DEPARTMENT OF ECOLOGY
State of Washington

Quality Assurance Project Plan

Aladdin Plating Site
Performance Groundwater Monitoring

November 2022

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Each study conducted by the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

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This plan was prepared by a licensed hydrogeologist. A signed and stamped copy of the report is available upon request.

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Quality Assurance Project Plan

Aladdin Plating Site
Performance Groundwater Monitoring

By Jacob Carnes

November 2022

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Signatures are not available on the Internet version.
EAP: Environmental Assessment Program
TCP: Toxics Cleanup Program
SWRO: Southwest Regional Office

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2.0 Abstract

The Aladdin Plating site is a former commercial electroplating facility in central Tacoma that operated from 1958 to 1994. After closure of the facility, metals associated with electroplating were identified in site soils and groundwater: chromium, lead, and nickel contaminated site soils, and chromium and nickel contaminated shallow groundwater. Pierce County acquired the property in the early 2000s, and the Washington State Department of Ecology (Ecology) managed the property as an orphan site. In 2021, a private party purchased the property from Pierce County. The site is presently vacant.

Remediation activities on the site began in the 2000s. During 2005-2007, buildings were demolished, contaminated soils were removed, and eight monitoring wells were installed on the site property and surrounding area. In 2014, Ecology contracted GeoEngineers to conduct a Remedial Investigation and Feasibility Study (RI/FS) and to develop a Cleanup Action Plan (CAP). In 2018, additional cleanup activities began. Five monitoring wells within the site were decommissioned and additional contaminated soils were removed. Following the 2018 excavation, two more monitoring wells were installed: one to replace a decommissioned well, and one downgradient of the former facility.

In February 2019, GeoEngineers sampled four monitoring wells; the fifth well is difficult to access for a prolonged amount of time due to traffic and parked vehicles. Results from that sampling confirmed nickel concentrations far exceeding established cleanup levels persist in two monitoring wells, one located on the site property and one downgradient.

Ecology will continue to conduct semi-annual groundwater monitoring at the site. The sampling program is designed to collect representative groundwater monitoring data in order to assess concentrations of nickel and chromium. This information will assist Ecology's Toxics Cleanup Program (TCP) in determining (1) the on-going effectiveness of past cleanup activities, and (2) whether additional cleanup actions are needed to protect groundwater quality. Semi-annual sampling will be conducted until contaminant concentrations are consistently below cleanup limits or TCP determines that additional cleanup activities are necessary.

3.0 Background

3.1 Introduction and problem statement

The Aladdin Plating site is a former commercial electroplating facility located at 1657 Center St., Tacoma, WA (Figure 1). Commercial electroplating occurred at the site from 1958 to 1994. Metals associated with electroplating were identified in soil and groundwater at the site. Chromium, lead, and nickel contaminated site soils, and chromium and nickel contaminated shallow groundwater. Pierce County acquired the property through foreclosure in the early 2000s, and Washington State Department of Ecology's (Ecology's) Toxics Cleanup Program (TCP) managed site cleanup activities at the property as an orphan site. The property was purchased from Pierce County by a private party in 2021. The site is presently vacant.

Initial site investigations were performed by Ecology and Landau Associates between 2005 and 2007. In 2014, GeoEngineers conducted a remedial investigation and feasibility study (RI/FS; GeoEngineers, 2014a) and developed a cleanup action plan (CAP; GeoEngineers, 2014b). Contaminated soils were excavated from the site in 2018. In February 2019, GeoEngineers conducted one round of groundwater monitoring. Results from that sampling confirmed nickel concentrations far exceeding established cleanup levels persist in two of the monitoring wells.

Ecology's Environmental Assessment Program will perform semi-annual groundwater sampling to monitor contaminant concentrations at the Aladdin Plating site, and assess the on-going effectiveness of the site cleanup and determine whether any additional cleanup actions are necessary.

3.2 Study area and surroundings

The Aladdin Plating site is located in a commercial and industrial area of Tacoma, approximately 100 feet northeast of the junction of Interstate-5 and State Route-16 (Figure 1). The site occupies a corner parcel at the intersection of Center St. and S. Alaska St. The parcel is approximately 30 feet wide by 100 feet long. The property is located about 240 feet above mean sea level. The site sits to the south of a bluff that rises approximately 80 feet, the rest of the surrounding area to the east, south, and west is relatively flat.

At land surface, the geology in the area immediately surrounding the site is mapped as Steilacoom Gravels, with Advance Outwash composing the hillside immediately north of the site, and Vashon Till mapped across the top of the bluff (Schuster et. al, 2015). Well logs indicate that the subsurface below the site is primarily composed of sand, with gravel and minor silt (GeoEngineers, 2014a). During the RI/FS, GeoEngineers (2014a) determined that groundwater flow direction in the vicinity of Aladdin Plating is to the east-southeast (Figure 2).

The site is within the Puyallup-White Watershed (WRIA 10). The annual precipitation in the watershed ranges from 30 to 40 inches per year. Most of the precipitation falls during the winter months (Ecology, 2020).

Figure 1. Former Aladdin Plating site location.

3.2.1 History of study area

Aladdin Plating conducted commercial electroplating on site between 1958 and 1994. Several toxic chemicals used in the electroplating process were stored on site, including chromium, nickel, lead, caustic soda, sulfuric acid, and alkaline cleaners.

Pierce County acquired the property through a tax foreclosure in the early 2000s. Ecology, through TCP, funded and managed the cleanup activities as an orphan site (Ecology, 2015). In 2021, the property was purchased from Pierce County by a private party. TCP continues to oversee and regulate the site under that Model Toxics Control Act (MTCA).

3.2.2 Summary of previous studies and existing data

Landau Associates

In the summer of 2005, Ecology contracted Landau Associates to demolish buildings on the Aladdin Plating site and to assess the impacts to soil and groundwater. Groundwater was sampled at six locations around the site using a direct push probe, completed at approximate depths of 38 – 40 feet below ground surface (bgs). Chromium concentrations in these samples were screened against MTCA method A cleanup levels. Nickel concentrations were screened against MTCA method B cleanup levels, as there are no method A cleanup levels for nickel. All six of these samples had concentrations of chromium and/or nickel above the applicable MTCA method A or method B cleanup levels. Chromium[1] concentrations were as high as 7,250 µg/L, and hexavalent chromium was detected up to 2,580, µg/L, both far exceeding the respective cleanup level of 50 µg/L and 48 µg/L. Nickel was detected in one sample at 918 µg/L, far exceeding the 320 µg/L cleanup level.

Soil samples were collected from nine test pits to depths from 15 – 17 feet bgs. In two samples, the concentration of several metals, including cadmium, total chromium, copper, lead, and nickel, exceeded the applicable MTCA method A or method B cleanup levels.

