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Subject: Work Plan Addendum No. 5 for Additional Upland Area Sulfide Sample Collection and Analysis at the Weyerhaeuser Mill A Former Site, Everett, Washington

This memorandum has been prepared as an addendum to the Weyerhaeuser Mill A Former Remedial Investigation/Feasibility Study (RI/FS) Work Plan (GeoEngineers 2014a) and Upland Area Sampling and Analysis Plan (SAP; GeoEngineers 2014b) for the Weyerhaeuser Mill A Former Site (Site). This addendum is being provided on behalf of the Port of Everett (Port) and describes additional sample collection and analysis to characterize hydrogen sulfide (H₂S) at the Site. This addendum has been prepared to supplement and meet the RI requirements specified in the RI/FS Work Plan.

The sample collection and testing described in this addendum is being performed as follow-up to the initial Upland Area groundwater investigation completed in September 2016 and March 2017. The additional sample collection and analysis is based on the results of initial sampling and analysis, and communication and coordination with the Washington State Department of Ecology (Ecology). The primary communications related to this work include the following:

- Upland Area Remedial Investigation Data Report Technical Memorandum, Weyerhaeuser Mill A Former, Everett, Washington, dated March 19, 2018 (GeoEngineers 2018).
- Meetings between representatives of Ecology, Port of Everett, Weyerhaeuser Company and Washington State Department of Natural Resources (DNR) held on June 26 and July 11, 2018.

The sample collection and analysis described in this addendum includes the collection of groundwater and porewater samples using the diffusive-gradient-in-thin-film (DGT) passive sampling technique to allow collection of samples for H₂S analysis from multiple locations and achieve a detection limit that is at or below the preliminary screening level that has been requested by Ecology for the Site. The sample collection and analysis will be performed to supplement the existing Upland Area groundwater investigation. The results will be incorporated into the data for the Upland Area to complete the RI for the Site. The following sections describe the background and sulfide investigation sampling and analysis approach for characterizing H₂S at the Site.



BACKGROUND

Groundwater Analysis for Total Sulfides

In accordance with the Ecology-approved RI/FS Work Plan, analysis for total sulfide was performed on groundwater samples collected from monitoring wells EST01 through EST16, EST18, and EST19 screened within the shallow and deep groundwater units. In addition, total sulfide analysis was also performed at surface water sample locations SW01 and SW02 located northeast and southwest of the Berth 1 Wharf. Detailed information for the Upland Area groundwater investigation including well installation and sampling collection and analysis is presented in the Upland Area Data Report Technical Memorandum (GeoEngineers 2018). Water quality parameters and total sulfide results for groundwater and surface water samples collected in in September 2016 (dry season monitoring event) and March 2017 (wet season monitoring event) are summarized in Table 1. Monitoring wells and surface water locations are shown on Figure 1.

Following completion of the Upland Area groundwater investigation, Ecology required that sulfides in groundwater be compared to a preliminary screening level of 2 micrograms per liter ($\mu\text{g/L}$) for protection of surface water based on Ambient Water Quality Criteria (AWQC) established under Section 304(a)(1) of the Clean Water Act for protection of aquatic life under chronic conditions. The screening level of 2 $\mu\text{g/L}$ is based on the concentration un-ionized H_2S which is the most toxic form of sulfide for aquatic organisms. However, total sulfide analysis completed as part of the Upland Area RI quantifies dissolved sulfides, including H_2S , hydrosulfide ion (HS^-), and disulfide ion (S^{2-}) species, as well as colloidal forms of suspended acid-soluble metallic sulfides. Because evaluation of sulfide against the required screening level requires dissolved sulfide analysis to accurately quantify un-ionized H_2S , and total sulfide analysis was performed to meet the objectives of the RI/FS Work Plan, Ecology determined that a data gap exists for the characterization of sulfides at the Site.

Sulfide Geochemistry

Sulfide is ubiquitous in marine environments as large quantities of H_2S are produced by sulfate-reducing microorganisms to anaerobically degrade organic matter (including wood debris). In solution, an equilibrium exists between H_2S , HS^- , and S^{2-} species where the relative proportion of these species is affected by pH, temperature, and salinity. In general, the relative proportion of S^{2-} constitutes less than 0.05 percent at a pH less than 11. Therefore, the relative proportion of S^{2-} is considered to be negligible in comparison to H_2S and HS^- . Dissolved sulfide (also referred to as total free sulfide) is the sum of H_2S and HS^- (S^{2-} being negligible). In general, the relative proportion of H_2S in solution decreases as pH, temperature and salinity increases.

From an analytical standpoint, sulfides are categorized and quantified by:

- **Total Sulfide** – Total sulfide includes dissolved forms H_2S and HS^- in solution, as well as colloidal forms of suspended acid-soluble metallic sulfides. As noted above, the concentration of S^{2-} is considered to be negligible.
- **Dissolved Sulfide** – Dissolved sulfide includes H_2S and HS^- in solution after procedures are performed to remove colloidal forms of metallic sulfides including filtering or flocculation and settling. However, filtering and flocculation and settling techniques may not remove all colloidal forms of metallic sulfides and therefore, may overestimate the concentration of H_2S and HS^- in solution.

- **Un-ionized H₂S** – Un-ionized H₂S is calculated from the concentration of dissolved sulfide based on pH, temperature, salinity, ionization coefficient and disassociation constant adjusted for seawater (further discussed below).

As stated above, total sulfide analysis using Environmental Protection Agency (EPA) Method 376.1/Standard Method (SM) 4500-S²⁻ quantifies both dissolved H₂S and HS⁻ in solution, as well as the colloidal forms of suspended acid-soluble metallic sulfides and therefore, does not specifically quantify dissolved sulfide. Methods for collection and analysis of dissolved groundwater samples from monitoring wells are well established but the concentration of dissolved sulfide may still be overestimated using these procedures as a result of the presence of colloidal sulfides. In addition, dissolved sulfide analysis on groundwater samples performed using EPA Method 376.1/SM 4500-S²⁻ has a practical quantitation limit (PQL) of between 20 and 50 µg/L which fails to meet the screening level based on the surface water standard of 2 µg/L required by Ecology.

DGT Sample Methodology

The DGT sampling methodology specifically allows dissolved H₂S and HS⁻ in solution to diffuse through a polyacrylamide hydrogel membrane which inhibits the diffusion of colloidal forms of suspended acid-soluble metallic sulfides. Dissolved sulfides which diffuse through this initial membrane react with a secondary silver iodide gel layer to form a solid-phase silver sulfide. This reaction transforms the dissolved sulfide into a stable form, thereby allowing it to be eluted under controlled conditions by the testing laboratory. Because penetration of the colloidal forms of sulfide is limited by the polyacrylamide hydrogel, the resulting sample analysis represents the dissolved sulfide concentration. This methodology is described in Teasdale et al. (1999). A schematic of the DGT sampler assembly is presented as Attachment 1.

DGT samplers are typically deployed over a period of time ranging between approximately 24 and 72 hours. Throughout the sampling period, dissolved sulfide in the media being evaluated (i.e., groundwater, sediment porewater or surface water) continuously reacts with the silver iodide gel. Because the calculated concentration of dissolved sulfide is inversely proportional to the deployment time, longer deployment durations may yield a lower detection limit. However, there is a finite amount of silver iodide gel contained within the DGT sampler in which the dissolved sulfide may react. Prolonged exposure to the media being evaluated may result in the depletion of the silver iodide gel prior to retrieval which would underestimate the dissolved sulfide concentration following analysis.

At the adjacent Kimberly-Clark (K-C) Worldwide Site in Everett, utilization of the DGT sampling methodology with deployment periods of approximately 48 hours were able to achieve a PQL for dissolved sulfide which resulted in a calculated un-ionized H₂S concentrations that meet Ecology's surface water screening criteria (Anchor 2015; Aspect 2015, 2016 and 2018). For the K-C Worldwide Site, water samples for dissolved analysis using EPA Method 376.1/SM 4500-S²⁻ were also collected at DGT sample locations for comparison. The results found that groundwater samples analyzed using EPA Method 376.1/SM 4500-S²⁻ commonly overestimated the concentration of un-ionized H₂S by 2 to 3 orders of magnitude when compared to the DGT sample results.

HYDROGEN SULFIDE INVESTIGATION

Additional sulfide sampling and analysis using the DGT sampling methodology following the approach used for the K-C Worldwide Site (described above) is proposed to characterize un-ionized H₂S concentrations for the Upland Area and screen for exceedances of the H₂S screening level at the point of compliance (where groundwater discharges to surface water) at the former Mill A Site. As indicated above, the DGT passive sampling technique has been demonstrated to be able to quantify un-ionized H₂S concentrations and achieve a PQL that is at or below the Ecology-required screening level. DGT samplers have also been used to sample multiple water media including groundwater, sediment porewater and surface water and is an Ecology-approved method that has been used at the K-C Worldwide Site in Everett as well as other Puget Sound Cleanup projects (e.g., Port Gamble). The DGT sampling methodology is being proposed to meet the following objectives:

- Allow collection of samples from multiple media (i.e., groundwater, sediment porewater and surface water);
- Specifically quantify dissolved sulfide (H₂S and HS⁻);
- Provide a detection limit that is less than the Ecology required screening level for un-ionized H₂S so that a comparison to the surface water criterion can be made; and,
- Evaluate H₂S concentrations at the point of compliance.

The Upland Area Sulfide Investigation will include characterization of dissolved sulfide in groundwater from selected shoreline wells, at locations where groundwater discharges to surface water in the nearshore sediment/surface water interface and in surface water. Dissolved sulfide analysis at these locations will be used to calculate the un-ionized H₂S concentrations (described below) for comparison to the Ecology required screening level.

The following sections provide detail for the Upland Area Sulfide Investigation. DGT sample devices for deployment will be obtained from DGT® Research (<http://www.dgtresearch.com>). The DGT samplers will be preloaded for sulfide measurement and consist of a standard DGT holder containing a 0.6 millimeter (mm) thick silver iodide (AgI) impregnated binding gel layer, overlain by a 0.78 mm thick polyacrylamide diffusive gel, and held in place by a 0.45 micrometer (µm) cellulose nitrate membrane filter.

Shoreline Monitoring Well Sample Collection and Analysis

DGT samplers will be deployed in shoreline monitoring wells EST08, EST09 and EST13 located in the northeast and southwest corners of South Terminal (Figure 1). Based on the results of the December 2016 tidal study completed as part of the RI, average flow gradients suggest that the existing bulkhead is restricting the flow of groundwater to the Marine Area and that discharge to surface water is occurring in the northeast and southwest corners of the South Terminal (i.e., in the vicinity of monitoring wells EST08, EST09 and EST13)¹. The presence of salinity in groundwater at EST08, EST09 and EST13 support the interaction of groundwater with marine surface water at these locations (Table 1). Sample collection and analysis at these shoreline wells will be used to characterize dissolved sulfides and calculate un-ionized

¹ A detailed summary of the December 2016 tidal study is presented in the Upland Area Remedial Investigation Data Report Technical Memorandum (GeoEngineers, 2018).



H₂S concentrations in groundwater immediately upgradient of the groundwater/surface water interface at the Site.

At well locations EST08, EST09 and EST13, a DGT sampler will be lowered on a cord and securely attached to the top of the well casing. Within each monitoring well, the DGT sampler will be positioned at a depth of approximately 1 to 2 feet above the base of the screened interval so that the sampler remains submerged throughout the sampling duration of approximately 48 hours. Upon retrieval, the DGT sampler will be removed from the monitoring well and rinsed with deionized water, sealed in a clean plastic bag, and transported to Analytical Resources, Inc. (ARI) of Seattle, Washington, in a cooler with ice under chain-of-custody for analysis. Laboratory analysis and calculation of H₂S concentrations are described below.

Prior to DGT sample deployment, each monitoring well will be purged using a peristaltic pump and polyethylene tubing. Groundwater will be pumped from each well at a rate not to exceed 0.5 liter per minute to minimize drawdown. The base of the tubing (i.e., intake) will be positioned at the approximate deployment depth of the DGT sampler. The following groundwater parameters will be recorded every 5 minutes on a field log until the water quality parameters vary by less than 10 percent on three consecutive measurements:

- Electrical conductivity (EC),
- Dissolved oxygen (DO),
- pH,
- Total dissolved solids (TDS),
- Oxygen reduction potential (ORP),
- Turbidity,
- Salinity, and
- Temperature.

Once the water quality parameters have stabilized, the DGT sampler will be placed in the well. At the time of DGT sampler deployment, a water quality datalogger (AquaTROLL 600 or similar) will be lowered into the well on a cord and securely attached to the top of the well casing so that the datalogger sensor is positioned at an elevation just above the DGT sampler. The datalogger will be set to collect pH, temperature and salinity readings at continuous 15-minute interval. Water quality parameters measured during the DGT deployment period will be averaged for use in calculating un-ionized H₂S at each monitoring location.

Reusable sampling equipment that comes in contact with groundwater will be decontaminated before each use. Decontamination procedures for this equipment are described in the Upland Area SAP (GeoEngineers 2014b). Purge and decontamination water generated during groundwater monitoring activities will be placed in labeled 30-gallon or 55-gallon drums. The drums will be sealed and temporarily stored at the Site in a secure location pending permitted off-site disposal. Incidental waste generated during sampling activities such as gloves, plastic sheeting, paper towels and similar expended and discarded field supplies will be disposed of at local trash receptacle or county disposal facility.

Porewater Sample Collection and Analysis

On July 11, 2018, a low tide survey of the shoreline area was completed to identify seep areas and potential DGT sample locations. Observations made with Ecology during the July 11, 2018 Site visit identified three general areas where seeps were present on the shoreline on the southwest portion of the South Terminal. Based on observations made during the low tide survey, sample stations PW01 through PW03 (Figure 1) were identified as locations for sample collection and analysis of porewater at the sediment/surface water interface to characterize dissolved sulfides and calculate un-ionized H₂S concentrations in water at the point of compliance for groundwater discharging to surface water. Porewater sample locations were selected based on visible evidence of water seepage from point or diffuse areas exceeding approximately 5-gallons per minute (gpm). In addition, sample locations were selected based on the general absence of accumulated wood debris (sawdust, bark and/or wood chips) below the mudline surface (i.e., deployment depth of the DGT sampler) that could potentially influence the DGT sample results. From previous investigation results, buried wood debris were not observed in this portion of the Site. If buried wood debris is encountered during deployment, the DGT sampler will be repositioned with the proposed sample area so that the sampler is not in contact with the buried wood.

At each station, a DGT sampler will be positioned in the intertidal sediment at depth interval between approximately 4 and 6 cm below the mudline to characterize porewater. The DGT samplers will be deployed during a low tide and secured to a stake that will be used to mark their location and hold the sampler in place. The DGT samplers will be deployed for approximately 48 hours, after which they will be retrieved at a low tide. Upon retrieval, the DGT sampler will be removed from the sediment and rinsed with deionized water, sealed in a clean plastic bag, and transported to ARI in a cooler with ice under chain-of-custody for analysis.

Measurement of water quality parameters will be performed during DGT sample deployment using an AquaTROLL 600 (or similar) datalogger deployed in a temporary, shallow piezometer located at each of the sample stations (i.e., PW01 through PW03). The datalogger sensor will be positioned at the same approximate elevation as the DGT sampler. The datalogger will be set to collect pH, temperature and salinity readings continuously at 15-minute intervals. Water quality parameters measured during the DGT deployment period will be averaged for use in calculating un-ionized H₂S at each monitoring location.

Reusable sampling equipment that comes in contact with the porewater at each location will be decontaminated before each use. Decontamination procedures for this equipment are described in the Upland Area SAP (GeoEngineers 2014b). Decontamination water generated during porewater monitoring activities will be placed in labeled 30-gallon or 55-gallon drums. The drums will be sealed and temporarily stored at the Site in a secure location pending permitted off-site disposal. Incidental waste generated during sampling activities such as gloves, plastic sheeting, paper towels and similar expended and discarded field supplies will be disposed of at local trash receptacle or county disposal facility.

Surface Water Sample Collection and Analysis

In addition to groundwater and porewater sample collection and analysis, a DGT sampler will be deployed at surface water sampling location SW02 (Figure 1) to characterize dissolved sulfides and calculate un-ionized H₂S concentrations in surface water adjacent to the Upland Area. At surface water sampling location SW02, a DGT sampler will be lowered on a cord and securely attached to the top of the mooring dolphin. The base of the cord will be weighted to hold the DGT sampler in place at a depth of approximately

1 to 2 feet above the mudline surface to ensure that the sampler is submerged throughout the sampling duration of deployment period (approximately 48 to 72 hours). Upon retrieval, the DGT sampler will be removed from the surface water and rinsed with deionized water, sealed in a clean plastic bag, and transported to ARI in a cooler with ice under chain-of-custody for analysis.

Measurement of water quality parameters will be performed during DGT sample deployment using an AquaTROLL 600 (or similar) datalogger. The datalogger sensor will be positioned at the same approximate elevation as the DGT sampler. The datalogger will be set to collect pH, temperature and salinity readings continuously at 15-minute intervals. Water quality parameters measured during the DGT deployment period will be averaged for use in calculating un-ionized H₂S for the surface water sample location.

Incidental waste generated during sampling activities such as gloves, plastic sheeting, paper towels and similar expended and discarded field supplies will be disposed of at local trash receptacle or county disposal facility.

Laboratory Analysis and Sulfide Calculation

DGT samples will be submitted to ARI for acid volatile sulfide analysis by EPA Method 1991. The accumulated sulfide mass extracted from the silver iodide gel will be used to calculate the dissolved sulfide concentration. This calculation is based on diffusive flux relationships and Fick's first law of diffusion as follows:

$$C_{DGT} = (F \cdot \Delta g) / D = (M \cdot \Delta g) / (D \cdot A \cdot t)$$

Where:

C_{DGT} = dissolved sulfide concentration (mg/L)

F = Flux (mg/cm²·s)

M = mass (μmol)

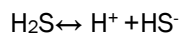
A = area of sample window (cm²)

T = time of sampler deployment (sec)

D = Sulfide Diffusion Coefficient (cm²/sec)

Δg = thickness of the polyacrylamide hydrogel membrane (cm)

As previously noted, H₂S and HS⁻ together constitute dissolved sulfide concentration (S²⁻ being negligible) and are in equilibrium with hydrogen ions:



The fraction of dissolved sulfide present as un-ionized H₂S can then be calculated based on ionic strength (A and B), dissociation constant for freshwater (pK₁) adjusted for salinity (pK'₁), ionization constant (K'₁) and ion activity of H₂S (α_{H₂S}) as follows:

$$A = -0.2391 + 35.685/T$$

$$B = 0.019 - 0.3776/T$$

$$pK_1 = 32.55 + 1519.44/T - 15.672 \text{ Log}_{10}T + 0.02722T \quad pK'_1 = pK_1 + A\sqrt{S} + BS$$

$$K'_1 = 10^{pH - pK'_1}$$

$$\alpha_{H_2S} = 1 / (K'_1 + 1)$$

$$C_{H_2S} = \alpha_{H_2S} \cdot C_{DGT}$$

Where:

T = temperature in degrees Kelvin (°K)

°K = °C + 273.15

°C = field measured water temperature in degrees Celsius

S = field measured water salinity in parts per thousand (ppt)

C_{DGT} = dissolved sulfide concentration (mg/L)

C_{H₂S} = un-ionized H₂S concentration (mg/L)

DATA VALIDATION

The sampling design, field procedures, laboratory procedures, and quality control (QC) procedures established for this project were developed to provide defensible data. Specific factors that may affect data usability include quantitative factors (precision, bias, accuracy, completeness, and reporting limits) and qualitative factors such as representativeness and comparability. The data quality objectives (DQOs) associated with the Site are detailed in the Upland Area SAP (Attachment 1 of the RI/FS Work Plan). QC procedures and acceptance criteria for the dissolved sulfide analysis that will be used for the additional Upland Area sulfide investigation are summarized in Table 2.

Laboratory data will undergo an EPA-defined Stage 2B data validation (EPA Document 540-R-08-005; EPA 2009) and will include review of the following QC elements:

- Data Package Completeness
- Chain-of-Custody Documentation
- Holding Times and Sample Preservation
- Surrogate Recoveries
- Initial Calibrations
- Initial Calibration and Continuing Calibration Verification
- Initial and Continuing Calibration Blanks
- Method Blanks
- Laboratory Control Samples/Laboratory Control Sample Duplicates
- Laboratory and Field Duplicates
- Reporting Limits

REPORTING

Upon completion, DGT sampling activities and laboratory results will be transmitted to Ecology to confirm that data gaps have been filled prior to preparing the RI/FS. The complete RI data set will be presented in the RI/FS report. The analytical data for groundwater, sediment porewater and surface water samples will be submitted to Ecology in electronic format in accordance with Ecology's Environmental Information Management (EIM) Policy 840 following review and validation.

SCHEDULE

DGT sampling and analysis described in this addendum will be performed following Ecology approval of this Work Plan addendum. Sulfide investigation activities are anticipated to be performed between August and September 2018 during a low tide window that will allow access to the proposed shoreline porewater sample locations for deployment and retrieval of the DGT samplers and water quality dataloggers.

LIMITATIONS

This report has been prepared for the exclusive use of the Port of Everett, their authorized agents and regulatory agencies in their evaluation of the Weyerhaeuser Mill A Former Site in Everett, Washington. No other party may rely on the product of our services unless we agree in advance and in writing to such reliance.

Any electronic form, facsimile or hard copy of the original document (email, text, table, and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, Inc. and will serve as the official document of record.

REFERENCES

- Anchor QEA (Anchor), 2015. Supplemental Porewater Sulfide Sampling and Analysis, K-C Worldwide Upland Area in Everett, Washington. Prepared for the Washington State Department of Ecology on behalf of Kimberly-Clark Corporation. April 2, 2105
- Aspect (Aspect Consulting), 2015. Plan for Supplemental Sampling and Analysis of Sulfide in Intertidal Porewater Kimberly-Clark Worldwide Site, Everett, Washington. Prepared for the Washington State Department of Ecology on behalf of Kimberly-Clark Corporation. February 13, 2015.
- Aspect Consulting (Aspect), 2016. RI/FS Work Plan Addendum: Additional Evaluation of Quality of Seep Water Discharging Along Shoreline, Kimberly-Clark Worldwide Site Upland Area RI/FS, Everett, Washington. Prepared for the Washington Department of Ecology on behalf of Kimberly-Clark Corporation. October 14, 2016.
- Aspect Consulting (Aspect), 2018. DRAFT - Shoreline Un-ionized Ammonia and Hydrogen Sulfide Cleanup Approach: Kimberly-Clark Worldwide Site, Everett, Washington. Prepared for the Washington Department of Ecology on behalf of Kimberly-Clark Corporation. January 9, 2018.
- GeoEngineers, 2018. Draft Dredged Material Characterization Sampling and Analysis Plan, South Terminal Maintenance Dredge Project, Weyerhaeuser Mill A Former Site, Everett, Washington, Prepared for the Dredged Material management Office on behalf of the Port of Everett, July 18, 2018.
- GeoEngineers, 2014a. Marine Area Remedial Investigation Sampling and Analysis Plan. Weyerhaeuser Former Mill A Site, Everett, Washington. Prepared for the Washington Department of Ecology on behalf of the Port of Everett, Weyerhaeuser Company, and Washington State Department of Natural Resources. October 16, 2014.

GeoEngineers, 2014b. Remedial Investigation and Feasibility Study Work Plan. Weyerhaeuser Former Mill A Site, Everett, Washington. Prepared for the Washington Department of Ecology on behalf of the Port of Everett, Weyerhaeuser Company, and Washington State Department of Natural Resources. October 16, 2014.

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

Attachments:

Table 1. Summary of Water Quality Parameters and Total Sulfide Data

Table 2. Quality Control Procedures and Acceptance Criteria for Sulfide Analysis

Figure 1. Proposed Sulfide Investigation Sample Locations

Attachment 1 - DGT Schematic

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Table 1
Summary of Water Quality Parameters and Total Sulfide Data
Weyerhaeuser Mill A Former Site
Everett, Washington

Monitoring Well ¹	Sample Identification	Sample Date	Field Measured Parameters										Total Sulfide ³ (µg/L)	
			Top of Casing Elevation ² (feet)	Depth to Groundwater (feet)	Groundwater Elevation (feet)	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Dissolved Solids (mg/L)	Oxidation Reduction Potential (mV)		Salinity (ppt)
South Terminal Area Monitoring Wells														
EST01	EST01_092916	09/29/16	20.13	11.25	8.88	6.37	0.79	12	0.20	19.8	0.58	-117.9	0.44	70
	EST01_03272017	03/27/17	20.13	9.29	10.84	6.39	0.55	2.67	0.71	10.6	0.49	-32.3	0.37	50 U
EST02	EST02_092916	09/29/16	20.03	11.1	8.93	6.15	1.21	16.8	0.16	19.0	0.89	-126.3	0.68	298
	EST02_03272017	03/27/17	20.03	10.03	10	6.1	1.64	5.21	6.16	12.2	1.42	-32.6	1.12	50 U
EST03	EST03_092816	09/28/16	21.89	11.81	10.08	6.18	0.90	17.1	0.21	18.6	0.69	-113.8	0.52	96
	EST03_03242017	03/24/17	21.89	10.98	10.91	5.97	0.49	5.01	0.62	13.3	0.41	-1.2	0.31	110
EST04	EST04_092816	09/28/16	19.92	9.69	10.23	10.92	1.98	77.1	0.11	18.8	1.46	-338.3	1.16	4,130
	EST04_03282017	03/28/17	19.92	8.92	11	10.38	1.44	33.8	0.31	12.0	1.27	-220.2	0.99	3,710
EST05	EST05_093016	09/30/16	21.63	12.56	9.07	6.68	0.89	10.8	0.91	17.5	0.69	-104.2	0.51	73
	EST05_03242017	03/24/17	21.63	10.96	10.67	6.23	0.74	5.01	0.37	12.5	0.63	-54.6	0.48	63
EST06	EST06_092616	09/28/16	19.75	9.94	9.81	6.37	0.81	4.25	0.19	16.9	0.62	-116.7	0.47	169
	EST06_03292017	03/29/17	19.75	8.68	11.07	6.28	0.59	2.47	0.59	13.1	0.49	-63.2	0.39	119
EST07	EST07_092616	09/26/16	18.65	8.81	9.84	6.47	0.63	14.7	0.18	18.0	0.47	-118.6	0.35	351
	EST07_03292017	03/29/17	18.65	7.68	10.97	6.52	0.78	6.29	1.01	12.7	0.66	-72.1	0.50	400
EST08	EST08_092616	09/26/16	16.9	7.91	8.99	6.81	15.77	3.05	0.24	19.1	11.56	-149.2	10.53	3,960
	EST08_03302017	03/31/17	16.9	6.82	10.08	7.05	6.79	1.21	0.98	11.4	5.95	-128.7	5.15	101
EST08D	EST08D_092616	09/26/16	17.03	8.58	8.45	6.63	1.28	3.81	0.23	15.1	1.03	-73.8	0.80	50 U
	EST08D_03302017	03/31/17	17.03	8.15	8.88	6.58	1.06	1.29	0.29	14.3	0.88	-78.5	0.67	162
EST09	EST09_092816	09/29/16	17.56	17.22	0.34	7.17	35.01	4.5	1.59	14.9	28.18	39.7	27.97	50 U
	EST09_03282017	03/28/17	17.56	8.67	8.89	6.54	16.84	2.29	2.01	7.9	16.28	-199.4	15.15	7,230
EST10	EST10_092916	09/29/16	17.14	7.94	9.2	6.31	7.23	8.21	0.16	17.2	5.66	-301.6	4.90	19,400
	EST10_03282017	03/28/17	17.14	6.92	10.22	6.35	5.05	4.52	6.98	10.7	4.51	-362.8	3.85	30,300
EST10D	EST10D_101016	10/10/16	17.88	19.64	-1.76	6.51	1,899	14.2	0.33	13.3	1,592.5	20.5	1.27	194
	EST10D_03282017	03/28/17	17.88	8.91	8.97	6.32	3.28	4.81	4.13	12.7	2.79	-82.6	2.29	117
EST11	EST11_101016	10/10/16	17.19	7.69	9.5	6.32	904.00	3.56	0.44	17.5	682.50	4.2	0.52	50 U
	EST11_03292017	03/29/17	17.19	6.41	10.78	6.17	0.80	2.06	1.09	12.4	0.69	-80.2	0.53	64
EST11D	EST11D_102116	10/21/16	17.22	8.33	8.89	6.4	1.10	9.89	0.08	14.3	0.90	-63.7	0.70	50 U
	EST11D_03292017	03/29/17	17.22	7.28	9.94	6.16	1.04	1.34	0.32	13.8	0.85	-65.7	0.66	50 U
EST12	EST12_092816	09/28/16	17.39	8.52	8.87	6.55	1.79	1.34	0.32	19.8	1.30	-118.2	1.02	50 U
	DUP01_092816	09/28/16	17.39	8.52	8.87	6.55	1.79	1.34	0.32	19.8	1.30	-118.2	1.02	--
	EST12_03302017	03/24/17	17.39	7.12	10.27	6.43	0.64	1.44	6.72	10.2	0.59	-103.7	0.45	125
	DUP01_03302017	03/24/17	17.39	7.12	10.27	6.43	0.64	1.44	6.72	10.2	0.59	-103.7	0.45	134
EST13	EST13_092716	09/27/16	17.36	14.06	3.3	8.03	32.35	5.32	0.33	15.4	25.84	-296.5	25.26	9260
	EST13_04032017	04/03/17	17.36	14.32	3.04	7.98	24.58	9.02	3.42	12.1	21.26	-261.4	20.41	24,500
EST14	EST14_093016	09/30/16	18.05	10.79	7.26	6.91	24.12	1.03	5.67	15.0	19.33	102.7	18.51	50 U
	EST14_03302017	03/30/17	18.05	12.01	6.04	6.94	19.81	1.22	7.85	11.8	17.23	-6.2	16.23	50 U

Monitoring Well ¹	Sample Identification	Sample Date	Field Measured Parameters										Total Sulfide ³ (µg/L)	
			Top of Casing Elevation ² (feet)	Depth to Groundwater (feet)	Groundwater Elevation (feet)	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Dissolved Solids (mg/L)	Oxidation Reduction Potential (mV)		Salinity (ppt)
EST15	EST15_092816	09/28/16	21.59	11.62	9.97	7.04	1.22	8.24	0.98	17.8	0.93	-160.8	0.71	50 U
	DUP02_092816	09/28/16	21.59	11.62	9.97	7.04	1.22	8.24	0.98	17.8	0.93	-160.8	0.71	--
	EST15_03242017	03/24/17	21.59	10.46	11.13	6.78	1.06	7.31	6.27	11.0	0.92	-80.2	0.72	50 U
	DUP02_03242017	03/24/17	21.59	10.46	11.13	6.78	1.06	7.31	6.27	11.0	0.92	-80.2	0.72	50 U
EST16	EST16_092716	09/27/16	20.77	11.51	9.26	6.53	0.66	13.9	0.25	14.8	0.53	-109.4	0.40	66
	EST16_04032017	04/03/17	20.77	10.33	10.44	6.68	0.82	3.15	0.26	12.9	0.69	-122.8	0.53	61
EST18	EST18_092916	09/29/16	17.63	10.64	6.99	6.3	5.89	0.67	0.32	16.6	4.59	28.4	3.91	50 U
	EST18_03302017	03/31/17	17.63	9.13	8.5	6.31	3.52	4.89	0.45	12.2	3.20	-20.8	2.58	50 U
EST19	EST19_101016	10/10/16	17.56	11.67	5.89	7.1	20.80	9.8	1.74	15.1	16,614	248.8	15.63	50 U
	EST19_03302017	03/30/17	17.56	8.76	8.8	7.09	20.05	2.47	3.84	10.2	18.09	-7.2	17.04	50 U
EST20	EST20_092716	09/27/16	20.36	10.35	10.01	6.44	0.83	5.02	0.21	20.1	0.59	-129.2	0.48	65
	EST20_03242017	03/24/17	20.36	9.01	11.35	6.03	0.64	4.19	1.38	12.3	0.55	-28.2	0.42	97
Pacific Terminal Area Monitoring Wells														
MW01	MW01_093016	09/30/16	20.36	13.32	7.04	7.2	32.00	1.23	0.77	16.0	24	32.5	23.52	--
	MW01_03272107	03/27/17	20.36	10.05	10.31	7.24	19.51	2.09	3.56	11.6	17.19	42.3	16.19	--
MW-02	MW02_093016	09/30/16	18.19	15.2	2.99	7.26	35.90	2.89	0.78	14.9	29	-30.2	28.79	--
	MW02_03272107	03/27/17	18.19	14.91	3.28	7.24	25.38	2.01	0.82	10.1	23.06	16.7	22.27	--
Surface Water Monitoring Locations														
SW01	SW01_093016	09/30/16	n/a	--	9.5 ⁴	8.27	36.02	8.2	8.90	14.3	29	32.7	29.33	50 U
	SW01_03302017	03/30/17	n/a	--	11 ⁴	7.51	23.12	19.7	9.98	9.1	21.47	-32.9	20.56	50 U
SW02	SW02_093016	09/30/16	n/a	--	10 ⁴	8.05	36.46	7.82	8.61	14.7	29	36.8	29.52	50 U
	SW02_03302017	03/30/17	n/a	--	11.25 ⁴	7.81	23.65	10.9	8.86	9.2	21.74	-34.4	21.09	50 U

Notes:

- ¹ Monitoring well locations are shown on Figure 1.
- ² Elevations referenced to mean lower low water (MLLW) from Metron and Associates Inc. October 2016 survey.
- ³ Conventional by EPA Method 376.1/SM-4500-S²⁻ (µg/L)
- ⁴ Elevations referenced to MLLW from Walker and Associates March 2009 Survey.
- = not analyzed
- C = Celsius
- mg/L = milligram per liter
- µg/L = microgram per liter
- mS/cm = millisiemens per centimeter
- mV = millivolt
- NTU = Nephelometric Turbidity Unit
- ppt = parts per thousand
- U = The analyte was not detected at a concentration greater than the value identified.

Table 2
Quality Control Procedures and Acceptance Criteria for DGT Sulfide Analysis¹
Weyerhaeuser Mill A Former Site
Everett, Washington

Quality Control Procedure	Frequency	Control Limit	Corrective Action
Instrument Quality Assurance/Quality Control			
Initial Calibration	Daily (each analytical run)	Coefficient of determination(r^2) greater than 0.990 (correlation coefficient $r > 0.995$)	Laboratory to optimize and recalibrate the instrument and reanalyze any affected samples.
Initial Calibration Blank (ICB)	Immediately after initial calibration	Analyte concentration \leq PQL.	Laboratory to resolve discrepancy prior to sample analysis.
Initial Calibration Verification (ICV)	Immediately after initial calibration and initial calibration blank.	90-110%	Laboratory to resolve discrepancy prior to sample analysis.
Continuing Calibration Blanks (CCB)	Immediately after initial calibration, after each 10 samples, and after the last sample in the analytical sequence.	Analyte concentration \leq PQL.	Laboratory to recalibrate and reanalyze affected samples
Continuing Calibration Verification (CCV)	Immediately after initial calibration, after each 10 samples, and after the last sample in the analytical sequence.	90-110%	Laboratory to recalibrate and reanalyze affected samples.
Method Quality Assurance/Quality Control			
Holding Times	All samples.	7 days	Laboratory to qualify results if holding times are exceeded. Data validator will use professional judgment to qualify results as part of data validation.
Method Detection Limits (MDL)	Update method detection limit studies per laboratory schedule	Following 40 CFR or the EPA MDL Revision 2	Revise detection limits as needed
Method Blanks	With every sample batch or every 20 samples, whichever is more frequent.	Analyte concentration \leq PQL. Control limits are not applicable if sample concentrations are $<$ MDL	Qualify data with a "B" flag.
Quality Control Procedure	Frequency	Control Limit	Corrective Action

Laboratory Control (LCS/LCSD)	One pair per sampling event of 20 or less samples; laboratory will prepare a spiked DGT pair that is submersed in a spiked solution for a period equivalent to the time field DGTs are deployed.	50-150%	Laboratory to qualify results if LCS/LCSD outside control limit. Data validator will use professional judgment to qualify results as part of data validation.
Field Quality Assurance/Quality Control			
Field Duplicates	One per every ten groundwater and sediment porewater samples.	50-150%	Modify field sampling procedures for duplicates.
Field Blanks	With every sample batch or every 20 samples, whichever is more frequent.	Analyte concentration \leq PQL	Compare to method blank results to evaluate contamination from field activities. Modify sample collection procedures. Data validator will use professional judgment to qualify results as part of data validation.

Notes:

¹ Instrument and method QA/QC to monitor the performance of the instrument and sample preparation procedures are the responsibility of the analytical laboratory. When an instrument or method control limit is exceeded, the laboratory is responsible for correcting the problem and reanalyzing the samples.

MDL = method detection limit

PQL = practical quantification limit

EPA = Environmental Protection Agency

CFR = Code of Federal Regulations

DGT = diffusive-gradients-in-thin-film



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Notes:

- The locations of all features shown are approximate.
- This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

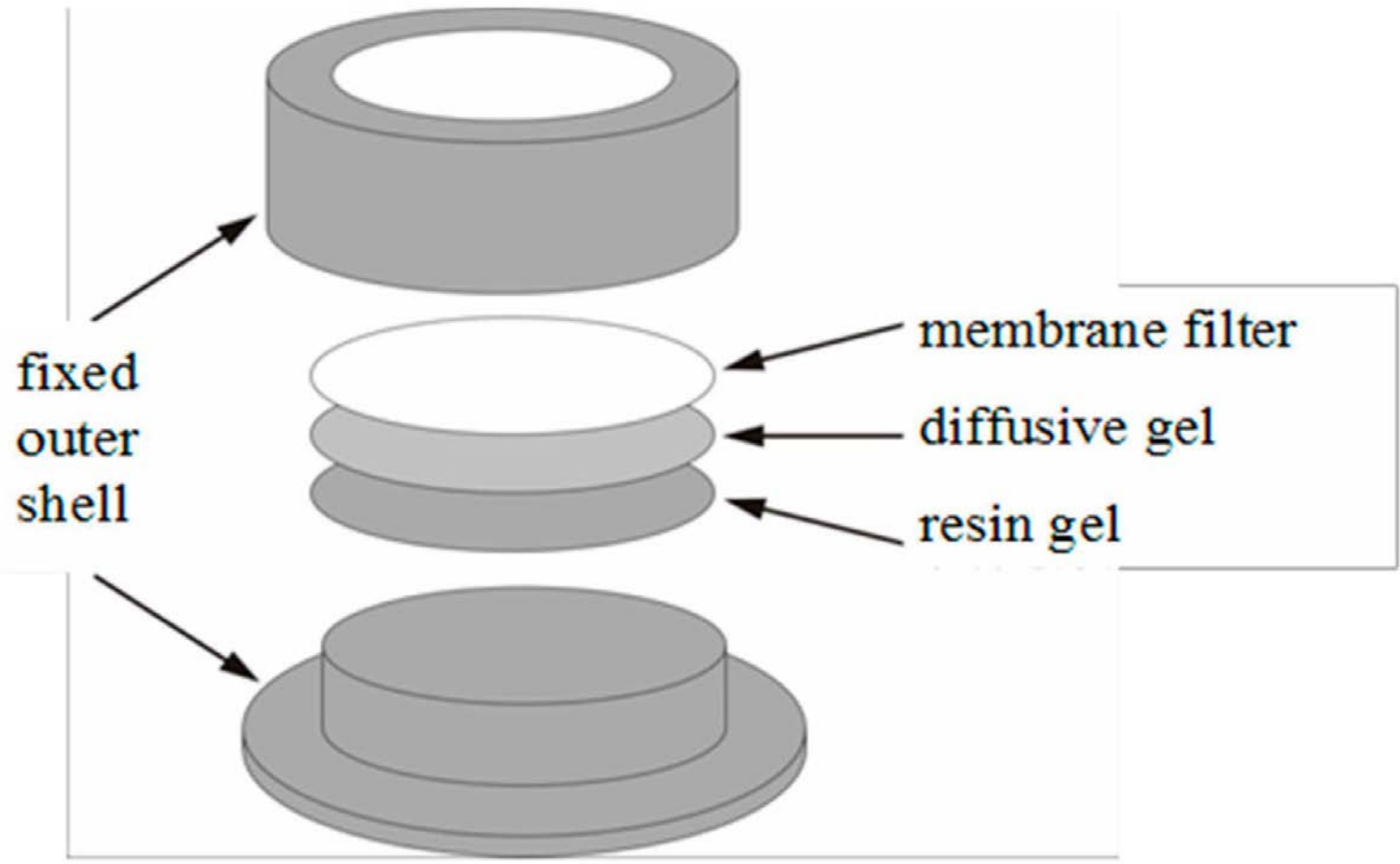
Data Source: Base aerial from Bing Maps, 2011.
 Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet


Legend	
	Shallow Soil Boring/Monitoring Well
	Deep Soil Boring/Monitoring Well
	Piezometer
	Surface Water Sample Location
	Soil Boring
	Decommissioned Monitoring Well
	Proposed Diffusive Gradient Thin Film (DGT) Sampling Location
	Groundwater Elevation Contour, Dashed Where Inferred
	10.72 Shallow Monitoring Well Groundwater Elevation (ft MLLW)
	9.65 Deep Monitoring Well Groundwater Elevation (ft MLLW)
	Construction Berm Fill
	Historical Pier
	Nearshore Confined Disposal (NCD) Facility
	Bulkhead
	Open Space
	Equipment Storage Area (Bone Yard)
	Construction Berm Fill
	Historical Industrial Outfall
	Former Combined Sewer Outfall (CSO)
	Former Stormwater Outfall
	Current CSO
	Current Stormwater Outfall
	Current Kimberly-Clark/City of Everett/City of Marysville Outfall 100 (Approximate)
	Current Kimberly-Clark/Weyerhaeuser Outfall SW001 (Approximate)
	Diffuse Seepage Area
	Point Seepage Area

Proposed Sulfide Investigation Sampling Locations	
Weyerhaeuser Mill A Former Everett, Washington	
	Figure 1

ATTACHMENT 1
DGT Schematic





DGT Schematic	
Weyerhaeuser Mill A Former Everett, Washington	
GEOENGINEERS 	Attachment 1