SAMPLING METHODOLOGY ADDENDUM

UNFUMED SLAG PROCESSING AND REMOVAL
GROUNDWATER MONITORING PLAN
EAST HELENA FACILITY

FEBRUARY 2022

Introduction

This Sampling Methodology Addendum to the Unfumed Slag (UFS) Processing and Removal Groundwater Monitoring Plan (the Plan) (Hydrometrics, 2021) provides an updated field methodology for well purging and collection of groundwater samples specified under the Plan. The Plan provides a scope, schedule, and strategy for collection and evaluation of groundwater data to assess potential changes in groundwater quality resulting from the UFS processing/removal (the UFS Project). The Plan outlines the number, type, and location of groundwater samples to be collected, as well as the sampling and analytical methodologies and data evaluation procedures to be employed. This addendum to the Plan presents an alternative sample collection methodology intended to reduce purge water handling requirements and monitoring costs. All other aspects of the Plan, including sample handling, analytical methods, data analysis and reporting remain as in the original Plan.

Rationale for Revised Sampling Methodology

The Plan currently specifies purging and sampling of monitoring wells using submersible pumps and the "standard purge" method of removing three to five well volumes while routinely monitoring field parameters (pH, dissolved oxygen, temperature, and specific conductance). This Addendum identifies a low-flow, low-volume purging and sampling method using a Waterra inertial pump as a preferred alternative to the standard purge method. The low-flow method provides the following advantages compared with the standard purge method:

1. Reduction of well purge water volumes and the amount of containerized purge water requiring storage and disposal by as much as 90%;
2. Use of all dedicated equipment at each well, eliminating the need for pump decontamination, generation of additional water requiring disposal, and the potential for cross-contamination between monitoring locations; and
3. Streamlining the purging and sampling procedure, which reduces the time required for sample collection and associated expenses.

Bullet items 1 and 2 are both intended to reduce the volume of sampling-derived water requiring storage and offsite disposal. Purge water removed from the well prior to sampling, and equipment decontamination water resulting from cleaning sampling pumps and tubing, needs to be stored on site for eventual offsite disposal at a licensed disposal facility. On site handling and storage of sampling-derived water as well as shipping and offsite disposal of water results in added project costs. Adopting a low-flow sampling methodology in lieu of the standard high purge method will greatly reduce the volume of sampling-derived water requiring disposal and associated costs. In addition, the low-flow sampling method is a streamlined approach to sample collection requiring less time and equipment than the standard three- to five-volume purge method. As a result, labor and equipment costs for low-flow sampling are generally less than the standard purge method. Therefore, adopting the low-flow purge sampling methodology for the UFS Project will result in a noticeable reduction in the monitoring program costs.

Standard/Low Flow Purge Data Comparison

One concern with changing sampling methodologies during a groundwater sampling program is the potential for a difference in sampling results from the various methods. For the UFS Project, where current sampling results are compared to historic data to determine if slag processing impacts groundwater quality, it is critical that the current sampling method and water quality data is comparable to the historic data. In order to assess the comparability of water quality data collected by the low-flow and standard purge methods, Hydrometrics collected groundwater samples at individual wells during November and December 2021 USF Project sampling events using both methods for direct comparison.

The comparison sampling conducted in November and December showed that the standard purge and low-flow/low-volume methods provide comparable analytical results, with concentrations largely showing relative percent differences (RPDs) of 0 to 15%, and most values less than 5% (Attachment 1). The typical RPD control limit for field duplicate water samples for inorganic parameters is 20%. Field dissolved oxygen values obtained using the Waterra inertial pump method were generally higher than those obtained with the standard purge method, although dissolved oxygen is utilized to assess purge stabilization and not as an indicator of potential slag processing impacts. In addition, one set of comparison samples (well EH-103 in November) showed higher concentrations of indicator parameters chloride, potassium, and magnesium using the low-volume method, with RPDs ranging from 24 to 35%. All comparisons for the key groundwater constituents arsenic and selenium were below the 20% threshold, averaging 8.7%.

Given the advantages of low-flow sampling outlined above, and the comparability of analytical data obtained with the low-flow and standard purge methods, especially for the COCs arsenic and selenium, use of the low-flow/low-volume method outlined below is recommended for future UFS Project sampling.

Waterra Inertial Pump Low-Flow/Low-Volume Sampling Methodology

As with the standard purge method, the collection of groundwater samples from site monitoring wells using the Waterra inertial pump generally will consist of three steps:

1. Measurement of static water level;
2. Well purging and monitoring for field parameter stabilization; and
3. Water quality sample collection.

Low-flow sampling will be conducted in general accordance with Hydrometrics' Standard Operating Procedure HSOP-105, *Low Flow/Minimal Drawdown Groundwater Sampling for Monitoring Wells*

(Attachment 2). Required equipment and supplies for Waterra sampling with dedicated tubing include the following:

