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State of Washington

Quality Assurance Project Plan

Little Squalicum Creek Estuary Soil and Groundwater Characterization

September 2012

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Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. 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.

The plan for this study is available on Ecology's website at
https://fortress.wa.gov/ecy/publications/SummaryPages/1203122.html

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, CHPI005

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NWRO: Northwest Regional Office
EAP: Environmental Assessment Program
EIM: Environmental Information Management database

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Abstract

A design proposal has been developed by the City of Bellingham, Washington to excavate and re-grade the southern portion of a city park (Little Squalicum Park) to create an estuarine embayment connected to Bellingham Bay. The proposed estuary would enhance the shoreline habitat of the bay, a benefit consistent with the strategic goals of the Bellingham Bay Demonstration Pilot Project.

The proposed estuary is located hydraulically downgradient of the Oeser Superfund site, which is being remediated under the oversight of the Region 10 office of the U.S. EPA (EPA). Wood-preserving contaminants associated with the Oeser facility have been identified in soils and groundwater in an area of the park that is immediately upgradient of the proposed estuary. Test-pit excavations within the estuary footprint have also revealed the presence of a limited amount of petroleum contamination (identified as diesel) in shallow soils and groundwater, although the origin and extent of this contamination is unclear.

The goal of the project described in this work plan is to conduct reconnaissance sampling and mapping of soil and groundwater conditions within and beneath the proposed estuary excavation in order to better characterize the presence and extent of chemical contamination. Sampling will be conducted using direct-push drilling techniques. It will focus on characterizing conditions both above and immediately below the design topographic surface of the proposed estuary. This information will help interested stakeholders judge the feasibility and potential costs of the estuary project, and determine if soils excavated during construction of the estuary are likely to require special handling and disposal.

Background

Little Squalicum Park is located in the northwestern portion of Bellingham, Washington (Figure 1). The 21-acre public park is comprised of two areas, one northeast of Marine Drive (the "upper" park), and one southwest of Marine Drive (the "lower" park). Little Squalicum Creek flows south-southwest through the park, ultimately discharging to Bellingham Bay. Creek flow (~1-10 CFS wet season) is largely sustained by groundwater springs and storm runoff from adjacent properties (Integral, 2008; E&E, 2002). The park is bordered by residential neighborhoods, industrial facilities, and a technical college.

The City of Bellingham has developed a proposal to excavate and re-grade portions of the lower park (Figure 1) to create an approximately 2-acre estuary, with the goal of enhancing the shoreline habitat of Bellingham Bay (approximately 28,000 cubic yard excavation volume).

Coastal Geologic Services (CGS), under contract with the City of Bellingham, prepared a final design document describing the construction elements of the proposed estuary, including the final surface topography of the embayment (CGS, 2010). During the course of geotechnical investigations related to the estuary design, field observations of petroleum contamination in shallow test-pit soils were reported by CGS near the northern end of the proposed estuary footprint (interpreted as diesel contamination, on the basis of odor). CGS recommended further investigation to determine the full extent of the contamination.

In August of 2010, during remedial investigation activities associated with the offsite migration of wood preserving contaminants from the Oeser Superfund site (Figure 1), an EPA Region 10 contractor completed 11 additional shallow soil test-pit excavations and follow-up field screening (olfactory observations, sheen tests, head-space tests) to delineate the extent of the petroleum contamination encountered by CGS (E&E, 2010; CH2M Hill, 2011). While no samples were submitted for laboratory analysis during this effort, E&E concluded that the extent of the petroleum contamination (again interpreted as diesel) was limited to a comparatively small (~3500 ft^2) area in the north-central portion of the lower park (E&E, 2010). These findings were consistent with those reported by Herrenkohl (2009).

The study area is hydraulically downgradient of the Oeser Superfund site (Figure 1). The Oeser Company has manufactured and treated utility poles at their facility since the mid 1940s. Treatment methods for poles included oil treatment using creosote and treatment using a 5% pentachlorophenol (PCP) oil-based (Diesel No. 2) solvent mix.

Wood preserving chemicals [polycyclic aromatic hydrocarbons (PAHs) and PCP] transported from the Oeser facility via stormwater drainage and groundwater flow have been identified in soil and groundwater samples collected and analyzed from the upper portion of the park (Integral, 2008). Although remediation activities conducted under the direction of the EPA during 2010 and 2011 resulted in the removal of most of this contamination (CH2M Hill, 2011), Herrenkohl (2010a; 2010b; 2011) reported concerns that obvious creosote contamination remained at depth in the southern portion of the upper park, possibly associated with a breach in a site-wide low permeability clay unit. Additional Oeser-related contamination was identified and remediated in the channel of Little Squalicum Creek in the lower park area during this same period (CH2M Hill, 2011).

The study area was used for a variety of industrial or commercial purposes in the past, including sand and gravel mining operations during the 1920s to 1960s, and raw log storage in the early 1970s by the Mt. Baker Plywood company. Herrenkohl (2009) also reported the existence of an asphalt-batch plant in the vicinity of the lower park in the 1930s. A variety of alterations to the physical state of the property have been made over time, including rerouting of the creek channel and changes to the site topography and lithology (excavations, backfilling and landfilling, road development, etc.). The property was converted to a public park beginning in the mid to late 1970s.

A landfill used for the burial of local municipal waste (Eldridge Municipal Landfill) was also operated in the upper park in the 1930s (Figure 1) (Integral, 2008; Landau, 1993; Herrenkohl et al., 2011). In 2011, an interim cleanup action was conducted by the City of Bellingham at the landfill, under the terms of an agreed order with the Washington State Department of Ecology (Ecology). Approximately 4300 tons of landfill debris and contaminated soil were removed from the area during this effort (Herrenkohl et al., 2011). In mid-2012, a follow-up sampling effort was conducted to determine the extent of any remaining contamination, with a focus on metals, PAHs, and PCP.

In association with remediation of contaminated sediments within the channel of Little Squalicum Creek, a portion of the proposed estuary excavation was logged, cleared, graded, and re-seeded with grass during 2010-2011 (Figure 2). The remainder of the estuary footprint is currently forested.

Study Area

The study area of this project is in Water Resource Inventory Area (WRIA) 1. The Hydrologic Unit Code (HUC) number is 1711004.

Study Area Hydrogeology

Previous remedial investigations conducted in association with the Oeser Superfund site have detailed the geologic and hydrogeologic conditions in the upper portion of the park. Borings completed during this work have revealed a stratified, variably distributed sequence of unconsolidated, Quaternary-age alluvial, glacial, and interglacial sediments (clays, silts, sands, gravels, peat deposits). Integral (2008) distinguished three primary geologic units in this area. A discontinuous surficial sand and gravel unit is underlain by a low permeability gray clay unit of varying thickness (0.1 to over 6 ft.) which, in turn, is underlain by a laterally continuous silty sand to clean sand unit. A detailed description of the subsurface geology of the upper park is presented in Integral (2008).

Subsurface conditions in the proposed estuary area are less well understood at this time, particularly at depth. A number of shallow excavations have been completed throughout the study area in the past 20 years, but all of these test pits have been focused in the upper 5 to 7 feet of site sediments (Landau, 1993; Integral, 2008; CGS, 2010). The native sediments encountered during these investigations (unconsolidated silts, sands, and gravels) are generally consistent with those described further to the north. Fill and compact fill has also been described in the upper 2 to 3 feet at some locations within the study area, including reworked, medium-dense to dense silts, sands, gravels and occasional cobbles, as well as metal, glass, ash, and wood debris. It is unknown if the gray clay unit observed in the upper park extends south to the area of the proposed estuary. Boring and test pits installed as part of the Little Squalicum Park remedial investigation did not encounter the clay unit in this area of the site.

The groundwater flow direction in the park within the uppermost aquifer is south-southwest towards Bellingham Bay, although some groundwater in the lower park may discharge to Little Squalicum Creek prior to reaching the marine shoreline (Integral, 2008; CH2M Hill, 2011). Depth to groundwater beneath the study area has been reported during test-pit excavations and borings to vary between approximately 1 to 5 feet below ground surface, depending on local topography.

Historic and Cultural Resources

An archaeological site survey was conducted in 2005 as part of the remedial investigation of the Little Squalicum Park cleanup site (Integral, 2008). One archeological resource was identified near the project area, a shell midden deposit located on the west side of Little Squalicum Creek in the lower park (Figure 1). The remainder of the area is characterized as an extensively disturbed landscape mostly due to historic sand and gravel mining activities. As a result the remaining deposits in these areas are believed to have virtually no prospect to contain potentially significant archeological resources.

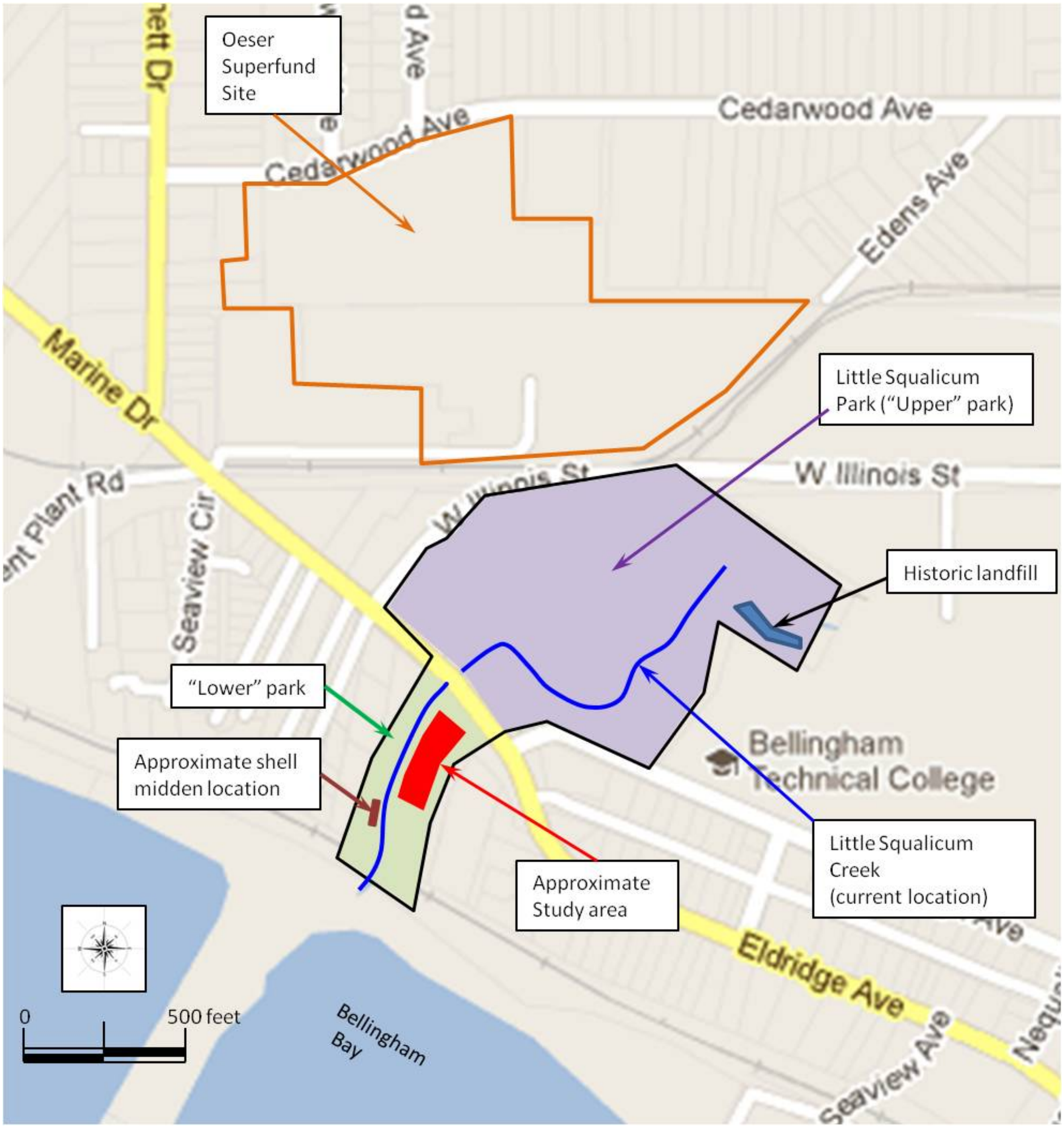

Figure 1. Little Squalicum Creek Estuary Project Location Map, Bellingham, WA.

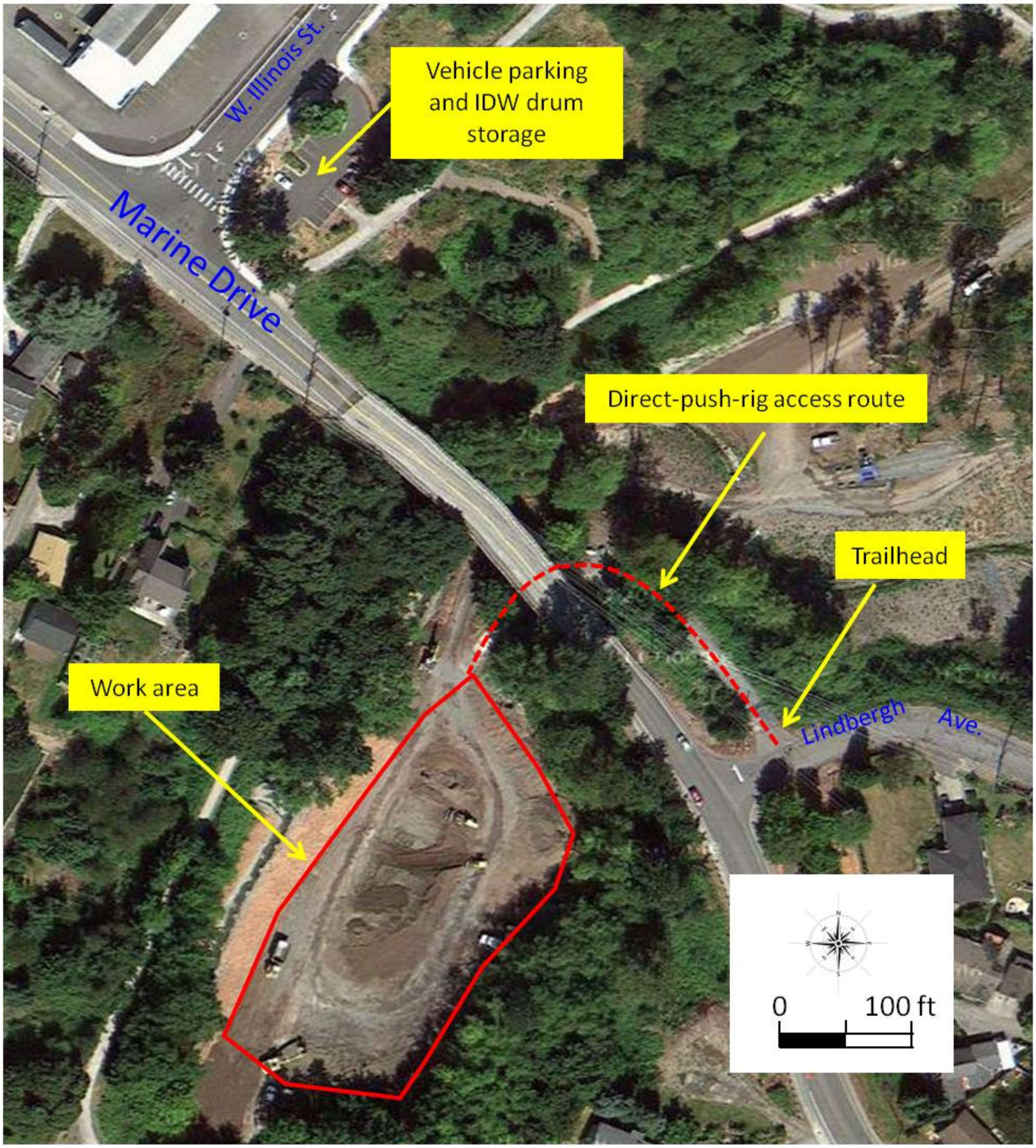

Figure 2. Little Squalicum Creek Estuary Project Site Map

Project Description

Goal

The goal of this project is to conduct reconnaissance mapping of contaminant conditions within and immediately beneath the proposed estuary excavation volume. Wood-treating and petroleum-related contaminants are of particular interest due to previous reports of wood preservative and diesel contamination within or upgradient of the study area.

The sampling activities described in this work plan will be focused in the vicinity of the area of previously reported shallow diesel contamination. Due to logistical concerns, only the portion of the proposed excavation currently cleared and resurfaced will be included in the study area. No subsurface investigation work will take place in the area of the park that is currently forested.

The drilling and sampling activities described in this QAPP will help:

- Delineate the presence and extent of soil and groundwater contamination within the estuary excavation volume, and evaluate these conditions against state cleanup criteria.
- Determine if soils excavated during the construction of the proposed estuary are likely to require special handling and disposal.
- Characterize contaminant conditions in the deposits that will form the upper surface of the new estuarine habitat, and evaluate these conditions against available state sediment management standards.

Objectives

The objectives of the proposed study are to:

- Collect and describe continuous soil cores from a network of environmental investigation wells installed at the site using direct-push drilling techniques, to a total depth ending just below the design estuary surface (depending on location).
- Sub-sample the continuous interval soil cores above the estuary surface for target contaminants of concern (PAHs, PCP, diesel).
- Collect soil samples from the horizon located immediately below the estuary surface for analysis of potential contaminants of concern (PAHs, PCP, diesel, metals)
- If feasible, collect groundwater samples from the shallow, unconfined aquifer beneath the site, using temporary direct-push screen points. Submit the samples to the laboratory for analysis of target contaminants.

Organization and Schedule

Table 1 lists the people involved in this project. All are Ecology employees. Table 2 presents the proposed schedule for this project.

Table 1. Organization of Project Staff and Responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Lucy McInerney Toxics Cleanup Program Northwest Regional Office Phone: 425-649-7272	EAP Client	Clarifies scopes of the project. Provides internal review of the QAPP and approves the final QAPP.
Charles F. Pitz Groundwater/Forests & Fish Unit, SCS Phone: 360-407-6775	Project Manager/ Project Hydrogeologist	Writes the QAPP. Oversees field sampling. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Randy Coots Toxics Studies Unit, SCS Phone: 360-407-6690	Toxics Studies Unit Representative/Field Assistant	Provides technical support on toxics and sediment characterization. Helps collect samples and records field information.
Pam Marti Groundwater/Forests & Fish Unit, SCS Phone: 360-407-6768	Field Assistant	Helps collect samples and records field information.
Martha Maggi Groundwater/Forests & Fish Unit, SCS Phone: 360-407-6453	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra SCS Phone: 360-407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Robert F. Cusimano Western Operations Section Phone: 360-407-6596	Section Manager for the Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Joel Bird Manchester Environmental Laboratory Phone: 360-871-8801	Director	Approves the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP: Environmental Assessment Program
SCS: Statewide Coordination Section
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

Table 2. Proposed Schedule for Completing Field and Laboratory Work, Data Entry Into EIM, and Reports.

Field and laboratory work	Due date	Lead staff
Field work completed	September 2012	Charles F. Pitz
Laboratory analyses completed	November 2012	
Environmental Information System (EIM) database		
EIM user study ID	CHPI005	
Product	Due date	Lead staff
EIM data loaded	January 2013	Charles F. Pitz
EIM quality assurance	February 2013	Randy Coots
EIM complete	March 2013	Charles F. Pitz
Groundwater report		
Activity Tracker code	12-032	
Author lead	Charles F. Pitz	
Schedule		
Draft due to supervisor	March 2013	
Draft due to client/peer reviewer	March 2013	
Draft due to external reviewer(s)	April 2013	
Final (all reviews done) due to publications coordinator	May 2013	
Final report due on web	June 2013	

Quality Objectives

The primary objective of this study is to collect data that are representative of subsurface contaminant conditions within and immediately beneath the proposed estuary excavation volume and to evaluate those conditions against state criteria. As in any subsurface investigation, large variations in soil and groundwater chemistry can occur between samples due to natural environmental heterogeneity. These variations can be compounded by errors introduced by sample handling and analysis techniques. The focus of the quality assurance steps outlined in this QAPP is to minimize and evaluate any error introduced into the final sample results by these techniques.

Ecology field staff will follow Ecology's standard Environmental Assessment Program (EAP) protocols when collecting field measurements or when collecting and handling groundwater samples that will be submitted for later laboratory analysis.

Table 3 presents the target parameters for the study and describes the field and laboratory measurement quality objectives (MQOs) for each parameter[1]. The applicable Washington State contaminant criteria or screening levels are included for comparison to the Manchester Environmental Laboratory (MEL) reporting limits (Ecology, 2007; Ecology, 1995). Standard laboratory quality control procedures will be used to estimate the accuracy, precision, and bias introduced by laboratory procedures and will be provided to the project manager as part of the formal laboratory data package for each sample event. (MEL, 2008).

These goals are based in part on performance characteristics of measurements conducted previously by MEL. Analytical and field quality control samples are discussed in the *Quality Control Procedures* section below. MEL's standard operating procedure for data qualification and best professional judgment will be used in the final determination of whether to accept, reject, or accept the results with qualification. The project manager will assess the overall quality of the data results for use, qualification, or rejection in the final project report on the basis of a review of both the laboratory QC and field QC results.

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[1] MQO standards can be difficult to meet in cases where sample parameter concentrations approach the method detection limit of the chosen analytical procedure.

Table 3. Measurement Quality Objectives.

Field Parameters

Parameter	Equipment/Method	Field Duplicate Precision	Reporting Limits
pH (s.u.)*	YSI ProPlus® multi-meter	± 0.2 s.u.	1-14 s.u.
Temperature (ºC)	YSI ProPlus® multi-meter	± 0.2ºC	1-30ºC
Specific conductance	YSI ProPlus® multi-meter	<5% RPD	1 umhos/cm
Dissolved Oxygen	YSI ProPlus® multi-meter (with CHEMetrics photometric indigo carmine method for <2mg/L concentration confirmation)	<15% RPD	0.2 to 15 mg/L
Turbidity	Hach® field turbidimeter	±0.1 NTU	0-100 NTU
Static Water Level	E-tape	±0.02 ft	NA

Laboratory Parameter	Method	Lab Duplicate Precision RPD	LCS or SRM recoveries	Matrix Spike recoveries	Matrix Spike Duplicates RPD	Method Reporting Limits (MRL)[C]	Washington Model Toxics Control Act (MTCA) Criteria[E]	Washington Marine Sediment Quality Standards[M]
Lab Parameters: Soil								
TPH-Diesel	NWTPH-Dx (Diesel Extended Range)	≤50%	35-150%	25-150%	50%	50 mg/Kg	2000 mg/Kg[F]	NA
Base/Neutral/Acid (BNA) semi-volatiles[A]	SW-846 Method 8270	≤ 50%	40 – 150%	40-150%	40%	PAHs: 0.025-0.125 mg/Kg	Benzo(a)pyrene: 0.1 mg/Kg[F]	Benzo(a)pyrene: 99 mg/Kg organic carbon
						PCP: 0.125 mg/Kg	PCP: 2.5 mg/Kg[G] 400 mg/Kg[H]	PCP: 360 ug/Kg dry weight
Total Organic Carbon (TOC)[B]	PSEP Protocols (104ºC)	≤20% (run in triplicate)	80 – 120%	NA	NA	0.1% carbon	NA	NA
Total Recoverable SMS Metals (Ag, As, Cd, Cr, Cu, Pb, Zn)[B]	PSEP Protocols EPA Method 200.8 (ICP-MS)	≤ 20%	85 – 115%	75 -125%	20%	Variable 0.1 – 5 mg/Kg	NA	Variable

Total Recoverable SMS Metals (Mercury)	PSEP Protocols EPA Method 245.5 (CVAA)	≤ 20%	85 – 115%	75 – 125%	20%	0.036 mg/Kg	NA	0.41 mg/Kg dry weight
Lab Parameters: Groundwater								
TPH-Diesel	NWTPH-Dx (Diesel Extended Range)	≤ 50%	50-150%	25-150%	50%	0.1 mg/L	0.5 mg/L[J]	NA
Base/Neutral/Acid (BNA) semi-volatiles[A]	SW-846 Method 8270	≤ 50%	40-150%	40-150%	40%	PAHs: 0.083 ug/L[D]	Benzo(a)pyrene: 0.1 ug/L[J]	NA
						PCP: 0.25 ug/L[D]	PCP: 0.22 ug/L[K] 80 ug/L[L]	NA

*s.u.: standard units

[A] See Appendix A for included parameters.

[B] Only for samples collected below the proposed estuary surface

[C] Soil MRLs wet weight basis

[D] Reporting limits for groundwater samples are dictated by the final sample volume field staff are capable of retrieving from the direct-push screen point. Sample volume and method reporting limits are inversely proportional – the smaller the sample volume, the higher the MRL. The standard sample volume required for BNA low level analysis is 1 gallon, which may be difficult to collect from a direct-push screen point in a cost-effective manner. The MRL for PAH analytes using a limited-volume sample (~1-Liter) would be approximately 0.25 ug/L, for PCP, approximately 1.3 ug/L(Weakland, 2012).

[E] Model Toxics Control Act (MTCA) Regulation 173-340 WAC

[F] Method A Soil Cleanup Criteria for Unrestricted Land Use (dry weight)

[G] Cleanup Levels and Risk Calculations (CLARC) Database Soil Screening Level – Method B, Carcinogen, standard formula value, direct contact (ingestion only), unrestricted land use

[H] CLARC Database Soil Screening Level – Method B, Non-carcinogen, standard formula value, direct contact (ingestion only), unrestricted land use

[J] Method A Groundwater Cleanup Criteria

[K] CLARC Database Groundwater Screening Level – Method B, Carcinogen, standard formula value

[L] CLARC Database Groundwater Screening Level – Method B, Non-carcinogen, standard formula value

[M] Washington Sediment Management Standards 173-204 WAC

NTU: nephelometric turbidity units
RPD: relative percent difference
LCS: laboratory control standards
SMS: Sediment Management Standards
PSEP: Puget Sound Estuary Program, 1997
ICP-MS: Inductively coupled plasma- mass spectrometry
CVAA: Cold vapor atomic absorbance (mercury only)
SRM: Standard reference material
NA: not available or applicable

Study Design

For this study, Ecology will use direct-push drilling techniques to collect samples of subsurface soil and groundwater to characterize conditions within and immediately below the proposed estuary excavation "prism". Due to logistical and schedule issues, no characterization work will take place in areas of the proposed estuary footprint that are currently forested, and no additional investigation or sampling is planned upgradient of the estuary. Sampling will primarily be focused in the vicinity of the area of previously reported shallow diesel contamination.

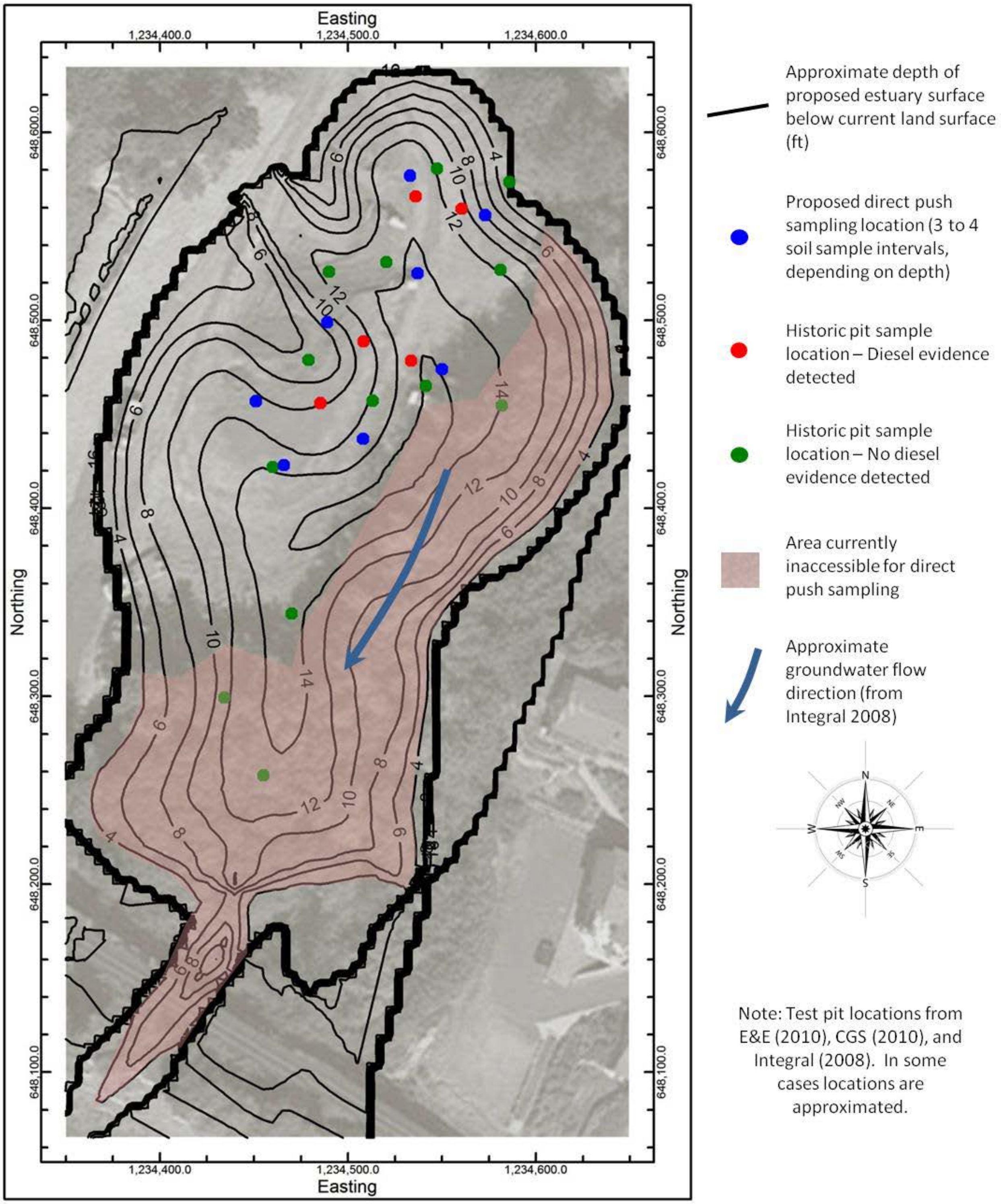
Figure 3 illustrates the proposed direct-push sampling locations for the project. The historic test-pit excavation stations are also presented on the figure to allow comparison to the proposed sample locations. Two to three soil samples will be collected at each drilling location *above* the proposed estuary surface, depending on location, to characterize the deposits that are proposed for excavation. An additional soil sample will be retrieved from each borehole from an interval located immediately *below* the design elevation of the estuary topographic surface. These samples will be submitted for analysis of BNAs, diesel, Sediment Management Standard metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc) and total organic carbon (TOC), to allow comparison to state sediment criteria. Due to sample volume limitations (and the absence of an applicable sediment regulatory criteria), no diesel analysis will be conducted for soil samples collected from this zone.

A contract driller will be employed to conduct all direct-push drilling, soil coring, and screen-point installation. Ecology will describe the retrieved soils and select soil intervals for further laboratory analysis, and will conduct all groundwater sampling. All samples submitted for analysis will be tested by Ecology's MEL. A summary of the proposed sample numbers and analytical costs is presented in Table 4.

Table 4. Project Analytical Costs.

Parameter	Estimated Number of Samples			Cost per Sample[B]	Cost per Parameter
	Field	QA[A]	Total		
Soil					
NWTPH-DX	29	5	34	$157	$5,338
BNAs	29	5	34	$298	$10,132
TOC	8	1	9	$45.52	$410
SMS Metals (Ag,As,Cd, Cr,Cu,Pb,Zn)	8	2	10	$147	$1470
Mercury (Hg)	8	2	10	$52.20	$522
Groundwater					
NWTPH-DX	3[C]	5[C,D]	8	$141	$1,128
BNAs	3[C]	5[C, D]	8	$270	$2,160
				Total Analytical Costs	$21,160

[A] See Table 7 for details.
[B] Costs assume 50% discount from MEL.
[C] See notes regarding sample volume and sample turbidity limits for groundwater samples and QA work.
[D] Includes one rinsate sample from soil sampling equipment.



Note: Test pit locations from E&E (2010), CGS (2010), and Integral (2008). In some cases locations are approximated.

Northing and Easting coordinates: NAD83 State plane WA North (ft)

Figure 3. Little Squalicum Creek Estuary Proposed Direct-Push Sampling Location Map.

Field Measurements and Sampling Procedures

Monitoring stations will be field-located by a licensed surveyor under a separate contract. All monitoring locations will be described and documented in field data sheets.

Soil

Samples of subsurface soils will be collected from the area of interest using direct-push drilling and sampling techniques, consistent with methods described in ASTM (2005a). Figure 3 presents the proposed borehole locations for the study; Figure 4 presents a three-dimensional schematic of the boring plan. Direct-push boreholes will be drilled to a final depth immediately below the designed estuary topographic surface[2]. Table 5 summarizes the coordinate locations, completion depths, and number of soil samples that will be collected for each proposed coring location. A contract driller will collect a continuous 4- to 5-foot interval soil core at each location of interest using a Geoprobe® Macro-Core MC5 Soil Sampler or equivalent, fitted with a clean, disposable liner (1.5 inch inner diameter).

Upon retrieval from the borehole, the EAP project hydrogeologist will expose a fresh core surface with a clean spatula and then describe the soil characteristics on a log. Two to three 18-inch-long vertical intervals of the core above the estuary surface (dependent on completion depth) will be selected and sub-sampled for further analysis of target parameters at each location. Soil intervals selected for sampling will favor portions of the retrieved core showing obvious signs of contamination (sheen, odor). Otherwise, samples will be selected in a manner to provide a representative vertical profile of the soil column above the estuary surface.

At each borehole, an additional soil sample will be collected from a vertical interval located immediately below the proposed estuary surface (see footnote 2). These samples will support characterization of the chemical condition of the deposits that will form the uppermost sediments of the new estuary. The vertical interval of greatest interest for this sample lies between 0 and 12 cm (0 to ~5 inches) below the estuary surface - the biologically active zone identified for Bellingham Bay sediments (McInerney, 2012). However, MEL sample-volume requirements for the chemical parameters of interest are likely to necessitate the collection of soil from a longer interval to support the analysis. As a result, the final concentrations reported for these “estuary surface” samples are likely to represent conditions over an 18- to 24-inch-long interval.
Soil samples will be transferred from the core liner to a clean stainless steel bowl and mixed with a clean stainless steel spoon until color and texture are consistent. All soil particles greater than 0.75 inches in diameter will be removed from the sample. After preparation, the sample will be placed in clean, laboratory-supplied sampling containers. Soil sample containers will be labeled and transferred immediately to an ice-filled cooler for transport to the laboratory, using standard MEL chain-of-custody procedures (MEL, 2008). Table 6 summarizes the container requirements, sample volume, sample handling, and maximum permissible holding time for the target analytes for soil samples.

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[2] Monitoring stations will be surveyed by a licensed surveyor under a separate contract prior to drilling. Surveyed ground surface elevation at each drilling location will be used to calculate appropriate drilling depths with respect to the proposed estuary surface.

Table 5. Coordinates, Depths, and Sampling Criteria for Soil Coring Locations.

Station ID[1]	X coordinate[2]	Y coordinate[2]	Depth to excavation surface (ft)[3]	Number of soil samples above excavation surface	Number of soil samples below excavation surface
LS-1	1234533	648577	13.1	3	1
LS-2	1234573	648556	7.7	2	1
LS-3	1234537	648525	14.5	3	1
LS-4	1234489	648499	9.3	2	1
LS-5	1234550	648474	15.9	3	1
LS-6	1234508	648437	13.3	3	1
LS-7	1234451	648457	10.6	2	1
LS-8	1234466	648423	13.3	3	1
			Totals	21	8

[1] Washington State well tag IDs will be assigned at the time of drilling.
[2] State Plane WA North, NAD83
[3] Completion depth of each borehole will be keyed to the upper surface of the proposed estuary, as reported by CGS, 2010. Depths are estimated assuming the current site surface topography has been increased by 1 foot since the 2008 White Shield survey effort. Actual depths will be recalculated using updated survey results.

Table 6. Sample Containers, Preservation, and Holding Times.

Parameter	Container	Preparation	Holding time
Soil			
TPH-Diesel	One 8 oz. wide-mouth glass jar with Teflon®-lined cap (250 gram minimum)	Preserve and transport at 0 to 6 ºC	14 days to extraction
BNA semi-volatiles: PAHs and pentachlorophenol	One 8 oz. wide-mouth glass jar with Teflon®-lined cap (250 gram minimum)	Preserve and transport at 0 to 6 ºC	14 days to extraction
TOC	2 oz. wide-mouth jar with Teflon® lined lid (25 gram minimum)	Preserve and transport at 0 to 6ºC	14 days cooled
SMS Metals (Ag, As, Cd, Cr, Cu, Pb, Zn)	One 4 oz. wide mouth jar with Teflon® lined lid (50 gram minimum)	Preserve and transport at 0 to 6ºC	6 months cooled
Mercury	One 4 oz. wide mouth jar with Teflon® lined lid (100 gram minimum)	Preserve and transport at 0 to 6ºC	28 days cooled
Groundwater			
TPH-Diesel	One 1-liter narrow-mouth amber bottle with Teflon®-lined cap	Preserve and transport at 0 to 6 ºC[A]	7 days to extraction
BNA semi-volatiles: PAHs and pentachlorophenol	One 1-gallon glass jar with Teflon®-lined cap	Preserve and transport at 0 to 6 ºC[A]	7 days to extraction

[A] Submittal of groundwater samples collected from direct-push screen points showing a turbidity of >5 NTU will be considered in consultation with the project client.

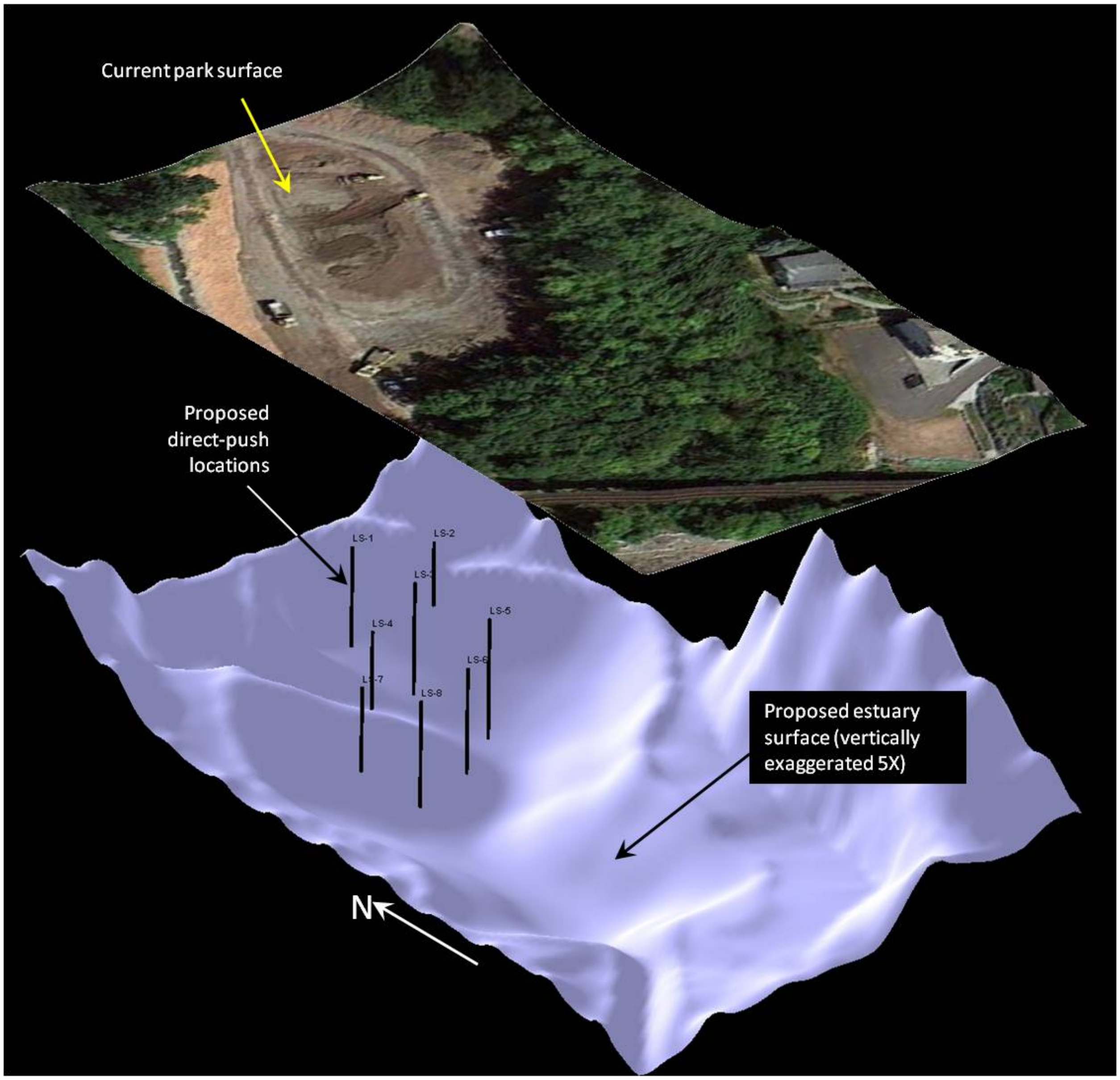

Figure 4. Little Squalicum Creek Estuary Proposed Sampling Plan 3-D Schematic.

Proposed estuary surface developed from CGS, 2010 data.

Groundwater

If feasible, groundwater samples will be collected at two to three of the soil sampling locations shown on Figure 3 by installing a temporary, discrete-depth screen-point using direct-push drilling techniques consistent with procedures outlined in ASTM (2005b).

Groundwater sample collection using direct-push techniques poses several technical challenges that may limit the cost-effectiveness of the sampling. The primary concerns for these samples include:

- The amount of sample volume that can be collected in a reasonable time-frame from the small diameter direct-push casing
- The degree of sample turbidity

Depending on the subsurface lithology and degree of hydraulic communication established between the screened interval and the aquifer formation, large groundwater sample volumes (like those required to support full BNA analysis -- including QA replicates and spikes) can be difficult to obtain in a time- and cost-effective manner from small-diameter direct-push screen-point installations. In practical terms, a reduced sample volume or sample flow rate likely results in either:

1. A reduction in the number of sample locations chosen for analysis, <u>or</u>
2. A reduction in the number of parameters submitted for analysis, <u>or</u>
3. A proportional increase in Method Reporting Limits the lab is capable of reaching, <u>or</u>
4. A reduction in the amount of quality assurance testing, <u>or</u>
5. Some combination of the above.

For example, the sampler can choose to dedicate a limited sample volume entirely to the analysis of the original sample in order to reach the lowest reporting limits possible. In this case, however, additional QA samples like duplicates or matrix spike samples would not be possible, therefore reducing the level of confidence in the data results.

Groundwater samples collected using direct-push methods can also often exhibit excess turbidity (>5 NTU), due to the lack of a sand pack and traditional casing development procedures. Filtration of turbid groundwater samples prior to analysis for organic compounds using traditional techniques is undesirable due to the significant biases that can be introduced into the sample results (Sandstrom, 1995). Low-stress sampling methods can help to reduce the amount of turbidity observed in the sample stream from a direct-push casing, but the filtration equipment and techniques necessary to field- or lab-filter turbid organic samples are expensive and time-consuming. Analytical results from unfiltered samples that do have excess turbidity can also have significant uncertainty.

EAP field samplers will attempt to collect full-volume, low-turbidity samples at each groundwater sampling location. If for any reason the volume or turbidity of groundwater sample produced is less than ideal, the project hydrogeologist, in consultation with the project client, will use best professional judgment in deciding whether to complete the sampling and proceed with submitting samples for analysis (including reduced sample volume or QA sampling). If field decisions on sample submittal result in a reduction in the level of QA confidence in the data, the concentration results reported will be qualified accordingly.

The groundwater sampling locations will be selected on the basis of previous field observations of shallow diesel contamination, and of field observations of subsurface conditions made during the soil coring described in this work plan. A contract driller will install and expose the screen point (Geoprobe® SP-16 or equivalent) below the water table at a depth interval designated by the EAP project hydrogeologist.

Prior to collecting a groundwater sample, EAP field staff will deploy a clean, calibrated electric tape through the direct-push screen point casing to measure and record the static water level position, following procedures described by Marti (2009).

After water level measurement, a clean, hand-operated mechanical bladder pump (Geoprobe MBP470; 145 micron screen) will be lowered downhole until the intake is adjacent to the mid-point of the exposed screened interval. The sample line (dedicated fluorinated ethylene propylene) will be routed through a closed-atmosphere flow cell instrumented with calibrated probes for measurement of field parameter condition (temperature, pH, specific conductance, dissolved oxygen). The screen point will be purged at a rate of 100 to 200 ml/min until field parameters have stabilized within standard criteria (Marti, 2011). Upon completion of purge, a sub-sample will be collected for analysis of turbidity using a calibrated field turbidimeter, for comparison to the 5 NTU turbidity criteria.

If the field personnel decide on the basis of sample production and turbidity to proceed with collection, the sample pump stream will be directed to clean, laboratory-supplied containers, which will then be labeled and transferred immediately to an ice-filled cooler for transport to the laboratory. Sample shipment will follow standard MEL chain-of-custody procedures (Ecology, 2008). Table 6 summarizes containers, preservation, and holding times for groundwater samples.

Laboratory Procedures

MEL will analyze all soil and groundwater samples. They will use standard methods, quality assurance testing, and reporting limits for analysis of all sample parameters shown on Table 3. MEL performs the requested analytical tests on a routine basis; no special services are required. Should any problems arise, MEL will contact the project manager and appropriate adjustments will be made.

Quality Control Procedures

Field

A variety of standard quality control steps will be used during this project to minimize and assess bias and cross contamination in the sampling results and field measurements.

All sample contact equipment will be factory new (e.g. tubing, filters, sample containers) or decontaminated prior to use (e.g., sampling spoons, direct-push sample contact equipment)[3]. Field staff will wear nitrile gloves while collecting samples to prevent cross-contamination. All sample containers will be supplied by MEL in new condition; containers will be certified organic-free with Teflon-lined lids.

All field meters used during this project will be calibrated in accordance with the manufacturer's instructions prior to the start of each sampling day. Meters will be rechecked using certified reference standards at mid-day to determine they haven't drifted unacceptably since the pre-sampling calibration.

Soil

Soil duplicate samples will be collected by homogenizing a select interval from the continuous core in a clean bowl with a spoon and then splitting the volume between two sets of sample containers. Duplicate locations will be selected on the basis of existing information, and field observations of subsurface conditions during drilling and soil core description. Soil duplicates will be collected for every 10 soil samples (Table 7).

One soil equipment rinsate sample will be collected to assess the bias introduced into the soil sample organic results by the sampling equipment. After decon, the soil sampling bowl and spoon will be rinsed with laboratory-supplied, reagent-grade, organic-free DI water. The rinsate will be captured directly into sampling containers for laboratory analysis.

Groundwater

Water level measuring devices will be cleaned using techniques outlined by Marti (2009).

If feasible, one duplicate groundwater sample will be collected to assess the combined bias effects of sample matrix, sample collection procedures, and analytical procedures (Table 7). Groundwater duplicates are collected by splitting the discharge from the sample pump between two sets of sample containers (after purge stabilization; see remarks on groundwater sample volume limitations in Groundwater sampling procedures above).

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[3] The drilling contractor will be responsible for decon of all direct-push equipment per contract requirements. The driller will also supply new core liners for each soil core interval. Decon of sample collection equipment (stainless steel bowls, spoons, spatulas, etc.) will consist of a scrub wash with an anionic detergent water solution (Liquinox or equivalent), and sequential rinses with tap water, deionized water, and pesticide-grade acetone (a dilute nitric acid rinse will be added for sample intervals requiring metals analysis).. Equipment will be air-dried and wrapped in foil if not used immediately.

If applicable, one reagent-grade, organic-free DI water equipment blank will also be submitted to the laboratory for the sampling effort to characterize bias introduced into the groundwater samples by the sampling system materials (Table 7). Groundwater equipment blanks consist of laboratory-supplied, reagent-grade, organic-free DI water that is processed in the same manner as a true water sample through new sample contact equipment (tubing, container, transport) and returned to MEL for analysis. Reagent-grade DI water for blank samples will be obtained from MEL prior to sampling.

Table 7. Field and Laboratory Quality Control Samples.

<table>
<tr><th>Analyte</th><th colspan="2">Equipment Blank</th><th colspan="2">Field Duplicate</th></tr>
<tr><td colspan="5">Field - Soil</td></tr>
<tr><td>TPH-Diesel</td><td colspan="2">1/batch[A]</td><td colspan="2">1/10 samples</td></tr>
<tr><td>BNA semivolatiles</td><td colspan="2">1/batch[A]</td><td colspan="2">1/10 samples</td></tr>
<tr><td>TOC</td><td colspan="2">-</td><td colspan="2">1/10 samples</td></tr>
<tr><td>SMS Metals</td><td colspan="2">-</td><td colspan="2">1/10 samples</td></tr>
<tr><td colspan="5">Field – Groundwater[B]</td></tr>
<tr><td>TPH-Diesel</td><td colspan="2">1/batch</td><td colspan="2">1/batch</td></tr>
<tr><td>BNA semivolatiles</td><td colspan="2">1/batch</td><td colspan="2">1/batch</td></tr>
<tr><th>Analyte</th><th>Method Blank</th><th>Check Standard</th><th>Surrogate Spikes</th><th>MS/MSD</th></tr>
<tr><td colspan="5">Laboratory - Soil</td></tr>
<tr><td>TPH-Diesel</td><td>1/batch</td><td>1/batch</td><td>NA</td><td>1/batch</td></tr>
<tr><td>BNA semivolatiles</td><td>1/batch</td><td>1/batch</td><td>All samples</td><td>1/batch</td></tr>
<tr><td>TOC</td><td>1/batch</td><td>1/batch(SRM)</td><td>NA</td><td>NA</td></tr>
<tr><td>SMS Metals</td><td>1/batch</td><td>NA</td><td>NA</td><td>1/batch</td></tr>
<tr><td colspan="5">Laboratory – Groundwater[B]</td></tr>
<tr><td>TPH-Diesel</td><td>1/batch</td><td>1/batch</td><td>NA</td><td>1/batch</td></tr>
<tr><td>BNA semivolatiles</td><td>1/batch</td><td>1/batch</td><td>All samples</td><td>1/batch</td></tr>
</table>

[A] Soil sampling equipment rinsate sample (submitted as water sample)
[B] If sample volumes retrieved are adequate; see remarks in text.
SRM – standard reference material

Laboratory

Routine quality control procedures will suffice to demonstrate that the Measurement Quality Objectives (MQOs) for this project have been met. Laboratory quality control tests can consist of method blanks, surrogate analysis, and lab duplicates and check standards (lab control standards). Analytical precision can be estimated from check standards and duplicate sample analysis. Analytical bias will be estimated from check standards, blanks, and matrix spike samples.

Laboratory staff will report results of quality control analyses in the same units as expressed for the MQOs. They will also conduct quality assurance review of all analytical data generated at MEL prior to releasing the data to the project manager. Laboratory QC samples analyzed along with project samples are presented below in Table 7.

Safety and Waste Management

An EAP health and safety site plan will be prepared under separate cover for all field work activities associated with this project.

Investigation-derived waste (IDW) will be handled and contained in the field per drilling contractor requirements. All IDW will be stored in 55-gallon steel drums in a secure on-site location, per arrangements with the City of Bellingham. Upon receipt of the analytical results for the soil and water samples, the state waste disposal contractor (Clean Harbors, Inc.), will be contacted to arrange for pickup and permanent off-site disposal, per appropriate state and federal regulations.

Data Management Procedures

All field measurements and core descriptions will be recorded in a field notebook or a standard field log at the time of collection. The project manager will review and verify that all measurements are made and appropriately recorded before leaving each sampling site. Verified field measurements will later be input into the Ecology Environmental Information Management (EIM) system.

Data generated by MEL will be managed by the Laboratory Information Management System (LIMS) and sent to the project manager in both electronic and hard copy format. The project manager will review the case narratives from MEL for any problems encountered during sample analysis, to understand any corrective action taken, or for any changes made to the requested analytical method.

The project manager will review laboratory data and quality control results against the project data quality objectives to evaluate data quality. The final verified and qualified results will be input into the EIM system (and reported in a final technical report). All soil results will be reported on a dry weight basis.

Audits and Reports

MEL participates in performance and system audits of their routine procedures. The audit results are available upon request.

Upon study completion, all project data will be entered into Ecology’s EIM system. Public access to electronic data and the final report for the study will be available through Ecology’s Internet homepage (www.ecy.wa.gov).

Data Verification

Verification of laboratory results is normally performed by a MEL unit supervisor or an analyst experienced with the analytical method. Verification involves a detailed examination of each data package to determine whether method data quality objectives have been met. MEL's standard operating procedures and EPA's functional guidelines are followed when performing the data assessment. MEL staff will provide a written report of their data review detailing whether:

- Measurement quality objectives were met.
- Proper analytical methods and protocols were followed.
- Calibrations and control were within limits.
- Data were consistent, correct, and complete. (MEL, 2008)

After receiving each laboratory-verified data package, the project manager will compare the quality assurance and analysis performance information with the project data quality objectives. Data will be assessed for completeness and for indications of bias introduced by field procedures.

Data Quality (Usability) Assessment

After the analytical results are received from the laboratory, the overall project data set will be evaluated for representativeness and completeness by the project manager. Data error(s) will be assessed against the initial project goals and the project manager will determine whether the data are of sufficient quality to meet the project objectives.

Reporting

A draft report will be prepared and forwarded to the internal reviewers in EAP and Ecology's Northwest Regional Office Toxics Cleanup program within six months of receiving the final round of sample results from MEL. The report will include the following elements:

- A description of the project purpose, goals, and objectives.
- Map(s) of the study area and sampling sites.
- Descriptions of field and laboratory methods.
- A discussion of data quality and the significance of any problems encountered in the analyses.
- Summary tables of field and laboratory chemical data with comparisons to regulatory criteria.
- Observations about significant or potentially significant findings.
- Possible recommendations related to the project goals.

The final data report should be ready for publication within three months of receiving review comments on the draft report.

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Appendix A. Analyte List for BNA (Semivolatile) Analysis by EPA Method 8270

Phenol
Bis(2-Chloroethyl)Ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,2-Dichlorobenzene
Benzyl Alcohol
2-Methylphenol
Bis(2-chloro-1-methylethyl) ether
N-Nitrosodi-n-propylamine
4-Methylphenol
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2,4-Dimethylphenol
Bis(2-Chloroethoxy)Methane
Benzoic Acid
2,4-Dichlorophenol
1,2,4-Trichlorobenzene
Naphthalene
4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-Methylphenol
2-Methylnaphthalene
1-Methylnaphthalene
Hexachlorocyclopentadiene
2,4,6-Trichlorophenol
2,4,5-Trichlorophenol
2-Chloronaphthalene
2-Nitroaniline
Dimethyl phthalate
2,6-Dinitrotoluene
Acenaphthylene
3-Nitroaniline
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
Diethyl phthalate
Fluorene
4-Chlorophenyl-Phenylether
4-Nitroaniline
4,6-Dinitro-2-Methylphenol
N-Nitrosodiphenylamine
1,2-Diphenylhydrazine
Triethyl citrate
4-Bromophenyl phenyl ether
Hexachlorobenzene
Tris(2-chloroethyl) phosphate (TCEP)
Pentachlorophenol
Phenanthrene
Anthracene
Caffeine
4-nonylphenol
Carbazole
Di-N-Butylphthalate
Triclosan
Fluoranthene
Pyrene
Bisphenol A
Retene
Butyl benzyl phthalate
Benz[a]anthracene
3,3'-Dichlorobenzidine
Chrysene
Bis(2-Ethylhexyl) Phthalate
Di-N-Octyl Phthalate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
3B-Coprostanol
Cholesterol
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(ghi)perylene
2-Fluorophenol

Surrogates

Phenol-D5
2-Chlorophenol-D4
Bis(2-Chloroethyl)Ether-D8
1,2-Dichlorobenzene-D4
4-Methylphenol-D8
Nitrobenzene-D5
2-Nitrophenol-D4
2,4-Dichlorophenol-D3
4-Chloroaniline-D4
2-Fluorobiphenyl
Dimethylphthalate-D6
Acenaphthylene-D8
4-Nitrophenol-D4
Fluorene-D10
4,6-Dinitro-2-methylphenol-D2
Anthracene-D10
Pyrene-D10
Terphenyl-D14
Benzo(a)pyrene-D12
1,4-Dichlorobenzene-D
Naphthalene-D8
Acenaphthene-D10
Phenanthrene-D10
Chrysene-D12
Perylene-D12

Appendix B. Glossary, Acronyms, and Abbreviations

Glossary

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

Parameter: A physical chemical or biological property whose values determine environmental characteristics or behavior.

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

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

decon	
DI	
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NTU	Nephelometric Turbidity Unit
PAH	Polycyclic aromatic hydrocarbons
PCP	5% pentachlorophenol
QA	Quality assurance
RSD	Relative standard deviation
SOP	Standard operating procedures
WAC	Washington Administrative Code

Units of Measurement

°C	degrees centigrade
Cm	centimeter
ft	feet
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
L/min	liters per minute
mg	milligram
mg/d	milligrams per day
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliters
s.u.	standard units
ug/Kg	micrograms per kilogram (parts per billion)
ug/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter