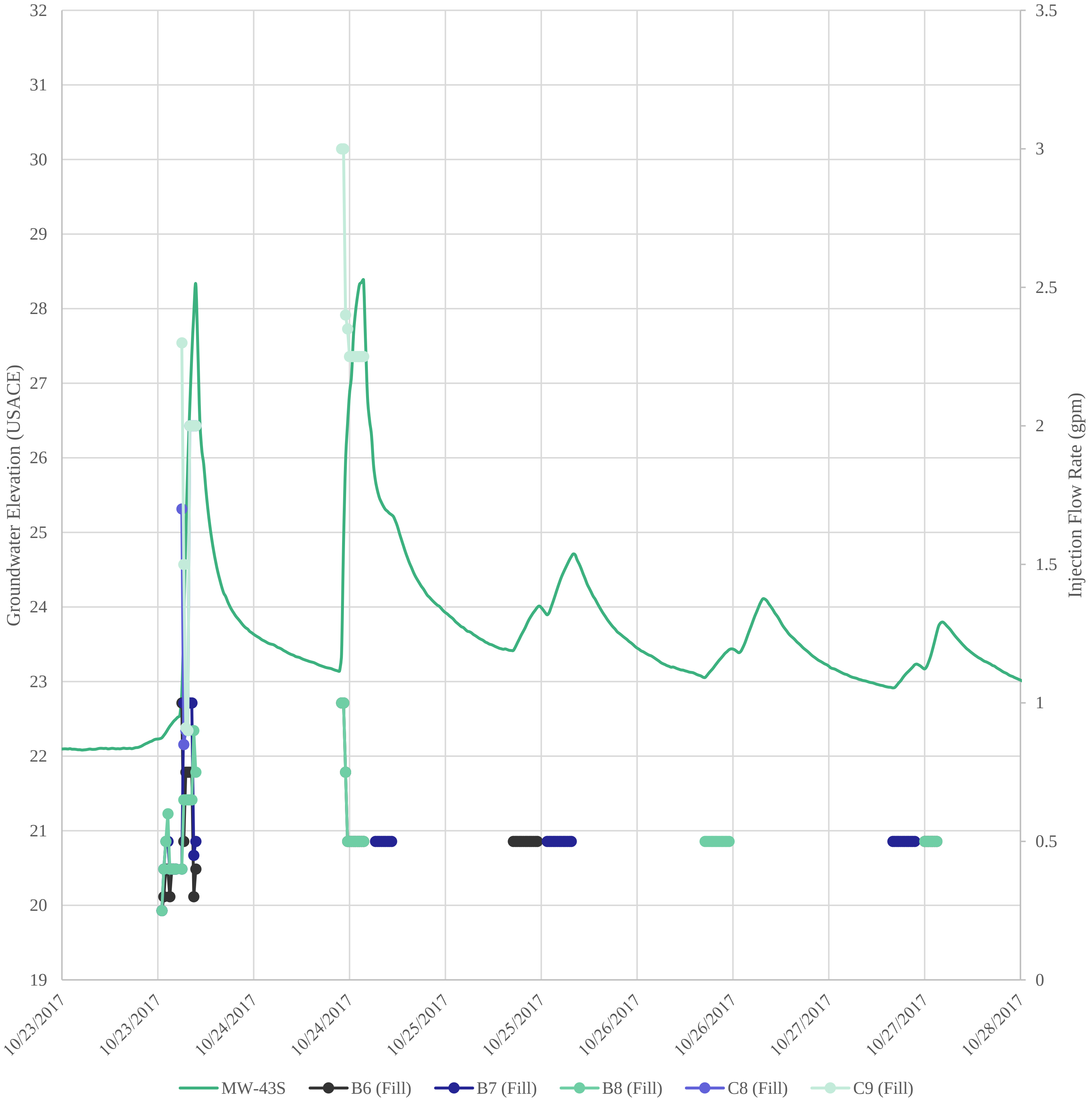


Notes:

1. Injection Round No. 1 is presented in upper graph. Groundwater elevation (USACE) is plotted on the primary axis and A- and B-Line injection rates are the secondary axis in gallons per minute (gpm).
2. Lake Union elevation data was gathered from USACE public web database. https://www.nwd-wc.usace.army.mil/nws/hh/www/

Fill Well MW-42S Response to Nearby Injection	
Play Area Interim Action Monitoring Report Seattle, Washington	
GEOENGINEERS	**Figure A-1**

Fill Well MW-43S and Nearby Fill Injection Wells
Groundwater Elevations and Injection Rates



Notes:

1. Injection Round No. 1 is presented in upper graph. Groundwater elevation (USACE) is plotted on the primary axis and B- and C-Line injection rates are the secondary axis in gallons per minute (gpm).
2. Lake Union elevation data was gathered from USACE public web database. https://www.nwd-wc.usace.army.mil/nws/hh/www/

Fill Well MW-43S Response to Nearby Injection

Play Area Interim Action Monitoring Report
Seattle, Washington

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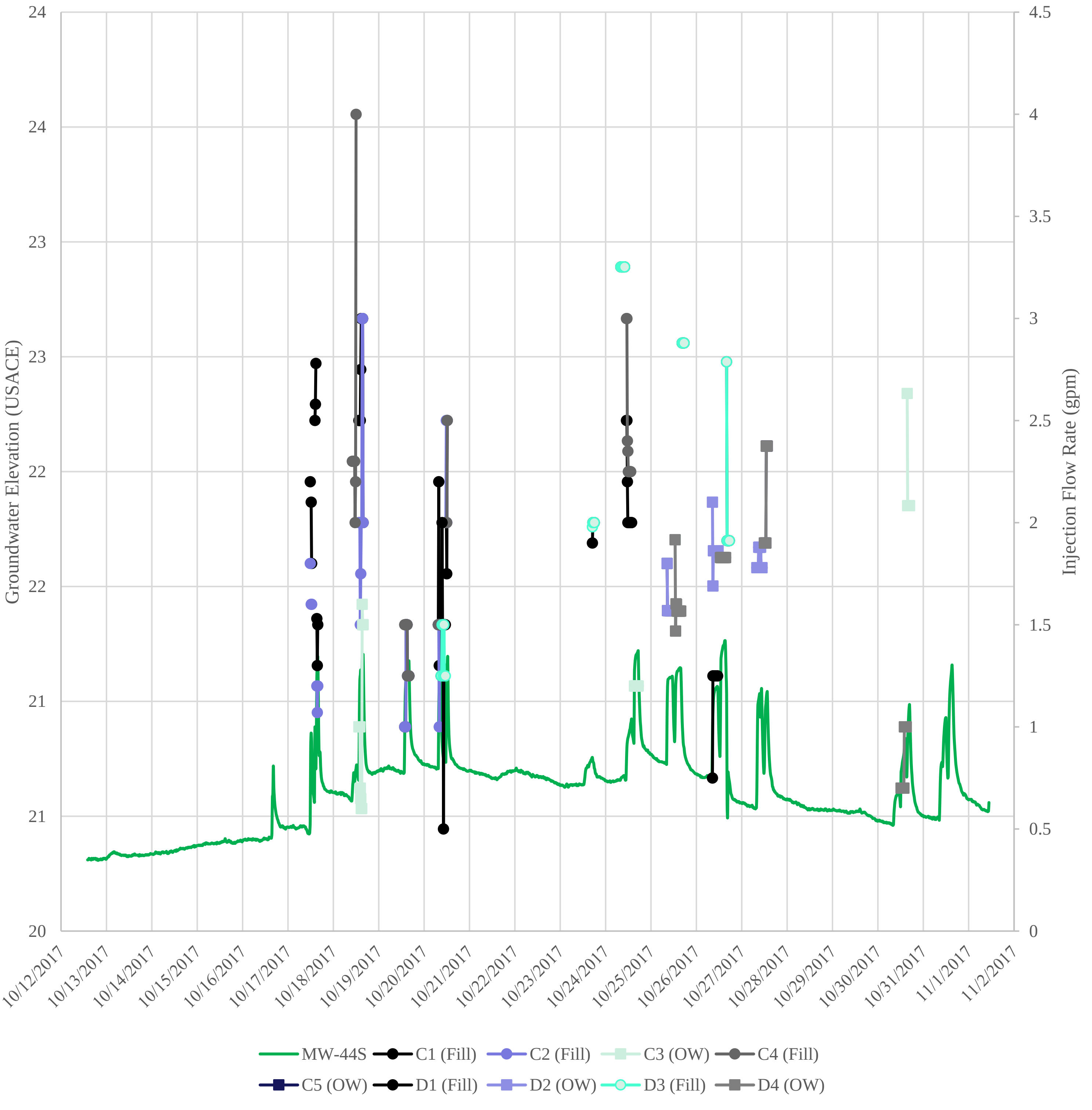
Figure A-2

Fill Well MW-44S and Nearby Fill and Outwash Injection Wells
Groundwater Elevations and Injection Rates



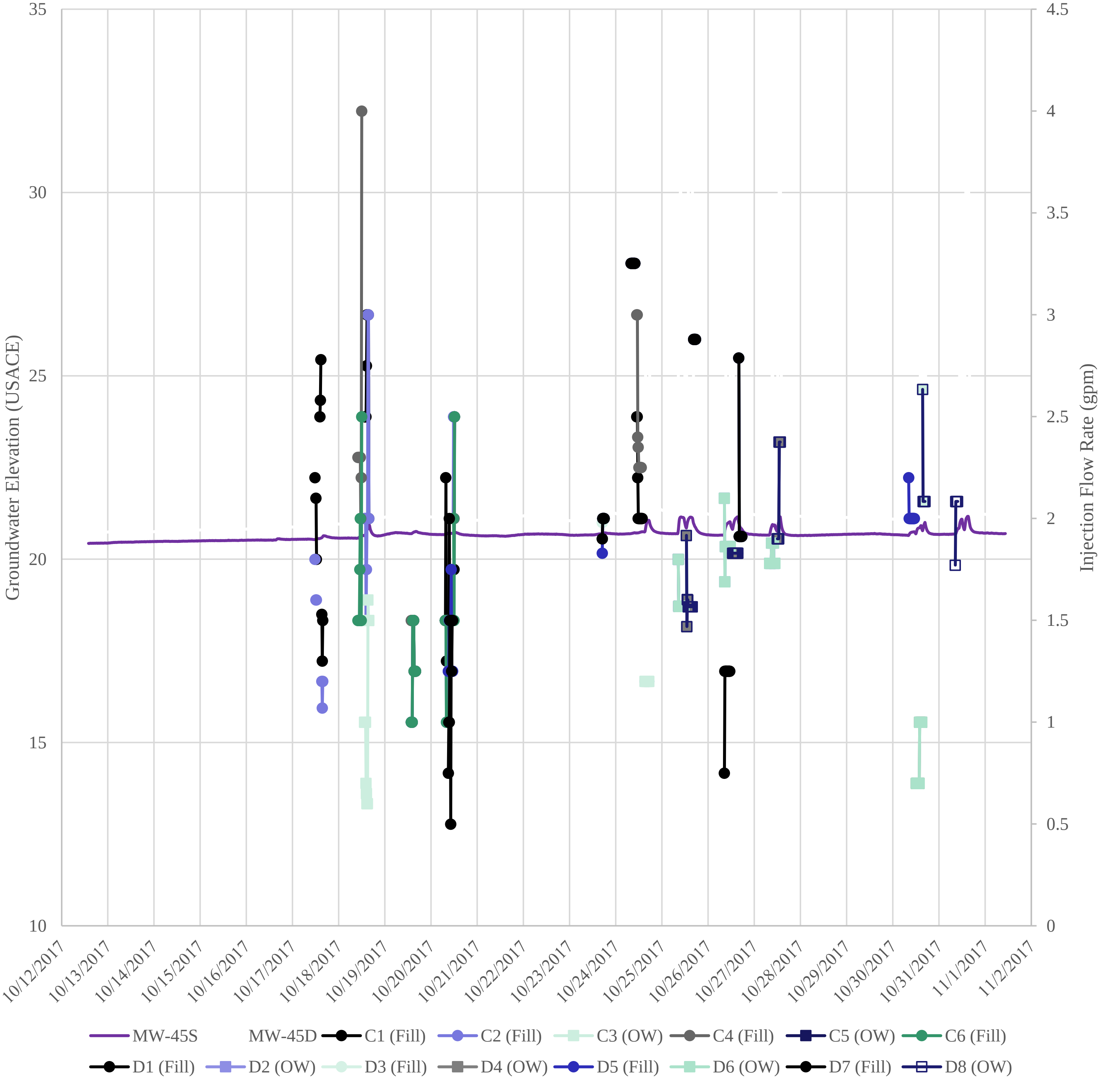
Notes:

1. Injection Round No. 1 is presented in upper graph. Groundwater elevation (USACE) is plotted on the primary axis and C- and D-Line injection rates are the secondary axis in gallons per minute (gpm).
2. Lake Union elevation data was gathered from USACE public web database. https://www.nwd-wc.usace.army.mil/nws/hh/www/

Fill Well MW-44S Response to Nearby Injection	
Play Area Interim Action Monitoring Report Seattle, Washington	
GeoEngineers	**Figure A-3**

https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport

Wells MW-45S and MW-45D and Nearby Fill and Outwash Injection Wells
Groundwater Elevations and Injection Rates

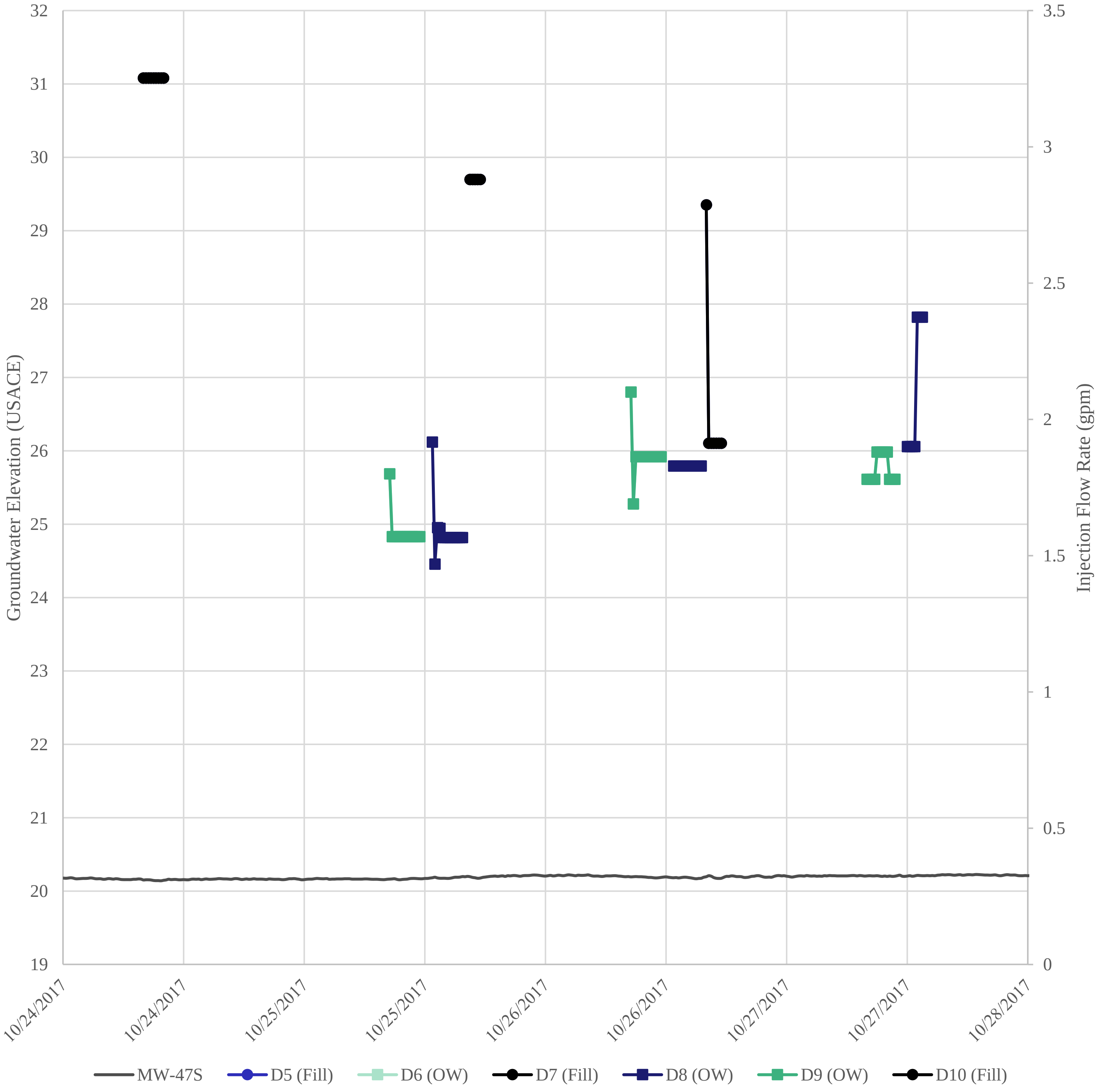


Notes:

1. Injection Round No. 1 is presented in upper graph. Groundwater elevation (USACE) is plotted on the primary axis and C- and D-Line injection rates are the secondary axis in gallons per minute (gpm).
2. Lake Union elevation data was gathered from USACE public web database. https://www.nwd-wc.usace.army.mil/nws/hh/www/

Fill Well MW-45S and Outwash Well MW-45D Response to Nearby Injection	
Play Area Interim Action Monitoring Report Seattle, Washington	
GeoEngineers	**Figure A-4**

Fill Well MW-47S and Nearby Fill and Outwash Injection Wells
Groundwater Elevations and Injection Rates



Notes:

1. Injection Round No. 1 is presented in upper graph. Groundwater elevation (USACE) is plotted on the primary axis and D-Line injection rates are the secondary axis in gallons per minute (gpm).
2. Lake Union elevation data was gathered from USACE public web database. https://www.nwd-wc.usace.army.mil/nws/hh/www/

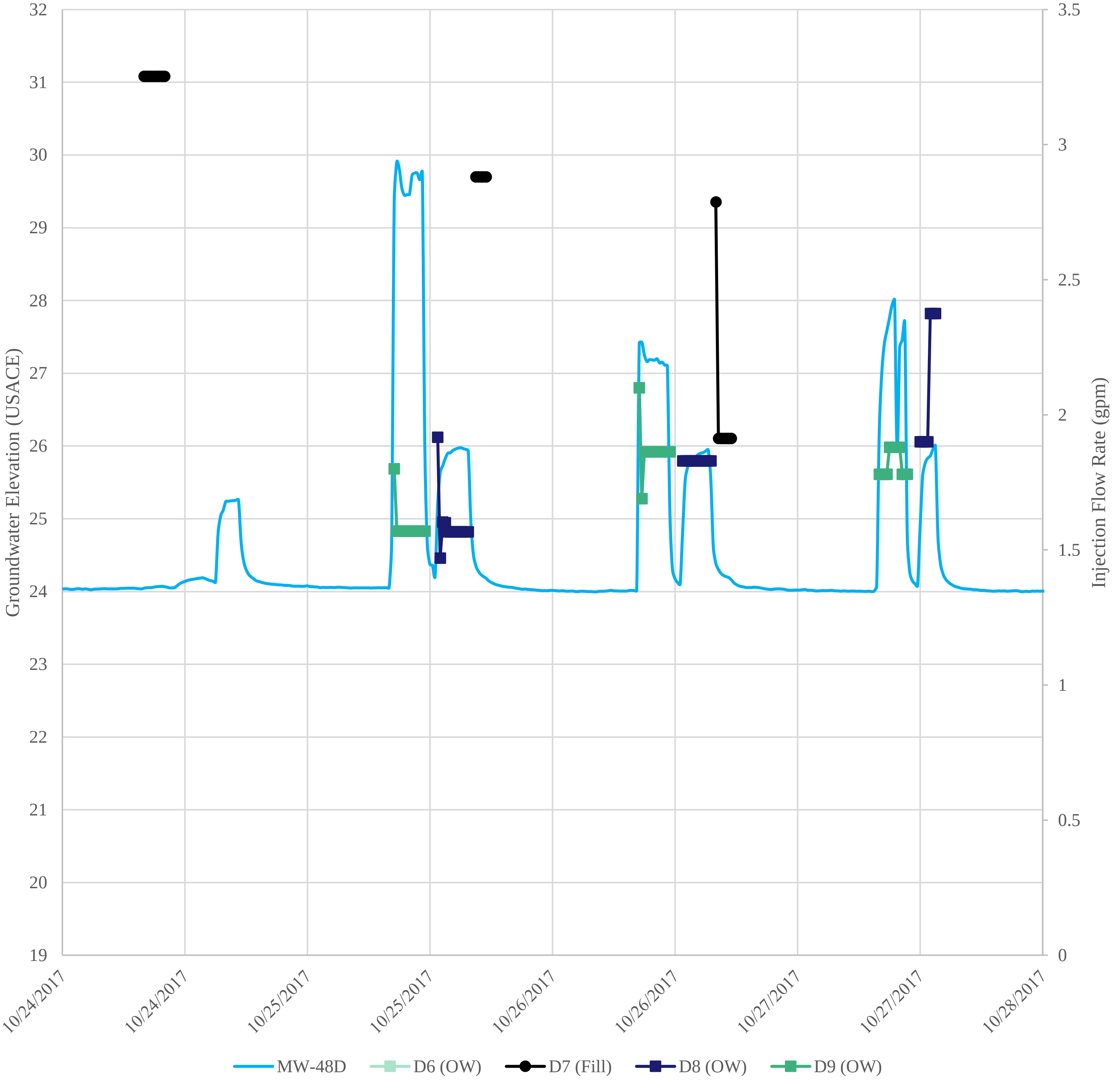
Fill Well MW-47S Response to Nearby Injection

Play Area Interim Action Monitoring Report
Seattle, Washington

GeoEngineers

Figure A-5

Outwash Well MW-48D and Nearby Fill and Outwash Injection Wells
Groundwater Elevations and Injection Rates