- Waterra Inertial Pump actuator.
- Dedicated sample tubing appropriate to the well diameter. Tubing should be constructed of inert materials appropriate for the target analytical constituents, such as stainless steel, low or high-density polyethylene (HDPE if > 50 feet to groundwater), Teflon®, or similar materials. Pump tubing should be graduated to allow for accurate placement of the pump intake at a specified depth.
- Check valve for tubing at each well. For small diameter tubing, it is recommended to set check valves in tubing prior to arrival at monitoring well. To prepare small diameter (1/4") check valves: insert the top piece, the ball and the bottom piece into the tubing, then heat until tubing shrinks to secure check valve. For larger diameter (3/4") tubing, check valves are a single unit and just need to be securely inserted into the bottom of the tubing.
- Tubing guides (2 – 3 foot hard plastic sleeves) and hose clamps to reduce flex in tubing above PVC well. The guides also help to stabilize the tubing in the center of the well reducing friction between tubing and PVC at depth.
- Peristaltic pump (if required) and associated tubing.
- Generator (and fuel) or other power supply
- Device for measuring depth to water (electric water level probe or other device).
- Flow measurement equipment, such as an inline flowmeter, calibrated bucket and stopwatch, or graduated cylinder. The bucket should be relatively small (< 1liter) for collection of low-flow measurements.
- Purge water collection bucket and storage container.
- Field multiparameter meter and flow-through cell for monitoring pH, specific conductance (SC), dissolved oxygen (DO), and water temperature.
- Sample collection supplies (e.g., bottles, preservatives, filters, coolers).
- Sampling documentation materials (field notebook, field sampling forms or data sheets, chain-of-custody documentation).

The procedure for implementing low-flow Waterra sampling is summarized below with the full procedure included in Attachment 2.

1. Remove well cap and measure depth to groundwater from the designated measuring point (and total well depth, if not known). Total well depth may also be obtained from well logs or previous measurements. Record information in field notebook and on field forms. Leave water level probe in well to monitor water level drawdown during purging.

2. Calculate one casing volume (volume of water in the casing) using the formula $V=0.0408 \times (TD\text{-}SWL) \times (D^2)$, where TD is the well total depth (feet below measuring point), SWL is the depth to water (feet

below measuring point), and D is the well casing inner diameter (inches). Record information in field notebook and on field sampling form.

3. Set up multimeter, flow through cell, and peristaltic pump (if appropriate).

4. Move Waterra arm to downstroke position. Set Waterra pump to lowest speed. Attach power supply cord.

5. Connect sample tubing to silicone tubing and auxiliary peristaltic pump (if using), and flow through cell.

6. Direct discharge line and flow-through cell waste line into containers to contain purge water and measure flow. Start Waterra on low speed to confirm free movement of the guides, and adjust alignment as necessary.

7. Slowly increase Waterra speed, note start time on field form. Measure pumping rate and allow several tubing/flow cell volumes to pass through equipment.

8. Begin recording field parameter measurements (pH, SC, DO, water temperature) and pumping groundwater level at three- to five-minute intervals. Per HSOP-105, drawdown during low-flow sampling should be maintained at less than 0.3 feet. Periodically remeasure pumping rate to determine any variability. Note that the interval between field parameter measurements should allow sufficient time for the volume of water in the flow-through cell to be completely replaced by fresh groundwater, so modifications to the three- to five-minute rule of thumb may be necessary.

9. Field parameter stabilization is based on <u>three successive readings</u> of field parameters that agree to within the project specific stabilization criteria noted in the Plan and in the table below.

10. When stabilization criteria have been met, record final field parameter measurements and mark bottles with sample collection time. Maintain or slightly reduce the pumping rate for collection of samples, and collect the samples directly from the discharge port of the pump (i.e., do not collect samples after water has passed through the field parameter flow through cell, inline flow meters, or other equipment). Rinse sample containers three times with sample water prior to filling (the rinsing step may be ignored if bottles are provided "pre-preserved," with preservatives already placed in the container). Sample containers should be filled by allowing water to gently flow down the inside of the container, minimizing turbulence.

11. For field-filtering, place an in-line single use filter on the end of the pump discharge tubing or peristaltic pump. Allow a small quantity of sample water (~100 to 200 mL) to pass through the filter prior to rinsing of sample bottles and collection of samples.

12. Preserve samples as appropriate for the analysis required, tightly cap containers, and place in coolers with ice for storage and transport.

UFS Project groundwater sampling criteria for field parameter stabilization are as follows:

Parameter (Units)	Stability Criteria
pH (standard units)	±0.1 pH unit
Water temperature (°C)	±0.2°C
Specific conductance (µmhos/cm)	±5% (SC ≤100 µmhos/cm) ±3% (SC >100 µmhos/cm)
Dissolved oxygen (mg/L)	±0.3 mg/L

NOTES:
Stability criteria obtained from USGS *National Field Manual for the Collection of Water Quality Data: Chapter A4, Collection of Water Samples* (September 2006).

All other procedures implemented for the UFS Project when using the alternative Waterra inertial pump low-flow/low-volume sampling methodology will be as specified in the Plan, including collection of field quality control samples, sample handling and documentation, laboratory analytical methods, data review, and data reporting.

The biweekly UFS Project groundwater monitoring results for October 1st, 2021 through mid-January 2022 are included in Attachment 3 with monitoring locations included in Attachment 4. Based on the relatively consistent monitoring results and lack of apparent groundwater quality impacts from the slag processing, monitoring will continue as of February 2022 on a monthly schedule. Per the original Plan, the sampling frequency may be increased and/or additional Tier 2/Tier 3 monitoring wells or residential wells included in the monitoring program if future monitoring results warrant.

References

Hydrometrics, 2021. Unfumed Slag Processing and Removal Groundwater Monitoring Plan – East Helena Facility. Prepared for Montana Environmental Trust Group, LLC. August 2021.