After the soil sampling, Ecology oversaw the removal and off-site disposal of 40 tons of contaminated soil and 47 tons of contaminated concrete. There is no available documentation regarding the depth or lateral extent of the excavation.

[1] In this QAPP, all references to chromium analyses are for unspeciated chromium unless hexavalent chromium is specifically mentioned.

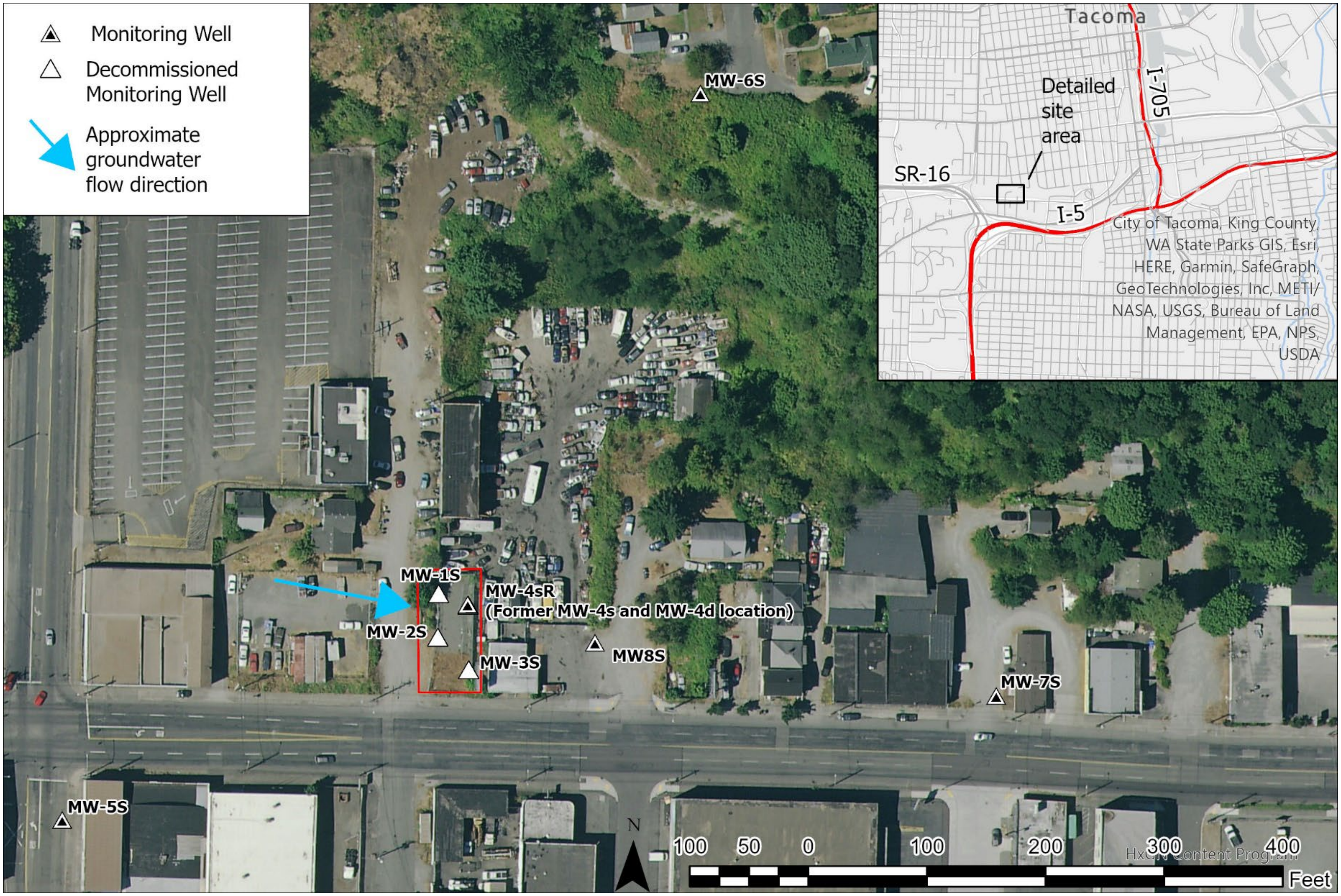

Figure 2. Detailed map of the former Aladdin Plating site.

In November 2005, Landau Associates installed five monitoring wells (MW-1s, MW-2s, MW-3s, MW-4s, MW-4d) on the former Aladdin Plating property (Figure 2). Wells with the suffix "s" were completed in a relatively shallow part of the aquifer. The well with the suffix "d" was completed in a relatively deep part of the aquifer. Groundwater samples collected after the installation of the monitoring wells found nickel present in groundwater in excess of the 320 µg/L cleanup level (Table A1; Landau Associates, 2007).

In June 2006, Landau installed three additional monitoring wells (MW-5s, MW-6s, MW-7s) in the vicinity of the site. Monitoring well MW-5s was installed upgradient of the site, MW-6s was installed approximately crossgradient, and MW-7s was installed downgradient of the site (Figure 2).

Landau Associates sampled all eight monitoring wells three times (July 2006, October 2006, and March 2007). The July 2006 samples were only analyzed for total metals. The October 2006 and March 2007 samples were analyzed for total and dissolved metals. In MW-3s nickel was consistently detected above the 320 µg/L cleanup level from November 2005 through March 2006. In MW-4s and chromium was consistently detected above the 50 µg/L cleanup level and nickel was consistently detected above the 320 µg/L cleanup level from July 2005 through March 2006 (Table A1; Landau Associates, 2007).

GeoEngineers

In March 2014, as part of an RI/FS, GeoEngineers sampled the eight onsite monitoring wells. The results of that sampling showed that nickel, chromium, and hexavalent chromium concentrations continued to exceed relevant cleanup levels in MW-4s.

Following the RI/FS, GeoEngineers developed a cleanup action plan (CAP, GeoEngineers, 2014b). MTCA Method B contaminant cleanup levels were established in the CAP. The cleanup levels are based on published values in the Safe Drinking Water Act and MTCA method B carcinogen and noncarcinogen standard formula values for human health protection obtained from Ecology's Cleanup Levels and Risk Calculation (CLARC) database.

In late 2018, additional remedial action was conducted at the former Aladdin Plating site under the direction of Ecology. Five on-site monitoring wells (MW-1s, MW-2s, MW3s, MW-4s, MW-4d) were decommissioned, contaminated soil within the property boundary was removed to depths ranging from 2.5 feet to 16 feet below ground surface.