Notes:

1. Injection Round No. 1 is presented in upper graph. Groundwater elevation (USACE) is plotted on the primary axis and D-Line injection rates are the secondary axis in gallons per minute (gpm).
2. Lake Union elevation data was gathered from USACE public web database. https://www.nwd-wc.usace.army.mil/nws/hh/www/

Outwash Well MW-48D Response to Nearby Injection

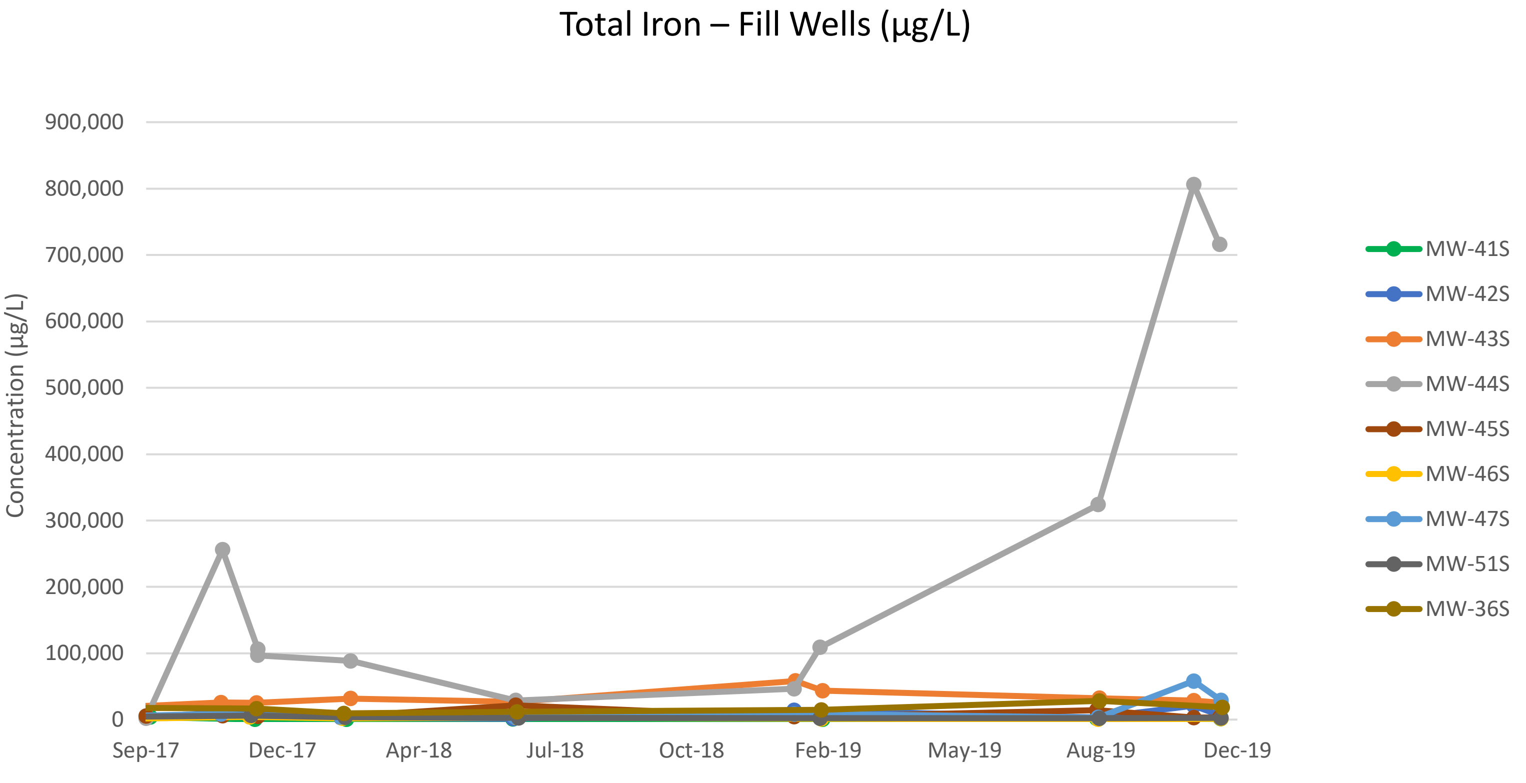
Play Area Interim Action Monitoring Report
Seattle, Washington

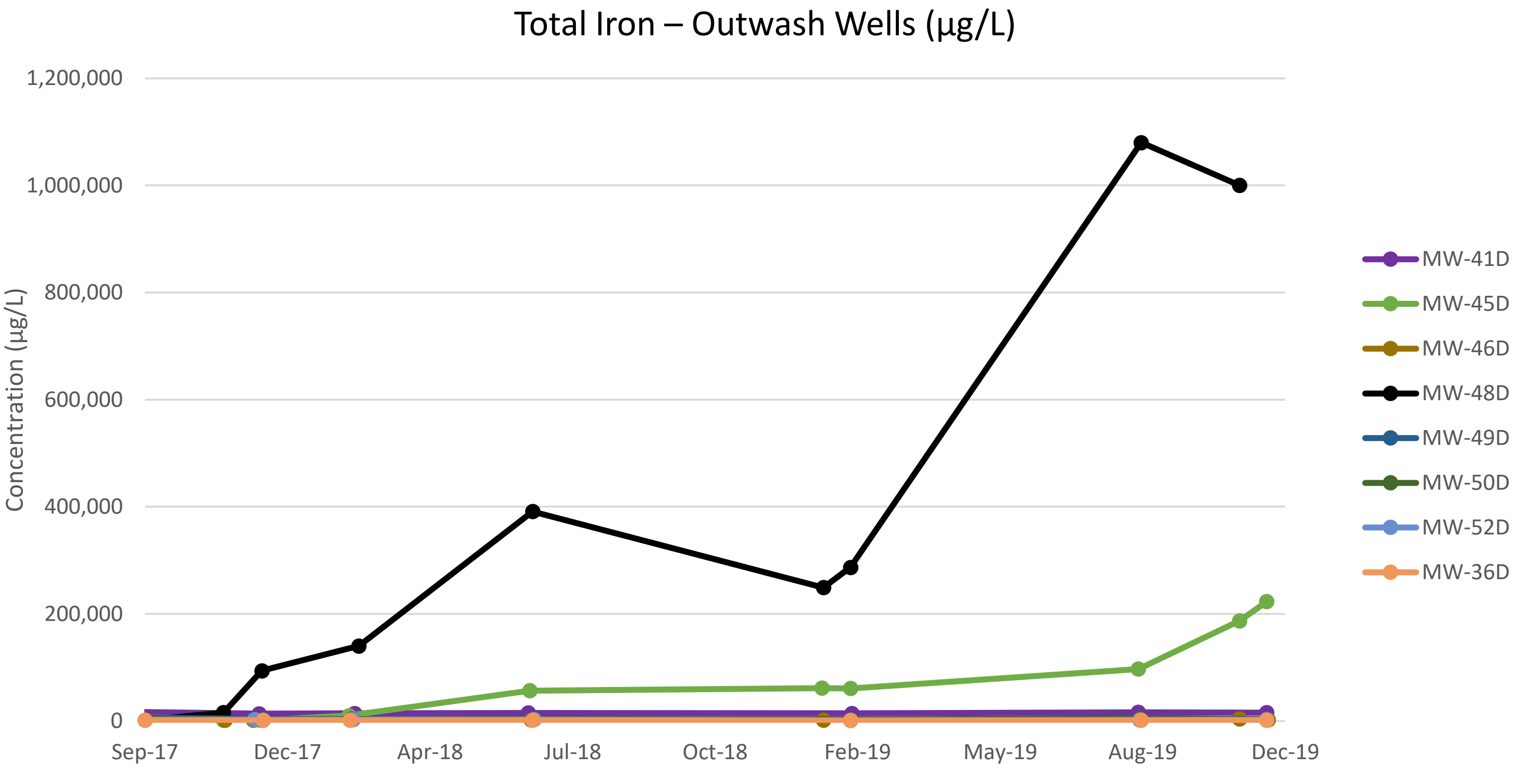
GeoEngineers

Figure A-6

APPENDIX B

Groundwater Data Graphs





Notes:

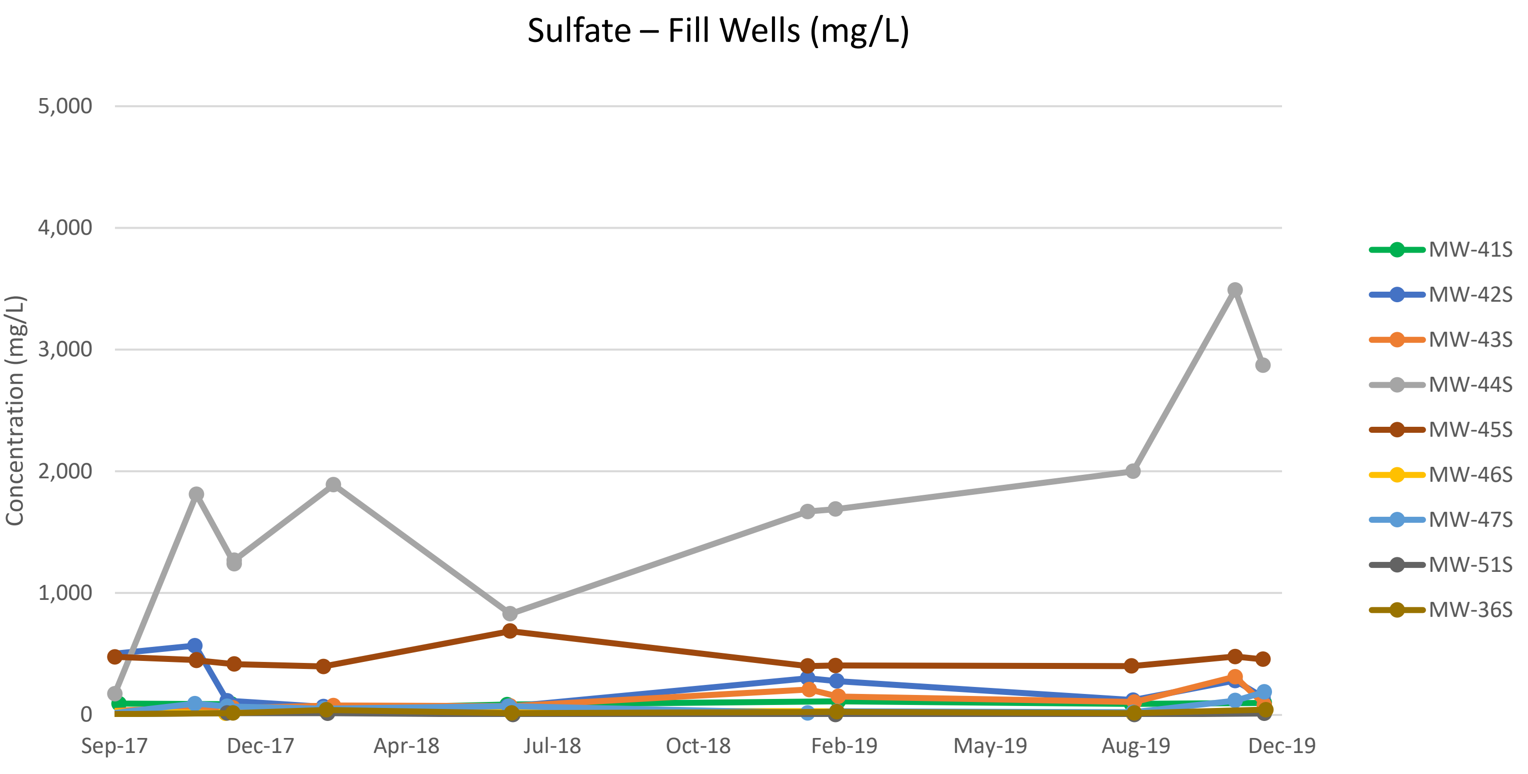
1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Total Iron is the primary axis in micrograms per liter (µg/L).
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

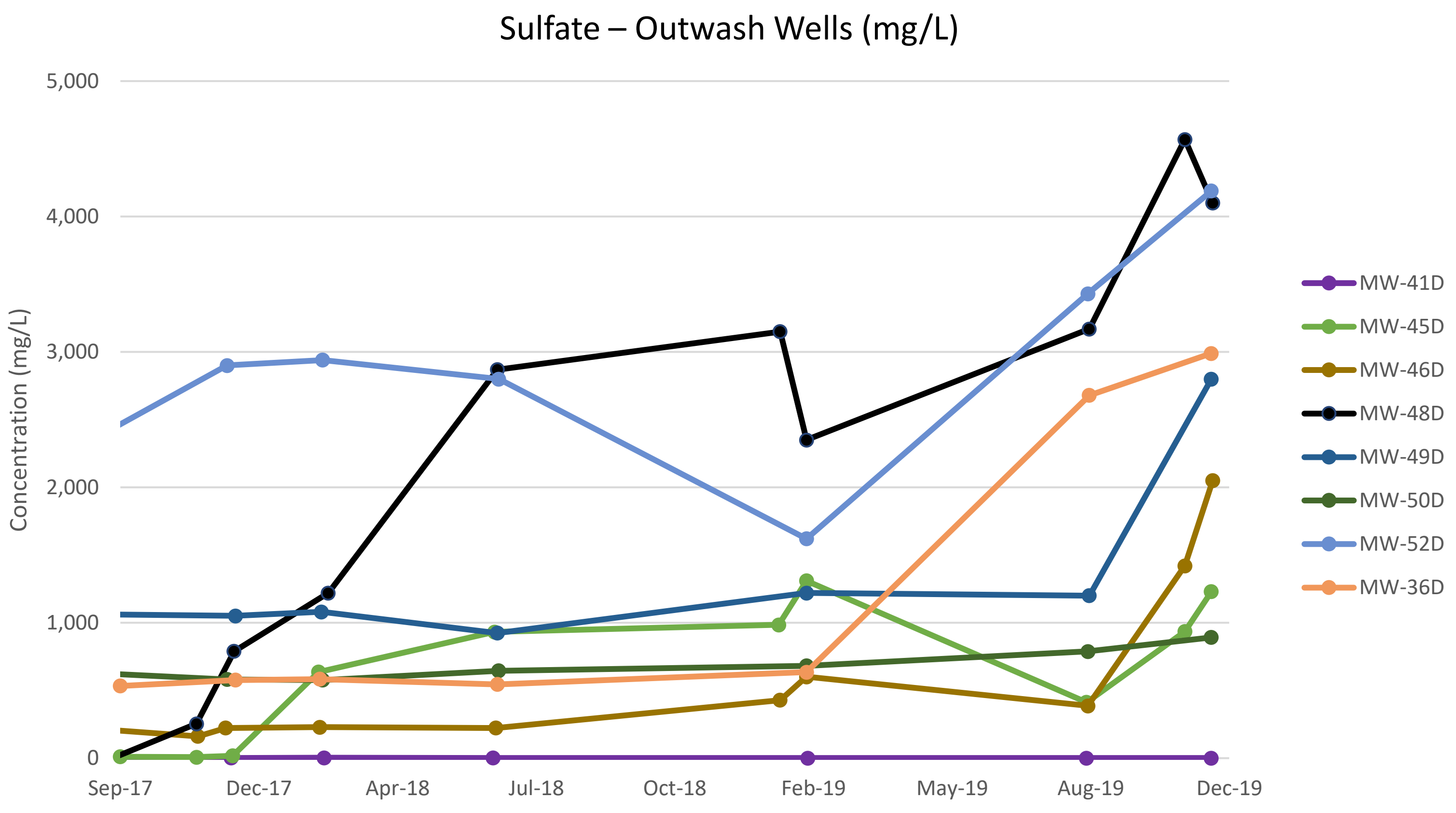
Total Iron Results

Play Area Interim Action Monitoring Report
Seattle, Washington

GeoEngineers

Figure B-1


Sulfate – Fill Wells (mg/L)

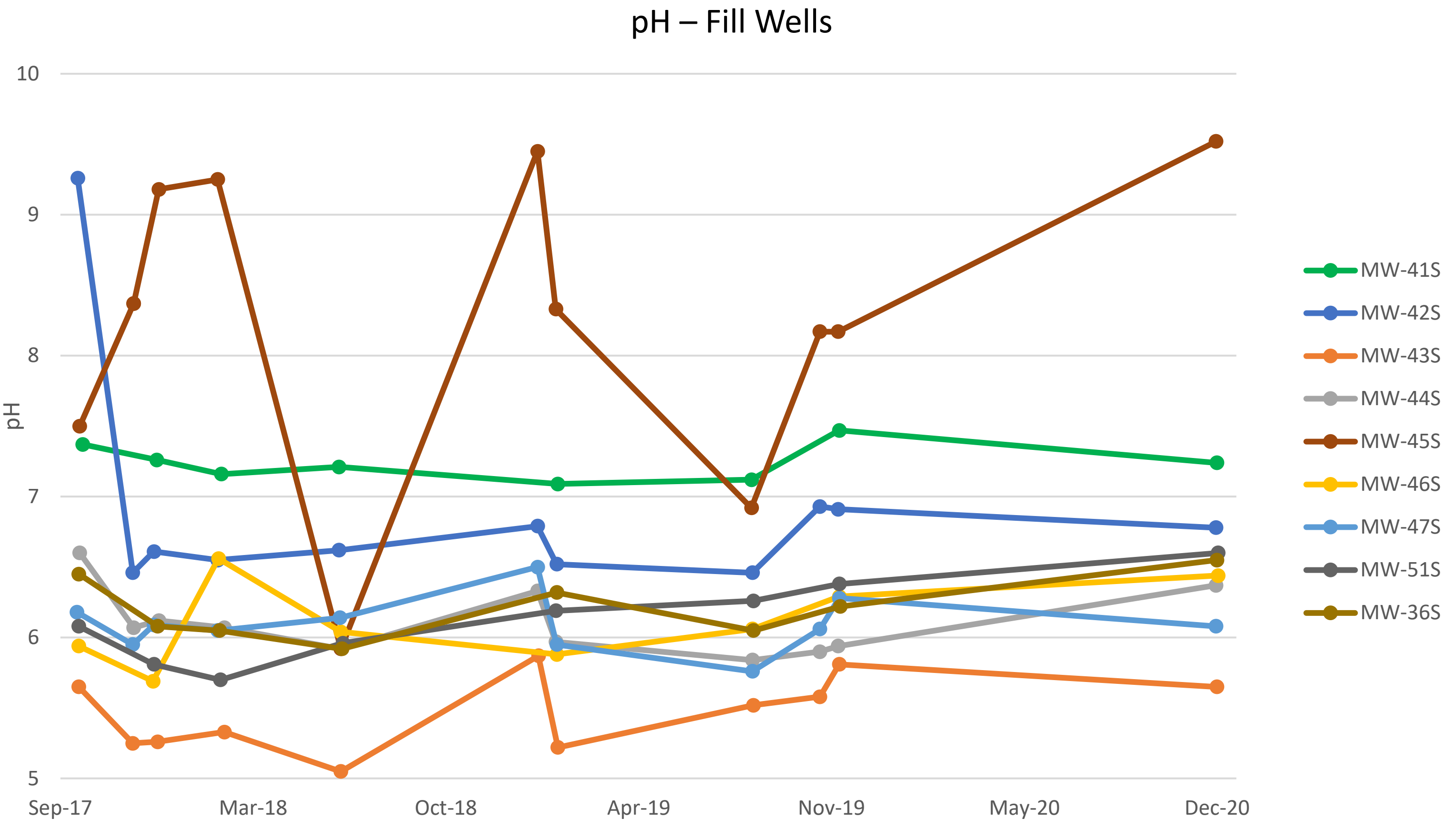

Sulfate – Outwash Wells (mg/L)

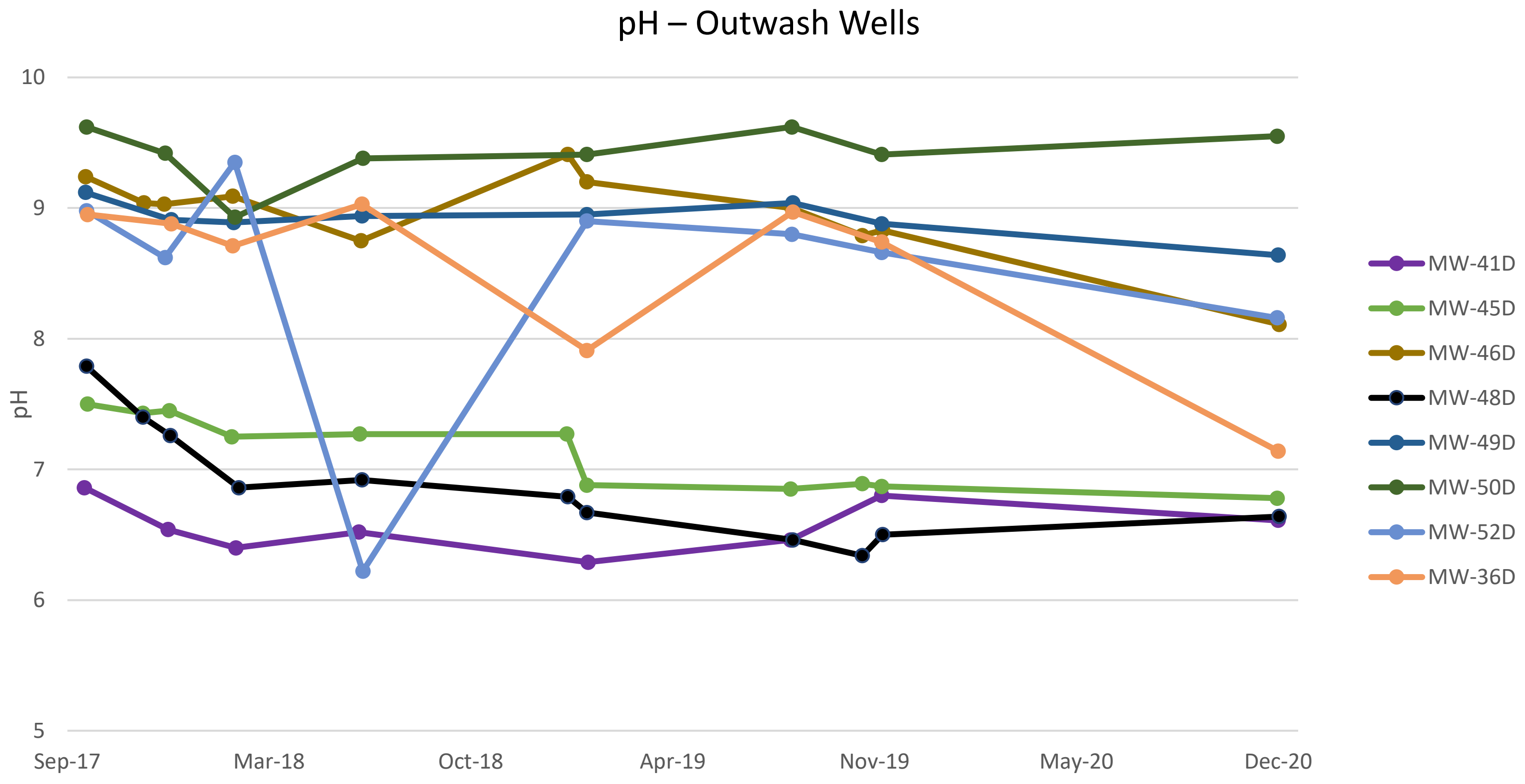
Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Sulfate is the primary axis in milligrams per liter (mg/L).
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

