Washington State Department of Ecology National Estuary Program (NEP) Quality Assurance Project Plan

Protecting the Strait of Juan de Fuca nearshore through Shoreline Master Program improvements: bluff development buffers and building setbacks, ecosystem services valuation, and community stewardship.

PC-00J29801-0

June, 2012

Prepared by:

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Prepared for:

Coastal Monitoring & Analysis Program
Washington State Department of Ecology

Publication Information

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Final feeder bluff erosion rates will be published as part of a report that will be available via Ecology's Shorelands and Environmental Assistance (SEA) Program web site (http://www.ecy.wa.gov/programs/sea/shorelan.html).

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1.0 Title Page

Quality Assurance Project Plan

Protecting the Strait of Juan de Fuca nearshore through Shoreline Master Program improvements: bluff development buffers and building setbacks, ecosystem services valuation, and community stewardship.

June, 2012

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3.0 Background

3.1 Study area and surroundings

Clallam County, and specifically the shoreline of the Elwha and Dungeness littoral cells, is the ideal location for initial application of the Ecology boat-based LiDAR system for coastal bluff erosion assessment (Figure 1). The Elwha and Dungeness drift cells offer actively eroding bluffs, easy access to protected harbors and marine facilities, and the opportunity to collaborate with researchers focused on the adjacent Elwha River Delta and coastal zone.

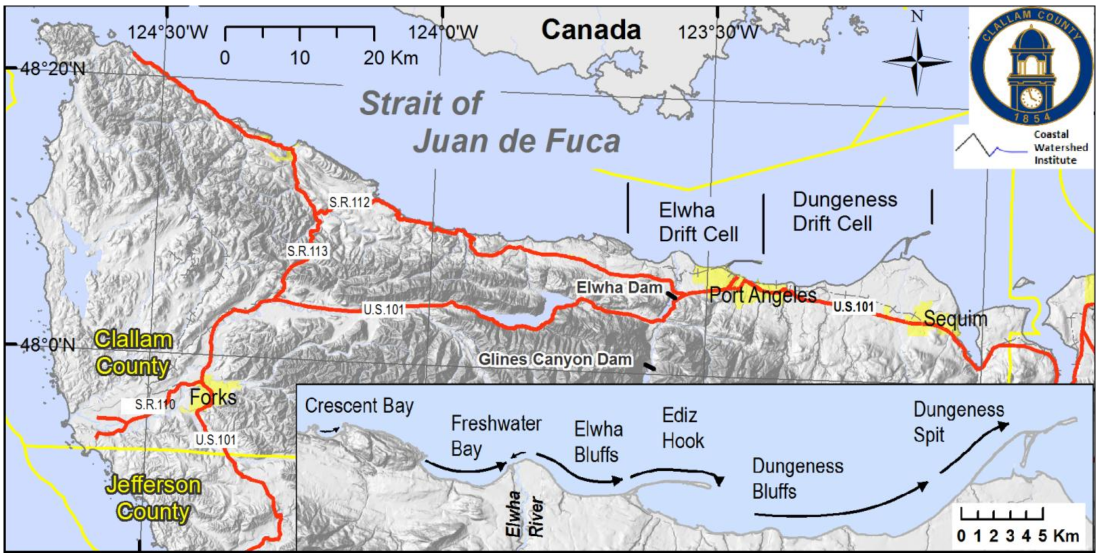

Figure 1. Map showing locations of the project site along the central Strait of Juan de Fuca in the Elwha and Dungeness drift cells along the northern Olympic Peninsula of Washington. The inert shows the project site in detail, identifying the Elwha and Dungeness Bluffs.

3.2 Logistical problems

The study area is easily accessed and surveyed by boat. Boat-launching facilities are less than 5 miles from the study site, and waters are generally navigable throughout the study area. Other than waves and weather constraints, we do not anticipate logistical problems.

3.3 History of study area

The nearshore zone, which extends from the areas of tidal influence as well as the riparian zone along the tops of the coastal bluffs to 30 meters mean lower low water (MLLW) and includes beaches, estuaries, and nearshore waters, is a critical component to the health of Puget Sound and has suffered extensive losses over the last one hundred years (Fresh, 2006; Shaffer et al., 2008; in press; Simenstad et al., 2011). Recently, many shoreline and coastal bluff landowners in Clallam County have expressed an interest in protecting the nearshore environment while at the same time preserving their property and ensuring their safety.

3.4 Contaminants of concern

N/A

3.5 Results of previous studies

Few quantitative measurements of bluff erosion rates are available for Puget Sound and the Strait of Juan de Fuca, largely because the available method, delineation of bluff edges on aerial photographs, is time-consuming and subject to large uncertainties. As part of the Ediz Hook Erosion Control Project in 1971, the U.S. Army Corps of Engineers published a bluff erosion study of the Elwha bluffs using historical photos and charts (USACE, 1971). However, the study was not accompanied by an assessment of uncertainty. Dave Parks of the Washington Department of Natural Resources (WA DNR) is currently engaged in a bluff erosion study, funded by the Clallam County Marine Resources Committee (MRC), using the best available methods for aerial photography analysis (personal communication, 2012). Randy Johnson (Jamestown S'Klallam Tribe) has quantified mean erosion rates of the bluff-edge using aerial photography for sections of the Dungeness drift cell (personal communication, 2012). However, poor temporal resolution of available aerial photography combined with the uncertainty of delineating bluff shorelines results in large uncertainties in erosion rates. In short, a new method – to be implemented in this study – is needed to quantify bluff erosion.

3.6 Regulatory criteria or standards

N/A

4.0 Project Description

4.1 Project goals

This QA Project Plan pertains only to Ecology's role within a larger project which involves:

- Enhancing public understanding of the connection between land-use, property management, and nearshore ecosystem functions and values along the Clallam County shoreline; and
- Supporting the No Net Loss provision in the Clallam County Shoreline Master Program by defining economic benefits of nearshore ecosystems in Clallam County.

The goals of the overall project most related to Ecology's role are to:

- Increase understanding of and thus compliance with building setbacks;
- Reduce challenges to the County's bluff setback requirements by providing high-quality data on bluff erosion, thus enhancing awareness of why they are needed.

4.2 Project objectives

To meet these goals, the project objectives will address both the technical data needs for supporting and improving SMP regulations and the community's need for sound information. The project will:

- Fill a knowledge gap regarding bluff erosion.
- Increase public and landowner understanding of bluff erosion processes and ecologically sound management options of properties adjacent to bluffs.
- Provide bluff erosion rates, timing, and processes as basis for changes in the County SMP.
- Enhance Clallam County and others' regulatory efforts by emphasizing bluff development buffers and building setbacks.

4.3 Information needed and sources

N/A

4.4 Target population

This project aims to capture the attention of decision-makers and facilitate a conversation among tribes and local governments, policy-makers, businessmen, scientists, and landowners.

4.5 Study boundaries

The project will take place along the central Strait of Juan de Fuca (see Figure 1). Ecology will be responsible for scanning and analyzing the shoreline and bluffs of the Dungeness and Elwha drift cells.

4.6 Tasks required

Ecology will be responsible for quantifying bluff edge erosion rates and total volume change in shoreline reaches using 3-5 high-resolution boat-based LiDAR surveys conducted between June 2012 and November 2013. We will collaborate with Ian Miller of Washington Sea Grant to perform these tasks. Seasonal and spatial patterns of erosion will be analyzed by binning erosion rates and volumes in 100-meter alongshore reaches. Reaches will be compared through time and within surveys to quantify temporal and spatial patterns. These data will be used to develop a generalized bluff erosion model to identify temporal bluff erosion trends averaged across each drift-cell and by shoreline reach.

We will use our survey data and older aerial photos to compare mean bluff erosion rates between armored and un-armored sections of bluff to investigate armoring impacts on sediment delivery. Aerial photos and survey data will also be combined to qualitatively explore the relationship between bluff erosion and upland development density and use.

To support management and regulation, outreach materials, primarily graphic images, will be developed that describe bluff erosion processes and scales of erosion (i.e., short-term failures and long-term rates). Details of the outreach materials will be defined by dialog with citizens and county as this task proceeds.

4.7 Practical constraints

Surveys will be conducted at the beginning (fall) and end (spring) of each winter storm season. Timing will be somewhat constricted by tides; we aim to survey as much of the beach as possible, so scheduling of the surveys will take times and heights of tides into account.

4.8 Systematic planning process used

Our project planning was based upon the information presented in sections 4.1-4.7. With respect to our objective of determining bluff erosion rates, timing, and processes, we have chosen survey techniques that are best fit for the location and overall project goals.

The orientation and location of the bluffs make boat-based LiDAR an accurate and effective survey tool. The schedule for surveying takes into account important external factors, like tides and possible effects of weather and seasonality.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities (project team, decision-makers, stakeholders, lab, etc.)

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5.2 Organization

Patricia Jatczak—overall project grant administration
Anne Shaffer—overall project manager
George Kaminsky—Chief Scientist; project coordination; data collection and analysis, production of final reports
Ian Miller—Scientist; field data collection, analysis, products and outreach
Heather Baron—Scientist; field data collection, QC, processing, and analysis, production of final reports
Diana McCandless—Scientist; historical data analysis; product generation
Rebecca Sexton—Technician; boat operations, field data collection

5.3 Project schedule

Surveys will be completed, at minimum, in spring of 2012, fall of 2012, and spring of 2013. Following initial surveys, reports will be given to CWI detailing initial findings and the status of the Dungeness and Elwha littoral cells. Two field reports will be filed, one in fall of 2012 and one in fall of 2013.

The following target completion dates have been set for the final products of the project:

- Final Sediment Budget Report: December 1, 2013
- Final Report on Bluff Erosion Model: December 15, 2013

.4 Limitations on schedule

Since surveying will take place aboard a research vessel on open water, weather will largely affect our ability to complete surveys at their scheduled times. Other factors for scheduling are addressed in Section 4.7.

5.5 Budget and funding

Washington Department of Fish and Wildlife (WDFW) was awarded Grant Number PC-00J29801-0 by the United States Environmental Protection Agency's National Estuary Program (EPA NEP). WDFW in turn, designated CWI as a sub-recipient of the grant. Ecology has been contracted by CWI to provide bluff erosion information. In addition to the grant funds received through CWI, Ecology has agreed to match $45,000 in project funding.

The following tasks and budget were extracted from the contract made between CWI and Ecology:

Deliverable 3.1. Report on Project Mobilization and Initial Data Collection. Summarizes acquisition, assembling and testing mobile laser scanning equipment and software, as well as identifying available geodetic control network.
Estimated Reimbursable Cost: $85,140

Deliverable 3.2. Report on 2012 Data Collection and Analysis. Includes description of collection of grain size data in the Elwha and Dungeness littoral cells, initiating beach monitoring based on high-resolution topographic mapping of bluffs and beaches, and performing fall 2012 beach monitoring and change analysis based on high-resolution topographic mapping of bluffs and beaches.
Estimated Reimbursable Cost: $8,000

Deliverable 3.3. Report on 2013 Data Collection and Analysis. Includes description of spring and fall beach monitoring and change analysis based on high-resolution topographic mapping of bluffs and beaches.
Estimated Reimbursable Cost: $8,000

Deliverable 3.4. Draft Report on Sediment budget, which quantifies sediment sources, transport pathways and rates, and beach change rates, both historical and contemporary.
Estimated Reimbursable Cost: $7,000

Deliverable 3.5. Final Report on Sediment budget
Estimated Reimbursable Cost: $0

Deliverable 4.1. Draft Report on Bluff Erosion Model. Includes identification of process-based erosion using available data and trends based on known sedimentology, calculation of mean and extreme rates of change based on LiDAR (will address process variability where possible), and compilation of historical shoreline change analysis for comparative purposes. Regression models of change rates (mean and extreme) will incorporate both data sets. Draft report will undergo

peer review. Outreach materials (graphics) that detail specific bluff erosion scales of erosion and bluff erosion processes will be included.
Estimated Reimbursable Cost: $22,882
Target Completion Date: November 1, 2013

Deliverable 4.2. Final Report on Bluff Erosion Model
Estimated Reimbursable Cost:$ 0
Target Completion Date: December 15, 2013

Total Estimated Reimbursable Cost for Ecology: $131,022
Match: $45,000

6.0 Quality Objectives

6.1 Data Quality Objectives (DQOs)

In order for contemporary bluff erosion rates to be calculated with acceptable/low uncertainty, a minimum of 3 high-resolution LiDAR surveys that meet Measurement Quality Objectives are needed.

6.2 Measurement Quality Objectives

Project objectives are to meet or surpass specified acceptability limits for different indicators of measurement quality. The LiDAR returns are georeferenced by the Position and Orientation System for Marine Vessels (POS MV) (see Section 7.1.3). Visual targets placed in the field of view of the scanner (see Section 10.1) will provide a means to measure the accuracy and precision of the geo-registration. The LiDAR returns reflected off each ground-control target will be examined so as to choose either a single point (return) that is closest to the center of the target (Figure 2) or a mathematically determined center by averaging the XYZ position of selected points within the inner circle of the target. Indicators of measurement quality are described as follows.

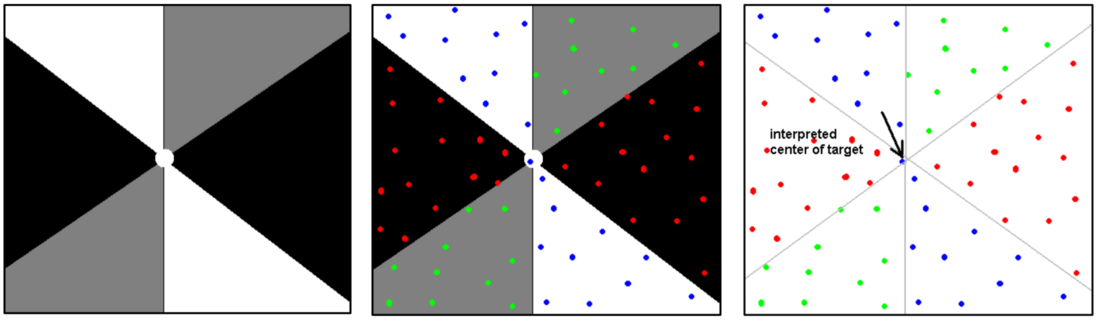

Figure 2. a) An example target design; b) schematic of LiDAR returns reflected off the target; and c) interpretation of LiDAR returns to position the target center.

6.2.1 Accuracy/bias

The accuracy of the collected LiDAR data must be within +/- 15 cm in 3-D position. This is the same vertical accuracy required by airborne LiDAR data and obtainable by ground-based GPS survey methods, thus the data will be comparable. The accuracy of our LiDAR system will be calculated as the root-mean-square (RMS) error between the GPS-surveyed center of the target and the LiDAR-detected center of the target. LiDAR point density will be greater than or equal to 8 pts/m^2. Data used for topographic change analysis will be based on ground laser returns that may involve removal of non-ground laser returns such as from vegetation surfaces (See Section 6.3.2).

6.2.2 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. With regard to topographic LiDAR data points, the major sources of random error are the sampling rate of the sensors in relation to the positional data provided by the Inertial Measurement Unit (IMU) and Global Positioning System (GPS) (See Section 7.1.3). The precision of the LiDAR data can be calculated as the spread in those error values; this quantity is akin to the qualities of “reproducibility” and “comparability”.

6.3 Targets developed for comparability, representativeness, and completeness

6.3.1 Comparability

In order to ensure comparability, all surveys will be set up with the same vessel positioning system and survey instruments, the same type of georeferencing targets, and will follow standard operating procedures. Our small research team will be conducting all of the surveys. Acceptable standard deviations and calculated error will ensure individual surveys were conducted with like experimental setup and procedures. On hard surfaces of assumed “no change”, we aim to see consecutive surveys agree to within +/- 15 cm. Areas of overlap from independent scans shall also align within +/- 15 cm.

6.3.2 Representativeness

Representativeness is a qualitative parameter that expresses the degree to which the collected data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness of the environmental conditions at the time of data collection is achieved by selecting locations, methods, and times so that the data describe the site conditions that the project seeks to evaluate. In the context of topographic LiDAR data representativeness is obtained by properly separating laser pulses that reflect from the ground surface from those that reflect from vegetation or buildings.

We will determine that our data is representative of the ground surface if our calculated error is within +/- 15 cm in 3-D position relative to GPS-measured ground control points and/or replicate measurements on stable surfaces (e.g., the sides of buildings).

6.3.3 Completeness

Completeness is a measure of the amount of valid data needed to be obtained from the measurement system. In the context of topographic LiDAR data, completeness is expressed in percentage of the target area for which data is successfully collected, and for which the data collected meets project specifications. For this project, we expect that 95% of the collected data will meet the project specifications, wherever ground surface data is visible.

7.0 Experimental Design

7.1 Study Design

The study design will contain the following elements:

7.1.1 Survey location and frequency

Surveys will take place from a vessel offshore of the Elwha and Dungeness littoral cells. For maps and further location information, see Section 4.5. The frequency of surveys is discussed in Section 5.3.

7.1.2 Parameters to be determined

The study design will determine 3-D positions across the topographic surface of beaches and bluffs.

7.1.3 Field measurements

Field measurements will be collected using the following equipment:

- Research Vessel – Surveying will take place from an aluminum 28' x 10' Munson Packcat beach-landing craft, the R/V George Davidson (Figure 3). With a draft of only 18 inches, the survey vessel is prepared for research in shallow water. The R/V George Davidson is outfitted with twin Yamaha 150 horsepower outboard engines and carries a maximum of 100 gallons of fuel. The hull was chosen for its extraordinary straight line tracking capability and the side to side stability, both important in shallow water hydrographic surveying. The boat has been custom-wired for LiDAR survey equipment and is outfitted with work benches for computers and survey gear.

Figure 3. Photo of the R/V George Davidson, Ecology's survey vessel. The laser scanner and IMU will be mounted to the top of the boat.

- LiDAR Survey System – The project will utilize an Optech ILRIS-HD ER with the Motion Compensation (MC) option (Figure 4; http://www.optech.ca/i3-Dprodline-ilris3D.htm).

Figure 4. Photo of the back panel of the Optech ILRIS-HD ER laser scanner.

- Inertial Measurement Unit -- An Applanix POS MV 320 system will be used (Figure 5; http://www.applanix.com/products/marine/pos-mv.html)

Figure 5. Photo of the Applanix POS MV system composed of three main components: the POS Computer System (PCS; orange box), the Inertial Measurement Unit (IMU; black box) and two Global Navigation Satellite System (GNSS) antennas (white disks).

The LiDAR survey system is integrated with the POS MV system to produce an accurately georeferenced point cloud of XYZ+Intensity. Data logging software displays the laser returns to provide real time quality assessment and ensure features of interest are being completely captured.

The POS MV system continually calibrates IMU and GNSS errors using a Kalman Filter to produce very accurate position, velocity, attitude and heading. POS MV continually monitors the status of its sensors and if required, automatically reconfigures itself to provide the best navigation and geo-referencing solution.

7.2 Maps

The study map is shown in Figure 1.

7.3 Assumptions underlying design

The main assumption underlying our project is that the bluffs in the study area will experience change that is measurable with the methods described over the timeframe of the project. In order to make our results significant, the bluff will need to erode more than our error estimates (+/- 15 cm). Randy Johnson has measured mean annual rates of change along an 8-mile segment of the Dungeness drift cell of between 15 and 30 cm (personal communication, 2012).

7.4 Relation to objectives and site characteristics

Our experimental design was created with attention to the objectives of the project and constraints of the location and equipment (see section 4). Any unforeseen safety concerns will be addressed as they arise in the field.

7.5 Characteristics of existing data

Until recently, shoreline and nearshore monitoring has relied largely on Global Positioning System (GPS) surveys and aerial photos. In the case of these bluffs, surveys were constrained by access to private property and their extreme slope. Aerial photos provide qualitative data, but require estimation when quantifying changes. This project employs remote sensing techniques, allowing access to the entire bluff face. The LiDAR scanner produces an unprecedented data density, taking readings every few centimeters. This new data collection process will result in reduced error relative to previous methods and will produce an accurate 3-dimensional model of the surveyed area.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

Section 7.1.3 describes field measurements in general terms. Details are provided in the manual for the Optech ILRIS-HD ER laser scanner, with MC option (Optech, 2008).

8.2 – 8.7 N/A

8.8 Field log requirements

Each day of data collection, we will keep detailed notes in a field log that pertain to the survey. For an example list of entries, see Appendix A.

The field log should be a bound, waterproof notebook with pre-numbered pages using permanent, waterproof ink for entries in the notebook. A single strikethrough (one line) will be used to correct information with all corrections initialed and dated. We will NOT use white-out or correction fluid.

We will also have a separate log for recording boat-related information and incidences, such as engine hours at beginning and end of day, fuel level, any engine or other mechanical problems, etc.

8.9 Other sampling-related activities

When maintenance that may affect the comparability of the surveys is done on the vessel, IMU, laser scanner, or any other equipment involved in the project, notes will be made in the field log detailing changes made and their possible effects.

9.0 Measurement Methods

N/A

10.0 Quality Control (QC) Procedures

10.1 Field and Office (Data Processing) Quality Controls

During the survey, field crew operating the laser scanner and acquisition computer will monitor the incoming data in real-time for holes or anomalies in the point cloud that may be caused by extensive vegetation, obstructions, speed of the survey vessel, wave/weather conditions, etc. The equipment operator will communicate with the boat driver to ensure adequate density of the point cloud for the area of interest and completeness of the data.

The Optech laser scanner will be calibrated using stationary ground-control targets ("reflectors"; Figure 2) on the beach and/or on the bluff-top. At least three reflectors will be deployed per survey day, with more added if conditions permit. The primary hurdle to the placement of reflectors is access to private property on the bluff-edge. Reflectors will be placed prior to scanning and removed immediately after scanning is completed. Each reflector will be surveyed with an RTK-GPS system, and its location in space sent to the boat survey team for "in-the-field" comparison to measurements. These control points can also be used in the post-processing stage to remove measurable bias from the point cloud prior to analysis (See Section 6.2). Stable surfaces will also be sampled during each survey to check and correct data for bias introduced between surveys.

In the field, we will also be surveying existing NGS and WS DOT monuments as control points that are routinely visited during each of the 3-5 surveys. The solution obtained in the field using RTK-GPS will be compared to the published values for the monuments to ensure positions are within the acceptable range of error.

10.2 Corrective action processes

When conducting these surveys, we will pay close attention to the data as it is relayed from the scanner to our acquisition software. If errors occur or data is not being properly received, we will restart the survey in order to attain acceptable returns or repeat scans for areas that do not meet specifications.

11.0 Data Management Procedures & Analysis

11.1 Data recording/reporting requirements

After real-time processing through the scanner/IMU a time-stamped series of four-dimensional (X-location, Y-location, Z-location, Intensity) points will be produced with nominal precision of 15 cm. Data will be manually processed to exclude outliers and gridded in three-dimensional space. Grids collected during different surveys can be differenced, with the result being volumetric estimates of loss from the bluff face, associated with a propagated uncertainty estimate. Volumetric differences between grids can be binned into shoreline reaches for spatial or temporal analysis. Analysis software including ArcGIS and Matlab will be utilized. More information is provided in Section 14.2.

11.2 Lab data package requirements

N/A

11.3 Electronic transfer requirements

During data collection in the field, data will be automatically stored to both a USB flash drive inserted into the scanner as well as to the acquisition computer itself, for redundancy. At the end of each survey day, raw data will be uploaded to the Ecology server from the acquisition computer. If this is not possible while in the field, data will be transferred to an external hard drive so that there is a copy that will not be on the survey vessel. Depending on the size of the files collected in each day, the flash drive may need to be cleared before storing additional data but only after another copy has successfully been made. Once we return to the office, all raw data will be uploaded to the Ecology server.

11.4 – 11.5 N/A

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

We will audit our data in the manner described in section 10. This will occur both in the field, as data is received, and while post-processing and analyzing the collected data in the office.

12.2 Responsible personnel

Heather Baron will be running the acquisition software while the survey is underway. She and Diana McCandless will continue to audit the data throughout the cleaning and analyzing procedures.

12.3 Frequency and distribution of report

Ecology will update CWI throughout the duration of the project. Specific deliverable reports are detailed in section 5.5.

12.4 Responsibility for reports

As Ecology's lead contact for the project, George Kaminsky will be responsible for the production of updates and the final reports.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

As stated in Section 5.3, the project will require at least three surveys. Verification of the field data will require that at least three sets are determined usable and acceptably accurate. The data processor will review field logs and compare them to the final uploaded data set. Data not meeting the stated MQOs will be qualified, with data qualifiers clearly defined.

13.2 – 13.3 N/A

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

The Project Manager will evaluate the final data set in relation to project goals and objectives. Of particular importance will be completeness of the data (adequate number of sampling events, boat transects, etc), comparability of the data obtained during different sampling events (no deviations from field/office methods used times of year), accuracy/precision (sufficient for estimation of erosion rates).

14.2 Data analysis and presentation methods

After real-time processing through the scanner/IMU, a time-stamped series of four-dimensional (X-location, Y-location, Z-location, Intensity) points will be produced with nominal precision of 15 cm. Data will be manually processed to exclude outliers and gridded in three-dimensional space. Grids collected during different surveys can be differenced, with the result being volumetric estimates of loss from the bluff face, associated with a propagated uncertainty estimate. Volumetric differences between grids can be binned into shoreline reaches for spatial or temporal analysis. Analysis software including ArcGIS and Matlab will be utilized.

In addition to gridded surfaces, 2-D cross sections can also be extracted from various locations alongshore that can be used to look at spatial and temporal cross-shore variability. The 2-D cross sections will be coupled with the volumetric difference grids to calculate erosion rates for landform sections and determine net overall erosion rate by study reach/drift cell.

Final results will be presented in a variety of ways that will be determined based on findings from the survey, such as a gridded, 3-D surface or digital terrain model, 2-D cross sections extracted along profiles, tables summarizing erosion rates by study reach/drift cell, aerial photos and maps to spatially display hotspot erosion areas, volumetric difference grids displaying change in bluff faces over time, etc.

14.3 Treatment of non-detects

N/A

14.4 Sampling design evaluation

Evaluation of our project design and use of the Optech ILRIS-HD-ER-MC laser scanner will hinge on whether enough bluff erosion occurred to be documented and assessed within our instrumental and experimental constraints. In other words, the signal of change must be greater than the uncertainty. Uncertainty will be empirically assessed by comparing the raw data to ground-control points (reflector targets) surveyed with an RTK-GPS, and by comparing repeatedly surveyed stable surfaces. Within the study area we have identified at least two such surfaces: The Nippon mill at the west end of Ediz Hook and the flight hangar of the US Coast Guard base at the east end of Ediz Hook. Other stable surfaces may be identified and utilized.

14.5 Documentation of assessment

Our final report will document whether our collected data is of acceptable quality and is fit for analysis addressing the initial project objectives.

15.0 References

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16.0 Figures

Figure 1. Map showing locations of the project site along the central Strait of Juan de Fuca in the Elwha and Dungeness drift cells along the northern Olympic Peninsula of Washington. The inert shows the project site in detail, identifying the Elwha and Dungeness Bluffs.

Figure 2. a) An example target design; b) schematic of LiDAR returns reflected off the target; and c) interpretation of LiDAR returns to position the target center.

Figure 3. Photo of the R/V George Davidson, Ecology's survey vessel. The laser scanner and IMU will be mounted to the top of the boat.

Figure 4. Photo of the back panel of the Optech ILRIS-HD ER laser scanner.

Figure 5. Photo of the Applanix POS MV system composed of three main components: the POS Computer System (PCS; orange box), the Inertial Measurement Unit (IMU; black box) and two Global Navigation Satellite System (GNSS) antennas (white disks).

17.0 Tables

N/A

18.0 Appendices

Appendix A. Example Field Log Entries

At minimum, the project field log will include the following entries for each survey date:

- Name and location of project
- Field personnel and roles, if applicable
- Date, time, location, ID, and description of each survey
- Environmental conditions (i.e., weather, waves, tide)
- Sequence of events
- Number of targets (reflectors) placed, a description of their placement location (e.g., beach, bluff, etc.), how they were mounted (e.g., on a tree, tripod, etc.), and any offsets that exist between the actual measured point and the center of the target
- List of monuments/benchmarks used as control points and length of occupation
- Any changes to plan
- Unusual circumstances that may affect interpretation of results

Appendix B. Glossary, Acronyms, and Abbreviations

Quality Assurance Glossary

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

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

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

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

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

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

Data Quality Indicators (DQI) - Data Quality Indicators (DQIs) are commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

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

Dataset - A grouping of samples, usually organized by date, time and/or analyte. (Kammin, 2010)

Data verification - Examination of a dataset for errors or omissions, and assessment of the Data Quality Indicators related to that dataset for compliance with acceptance criteria (MQO's). Verification is a detailed quality review of a dataset. (Ecology, 2004)

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

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

%RSD = (100 * s)/x
Where s = sample standard deviation, and x = sample mean (Kammin, 2010)

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

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

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

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

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

Abs(a-b)/((a+b)/2) * 100
Where a and b are 2 sample results, and abs() indicates absolute value

The RPD is used with only 2 values. The %RSD is used with more replicates (Ecology, 2004)

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

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

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

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

References

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

Glossary – General Terms

See http://www.ecy.wa.gov/programs/sea/swces/products/glossary.htm.

Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

e.g.	For example
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
RTK-GPS	Real-Time Kinematic Global Positioning System
i.e.	In other words
IMU	Inertial Measurement Unit
LiDAR	Light Detection and Ranging
MLLW	Mean Low Low Water
MQO	Measurement Quality Objective
NEP	National Estuary Program
POS MV	Position and Orientation System for Marine Vessels
QA	Quality assurance
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
USGS	U.S. Geological Survey
WDFW	Washington Department of Fish and Wildlife

Units of Measurement

°C	degrees centigrade
ft	feet
km	kilometer, a unit of length equal to 1,000 meters.
m	meter
mm	millimeter
s.u.	standard units