ATTACHMENT 1

LOW FLOW AND STANDARD PURGE

COMPARISON SAMPLING RESULTS

November 2 2021 Comparison Sampling

Site	Date	Purge Rate	Purge Vol (gal)	pH (s.u.)	SC (µmhos/cm)	Dissolved O2 (mg/L)	Temperature (°C)	Arsenic (mg/L)	Selenium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Potassium (mg/L)	Magnesium (mg/L)
DH-55 (Low Volume)	11/2/2021	0.4 lpm	1.1	7.19	1820	1.26	7.6	0.128	0.056	728	19	132	18
DH-55 (Standard)	11/2/2021	1 gpm	10	7.24	1915	0.53	9.4	0.132	0.064	760	19	137	19
DH-55	**RPD (%)**	--	--	**0.7%**	**5.1%**	**81.6%**	**21.2%**	**3.1%**	**13.3%**	**4.3%**	**0.0%**	**3.7%**	**5.4%**
EH-103 (Low Volume)	11/2/2021	0.5 lpm	1.6	6.84	1711	0.49	10.6	<0.002	0.328	780	32	7	51
EH-103 (Standard)	11/2/2021	2 gpm	24	6.86	1709	0.22	11.8	<0.002	0.311	753	25	10	37
EH-103	**RPD (%)**		--	**0.3%**	**0.1%**	**76.1%**	**10.7%**	**NC**	**5.3%**	**3.5%**	**24.6%**	**35.3%**	**31.8%**

December 2 2021 Comparison Sampling

Site	Date	Purge Rate	Purge Vol (gal)	pH (s.u.)	SC (µmhos/cm)	Dissolved O2 (mg/L)	Temperature (°C)	Arsenic (mg/L)	Selenium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Potassium (mg/L)	Magnesium (mg/L)
DH-6 (Low Volume)	12/2/2021	0.5 lpm	1.4	7.57	654	3.60	10.5	1.17	0.041	142	8	56	2
DH-6 (Standard)	12/2/2021	1 gpm	10	7.52	656	2.56	10.7	1.08	0.043	142	8	54	2
DH-6	**RPD (%)**	--	--	**0.7%**	**0.3%**	**33.8%**	**1.9%**	**8.0%**	**4.8%**	**0.0%**	**0.0%**	**3.6%**	**0.0%**
DH-53 (Low Volume)	12/2/2021	0.75 lpm	1.8	7.15	412	0.27	11.5	0.150	0.006	73	7	29	6
DH-53 (Standard)	12/2/2021	1 gpm	10	7.12	416	0.05	12.1	0.168	0.007	72	7	29	6
DH-53	**RPD (%)**	--	--	**0.4%**	**1.0%**	**137.5%**	**5.1%**	**11.3%**	**15.4%**	**1.4%**	**0.0%**	**0.0%**	**0.0%**

ATTACHMENT 2

STANDARD OPERATING PROCEDURE

HSOP-105

LOW FLOW/MINIMAL DRAWDOWN GROUNDWATER SAMPLING

FOR MONITORING WELLS

STANDARD OPERATING PROCEDURE

HSOP-105

LOW FLOW/MINIMAL DRAWDOWN GROUNDWATER SAMPLING FOR MONITORING WELLS

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1.0 SCOPE AND APPLICATION

Collection of representative groundwater samples requires the use of appropriate standard procedures, using equipment and methods that will maintain the chemical, physical, and biological integrity of the water sample and therefore accurately represent the characteristics of groundwater within the aquifer. Typically, groundwater samples are collected using a "standard purge procedure," where a minimum number of well volumes are purged from the well while monitoring field parameters for stabilization, and samples are collected after removal of the required volume of water has occurred and stabilization of parameters has been demonstrated (USGS, 2006). In certain circumstances, however, use of an alternative low flow/minimal drawdown purging and sampling technique is warranted. HSOP-105 presents guidelines for implementing the low flow/minimal drawdown purging and sampling method for groundwater sampling.

The methods described in HSOP-105 are based primarily on the *Groundwater Sampling Guidance* developed by the Montana Department of Environmental Quality (DEQ, 2018). This guidance was prepared to assist responsible parties, environmental professionals, and DEQ technical staff in performing appropriate groundwater sampling activities, including low flow sampling. The U.S. Environmental Protection Agency has also prepared useful documents including *Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells from September 19, 2017* (USEPA, 2017). The EPA SOP reference should be consulted for additional suggestions and guidance on performing low-flow sampling. The purpose of this procedure is to provide a sampling method that will (1) minimize the potential impact of purging on groundwater chemistry, and (2) minimize the volume of purge water requiring disposal.

Implementation of the low-flow purging and sampling procedure will usually be specified in project planning documents (work plans, field sampling plans, and/or quality assurance plans). In general, HSOP-105 should be implemented at monitoring wells with a screen length of ten feet or less. While dedicated equipment is preferred to minimize potential disturbances due to placement of pumping equipment, the method may also be employed using non-dedicated equipment. Groundwater samples for the full spectrum of chemical constituents may be collected using the low-flow purge technique, including metals and other inorganics, and organic compounds (e.g., volatile, semi-volatile, PCBs, pesticides, herbicides).

This method is not generally applicable to water supply wells, which usually include dedicated pumps without the ability to accurately control purge rates. The low-flow method should not be used when non-aqueous phase liquids (NAPLs) are present within the well.

When performing low flow sampling in Montana, these procedures should be compared to the DEQ's Groundwater Sampling Guidance (DEQ, 2018). The intent of this SOP is to confirm to this DEQ Guidance; however, in the unlikely event of discrepancies in procedure, the DEQ guidelines should be followed.

2.0 SUMMARY OF METHOD

The low-flow purging and sampling method consists of the following steps:

- Measurement of the depth to groundwater;
- Installation of pumping equipment (if non-dedicated equipment is used) so that the pump intake is located at an appropriate location within the screened interval;

- Purging of the well at a low flow rate to maintain less than 0.3 feet of drawdown;
- Monitoring of field parameters at regular intervals (3 to 5 minute intervals are recommended for typical flow rates) to ascertain stabilization; and
- Collection of groundwater samples after field parameter stabilization has occurred.