Sulfate Results	
Play Area Interim Action Monitoring Report Seattle, Washington	
GeoEngineers	**Figure B-2**

https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport





Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. The measurement of pH is the primary axis.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

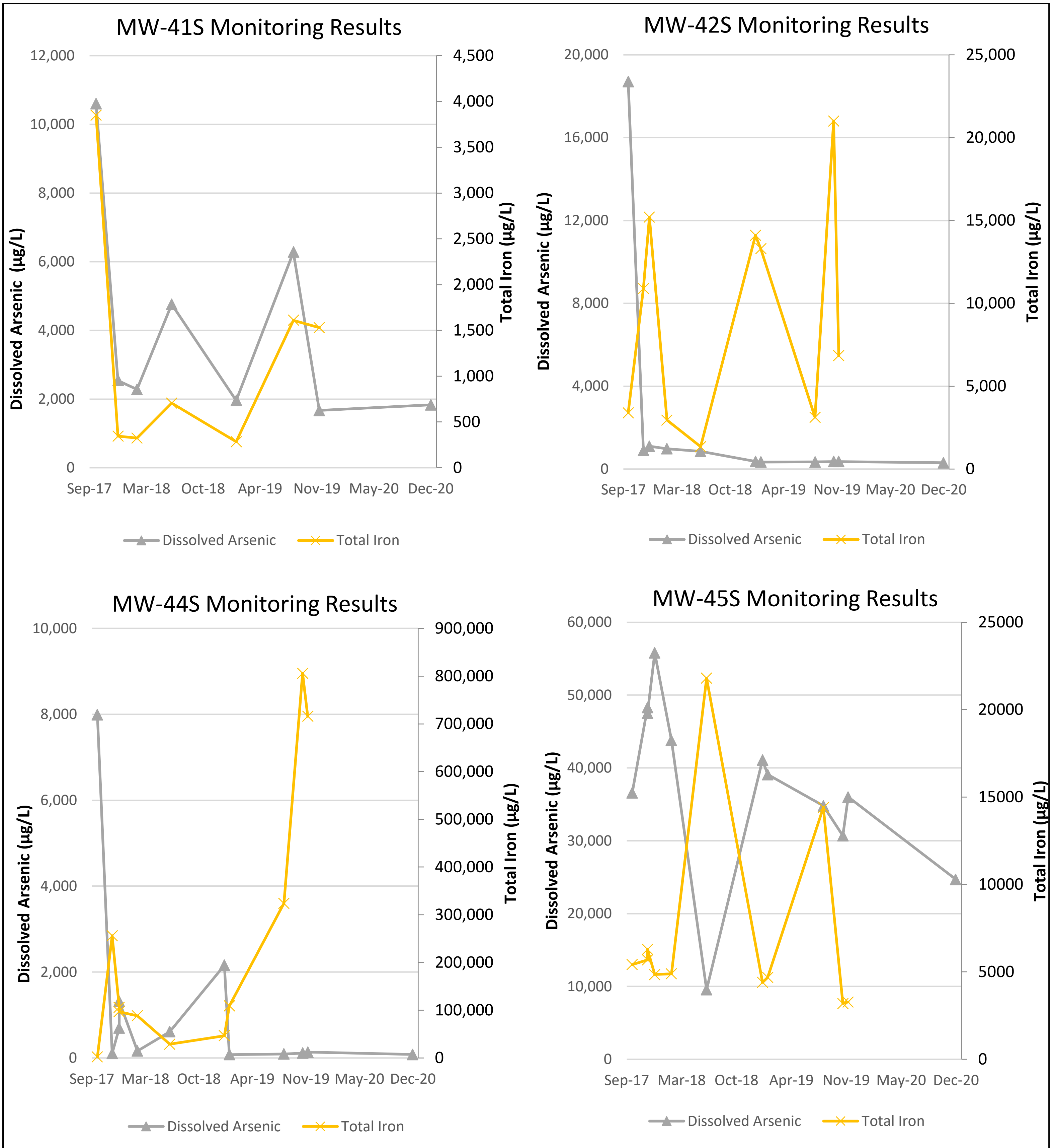
pH Measurements

Play Area Interim Action Monitoring Report
Seattle, Washington

GeoEngineers

Figure B-3

https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport



Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is the primary axis in µg/L and Total Iron is the secondary axis in µg/L.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

Total Iron versus Dissolved Arsenic, Select Fill Wells

Play Area Interim Action Monitoring Report
Seattle, Washington

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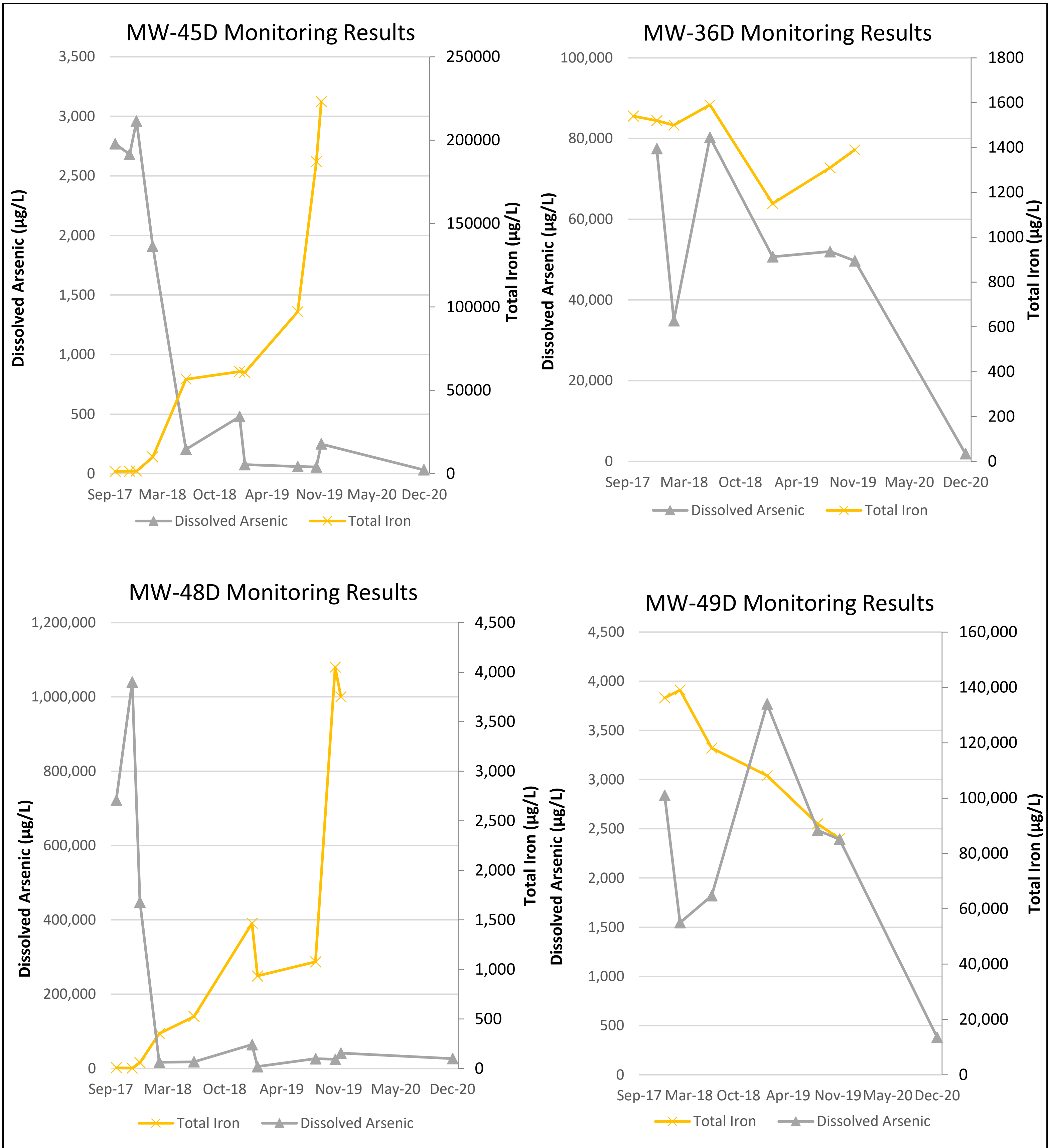
Figure B-4


MW-45D Monitoring Results

MW-36D Monitoring Results

MW-48D Monitoring Results

MW-49D Monitoring Results

Notes:

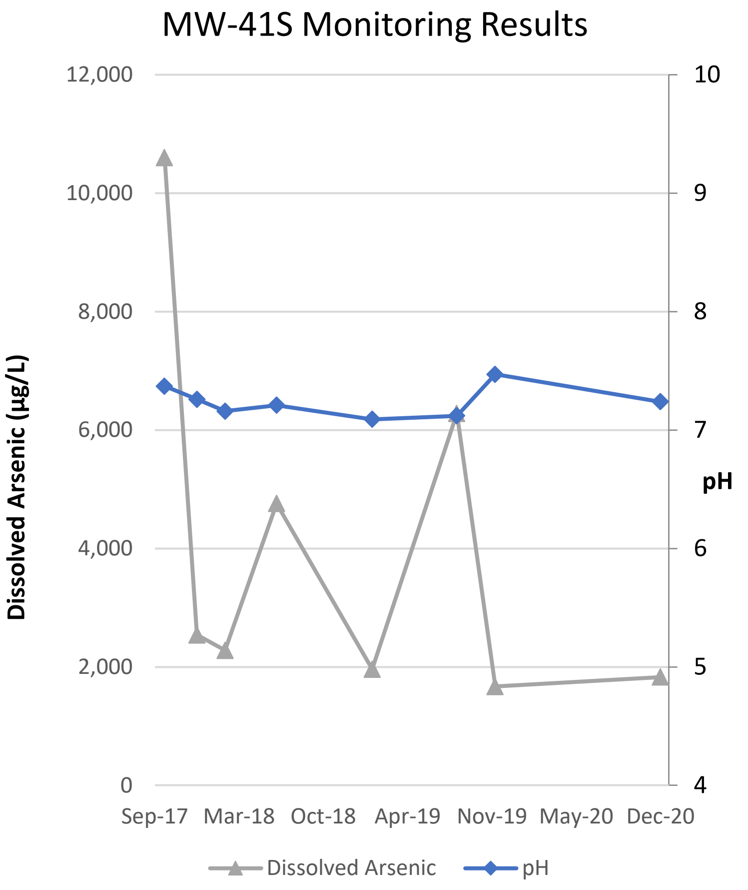
1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is the primary axis in µg/L and Total Iron is the secondary axis in µg/L.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

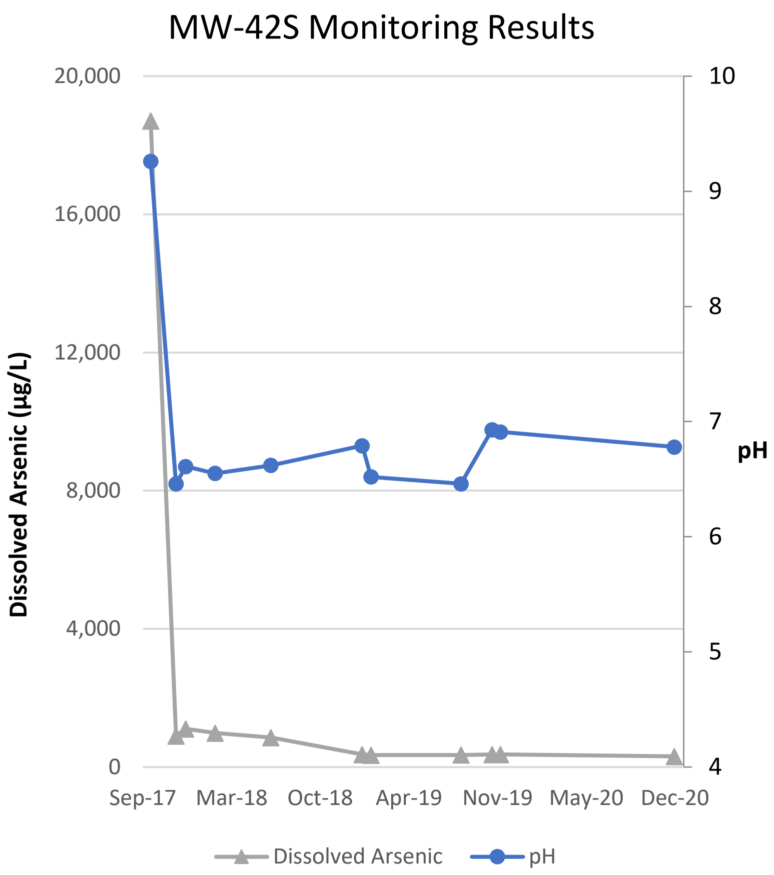
Total Iron versus Dissolved Arsenic,
Select Outwash Wells

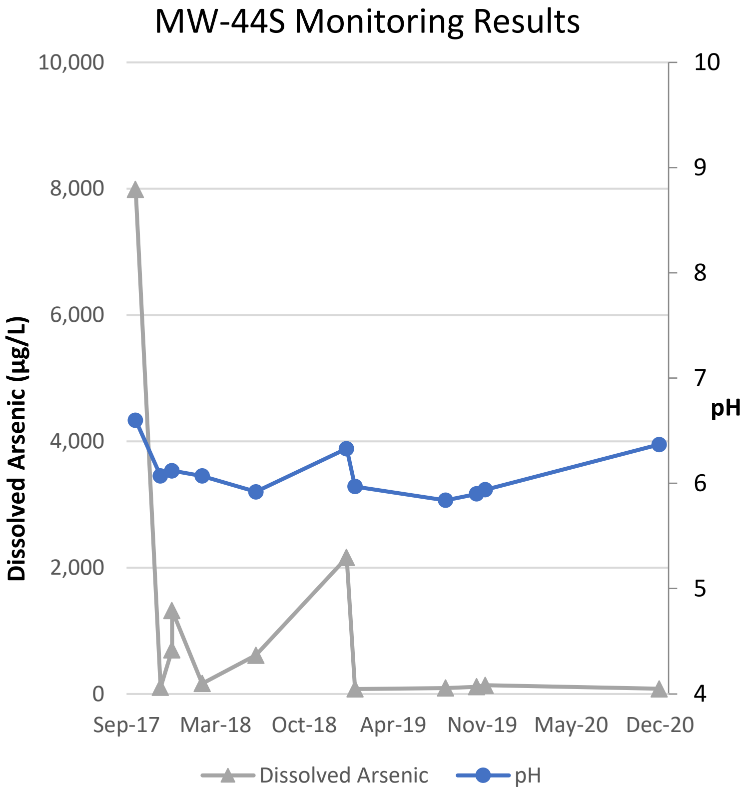
Play Area Interim Action Monitoring Report
Seattle, Washington

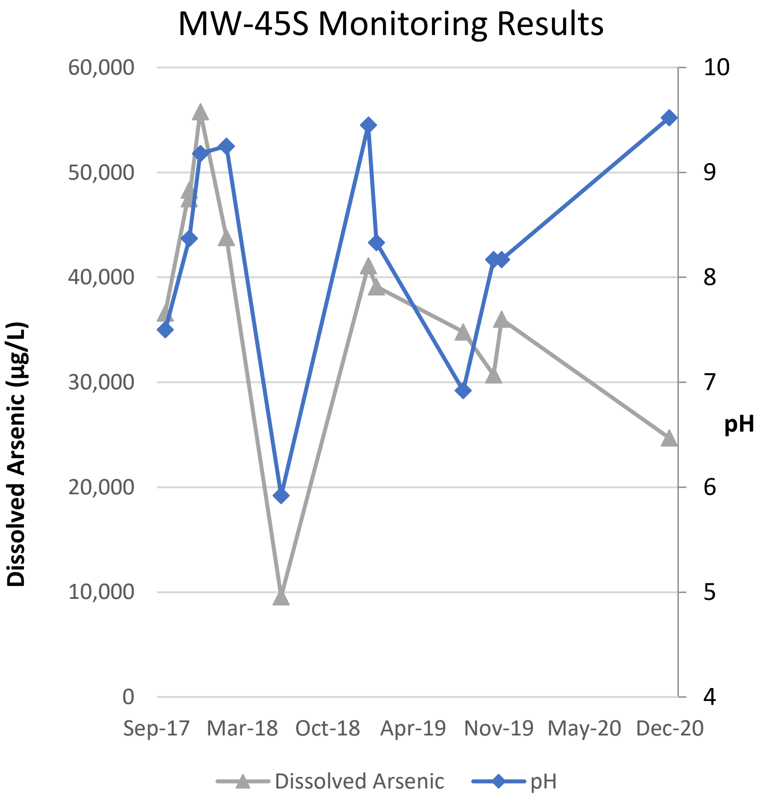
GEOENGINEERS

Figure B-5


MW-41S Monitoring Results


MW-42S Monitoring Results


MW-44S Monitoring Results


MW-45S Monitoring Results

Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is the primary axis in µg/L and pH is the secondary axis.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

pH versus Dissolved Arsenic, Select Fill Wells

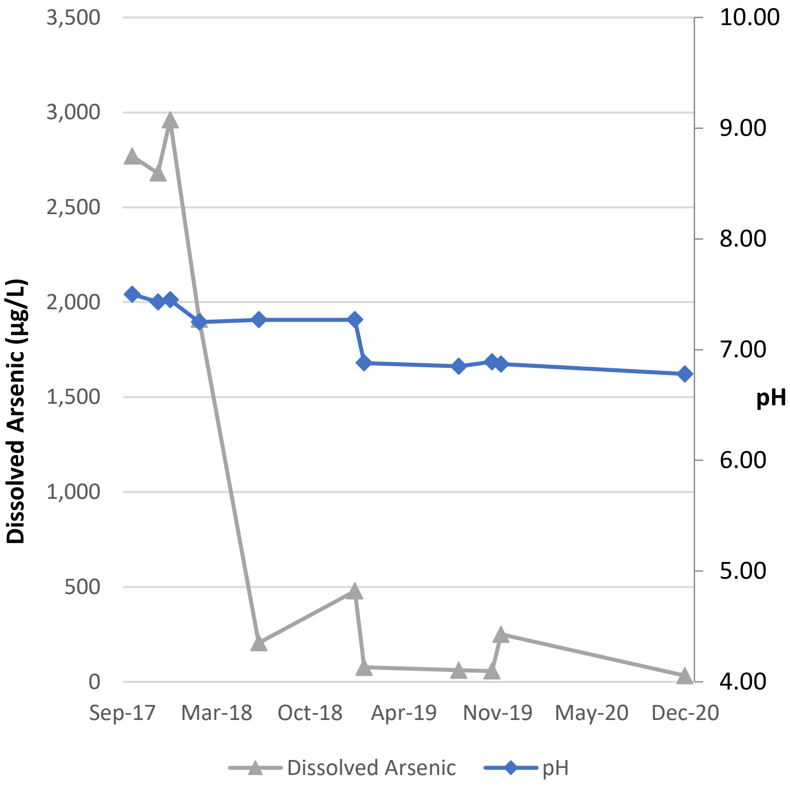
Play Area Interim Action Monitoring Report
Seattle, Washington