Following the excavation two new monitoring wells were installed. MW-4sR was installed at the former location of MW-4s; the "R" in the suffix denotes that this well replaces a previously decommissioned well. MW-8s was installed downgradient of the site (Figure 2; GeoEngineers, 2019). Construction details and links to well logs for the five existing monitoring wells are given in Table 1.

GeoEngineers sampled four of the existing site monitoring wells (MW-4sR, MW-6s, MW-7s, MW-8s) in February 2019. Monitoring well MW-5s is located in a parking zone on a busy street, making prolonged access difficult, and was not sampled. Results from February 2019 sampling indicate that groundwater contamination above the applicable cleanup levels persists. Total and dissolved nickel was detected at concentrations far exceeding the established 320 µg/L cleanup level in two monitoring wells: MW-4sR and MW-8. In MW-4sR, total and dissolved nickel concentrations were 2,600 µg/L and 2,700 µg/L, respectively. In MW-8s, nickel concentrations were 13,000 µg/L in both the total and dissolved fractions. Total chromium was detected in all four sampled wells, and dissolved chromium was detected in MW-4sR and MW-8. Chromium concentrations did not exceed the 50 µg/L cleanup level in any of the sampled wells (Table A1).

Table 1. Well construction details for existing monitoring wells associated with the Former Aladdin Plating site.

Monitoring Well	Well Tag ID	Completion Date	Latitude (decimal degrees)	Longitude (decimal degrees)	Well Depth (ft. bgs)	Screened Interval (ft. bgs)	Ground Surface Elevation[1] (ft.)	TOC Elevation[1] (ft.)	TOC Stickup (ft.)
MW-4sR	BLI209	12/12/2018	47.23418	-122.458	40	24-39	245.43	245.13	-0.40
MW-5s	APP441	6/20/2006	47.23365	-122.459	45	35-45	248.55	248.01	-0.54
MW-6s	APP440	6/20/2006	47.23537	-122.457	153.5	143-153	358.44	358.19	-0.28
MW-7s	APP442	6/20/2006	47.234	-122.456	42	32-42	242.98	242.57	-0.41
MW-8s	BLI208	12/11/2018	47.2341	-122.457	42.5	24-39	243.40	242.96	-0.44

[1]Vertical datum is NVAD88
bgs: Below ground surface
TOC: Top of casing

3.2.3 Parameters of interest and potential sources

The primary contaminants of concern (COCs) in groundwater at the Aladdin Plating site are chromium and nickel.

3.2.4 Regulatory criteria or standards

TCP regulates the Aladdin Plating site under the Model Toxics Cleanup Act (MTCA) (WAC 173-340). Results will be compared to the groundwater cleanup levels established in the CAP (Table 2; GeoEngineers, 2014b). The cleanup levels are based on published values in the Safe Drinking Water Act and MTCA method B carcinogen and noncarcinogen standard formula values for human health protection obtained from Ecology's CLARC database.

Table 2. Cleanup levels for the Aladdin Plating Site.

Parameter	Cleanup Limit (µg/L)
Chromium (Total)	50
Chromium (Dissolved)	50
Nickel (Total)	320
Nickel (Dissolved)	320

4.0 Project Description

The primary cleanup action (CAP) at the former Aladdin Plating site was removal of contaminated soils. The CAP anticipates that the soil removal will result in a gradual reduction of metal concentrations in groundwater (GeoEngineers, 2014b). This monitoring project is being conducted to evaluate the effectiveness of the cleanup actions.

4.1 Project goals

The project goal is to procure groundwater samples and analyze those samples for contaminants of concern that are representative of current concentrations at each sample location. The data produced by this project will document current concentrations of COCs to assist TCP in decision making in the management of the cleanup.

4.2 Project objectives

The project objective is to collect representative groundwater samples semi-annually for analysis of COCs from the four site monitoring wells (MW-4sR, MW-6s, MW-7s, MW-8s).

4.3 Information needed and sources

Groundwater quality data for this project are needed to assess the on-going effectiveness of clean-up activities on the site. Groundwater quality data will be collected from the four monitoring wells for the contaminants of concern discussed in Section 3.2.3. This data will be compared to the cleanup levels established in the CAP (GeoEngineers, 2014b), and to previously collected groundwater quality data from before and after cleanup activities (e.g. Landau Associates, 2007; GeoEngineers, 2019).

4.4 Tasks required

- Measure depth to water in five site monitoring wells (MW-4sR, MW-5s, MW-6s, MW-7s, MW-8s) semi-annually until cleanup levels are met, or TCP determines additional cleanup actions are necessary.
- Sample the four site monitoring wells (MW-4sR, MW-6s, MW-7s, MW-8s) for water quality parameters and contaminants of concern semi-annually.
- Evaluate results for quality assurance (QA) using EAP QA procedures.
- Compare analytical data for contaminants of concern to cleanup levels established in the CAP.
- Enter project data into Ecology's Environmental Information Management database (EIM).
- Prepare a summary report of the results of the above 5 activities, annually.

4.5 Systematic planning process

This QAPP serves as the planning document for the project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 3 shows the responsibilities of those who will be involved in this project.

Table 3. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Andy Smith Toxics Cleanup Program Southwest Regional Office Phone: 360-485-3987	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Jacob Carnes GMU, SCS Phone: 360-688-4413	Project Manager	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Available GMU Staff GMU, SCS	Field Assistant	Helps collect samples and records field information.
Pam Marti GMU, SCS Phone: 360-628-3852	Unit Supervisor for Project Mgr./ Licensed Hydrogeologist	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP. Reviews draft report and final report.
Jessica Archer SCS Phone: 360-890-2721	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Stacy Polkowske WOS Phone: 360-464-0674	Section Manager for the Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Alan Rue MEL Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

[1]All staff except the client are from EAP.
EAP: Environmental Assessment Program
EIM: Environmental Information Management database
GMU: Groundwater Monitoring Unit, EAP
MEL: Manchester Environmental Laboratory, EAP
QAPP: Quality Assurance Project Plan
SCS: Statewide Coordination Section, EAP
WOS: Western Operations Section

5.2 Special training and certifications

A hydrogeologist license is required for the person overseeing hydrogeologic studies (Chapter 18.220.020 RCW). This project is being conducted under the supervision of a licensed hydrogeologist.

All EAP field staff who work on hazardous waste sites are required to complete a 40-hour Hazardous Materials Safety & Health Training and take an annual 8-hour annual hazard recognition refresher training. They are also required to maintain certification in First Aid/CPR.

All field staff should have a detailed working knowledge of the project QAPP and any applicable SOPs to ensure credible and useable data are collected. This includes being familiar with the sample equipment and instruments being used. See Section 8.0.

5.3 Organization chart

See Table 3.