Note that stable drawdowns of less than 0.3 feet, while desirable, are not mandatory (EPA, 2017).

3.0 HEALTH AND SAFETY WARNINGS

Field personnel should be aware of the health and safety precautions to be followed during any field event, and should be familiar with any project-specific hazards. This may include review of project-specific health and safety plans, along with site-specific and/or organization-specific safety requirements and training.

Hazards specific to groundwater sampling may include electrical shock hazards during operation of generators, pump control boxes, batteries, etc.; lifting hazards encountered during setting and retrieval of pumps; contact with groundwater and associated organic or inorganic contaminants; and contact with chemical preservatives. Appropriate personal protective equipment should be used at all times during field activities. Some samples may contain biological and chemical hazards. These samples should be handled with suitable protection to skin, eyes, etc. Good field practice also includes setting aside time prior to, during, and following field activities to consider potential health and safety issues and their resolution (e.g., “tailgate” safety meetings).

4.0 INTERFERENCES

Problems with the low-flow purging and sampling procedure may occur with extremely low-yield/low recharge wells, when drawdown of less than 0.3 feet cannot be maintained even at very low pumping rates. In general, these wells should be identified prior to field sampling, and a different purging/sampling technique should be utilized such as the use of special pumps capable of maintaining very low pumping rates (bladder, peristaltic). However, if low-yield conditions are encountered in new wells or wells where the situation has not occurred before, or the well is dewatered during sampling using the low-flow method, the EPA SOP (USEPA, 2017) gives the following recommendations:

> *the well should be sampled as soon as the water level has recovered sufficiently to collect the volume needed for all anticipated samples. The project manager or field team leader will need to make the decision when samples should be collected, how the sample is to be collected, and the reasons recorded on the purge form or in the field logbook. A water level measurement needs to be performed and recorded before samples are collected. If the project manager decides to collect the samples using the pump, it is best during this recovery period that the pump intake tubing not be removed, since this will aggravate any turbidity problems. Samples in this specific situation may be collected without stabilization of indicator field parameters. Note that field conditions and efforts to overcome problematic situations must be recorded in order to support field decisions to deviate from normal procedures described in this SOP. If this type of problematic situation persists in a well, then water sample collection should be changed to a passive or no-purge method, if consistent with the site’s DQOs, or have a new well installed.*

It is also recommended that low-flow sampling be conducted when the air temperature is above 32°F (0°C). If the procedure is used below 32°F, special precautions will need to be taken to prevent the groundwater from freezing in the equipment. Because sampling during freezing temperatures may adversely impact the data quality objectives, the need for water sample collection during months when these conditions are likely to occur should be evaluated during site planning and special sampling measures may need to be developed. Ice formation in the flow-through-cell will cause the monitoring probes to act erratically. A transparent flow-through-cell needs to be used to observe if ice is forming in the cell. If ice starts to form on the other pieces of the sampling equipment, additional problems may occur.

5.0 PERSONNEL QUALIFICATIONS

Personnel should be familiar with the project planning documents (work plans, field sampling plans, and quality assurance plans), as well as the overall project objectives. Review of well logs and previous sampling documentation regarding well total depths, screened intervals, pump intake depths, pumping rates, field parameter measurements, and other pertinent information should be reviewed prior to field activities. Personnel should also be proficient with the operation of equipment listed in Section 6.0 below. Site safety and training requirements (including HAZWOPER training) must also be met as necessary.

6.0 EQUIPMENT AND SUPPLIES

Minimum equipment requirements for implementing the low-flow method for purging and sampling groundwater include the following:

6.1 DOCUMENTS

- SAP/QAPP;
- HASP;
- Field data from previous events;
- Location maps, directions, site access requirements, phone numbers, etc.;
- Sampling documentation materials (field notebook, field sampling forms or data sheets, chain-of-custody documentation); and
- Relevant associated SOPs.

6.2 EQUIPMENT

- Water level probe for measuring depth to water.
- Device for measuring well total depth (steel tape and weight or other device), if total depth measurement is required.
- Sampling pump and associated equipment (submersible, bladder, or peristaltic pump and tubing, power supply). Pumps and tubing should be constructed of inert materials appropriate for the target analytical constituents, such as stainless steel, high-density polyethylene, Teflon®, or similar materials. Pump tubing should be graduated to allow for accurate placement of the pump intake at a specified depth.
- Flow measurement equipment, such as an inline flowmeter, calibrated bucket and stopwatch, or graduated cylinder.

- Field parameter meters (multiple single-parameter type, or multiparameter meters). Indicator parameters for groundwater sampling typically include pH, specific conductance (SC), dissolved oxygen (DO), and water temperature. Turbidity measurements and oxidation-reduction potential (ORP) may also be monitored. The list of required field parameters will usually be included in the project planning documents.
- Flow-through cell. The flow-through cell should be relatively small (≤ 1 liter), and a manufactured and completely closed (threaded) cell is preferred. The discharge line to the flow-through cell should be separate from the discharge line used for collection of samples using the necessary fittings (usually tees and valves).
- Power source(s) for computer, pump, etc. (non-petroleum powered power source preferred, otherwise additional sampling precautions should be taken to prevent sample interference for sampling for SVOCs and hydrocarbons).
- Resource grade GPS (as necessary).

6.3 MATERIALS AND SUPPLIES

- Sample collection supplies (e.g., bottles, labels, preservatives, filters, coolers, nitrile gloves);
- Pens, markers sample tape etc.;
- Decontamination supplies;
- Chain of custody forms; and
- Ice for preserving laboratory samples.

7.0 PROCEDURE

1. Position vehicles for sampling such that any vehicle or generator exhaust is produced downwind of the sampling area.
2. Remove well cap and measure depth to groundwater from the designated measuring point (and total well depth, if required). Total well depth may also be obtained from well logs or previous measurements. Record information in field notebook and on field forms. Occasional re-measurement of depth to water is recommended to confirm initial measurement, and the reproducibility of the depth to water measurements.
3. Calculate one casing volume (volume of water in the casing) using the formula V=0.0408 x (TD-SWL) x (D^2), where TD is the well total depth (feet below measuring point), SWL is the depth to water (feet below measuring point), and D is the well casing inner diameter (inches). Record information in field notebook and on field sampling form.
4. For sampling with non-dedicated equipment, place the pump and tubing slowly and carefully into the well to avoid agitating the water or generating turbidity, setting the pump intake at the pre-determined location within the well screen interval, or at approximately the center of the screened interval if no location is specified. For dedicated systems, the pump will already be installed with the intake at the desired depth.
5. For sampling with non-dedicated equipment, remeasure the depth to water after the pump has been placed in the well, and record in field notebook and on field form. The water level probe or measuring device should be left in place at this time to allow for measurement of drawdown during the purging/sampling procedure.
6. Connect pump tubing to discharge line and flow-through cell line. Make electrical connections to allow operation of pump. Direct discharge line and flow-through cell waste line into containers to contain purge water, if required by the project sampling plan.

Alternatively, direct purge water to the ground away from the well head and from electrical equipment.

7. Begin pumping at a low rate while monitoring drawdown using water level probe. Records from previous monitoring events may also provide guidance on appropriate pumping rates for a particular well. Slowly increase pump rate while maintaining drawdown of less than 0.3 feet. Record pump rates and associated water level measurements on field documentation. In addition to minimizing drawdown, the final pumping rate should be low enough to avoid producing excessive turbulence or high levels of turbidity within the well. However, higher purge rates may be used for larger diameter wells, or if field parameter measurements, historic data, and/or drawdown measurements suggest that higher pumping rates do not compromise the representativeness of groundwater samples.
8. Estimate one “tubing volume” (volume of water in the pump, tubing, and flow through cell) using approximate length and inner diameter of pump tubing and volume of flow cell. After a minimum of one tubing volume has been purged, begin recording field parameter measurements (pH, SC, DO, water temperature, and, if indicated, turbidity and/or ORP) at three- to five-minute intervals. Water level measurements and pumping rate measurements (if varied) should also be recorded at this time. Note that the interval between field parameter measurements should allow sufficient time for the volume of water in the flow-through cell to be completely replaced by fresh groundwater, so modifications to the three- to five-minute rule of thumb may be necessary.
9. Stabilization criteria are based on three successive readings of field parameters that agree to within the stabilization criteria given in Table 1. Criteria for turbidity and ORP are included in Table 1, although these parameters are less frequently included as required field parameters for groundwater monitoring projects. The USGS does not consider ORP a “routine field measurement” due to difficulties associated with the accurate measurement and interpretation of the data. This SOP specifies stabilization over three successive measurements during low-flow purging and sampling as adequate for the majority of applications.

Table 1. Low-Flow Groundwater Sampling
Field Parameter Stabilization Criteria

Parameter	Stabilization Criteria[1]
water temperature	±0.2°C
specific conductance	±3% (SC>100) ±5% (SC<100)
dissolved oxygen	±0.2 to 0.3 mg/L
pH	±0.1 to 0.2 pH units
turbidity	±10%
ORP	±10 mV[2]

[1]Criteria from USGS (2012) unless otherwise noted.
[2]Criteria from DEQ (2018).

10. When stabilization criteria have been met, record final field parameter measurements and depth to water, and collect the groundwater sample. Maintain or slightly reduce the pumping rate for collection of samples, and collect the samples directly from the discharge port of the pump (i.e., do not collect samples after water has passed through the field parameter flow

through cell, inline flow meters, or other equipment). Rinse sample containers three times with sample water prior to filling (the rinsing step may be ignored if bottles are provided "pre-preserved," with preservatives already placed in the container). Sample containers should be filled by allowing water to gently flow down the inside of the container, minimizing turbulence.

11. If field-filtered samples are required, an in-line filter should be placed at the end of the pump discharge tubing. A small quantity of sample water (250 to 500 mL) should be allowed to pass through the filter prior to rinsing of sample bottles and collection of samples. Filters are single-use only; discard filters after collecting a sample and do not reuse.
12. Preserve groundwater samples as appropriate for the analysis required, tightly cap containers, and place in coolers with ice for storage and transport.
13. Shut off pump and complete sample documentation (field notebook and field sampling forms). For non-dedicated equipment, disconnect electrical and pump tubing connections, and decontaminate equipment as required by the project planning documents.
14. Close and lock well.

8.0 DATA AND RECORDS MANAGEMENT

Copies of all field notes and documentation collected during the low-flow purging and sampling procedure will be maintained in a project file (hard copies) and/or on the network directory dedicated to the project (electronic files). Field documentation should include notes regarding any difficulties encountered during implementation of the procedure, and any modifications to or deviations from this procedure or any other prescribed methods outlined in the project planning documents.

9.0 QUALITY CONTROL/QUALITY ASSURANCE

Quality control and quality assurance for low-flow groundwater sampling is similar to standard procedures for any type of water sampling, including adherence to methods stipulated in project planning documents, and collection and analysis of field quality control (QC) samples. Field QC sample types may include blanks (equipment rinsate blanks, trip blanks, bottle blanks, or other types), field duplicates, and standards (samples with known concentration) obtained from third-party vendors. The project sampling plan or quality assurance plan should be consulted to verify the frequency of field QC sample collection and to provide additional details concerning collection of these samples. In many cases, field blank and duplicate samples are collected at a frequency of 1 per 20 samples or 1 per day, whichever is more frequent.

10.0 REFERENCES

DEQ, 2018. Groundwater Sampling Guidance. March 6.

USEPA, Region I. 2017. Low Stress (low-flow) Purging and Sampling Procedures for the Collection of Groundwater Samples from Monitoring Wells. Quality Assurance Unit, North Chelmsford, MA. Revised September 19.

USGS, 2006. Collection of Water Samples (v. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Chapter A4, National Field Manual for the Collection of Water-Quality Data.

USGS, 2012. Use of Multiparameter Instruments for Routine Field Measurements (v. 1.1). Chapter A6. Field Measurements, Section 6.8, National Field Manual for the Collection of Water-Quality Data. March.

USGS, 2013. Dissolved Oxygen (v. 2.0). Chapter A6. Field Measurements, Section 6.2, National Field Manual for the Collection of Water-Quality Data. September.

USGS, 2019. Specific Conductance Chapter A6. Field Measurements, Section 6.3, National Field Manual for the Collection of Water-Quality Data. February.

ATTACHMENT 3

UNFUMED SLAG REPROCESSING PROJECT

GROUNDWATER SAMPLING RESULTS TO DATE

Site	Sample Date	Purge Method	SWL (ft bmp)	pH (s.u.)	SC (µmhos/cm)	Dissolved O2 (mg/L)	Temperature (°C)	Arsenic (mg/L)	Selenium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Potassium (mg/L)	Magnesium (mg/L)
DH-6	*7/29/2021 (Pre-Crushing)*	*Standard*	*22.07*	*7.47*	*786*	*2.55*	*9.9*	*1.1*	*0.059*	*192*	*8*	*66*	*3*
DH-6	10/1/2021	Standard	22.04	7.61	656	2.14	10.4	1.22	0.036	153	8	59	2
DH-6	10/18/2021	Low-Flow	22.36	7.58	655	2.90	10.9	1.38	0.038	133	7	59	2
DH-6	11/3/2021	Low-Flow	22.63	7.54	644	4.61	10.1	1.38	0.033	141	8	60	2
DH-6	11/17/2021	Low-Flow	22.97	7.60	651	3.83	9.7	1.43	0.037	135	8	60	2
DH-6	12/2/2021	Low-Flow	23.23	7.57	654	3.60	10.5	1.17	0.041	142	8	56	2
DH-6	12/2/2021	Standard	23.23	7.52	656	2.56	10.7	1.08	0.043	142	8	54	2
DH-6	12/21/2021	Low-Flow	23.45	7.66	697	3.82	9.6	1.14	0.046	158	8	62	3
DH-6	1/12/2022	Low-Flow	23.25	7.57	687	3.39	9.4	1.07	0.044	158	8	60	3
DH-6	**95% USL**		**--**	**--**	**--**	**--**	**--**	**3.81**	**0.885**	**1330**	**37**	**288**	**23**
DH-15	*7/29/2021 (Pre-Crushing)*	*Standard*	*22.08*	*7.00*	*1324*	*0.03*	*11.2*	*<0.002*	*0.258*	*525*	*12*	*6*	*28*
DH-15	10/1/2021	Standard	22.10	7.05	1311	0.04	11.0	<0.002	0.237	554	12	6	30
DH-15	10/18/2021	Low-Flow	22.37	7.14	1231	0.58	10.5	<0.002	0.218	471	10	5	28
DH-15	11/3/2021	Low-Flow	22.63	7.00	1211	0.59	9.5	<0.002	0.206	480	11	5	27
DH-15	11/17/2021	Low-Flow	22.98	6.99	1223	0.16	9.2	<0.002	0.225	453	11	5	26
DH-15	12/2/2021	Low-Flow	23.25	6.99	1200	0.22	10.1	<0.002	0.209	459	11	5	26
DH-15	12/21/2021	Low-Flow	23.44	7.12	1226	0.22	9.2	<0.002	0.206	487	11	5	27
DH-15	1/12/2022	Low-Flow	23.24	7.08	1204	0.24	8.8	<0.002	0.205	469	11	5	27
DH-15	**95% USL**		**--**	**--**	**--**	**--**	**--**	**0.003**	**0.530**	**1351**	**68**	**9**	**68**
DH-52	*7/29/2021 (Pre-Crushing)*	*Standard*	*8.28*	*7.30*	*766*	*0.26*	*11.0*	*0.508*	*0.023*	*207*	*7*	*66*	*8*
DH-52	10/1/2021	Standard	8.82	7.41	676	0.32	11.5	0.517	0.016	178	6	65	7
DH-52	10/18/2021	Low-Flow	8.77	7.31	689	0.90	12.1	0.487	0.018	159	6	63	8
DH-52	11/2/2021	Low-Flow	8.98	6.92	660	2.10	9.6	0.445	0.019	166	6	65	8
DH-52	11/17/2021	Low-Flow	9.15	7.28	707	1.40	9.8	0.463	0.020	175	6	62	8
DH-52	12/2/2021	Low-Flow	9.19	7.19	709	1.38	10.1	0.450	0.018	186	6	62	8
DH-52	12/21/2021	Low-Flow	7.82	7.37	709	1.27	8.9	0.457	0.017	180	7	63	8
DH-52	1/12/2022	Low-Flow	7.74	7.37	463	**	8.2	0.558	0.025	87	8	47	4
DH-52	**95% USL**		**--**	**--**	**--**	**--**	**--**	**2.19**	**0.090**	**474**	**11**	**87**	**15**
DH-53	*7/29/2021 (Pre-Crushing)*	*Standard*	*10.83*	*7.20*	*468*	*0.22*	*10.7*	*0.196*	*0.034*	*88*	*6*	*36*	*6*
DH-53	10/1/2021	Standard	11.25	7.27	444	0.10	13.1	0.188	0.011	71	7	36	6
DH-53	10/18/2021	Low-Flow	11.34	7.19	454	0.54	13.6	0.186	0.004	65	7	35	6
DH-53	11/2/2021	Low-Flow	11.49	6.96	439	0.90	11.5	0.215	0.005	73	8	34	7
DH-53	11/17/2021	Low-Flow	11.63	7.18	434	0.57	10.8	0.170	0.004	72	7	34	6
DH-53	12/2/2021	Low-Flow	11.65	7.15	412	0.27	11.5	0.150	0.006	73	7	29	6
DH-53	12/2/2021	Standard	11.65	7.12	416	0.05	12.1	0.168	0.007	72	7	29	6
DH-53	12/21/2021	Low-Flow	10.39	7.37	403	0.27	9.9	0.140	0.011	75	7	27	6
DH-53	1/12/2022	Low-Flow	10.22	7.27	431	0.42	8.6	0.148	0.028	85	8	29	7
DH-53	**95% USL**		**--**	**--**	**--**	**--**	**--**	**0.86**	**0.028**	**277**	**12**	**63**	**8**

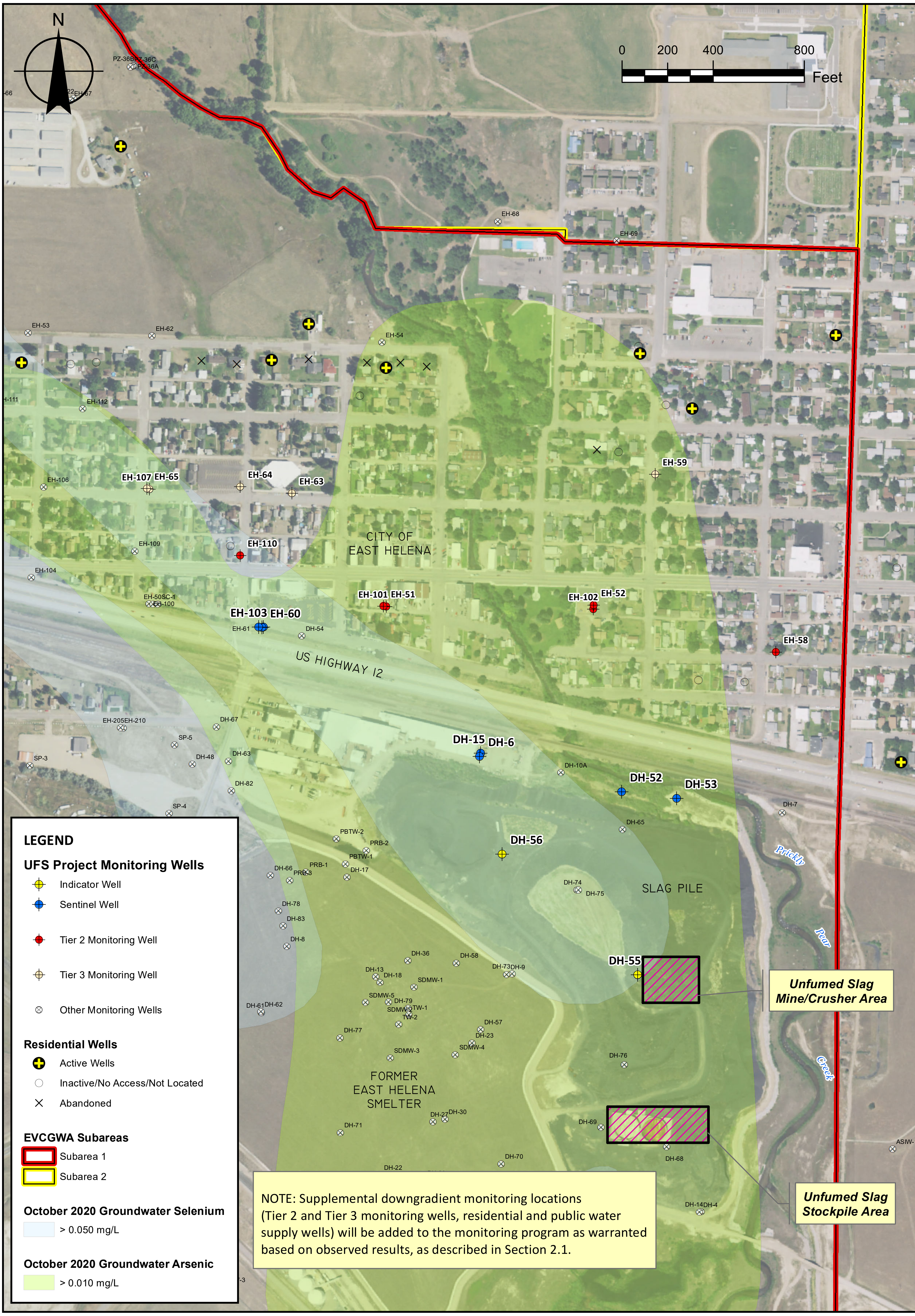
Site	Sample Date	Purge Method	SWL (ft bmp)	pH (s.u.)	SC (µmhos/cm)	Dissolved O2 (mg/L)	Temperature (°C)	Arsenic (mg/L)	Selenium (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Potassium (mg/L)	Magnesium (mg/L)
DH-55	*7/29/2021 (Pre-Crushing)*	*Standard*	*81.37*	*7.25*	*1611*	*0.57*	*9.9*	*0.148*	*0.059*	*576*	*17*	*122*	*14*
DH-55	10/1/2021	Standard	81.59	7.31	1741	0.61	9.5	0.142	0.049	660	18	135	16
DH-55	10/18/2021	Low-Flow	81.69	7.19	1950	0.82	9.3	0.124	0.073	686	16	146	19
DH-55	11/2/2021	Low-Flow	81.67	7.19	1820	1.26	7.6	0.128	0.056	728	19	132	18
DH-55	11/2/2021	Standard	81.76	7.24	1915	0.53	9.4	0.132	0.064	760	19	137	19
DH-55	11/17/2021	Low-Flow	81.82	7.23	1946	0.68	7.6	0.132	0.064	792	19	139	18
DH-55	12/2/2021	Low-Flow	81.85	7.22	1917	0.54	8.8	0.132	0.056	734	19	133	18
DH-55	12/21/2021	Low-Flow	81.85	7.33	1960	1.34	7.6	0.138	0.048	747	20	136	19
DH-55	1/12/2022	Low-Flow	81.26	7.28	1880	1.29	7.3	0.135	0.057	694	18	132	18
DH-55	**95% USL**		**--**	**--**	**--**	**--**	**--**	**1.48**	**0.316**	**1232**	**24**	**198**	**43**
EH-61	10/1/2021	Standard	30.00	6.95	1900	0.08	11.7	<0.002	0.299	814	23	16	23
EH-61	10/18/2021	Low-Flow	30.28	6.79	1838	**	11.0	<0.002	0.314	742	21	15	23
EH-61	11/3/2021	Low-Flow	30.47	7.01	1861	**	10.6	<0.002	0.299	755	22	15	23
EH-61	11/17/2021	Low-Flow	30.71	6.90	1884	0.29	9.9	<0.002	0.305	740	23	16	23
EH-61	12/2/2021	Low-Flow	30.90	6.87	1848	0.45	11.4	<0.002	0.301	719	21	15	23
EH-61	12/21/2021	Low-Flow	31.05	7.14	1866	2.45	10.5	<0.002	0.277	772	22	15	23
EH-61	1/12/2022	Low-Flow	31.20	7.08	1853	1.57	10.0	<0.002	0.281	732	22	15	23
EH-61	**95% USL**		**--**	**--**	**--**	**--**	**--**	**<0.002**	**0.535**	**1132**	**42**	**16**	**44**
EH-103	*7/29/2021 (Pre-Crushing)*	*Standard*	*30.58*	*6.91*	*1768*	*0.02*	*12.3*	*<0.002*	*0.335*	*711*	*24*	*11*	*33*
EH-103	10/1/2021	Standard	30.58	6.93	1741	0.06	11.9	<0.002	0.312	787	24	11	32
EH-103	10/18/2021	Low-Flow	30.85	6.85	1867	**	11.6	<0.002	0.370	753	30	7	52
EH-103	11/2/2021	Low-Flow	31.02	6.84	1711	0.49	10.6	<0.002	0.328	780	32	7	51
EH-103	11/2/2021	Standard	31.02	6.86	1709	0.22	11.8	<0.002	0.311	753	25	10	37
EH-103	11/17/2021	Low-Flow	31.29	6.71	1755	0.20	9.8	<0.002	0.369	743	31	7	50
EH-103	12/2/2021	Low-Flow	31.50	6.69	1728	0.17	11.4	<0.002	0.347	733	30	6	52
EH-103	12/21/2021	Low-Flow	31.64	6.90	1748	0.29	10.5	<0.002	0.343	773	32	7	51
EH-103	1/12/2022	Low-Flow	31.79	6.84	1722	0.21	10.4	<0.002	0.311	762	30	7	50
EH-103	**95% USL**		**--**	**--**	**--**	**--**	**--**	**<0.002**	**0.484**	**1088**	**47**	**11**	**55**

NOTES: 7/29/2021 sampling event conducted prior to initiation of slag crushing; other events conducted after crushing began on 9/21/2021.
Purge method comparison samples (low-flow and standard sampling methods) were collected at wells DH-55 and EH-103 on 11/2/2021, and at wells DH-6 and DH-53 on 12/2/2021.
Field parameters (pH, SC, dissolved oxygen, water temperature) are monitored as groundwater purging/stabilization indicators.
**Dissolved oxygen not recorded due to air entrainment in flowthrough cell.

ATTACHMENT 4

UNFUMED SLAG PROJECT

GROUNDWATER MONITORING LOCATIONS



Hydrometrics, Inc. Consulting Scientists and Engineers Date Saved: 2/14/2022 9:28:30 AM	UNFUMED SLAG PROCESSING AND REMOVAL GROUNDWATER MONITORING PLAN EAST HELENA FACILITY	UFS PROJECT GROUNDWATER MONITORING LOCATIONS	ATTACHMENT 4

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