GeoEngineers

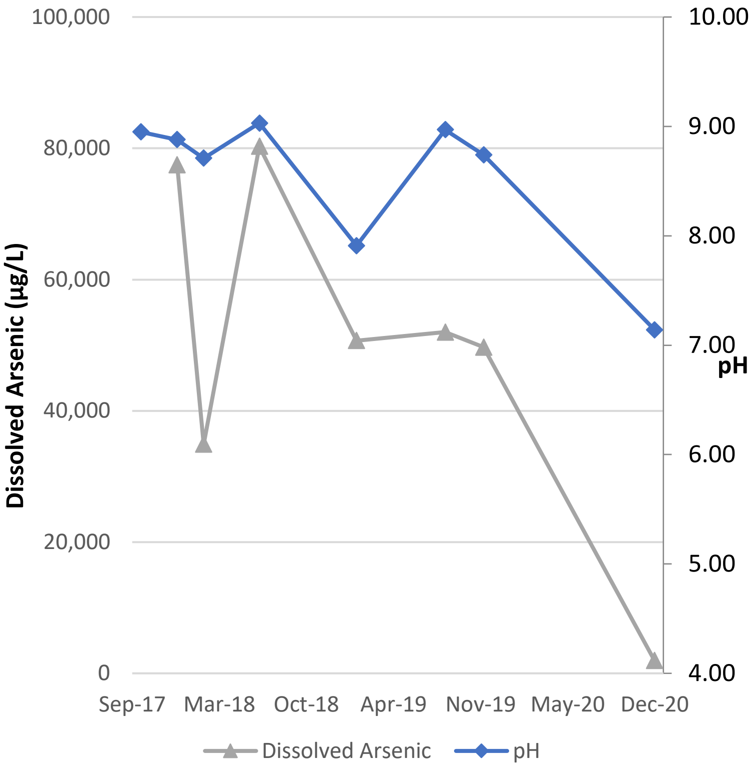
Figure B-6

https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport

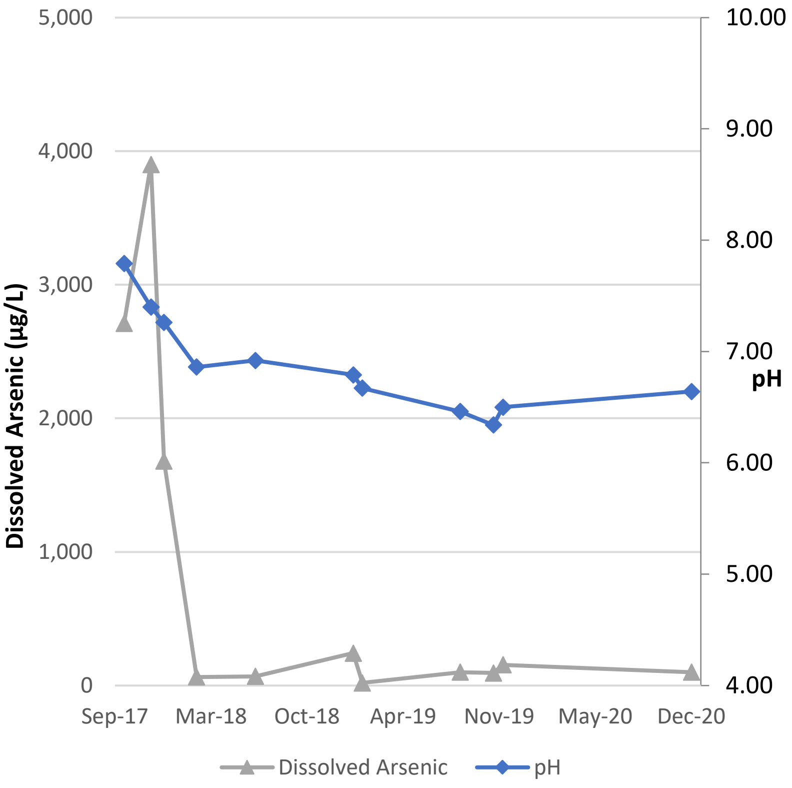
MW-45D Monitoring Results



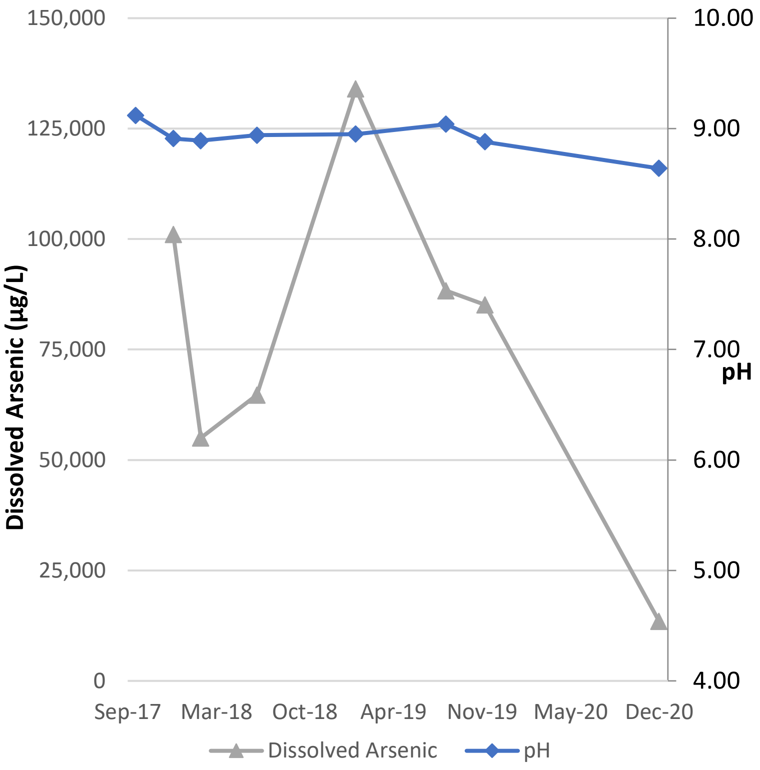
MW-36D Monitoring Results



MW-48D Monitoring Results



MW-49D Monitoring Results



Notes:

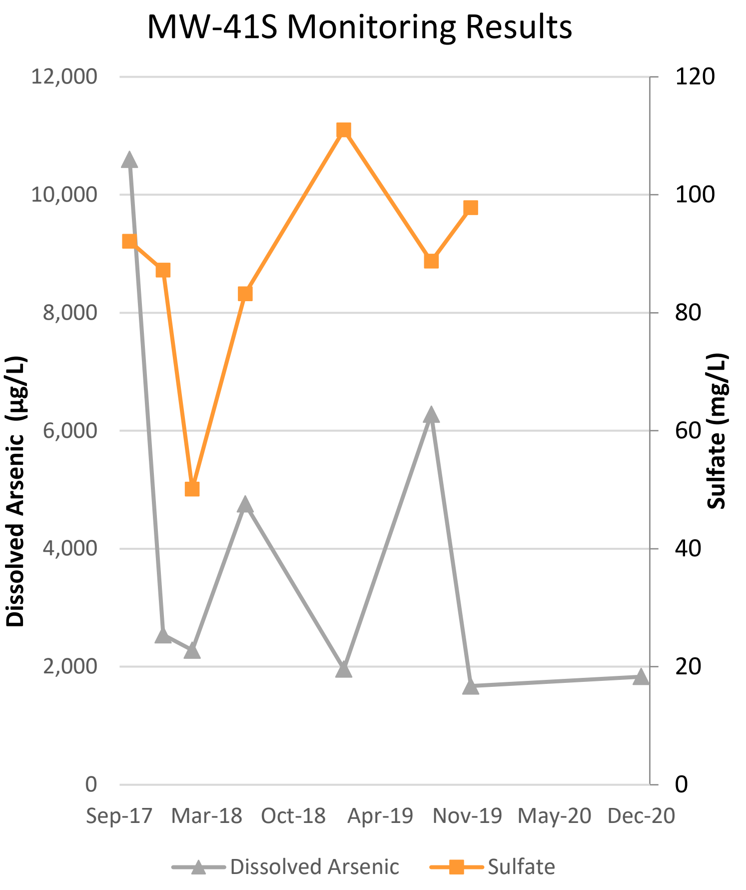
1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is the primary axis in µg/L and pH is the secondary axis.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

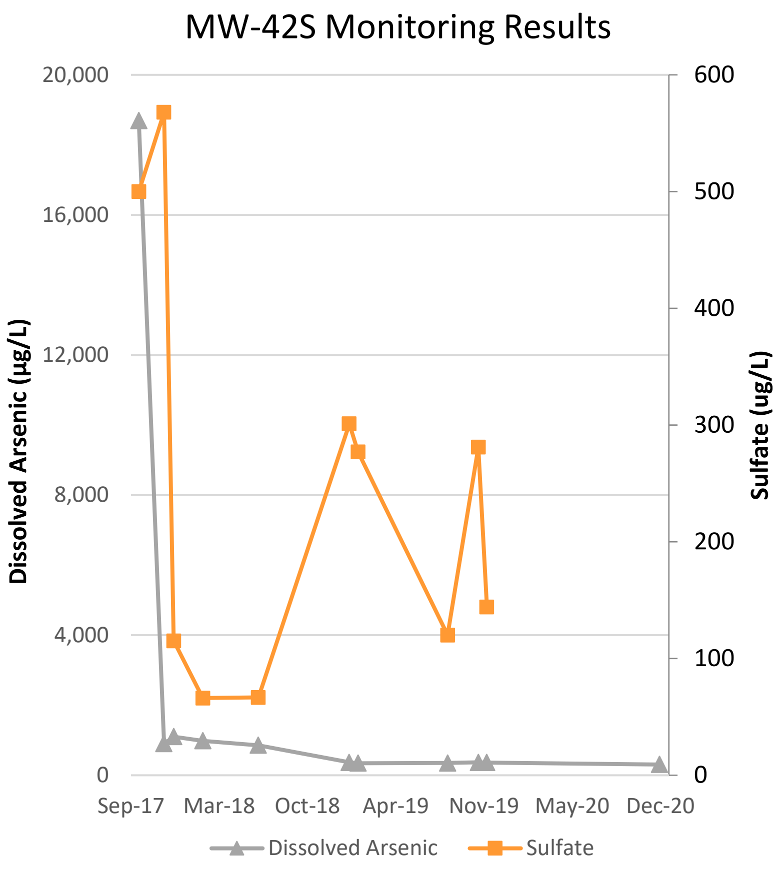
pH versus Dissolved Arsenic,
Select Outwash Wells

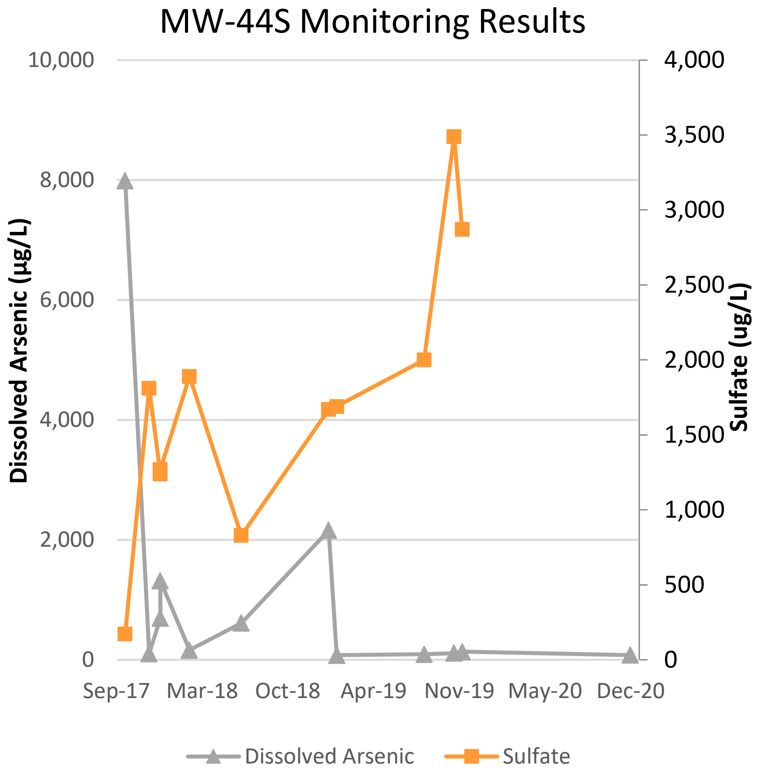
Play Area Interim Action Monitoring Report
Seattle, Washington

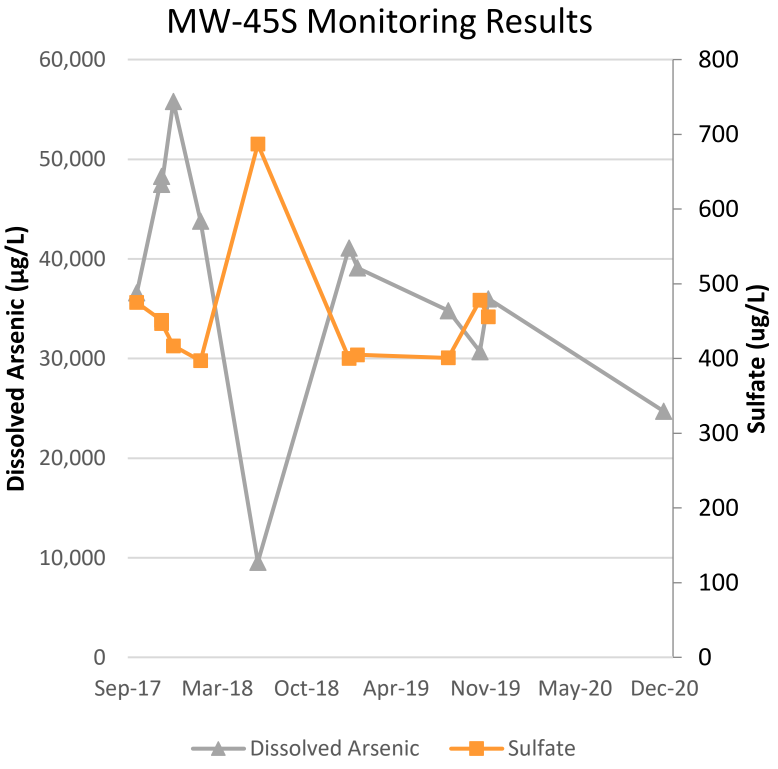
GeoEngineers

Figure B-7


MW-41S Monitoring Results


MW-42S Monitoring Results


MW-44S Monitoring Results


MW-45S Monitoring Results

Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is the primary axis in µg/L and Sulfate is the secondary axis in mg/L.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

Sulfate versus Dissolved Arsenic,
Select Fill Wells

Play Area Interim Action Monitoring Report
Seattle, Washington

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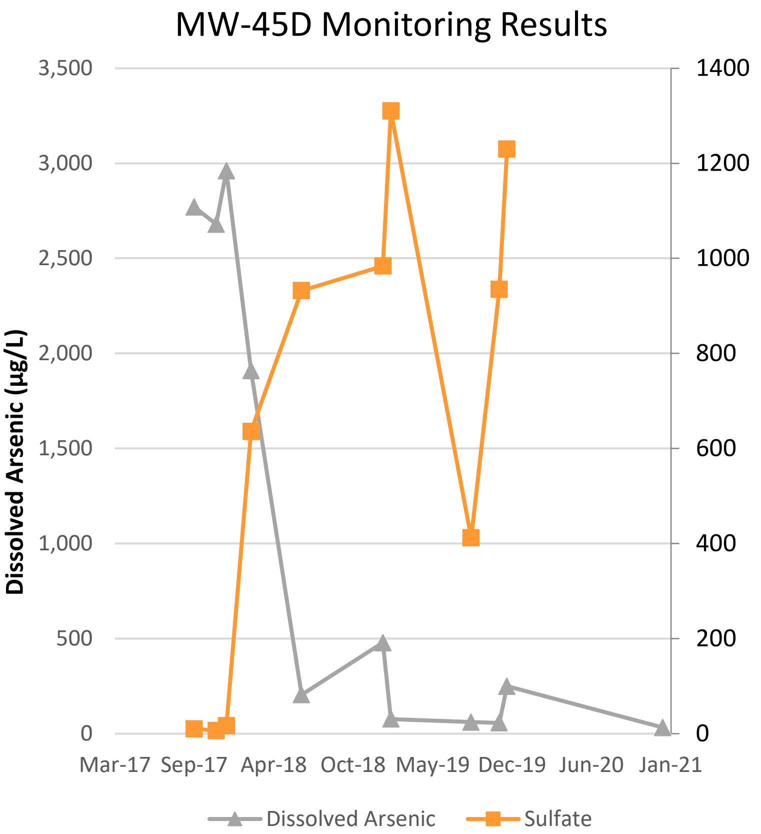
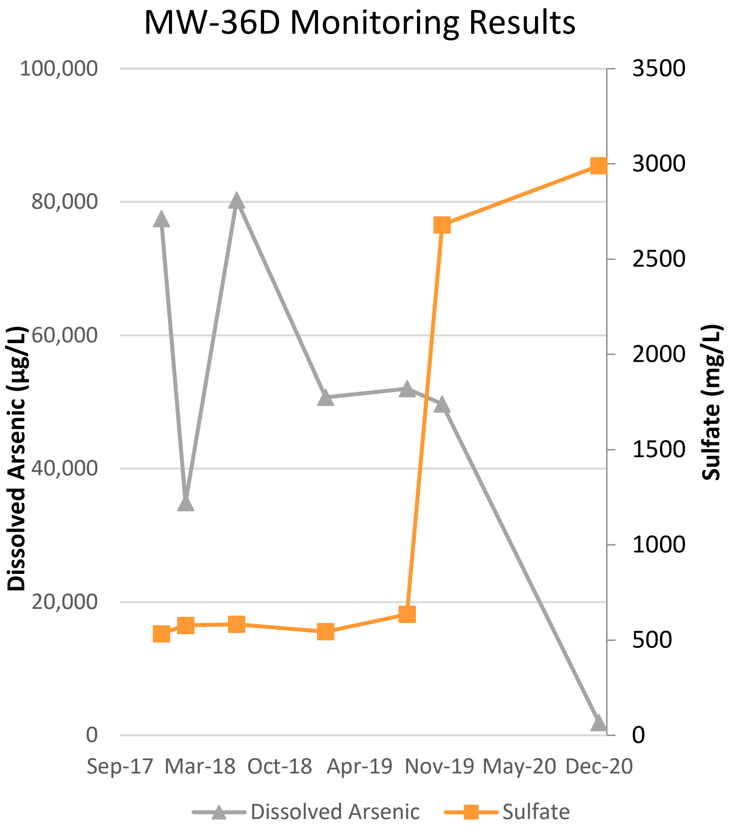
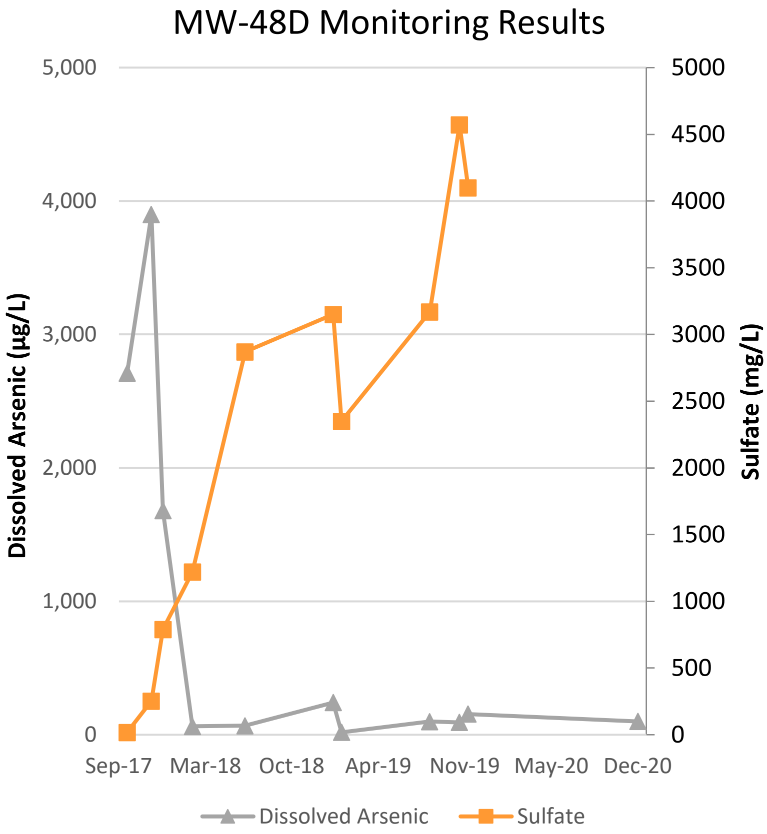
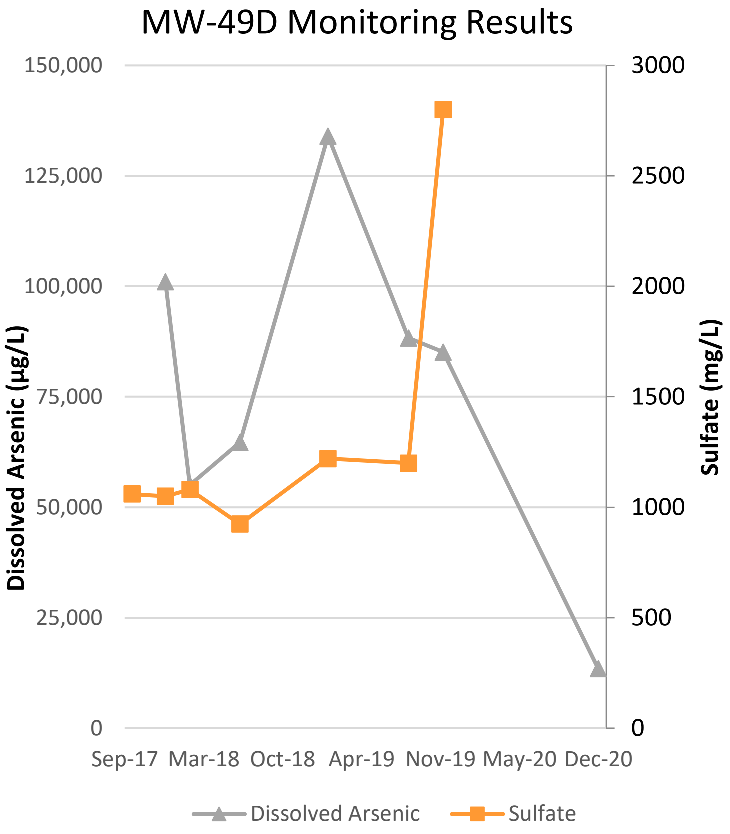
Figure B-8









<u>Notes:</u>

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is the primary axis in µg/L and Sulfate is the secondary axis in mg/L.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

Sulfate versus Dissolved Arsenic,
Select Outwash Wells

Play Area Interim Action Monitoring Report
Seattle, Washington

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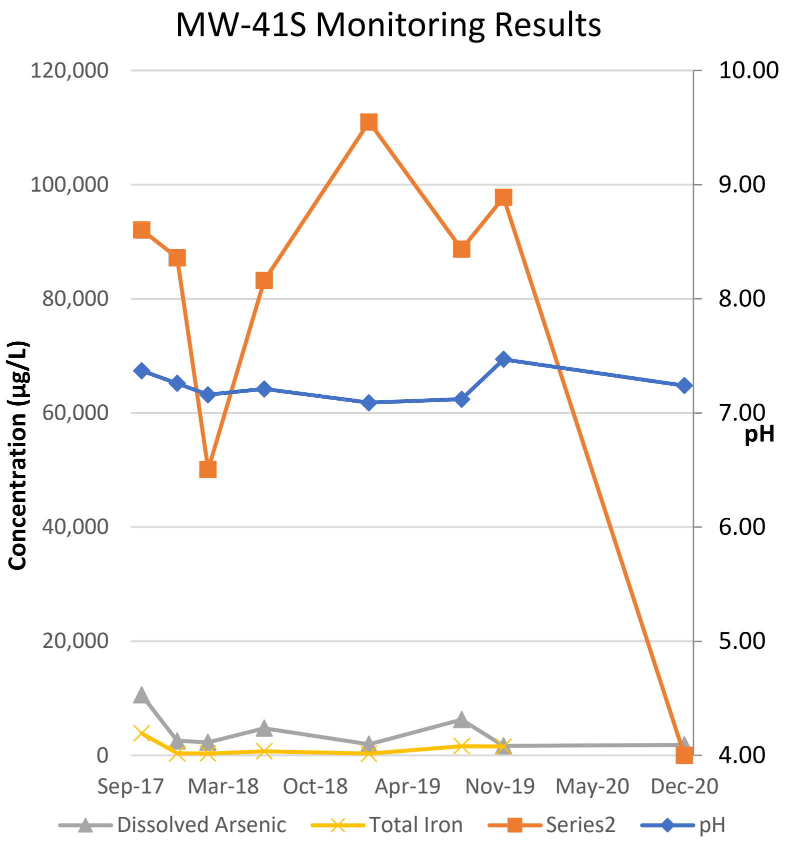
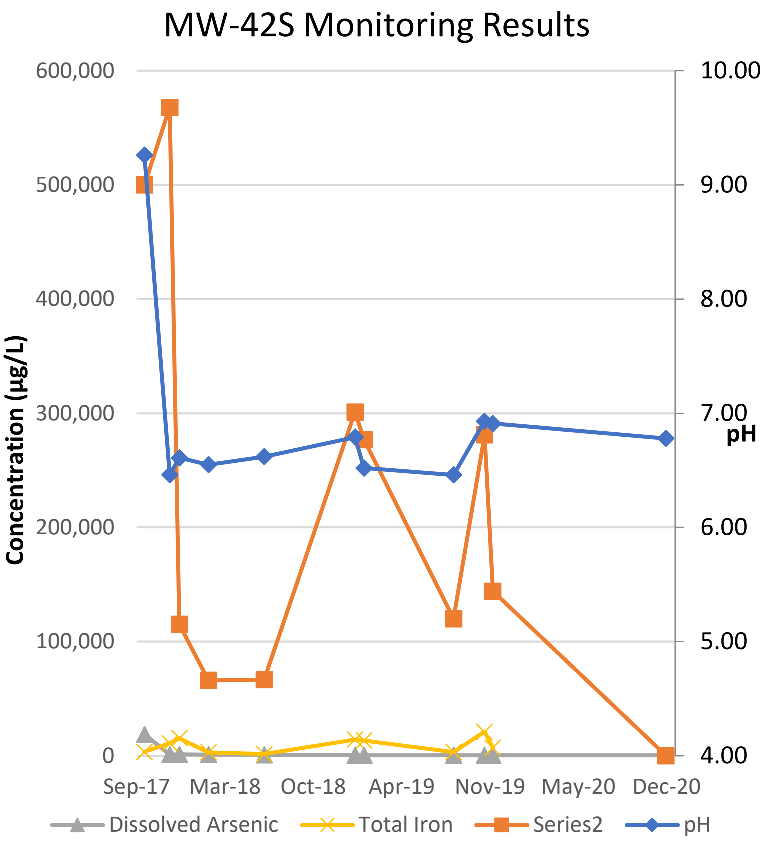
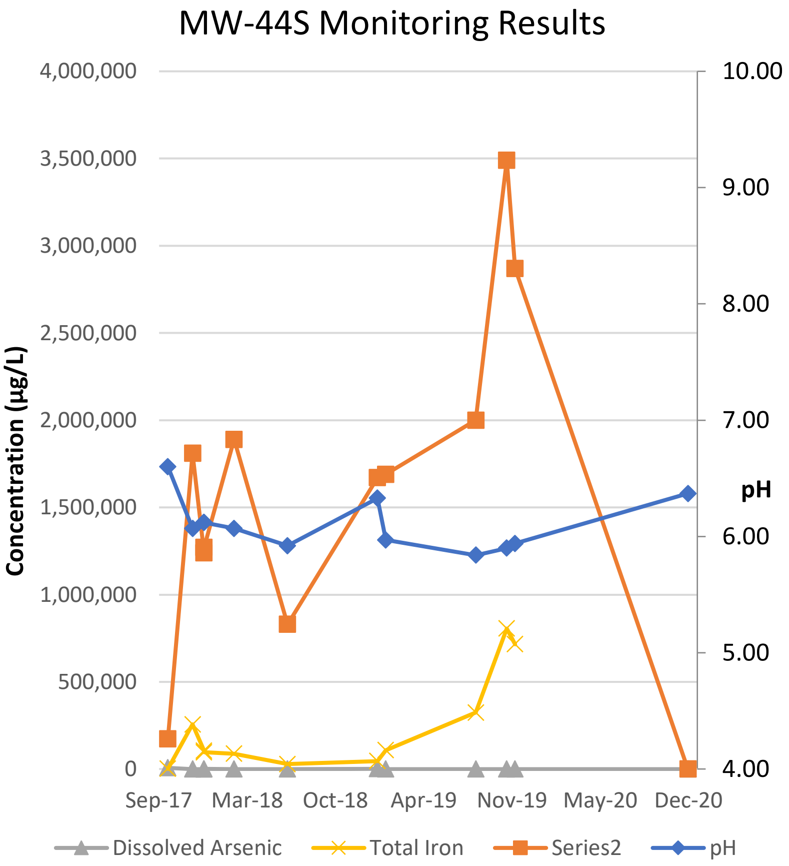
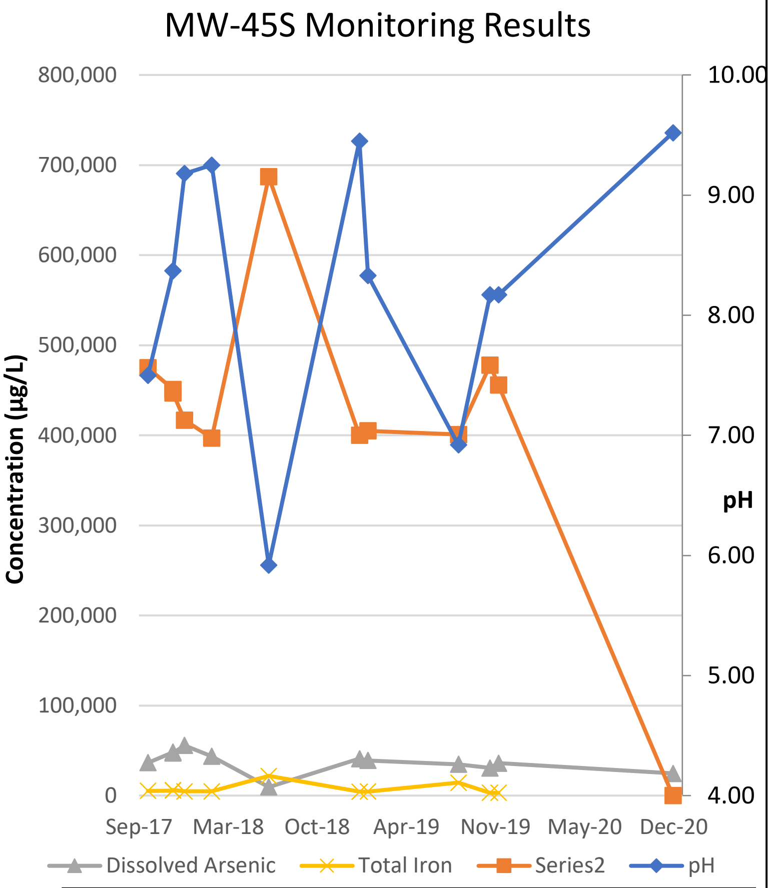
Figure B-9


MW-41S Monitoring Results


MW-42S Monitoring Results


MW-44S Monitoring Results


MW-45S Monitoring Results

Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic, Total Iron, and Sulfate are plotted on the primary axis in µg/L and pH is the secondary axis.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

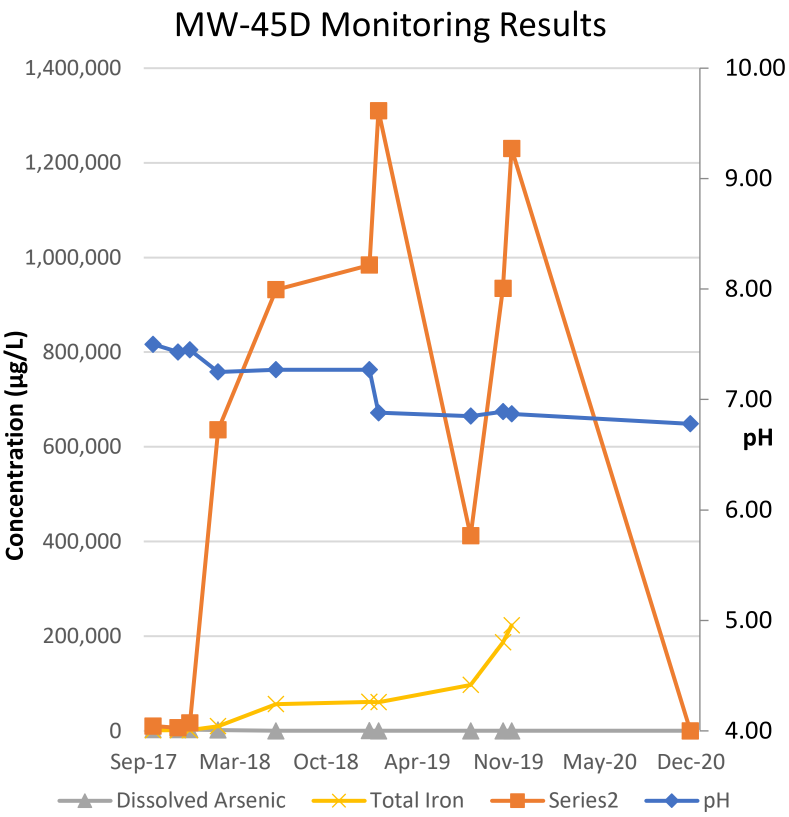
All Treatment Indicators, Select Fill Wells

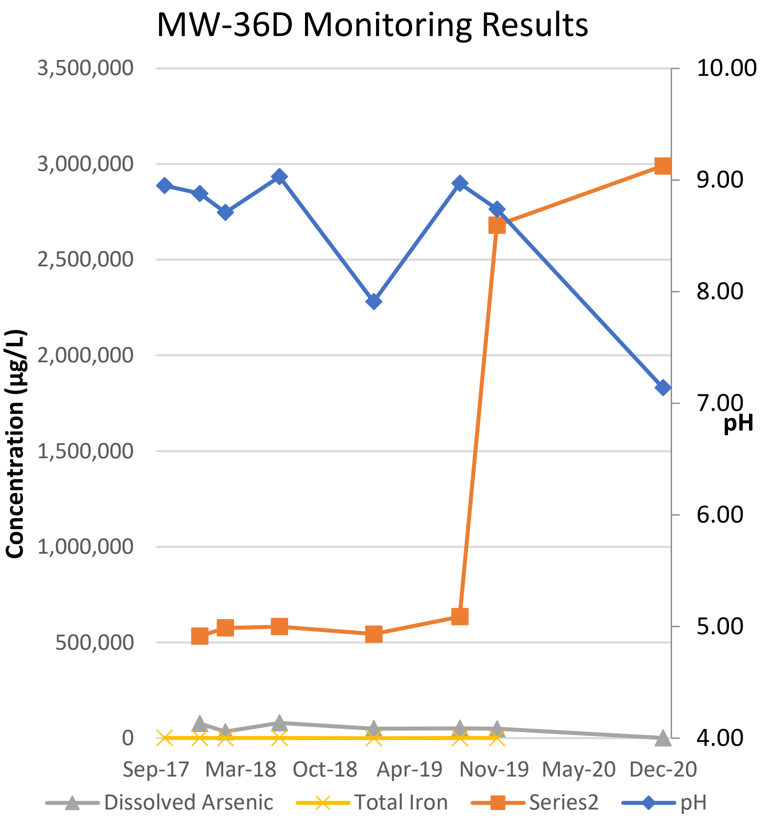
Play Area Interim Action Monitoring Report
Seattle, Washington

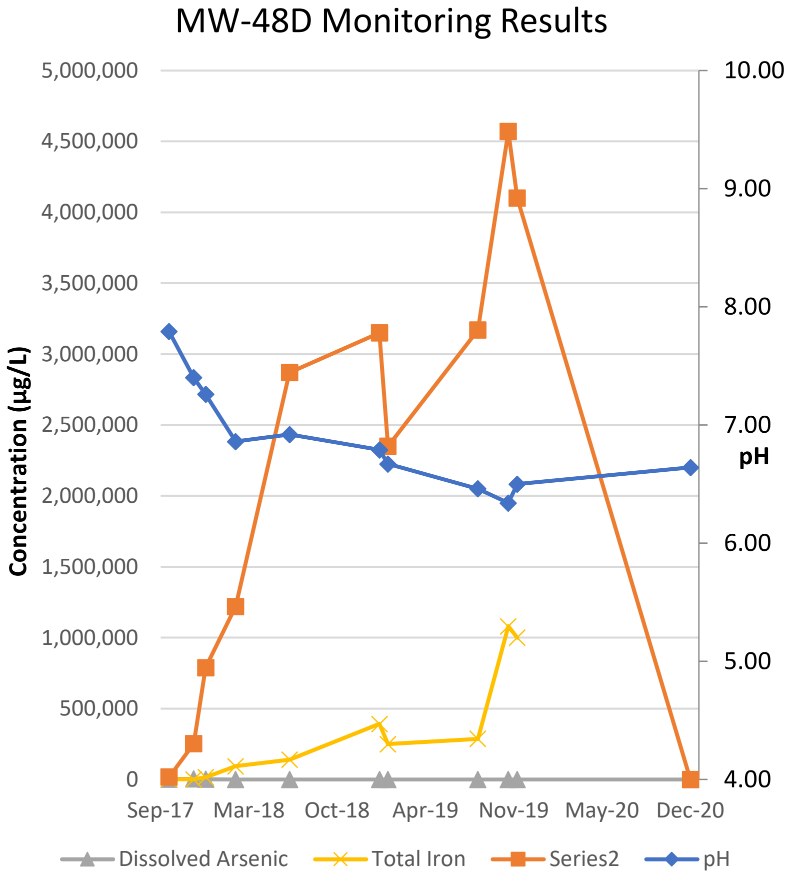
GeoEngineers

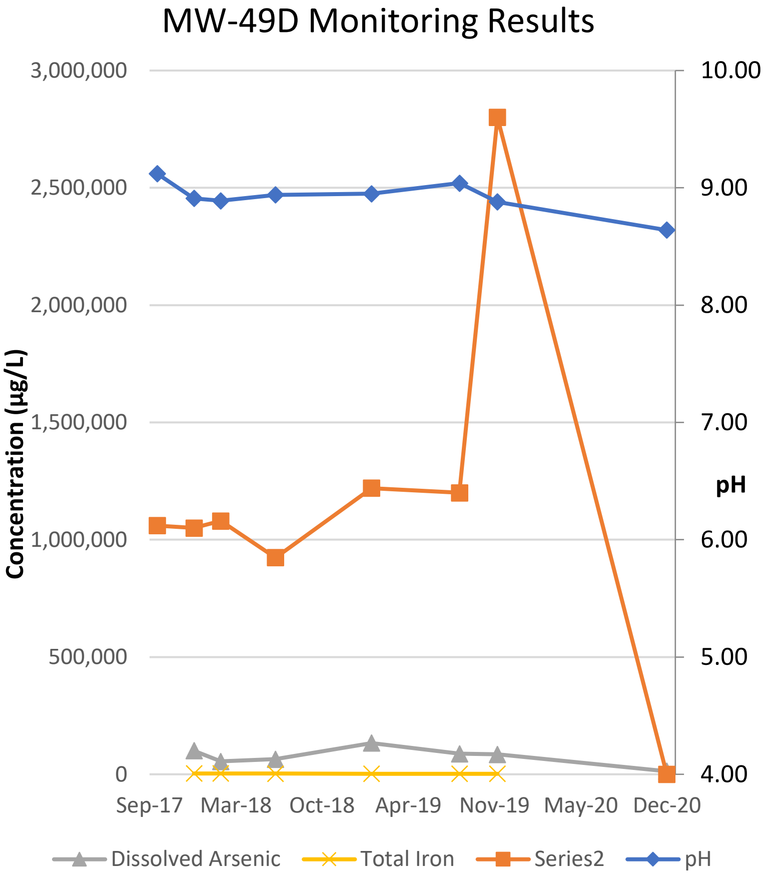
Figure B-10

https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport


MW-45D Monitoring Results


MW-36D Monitoring Results


MW-48D Monitoring Results


MW-49D Monitoring Results

Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic, Total Iron, and Sulfate are plotted on the primary axis in µg/L and pH is the secondary axis.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

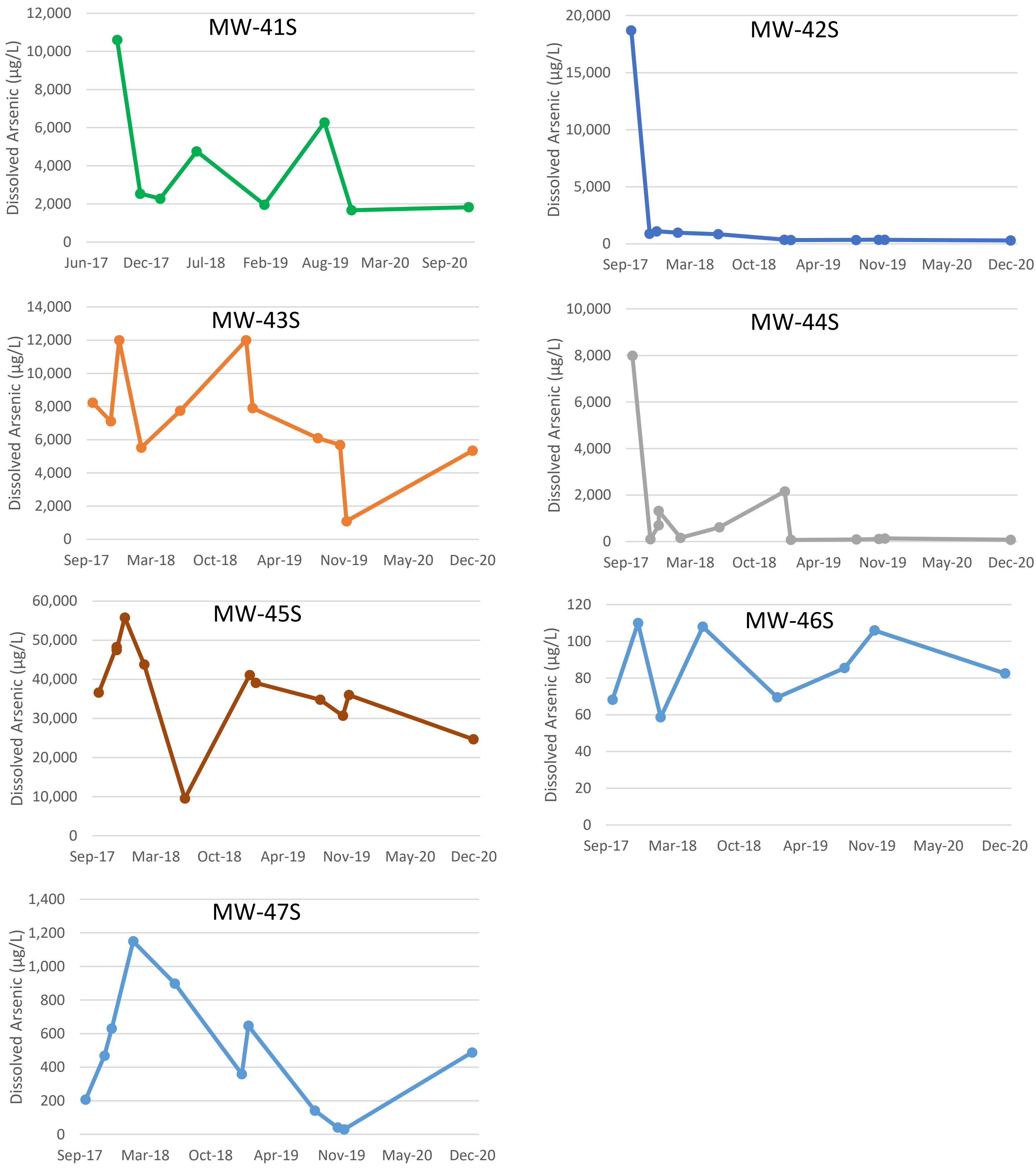
All Treatment Indicators, Select Outwash Wells

Play Area Interim Action Monitoring Report
Seattle, Washington

GeoEngineers

Figure B-11

https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport



Notes:

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is plotted on the primary axis in µg/L.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

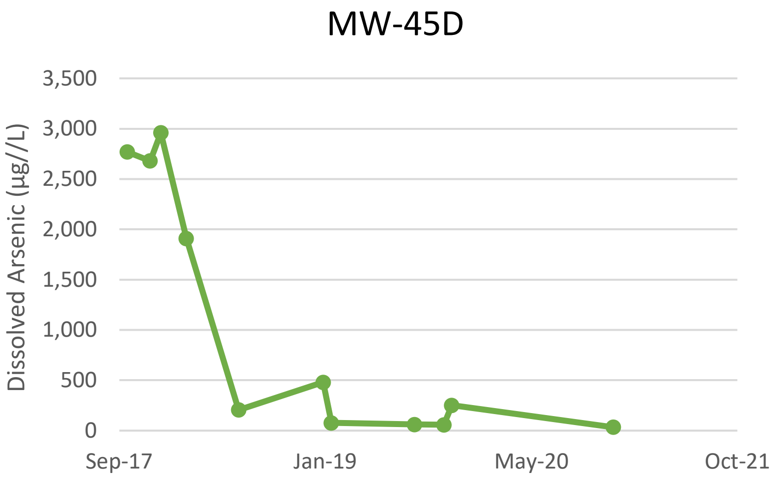
Dissolved Arsenic Concentration Trends – Fill Unit

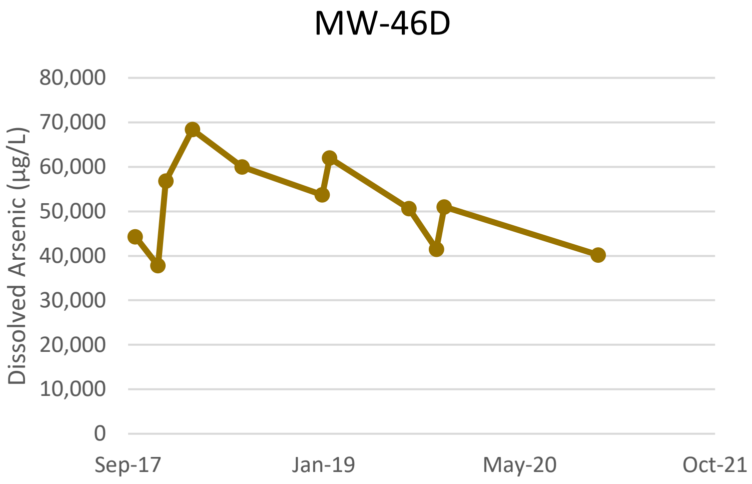
Play Area Interim Action Monitoring Report
Seattle, Washington

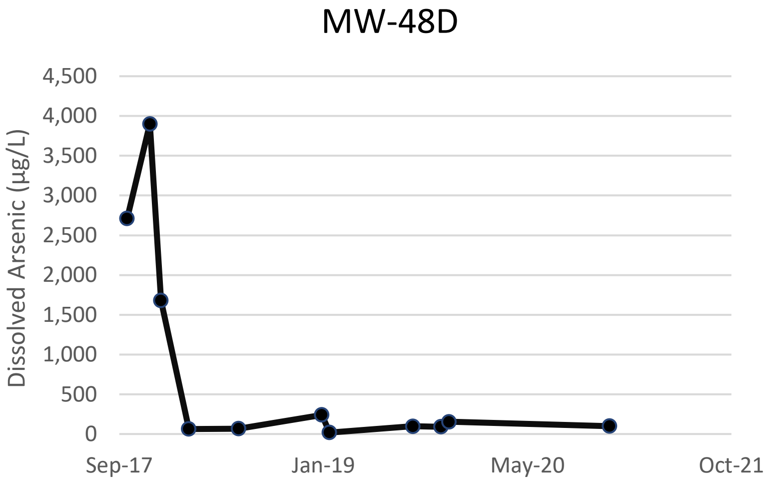
GeoEngineers

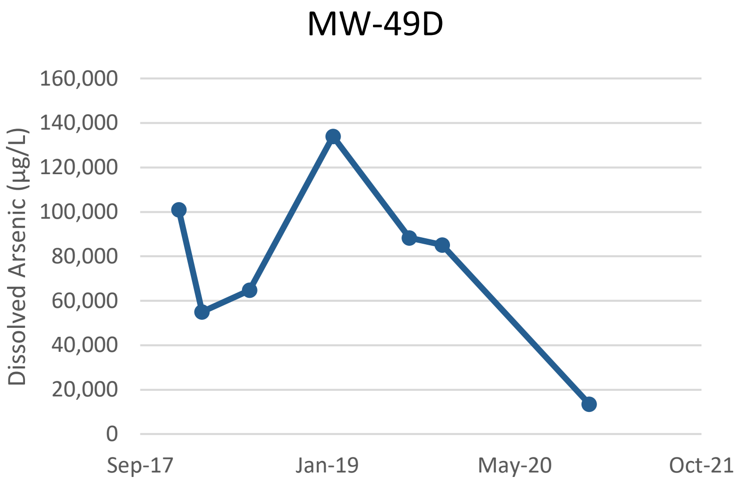
Figure B-12

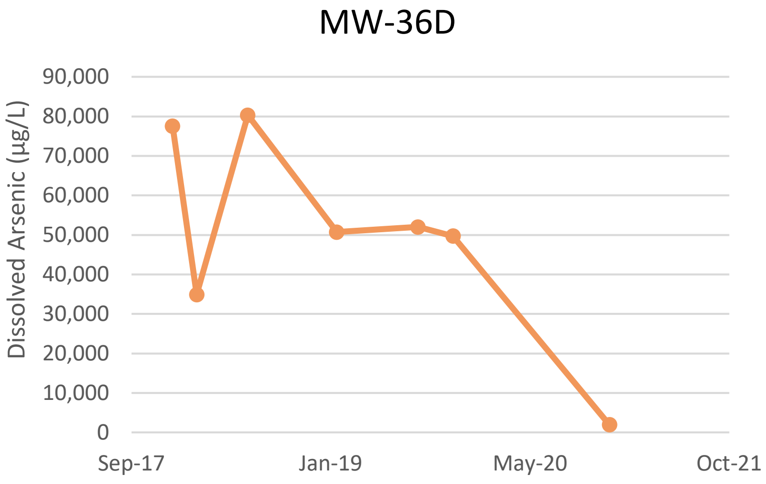
https://projects.geoengineers.com/sites/0018684600/Draft/PlayAreaMonitoringReport











<u>Notes:</u>

1. All Injection Rounds are presented in upper graphs from September 2017 to December 2019. Concentration of Dissolved Arsenic is plotted on the primary axis in µg/L.
2. Groundwater monitoring well data is presented in Table 3 Groundwater Quality Field Parameters in the Play Area Monitoring Report (GeoEngineers, 2021).

Dissolved Arsenic Concentration Trends – Outwash Unit

Play Area Interim Action Monitoring Report
Seattle, Washington

GEOENGINEERS

Figure B-13

APPENDIX C

Laboratory Data Validation Reports

GeoEngineers

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Data Validation Report

Project: PSE North Lake Union – 2017 Play Area Interim Action Baseline Groundwater Monitoring

File: 0186-846-01

Date: January 9, 2018

Lab Report(s): 17I0326, 17I0329, 17I0356, and 17J0443 (Total Arsenic using unpreserved samples)

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action at the Gas Works Park Site, Seattle, Washington. Samples obtained were submitted to Analytical Resources, Incorporated (ARI)[1] of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (Arsenic and Iron) by EPA Methods 200.8 and 6010C
- Sulfate by EPA Method 300.0 and 375.2
- Sulfide by Standard Method 4500-D-0

Analytical data from Sample Delivery Groups (SDGs) 17I0326, 17I0329, 17I0356 were reviewed by GeoEngineers in October 2017. Based on a comparison of the arsenic concentrations between filtered and unfiltered samples from these SDGs[2], arsenic was reanalyzed using unpreserved samples under SDG 17J0443. Results from both preserved and unpreserved samples were processed, validated and presented in this report.

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI Sample Delivery Groups (SDGs) noted above were reviewed for the following quality control (QC) elements:

- Chain of Custody
- Holding Times
- Surrogates

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[1] Additional analyses of groundwater samples (arsenic speciation) were subcontracted by ARI to Brooks Applied Labs. These analyses are not included in this data validation report because they are specialized analyses that are not used for regulatory compliance.

[2] In some cases, the concentration of arsenic in the field filtered sample was greater than the concentration of arsenic in the unfiltered sample. In addition, some filtered samples contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may have influenced the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Monitoring Report.

- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates
- Field Duplicate

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using guidance in two USEPA documents: National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms, as the samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the temperatures were slightly less than 2 degrees Celsius, or the samples were transported immediately to the laboratory from the field and did not have time to chill. Minor transcription errors were found, and the appropriate signatures were applied. No qualifiers were required in either case.

The following transcription errors were found:

SDG 17I0326: The laboratory noted that the container label for Sample MW-51S-170921 was mis-labeled as MW-50S-170921. Also, the time on one of the containers for Sample MW-50D-170920 was listed as 16:00, whereas the COC listed the sampling time as 14:00. No other action was taken other than to note in this report.

SDG 17I0326: The laboratory noted that Sample DUP_Play Area was included in the cooler, but not listed on the COC. No other action was taken other than to note in this report.

Holding Times and Preservation

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

The following preservation discrepancies were found:

SDGs 17I0326, 17I0329, and 17I0356 (EPA 200.8): The total and dissolved arsenic results from these SDGs were found to be incongruous and noticeable amounts of particulates were observed in the field-filtered sample containers upon receipt at the laboratory. The particulates present may be because the sample matrix from this area of the site is likely to include thioarsenates (which are forms of arsenic) and susceptible to precipitation under acid conditions from the nitric acid preservative. All total and dissolved arsenic results from the EPA 200.8 analyses were qualified as estimated (J) in these SDGs.

SDG 17I0326: The sulfide container for Sample MW-42S_170920 was erroneously preserved with NaOH in the laboratory and consequently the laboratory was unable to analyze the sulfide sample by the expected method EPA300.0. Instead, method EPA375.2 was used. The positive results for sulfide were qualified as estimated (J) in this sample.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfide were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, excepted as noted below. If a qualifier was applied due to blank contamination exceeding the reporting limit, the effective reporting limit for that compound was set equal to the concentration of the positive result.

SDG 17I0326 (Metals): There were positive results for both total and dissolved arsenic in the method blanks digested on 9/25/17 and 9/27/17 that were less than the reporting limit. There were also positive results for both total and dissolved iron in the method blank digested on 9/27/17 and 9/28/17 that were less than the contract required quantitation limit. However, there were no positive results that were less than contract required quantitation limit in any samples within the same laboratory prep batch. Also, the positive results for arsenic and iron were greater than ten times the concentration reported in the method blank. No further action was required.

SDG 17I0329 (Metals): There was a positive result for dissolved arsenic in the method blank digested on 9/26/17 that was less than the reporting limit. There were also positive results for both total and dissolved iron in the method blank digested on 9/26/17 that were less than the reporting limits. However, in both cases there were no positive results that were less than reporting limit in any samples within the same laboratory prep batch. Also, the positive results for arsenic and iron were greater than ten times the concentration reported in the method blank. No further action was required.

SDG 17I0356 (Metals): There was a positive result for dissolved arsenic in the method blank digested on 9/27/17 that was less than the reporting limit. There were also positive results for both total and dissolved iron in the method blank digested on 9/27/17 and 9/87/17 that were less than the reporting limits. However, in both cases there were no positive results that were less than reporting limit in any samples within the same laboratory prep batch. Also, the positive results for arsenic and iron were greater than ten times the concentration reported in the method blank. No further action was required.

SDG 17J0443 (Unpreserved Metals): There were no positive results for total arsenic in the method blank digested on 10/30/17. This method blank was used to assess blank contamination for samples taken from unpreserved containers for special analysis.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits, with the exceptions below:

SDG 17I0326 (Conventionals-Sulfide): The laboratory performed a matrix spike on Sample MW-50D_190920. The %R value for sulfide was greater than the control limits in the matrix spike. The primary sample concentration was greater than four times the amount spiked into the sample; therefore, no action was taken.

SDG 17I0356 (Conventionals-Sulfide): The laboratory performed a matrix spike on Sample MW-52D_170925. The %R value for sulfide was greater than the control limits in the matrix spike. The primary sample concentration was greater than four times the amount spiked into the sample; therefore, no action was taken.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met, with the following exceptions:

SDG 17I0326 (Conventionals-Sulfide): The laboratory performed a laboratory duplicate on Sample MW-50D_190920. The RPD value for sulfide was greater than the control limits in the duplicate sample set. The positive result for sulfide was qualified as estimated (J) in Sample MW-50D_170920. This sample was the only sample included in the associated batch

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria, with the exception of total arsenic described below:

SDG 17I0329 (Metals): One field duplicate sample pair, MW-48D_170922/DUP_PLAY AREA, was analyzed with this SDG. The RPD value for total arsenic was greater than the control limits in this duplicate pair. The positive results for total arsenic were qualified as estimated (J) in both samples.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS, laboratory duplicates, and the MS/MSD %R values, with the exceptions noted above. Precision was acceptable, as demonstrated by the laboratory duplicate, field duplicates, LCS/LCSD and MS/MSD RPD and absolute difference values, with the exceptions noted above.

Arsenic data were qualified as estimated because of nitric acid sample preservation and a field duplicate precision outlier. Sulfide analyses were qualified as estimated because of preservation and laboratory duplicate issues. See Table 1 for a summary of qualifiers.

No data points were rejected.

Based on the data quality review, it is our opinion that the analytical data, including data qualified as noted above, are of acceptable quality for their intended use.

TABLE 1

GeoEngineers Sample ID	Analyte	Total/Dissolved	Result	Unit	Qualifier	Reason
MW-42S_170920	Sulfide	T	8.32	mg/l	J	Sample Preservation
MW-50D_170920	Sulfide	T	260	mg/l	J	Laboratory Duplicate
DUP_PLAY AREA	Arsenic	T	1880	ug/l	J	Field Duplicate and Sample Preservation
DUP_PLAY AREA	Arsenic	D	3540	ug/l	J	Sample Preservation
MW-36D_170922	Arsenic	T	40100	ug/l	J	Sample Preservation
MW-36D_170922	Arsenic	D	7730	ug/l	J	Sample Preservation
MW-36S_170921	Arsenic	T	141	ug/l	J	Sample Preservation
MW-36S_170921	Arsenic	D	117	ug/l	J	Sample Preservation
MW-41D_170919	Arsenic	T	52.2	ug/l	J	Sample Preservation
MW-41D_170919	Arsenic	D	61.8	ug/l	J	Sample Preservation
MW-41S_170925	Arsenic	T	8680	ug/l	J	Sample Preservation
MW-41S_170925	Arsenic	D	10600	ug/l	J	Sample Preservation
MW-42S_170920	Arsenic	T	19000	ug/l	J	Sample Preservation
MW-42S_170920	Arsenic	D	18700	ug/l	J	Sample Preservation
MW-43S_170921	Arsenic	T	9510	ug/l	J	Sample Preservation
MW-43S_170921	Arsenic	D	8230	ug/l	J	Sample Preservation
MW-44S_170922	Arsenic	T	20100	ug/l	J	Sample Preservation
MW-44S_170922	Arsenic	D	7990	ug/l	J	Sample Preservation
MW-45D_170922	Arsenic	T	2620	ug/l	J	Sample Preservation
MW-45D_170922	Arsenic	D	2770	ug/l	J	Sample Preservation
MW-45S_170925	Arsenic	T	38800	ug/l	J	Sample Preservation
MW-45S_170925	Arsenic	D	36600	ug/l	J	Sample Preservation
MW-46D_170920	Arsenic	T	42200	ug/l	J	Sample Preservation
MW-46D_170920	Arsenic	D	44300	ug/l	J	Sample Preservation
MW-46S_170921	Arsenic	T	80.1	ug/l	J	Sample Preservation
MW-46S_170921	Arsenic	D	68.3	ug/l	J	Sample Preservation
MW-47S_170919	Arsenic	T	164	ug/l	J	Sample Preservation
MW-47S_170919	Arsenic	D	207	ug/l	J	Sample Preservation
MW-48D_170922	Arsenic	T	2710	ug/l	J	Sample Preservation
MW-48D_170922	Arsenic	D	2710	ug/l	J	Field Duplicate and Sample Preservation
MW-49D_170919	Arsenic	T	26800	ug/l	J	Sample Preservation
MW-49D_170919	Arsenic	D	6150	ug/l	J	Sample Preservation
MW-50D_170920	Arsenic	T	213000	ug/l	J	Sample Preservation

MW-50D_170920	Arsenic	D	82100	ug/l	J	Sample Preservation
MW-51S_170921	Arsenic	T	5.50	ug/l	J	Sample Preservation
MW-51S_170921	Arsenic	D	4.07	ug/l	J	Sample Preservation
MW-52D_170925	Arsenic	T	15600	ug/l	J	Sample Preservation
MW-52D_170925	Arsenic	D	98600	ug/l	J	Sample Preservation

REFERENCES

U.S. Environmental Protection Agency (USEPA). “National Functional Guidelines for Inorganic Superfund Methods Data Review,” OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). “Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use,” EPA-540-R-08-005. January 2009.

Data Validation Report

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Project: PSE North Lake Union – 2017 Play Area Short-Term Sampling (Groundwater)

File: 00186-846-01

Date: January 17, 2018

Lab Report(s): 17K0336 (Total Arsenic using unpreserved container)

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action Short Term Monitoring at the Gas Works Park Site, Seattle, Washington. Samples obtained were submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (Arsenic and Iron) by EPA Methods SW-846 6010C
- Sulfate by EPA Method 300.0

Based on comparison of the arsenic concentrations between filtered and unfiltered samples from the Baseline Groundwater Monitoring Event[1], it was decided that the arsenic samples for the Short-Term Monitoring Event would not be preserved before analysis.

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI Sample Delivery Groups (SDGs) noted above were reviewed for the following quality control (QC) elements:

In some cases, the concentration of arsenic in the field filtered sample was greater than the concentration of arsenic in the unfiltered sample. In addition, some filtered samples contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may have influenced the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Groundwater Monitoring Report.

- Chain of Custody
- Holding Times
- Method Blanks
- Laboratory Control Samples
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Duplicates
- Field Duplicates

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms, as the samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius. No transcription errors were found, and the appropriate signatures were applied. It was noted by the laboratory that some sample bottles in this SDG were received less than half full. No qualifiers were applied for this observation.

Holding Times

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals and sulfate were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, excepted as noted below. If a qualifier was applied due to blank contamination exceeding the reporting limit, the effective reporting limit for that compound was set equal to the concentration of the positive result.

SDG 17K0336 (Metals): There were positive results for both total and dissolved iron in the method blank digested on 11/27/17 that were less than the contract required quantitation limit. However, there were no positive results that were less than contract required quantitation limit in any samples within the same laboratory prep batch. Also, the positive results for iron were greater than ten times the concentration reported in the method blank. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicates

Field duplicate analyses are performed as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria for the field duplicate pair, as described below:

SDG 17K0336 (Metals): One field duplicate sample pair, MW-45S_171117/DUP_171117, was analyzed with this SDG. The precision criteria were met for all target analytes in this duplicate pair.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS, laboratory duplicates, and the MS/MSD %R values. Precision was acceptable, as demonstrated by the laboratory duplicate, field duplicates, LCS/LCSD and MS/MSD RPD and absolute difference values.

No data points were qualified for any reason.

No data points were rejected.

Based on the data quality review, it is our opinion that the analytical data, including data qualified as noted above, are of acceptable quality for their intended use.

REFERENCES

U.S. Environmental Protection Agency (USEPA). "National Functional Guidelines for Inorganic Superfund Methods Data Review," OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). "Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use," EPA-540-R-08-005. January 2009.

GeoEngineers

Data Validation Report

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Project: PSE North Lake Union – 2017 Play Area Interim Action Performance Groundwater Monitoring

File: 0186-846-01

Date: January 18, 2018

Lab Report(s): 17L0188, 17L0238, and 17L0293

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action Performance Monitoring at the Gas Works Park Site, Seattle, Washington. Samples obtained were submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (Arsenic and Iron) by EPA Methods 200.8 and 6010C
- Sulfate by EPA Method 300.0
- Sulfide by Standard Method 4500-D-0

Analytical data from Sample Delivery Groups (SDGs) 17L0188, 17L0238, and 17L0293 were reviewed by GeoEngineers in January 2018. Based on an earlier comparison of the arsenic concentrations between filtered and unfiltered samples from the Baseline Groundwater Monitoring Event, arsenic was analyzed using preserved and unpreserved samples under the SDGs listed above. Results from both preserved and unpreserved samples were processed and validated.

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI Sample Delivery Groups (SDGs) noted above were reviewed for the following quality control (QC) elements:

- Chain of Custody
- Holding Times
- Surrogates
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates
- Field Duplicate

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using USEPA's National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms, as the samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the temperatures were slightly less than 2 degrees or the samples were transported immediately to the laboratory from the field and the samples did not have time to chill. Minor transcription errors were found, and the appropriate signatures were applied. No qualifiers were required in either case.

The following sampling issues and/or transcription errors were found:

SDG 17L0188: The laboratory noted that the COC ID for Sample MW-50D-120717 was erroneously written as MW-49D-120717. It was corrected upon receipt at the laboratory. Also, there were no sample times written on the containers for Samples MW-42S-120817, MW-46S-120717, and MW-49S-120817. All discrepancies were rectified, and no other action was taken other than to note in this report.

SDG 17L0238: The laboratory noted that several of the sample containers were filled halfway. No other action was taken other than to note in this report.

Holding Times (and Preservation)

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

The following preservation discrepancies were found:

SDGs 17L0188, 17L0238, and 17L0293 (arsenic): Analytical results from preserved arsenic samples were qualified as estimated (J) because, some filtered samples collected from these monitoring wells during earlier baseline monitoring contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may influence the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Groundwater Monitoring Report.

SDGs 17L0188 and17L0238 (Sulfides): Because of an instrument failure during the initial analyses for sulfide, the sulfide samples in these SDGs were re-analyzed outside of the holding time of seven days. The positive results for these sulfide results were qualified as estimated (J) in all the samples in this SDG.

See the Miscellaneous section below for details regarding these holding time outliers.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfite were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, excepted as noted below. If a qualifier was applied due to blank contamination exceeding the reporting limit, the effective reporting limit for that compound was set equal to the concentration of the positive result.

SDG 17L0188 (Metals): There was a positive result for dissolved arsenic in the method blank digested on 12/14/17 that was less than the reporting limit. However, the positive results for dissolved arsenic were greater than the reporting limits in all of the samples within the same laboratory prep batch. No further action was required.

SDG 17L0238 (Unpreserved metals): There was a positive result for dissolved arsenic in the method blank digested on 12/22/17 that was less than the reporting limit. However, in this case there were no positive results that were less than reporting limit in any samples within the same laboratory prep batch. Also, the positive results for dissolved arsenic were greater than ten times the concentration reported in the method blank. No further action was required.

SDG 17L0293 (Unpreserved metals): There were positive results for total arsenic and dissolved iron in the method blank digested on 12/21/17 and 1/2/18 that were less than their respective reporting limits. However, in both cases, there were no positive results that were less than the reporting limits in any samples within the same laboratory prep batch. Also, the positive results for total arsenic and dissolved iron were greater than ten times the concentrations reported in the method blank. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits, with the exceptions below:

SDG 17L0188 (Metals): The laboratory performed a matrix spike on Sample MW-46D_120717. The %R value for dissolved arsenic was greater than the control limits in the matrix spike. The primary sample concentration was greater than four times the amount spiked into the sample; therefore, no action was taken.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits, except as noted below.

SDGs 17L0188 and 17L0238 (Sulfide): The %R value was less than the control limit in the LCS prepared on 12/15/17 (Batch ID: BFL0354). The internally associated samples that were representative of this QC batch were not used for reporting because of laboratory instrument failure, and have not been reported (see Miscellaneous section below). As a result, these samples were reanalyzed for sulfide outside of holding times (see Holding Times section above) and qualified as estimated (J). No other action was necessary in response to this outlier. All reportable data are associated with QC samples, including an LCS, that was within the control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met, with the following exceptions:

SDG 17L0188 (Sulfide): The laboratory performed a laboratory duplicate on Sample MW-50D_120717, which was prepared on 12/14/17 and re-prepared 12/20/17. The internally associated samples that were representative of this QC batch were not used for reporting because of laboratory instrument failure (see Miscellaneous section below). No other action was necessary in response to this outlier. All reportable data are associated with QC samples, including a laboratory duplicate that were within the control limits, with the exception of the holding time (see Holding Times section above).

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria, with the exception of total arsenic described below:

SDG 17L0293: One field duplicate sample pair, MW-44S_121317/DUP-121317, was analyzed with this SDG. The precision criteria for total and dissolved arsenic by SW6010 were greater than the control limits in this duplicate pair. The positive results for total and dissolved arsenic by SW6010 were qualified as estimated (J) in both samples.

Miscellaneous

SDG 17L0188, 17L0238, and 17L0293 (Sulfides): The initial associated laboratory batch (prepared from 12/14/17 to 12/20/17) for sulfides were reported with a known instrumental bias of 3 times the actual concentration in each sample. For this reason, the samples were re-prepped and analyzed outside of the holding time of seven days. Both sets of data were reported by the laboratory.

The results for the initial prep batch were labeled as Do-Not-Report (DNR) and should not be used for any purpose. The results for the second batch of data were qualified as estimated (J) because they were analyzed outside of the holding time of seven days.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS, laboratory duplicates, and the MS/MSD %R values, with the exceptions noted above. Precision was acceptable, as demonstrated by the laboratory duplicate, field duplicates, LCS/LCSD and MS/MSD RPD and absolute difference values, with the exceptions noted above.

Sulfide data were qualified as estimated because of samples being analyzed outside of the holding time of seven days. See Table 1 for a summary of qualifiers.

Sulfide data analyzed from 12/14/17 to 12/20/17 were labeled as Do-Not-Report.

Based on the data quality review, it is our opinion that the analytical data, including data qualified as noted above, are of acceptable quality for their intended use.

TABLE 1

GeoEngineers Sample ID	Analyte	Total/Dissolved; (Preservation)	Result	Unit	Qualifier	Reason
MW-42S_120817	Sulfide	T	1.20	mg/l	J	Holding Time
MW-46D_120717	Sulfide	T	31.6	mg/l	J	Holding Time
MW-46S-120717	Sulfide	T	1.63	mg/l	J	Holding Time
MW-47S_120817	Sulfide	T	2.44	mg/l	J	Holding Time
MW-50D_120717	Sulfide	T	92.1	mg/l	J	Holding Time
MW-51S_120817	Sulfide	T	1.11	mg/l	J	Holding Time
MW-52D_120817	Sulfide	T	121	mg/l	J	Holding Time
MW-42S_120817	Sulfide	T	1.63	mg/l	R	Do-Not-Report
MW-46D_120717	Sulfide	T	121	mg/l	R	Do-Not-Report
MW-46D_120717	Sulfide	T	170	mg/l	R	Do-Not-Report
MW-46S-120717	Sulfide	T	3.78	mg/l	R	Do-Not-Report
MW-47S_120817	Sulfide	T	5.88	mg/l	R	Do-Not-Report
MW-50D_120717	Sulfide	T	466	mg/l	R	Do-Not-Report
MW-50D_120717	Sulfide	T	693	mg/l	R	Do-Not-Report
MW-51S_120817	Sulfide	T	2.36	mg/l	R	Do-Not-Report
MW-52D_120817	Sulfide	T	544	mg/l	R	Do-Not-Report
MW-52D_120817	Sulfide	T	424	mg/l	R	Do-Not-Report
MW-41D_121117	Sulfide	T	0.121	mg/l	J	Holding Time
MW-41S_121117	Sulfide	T	0.050	mg/l	J	Holding Time
MW-43S_121217	Sulfide	T	0.241	mg/l	J	Holding Time
MW-45D_121217	Sulfide	T	0.702	mg/l	J	Holding Time
MW-45S_121217	Sulfide	T	65.0	mg/l	J	Holding Time
MW-41D_121117	Sulfide	T	0.226	mg/l	R	Do-Not-Report
MW-41S_121117	Sulfide	T	0.050	mg/l	R	Do-Not-Report
MW-43S_121217	Sulfide	T	0.418	mg/l	R	Do-Not-Report
MW-45D_121217	Sulfide	T	1.28	mg/l	R	Do-Not-Report
MW-45S_121217	Sulfide	T	180	mg/l	R	Do-Not-Report
MW-45S_121217	Sulfide	T	185	mg/l	R	Do-Not-Report
MW-36D-121417	Sulfide	T	84.3	mg/l	J	Holding Time
MW-36S-121317	Sulfide	T	2.35	mg/l	J	Holding Time
MW-44S-121317	Sulfide	T	15.4	mg/l	J	Holding Time
MW-48D-121317	Sulfide	T	0.115	mg/l	J	Holding Time
MW-49D-121417	Sulfide	T	82.9	mg/l	J	Holding Time
DUP-121317	Sulfide	T	15.5	mg/l	J	Holding Time
MW-36D-121417	Sulfide	T	275	mg/l	R	Do-Not-Report
MW-36S-121317	Sulfide	T	7.32	mg/l	R	Do-Not-Report
MW-44S-121317	Sulfide	T	49.3	mg/l	R	Do-Not-Report

MW-48D-121317	Sulfide	T	0.321	mg/l	R	Do-Not-Report
MW-49D-121417	Sulfide	T	260	mg/l	R	Do-Not-Report
DUP-121317	Sulfide	T	49.4	mg/l	R	Do-Not-Report
MW-44S-121317	Arsenic	T; None	7.27	mg/l	J	Field Duplicate
MW-44S-121317	Arsenic	D; None	1.32	mg/l	J	Field Duplicate
DUP-121317	Arsenic	T; None	13.9	mg/l	J	Field Duplicate
DUP-121317	Arsenic	D; None	0.697	mg/l	J	Field Duplicate
MW-36D-121417	Arsenic	D; HNO3	58000	ug/l	J	Sample Preservation
MW-36S-121317	Arsenic	D; HNO3	122	ug/l	J	Sample Preservation
MW-41D_121117	Arsenic	D; HNO3	54.6	ug/l	J	Sample Preservation
MW-41S_121117	Arsenic	D; HNO3	2580	ug/l	J	Sample Preservation
MW-42S_120817	Arsenic	D; HNO3d	977	ug/l	J	Sample Preservation
MW-43S_121217	Arsenic	D; HNO3	14400	ug/l	J	Sample Preservation
MW-44S-121317	Arsenic	D; HNO3	1680	ug/l	J	Field Duplicate and Sample Preservation
DUP-121317	Arsenic	D; HNO3	5450	ug/l	J	Field Duplicate and Sample Preservation
MW-45D_121217	Arsenic	D; HNO3	2460	ug/l	J	Sample Preservation
MW-45S_121217	Arsenic	D; HNO3	34200	ug/l	J	Sample Preservation
MW-46D_120717	Arsenic	D; HNO3	44200	ug/l	J	Sample Preservation
MW-46S-120717	Arsenic	D; HNO3	112	ug/l	J	Sample Preservation
MW-47S_120817	Arsenic	D; HNO3	820	ug/l	J	Sample Preservation
MW-48D-121317	Arsenic	D; HNO3	3300	ug/l	J	Sample Preservation
MW-49D-121417	Arsenic	D; HNO3	79700	ug/l	J	Sample Preservation
MW-50D_120717	Arsenic	D; HNO3	134000	ug/l	J	Sample Preservation
MW-51S_120817	Arsenic	D; HNO3	9.94	ug/l	J	Sample Preservation
MW-52D_120817	Arsenic	D; HNO3	68600	ug/l	J	Sample Preservation

REFERENCES

U.S. Environmental Protection Agency (USEPA). “National Functional Guidelines for Inorganic Superfund Methods Data Review,” OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). “Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use,” EPA-540-R-08-005. January 2009.

GEOENGINEERS

Data Validation Report

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Project:	PSE North Lake Union – Play Area Interim Action Supplemental Performance Groundwater Monitoring
File:	0186-846-01
Date:	March 29, 2018
Lab Report(s):	18B0160, 18B0177, 18B0194, 18B0223, 18B0244, and 18B0272

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action Supplemental Performance Monitoring at the Gas Works Park Site, Seattle, Washington. Samples were collected from February 12 to 19, 2018, and submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (unpreserved arsenic and preserved iron) by EPA Method 6010C
- Sulfate by EPA Method 300.0
- Sulfide by Standard Method 4500-S2 D-00

Analytical data from Sample Delivery Groups (SDGs) 18B0160, 18B0177, 18B0194, 18B0223, 18B0244 and 18B0272 were reviewed by GeoEngineers in March 2018. Based on an earlier comparison of the arsenic concentrations between preserved and unpreserved samples from the baseline groundwater monitoring event, arsenic was analyzed using only the unpreserved samples under the SDGs listed above. In this sampling event, dissolved arsenic results from both lab-filtered and field-filtered samples were processed and validated.

The objective of this data quality assessment is to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI Sample Delivery Groups (SDGs) noted above were reviewed for the following quality control (QC) elements:

- Chain-of-Custody Documentation
- Holding Times
- Surrogate Recoveries
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates

- Field Duplicate

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using USEPA's National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms, as the samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the temperatures were slightly outside of of the 2 to 6 degrees or the samples were transported immediately to the laboratory from the field and the samples did not have time to chill. Minor transcription errors were found, and the appropriate signatures were applied. No qualifiers were required in either case.

The following sampling issues and/or transcription errors were found:

SDG 18B0194: The laboratory noted that the COC ID for samples MW-36D-021318, MW-36S-021418, and MW-49D-021418 were erroneously written as MW-36D-021317, MW-36S-021417, and MW-49D-021417. These errors were corrected upon receipt at the laboratory. All discrepancies were rectified, and no other action was taken other than to note in this report.

SDG 18B0244: The laboratory noted that the container label for sample MW-41S-021618 was left blank. This discrepancy were rectified upon inspection of the error, no other action was taken other than to note in this report.

Holding Times

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfite were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, excepted as noted below. If a qualifier was applied due to blank contamination exceeding the reporting limit, the effective reporting limit for that compound was set equal to the concentration of the positive result.

SDG 18B0160, 18B0177, 18B0194, 18B0223, 18B0244 (Metals): There were positive results for total iron in the method blank digested on 2/13/18 and dissolved arsenic in the method blank digested on 2/20/18 that were both less than the respective reporting limits. However, the positive results for these analytes were greater than the reporting limits in all of the samples within the corresponding laboratory prep batches, with the exception of dissolved arsenic results in samples MW-41D-021618 and MW-51S-021518, which were below the reporting limits. The positive results for dissolved arsenic were qualified as not-detected (U) in these samples. No further action was required for the other batched field samples.

SDG 18B0272 (Metals): There were positive results for total iron in the method blank digested on 2/21/18 and dissolved iron in the method blank digested on 2/26/18 that were both less than the respective reporting limits. However, the positive results for these analytes were greater than the reporting limits in all of the samples within the corresponding laboratory prep batches. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits, with the exceptions below:

SDG 18B0272 (Metals): The laboratory performed a matrix spike on sample MW-48D-021618. The %R value for dissolved iron was less than the control limits in the matrix spike; however, the primary sample concentration was greater than four times the amount spiked into the sample. Because the primary sample concentration was substantially greater than the spike concentration, no further action was taken.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known concentration of an analyte, and then analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria.

SDG 18B0272: One field duplicate sample pair, MW-48D-021618/ DUP, was analyzed with this SDG. The precision criteria for all target analytes were within their respective control limits described above.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS, laboratory duplicates, and the MS/MSD %R values, with the exceptions noted above. Precision was acceptable, as demonstrated by the laboratory duplicate, field duplicates, and LCS/LCSD RPD.Based on the data quality review, it is our opinion that the analytical data, including data qualified as noted above and summarized in Table 1, are of acceptable quality for their intended use.

TABLE 1

GeoEngineers Sample ID	Analyte	Total/Dissolved; (Preservation)	Result	Unit	Qualifier	Reason
MW-41D-021618	Arsenic	D (none)	398	mg/l	U	Method Blank Contamination
MW-51S-021518	Arsenic	D (none)	0.0133	mg/l	U	Method Blank Contamination

REFERENCES

U.S. Environmental Protection Agency (USEPA). "National Functional Guidelines for Inorganic Superfund Methods Data Review," OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). "Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use," EPA-540-R-08-005. January 2009.

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Project:	PSE North Lake Union – 2018 Play Area Interim Action Baseline Groundwater Monitoring
File:	0186-846-01
Date:	July 26, 2018
Lab Report(s):	18F0286, 18F0308, 18F0326, and 18F0350 (Total/Dissolved Arsenic using unpreserved samples)

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action at the Gas Works Park Site, Seattle, Washington. The samples were obtained for the Second Baseline 2018 sampling event and were submitted to Analytical Resources, Incorporated (ARI)[1] of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (Arsenic and Iron) by EPA Method 6010C
- Sulfate by EPA Method 300.0
- Sulfide by Standard Method 4500-D-0

Analytical data from Sample Delivery Groups (SDGs) 18F0286, 18F0308, 18F0326, and 18F0350 were reviewed by GeoEngineers in June 2018. Based on a previous sampling event in 2017, a comparison of the arsenic concentrations between filtered and unfiltered samples was conducted.[2] In this comparison, it was concluded that arsenic sampling procedures should be adjusted to employ the use of an unpreserved bottle or container to transport the sample to the laboratory. Results from unpreserved samples were processed, validated and presented in this report.

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI Sample Delivery Groups (SDGs) noted above were reviewed for the following quality control (QC) elements:

- Chain of Custody

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[1] Additional analyses of groundwater samples (arsenic speciation) were subcontracted by ARI to Brooks Applied Labs. These analyses are not included in this data validation report because they are specialized analyses that are not used for regulatory compliance.

[2] In some cases, the concentration of arsenic in the field filtered sample was greater than the concentration of arsenic in the unfiltered sample. In addition, some filtered samples contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may have influenced the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Groundwater Monitoring Report (2017).

- Holding Times
- Surrogates
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates
- Field Duplicate

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using guidance in two USEPA documents: National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody (COC) forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms, as the samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the temperatures were slightly less than 2 degrees Celsius, or the samples were transported immediately to the laboratory from the field and did not have time to chill. Minor transcription errors were found, and the appropriate signatures were applied. No qualifiers were required in either case.

The following transcription errors were found:

SDG 18F0308: The laboratory noted that the sampling times were missing from the COC. Also, the container label was missing for Sample MW-45D_061918. No other action was taken other than to note in this report.

SDG 18F0326: The laboratory noted that there was no specification on the sample containers regarding what methods were being requested. Also, the ‘No. Containers’ column on the COC was left blank. The project manager was notified of this discrepancy, no other action was taken other than to note in this report.

Holding Times and Preservation

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfide were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, excepted as noted below. If a qualifier was applied due to blank contamination exceeding the reporting limit, the effective reporting limit for that compound was set equal to the concentration of the positive result.

SDG 18F0286, 18F0308 (Metals): There was a positive result for dissolved iron in the method blank digested on 6/26/18 that were less than the reporting limit. However, there were no positive results that were less than the reporting limit in any samples within the same laboratory prep batch. No further action was required.

SDG 18F0326, 18F0350 (Metals): There was a positive result for dissolved iron in the method blank digested on 7/5/18 that were less than the reporting limit. However, there were no positive results that were less than the reporting limit in any samples within the same laboratory prep batch. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits, with the exceptions below:

SDG 18F0326 (Metals): The laboratory performed a matrix spike on Sample MW-43S-062018. The %R value for dissolved iron was less than the control limits in the matrix spike. The positive results for dissolved iron were qualified as estimated (J) in Samples MW-43S-062018, DUP_062018, MW-44S-062018, MW-36S-062018, MW-48D-062018 and MW-49D-062018.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria.

SDG 18F0326 (Metals): One field duplicate sample pair, MW-43S_062018/DUP_062018, was analyzed with this SDG. The precision criteria were met for all analyses.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS, laboratory duplicates, and the MS/MSD %R values, with the exceptions noted above. Precision was acceptable, as demonstrated by the laboratory duplicate, field duplicates, and MS/MSD RPD and absolute difference values.

Data were qualified because of Matrix spike %R values.

No data points were rejected.

Based on the data quality review, it is our opinion that the analytical data, including data qualified as noted above, are of acceptable quality for their intended use.

TABLE 1

GeoEngineers Sample ID	Analyte	Total/Dissolved	Result	Unit	Qualifier	Reason
MW-43S-062018	Iron	Dissolved	24.5	mg/L	J	Matrix spike %R
DUP_062018	Iron	Dissolved	24.0	mg/L	J	Matrix spike %R
MW-44S-062018	Iron	Dissolved	28.3	mg/L	J	Matrix spike %R
MW-36S-062018	Iron	Dissolved	8.63	mg/L	J	Matrix spike %R
MW-48D-062018	Iron	Dissolved	100	mg/L	J	Matrix spike %R
MW-49D-062018	Iron	Dissolved	2.97	mg/L	J	Matrix spike %R

REFERENCES

U.S. Environmental Protection Agency (USEPA). “National Functional Guidelines for Inorganic Superfund Methods Data Review,” OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). “Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use,” EPA-540-R-08-005. January 2009.

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Data Validation Report

Project: PSE North Lake Union – Play Area Interim Action 2019 Short-Term Groundwater Monitoring

File: 00186-846-01

Date: March 18, 2019

Lab Report(s): 19A0142 and 19A0156

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action 2019 Second Short-Term Monitoring at the Gas Works Park Site, located in Seattle, Washington. Samples were collected on January 10th and 11th, 2019, and submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (unpreserved arsenic and preserved iron) by EPA Method 6010C
- Sulfate by EPA Method 300.0

Analytical data from Sample Delivery Groups (SDGs) 19A0142 and 19A0156 were reviewed by GeoEngineers in March 2019. Based on comparison of the arsenic concentrations between filtered and unfiltered samples from the Baseline Groundwater Monitoring Event[1], it was decided that the total and dissolved arsenic samples for the Short-Term Monitoring Event would not be preserved before analysis.

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well-defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI SDGs noted above were reviewed for the following quality control (QC) elements:

- Chain of Custody Documentation
- Holding Times
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates

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[1] In some cases, the concentration of arsenic in the field filtered sample was greater than the concentration of arsenic in the unfiltered sample. In addition, some filtered samples contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may have influenced the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Groundwater Monitoring Report.

- Field Duplicates

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms. The samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius. No transcription errors were found, and the appropriate signatures were applied.

Holding Times

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals and sulfate were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, except as noted below.

SDG 19A0142 (Metals): There was a positive result for total iron in the method blank digested on 1/16/2019 that was less than the contract required quantitation limit. However, there were no positive results for this target analyte less than contract required quantitation limit in any field samples within the same laboratory prep batch. Also, the positive results for total iron in the field samples were greater than ten times the concentration reported in the method blank. No further action was required.

SDG 19A0156 (Metals): There was a positive result for total iron in the method blank digested on 1/22/2019 that was less than the contract required quantitation limit. However, there were no positive results for this target analyte less than contract required quantitation limit in any field samples within the same laboratory prep batch. Also, the positive results for total iron in the field samples were greater than ten times the concentration reported in the method blank. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicates

Field duplicate analyses are performed as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria for the field duplicate pair.

SDG 19A0156 (Metals): One field duplicate sample pair, MW46d_20190111/DUP_20190111, was analyzed with this SDG. The precision criteria were met for all target analytes in this duplicate pair.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS/LCSD and MS/MSD %R values. Precision was acceptable, as demonstrated by the laboratory duplicates, field duplicate, LCS/LCSD, and MS/MSD RPD and absolute difference values.

No data points were qualified for any reason.

No data points were rejected.

Based on the data quality review, it is our opinion that the analytical data are of acceptable quality for their intended use.

REFERENCES

U.S. Environmental Protection Agency (USEPA). “National Functional Guidelines for Inorganic Superfund Methods Data Review,” OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). “Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use,” EPA-540-R-08-005. January 2009.

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Data Validation Report

Project: PSE North Lake Union – Play Area Interim Action 2019 Performance Groundwater Monitoring

File: 0186-846-01

Date: March 18,2019

Lab Report(s): 19A0426, 19A0440, and 19A0460

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action 2019 Second Performance Monitoring at the Gas Works Park Site, located in Seattle, Washington. Samples were collected from January 29th to 31st, 2019, and submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (unpreserved arsenic and preserved iron) by EPA Method 6010C
- Sulfate by EPA Method 300.0
- Sulfide by Standard Method 4500-S2 D-00

Analytical data from Sample Delivery Groups (SDGs) 19A0426, 19A0440, and 19A0460 were reviewed by GeoEngineers in March 2019. Based on an earlier comparison of the arsenic concentrations between preserved and unpreserved samples from the baseline groundwater monitoring event, total and dissolved arsenic were analyzed using only the unpreserved samples under the SDGs listed above.

The objective of this data quality assessment is to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well-defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI SDGs noted above were reviewed for the following quality control (QC) elements:

- Chain-of-Custody Documentation
- Holding Times
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates
- Field Duplicates

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms. The samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the samples were transported immediately to the laboratory from the field and the samples did not have time to chill. No transcription errors were found, and the appropriate signatures were applied.

Holding Times

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfide were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits, with the exceptions below:

SDG 19A0440 (Metals): The laboratory performed an MS/MSD on sample MW36s-20190130. The %R values for total iron were less than the control limits in the MS and MSD; however, the primary sample concentration was greater than four times the amount spiked into the sample. Because the primary sample concentration was substantially greater than the spike concentration, no further action was taken.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known concentration of an analyte, and then analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria.

SDG 19A0426: One field duplicate sample pair, MW51s_20190129/DUP_20190129, was analyzed with this SDG. The precision criteria were met for all target analytes in this duplicate pair.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS and MS/MSD %R values, with the exceptions noted above. Precision was acceptable, as demonstrated by the laboratory duplicates, field duplicate, LCS/LCSD, and MS/MSD RPD and absolute difference values.

No data points were qualified for any reason.

No data points were rejected.

Based on the data quality review, it is our opinion that the analytical data are of acceptable quality for their intended use.

REFERENCES

U.S. Environmental Protection Agency (USEPA). "National Functional Guidelines for Inorganic Superfund Methods Data Review," OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). "Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use," EPA-540-R-08-005. January 2009.

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Data Validation Report

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Project:	PSE North Lake Union – 2019 Play Area Interim Action 3rd Baseline Groundwater Monitoring Event
File:	0186-846-01
Date:	October 25, 2019
Lab Report(s):	19H0290, 19H0320, 19H0345 (Total/Dissolved Arsenic used unpreserved method)

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action at the Gas Works Park Site, Seattle, Washington. The samples were obtained for the Third Baseline 2019 sampling event and were submitted to Analytical Resources, Incorporated (ARI)[1] of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (Arsenic and Iron) by EPA Method 6010C
- Sulfate by EPA Method 300.0
- Sulfide by Standard Method 4500-D-0

Additional analyses of groundwater samples (arsenic speciation) were subcontracted by ARI to Brooks Applied Labs (BAL). These analyses were conducted using a proprietary method (SOP BAL-4100), which incorporates the use of ICP/MS technology with a collision reaction cell (CRC) in a pressurized chamber. This chamber contains a specific reactive gas which reacts preferentially with arsenic, and the laboratory can differentiate between arsenite, arsenate, monomethylarsonic acid and dimethylarsinic acid.

Analytical data from ARI Sample Delivery Groups (SDGs) 19H0290, 19H0320, and 19H0345 were reviewed by GeoEngineers in October 2019, along with the corresponding sub-contracted SDGs from BAL: 1934059, 1934060, and 1934061.

Based on a previous sampling event in 2017, which served as the 1st Baseline event, a comparison of the arsenic concentrations between filtered and unfiltered samples was conducted.[2] In this comparison, it was concluded that arsenic sampling procedures should be adjusted to employ the use of an unpreserved bottle or container to transport the sample to the laboratory. Results from unpreserved samples were processed, validated and presented in this report.

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[1] Additional analyses of groundwater samples (arsenic speciation) were subcontracted by ARI to Brooks Applied Labs. These analyses are included in this data validation report even though they are specialized analyses that are not used for regulatory compliance.

[2] In some cases, the concentration of arsenic in the field filtered sample was greater than the concentration of arsenic in the unfiltered sample. In addition, some filtered samples contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may have influenced the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Groundwater Monitoring Report (2017).

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI Sample Delivery Groups (SDGs) noted above were reviewed for the following quality control (QC) elements:

- Chain of Custody
- Holding Times
- Surrogates
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates
- Field Duplicate

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using guidance in two USEPA documents: National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody (COC) forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms, as the samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the temperatures were slightly less than 2 degrees Celsius, or the samples were transported immediately to the laboratory from the field and did not have time to chill. Minor transcription errors were found, and the appropriate signatures were applied. No qualifiers were required in either case.

The following transcription errors were found:

SDG 19H0320: The laboratory noted that Sample MW-52D_20190821 was incorrectly labeled as MW-48D_20190821 on the sample jar. Also, the Sample DUP_20190821 was not listed on the COC. The project manager was notified of these discrepancies, no other action was taken other than to note in this report.

Holding Times and Preservation

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfide were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, excepted as noted below. If a qualifier was applied due to blank contamination exceeding the reporting limit, the effective reporting limit for that compound was set equal to the concentration of the positive result.

SDG 19H0290 (Metals): There was a positive result for dissolved iron in the method blank digested on 8/21/19 that were less than the reporting limit. However, there were no positive results that were less than the reporting limit in any samples within the same laboratory prep batch. No further action was required.

SDG 19H0345 (Metals): There was a positive result for dissolved iron in the method blank digested on 9/5/19 that were less than the reporting limit. However, there were no positive results that were less than the reporting limit in any samples within the same laboratory prep batch. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits, with the exceptions below:

SDG 19H0345 (Metals): The laboratory performed a matrix spike on Sample MW-48D_20190822. The %R value for Total iron was less than the control limits in the matrix spike. The parent sample concentration for Total iron exceeded 4 times the amount spiked into the sample. For this reason, no qualifiers were applied for this sample.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria.

SDG 19H0320 (Metals): One field duplicate sample pair, MW-46D_20190821/DUP_20190821, was analyzed with this SDG. The RPD for sulfate and sulfide exceeded the control limit or 35%, the results for sulfate and sulfide were qualified as estimated (J) in these samples.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS, laboratory duplicates, and the MS/MSD %R values, with the exceptions noted above. Precision was acceptable, as demonstrated by the laboratory duplicate, field duplicates, and MS/MSD RPD and absolute difference values, with the exceptions noted above.

Data were qualified because of field duplicate precision outliers.

Based on the data quality review, it is our opinion that the analytical data, including data qualified as noted above, are of acceptable quality for their intended use.

TABLE 1

GeoEngineers Sample ID	Analyte	Total/Dissolved	Result	Unit	Qualifier	Reason
MW-46D-20190821	Sulfate	Total	386	mg/L	J	Field Duplicate RPD
MW-46D-20190821	Sulfide	Total	20.7	mg/L	J	Field Duplicate RPD
DUP_20190821	Sulfate	Total	661	mg/L	J	Field Duplicate RPD
DUP_20190821	Sulfide	Total	30.4	mg/L	J	Field Duplicate RPD

REFERENCES

U.S. Environmental Protection Agency (USEPA). "National Functional Guidelines for Inorganic Superfund Methods Data Review," OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). "Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use," EPA-540-R-08-005. January 2009.

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Data Validation Report

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Project:	PSE North Lake Union – 2019 Play Area Interim Action 3rd Short-Term Groundwater Monitoring Event
File:	00186-846-01
Date:	December 5, 2019
Lab Report(s):	19J0488

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action 2019 Third Short-Term Monitoring at the Gas Works Park Site, located in Seattle, Washington. Samples were collected on October 30, 2019, and submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (unpreserved arsenic and preserved iron) by EPA Method 6010C
- Sulfate by EPA Method 300.0

Analytical data from Sample Delivery Group (SDG) 19J0488 were reviewed by GeoEngineers in October 2019. Based on comparison of the arsenic concentrations between filtered and unfiltered samples from the First Baseline Groundwater Monitoring Event[1], it was decided that the total and dissolved arsenic samples for the Short-Term Monitoring Event would not be preserved before analysis.

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well-defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI SDGs noted above were reviewed for the following quality control (QC) elements:

- Chain of Custody Documentation
- Holding Times
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates

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[1] In some cases, the concentration of arsenic in the field filtered sample was greater than the concentration of arsenic in the unfiltered sample. In addition, some filtered samples contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may have influenced the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Groundwater Monitoring Report.

- Field Duplicates

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms. The samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius. No transcription errors were found, and the appropriate signatures were applied.

Holding Times

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals and sulfate were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks, except as noted below.

SDG 19J0488 (Metals): There was a positive result for total iron in the method blank digested on 11/8/2019 that was less than the contract required quantitation limit. However, the positive results for total iron in the field samples were greater than ten times the concentration reported in the method blank. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicates

Field duplicate analyses are performed as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria for the field duplicate pair.

SDG 19J0488 (Metals): One field duplicate sample pair, MW-45S_20191030/DUP_20191030, was analyzed with this SDG. The RPD values for Total iron and Dissolved iron exceeded the control limit of 35%, the results for Total iron and Dissolved iron were qualified as estimated (J) in these samples.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS/LCSD and MS/MSD %R values. Precision was acceptable, as demonstrated by the laboratory duplicates, field duplicate, LCS/LCSD, and MS/MSD RPD and absolute difference values, with the exceptions mentioned above.

Data were qualified because of field duplicate precision outliers.

Based on the data quality review, it is our opinion that the analytical data are of acceptable quality for their intended use.

TABLE 1

GeoEngineers Sample ID	Analyte	Total/Dissolved	Result	Unit	Qualifier	Reason
MW-45S_20191030	Iron	Total	3.19	mg/L	J	Field Duplicate RPD
MW-45S_20191030	Iron	Dissolved	1.69	mg/L	J	Field Duplicate RPD
DUP_20191030	Iron	Total	45.4	mg/L	J	Field Duplicate RPD
DUP_20191030	Iron	Dissolved	2.49	mg/L	J	Field Duplicate RPD

REFERENCES

U.S. Environmental Protection Agency (USEPA). “National Functional Guidelines for Inorganic Superfund Methods Data Review,” OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). “Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use,” EPA-540-R-08-005. January 2009.

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Data Validation Report

Project:	PSE North Lake Union –2019 Play Area Interim Action 3rd Performance Groundwater Monitoring Event
File:	0186-846-01
Date:	December 11,2019
Lab Report(s):	19K0270, 19K0295, and 19K0319

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action 2019 Third Performance Monitoring at the Gas Works Park Site, located in Seattle, Washington. Samples were collected in November of 2019, and submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (unpreserved arsenic and preserved iron) by EPA Method 6010C
- Sulfate by EPA Method 300.0
- Sulfide by Standard Method 4500-S2 D-00

Analytical data from Sample Delivery Groups (SDGs) 19K0270, 19K0295, and 19K0319 were reviewed by GeoEngineers in December 2019. Based on an earlier comparison of the arsenic concentrations between preserved and unpreserved samples from the baseline groundwater monitoring event, total and dissolved arsenic were analyzed using only the unpreserved samples under the SDGs listed above.

The objective of this data quality assessment is to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well-defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI SDGs noted above were reviewed for the following quality control (QC) elements:

- Chain-of-Custody Documentation
- Holding Times
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates
- Field Duplicates

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms. The samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the samples were transported immediately to the laboratory from the field and the samples did not have time to chill. Transcription errors were found on the COC in one case, resulting in no validator qualifiers described below.

SDG 19K0270: Sample DUP_2019118 was originally listed on the COC, however this sample was later crossed off by GeoEngineers project management. No further action was required.

Holding Times

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfide were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. Analytes of interest were not detected in the method blanks.

SDG 19K0270, 19K0295, 19K0319 (Metals): There was a positive result for total iron in the method blank digested on 11/29/19 that was less than the reporting limit. However, there were no positive results for total iron that were less than the reporting limit in any samples within the same laboratory prep batch. No further action was required.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check. For some organic analytical methods, a laboratory control sample/ laboratory control sample duplicate (LCS/LCSD) sample set is performed in lieu of a MS/MSD analysis.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits, with the exceptions below:

SDG 19K0295 (Metals): The laboratory performed an MS/MSD on Sample MW-48d_20191119. The %R values for total iron and sulfate were outside the control limits in the MS and MSD; however, the parent sample concentration was greater than four times the amount spiked into the MS/MSD sample set. Because the parent sample concentration was substantially greater than the spike concentration, no further action was taken.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known concentration of an analyte, and then analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria.

SDG 19K0295: One field duplicate sample pair, MW-46D_20191119/ DUP_20191119, was analyzed with this SDG. The precision criteria were met for all target analytes in this duplicate pair.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS and MS/MSD %R values, with the exceptions noted above. Precision was acceptable, as demonstrated by the laboratory duplicates, field duplicate, LCS/LCSD, and MS/MSD RPD and absolute difference values.

No data points were qualified for any reason.

No data points were rejected.

Based on the data quality review, it is our opinion that the analytical data are of acceptable quality for their intended use.

REFERENCES

U.S. Environmental Protection Agency (USEPA). “National Functional Guidelines for Inorganic Superfund Methods Data Review,” OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). “Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use,” EPA-540-R-08-005. January 2009.

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Data Validation Report

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Project:	PSE North Lake Union – 2020 Play Area Interim Action 2020 Confirmation Monitoring Event
File:	0186-846-01
Date:	January 13, 2021
Lab Report(s):	20L0234, 20L0262, 20L0287 (Total/Dissolved Arsenic used unpreserved method)

This report presents the results of a United States Environmental Protection Agency (USEPA)-defined Stage 2A validation (USEPA Document 540-R-08-005; USEPA, 2009) of analytical data from the analyses of groundwater samples obtained for the Play Area Interim Action at the Gas Works Park Site, Seattle, Washington. The samples were obtained for the 2020 Confirmation Monitoring event and were submitted to Analytical Resources, Incorporated (ARI) of Tukwila, Washington, for chemical analysis by the following methods.

- Total and Dissolved Metals (Arsenic) by EPA Method 6010C

Analytical data from Sample Delivery Groups (SDGs) 20L0234, 20L0262, and 20L0287 were reviewed by GeoEngineers in January of 2021. Based on an earlier comparison of the arsenic concentrations between preserved and unpreserved samples from the original baseline groundwater monitoring event in 2017, total and dissolved arsenic were analyzed using only the unpreserved samples under the SDGs listed above.

Based on a previous sampling event in 2017, which served as the 1st Baseline event, a comparison of the arsenic concentrations between filtered and unfiltered samples was conducted.[12] In this comparison, it was concluded that arsenic sampling procedures should be adjusted to employ the use of an unpreserved bottle or container to transport the sample to the laboratory. Results from unpreserved samples were processed, validated and presented in this report.

The objective of this data quality assessment was to review laboratory analytical procedures and QC results to evaluate whether the samples were analyzed using well-defined and acceptable methods that provide quantitation limits below applicable regulatory criteria, the precision and accuracy of the data are well defined and sufficient to provide defensible data, and the quality assurance/quality control (QA/QC) procedures used by the laboratory meet acceptable industry practices and standards.

The ARI Sample Delivery Groups (SDGs) noted above were reviewed for the following quality control (QC) elements:

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[1] In some cases, the concentration of arsenic in the field filtered sample was greater than the concentration of arsenic in the unfiltered sample. In addition, some filtered samples contained solid material, possibly a precipitate, raising concerns that sample preservation with nitric acid may have influenced the arsenic concentrations in the samples. A detailed description of the filtered and unfiltered sample comparison and conclusions will be presented in the Play Area Interim Action Groundwater Monitoring Report (2017).

- Chain of Custody
- Holding Times
- Surrogates
- Method Blanks
- Matrix Spikes/Matrix Spike Duplicates
- Laboratory Control Samples
- Laboratory Duplicates
- Field Duplicate

DATA QUALITY ASSESSMENT SUMMARY

The results for each of the QC elements are summarized below. The data assessment was performed using guidance in two USEPA documents: National Functional Guidelines for Inorganic Superfund Methods Data Review (USEPA, 2017).

Chain-of-Custody Documentation

Chain-of-custody (COC) forms were provided with the laboratory analytical reports. Any anomalies regarding sample receipt protocols were documented in the sample receipt forms, as the samples were transported to the laboratory at the appropriate temperatures of between 2 and 6 degrees Celsius, except in cases when the temperatures were slightly less than 2 degrees Celsius, or the samples were transported immediately to the laboratory from the field and did not have time to chill. No transcription errors were found in this data package.

The following transcription issue was found:

SDG 20L0287: The laboratory noted that Sample MW-48D_20201216 was not labeled on the sample jar. Instead, the Sample ID was listed on the bag containing the sample jar. The project manager was notified of these discrepancies, no other action was taken other than to note in this report.

Holding Times and Preservation

The holding time is defined as the time that elapses between sample collection and sample analysis. Maximum holding time criteria exist for each analysis to help ensure that the analyte concentrations found at the time of analysis reflect the concentration present at the time of sample collection. Established holding times were met for all analyses. The normal preservation of Nitric Acid was not used in this sampling event, and the laboratory documented that the individual pH of each sample was of the appropriate values.

Surrogate Recoveries (used only for organic analyses)

Only inorganic analyses for metals, sulfate, and sulfide were performed for this sampling event, so surrogates were not used.

Method Blanks

Method blanks are analyzed to make sure that laboratory procedures and reagents do not introduce measurable concentrations of the analytes of interest. Method blanks were analyzed with each batch of samples, at a frequency of one per twenty samples. For all sample batches, method blanks for all applicable methods were analyzed at the required frequency. The target analyte of interest was not detected in the method blanks.

Matrix Spikes/Matrix Spike Duplicates

Because the actual analyte concentration in an environmental sample is not known, the accuracy of an analysis is usually inferred by performing a matrix spike (MS) analysis. One aliquot of sample is analyzed in the normal manner, and then a second aliquot of the sample is spiked with a known concentration of analyte and analyzed. From these analyses, a percent recovery (%R) is calculated. Matrix spike duplicate (MSD) analyses are generally performed for organic analyses as a precision check.

For inorganics methods, the matrix spike (referred to as a “spiked sample”) is typically followed by a post-spike sample if any element recoveries were outside the control limits in the “spiked sample”.

Matrix spike analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for matrix spikes and laboratory control samples are specified in the laboratory documents as are the relative percent difference (RPD) values. The frequency requirements were met for all analyses and the %R/RPD values were within the proper control limits.

Laboratory Control Samples

A laboratory control sample is essentially a blank sample that is spiked with a known amount of analyte concentration and analyzed. It is to be treated much like a matrix spike, without the possibility for matrix interference. As there is no actual sample matrix in the analysis, the analytical expectations for accuracy and precision are usually more rigorous and qualification would apply to all samples in the batch, instead of the primary sample only.

Laboratory control sample analyses should be performed once per analytical batch or every twenty field samples, whichever is more frequent. The recovery criteria for laboratory control samples are specified in the laboratory documents as are the RPD values. The frequency requirements were met for all analyses, and the %R/RPD values were within the proper control limits.

Laboratory Duplicates

Internal laboratory duplicate analyses are performed to monitor the precision of the specific laboratory analyses. Two separate aliquots of a sample are analyzed as distinct samples in the laboratory, and the RPD between the two results is calculated. Duplicate analyses should be performed once per analytical batch. If one or more of the samples used has a concentration greater than five times the reporting limit for that sample, the absolute difference is used instead of the RPD as a measurement of precision.

Laboratory duplicates were analyzed at the proper frequency and the specified acceptance criteria were met.

Field Duplicate

Field duplicate analyses are performed to monitor as a measure of the precision of the sampling process. To do this, two separate field samples are collected from the same monitoring well or boring location in the field and submitted to and analyzed as separate samples in the laboratory. Field duplicate analyses should be performed once per every twenty samples collected at the study site. Field duplicate analyses use different control limits than those used for internal laboratory duplicates, which is an RPD of 35%. However, like the internal laboratory duplicates, the validator distinguishes whether one or more of the samples used has a concentration less than five times the reporting limit for that sample. If so, the absolute difference is used instead of the RPD as a measurement of precision. Field duplicates were analyzed at the proper frequency. Precision criteria for all target analytes were within the criteria.

SDG 20L0234 (Metals): One field duplicate sample pair, MW-46D_20191119/DUP_20191119, was analyzed with this SDG. The RPD for total and dissolved arsenic were within the control limits of 35%. Precision was acceptable for the field duplicates.

OVERALL ASSESSMENT

As was determined by this data validation, the laboratory followed the specified analytical methods. Accuracy was acceptable, as demonstrated by the LCS %R and the MS %R values. Precision was acceptable, as demonstrated by the laboratory duplicates and field duplicates RPD and/or absolute difference values.

No data points were qualified for any reason.

Based on the data quality review, it is our opinion that the analytical data, including data qualified as noted above, are of acceptable quality for their intended use.

REFERENCES

U.S. Environmental Protection Agency (USEPA). “National Functional Guidelines for Inorganic Superfund Methods Data Review,” OLEM 9355.0-135, EPA 540-R-2017-001. January 2017.

U.S. Environmental Protection Agency (USEPA). “Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use,” EPA-540-R-08-005. January 2009.

APPENDIX D
Laboratory Chemical Analysis Data Reports

GeoEngineers