Appendix D
Quality Assurance Project Plan: Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach

Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

Quality Assurance Project Plan:

Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach

FINAL

Prepared for:

The U.S. Environmental Protection Agency
Region 10
Seattle, WA

April 11, 2019

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TITLE AND APPROVAL PAGE

QUALITY ASSURANCE PROJECT PLAN:

PRE-DESIGN SURVEYS OF THE LOWER DUWAMISH WATERWAY UPPER REACH

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ABBREVIATIONS

QAPP	quality assurance project plan
DGPS	differential global positioning system
DQO	data quality objective
DTM	digital terrain model
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
GIS	geographic information system
GPS	global positioning system
HASP	Health and Safety Plan
LDW	Lower Duwamish Waterway
LiDAR	light detection and ranging
LDWG	Lower Duwamish Waterway Group
MLLW	mean lower low water
NAD	North American Datum
NOAA	National Oceanic and Atmospheric Administration
NWH	Northwest Hydro, Inc.
PDI	Pre-Design Investigation
POS/MV	Position and Orientation System for Marine Vessels
QC	quality control
RD	Remedial Design
ROD	Record of Decision
RM	river mile
RTK	real-time kinematic
S/V	survey vessel
SVP	sound velocity profiles
True North	True North Land Surveying, Inc.
USACE	U.S. Army Corps of Engineers

1 Introduction

This quality assurance project plan (QAPP) describes the methods and quality control (QC) for conducting river bed elevation surveys for the Lower Duwamish Waterway (LDW) Upper Reach, from river miles 3.0 to 5.0, consistent with the Lower Duwamish Waterway Fourth Amendment of the Administrative Order on Consent (EPA 2018). Bathymetric surveying (using a survey vessel) will need to be conducted over all aquatic areas between river mile (RM) 3.0 to 5.0 to the extent practicable, to support the design of the remedy in the Upper Reach.

This Survey QAPP is focused on bathymetric surveying methods and QC, in order to expedite collecting bathymetric data to inform the Remedial Design (RD) and Pre-Design Investigation (PDI) Work Plans. Topographic surveying (or land surveying) may be needed in shoreline areas where remedial action is determined to be required, but a topographic survey will not be needed throughout the entire Upper Reach. Because final remedial action areas will be determined after future PDIs are completed, topographic surveying will be conducted at a future date, to be determined. Topographic survey methods and QC will be described in a QAPP addendum prior to conducting required topographic surveys.

Access restrictions and river conditions (e.g., moored vessels and tidal elevations) at the time of the initial bathymetric survey may prevent obtaining all bathymetric data required for RD in one survey event, but an initial expedited bathymetric survey is proposed to support the development of the RD Work Plan and related documents (e.g., PDI Work Plan). Additional bathymetric survey(s), if needed to obtain full coverage of the LDW Upper Reach, will be proposed in the PDI Workplan. The scope of any additional bathymetric surveys would be proposed to the U.S. Environmental Protection Agency (EPA) for review; the initial and any subsequent bathymetric surveys will follow the methods and QC procedures as described in this QAPP.

EPA guidance for QAPPs was followed in the preparation of this project plan (EPA 2002). This plan is organized into the following sections:

- Section 2 – Project Management and Data Quality Objectives
- Section 3 – Data Generation and Acquisition
- Section 4 – Assessment and Oversight
- Section 5 – Data Validation and Usability
- Section 6 – References

2 Project Management and Data Quality Objectives

2.1 Project Organization

The bathymetric survey will be conducted by Northwest Hydro, Inc. (NWH), under the direction of Anchor QEA. Anchor QEA will be responsible for overall project coordination and for performing the administrative tasks needed to ensure timely and successful completion of the project. Anchor QEA will also be responsible for communicating with King County, the Lower Duwamish Waterway Group (LDWG), and EPA on schedule, any significant deviations from the QAPP, and administrative details. NWH will be responsible for conducting the survey, conducting post-processing of the survey data, and for reporting deviations from the QAPP to the Anchor QEA project manager. Tom Wang will serve as the Anchor QEA project manager:

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Tim Ingraham, of True North Land Surveying, Inc. (True North), will serve as the quality assurance manager for the bathymetric survey.

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True North is part of the overall surveying team for the project, primarily responsible for topographic surveying, and is not directly involved in collecting bathymetric survey data.

2.2 Problem Definition and Background

The last site-wide bathymetry survey of the Upper Reach was completed in 2003. Updated[1] bathymetric survey data are required to inform the PDI and provide a base map for the RD. The bathymetric data are planned to be used to:

- Establish the current waterway bed elevations in the LDW Upper Reach.
- Develop an accurate base map, representative of current bathymetric conditions, which is needed to develop engineering drawings and quantity calculations.
- Provide physical conditions information, as noted in Table 23 of the Record of Decision (ROD), to help refine, if needed, areal designations of Recovery Categories, which is also based, in part, on the Sediment Transport Modeling completed during the LDW Feasibility Study (FS) in 2012; and the Waterway User Survey (Integral 2018) and contaminated trends analysis summarized in the Recovery Categories Recommendation Report (Integral 2019), completed during the LDW Third Amendment to the Administrative Order on Consent.
  - Update the delineation of potential vessel scour areas identified in the FS (AECOM 2012), to inform Recovery Category designation
  - Provide the data to generate new sun illumination maps that identify areas with scour from propellers and other vessel interactions with the sediment
  - Update the depth contours that define the upper and lower bounds for the propeller scour potential area
- Use updated bathymetric elevations to inform sampling locations for the PDI. Bed elevations will be considered when selecting sample locations.
- Use updated bathymetric survey to identify elevations of new surface and subsurface data.

2.3 Project Description

A multibeam bathymetric survey will be performed to produce an accurate, up-to-date bathymetric dataset containing bank-to-bank data (where possible) for the LDW Upper Reach RD, addressing the data needs identified in Section 2.2. As much as possible, the survey will be performed at high tide when surveying near shorelines, to allow collection of

[1] The U.S. Army Corps of Engineers (USACE) periodically surveys the navigation channel of the LDW, and survey data from the USACE will be evaluated in the PDI.

data as high as possible on the banks of the waterway using bathymetric multibeam survey equipment. Limited use of single-beam equipment may need to be implemented in areas of very shallow water depth where the multibeam equipment may not be as effective.

Data coverage will be extended upstream and downstream of LDW Upper Reach boundaries to the extent practicable, including approximately 100 feet into Slip 4, to provide overlap for potential future survey work and to allow for engineering evaluations along the boundaries of the study area. The bathymetric survey coverage area will extend from RM 2.75 (approximately adjacent to Slip 4) to RM 5.25 (approximately 0.5 mile upstream of the Upper Turning Basin), as shown on Figure 1. Bathymetric surveying upstream of RM 5.0, which is outside of the Upper Reach, will be attempted if water depth conditions and overhead clearance at the bridge at RM 5.0 allow a small survey vessel to pass underneath. Future topographic surveys may be needed in shoreline areas where remedial action is determined to be required and will be performed at low tide to allow overlap with the bathymetric survey data. Bathymetric data will be collected using methods described in Sections 3 through 5 of this QAPP, to meet the needs identified in Section 2.2.

The location and extent of the enhanced natural recovery-activated carbon pilot study Intertidal Plot, which is near RM 3.9 on the east side, is shown on Figure 1. The bathymetric surveyor will use caution when surveying in the area of the pilot study plot to avoid disturbing the sediment.

The survey will be performed as soon as practical after receiving EPA approval of this QAPP, considering factors such as the occurrence of daytime high tides, to allow for the use of the information in preparation of the RD and PDI Work Plans. The schedule for completing the survey and preparing deliverables is presented in Section 3.2.5.

2.4 Data Quality Objectives and Criteria

The data collection and targeted methods selected for this survey will be implemented using state-of-the-art equipment and technology and will meet the data needs presented in Sections 2.2 and 2.3. The completeness of final data (i.e., areal coverage) will be evaluated in consultation with EPA to determine if there are data gaps requiring further bathymetric surveying to support RD, and the need for alternative surveying methods (e.g., upland topographic surveys, single-beam bathymetric survey, or light detection and ranging [LiDAR]). The overall data quality objectives (DQOs) for this project include the following elements:

1. Provide the bathymetric data to generate new sun illumination maps that identify areas with scour from propellers and other vessel interactions with the sediment; this information will be used to potentially modify the Recovery Category area designations
2. Define the current bathymetry of the LDW Upper Reach with sufficient confidence (as presented in the accuracy discussion in this section) to inform selection of sampling locations for Pre-Design Investigation data collection to support the RD
3. Provide a base map, subject to modification with the addition of follow-up bathymetric and topographic survey data, if needed, for the RD.

The DQOs were developed in conformance with the *Guidance for the Data Quality Objectives Process* (EPA 2000) and are outlined in Table 1. Parameters used to assess data quality include precision, bias, accuracy, representativeness, comparability, completeness, and sensitivity. These data quality parameters are discussed as follows:

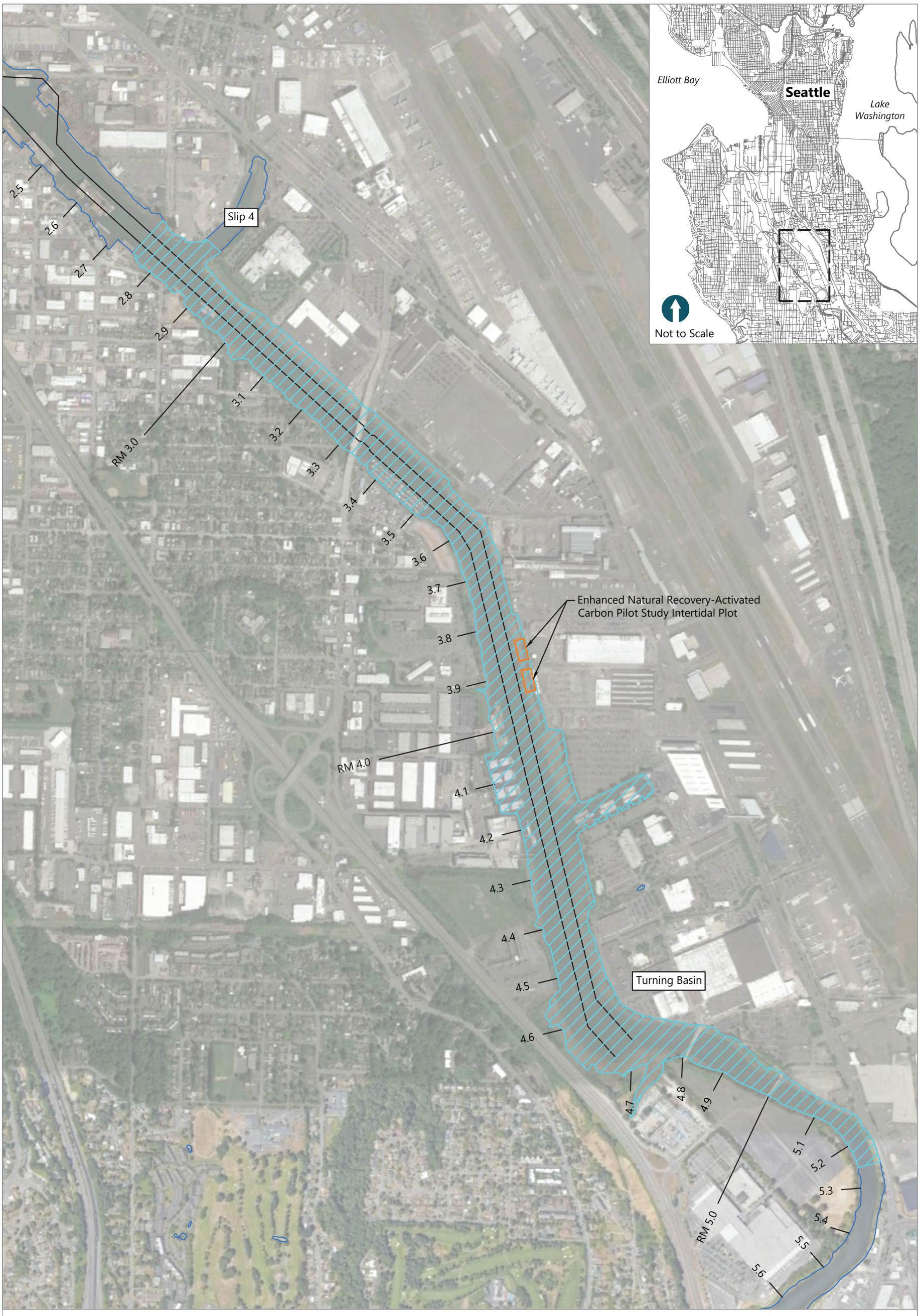
Precision: The measure of agreement among repeated measurements will be evaluated during data processing using a HyPack HySweep multibeam editor by comparing overlapping swaths. During swath editing, each individual swath will be color-coded to allow for comparison of horizontal and vertical features from swath to swath.

Bias: Bathymetric surveying methods are not prone to systemic or persistent distortions that cause errors in one direction. Corrections for various distortions are discussed in Section 3.2. Readings from the multibeam survey will be referenced to control points to tie into topographic surveys and for comparison to previous bathymetric information.

Accuracy: The target horizontal accuracy is 3 feet at a 95% confidence level, and target vertical accuracy is +/- 0.5 foot at a 95% confidence level.[2] These accuracy levels meet or exceed the minimum performance standards for measurement and payment level surveys for soft bottom material navigation and dredging support surveys in the U.S. Army Corps of Engineers (USACE) Hydrographic Surveying Engineering Manual (USACE 2013). Accuracy will be demonstrated in the cross-line analysis,[3] which provides a confidence level for each sonar beam. The horizontal and vertical datums for the survey are identified in Section 3.1.

[2] Although data are collected and processed using metric units with the hydrographic information processing system (see Section 3.4), final maps will be produced in units of feet for consistency with previous surveys in the LDW.

[3] Cross-line analysis is a method of quality assurance that compares measurements made at intersecting points from survey lines run across the primary survey lines to the data obtained from the same points on the primary survey lines.



SOURCE: Aerial by Google Earth dated 5/26/18.

LEGEND:

Bathymetric Survey Area

Enhanced Natural Recovery-Activated Carbon Pilot Study Intertidal Plot

0 1000
Feet

Publish Date: 2019/04/05 9:33 AM | User: tgriga
Filepath: K:\Projects\0067-King County\LDW Upper Reach Engineering Services\0067-RP-001 LDW Bathy.dwg Figure 1

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Figure 1
Coverage for Bathymetric Survey of the Lower Duwamish Waterway Upper Reach

Quality Assurance Project Plan
Pre-Design Surveys of the Lower Duwamish Waterway Upper Reach

Table 1
DQO Process for Bathymetric Survey

DQO Step	DQO No. 1 Inform Recovery Category Designation Modifications	DQO No. 2 Inform Selection of Sampling Locations	DQO No. 3 Provide a Base Map for the Remedial Design
1. State the Problem	Recovery Categories were identified based on lines of evidence indicated in the ROD. These include using 2003 bathymetric data, sediment-transport modeling output, empirical chemistry data, and the waterway user survey. Bathymetric data are now more than 15 years old and may not reflect current navigational uses of the waterway.	The selection of sediment and geotechnical sampling locations for Pre-Design Investigation and remedial design should be informed by bathymetric conditions. Establishing required elevations for remedial actions needs accurate bathymetry elevations.	The current site base map is based on bathymetric data that are more than 15 years old. Current data are needed to design activities such as dredging and capping, and to calculate accurate quantities.
2. Identify the Decision	Recovery Category designation areas will be reviewed during remedial design using new bathymetric data (sun illumination maps) to assess evidence of vessel scour or other disturbances to the bed (as one line of evidence to inform potential recovery category modifications).	The results of the bathymetric survey will be considered when selecting sampling locations. Remedial design sampling data will be referenced to elevations from the new bathymetric survey.	Current bathymetry mapped to a contour interval of 1.0 foot will be used in the remedial design to define extents of remedial construction activities (such as dredging and capping), calculate quantities, and define water depths to inform contractor's equipment selection to perform construction activities.
3. Identify the Inputs to the Decision	The density of bathymetric survey data and the accuracy of the survey method will follow USACE hydrographic survey guidance for design-level surveys and be sufficient to have confidence that the bathymetric surface created from the survey is representative of actual conditions.		
4. Define the Boundaries of the Study	The boundaries of the study are defined by the Record of Decision, the Fourth Amendment to the Administrative Order on Consent, and the scope of work as RM 3.0 to 5.0. To the extent practicable, the sediment surface between RM 2.75 and 5.25 (excluding Slip 4, which is downstream of the Upper Reach) will be surveyed.		

DQO Step	DQO No. 1 Inform Recovery Category Designation Modifications	DQO No. 2 Inform Selection of Sampling Locations	DQO No. 3 Provide a Base Map for the Remedial Design
5. Develop a Decision Rule	Established techniques for collecting and processing bathymetric survey data, including QC and quality assurance, will be used to collect data. The techniques are described in Sections 3 through 5.		
6. Specify Tolerable Limits on Decision Errors	The probability of decision errors will be minimized through strategies to minimize statistical sampling errors and measurement errors. "Sampling errors," which in the context of a bathymetric survey are a failure to account for the variability of the bathymetry, are addressed by the data density in the design of the survey. Several techniques are used to detect and correct for measurement errors. Survey design is described in Section 3.1, QC techniques are described in Section 3.5, and data validation is described in Section 5.		
7. Optimize the Design for Obtaining Data	The bathymetric survey methods, equipment, and spacing of survey lines were selected to provide data that would meet the needs of the RD project. The details of the survey design are described in Section 3.1.		
8. Applicable Survey Method to Meet DQO	Bathymetric Survey	Bathymetric Survey	Bathymetric and Topographic Surveys

Representativeness: The overall degree to which the data appropriately reflect the LDW environment will be evaluated through visual analysis of the resulting sun-illuminated image to identify data anomalies or artifacts, and through comparison to prior surveys.

Comparability: The results of the 2003 and 2019 surveys should be directly comparable, given the similarities in the survey methods and equipment. The same horizontal and vertical datums will be used for the 2019 survey as those used in 2003 (as discussed in Section 3.1). Table 2 provides a summary of the equipment and software used and the target accuracies for the two surveys.

Table 2
Comparison of 2003 and 2019 Bathymetric Survey Methods

Feature	2003 Survey	2019 Survey
Multibeam Sonar System	Reason 8101	R2Sonic 2022
RTK GPS Inertial Navigation System	Applanix POS-MV	Applanix POS-MV
Hydrographic Processing Software	Caris Hydrographic Information Processing System	HyPack HySweep
Sounding Selection Method	1-foot by 1-foot average	1-foot by 1-foot average
Horizontal Accuracy	+/- 3 feet	+/- 3 feet
Vertical Accuracy	+/- 0.5 feet	+/- 0.5 feet

Completeness: The objective of the survey is to provide bank-to-bank coverage where the survey vessel can safely navigate. The targeted water elevation for surveying shorelines is ≥5 feet above mean lower low water (MLLW). The following factors will affect the ability to collect bank-to-bank data:

- Tidal stage: increased water depth allows for increased coverage toward shore from the survey vessel. The progress of the survey will be timed to gather data from the banks at the time around the high tide and from deeper water within the channel when tide levels are not critical to data collection.
- Obstructions such as docks, moored vessels, or pilings, which may restrict vessel operations or block sonar signals. The survey vessel will work around existing structures as they are encountered. LDWG will ask owners of moored vessels to move their vessels, but vessel owners may choose not to comply with requests from LDWG. Obstructions that prevent access for surveying will be noted in the field log and

reported as explanatory notes with the final survey drawings. The nature of the obstruction and the size of the affected area will be noted.

- Bank slope: a long shallow bank will not be mapped as close to shore as a steep bank. The survey vessel operator will adjust survey methods to the extent practicable, as described in Section 3.2, to collect data as high as possible on shallowly sloped banks.

It is expected that there will be data gaps that cannot be avoided, such as those caused by obstructions[4] or shallow areas. These areas will be evaluated on a case-by-case basis, and an assessment will be made in consultation with EPA to determine whether further bathymetric surveying or alternative surveying methods (e.g., upland topographic surveys, single-beam bathymetric survey, or LiDAR) are required to fill data gaps to inform the RD.

Sensitivity: The sonar swath will be limited to 60° throughout the project area with the exception of shoreline banks and slopes under existing piers and floats. The hydrographer that is onboard during data acquisition will make the determination on when it is appropriate to use sonar beams beyond 60°.

2.5 Special Training and Certification

NWH personnel have specialized training and extensive experience in conducting high-resolution multibeam surveys. NWH's field operations manager is a certified hydrographer under the American Congress on Surveying and Mapping Hydrographer Certification Program. Additional specialized training includes the following:

- University of New Brunswick: Ocean Mapping Group Multibeam Sonar Training Course (March 2007)
- HyPack Annual Training (latest: January 2018)
- Caris Hydrographic Information Processing System (March 2010)

2.6 Documentation and Records

Prior to mobilization for the bathymetric survey, the approved QAPP will be provided to all field personnel for review. The Anchor QEA project manager or his designee will confirm that all field personnel receive the final QAPP, including any addenda and modifications. The leader of the field operations will be responsible for conducting the survey in conformance

[4] LDWG does not have day-to-day control over the location of ships and barges in the LDW to enable removal of these types of obstructions prior to the survey.

with the requirements of the approved QAPP, and the NWH field operations manager will be responsible for overall quality assurance of the bathymetric survey product.

Multibeam bathymetric data will be presented as a series of maps that will be overlaid on sun-illuminated images of the bathymetric digital terrain model (DTM). Drawings will be compiled in AutoCAD at a mutually agreed-upon scale, to be determined during design. The maps will be projected in North American Datum (NAD) 83 through the 1991 adjustment (NAD83/91) Washington State Plane North (feet) and will include 1-foot elevation contours in feet MLLW. The multibeam sun-illuminated maps will represent a full coverage survey over the area imaged and will provide details of riverbed features. Sun-illuminated images will be produced in color. The multibeam data will also be imported into an ASCII format for use in a geographic information system (GIS).

The following information will be provided in the bathymetric survey data report, which will be submitted as part of the PDI Data Evaluation Report:

- Written report of the survey describing survey methodology, equipment (including the sensitivity of the equipment), and analysis methodology (submitted as draft and final versions)
- Documentation of QC checks and identification of QC issues
- Deviations from this QAPP
- Contour maps at a mutually agreed-upon scale, to be determined during design
- Sun-illuminated maps at the same scale and layout as contour maps
- Electronic versions of data products, which will include Portable Document Format (PDF) files for reports, AutoCAD files (DWG format) of contours and imagery, ArcMap shape files of contours, and georeferenced TIFF files of imagery
- ASCII files of 1-foot binned data sets

3 Data Generation and Acquisition

3.1 Survey Design

The bathymetric survey of the LDW will collect precision data in the primary survey area covering approximately 2.5 miles of the waterway starting at RM 2.75 and extending upstream to RM 5.25 (if feasible), as shown on Figure 1.

The survey will be conducted using multibeam sonar over most of the project area. In areas with sufficient water depth (greater than 8 feet), multibeam sonar allows for the collection of data with up to 100% coverage of the riverbed, compared to single-beam methodology, which covers a single track directly below the survey vessel and allows for only partial coverage. This method allows for the collection of high-resolution bathymetric data. The multibeam bathymetric data will be used to create a digital terrain model of the riverbed morphology, from which sun-illuminated images will be generated.

Data will be collected by running several lines parallel to the shoreline. Several perpendicular crosstie lines will also be surveyed to confirm system calibration and document accuracy.

The survey will be conducted on an established coordinate system, referenced by monuments established or recovered during a geodetic control survey of the site. The same horizontal and vertical datums will be used for the 2019 survey as those used in 2003. The horizontal datum for this survey is NAD83 through the 1991 adjustment (NAD83/91), State Plane Coordinate System, Washington North Zone, measured in U.S Survey Feet. Vertical datum for this survey will be feet MLLW. The GEOID12B model will be used to relate soundings to North American Vertical Datum of 1988. Both the 2003 and 2019 bathymetric surveys will be on the same National Tidal Datum Epoch. The target horizontal and vertical accuracy of the bathymetric survey is presented in Section 2.4.

3.2 Survey Methods

This section describes the survey vessel and crew, control network, positioning, and acquisition of multibeam data. Safe working practices for conducting this survey are described in the Health and Safety Plan (HASP; see Appendix A).

3.2.1 Survey Vessel and Crew

The survey vessel (S/V) will be the S/V Soundwave, or equivalent, an 8-meter custom aluminum survey boat owned and operated by NWH. This vessel is equipped with an integrated navigation and data acquisition system and a custom mount for the R2Sonic 2022 sonar head and is ideal for shallow-water survey operations in tight quarters. A smaller vessel will be used in areas with restricted overhead clearance. The same survey equipment and QC procedures will be used with either vessel. The bathymetric survey crew will consist of a lead hydrographer and an assisting hydrographer from NWH.

3.2.2 Control Network

Prior to the multibeam survey, True North will establish a control network along the LDW. This control network will be based on NAD83/91, Washington North Zone horizontal positions, and MLLW elevations. As the primary vertical control for this survey will be provided by real-time kinematic (RTK) GPS observations based on this control network, an accurate ellipsoid separation model, which is built into the Hypack software, will be used to provide on-the-fly conversion from the WGS84 ellipsoid (ellipsoid from which GPS heights are derived) to MLLW. This requires ties to existing monuments for which MLLW elevations and NAD83/91 positions are published and placement of new monuments along the project corridor.[5] In addition, the control network will be expanded to include ties to staff gauging sites positioned approximately 1 to 2 miles apart within the study area. If existing staff gauges are not positioned approximately 1 to 2 miles apart, new gauges will be placed along the LDW at approximately RM 3, 4, and 5. Exact locations will be determined in the field (as a standard practice) and documented in the hydrographer's field log. Adjustments will be computed for each staff gauge to allow for a real-time comparison to RTK GPS-derived water surface elevations, which will be recorded at 1-minute intervals at a temporary monitoring station set up for the bathymetric survey.

A geodetic control survey will be conducted using GPS techniques from monuments with published positions and elevations. A network of observations will be made with redundant comparisons to document accuracy of the survey. The details of the geodetic control survey will be reported with the results of the bathymetric survey.

[5] Upland survey monuments will be placed at each end of the study area and at two locations within the study area. In addition, staff gauging locations will be positioned approximately 1 mile apart within the study area.

3.2.3 Positioning

Horizontal positions will be acquired with an Applanix Position and Orientation System for Marine Vessels (POS/MV) RTK positioning system and inertial navigation system. This system integrates two GPS receivers with a motion reference unit. Additionally, RTK GPS corrections will be input into the system to improve horizontal positioning accuracy to better than 0.5 meter (1.6 feet). The advantage of this system is that it not only provides motion information (i.e., heading, roll, pitch, and heave) to compute X, Y, Z data from the multibeam sonar measurements, but it also provides accurate inertial navigation through GPS outages for up to 30 seconds, which has been a major problem with conventional differential global positioning system (DGPS) equipment. These systems are preferred because the use of conventional equipment near bridges and alongside ships, a typical environment in the LDW, causes satellite signals to be blocked and/or reflected from these structures (multi-path), resulting in position jumps or large drifts in position, which can exceed survey tolerances. During these GPS signal outages, the inertial system takes over and provides accurate navigation until GPS signals are reestablished after passing the obstruction.

Position data will be used in real-time to provide navigation information to the vessel operator. A preliminary coverage plot will be generated in real-time to show multibeam swath coverage. The helmsman will be presented with a plan view of the survey area, with the vessel position and track. A color-coded swath of the multibeam coverage will be painted to the screen and used to navigate the survey vessel to fill the area. To check the accuracy of the positioning system and confirm that the geodetic parameters used in the real-time projection to the NAD83/91 Washington North Zone coordinate system are correct, a position check will be conducted daily on an established monument with a known position. Water surface measurements will be obtained by RTK GPS with on-the-fly ambiguity resolution, which is the ability to determine very accurate RTK GPS measurements while the survey vessel is moving. Water surface elevations obtained by RTK GPS will be checked against a primary National Oceanic and Atmospheric Administration (NOAA) tide station (9447130), located at the Colman Ferry Terminal in downtown Seattle, at staff gauges placed every 1 to 2 miles along the study corridor, and at an automated water-level gauge deployed by NWH at the upper reach of the study area. All soundings will be reduced to MLLW elevations in the delivered data set.

The automated water-level gauge will be deployed continuously during the survey to record and time-tag 1-minute water level observations at the upper reach of the study area. The gauge consists of a pressure transducer and a surface interface and recording device. The following procedures will be followed for deployment:

- A temporary staff gauge will be surveyed in at the gauging site.
- The system clock will be synchronized with the data acquisition computers aboard the survey vessel prior to the survey.
- The pressure transducer will be calibrated relative to the staff gauge.

During the survey, system clock checks and comparisons of staff gauge results to automated gauge results will be conducted at least three times (beginning, middle, and end) per day of survey.

3.2.4 Bathymetric Data Acquisition

Soundings, or precision water depth measurements, will be acquired with a R2Sonic 2022 broadband multibeam bathymetric sonar. Using a frequency of 400 kHz, the R2Sonic sonar illuminates up to a 160° (80° to starboard and 80° to port) by 1.0° swath along the riverbed, perpendicular to the ship's track, and resolves a slant-range measurement to the riverbed every 1.0° along the swath. Sonar ping rates vary, depending on the depth of the water and sonar range settings, but generally will be a minimum rate of 17 Hz as the vessel transits along the survey track line.

Multibeam data will be collected by running lines parallel with the shoreline. Although the R2Sonic multibeam sonar can acquire data out to 80° on both port and starboard sides under the standard deployment, data will not meet target vertical criteria beyond 60° on a flat bottom. During survey operations all lines offshore of the shoreline runs will have the sonar swath width limited to a maximum of 60° on both starboard and port beams (or less, depending on refraction and cross-line analysis) during processing. While collecting sloped shoreline and under-dock bathymetry, it may be necessary to tilt the multibeam sonar head, which is mounted on the starboard side of the vessel, to starboard 20°. In this configuration, shoreline data can be collected as far up the bank as possible, on a steep bank, by making shoreline runs with the starboard side toward shore. Survey lines offshore of the shoreline runs will limit the starboard beams at 60° (or less, depending on refraction and cross-line analysis) during processing.

Running with a 120° swath (60° to port and starboard), the system still provides 3.5 times the water depth coverage in a single pass. The total swath width of full coverage mapping in a single pass will vary with the water depth, the cross-line comparison, and refraction analysis. If ships or barges, which may obstruct a planned survey transect, are shallow draft and not too wide, it may be possible to survey under them with the wide swath of the R2Sonic 2022. The POS/MV system will enable the survey vessel to run near ships at berth with minimal loss of positioning integrity. In addition to several parallel lines down the channel, crosstie lines will be run over the main scheme lines to confirm system calibration and document the accuracy of the survey. In addition, single-beam comparison lines will be run in shallow water along the shore to confirm accuracy of the outer beams. To account for vessel heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor, or equivalent, will be utilized. The POS/MV system will also be used to record vessel heading (yaw) from which the sonar beam orientation is derived. The POS/MV provides a higher degree of accuracy for heading measurements than a conventional gyrocompass.

Multibeam data will be acquired with HyPack HySweep data acquisition software. HySweep acquires and time-tags all sensor data, including multibeam sonar, position, heading, heave, pitch, and roll. The navigation system provides navigation output to the vessel operator's monitor and manages the survey. The acquisition systems can also be used to replay the survey so that the coverage and quality of the data can be reviewed prior to demobilization from the site.

Detailed measurements of the sound velocity profile through the water column are crucial in multibeam surveys and will be measured at 0.5-meter depth intervals from the water surface to the mudline in the part of the survey area with the deepest water. Changes in the sound velocity profile will not only affect acoustic distance measurements but can also cause refraction or bending of the sonar path as it passes through layers in the water column at different velocities. Because the velocity of sound is directly related to the density and temperature of water, changes in the sound velocity profile are expected to occur in the LDW due to the mixing of fresh and salt water during tidal changes. For this survey, an AML BaseX_2 sound velocity profiler, or equivalent, will be used to directly measure sound velocity profiles (SVP) of the water column. It is anticipated that the SVP will have spatial and temporal variation. To account for spatial variation, the LDW will be divided into subsections. The size of the survey subsections will be determined at the time of surveying by collecting SVP data and adjusting the length of a subsection so that similar results are

obtained at each end. Temporal change will be addressed by taking SVP measurements as the subsection is surveyed. Initial SVP measurements will be taken at least hourly through at least one complete tidal cycle. Subsequent measurements may be extended to every 2 hours, at the discretion of the lead hydrographer, based on the tidal cycle and observed measurement differences.

To confirm alignment of the sensor data with the sonar swath and verify delay times applied to the time-tagged sensor data, a patch test will be conducted. A patch test is a series of lines run in a specific pattern that are used in pairs to analyze roll, pitch, and heading alignment angles with the sonar swath, as well as latency (time delays) in the time tagging of the sensor data. A bar check and lead line check will be conducted to confirm draft of the sonar head. These tests will be conducted at the beginning and end of the survey and any time there are changes in the instrument configuration.

Data acquisition involves setting the motion sensor to the survey conditions and running slow, uniform lines in a systematic pattern. Adjustments will be made to scale and gain settings, as required, to maximize resolution of the survey.

During the survey, preliminary multibeam bathymetric data will be displayed in real-time on the HyPack computer. Pixels color-coded by depth will be drawn on screen, showing the coverage and agreement between adjacent swaths.

The high-resolution multibeam sonar system will be used during data acquisition for the vast majority of the site. In shallow areas (i.e., water depths less than 8 feet deep at high tide, a single-beam sonar system will be used in lieu of the multibeam), due to limitations of the multibeam system in shallow water depths. Examples of these areas might include: shorelines with low-angle slopes that prevent the vessel from getting close to the actual edge-of-water, inter-tidal mudflats, and shallow Green River areas above the turning basin. Line spacing for single-beam transects (if used) will be kept small (as determined by the field operations manager, based on survey vessel safe access and size of the area) to develop accurate modeling of the sediment contours. Bathymetry data acquisition will be strategically planned to collect shallow-water data during daily high tide events to maximize the amount of high-resolution multibeam sonar coverage of the project area. Deeper, mid-channel multibeam bathymetry can be collected during any tidal state and will be the focus of data collection efforts during low tides.

3.2.5 Survey Schedule

It is anticipated that the bathymetric survey will be conducted in April 2019, and field work is expected to require approximately 8 days, subject to factors such as tide conditions and interference from larger vessels. Within the planned bathymetric survey period, the surveyor will return to an incomplete coverage area if a moored vessel is moved to provide survey vessel access. The survey results will be used by subsequent documents, such as the PDI Work Plan. Any deviations from this QAPP in acquiring the bathymetric data will be noted in the bathymetric survey data report, which will be submitted as part of the PDI Data Evaluation Report.

3.3 Data Processing Methods

Post-processing of multibeam data will be completed using HyPack HySweep multibeam editing and analysis software. Patch test data will be analyzed and any alignment corrections will be applied. Water-level data will be verified and applied to adjust all depth measurements to MLLW. A sound velocity profile will be generated from the AML SVP measurements taken in the field and used to correct slant range measurements and compensate for ray path bending.

Processing will begin with review of each survey line using the HySweep swath editor. Verified water surface correctors will be applied to the data set at this time. Position and sensor data will be reviewed and accepted, if no outliers are present, or removed if erroneous data are observed. Sounding data will be reviewed and edited for data flyers such as bottom multiples, returns from pilings and passing vessel wakes. These data points will be removed and will not be used as part of the final data set. Sounding data, including sonar beams reflecting from sediment in the water column or noise due to aeration in the water column, will be carefully reviewed to determine if these data points should be removed.

After swath editing, all data will be reviewed through the HySweep's area-based editing tools to ensure no flyers remained in the data set. In the HySweep editor, a set of lines will be reviewed together for line-to-line comparison to ensure agreement to one another.

To take advantage of the level of detail the multibeam survey will provide, a 1-foot resolution sun-illuminated model and 1-foot gridded data set will be exported from HySweep. This gridding process will use an inverse weighted mean of all soundings within a 1-foot by 1-foot cell. The 1-foot grid size will allow for comparisons with previous

bathymetric surveys that were conducted with similar high-resolution methods, in order to interpret the possibility of shoaling or scouring. All original data will be archived at full resolution. The cross-line analysis for selected soundings will be performed on the data set at this stage. The sun-illuminated images will be reviewed for survey coverage and analyzed to determine if subtle artifacts remain in the data set, which may require further processing. The sun-illuminated plots will be exported as a georeferenced TIFF file that can be imported into AutoCAD or any GIS program for final presentation and plotting.

Export of accepted multibeam data will be imported into TerraModel software for generation of a DTM, from which contours will be generated.

3.4 Quality Control

The acquisition system and survey protocols are designed with some redundancy to demonstrate that the required accuracy is being achieved during the survey and to provide a backup to primary systems. Data integrity will be monitored throughout the survey by redundant system comparisons and checks against known values. All raw data are recorded to allow for adjustments to be made to any of the data during postprocessing, based on the results of comparisons and checks. Sound velocity and tide correctors can be modified at any time during processing. Data removed manually or through filtering will not be deleted, and this approach allows for review of all data to confirm or disprove anomalies.

Positioning: Positions will be recorded and archived in WGS84 geographic coordinates and projected onto NAD83/91 Washington North Zone coordinate system. A geodetic control survey will be conducted to provide positions for monuments within the study area. A position confidence check will be conducted daily on a monument that is accessible from the water. The check will consist of placement of an RTK GPS antenna over a project survey control monument. The obtained position will be compared to the surveyed value to assure the target horizontal and vertical accuracies are being obtained.

Tides: RTK GPS derived heights will be checked daily during the position checks. In addition, staff gauge observations will be made and compared to RTK GPS derived water elevations twice per day. Backup tidal observations from the NOAA automated gauge and the NWH-deployed automated gauge will be used to confirm and evaluate any anomalous data in the RTK GPS tidal values.

Sonar draft:

- A bar check will be conducted at the beginning and end of the project to confirm multibeam and single-beam[6] (if used) sonar draft below the water line. A bar will be lowered below the sonar to specific intervals below the water surface using calibrated marks on the attached chain.
- Sonar draft marks will be observed with the vessel trimmed to zero roll angle to confirm the static draft of the sonar.
- A comparison of multibeam and single-beam depth soundings will be performed at the beginning and end of the project to confirm multibeam and single-beam sonar draft below the water line in conformance with the Hydrographic Surveying Engineering Manuals (USACE 2013).
- A leadline depth observation will be made at the beginning and end of the project to confirm multibeam and single-beam sonar draft and sound velocity observations.

Motion sensor, positioning system latency, and vessel heading calibration: A patch test will be conducted at the beginning and end of the project to confirm that the sensor mounting angles and timing bias are correctly applied to multibeam sonar data.

Cross-line analysis: A cross-line analysis will be conducted across the full width of the survey, when there is sufficient water depth, to confirm that the beams used meet target accuracy. In addition, single-beam comparison lines will be run in shallow water along the shoreline to confirm accuracy of outer beams. In areas of shallow water (i.e., less than 8-foot depth), cross-line analysis will be used for verification in conformance with the Hydrographic Surveying Engineering Manual (USACE 2013).

Sun-illuminated analysis: A sun-illuminated image will be generated from a DTM of the accepted bathymetric data set. The image will be reviewed for anomalous data and consistency between adjacent sonar swaths.

3.5 Instrument/Equipment Testing, Inspection, and Maintenance

Prior to mobilization, the survey vessel and equipment will be inspected and confirmed to be in operating order. The vessel is inspected and maintained daily by the vessel operator.

[6] Some selected single-beam lines may be run to confirm multibeam measurements.

During mobilization, instrumentation will be tested and system performance testing will be conducted. Performance testing will include a bar check, patch test, leadline comparison to multibeam, single-beam echosounder comparison to multibeam, and position confidence check.

3.6 Instrument/Equipment Calibration and Frequency

Equipment calibration is verified through system performance testing (e.g., bar checks, position checks, staff or automated gauge comparison, multibeam patch test, leadline comparison, single beam comparison, and cross-line analysis). The exception is the AML SVP profiler, which is calibrated prior to the survey, verified with a pre- and post-survey bar check, and compared weekly to an independent temperature sensor.

Frequency of observations is as follows:

- Bar check, sonar draft mark observations, leadline and single beam comparison: beginning and end of project or any change in sonar mounting
- Position checks: daily
- Staff or automated gauge comparison: three times daily
- SVP profile: minimum of twice daily
- Multibeam patch test: beginning and end of project or any change in instrumentation
- Cross-line analysis: once per project

3.7 Inspection/Acceptance of Supplies and Consumables

No significant consumables are required because all data are digitally recorded. The survey vessel is equipped with survey log forms for survey documentation and a supply of solid state external hard-drives for data backup.

3.8 Non-Direct Measurements

The geodetic control survey will be based on existing monuments with published positions and elevations. Horizontal positions and elevations based on the North American Vertical Datum of 1988 will be based on National Geodetic Survey published monuments. MLLW elevations along the LDW will be based on NOAA tidal benchmarks at Station 9447130, Seattle, Washington, and the USACE tide datum at Station 92 on the LDW.

3.9 Data Management

Data from the survey vessel will be backed up to solid-state external hard drives at the end of each survey day. Data will not be removed from the acquisition computers until they have been loaded and verified on archived NWH data server located in the home office.

4 Assessment and Oversight

4.1 Assessments and Response Actions

EPA or its designees may observe the survey, as needed. If situations arise wherein there is a significant inability to follow the QAPP methods precisely, the NWH field operations manager will coordinate with the Anchor QEA project manager to determine the appropriate actions and consult with EPA if the issue is significant. No field audits are proposed for this work. The NWH field operations manager will audit system checks and sun-illuminated imagery during post-processing. True North will perform QA on the complete scope of the bathymetric survey.

4.2 Reports to Management

Primary communications will be through the NWH field operations manager and the Anchor QEA project manager. This correspondence will primarily consist of emails sent every evening during survey operations, which will include coverage images, general overview of survey progress, and any problems encountered during surveying. Anchor QEA will send copies of all communication to the King County project manager and LDWG.

5 Data Validation and Usability

5.1 Data Review, Verification, and Validation

Data will be reviewed and verified by evaluation of sun-illuminated imagery, cross-line analysis, comparison of multibeam data to redundant depth measurement techniques and comparison to adjacent soundings.

5.2 Verification and Validation Methods

Verification of multibeam data will be performed by comparison to intersecting and overlapping swath soundings, single-beam data, and (in areas of firm material) leadline soundings. Patch test data will be analyzed and a cross-line analysis will be performed to document the system performance. In areas where only single-beam surveying is possible (e.g., where water depth is insufficient for effective multibeam survey), cross-line analysis will be used for verification in conformance with the Hydrographic Surveying Engineering Manual (USACE 2013).

Sun-illuminated images will be reviewed for anomalous data and inconsistency between adjacent sonar swaths. Artifacts in the image will be investigated in HyPack HySweep editor by comparing the data to adjacent soundings and swaths.

5.3 Reconciliation with Data Quality Objectives

Data quality objectives for accuracy will be achieved by meeting the target horizontal and vertical accuracies at a 95% confidence level for the survey. Methods outlined in Sections 3.5, 3.7, and 5.2, will verify that the target accuracies are being obtained. Other data quality indicators, including completeness, representativeness, and precision, will be evaluated with a color-by-depth, sun-illuminated, coverage image generated in HyPack HySweep. This image processing system provides tools for data quality review (i.e., swath-to-swath comparison, 3D presentation color-coded by swath, etc.). Final review by the lead hydrographer will include the evaluation of sun-illuminated images for artifacts from system bias, and comparison to prior surveys.

Table 3 summarizes the key targets and related datums for the bathymetric survey. Horizontal accuracy of the survey is affected by several factors, including the positioning accuracy of the survey vessel and factors that can affect sonar data acquisition, such as vessel heave, pitch, and roll and signal interferences.

Table 3
Key Targets and Related Datums

Description	Quantity or Datum
Horizontal Positioning Accuracy	1.6 feet minimum
Horizontal Survey Accuracy	3 feet at a 95% confidence interval
Horizontal Datum	NAD83/91 Washington North Zone
Vertical Survey Accuracy	+/- 0.5 feet at a 95% confidence interval
Vertical Datum	MLLW

6 References

AECOM, 2012. *Final Feasibility Study Lower Duwamish Waterway*. Prepared for Lower Duwamish Waterway Group. October 2012.

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EPA, 2018. Fourth Amendment of the *Administrative Order on Consent/or Remedial Investigation/Feasibility Study*, U.S. EPA, Region 10 Docket No. CERCLA 10-2001-0055, Ecology Docket No 00TCPNR-1895 (12/20/2000). July 2018.

Integral (Integral Consulting Inc.), 2018. *Waterway User Survey and Assessment of In-Water Structures—Data Report*. Prepared for Lower Duwamish Waterway Group. July 2018.

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USACE (U.S. Army Corps of Engineers), 2013. *Engineering and Design: Hydrographic Surveying*. EM 1110-2-1003. Department of the Army, US Army Corps of Engineers. November 2013.

Appendix A
Health and Safety Plan

Appendix A. Health and Safety Plan

By their signature, the undersigned certify that this Health and Safety Plan (HASP) is approved and that it will be used to govern health and safety aspects of fieldwork described in the Quality Assurance Project Plan to which it is attached.

Thomas Wang

Tom Wang
Anchor QEA, LLC, Project Manager

April 10, 2019
Date

CR Torell

Chris Torell
Anchor QEA, LLC, Corporate Health and Safety Manager

April 10, 2019
Date

James Glaeser
Northwest Hydro, Inc., Field Operations Manager/Health and Safety Officer

April 10, 2019
Date

ACRONYMS

CPR	cardiopulmonary resuscitation
EPA	US Environmental Protection Agency
FOM	Field Operations Manager
HAZMAT	hazardous materials
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSM	Project Health and Safety Manager
HSO	Field Health and Safety Officer
HASP	health and safety plan
LDW	Lower Duwamish Waterway
NWH	Northwest Hydro, Inc.
OSHA	Occupational Safety and Health Administration
PFD	personal flotation device
PM	project manager
PPE	personal protective equipment
TNLS	True North Land Surveying, Inc.
USCG	United States Coast Guard
VHF	very high frequency
WAC	Washington Administrative Code

A.1.0 Introduction

This site-specific health and safety plan (HASP) describes safe working practices for conducting field activities at potentially hazardous sites. This HASP is consistent with the relevant elements of Washington Administrative Code (WAC) 296-843. The goal of the HASP is to establish procedures for safe working practices for all field personnel.

This HASP addresses activities associated with collection of bathymetric data in the Lower Duwamish Waterway (LDW). During site work, this HASP will be implemented by the Northwest Hydro, Inc. (NWH), Field Operations Manager (FOM), who is also the designated site Health and Safety Officer (HSO), in cooperation with the Corporate Health and Safety Manager (HSM). Anchor QEA has overall responsibility for the remedial design and project management responsibility for the bathymetric survey. Field operations for bathymetric surveying will be performed by NWH, and upland survey control points will be established by True North Land Surveying, Inc. (TNLS). Anchor QEA personnel will not be present during field activities. NWH and TNLS are responsible for their respective employees' safety in the field.

All personnel involved in fieldwork on this project are required to comply with this HASP. The contents of this HASP reflect anticipation of the types of activities to be performed, knowledge of the physical characteristics of the site, and consideration of preliminary chemical data from previous investigations at the site. The HASP may be revised based on new information and/or changed conditions during site activities. Revisions will be documented in the project records.

A.2.0 Site Description and Project Scope

The surveying area is in the LDW (see Figure 1 in the attached QAPP). The area is affected by tidal fluctuations. The QAPP to which this HASP is attached provides complete details of the bathymetric survey. The survey will be conducted using an 8-meter aluminum vessel, as described in the QAPP. The duration of the survey is expected to be approximately 8 days.

A.3.0 Health and Safety Personnel

Key health and safety personnel and their responsibilities are described below. These individuals are responsible for the implementation of this HASP.

Anchor QEA Project Manager: The PM has overall responsibility for the successful outcome of the project. The PM will ensure that adequate resources and budget are provided for the health and safety staff to carry out their responsibilities during fieldwork.

NWH Field Operations Manager/Health and Safety Officer: Because of the limited scope and duration of fieldwork, the NWH FOM and HSO will be the same person. The FOM/HSO will direct field surveying activities, coordinate the technical components of the field program with health and safety components, and ensure that work is performed according to the QAPP.

The FOM/HSO will implement this HASP at the work location and will be responsible for all health and safety activities and the delegation of duties to a health and safety technician in the field, if appropriate. The FOM/HSO also has stop-work authority, to be used if there is an imminent safety hazard or potentially dangerous situation. The FOM/HSO or his designee shall be present during surveying operations.

Anchor QEA Corporate Health and Safety Manager: The HSM has overall responsibility for preparation, approval, and revisions of this HASP. The HSM will not be present during fieldwork, but will be readily available, if required, for consultation regarding health and safety issues during fieldwork.

Field Crew: All field crew members must be familiar with and comply with the information in this HASP. They also have the responsibility to report any potentially unsafe or hazardous conditions to the FOM/HSO immediately.

A.4.0 Hazard Evaluation and Control Measures

This section covers potential physical and chemical hazards that may be associated with the proposed project activities and presents control measures for addressing these hazards. The activity hazard analysis, Section A.4.3, lists the potential hazards associated with each site activity and the recommended site control to be used to minimize each potential hazard.

Confined space entry will not be necessary for this project. Therefore, hazards associated with this activity are not discussed in this HASP.

A.4.1 Physical Hazards

For this project, it is anticipated that physical hazards will present a greater risk of injury than chemical hazards. Chemical hazards are not present during the bathymetric surveying, as explained in Section A.4.2. Physical hazards are identified and discussed below.

A.4.1.1 Slips, Trips, and Falls

As with all fieldwork sites, caution should be exercised to prevent slips on slick surfaces. In particular, surveying from a boat or other floating platform requires careful attention to minimize the risk of falling down or of falling overboard. The same care should be used in rainy conditions or on the shoreline where slick rocks are found. Slips will be minimized by wearing boots with good tread, made of material that does not become overly slippery when wet.

Trips are always a hazard on the uneven deck of a boat, in a cluttered work area, or in the intertidal zone where uneven substrate is common. Personnel will keep work areas as free as possible from items that interfere with walking.

Falls may be avoided by working as far from exposed edges as possible, by erecting railings, and by using fall protection when working on elevated platforms. For this project, no work is anticipated that would present a fall hazard. However, some of the surveying will be done from a boat. As with any work from a floating platform, there is a chance of falling overboard. Personal flotation devices (PFDs) will be worn while working on deck or working from an open boat. PFDs need not be worn while working inside an enclosed cabin, but must be readily available when going on deck from the cabin area. An individual in the water shall be considered a "person overboard" and appropriate rescue actions shall be taken immediately to prevent hypothermia.

A.4.1.2 Manual Lifting

Equipment must be lifted and carried. Back strain can result if lifting is done improperly. During any manual handling tasks, personnel should lift with the load supported by their legs and not their backs. For heavy loads, an adequate number of people will be used, or if possible, a mechanical lifting/handling device will be used.

A.4.1.3 Heat Stress, Hypothermia, or Frostbite

Surveying operations and conditions that might result in the occurrence of heat stress or frostbite are not anticipated. The surveying will occur during the time of year when extreme weather conditions are not expected to occur. Nonetheless, the vessel crew and other personnel shall have adequate clothing and foul-weather gear in their possession prior to vessel departure. Hypothermia is a potential hazardous condition for a crewmember who falls into the water.

Hypothermia is characterized by pain in the extremities and loss of manual dexterity, with severe, uncontrollable shivering, and an inability to maintain the level of activity. Symptoms include excessive fatigue, drowsiness, irritability, or euphoria. Severe hypothermia includes clouded consciousness, low blood pressure, pupil dilation, cessation of shivering, unconsciousness, and possible death.

Move the individual to a warm, dry place. If the individual's clothing is wet, remove it and replace it with dry clothing. Keep the individual warm. Rewarming the individual should be gradual to avoid stroke symptoms. Dehydration, or the loss of body fluids, may result in a cold injury due to a significant change in blood flow to the extremities. If the individual is conscious and alert, warm sweet liquids should be provided. Coffee and other caffeinated liquids should be avoided because of diuretic and circulatory effects. Extremities affected by frostbite should be gradually warmed and returned to normal temperature. Moist compresses should be applied; begin with lukewarm compresses and slowly increase the temperature as changes in skin temperature are detected. Keep the individual warm and calm and move to a medical facility as soon as possible.

A.4.1.4 Weather

In general, field team members will be equipped for the normal range of weather conditions. Work shall be preceded by an evaluation of weather reports and conditions by the FOM/HSO and vessel pilot to ascertain that safe working conditions exist and safe refuge of personnel is assured. An alternate safe harbor shall be designated for emergency situations. Field personnel shall maintain monitoring of the local area weather broadcasts or other readily available weather forecasting services. Some conditions that might force work stoppage are electrical storms, high winds, or high waves resulting from winds.

A.4.1.5 Boating Operations

The following precautions shall be taken when conducting boating trailer and launch activities. These procedures are provided as a reference; NWH will follow their own internal boating safety procedures and consider the procedures below.

- Follow the trailer and boat manufacturers' instructions for securing the boat to the trailer.
- Follow the trailer manufacturer's instructions for securing the trailer to the towing vehicle.
- Prohibit site personnel from moving into trailer/vehicle pinch points without advising the vehicle operator.
- Use experienced operators when backing trailers on boat ramps.
- Wear proper work gloves when the possibility of pinching or other injury may be caused by moving or handling large or heavy objects.
- Maintain all equipment in a safe condition.
- Launch boats one at a time to avoid collisions.
- Use a spotter for vehicles backing boats to the launch area.
- Understand and review hand signals.
- Wear boots with non-slip soles when launching boats.
- Wear USCG-approved PFDs when working within 10 feet of the water.
- Keep ropes and lines coiled and stowed to eliminate trip hazards.
- Maintain three-point contact on dock/pier or boat ladders.
- Verify that drain plugs are in place.

The following precautions shall be followed when conducting boating operations:

- Maintain a current boater's license(s) as required.
- Wear USCG-approved PFDs for work activities within 10 feet of the water.
- Obtain and review information regarding dams that may be present in work areas, particularly with regard to "no boating" zones and safety buoys, cables, and warning signage.
- Maintain boat anchorage devices commensurate with anticipated currents, distance to shore, and water depths.
- Provide a floating ring buoy in the immediate boat launch/landing areas with at least 60 feet (18.3 meters) of line for a vessel less than 65 feet (19.8 meters) in length, or

90 feet (27.4 meters) of line for a vessel 65 feet (19.8 meters) or greater in length (see https://www.law.cornell.edu/cfr/text/46/117.70 for more information).

- Step into the center of the boat.
- Keep your weight low when moving on the boat.
- Move slowly and deliberately.
- Steer directly across other boat wakes at a 90-degree angle to avoid capsizing.
- Steer the boat facing forward.
- Watch for floating objects in the water.
- Right-of-way is yielded to vessels on your boat's right, or starboard, and vessels with limited ability to maneuver such as any wind-propelled vessel.

The following precautions shall be followed when working on a boat:

- Observe proper lifting techniques.
- Wear USCG-approved PFDs for work activities within 10 feet of the water.

The safety-related items listed in Table A-1 shall be available when conducting boating operations.

Table A-1
Safety equipment specific to in-water work

Additional Safety Equipment for Sampling Vessel per U.S. Coast Guard Requirements	
• Proper vessel registration, numbering, and documentation (registered with state, certificate of vessel registration number displayed, and carrying a valid certificate of number) • USCG-approved personal flotation devices (PFDs; or life jackets) for every person on the sampling vessel (Type I, II, III, or V are required). High-visibility required by Anchor QEA. • Appropriate, non-expired, visual distress devices for day and night use from the following: – Three hand-held red flares (day and night), or – One hand-held red flare and two parachute flares (day and night), or – One hand-held orange smoke signal, two floating orange smoke signals (day), and one electric distress light (night only) • Alternate means of propulsion (oars or paddles) • Dewatering device (pump or bailer) • Properly maintained and inspected USCG-approved fire extinguishers (no fixed system = (2) B-1 or (1) B-2 type extinguishers; fixed system = (1) B-1 type extinguisher) • Proper ventilation of gasoline-powered vessels • Sound-producing device (whistle, bell, or horn) • VHF 2-way radio • Proper navigational light display • Throwable life ring with attached line (any vessel larger than 16 feet is required to carry one Type IV [throwable] PFD)	
Additional USCG Recommended Equipment Includes:	
• Extra visual distress signals • Primary and spare anchor • Heaving line • Fenders • First aid kit • Flashlight • Mirror • Searchlight • Sunburn lotion • Tool kit • Spare fuel	• Boat hook • Spare propeller • Mooring line • Food and water • Binoculars • Spare batteries • Sunglasses • Marine hardware • Extra clothing • Spare parts • Pertinent navigational chart(s) and compass

A.4.1.6 Working in a Roadway

These procedures are provided as reference; NWH will follow their own internal safety procedures for working in a roadway and consider the procedures below:

- Plan and conduct work in a manner that traffic may be continuously observed. This may require having a spotter equipped with a noise-making device such as an air horn or a whistle, as appropriate.
- Wear a high-visibility traffic vest and hardhat when a vehicle hazard exists. Include lighted elements when possible in high-hazard environments.
- Use cones, flag-mounted cones, caution tape, and/or barricades.
- Protect the work area with a vehicle or piece of heavy equipment if this does not pose an additional hazard. The vehicle should have a strobe light and operating headlights or running lights (if equipped).

A.4.2 Chemical Hazards

Previous investigations have shown that some chemical substances are present at higher-than-background concentrations in sediments from the surveying area. However, no direct or indirect contact with contaminated sediments is expected during this survey. The survey vessel will be launched from a concrete boat ramp or outside of the site, and once on site, personnel will not contact sediment or bring sediment onto the vessel. If a person falls overboard, the water depth should prevent contact with sediment and the person will be rescued to the boat. Swimming to shore should be avoided. Previous investigations determined that surface water does not present an acute health hazard. Public boating access in the study area is unrestricted. Consequently, no chemical hazards are expected.

A.4.3 Activity Hazard Analysis

The activity hazard analysis summarizes the field activities to be performed during the project, outlines the hazards associated with each activity, and presents controls that can reduce or eliminate the risk of the hazard occurring.

Table A-2 presents the activity hazard analysis for conducting the bathymetric survey from the surveying vessel.

Table A-2
Activity hazard analysis

Activity	Hazard	Control
Surveying from a boat	Falling overboard	Use care in boarding/departing from vessel. Deploy and recover the sonar head according to protocols specified in the QAPP and by the vessel captain. Wear PFD when on deck. Follow safe work practices related to vessel operations specified in Section A.6.0.
Launching a boat	Physical injury from moving heavy equipment	Follow procedures outlined in Section A.4.1.5 for safely launching a boat from a trailer.
Accessing survey control points	Vehicular traffic	Wear high-visibility clothing and remain aware of traffic while on the roadside. Refer to Section A.4.1.6

A.5.0 Work Zones and Shipboard Access Control

Because no direct contact with contaminated media is expected and no physical sample collection or processing will occur, there will be no designated work zone to which access must be controlled. Security and control of access to the boat will be the responsibility of the FOM/HSO and boat captain. Boat access will be granted only to necessary project personnel and authorized visitors. Visitors will be provided a copy of the HASP, a briefing on the project and related health and safety requirements, and an opportunity to ask questions about the HASP, and they will be required to sign the acknowledgement in Attachment A.1. Any security or access control problems will be reported to the client or appropriate authorities.

A.6.0 Safe Work Practices

Due to the nature of the survey, safe work practices are primarily related to vessel operations. All employees actively working on projects involving vessel operations will be thoroughly trained in the applicable safety, underway, docking, fueling, and various necessary operational procedures. The minimum responsibilities of the vessel crew members are as follows:

1. During all vessel operations the boat captain is in charge and takes full responsibility for safe operation of the vessel.
2. All vessel operators shall have adequate knowledge of the US Coast Guard (USCG) regulations, "Rules of The Road" and shall be approved for vessel operation by the FOM.

3. Vessels over 20 feet shall be inspected annually by a qualified marine surveyor to ensure structural integrity and safe operating conditions exist. Records of inspections shall be maintained on the vessel for vessels over 20 feet and shall be available to the designated authority.
4. When the vessel is brought onto a job site, it shall be inspected and tested by the vessel crew and determined to be in safe operating condition prior to the initiation of prescribed work.
5. Any vessel found to be in an unsafe condition shall be taken out of service and its use prohibited until the specified unsafe conditions have been corrected.
6. Prior to vessel departure from the dock, all onboard personnel shall be familiar with their duties and responsibilities in the event of an emergency, and the location of the vessel's emergency first-aid and firefighting equipment, as verbally communicated by a qualified member of the vessel crew.
7. All vessels shall be equipped with a PFD for each person onboard, a VHF marine radio and all USCG required safety equipment.
8. Navigation lights, radar systems, radios, depth sounders, and other navigational equipment shall be operated, inspected, and recorded each week and prior to each job by qualified personnel to ensure their proper operation.
9. A detailed daily work schedule that includes the approximate times, site locations, access points and other pertinent information necessary to locate crew members in the event of emergency, will be filed with the local field office or appropriate shore-side personnel.
10. Prior to departure from the dock, the vessel's fuel capacity will be checked to ensure adequate fuel is available to complete the day's work and maintain sufficient fuel reserves to allow for a reasonable margin of safety.
11. Fuel used on the outbound trip to assigned work areas shall not exceed one-third of the total fuel reserves. The pilot shall monitor fuel consumption throughout the work day and begin the inbound transit when remaining fuel reserves approach 150% of the fuel quantity used during the outbound transit.
12. Coast Guard approved PFDs shall be worn by all personnel when on deck or in an open vessel, regardless of other safety devices utilized. All safety devices must be inspected for defects prior to each use and those found to be defective replaced immediately. PFDs need not be worn while working inside an enclosed cabin, but must be readily available when going on deck from the cabin area.

13. Additional emergency/rescue equipment onboard vessels will include, but not be limited to, throw rings, throw ropes, dye markers, strobes, flares, boat hooks, and other safety equipment required by the USCG.
14. Vessel fuel valves shall be in the closed position when shutting down boat operations for the night or more than 8 hours.
15. Smoking shall be prohibited on the boat at all times and/or within 20 feet of fuel tanks.
16. A minimum of one 10-pound A-B-C fire extinguisher will be properly certified, maintained, and located conspicuously onboard all motor-driven vessels.
17. Work areas and access-ways shall be kept clean and clear of obstructions at all times.
18. A proper watch shall be maintained in order to avoid other vessels, floating debris, deadheads, and other obstructions.
19. When conducting night operations or working in reduced visibility, proper navigation lights shall be displayed, a safe speed (as warranted by the conditions) shall not be exceeded, and a proper watch shall be posted.

Other general safety rules will also be followed on site:

1. Do not climb over or under obstacles of questionable stability
2. Work only in well-lighted spaces
3. Make eye contact with equipment operators when moving within the range of their equipment
4. Be aware of the movements of shipboard equipment when not in the operator's range of vision
5. Get immediate first aid for all cuts, scratches, abrasions, or other minor injuries
6. Always use the buddy system
7. Be alert to your own and other workers' physical condition
8. Report all accidents, no matter how minor, to the FOM/HSO
9. Do not do anything dangerous or unwise even if ordered by a supervisor

A.7.0 Personal Protective Equipment and Safety Equipment

Appropriate PPE will be worn as protection against potential hazards. There are no chemical hazards associated with the surveying activities for the reasons presented in Section A.4.2. Therefore, there are no requirements for chemically resistant gloves or coveralls. For this survey, a PFD is the only required PPE when working aboard the boat or within 10 feet of

the water, and high-visibility clothing is required when accessing roadside survey control points. In addition to PPE that will be worn by survey personnel, basic emergency and first aid equipment will also be provided. Equipment for the field team will include:

1. A copy of this HASP
2. First aid kit adequate for the number of personnel

The FOM/HSO will ensure that the safety equipment is aboard. Equipment will be checked daily to ensure its readiness for use.

A.8.0 Monitoring Procedures for Site Activities

For this project, the monitoring program will consist of all workers monitoring themselves and their co-workers for signs that might indicate physical stress or illness. All personnel will be instructed to look for and inform each other of any deleterious changes in their physical or mental condition during the performance of all field activities. Examples of such changes are as follows:

1. Headaches
2. Dizziness
3. Nausea
4. Symptoms of heat stress
5. Blurred vision
6. Cramps
7. Irritation of eyes, skin, or respiratory system
8. Changes in complexion or skin color
9. Changes in apparent motor coordination
10. Increased frequency of minor mistakes
11. Excessive salivation or changes in papillary response
12. Changes in speech ability or speech pattern
13. Shivering
14. Blue lips or fingernails

If any of these conditions develop, work shall be halted immediately and the affected person(s) evaluated. If further assistance is needed, personnel at the local hospital will be notified, and an ambulance will be summoned if the condition is thought to be serious. If

the condition is the direct result of sample collection or handling activities, procedures will be modified to address the problem.

A.9.0 Decontamination

There are no chemical hazards associated with the surveying activities for the reasons presented in Section A.4.2. Therefore, no decontamination will be necessary.

A.10.0 Disposal of Contaminated Materials

No contaminated materials will be generated during the conduct of this survey.

A.11.0 Training Requirements

Project-specific training is described in Section 2.5 of the QAPP. Because no contact with contaminated media is expected, HAZWOPER training for surveying personnel is not required. At least one member of the field team must have first-aid and cardiopulmonary resuscitation (CPR) training. Documentation of which individuals possess first-aid and CPR training will be kept in the project health and safety files.

The FOM/HSO or a designee will provide project-specific training prior to the first day of fieldwork and whenever new workers arrive. Field personnel will not be allowed to begin work until project-specific training is completed and documented by the FOM/HSO. Training will address the HASP and all health and safety issues and procedures pertinent to field operations. Training will include, but not be limited to, the following topics:

- Activities that pose physical hazards, and actions to control the hazard
- Ship access control and procedure
- Use and limitations of PPE
- Emergency procedures
- Location of emergency equipment on the vessel
- Vessel safety practices
- Vessel evacuation and emergency procedures.

At the beginning of each day of work, the FOM/HSO will review with the team the activities planned for the day, potential hazards associated with the work, and control measures.

A.12.0 Medical Surveillance

A medical surveillance program conforming to the provisions of WAC 296-843-210 is not necessary for field team members because they do not meet any of the four criteria outlined in WAC 296-843-21005 for implementation of a medical surveillance program.

As described in Section A.8, employees will monitor themselves and each other of any deleterious changes in their physical or mental condition during the performance of all field activities.

A.13.0 Reporting and Record Keeping

Each member of the field crew will sign the HASP review form (see Attachment 1). If necessary, accident/incident report forms and OSHA Form 200s will be completed by the FOM/HSO.

The FOM/HSO or a designee will note health- and safety-related details of the project in the field logbook and record. The logbook must be bound, and the pages must be numbered consecutively. Entries will be made with indelible ink. At a minimum, each day's entries must include the following information:

1. Project name or location
2. Names of all personnel onboard
3. Weather conditions
4. Type of fieldwork being performed

The person maintaining the entries will initial and date the bottom of each completed page. Blank space at the bottom of an incompletely filled page will be lined out. Each day's entries will begin on the first blank page after the previous workday's entries.

A.14.0 Emergency Response Plan

As a result of the hazards onboard and the conditions under which operations will be conducted, the potential exists for an emergency situation to occur. Emergencies may include personal injury, fire, or explosion. OSHA regulations require that an emergency response plan be available for use onboard to guide actions in emergency situations.

Onshore organizations will be relied upon to provide response in emergency situations. The local fire department and ambulance service can provide timely response. Field personnel will be responsible for identifying an emergency situation, providing first aid if applicable,

notifying the appropriate personnel or agency, and evacuating any hazardous area. Shipboard personnel will attempt to control only very minor hazards that could present an emergency situation, such as a small fire, and will otherwise rely on outside emergency response resources.

The following sections identify the onboard individual(s) who should be notified in case of emergency, provide a list of emergency telephone numbers, offer guidance for particular types of emergencies, and provide directions and a map for getting from any surveying location to a hospital.

A.14.1 Pre-Emergency Preparation

Before the start of field activities, the FOM/HSO will ensure that preparation has been made in anticipation of emergencies. Preparatory actions include the following:

1. Meeting with the FOM/HSO and equipment handlers concerning the emergency procedures in the event that a person is injured
2. A training session given by the FOM/HSO informing all field personnel of emergency procedures, locations of emergency equipment and their use, and proper evacuation procedures
3. A training session given by senior staff operating field equipment, to apprise field personnel of operating procedures and specific risks associated with that equipment
4. Ensuring that field personnel are aware of the existence of the emergency response plan in the HASP and ensuring that a copy of the HASP accompanies the field team

A.14.2 Project Emergency Coordinator

The FOM/HSO will serve as the Project Emergency Coordinator in the event of an emergency. He will designate his replacement for times when he is not onboard or is not serving as the Project Emergency Coordinator. The designation will be noted in the logbook. The Project Emergency Coordinator will be notified immediately when an emergency is recognized. The Project Emergency Coordinator will be responsible for evaluating the emergency situation, notifying the appropriate emergency response units, coordinating access with those units, and directing interim actions onboard before the arrival of emergency response units. The Project Emergency Coordinator will notify the HSM and the Project Manager as soon as possible after initiating an emergency response action. The Project Manager will have responsibility for notifying the client.

A.14.3 Emergency Response Contacts

All onboard personnel must know whom to notify in the event of an emergency situation, even though the FOM/HSO has primary responsibility for notification. Table A-2 lists the names and phone numbers for emergency response services and individuals.

Table A-2
Emergency response contacts

Contact	Telephone Number
Emergency Numbers	
Ambulance	911
Police	911
Fire	911
Harborview Medical Center	(206) 323-3074
Emergency Responders	
U.S. Coast Guard	
Emergency General information	(206) 286-5400 (206) 442-5295 UHF Channel 16
National Response Center	(800) 424-8802
EPA	(908) 321-6660
Washington State Department of Ecology – Northwest Region Spill Response (24-hour emergency line)	(206) 649-7000
Emergency Contacts	
King County Project Representative	
Sonia-Lynn Abenojar	(206) 477-5424 (office)
Project Manager	
Tom Wang	(206) 903-3314 (office) (206) 465-0900 (cell)
Corporate Health and Safety Manager	
Chris Torell	(315) 414-2017 (office) (315) 254-4954 (cell)
Field Operations Manager/Field Health and Safety Officer	Site cellular telephone:
James Glaeser	(360) 241-7313

A.14.4 Recognition of Emergency Situations

Emergency situations will generally be recognizable by observation. An injury or illness will be considered an emergency if it requires treatment by a medical professional and cannot be treated with simple first-aid techniques.

A.14.5 Emergency Procedures Related to Vessel Operations

In deteriorating weather/sea conditions, radio the field office or USCG with your location, direction of travel, and approximate speed before a dangerous situation can develop. In an emergency, contact the USCG on VHF channel 16. Emergency VHF radio broadcasts should be proceeded by "Pan-Pan, Pan-Pan, Pan-Pan" for non-life threatening emergencies and "Mayday, Mayday, Mayday" for life threatening situations. Be prepared to provide your vessel name, location and the nature of the emergency. Don life jackets and/or survival suits, take necessary measures to prevent hypothermia, and wait for the search and rescue.

A.14.6 Fire

Field personnel will attempt to control only small fires, should they occur. If an explosion appears likely, personnel will follow evacuation procedures specified during the training session. If a fire cannot be controlled with a fire extinguisher on board that is part of the required safety equipment, personnel will either withdraw from the vicinity of the fire or evacuate the boat as specified in the training session.

A.14.7 Personal Injury

In the event of serious personal injury, including unconsciousness, possibility of broken bones, severe bleeding or blood loss, burns, shock, or trauma, the first responder will immediately do the following:

1. Administer first aid, if qualified
2. If not qualified, seek out an individual who is qualified to administer first aid, if time and conditions permit
3. Notify the Project Emergency Coordinator of the incident, the name of the individual, the location, and the nature of the injury
4. The Project Emergency Coordinator will immediately do the following:
5. Notify the boat captain and the appropriate emergency response organization.
6. Assist the injured individual.

7. Follow the emergency procedures for retrieving or disposing equipment reviewed in the training session and leave the site en route to the predetermined land-based emergency pick-up.
8. Designate someone to accompany the injured individual to the hospital.
9. If a life-threatening emergency occurs, i.e., injury where death is imminent without immediate treatment, the FOM/HSO or boat captain will call 911 and arrange to meet the Medic One unit at the nearest accessible dock. Otherwise, for emergency injuries that are not life threatening (i.e., sprains, minor lacerations, etc.) the Project Emergency Coordinator will follow the procedures outlined above and proceed to the Harbor Island Marina or to an alternative location of his choice if that would be more expedient.
10. Notify the HSM and the Project Manager.

If the Project Emergency Coordinator determines that emergency response is not necessary, he or she may direct someone to transport the individual by vehicle to the nearest hospital. Directions and a map showing the route to the hospital are in Section A.14.10.

If a worker leaves the boat to seek medical attention, another worker should accompany them to the hospital. When in doubt about the severity of an injury or exposure, always seek medical attention as a conservative approach, and notify the Project Emergency Coordinator.

The Project Emergency Coordinator will have responsibility for completing all accident/incident field reports, OSHA Form 200s, and other required follow-up forms.

A.14.8 Overt Personal Exposure or Injury

No overt exposure to toxic materials is expected to occur. Accordingly, no emergency procedures related to such exposure are required for this project.

A.14.9 Spills and Spill Containment

No bulk chemicals or other materials subject to spillage are expected to be used during this project. Accordingly, no spill containment procedure is required for this project.

A.14.10 Emergency Route to the Hospital

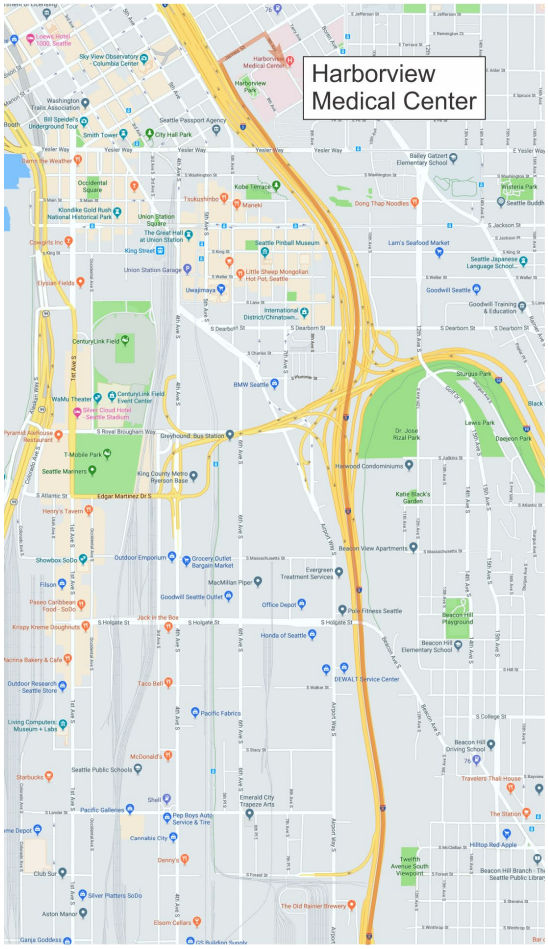
The name, address, and telephone number of the hospital that will be used to provide medical care is as follows:

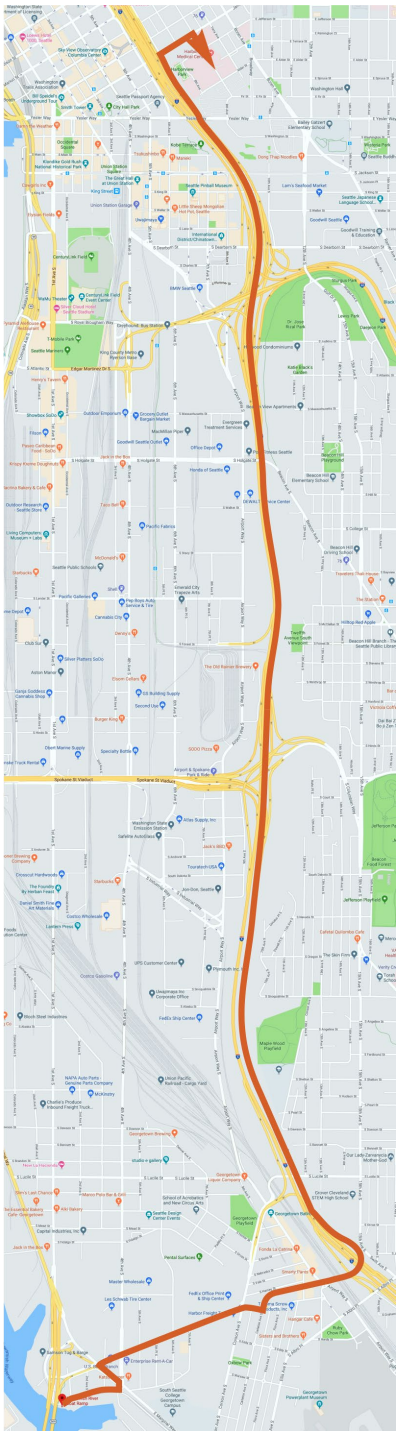
Harborview Medical Center
325 - 9th Avenue
Seattle, WA
(206) 323-3074

Directions from the vicinity of LDW to Harborview Medical Center are as follows:

1. Dock the vessel at the 1st Avenue S boat launch (Duwamish River Boat Ramp)
2. Drive east on S River Street
3. Turn left on 4th Avenue S
4. Turn left on E Marginal Way S
5. Turn right on S Michigan Street
6. Look for entrance ramps to I-5 Northbound (left turn)
7. Head north on I-5
8. Take the James Street exit
9. Turn right on James Street to 9th Avenue
10. Turn right on 9th Avenue
11. Emergency entrance will be two blocks south on the right

Figure A
Hospital Route Map





Attachment A1. Field Team Health and Safety Plan Review

I have read a copy of the Health and Safety Plan, which covers field activities that will be conducted to investigate potentially contaminated areas in the LDW. I understand the health and safety requirements of the project, which are detailed in this Health and Safety Plan.

Signature	Date
Signature	Date
Signature	Date
Signature	Date
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