5.4 Proposed project schedule

Tables 4 – 6 list key activities, due dates, and lead staff for this project.

Table 4. Annual schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	Oct/Apr	Jacob Carnes
Laboratory analyses	Nov/May	MEL

Table 5. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded* [1]	Within 90 days of sampling	Jacob Carnes
EIM QA [2]	Within 120 days of sampling	Available GMU staff
EIM complete [3]	Within 150 days of sampling	Jacob Carnes

*EIM Project ID: FS1277
EIM: Environmental Information Management database
[1] All data entered into EIM by the lead person for this task.
[2] Data verified to be entered correctly by a different person; any data entry issues identified. Allow one month.
[3] All data entry issues identified in the previous step are addressed (usually by the original entry person); EIM Data Entry Review Form signed off and submitted to Melissa Peterson (who then enters the "EIM Completed" date into Activity Tracker). Allow one month for this step. Normally the final EIM completion date is no later than the final report publication date.

Table 6. Annual schedule for final report, after each two rounds of sampling.

Task	Annual due date	Lead staff
Draft to supervisor	September	Jacob Carnes
Draft to client/ peer reviewer	October	Jacob Carnes
Final draft to publications team	November	Jacob Carnes
Final report due on web	January	Publications team

5.5 Budget and funding

Tables 7 and 8 summarize the estimated annual costs for this project. Ecology's Manchester Environmental Laboratory (MEL) will perform all analyses shown in Table 8.

Table 7. Annual project budget and funding

Item	Cost ($)
Equipment	200
Travel and other	200
Laboratory (see Table 8 for details.)	1,952
Total Annual Cost	**2,352**

Table 8. Annual laboratory budget details

Parameter	Number of Samples[1]	Number of QA Samples[2]	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Chromium (Total)	12	4	16	31	496
Chromium (Dissolved)	12	4	16	30	480
Nickel (Total)	12	4	16	31	496
Nickel (Dissolved)	12	4	16	30	480
Total Annual Lab Cost					**1,952**

[1] Includes primary samples from monitoring wells, field duplicate samples, and field equipment blanks.
[2] Includes matrix spike and matrix spike duplicate samples.

6.0 Quality Objectives

6.1 Data quality objectives [2]

Data quality objectives (DQOs) establish acceptable quantitative criteria for the quality and quantity of the data to be collected, relative to the ultimate use of the data. DQOs serve as performance or acceptance criteria and represent the overarching quality objectives of the study. The main DQO for this project is to collect groundwater samples for the contaminants of concern that are representative of current concentrations at four site monitoring wells (MW-4sR, MW-6s, MW-7s, MW-8s; Figure 2), semi-annually. Fieldwork to collect samples will be conducted following SOPs EAP052 for depth to water measurements (Marti, 2020), and EAP100 for purging and sampling monitoring wells for metals analysis (Pitz, 2019). Samples will be analyzed using accredited methods (see Appendix C) to obtain data that meet the Measurement Quality Objectives (MQOs) that are described below and that are comparable to previous study results.

6.2 Measurement quality objectives

MQOs are performance or acceptance criteria for individual data quality indicators, including quantitative factors (precision, bias, sensitivity, and completeness) and qualitative factors (comparability and representativeness).

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Tables 9 and 10.

6.2.1.1 Precision

Precision is a measure of the variability between results of replicate measurements that is due to random error. It is usually assessed using duplicate field measurements or laboratory analysis of duplicate samples. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). One duplicate sample will be collected per sampling trip. Duplicate samples will be collected by filling two sets of bottles at the same time from a pre-selected well. The most recently available analytical results from previous sampling will be used to select an appropriate well, based on the highest concentration of contaminants. Precision for field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 10. The smaller the RPD, the more precise the measurement process. Good precision is indicative of relative consistency and comparability between different samples. The targets for precision are based on past performance characteristics of measurements performed by MEL.

[2] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence.

Table 9. Measurement quality objectives for field measurements of water purged prior to sampling

Parameter	Acceptance Criteria[1]	Instrument Sensitivity
Water Level	< 0.3 ft. drawdown	0.01 ft.
Temperature	+/- 0.1 °C	0.01 °C
pH	+/- 0.1 standard unit	0.01 standard unit
Specific Conductivity	+/- 10 µS/cm (<1000 µS/cm) +/- 20 µS/cm (<2000 µS/cm)	0.1 µS/cm
Dissolved Oxygen	+/- 0.2 mg/L (>1 mg/L) +/- 0.05 mg/L (<1 mg/L)	0.01 mg/L
Oxidation Reduction Potential	+/- 10 mV	1 mV
Turbidity	< 10 NTU	0.01 NTU

[1] Acceptance criteria is based on three consecutive readings.

Table 10. Measurement quality objectives (e.g., for laboratory analyses of water samples).

Parameter	Laboratory Duplicate (RPD)	Field Duplicate (RPD)	Matrix Spike (% Recovery)	Matrix Spike Duplicate (RPD)	Blank Spike (% Recovery)	Blank Spike (RPD)	MRL (µg/L)
Chromium (Total)	≤ 20	≤ 20	75-125	≤ 20	85-115	≤ 20	0.200
Chromium (Dissolved)	≤ 20	≤ 20	75-125	≤ 20	85-115	≤ 20	0.100
Nickel (Total)	≤ 20	≤ 20	75-125	≤ 20	85-115	≤ 20	0.100
Nickel (Dissolved)	≤ 20	≤ 20	75-125	≤ 20	85-115	≤ 20	0.100

RPD = Relative percent difference.
MRL = Method reporting limit

6.2.1.2 Bias

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias is usually addressed by calibrating field and laboratory instruments, and by analyzing lab control samples, matrix spikes, and standard reference materials (see Table 10). Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as a detection limit. For this project, the applicable measure of sensitivity is the method reporting limit (MRL). The MRL not only takes into account whether a compound is present, but also accuracy and precision of the measured value. The analytical method for the chromium and nickel (EPA method 200.8) employs MRLs, and an associated method detection limit (MDL), which is the lowest concentration of a compound that can be positively identified. The MRLs for total and dissolved chromium and nickel are listed in Table 10.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Comparability expresses the confidence with which one set of data can be compared to another. Comparability will be ensured to the extent possible by implementing standardized procedures for sampling and analysis. SOPs to be used during this project are listed in Section 8.2. Laboratory analyses will follow the methods described in Section 9.1 (Lab procedures). Laboratory-specific SOPs for the preparation and analysis of samples, data reduction, and data review for each analysis are expected to be followed.

6.2.2.2 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent the actual site conditions. Groundwater samples will be collected semi-annually to account for seasonal variability. Samples are assumed to be representative of site conditions at the time they are collected. Groundwater samples will be collected using industry standard sampling methods, which will help ensure that representative samples are collected.

6.2.2.3 Completeness

Completeness establishes whether a sufficient number of valid measurements were obtained to meet project objectives. The number of samples and results expected establishes the comparative basis for completeness. The completeness goal for this project is to collect and analyze 100% of the measurements and samples. However, problems occasionally arise during sample collection that cannot be controlled; thus, a completeness of 95% is acceptable. Examples of potential problems that may be encountered are low yielding wells or equipment failure.

6.3 Acceptance criteria for quality of existing data

Previous groundwater monitoring results related to this project are limited to those collected by Landau Associates from 2005 to 2007, and GeoEngineers from 2014 - 2019. The data quality criteria used by both of those consulting firms are acceptable for this project.

6.4 Model quality objectives

Not applicable, this project will not involve any modeling.

7.0 Study Design

7.1 Study boundaries

The study boundaries will be defined by the locations of existing site monitoring wells as shown in Figure 2.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Groundwater samples will be collected semi-annually from four site monitoring wells (MW-4sR, MW-6s, MW-7s, MW-8s; Figure 2). Semi-annual sampling will account for seasonal variability.

7.2.2 Field parameters and laboratory analytes to be measured

The parameters to be measured and sampled include:

- Depth to water (Field)
- Temperature (Field)
- pH (Field)
- Specific conductivity (Field)
- Dissolved oxygen (DO) (Field)
- Oxidation/reduction potential (ORP) (Field)
- Turbidity (Field)
- Total Chromium (Laboratory)
- Dissolved Chromium (Laboratory)
- Total Nickel (Laboratory)
- Dissolved Nickel (Laboratory)

7.3 Modeling and analysis design

Not applicable.

7.4 Assumptions underlying design

The study design is based on the following assumptions:

- Sampling of four site monitoring wells will provide information representative of site conditions.
- Sampling on a semi-annual basis will provide information on seasonal variation when comparing results. This assumes that seasonal climate factors that affect sample results are consistent each year (i.e., precipitation, temperature). A related assumption is that precipitation events during or shortly before sampling will not significantly bias results.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Potential logistical problems will likely be unanticipated challenges involving access to site monitoring wells (e.g., car park on a well location). If such a challenge arises, attempts will be made to resolve the limited access (e.g., locating the owner of a vehicle parked over a well to ask that they relocate it).

7.5.2 Practical constraints

Practical constraints to groundwater sampling are typically determined by characteristics of the site's geology or monitoring well construction. Previous work at the site, including well logs and monitoring reports, indicate that the wells are completed in sandy, transmissive units, and that the monitoring wells are quick to recover.

Any practical constraints encountered will be discussed in the final report.

7.5.3 Schedule limitations

Changes in project prioritization and workload for EAP staff could affect the project schedule. Factors that can cause delays to the proposed project schedule include:

- Time required for QAPP review and approval.
- Unforeseen field or laboratory complications (e.g., inability to collect samples from selected wells, problems with laboratory analytical equipment).

Any unforeseen limitations which affect the project schedule will be discussed with the client and appropriate supervisor as needed and discussed in the final report.

8.0 Field Procedures

8.1 Invasive species evaluation

Does not apply to this type of study.

8.2 Measurement and sampling procedures

Groundwater measurements and sampling activities for this study will follow SOPs developed by EAP. These include the following SOPs:

- EAP052 for depth to water measurements (Marti, 2020)
- EAP100 for purging and sampling monitoring wells for metals analysis (Pitz, 2019)

Field measurements will be made at all sampling sites and recorded on waterproof field datasheets at regular intervals.

Staff will measure static water levels in all the monitoring wells upon arriving at the site. Staff will also measure water levels before and during the purging process to ensure the wells are not being over-pumped. For optimal sampling, the drawdown should not exceed 0.3 ft. Measurements will be collected according to SOP EAP052 (Marti, 2020).

To prevent potential cross-contamination of the sample equipment, the wells will be sampled in order of the lowest concentration of contaminants to the highest. Sample order will be based on previous sample results and professional judgment.

The depth to water in at least one of the monitoring wells is expected to exceed the maximum depth of a peristaltic pump (~27 feet). Due to this, the monitoring wells will be sampled using a stainless-steel bladder pump, with new polyethylene bladders used at each well. Wells will be purged at a rate of < 0.3-liter/minute. Dedicated Teflon-lined polyethylene tubing will be used at each well.

The wells will be purged through a continuous flow cell until field parameters stabilize (pH, temperature, specific conductance, dissolved oxygen, and oxidation reduction potential) as specified in SOP EAP078 (Marti, 2020). A Hydrolab MS5 multiparameter sonde, or equivalent, will be used to measure these field parameters. A Hach 2100Q turbidity meter will be used to measure turbidity.

Should any water levels drop more than the accepted criteria as specified in SOP EAP078 (Marti, 2020), they will be allowed to recharge with native formation water to complete the purging process before sampling. If it appears that a well may purge dry, then it will be determined in the field what actions will be taken. Either the well will be allowed to recharge and equilibrate before sampling or samples will be collected with minimal purging. Any deviations from the sample plan will be discussed in the final report.

Samples will be collected from the monitoring wells directly from the pump discharge line after the well is fully purged. The sample container for total chromium and total nickel will be filled first. A clean in-line 0.45 µm filter will then be fitted to the sample tubing, then the sample container for dissolved chromium and dissolved nickel will be filled. Field blanks will be used to detect potential sample contamination from the pump or filters. Samples will be stored on ice while being transferred to MEL using standard chain-of-custody procedures.

8.3 Containers, preservation methods, holding times

Table 11 summarized sample container and holding time requirements.

Table 11. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
Total Chromium and Nickel	Water	350 mL	500 mL HDPE bottle	Pre-acidified with 1:1 HNO_3 Cool to ≤6°C	6 Months
Dissolved Chromium and Nickel	Water, Filtered	350 mL	500 mL HDPE bottle	Pre-acidified with 1:1 HNO_3 Cool to ≤6°C	6 Months

8.4 Equipment decontamination

The bladder pump will be disassembled and decontaminated after each monitoring wells. The decontamination procedure will include washing the pump parts in with a liquinox solution and soft-bristled brushes, then rinsing with DI water.

8.5 Sample ID

MEL will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with a field ID number that is given by the field lead. This combination of work order number and field ID number constitute the sample ID. All sample IDs will be recorded in field logs and in an electronic spreadsheet for tracking purposes.

8.6 Chain of custody

Chain-of-custody procedures will be followed according to MEL protocol (Ecology, 2016). Once collected, samples will be properly labeled and stored in an ice-filled cooler inside the sampling vehicle. If the sample vehicle is left unattended, it will be locked to maintain chain-of custody. Samples will be transported to Ecology's Operation Center in Lacey, Washington. Samples will be kept in a secure walk-in cooler until picked up by the laboratory courier and transported to the MEL in Manchester, Washington.

8.7 Field log requirements

A field log is an important component of many projects. It is used to record irreplaceable information, such as:

- Name and location of project
- Field personnel
- Sequence of events

- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results
- Identity of QC samples collected
- Unusual circumstances that might affect interpretation of results

Field logs will consist of waterproof 8.5 x 11-inch field sheets pre-printed for ease of recording and kept in an enclosed metal clipboard. Permanent, waterproof ink or pencil will be used for all entries. Corrections will be made with single line strikethroughs, initialed and dated.

8.8 Other activities

Field staff new to the type of sampling conducted for this study will be trained by senior field staff or the project manager following relevant Ecology SOPs and the site safety worksheet.

The field lead will notify MEL of the schedule for sampling events at least 3 weeks before sampling. The lab will be notified immediately if there will be any deviations from the scheduled date of sampling. The field lead will work with the lab to develop a schedule for delivery of sampling containers in order to ensure that the appropriate number and type of required sample containers are available. If a sample is damaged during transit or testing, a new sample may be collected and submitted for analysis. The lab should notify the project lead as soon as possible when a sample is unsuitable.

Purge water from the wells will be stored on-site in properly labeled 55-gallon drums. This waste will be transported and disposed of in accordance with State of Washington regulations (Chapter 173-340-400 WAC).

9.0 Laboratory Procedures

9.1 Lab procedures table

Analytes for this project, along with the expected number of samples and an expected range of results are listed in Table 12.

Table 12. Laboratory measurement methods.

Analyte	Sample Matrix	Samples (Number/ Interval)	Expected Range of Results (µg/L)	MRL (µg/L)	Analytical (Instrumental) Method
Chromium (Total)	Water	8/semi-annually	<0.200-1,000	0.200	EPA 200.8 (Creed et al., 1994)
Chromium (Dissolved)	Water	8/semi-annually	<0.100-1,000	0.100	EPA 200.8 (Creed et al., 1994)
Nickel (Total)	Water	8/semi-annually	<0.100-43,000	0.100	EPA 200.8 (Creed et al., 1994)
Nickel (Dissolved)	Water	8/semi-annually	<0.100-43,000	0.100	EPA 200.8 (Creed et al., 1994)

MRL = Method reporting limit

9.2 Sample preparation method(s)

The laboratory will follow standard sample preparation procedures for analytical methods listed in Table 12.

9.3 Special method requirements

There are no special method requirements for this project.

9.4 Laboratories accredited for methods

MEL is accredited to perform the analyses listed in Table 12.

10.0 Quality Control Procedures

Quality control (QC) procedures provide the information needed to assess the quality of the collected data. They can also help identify problems or issues associated with data collection and analysis while the project is underway.

Total precision for field sampling and laboratory analysis will be assessed by collecting replicate samples. MEL routinely duplicates sample analyses in the laboratory to determine laboratory precision. The difference between the variability in field duplicates and the variability in laboratory duplicates is an estimate of the field variability. Field blanks, such as an equipment blank and a filter blank, will be used to check for sample contamination.

The primary types of QC samples used to evaluate and control the accuracy of lab analyses are check standards, duplicates, spikes, and blanks (Ecology, 2016). Check standards serve as an independent check on the calibration of the analytical system and can be used to evaluate bias. Duplicates are used to evaluate laboratory precision. Matrix spikes are used to check for matrix interference with detection of the analyte and also can be used to evaluate bias as it relates to matrix effects. Blanks are used to check for sample contamination in the laboratory process.

10.1 Table of field and laboratory quality control

Table 13 presents the type and frequency of QC samples to be collected.

Table 13. Quality control samples, types, and frequency.

Parameter	Field Blanks	Field Replicates	Laboratory Check Standards	Laboratory Method Blanks	Matrix Spike/Matrix Spike Duplicate
Chromium (Total)	1	1/10 samples	1/batch	1/batch	1 pair/batch
Chromium (Dissolved)	1	1/10 samples	1/batch	1/batch	1 pair/batch
Nickel (Total)	1	1/10 samples	1/batch	1/batch	1 pair/batch
Nickel (Dissolved)	1	1/10 samples	1/batch	1/batch	1 pair/batch

10.2 Corrective action processes

Corrective actions will be taken if activities are found to be inconsistent with the QAPP, field procedures, laboratory analyses, data review processes, MQOs or performance expectations, or if some other unforeseen problem arises. Such actions may include:

- Re-calibrating the analytical instrument.
- Collecting new samples using the method described in the approved QAPP.
- Accepting and qualifying lab results that do not meet all QC criteria.
- Reanalyzing lab samples that do not meet QC criteria.
- Convening project personnel and technical experts to decide on the next steps that need to be taken to improve performance of project components.

11.0 Data Management Procedures

As field and lab data are completed, data will be organized using various tabular and graphical formats for additional review, calculations, characterization, and reporting.

11.1 Data recording and reporting requirements

All field data will be recorded in a field notebook/data sheets. Field notes will be checked for missing or improbable measurements before leaving each site. Field-generated data will be quality assured and entered into EIM as soon as practical after returning from the field. Data entry will be checked against the field notes for any errors and omissions. Missing or unusual data will be brought to the attention of the project manager and client for consultation.

Lab results will be checked for missing and/or improbable data. Data received from MEL through Ecology's Laboratory Information Management System (LIMS) will be checked for omissions against the Request for Analysis forms by the field lead. Data requiring additional qualifiers will be reviewed by the project manager.

The Environmental Information System (EIM) Study ID for this project is FS1277-PerfMonGW.

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Users' Manual (Ecology, 2016). Variability in lab duplicates will be quantified using the procedures outlined in the MEL Users' Manual. Any estimated results will be qualified and their use restricted as appropriate. MEL will send a standard case narrative of laboratory QA/QC results to the project manager for each set of samples.

Laboratory results from MEL analyses will be sent to the Project Manager in pdf format (from LIMS) and be accompanied by a Case Narrative. The Case Narrative will address various data verification checks described in Section 13 below.

11.3 Electronic transfer requirements

Laboratory data generated by MEL will be entered into the Laboratory Information Management System (LIMS) by MEL staff. When notified of the availability of data, project staff can then access data through EIM loader.

11.4 EIM/STORET data upload procedures

Data will be loaded into Ecology's Environmental Information Management (EIM) database following EIM guidance. Data from the field and MEL will be entered into an EIM upload template. After entering laboratory data into EIM, the project manager will manually check 10% of the entered data for correctness, following EIM Data Review Procedures.

11.5 Model information management

Not applicable, this project will not involve any modeling.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Field audits are always appropriate for a project involving either field measurements or sampling. It is likely that insufficient QA resources are currently available for auditing activities; however, there could be a field consistency review of the project by another experienced EAP hydrogeologist. The aim of such reviews is to improve field-work consistency, improve adherence to SOPs, provide a forum for sharing innovations, and strengthen our data quality assurance program.

12.2 Responsible personnel

See Section 12.1.

12.3 Frequency and distribution of reports

A summary report of sample results will be published annually according to the project schedule shown in Section 5.4. Interim results will be communicated to the project client and TCP staff as they become available.

12.4 Responsibility for reports

The EAP project manager will be the lead on the final technical report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Initial field data verification will be performed by the project manager immediately after completing field measurements/sample collection and prior to departing the site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

After the sampling event, the project manager will compare all field data to determine compliance with MQOs. Values that are out of compliance with the MQOs will be noted. At the conclusion of the study, all out-of-compliance values (if any) will be compiled and assessed for usability by the project lead.

13.2 Laboratory data verification

MEL staff will perform the laboratory verification following standard laboratory practices. After the laboratory verification, a secondary verification of each data package will be performed by the project manager. This secondary verification will entail a detailed review of all parts of the laboratory data package with special attention being paid to laboratory QC results. If any issues are discovered, they will be resolved by the project manager.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

After all laboratory and field data are verified, a detailed examination of the data package using statistics and professional judgment will be performed. The project manager will examine the entire data package to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected based upon the decision criteria from the QAPP. The project manager and client will decide how any qualified data will be used in the technical analysis.

14.2 Treatment of non-detects

Any non-detects will be loaded into EIM and included in the study analysis. Analytical results that are below the MRL will be flagged with the appropriate data qualifier (e.g. U, J, UJ). For summary statistics and analysis, non-detects will be treated in the method described in MTCA [WAC 173-340-709(5)].

14.3 Data analysis and presentation methods

Once the data have been reviewed, verified, and validated, the project manager will determine if the data can be used toward the project goals and objectives. Verified analytical data will be shared with the client in a technical report.

The final technical report will be prepared at the completion of the sampling and will include the following:

- Maps of the study area showing sample sites, contaminant concentrations and distribution
- Description of field and laboratory methods
- Discussion of data quality and the significance of any problems encountered
- Summary tables of field and analytical data
- Discussion of water quality results and comparison of results to site's historical data if available
- Conclusions and recommendations

14.4 Sampling design evaluation

The project manager will decide whether the data package meets the MQOs, criteria for completeness, representativeness, and comparability, and whether meaningful conclusions can be drawn from the data. If so, the sampling design will be considered effective.

14.5 Documentation of assessment

The project manager will include a section in the final technical report summarizing the findings of the data quality assessment.

15.0 References

Creed, J.T., C.A. Brockhoff, and T.D. Martin, 1994. Determination of Trace Elements in Water and Wastes by Inductively Coupled Plasma – Mass Spectrometry, Revision 5.4. Environmental Monitoring Systems Laboratory, Office of Research and Development, United States Environmental Protection Agency. Cincinnati, OH. https://www.epa.gov/sites/production/files/2015-08/documents/method_200-8_rev_5-4_1994.pdf.

Ecology, 2015. Fact Sheet for Aladdin Plating Remedial Investigation and Feasibility Study and Cleanup Action Plan. Washington State Department of Ecology, Toxics Cleanup Program publication 15-09-104. Olympia, WA.

Ecology, 2020. Focus on: WRIA 10 Puyallup-White Watershed Water Availability. Water Resources Program, Washington State Department of Ecology, Olympia. https://apps.ecology.wa.gov/publications/SummaryPages/2011010.html

GeoEngineers, 2014a. Remedial Investigation/Feasibility Study Report: Former Aladdin Plating site, 1657 Center St. Tacoma Washington. https://apps.ecology.wa.gov/gsp/DocViewer.ashx?did=46335

GeoEngineers, 2014b. Cleanup Action Plan: Former Aladdin Plating site, 1657 Center St. Tacoma Washington. https://apps.ecology.wa.gov/gsp/DocViewer.ashx?did=48148

GeoEngineers, 2019. Aladdin Plating Groundwater Monitoring Event – February 2019. Former Aladdin Plating site, 1657 Center St. Tacoma Washington. https://apps.ecology.wa.gov/gsp/DocViewer.ashx?did=82251

Landau Associates, 2007. Groundwater Monitoring Report, Fall 2006 through Spring 2007, Former Aladdin Plating Facility, Tacoma, Washington. July 31, 2007.

Marti, P., 2020. Standard Operating Procedure EAP052, Version 1.2: Standard Operating Procedure for Manual Well-Depth and Depth-to-Water Measurements. Washington State Department of Ecology, Environmental Assessment Program, SOP EAP052, Version 1.2. https://apps.ecology.wa.gov/publications/SummaryPages/1803215.html

MEL, 2016. Manchester Environmental Laboratory *Lab Users' Manual*, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Pitz, C., 2019. Standard Operating Procedure EAP100, Version 1.1: Collecting Groundwater Samples for Metals Analysis from Monitoring Wells. Washington State Department of Ecology, Environmental Assessment Program, SOP EAP100, Version 1.1.

Schuster, J.E., A.A. Cabibbo, J.F. Schilter, and I.J. Hubert, 2015. Geologic Map of the 1:100,000-scale Quadrangle, Washington. Washington Division of Geology and Earth Resources MS-47007. Olympia, WA.

WAC 173-340. Model Toxics Control Act-Cleanup. Washington State Department of Ecology, Olympia, WA. http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340.

16.0 Appendices

Appendix A. Existing Data.

Table A1. Previous sampling results (µg/L) from Aladdin Plating monitoring wells.

Well	Analyte	CUL	Nov. 2005[1]	July 2006[1]	Oct. 2006[1]	Mar. 2006[1]	Mar. 2014[2]	Feb. 2019[3]
MW-1s	Chromium (Total)	50	--	**5.61**	**4.8**	**3.3**	<5	--
	Nickel (Total)	320	--	**6.59**	**6.34**	**3.91**	<0.01	--
	Hexavalent Chromium (Total)	48	--	<11	<11	<11	<10	--
	Chromium (Dissolved)	50	--	--	**4.87**	**2.1**	--	--
	Nickel (Dissolved)	320	--	--	**3.69**	**2.41**	<10	--
	Hexavalent Chromium (Dissolved)	48	--	--	<11	<11	--	--
MW-2s	Chromium (Total)	50	**29.3**	**25.4**	**9.8**	**62.8**	<5	--
	Nickel (Total)	320	**5.74**	**11.1**	**9.43**	**12.3**	<0.01	--
	Hexavalent Chromium (Total)	48	**28**	**12**	**26**	**13**	<10	--
	Chromium (Dissolved)	50	--	--	**4.95**	**44.2**	--	--
	Nickel (Dissolved)	320	--	--	**3.07**	**4.15**	<10	--
	Hexavalent Chromium (Dissolved)	48	--	--	<11	**58**	--	--
MW-3s	Chromium (Total)	50	**13.6**	**49.6**	**27.1**	**100**	<5	--
	Nickel (Total)	320	**348**	**1,710**	**343**	**2,270**	**270**	--
	Hexavalent Chromium (Total)	48	<11	**15**	**20**	**85**	<10	--
	Chromium (Dissolved)	50	--	--	**22.9**	**78**	--	--
	Nickel (Dissolved)	320	--	--	**314**	**2100**	**250**	--
	Hexavalent Chromium (Dissolved)	48	--	--	**26**	**106**	--	--
MW-4s	Chromium (Total)	50	**4.5**	**286**	**174**	**920**	**98**	--
	Nickel (Total)	320	**11**	**17,200**	**17,300**	**42,400**	**7,770**	--
	Hexavalent Chromium (Total)	48	<11	**361**	**199**	**933**	**44**	--
	Chromium (Dissolved)	50	--	--	**194**	**817**	--	--
	Nickel (Dissolved)	320	--	--	**16,300**	**41,900**	**7960**	--
	Hexavalent Chromium (Dissolved)	48	--	--	**193**	**951**	--	--
MW-4sR	Chromium (Total)	50	--	--	--	--	--	**15**
	Nickel (Total)	320	--	--	--	--	--	**2,600**
	Hexavalent Chromium (Total)	48	--	--	--	--	--	**12**
	Chromium (Dissolved)	50	--	--	--	--	--	**11**
	Nickel (Dissolved)	320	--	--	--	--	--	**2,700**
	Hexavalent Chromium (Dissolved)	48	--	--	--	--	--	--
MW-4d	Chromium (Total)	50	<0.50	**49.1**	**18.4**	**4.9**	<5	--
	Nickel (Total)	320	**1.86**	**36.6**	**14.6**	**8.58**	**10**	--
	Hexavalent Chromium (Total)	48	<11	**15**	<11	<11	<10	--

Well	Analyte	CUL	Nov. 2005[1]	July 2006[1]	Oct. 2006[1]	Mar. 2006[1]	Mar. 2014[2]	Feb. 2019[3]
MW-4d	Chromium (Dissolved)	50	--	--	**3.21**	**1.9**	--	--
	Nickel (Dissolved)	320	--	--	**3.5**	**6.67**	**260**	--
	Hexavalent Chromium (Dissolved)	48	--	--	<11	<11	--	--
MW-5s	Chromium (Total)	50	--	**9.27**	**11.4**	**6.27**	<5	--
	Nickel (Total)	320	--	**14.3**	**18.7**	**8.96**	<10	--
	Hexavalent Chromium (Total)	48	--	**12**	<11	<11	<10	--
	Chromium (Dissolved)	50	--	--	**2.1**	**2.3**	--	--
	Nickel (Dissolved)	320	--	--	**7.02**	**5.45**	<10	--
	Hexavalent Chromium (Dissolved)	48	--	--	<11	<11	--	--
MW-6s	Chromium (Total)	50	--	**135**	**1,630**	**36**	**10**	**8.1**
	Nickel (Total)	320	--	**118**	**1,780**	**45.3**	**10**	**12**
	Hexavalent Chromium (Total)	48	--	**19**	**47**	<11	<10	10 U
	Chromium (Dissolved)	50	--	--	**2.1**	**1.2**	--	1.0 U
	Nickel (Dissolved)	320	--	--	**19.2**	**11**	<10	8.0 U
	Hexavalent Chromium (Dissolved)	48	--	--	<11	<11	--	--
MW-7s	Chromium (Total)	50	--	**18.4**	**2.5**	**3.4**	<5	**2.1**
	Nickel (Total)	320	--	**18.2**	**4.86**	**4.76**	<10	8.0 U
	Hexavalent Chromium (Total)	48	--	**25**	<11	<11	<10	10 U
	Chromium (Dissolved)	50	--	--	**1.1**	**1.4**	--	1.0 U
	Nickel (Dissolved)	320	--	--	**1.93**	**3.08**	--	8.0 U
	Hexavalent Chromium (Dissolved)	48	--	--	<11	**11**	--	--
MW-8s	Chromium (Total)	50	--	--	--	--	--	**32**
	Nickel (Total)	320	--	--	--	--	--	**13,000**
	Hexavalent Chromium (Total)	48	--	--	--	--	--	**31**
	Chromium (Dissolved)	50	--	--	--	--	--	**28**
	Nickel (Dissolved)	320	--	--	--	--	--	**13,000**
	Hexavalent Chromium (Dissolved)	48	--	--	--	--	--	--

[1] Landau Associates, 2007
[2] GeoEngineers, 2014a
[3] GeoEngineers, 2019
U: Analyte not detected at or above the reported value
--: Not analyzed for

Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

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

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

Oxidation Reduction Potential: A measure of the tendency of a chemical species to acquire electrons and thereby be reduced. Each species has its own intrinsic reduction potential; the more positive the potential, the greater the species affinity for electrons and tendency to be reduced.

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

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Acronyms and Abbreviations

CLARC	Cleanup Levels and Risk Calculation
DO	(see Glossary above)
e.g.	For example
Ecology	Washington State Department of Ecology
EAP	Environmental Assessment Program
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
MRL	Method Reporting Limit
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
TCP	Toxics Cleanup Program
USGS	United States Geological Survey
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
ft.	feet
mg/L	milligrams per liter (parts per million)
NTU	nephelometric turbidity units
s.u.	standard units
μg/L	micrograms per liter (parts per billion)
μmhos/cm	micromhos per centimeter
μS/cm	microsiemens per centimeter, a unit of conductivity

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USGS, 1998).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI) (Kammin, 2010; Ecology, 2004).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 1997).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 1997).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:
- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:
- Gas Chromatography (GC).

- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier – data are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 1997).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA, 1997).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (EPA, 1997).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

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

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where “Abs()” is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1997).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 1997).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 1997).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

References for QA Glossary

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. https://apps.ecology.wa.gov/publications/SummaryPages/0403030.html

Kammin, B., 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4.
http://www.epa.gov/quality/qs-docs/g4-final.pdf

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. U.S. Geological Survey.
http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf