Quality Assurance Project Plan
Elwha River Channel Migration Zone Assessment

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SEASPC-2325-ClCoCD-00006

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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1.0 Abstract

Channel migration zones (CMZs) are intended to provide private landowners and county governments with valuable information about flood and erosion hazards. The delineations also provide information regarding fluvial processes, slope stability and aquatic and riparian habitat. This study entails a CMZ delineation on the Elwha River from the Altair Campground (approximately RM 11.8) to the Strait of Juan de Fuca, Little River from the Olympic National Park (ONP) boundary (approximate RM 7) to Elwha River, and Indian Creek from the outlet of Lake Sutherland (approximate RM 6) to Elwha River (Figure 1).

2.0 Background

2.1 Introduction and problem statement

The Elwha River has a steep gradient, large sediment supply, and an actively migrating channel within alluvial valley reaches. The Elwha previously had two large dams, the Elwha Dam at River Mile (RM) 4.9 built in 1912 and the Glines Canyon Dam built in 1927 at RM 11.9. Both dams were removed as part of the Elwha Restoration Act, the Elwha in 2012 and Glines Canyon in 2014. The two dams stored about 21 million cubic meters of sediment (16 in Lake Mills behind the Glines Canyon dam, and 5 in Lake Aldwell behind the Elwha dam). Randle et al. (2015) reported that over 7 million cubic meters had been released from the reservoirs two years after the Elwha Dam removal was completed, and while only three quarters of Glines Canyon Dam had been removed. Much of the remaining sediment has been eroded since then. Dam removal restored fish passage and the river's natural flow and sediment regime. Following dam removal, the river experienced significant bed aggradation due to the artificially high sediment supply from the reservoir areas. This resulted in more channel migration, particularly within the reservoir areas (previous Lake Aldwell and Lake Mills). Over the ten years since dam removal much of the stored sediment has been transported to the Strait of Juan de Fuca. The river is also expected to change as a result of the warming climate. Climate change predictions for the region indicate more extreme weather patterns in the near future, which will only increase the dynamic nature of the Elwha River in the form of channel migration, avulsion, planform evolution, and floodplain inundation. These processes are essential for forming critical salmonid habitat but also pose risks to infrastructure and property.

2.2 Study area and surroundings

The Elwha River is a major drainage on Washington State's Olympic Peninsula and the largest river in Clallam County. It flows mainly north from high mountain snowmelt headwaters in Olympic National Park, through the former dam sites near the edge of the mountains, through a narrow band of lowland development on the outskirts of the city of Port Angeles, and then into the Strait of Juan de Fuca immediately west of Port Angeles (Figure 1). The river flows through a typical Western Washington ecosystem, with a climate in between the rainforest extremes of the western Olympic Peninsula and the rain shadow of the northeastern peninsula. The Elwha also provides important fish habitat. The Lower Elwha River has two major tributaries, Indian Creek and Little River. Indian Creek originates at Lake Sutherland and flows east to the Elwha. Much of the Indian Creek valley is private land. Indian Creek enters the Elwha just downstream of the U.S. Highway 101 bridge at RM 7.5. Little River originates within Olympic National Park (ONP), flowing north into state land and then turns to the west, flowing through private property before joining the Elwha River immediately upstream of the U.S. Highway 101 bridge (Figure 1).

Infrastructure and human development are present in varying degrees throughout floodplains in the Elwha, Little River, and Indian Creek systems. Along with roads, structures, and homes on private land, notable infrastructure includes the City of Port Angeles water treatment facilities at RM 3.0. The Lower Elwha Klallam Tribe Reservation is located along the delta of the Elwha River and is protected by a certified USACE (US Army Corps of Engineers) levee. Near the upstream extent of the study area is the National Park boundary, where recent channel migration has affected road access.

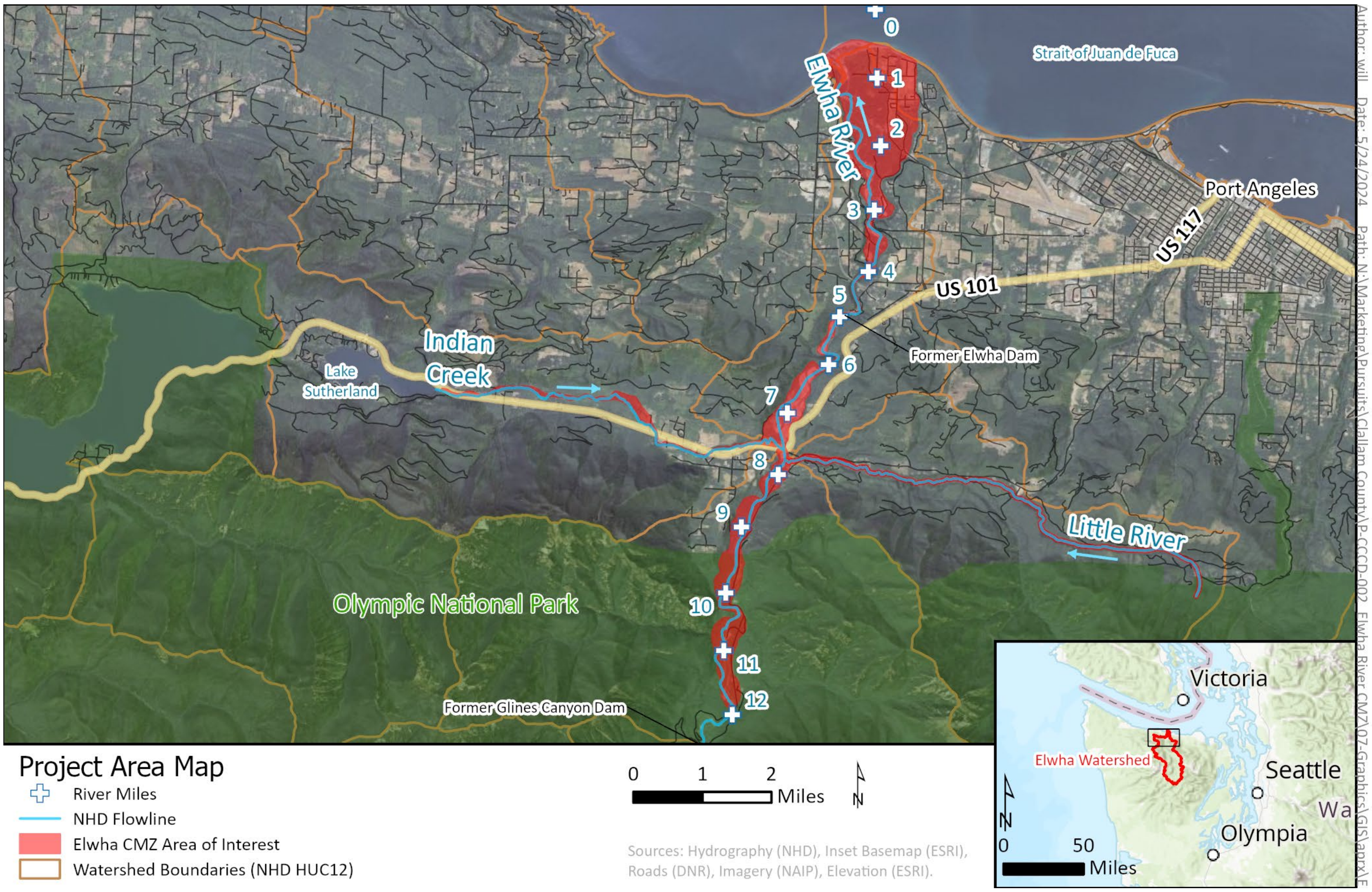

Figure 1. Map of study area.

2.2.1 History of study area

Euro-American settlement of the coastal areas on the Olympic Peninsula (OP) began in earnest in the mid-19th century, with the arrival of fur trappers, surveyors seeking ship building materials in the form of timber, and migrants looking for fertile areas to settle (Evans 1983). Prior to their arrival, native people fished abundant salmon runs within the coastal rivers, and hunted and gathered in the valleys, foothills, and coastal plains. The formation of the Olympic Forest Reserve (OFR) in 1897 comprised a large portion of the Peninsula, including the entire present day ONP, but did not encompass the lower portion of the Elwha River. Still, the OFR and ONP have preserved a large proportion of the watershed in an unaltered state. In the lower valley and much of Indian Creek and Little River, logging and development have been ongoing for more than a century. The

Elwha and Glines Canyon Dams, constructed in 1911 and 1927, respectively, heavily impacted salmon runs and dramatically altered the hydrology and sediment flow through the lower watershed. The removal of the two dams, completed in 2014, is the largest dam removal and associated restoration effort in the world to date and provides an important study area for restoration and dam removal projects at this scale.

2.2.2 Summary of previous studies and existing data

The previous studies of the Elwha watershed are too extensive to describe in full detail here. Most relevant to the current work are a pair of papers called "Channel Evolution on the Lower Elwha River, Washington, 1939-2006" (Draut et. al. 2008), and "Channel evolution on the dammed Elwha River, Washington, USA" (Draut et. al. 2011). These papers both describe channel evolution prior to dam removal and note that further investigation of channel characteristics would be required after dam removal.

A more recent paper, "Large-scale dam removal on the Elwha River, Washington, USA: River channel and floodplain geomorphic change," (East et al 2015) describes the influx of sediment into the lower Elwha River after dam removal, and the geomorphic changes associated with it.

This project will also build on a previous planning-level delineation of Clallam County Rivers (Olson et al., 2014)

This project will mainly rely on a LiDAR dataset collected by Washington State DNR in 2018, as well as historical imagery. A LiDAR dataset acquired in 2014 by the United States Geological Survey (USGS) will be used for the uppermost portion of the Elwha within the project area. The years and sources of historical imagery have yet to be determined but will be selected to create a representative record of channel evolution over time.

2.2.3 Parameters of interest and potential sources

This project does not involve pollutants or contaminants. The parameters of interest that will be collected and analyzed for this study are:

- Topographic surface elevations derived from LiDAR.
- Historical channel locations derived from historical imagery analysis.
- Location of stream channel alignments checked on site, in the field.
- Location and characteristics of eroding streambanks checked on site, in the field.
- Hydraulic and hydrologic conditions (e.g., peak flow, depth, velocity, and inundation extent) derived from stream gages, elevation data, hydraulic modeling, and checked on site, in the field.

2.2.4 Regulatory criteria or standards

Not Applicable. The study does not include assessing regulatory compliance. The delineation of the Channel Migration Zone will follow and be delivered under the guidance of Washington State Department of Ecology publication #03-06-027.

2.3 Water quality impairment studies

Not Applicable

2.4 Effectiveness monitoring studies

Not Applicable

3.0 Project Description

3.1 Project goals

Natural Systems Design and Coastal Geologic Services (NSD+CGS) will provide planning guidance through CMZ mapping consistent with the Washington Department of Ecology (WDOE). This mapping and supporting analysis will increase the County's understanding of current and future erosion and flood risks, thereby improving the ability to incorporate risk-informed decisions within its largest river system into the planning process, for the benefit of public safety, ecology, private property, and infrastructure.

No formal CMZ delineation has been conducted for the Elwha River or its tributaries. The detailed CMZ delineation will provide planners and resource managers with the information necessary for establishing jurisdictional boundaries at the reach-scale that will better protect citizens, infrastructure, development and natural resources from flood and erosion hazards, as well as preventing future development in hazard areas.

3.2 Project objectives

To achieve the goals of the CMZ Assessment, using the Department of Ecology CMZ Delineation framework (Rapp, Abbe 2003), the project is divided into objectives as follows:

1. Synthesize existing geomorphic, elevation, hydrologic, and historic channel location data.
2. Identify distinct geomorphic reaches of the study area based on geomorphic characteristics.
3. Prepare coarse, reach-scale 2D hydraulic modeling (results map and digital data) to assess flood dynamics for existing conditions, including flood frequency analysis of USGS stream gage data.
4. Delineate the historical channel migration zone, channel avulsion hazard zone, erosion hazard area, disconnected migration area, and risk of erosion hazards following Rapp and Abbe (2003).
5. Consider channel response from dam removal and any other significant changes in hydrology where appropriate.
6. Conduct a limited but targeted field investigation to verify findings from both the hydraulic and desktop analyses where site-specific conditions are not adequately explained by desktop methods.
7. Conduct public outreach activities including a webpage, stakeholder mail notification, stakeholder questionnaire, and at least two stakeholder meetings where 1) the project will be introduced, and 2) findings will be presented.

The products and findings of each of these objectives will be synthesized in maps, GIS datasets, a technical report, and public outreach materials.

3.3 Information needed and sources

The information required to achieve the project goals and objectives will be assembled from existing sources where available (Table 1) and otherwise be generated by hydraulic modeling and CMZ delineation, or collected during a field visit in early fall 2024 (Table 2). The methods by which each of these datasets will be collected are listed in section 7.2, and data that will be used for and developed by the hydraulic model is described in detail in section 6.3.

Table 1. Existing data to be assembled.

DATASET	REASON	SOURCE
Digital elevation model	Develop topo-surface	Olympics North 2018 lidar, Elwha River 2014 lidar, hosted by WDNR.
Historic and recent aerial imagery	Identify regions of channel migration	National Agriculture Imagery Program, hosted by USDA. Historical Channel Mapping from various years since 1939, hosted by the USGS. Other imagery hosted by Clallam County and the Department of Ecology. Specific years will be determined in the data gathering process, but the target will be at least one dataset per decade, depending on availability.
Existing hydrologic conditions	Inform hydraulic modeling	Primary USGS Gauge: Elwha River 12045500.
FEMA Flood Insurance Study (FIS) and Federal Insurance Rate Maps (FIRM)	Inform hydraulic modeling	FEMA map service center, revised study for Clallam County (2001) based on 1979 detailed analysis.
Geologic maps	Inform assessment of erosion and channel migration risks	1:24k Surface Geology and 1:100k Surface Geology, both hosted by WDNR

Table 2. New data to be collected or generated.

DATASET	REASON	FIELD or DESKTOP	FREQUENCY/EXTENT
Hydraulic outputs (water depth, flow velocity, inundation extent, etc.)	Inform CMZ delineation	Desktop	NSD will build a 2D hydraulic model of the entire study reach.
CMZ Delineation	Primary project product	Desktop with Field Check	Throughout the study area. A desktop analysis will identify areas of greatest channel change, and a field visit will be used to answer questions formed during analysis and fill in data gaps. This dataset will include sub datasets showing the historical channel migration zone, the avulsion hazard zone, the erosion hazard area, the disconnected migration area, and the delineation of areas of relative erosion hazard risks.

Field observations	Inform and verify CMZ delineation	Field	Focused locations throughout the study reach. Number and locations of field observations will be determined based on questions that arise during the desktop CMZ delineation analysis. A minimum of one day and maximum of two days (for two staff) will be allocated for field observations.

3.4 Tasks required

Task 1: Complete QAPP and have it approved by the Department of Ecology.

Task 2: Compile and review existing data.

Task 3: Perform hydraulic modeling analysis.

Task 4: Map geomorphic subreaches, surficial geology, historic channels, and produce relative elevation model.

Task 5: Prepare public and stakeholder outreach materials and conduct project kickoff meetings for public and stakeholders.

Task 6: Perform field visit to confirm mapping and inform CMZ delineation.

Task 7: Perform CMZ delineation.

Task 8: Create technical report and CMZ maps to document and present results.

Task 9: Conduct project results meetings for the public and stakeholders.

3.5 Systematic planning process

Not applicable

4.0 Organization and Schedule

4.1 Key individuals and their responsibilities

Table 3 shows the responsibilities of those who will be involved in this project.

Table 3. Project organization and distribution list for Elwha.

NAME	TITLE	RESPONSIBILITIES
Rebecca Mahan Clallam County DCD Rebecca.mahan@clallamcountywa.gov 360-417-2322	Habitat Biologist, MRC Coordinator	Clarifies scope of the project. Provides internal review of the QAPP.
Tim Abbe Natural Systems Design tim@naturaldes.com 360-406-4202	Contractor Senior Principal Scientist, LG	Quality assurance, oversight and assessments, data verification, evaluation, and usability, ensuring corrective actions are completed, etc. Licensed Geologist.
Aaron Lee Natural Systems Design aaron@naturaldes.com 360-797-5913	Contractor Project Manager, Project Engineer, PE	Oversees day to day logistics. Reviews the QAPP and draft and final report. Helps collect data, runs hydraulic model. Professional Engineer.
Mike Ericsson Natural Systems Design mike@naturaldes.com 206-480-1126	Contractor Senior Scientist / Geomorphologist, LG	Contributes to data collection and analysis, hydraulic analysis, CMZ delineation and mapping, as well as community outreach. Licensed Geologist.
Shawn Higgins Natural Systems Design shawn@naturaldes.com 360-966-8081	Contractor Senior Scientist / Geomorphologist	Contributes to data collection and analysis, hydraulic analysis, CMZ delineation and mapping, as well as community outreach.
Olivia Vito Natural Systems Design olivia@naturaldes.com 360-477-4848	Contractor Project Scientist	Contributes primarily to data collection and analysis, hydraulic analysis, and CMZ delineation and mapping, and community outreach.
Will Wright Natural Systems Design will.wright@naturaldes.com 907-888-9649	Contractor Project Scientist	Prepares QAPP, contributes to CMZ delineation and mapping.
Taylor Cagle Natural Systems Design taylor@naturaldes.com 360-966-8107	Contractor Staff Engineer / Hydraulics, EIT	Contributes primarily to hydraulic analysis.
Ginevra Moore Natural Systems Design ginevra@naturaldes.com 970-319-2173	Contractor Staff Scientist	Contributes primarily to hydraulic analysis and CMZ delineation and mapping.
Michelle McConnell Department of Ecology micm461@ecy.wa.gov Phone: 360-701-5262	Project Manager	Reviews the draft QAPP and recommends the final QAPP for approval.
Amy Krause Department of Ecology amkr461@ecy.wa.gov Phone: 360-742-7789	Financial Manger	Reviews the draft QAPP.
Amy Yahnke Department of Ecology ayah461@ecy.wa.gov Phone: 360-688-4263	SEA Program Quality Assurance Coordinator	Coordinates review of the draft QAPP and reviews and approves the final QAPP.

4.2 Special training and certifications

All project staff will review and follow the procedures outlined in this Quality Assurance Project Plan (QAPP) and the referenced Standard Operating Procedures (SOPs). Select project staff and supporting NSD technical staff are experienced in CMZ delineation, complex GIS analysis, and hydraulic modeling. Table 4 below lists the key personnel and relevant specialized expertise as it will be applied to achieve the project objectives. Figure 2 below shows the project team organization chart.

Table 4. Specialized experience of GIS, modeling, and project management personnel.

PERSON	SPECIALIZED EXPERIENCE	YEARS OF EXPERIENCE
Tim Abbe, PhD, LEG, LHG Natural Systems Design	Channel migration zone delineation, fluvial and coastal geomorphology, hydrology and hydraulics, sedimentology and sediment transport, wood stability and engineered log jam design, flood, erosion and slope stability hazard assessments, watershed assessment, sustainable land management, restorative flood and erosion protection, river and coastal restoration.	33
Aaron Lee, MSc, PE Natural Systems Design	Hydraulic, hydrologic, and morphodynamic modeling and analysis, geomorphic and habitat field assessment, habitat restoration and engineered logjam design, topographic and hydrographic surveying.	14
Shawn Higgins, MS Natural Systems Design	Channel migration zone delineation, geomorphic assessment, Hydraulic analysis and sediment transport, GIS analysis and terrain mapping.	18
Mike Ericsson, MS, LG Natural Systems Design	Channel migration zone delineation, geomorphic and hydrologic assessment, process-based river and floodplain restoration design, hydraulic modeling, sediment budgets and transport, flood, erosion and slope stability hazard assessments.	14
Olivia Vito, MNR Natural Systems Design	Remote sensing analysis and terrain modeling, historical channel migration mapping, geospatial analysis and database management, geomorphic analysis and habitat assessment, landowner and community outreach and presentations	8
Will Wright, BA Natural Systems Design	GIS Analysis, geomorphic assessments, ecological assessments	14
Taylor Cagle, MSCE, EIT Natural Systems Design	Hydrologic and hydraulic modeling and analysis, sediment transport, river dynamics, geographic information science, ecological engineering	5

4.3 Organization chart

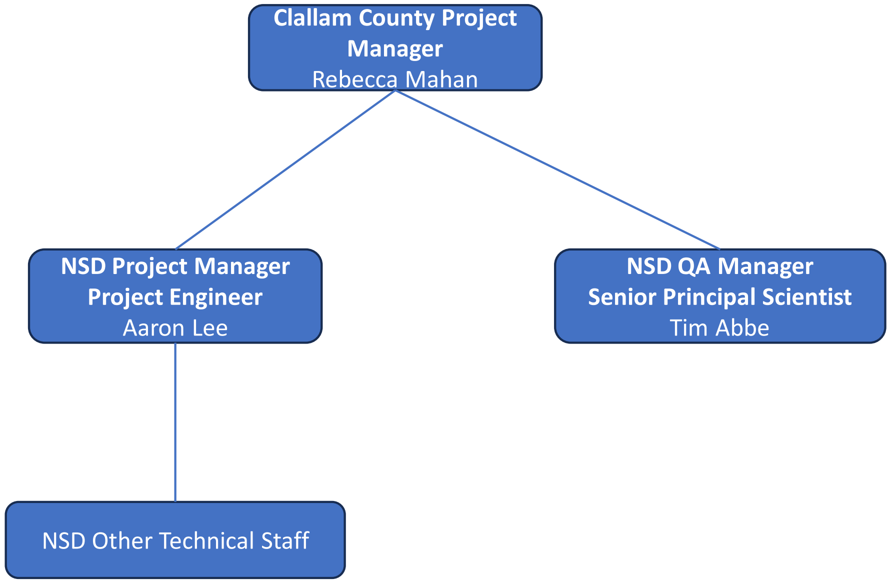

Figure 2. Project Organization Chart.

4.4 Proposed project schedule

Table 5. Project schedule.

ACTIVITIES	ORGANIZATION/INDIVIDUAL RESPONSIBLE FOR COMPLETION	TIMEFRAME
Prepare QAPP	Contractor Project Manager	May 2024
Data collection and analysis	NSD Technical Staff	May 2024 - June 2024
Geomorphic subreach delineation, geologic and historic channel mapping	NSD Technical Staff	May 2024 - August 2024
Hydraulic analysis and modeling	NSD Technical Staff	May 2024 - September 2024
Review QAPP	Individuals listed on approvals page	June 2024
Approve QAPP	WA Department of Ecology	June 2024
Community Outreach	NSD Technical Staff	July 2024 - September 2024 and March 2025 - May 2025
Field reconnaissance	Project Manager, NSD Technical Staff	September 2024 - October 2024
CMZ Delineation	NSD Technical Staff	September 2024 - April 2025
Data collection and hydraulics analysis results map and GIS shape files	NSD Technical Staff	March 2025 - June 2025

Draft CMZ Delineation GIS shape files, mapping, and technical report	NSD Technical Staff	March 2025 - June 2025
Final CMZ delineation GIS shape files, mapping, and technical report	NSD Technical Staff	March 2025 - June 2025

4.5 Budget and funding

The CMZ delineation study including the desktop analysis and field data collection covered by this QAPP is funded by the Washington State Department of Ecology Agreement Number: SEASPC-2325-ClCoCD-00006. The funding comes from Ecology's Model Toxics Control Operating Account (MTCOA) and is divided into three tasks. Task 1 includes $29,569 for project administration and management. Task 2 allocates $150,000 for channel migration delineation, and includes channel migration zone analysis, hydraulic modeling, data collection, and reporting, and is the primary task covered by this QAPP. Task 3 includes $17,562 for stakeholder outreach and engagement. In total, the three tasks total $197,131 for the completion of this study. Table 5 above lists the project schedule for achieving these tasks.

5.0 Quality Objectives

5.1 Data quality objectives

The data quality objectives (DQO) for this project are to gather a set of agency-curated publicly available datasets (Table 1), supplemented with field data (Table 2) that are comparable with channel migration zone assessments in other riverine settings and use these data to follow the CMZ delineation methodology described in the Washington Department of Ecology framework (Rapp, Abbe 2003). In addition to the CMZ delineation and associated maps and report, the data will be used to produce a hydraulic model for the project reach, as well as public outreach materials. Field data will be acquired using the GPS built into Apple iPads (approximately 25ft horizontal and vertical accuracy) and is intended to be more descriptive than quantitative.

5.2 Measurement quality objectives

The measurement quality objective (MQO) is to collect data that accurately describes conditions occurring at the site. The development of this study was informed by protocols that have been established by reputable institutions to collect data that are accurate, repeatable, and representative. Specific MQOs for this project are detailed below.

5.2.1 Targets for precision, bias, and sensitivity

This CMZ delineation primarily utilizes existing publicly available datasets such as LiDAR and historical imagery, so most precision, bias, and sensitivity are a result of the process, resolution, and projection of these data. The 2018 Olympics North Lidar DEM and 2014 Elwha Lidar DEM each have a pixel resolution of 3 ft and a reported vertical accuracy of approximately 0.1 ft. Historical imagery has variable horizontal resolution based on the flight height and source of acquisition. The most commonly used dataset will be from the National Agricultural Imagery Program (NAIP), which has a horizontal resolution of 1 meter or less. For imagery older than 2004, bias and accuracy may be affected by differences in georeferencing. The experienced image analyst will ensure that images are geo-referenced appropriately by cross checking the locations of a minimum of five known landmarks in each image. The analyst will also decide whether historical images are suitable for use, and how they should be interpreted relative to other imagery available. An image will be determined suitable if geomorphic landmarks required for channel migration zone mapping are visible in the given resolution, such as boulders, trees, and gravel bars.

5.2.1.1 Precision

Table 6 lists the anticipated precision and the methods proposed to identify and correct for error. Because the data sets are large scale and/or qualitative, replicates are less applicable, and alternative methods are proposed instead.

Table 6. Precision for new data collection.

DATASET	PRECISION	Alternative Methods
Field measurements of locations of eroding stream banks	± 25 ft horizontal precision for location	None
Field measurements of locations of streambank armoring and related channel modifications	± 25 ft horizontal precision for location	Review with local landowners and advisory committee members to compare to their understanding of riprap extents.
Hydraulic model outputs	± 1 ft vertical and ± 6 ft horizontal	None; model outputs will be compared to known or measured inundation extents (such as FEMA flood maps) and gauged water surface elevations.

5.2.1.2 Bias

The CMZ delineation will entail georeferencing historical imagery and digitizing the locations of historical channel alignments. The accuracy of georeferencing will be determined using known structure and infrastructure locations, and if bias is consistent in one direction (e.g. west or east) a given image will be re-geo-referenced until an accurate alignment is reached. To ensure consistent and accurate mapping of active channel features and areas of migration in historical imagery, regular and iterative meetings will be held with senior geomorphologists for review and refinement.

Field checking will identify any substantial bias in the CMZ mapping products resulting from errors in processing of source datasets. This bias can then be systematically corrected.

Water surface bias will be accounted for by reducing the inflow value associated with the respective LiDAR collection date (gage flow minus lidar flow). If there are major inconsistencies between adjoining LiDAR datasets, then adjustments to inflows or hydraulic roughness will be performed to reduce bias.

5.2.1.3 Sensitivity

The LiDAR DEM surface has a horizontal pixel resolution of 3 ft. Historical imagery has variable resolution. Surface geologic mapping from the Washington Geological Survey will also be used for the project. The majority of the project area is covered by geologic mapping intended for use at 1:24,000 scale, while a portion of Indian Creek is covered only by coarser scale mapping intended for use at 1:100,000 scale. Table 7 below lists the sensitivity and detection thresholds for field data that will be collected and data that will be computationally derived through hydraulic modeling.

Table 7. Sensitivity thresholds for data collection.

DATASET	DETECTION THRESHOLD
Locations of eroding stream banks	Areas of active bank erosion with greater than 20 feet in length and bare of vegetation will be mapped.
Hydraulic model	Modeled inundation and changes in water surface elevation (WSE) in the hydraulic model will be based on flow depths or changes in WSE > 0.1 feet. Areas with < 0.1 feet of flow depth or changes in WSE < 0.1 feet will be omitted due to computational limits of the hydraulic model.

5.2.2 Targets for comparability, representativeness, and completeness

5.2.2.1 Comparability

This project will follow the methodology and standard operating procedures as presented in Ecology Publication #03-06-027: A Framework for Delineating Channel Migration Zones (Rapp, Abbe, 2003). The hydraulic modeling component of the study will follow the standard operating procedures detailed in the HEC RAS software user manual (Hydraulic Engineering Center, 2021) and the National Cooperative Highway Research Program hydraulic modeling guidelines (Liu, 2024). Both of these procedures follow standardized and/or reputable methodology from peer reviewed publications, and thus are comparable to other studies that follow the same approaches.

5.2.2.2 Representativeness

The CMZ delineation and hydraulic modeling will span the entire project area (Figure 1). The location of field data collection will be informed by the preceding desktop analysis, as well as local knowledge and experience. Areas of interest, concern, confusion, or rapid change identified during desktop analysis or through communication with knowledgeable stakeholders will be prioritized for field data collection. Field data will be collected in the early fall to target low flow conditions for ease of access and maximum visibility of geomorphic features.

5.2.2.3 Completeness

Successful data collection to meet the project objectives aims for 95% of field observation points to be included following review by the quality assurance manager. The quality assurance manager and two licensed geologists will review the final CMZ, along with intermediate processing steps from which the CMZ is derived (e.g. historic active channel mapping).

5.3 Acceptance criteria for quality of existing data

Existing data that will be integrated into this study are listed in Table 1. All data that comes from reputable public and peer-reviewed sources meet the acceptance criteria for this study. Assessment work for this study based on desktop data (e.g., aerial photographs, LiDAR, surficial geology) or anecdotal information from local landowners will be improved upon or verified using observations and measurements during field data collection.

5.4 Model quality objectives

As part of the channel migration zone assessment process, a thorough understanding of hydraulic conditions is needed. Specific questions regarding hydraulic conditions that need to be answered are:

- What are the hydraulic conditions in the Elwha River, Little River, and Indian Creek under the 100-year flow scenario?
- How do hydraulic conditions contribute to observed changes in channel bank erosion, channel migration, and channel form?

The hydraulic model developed for the study area will be representative of existing conditions using the best available data, published lidar data, and interpretations of channel and floodplain roughness based on values used in previous peer reviewed models, aerial photographs, and field observations. Model inflows will be based on effective FEMA Flood Insurance Study (FIS) information and may be updated with more recent USGS streamflow gage data for the Elwha River at Mcdonald Bridge (12045500). The hydraulic model for the estimated 100-year flood flow will be compared with mapped floodplain extents from the effective FEMA FIRMs.

6.0 Study Design

6.1 Study boundaries

The study will include CMZ delineation on the Elwha River from the Altair Campground (approximate RM 11.8) to the Strait of Juan de Fuca, Little River from the ONP boundary (approximate RM 7) to Elwha River, and Indian Creek from the outlet of Lake Sutherland (approximate RM 6) to Elwha River (Figure 3). The study focuses on floodplain geomorphology and channel hydraulics, so the boundaries of the study area are the stream channel, adjacent floodplain, and erosion-prone terraces within the valley bottom of the Elwha River and its two largest tributaries.

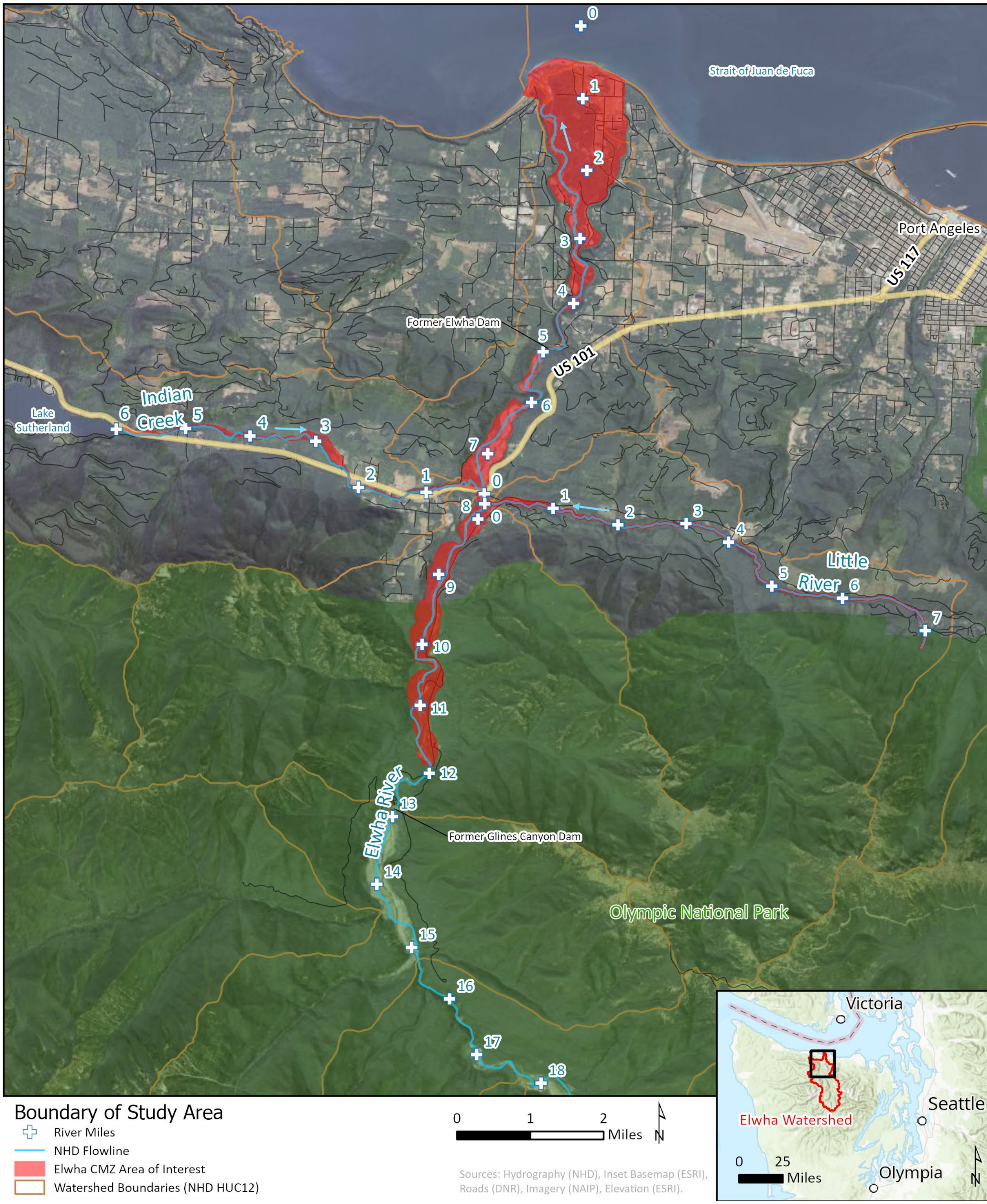

Figure 3. Map showing boundary of project study area.

6.2 Field data collection

6.2.1 Sampling locations and frequency

The locations of present channel alignment and of eroding stream banks will be checked in the field. This will not be a comprehensive field survey, but a targeted one, based on the findings of the preceding desktop analysis. Specifically, and as an example, the existing channel location of Indian Creek is difficult to determine with available remotely sensed data in several locations, particularly near its confluence with the Elwha. This will be a location prioritized for a field visit and description. It is expected that other field sampling locations will be identified during the initial historical channel location analysis.

6.2.2 Field parameters and laboratory analytes to be measured

Parameters captured in the field will be limited to qualitative descriptions, GPS locations, and photographs.

6.3 Modeling and analysis design

6.3.1 Hydraulic Model

6.3.1.1 Analytical framework

The work described in this QAPP will involve the creation of a 2D hydraulic model for the Elwha River between RM 0 and 11.8, Little River between RM 0 and 7, and Indian Creek between RM 0 and 6. The 2D model will be developed in HEC-RAS 6.1 (US Army Corp of Engineers) and will use USGS gage data to provide stage and discharge information. Hydraulic analysis of the study reaches is intended to help define the active channel corridor and will use inputs from the data collection effort. This task will be completed prior to the CMZ delineation as an additional source of data to characterize existing conditions by means of identifying contemporary floodplain surfaces. Sediment transport trends will be informed by an incipient motion analysis of peak flows, including changes predicted to occur as a result of the warming climate.

6.3.1.2 Model setup and data needs

Hydraulic models are simplified mathematical representations of flow through a real-world system. Models do not fully reflect the true nature of a river system with 100-percent accuracy due to the multitude of processes occurring spatially and temporally. Models are useful for predicting the interrelationships between variables to predict how a change in landscape will affect discharge, velocity, stage, and shear stress. Models can provide a useful framework for better understanding how a system is likely to respond to given project actions.

Direct measurements of hydraulics across a large area and under multiple flow scenarios is not feasible. To reasonably represent and assess hydraulics a model will be developed to simulate hydraulic conditions. A hydraulic model needs multiple data inputs including information on flow, terrain, and roughness. Inputs will be synthesized from existing data sources:

- Terrain data: acquired from existing topographic data sources (2018, 2014 lidar).

- Flow data: acquired from existing flow monitoring information from United States Geologic Survey (USGS) Elwha River #12045500. This includes a time series history of discharge and gage height.
- Tidal data: Tidal datum elevations will be referenced from the 100-year recurrence interval elevations from the effective FEMA FIS. Additionally, current tidal datum elevations for the NOAA gage at Station 9444090 for Port Angeles, WA may be used.
- Roughness data: acquired from past calibrated modeling efforts and reference text values for roughness using field observations and remote sensing data.

The hydraulic model will run under quasi-steady-state conditions at the 100-year recurrence interval event. A detailed calibration analysis will not be performed. Input parameters, namely Manning's n-value for hydraulic roughness, will be informed by the effective study of the Elwha River (FEMA, 2001). It is acknowledged that the effective FEMA study was based on conditions with the Elwha River dams in place.

Computational mesh cells will be scaled relative to the hydraulic complexity of the adjacent area. Cells in the channel will be smaller than cells in the floodplain/upland areas. Break lines are defined at topographic grade breaks to account for potential flow pathways and barriers. Table 8 lists the average mesh spacing for different model elements. Areas where greater resolution is needed will be adjusted accordingly.

Table 8. General mesh spacing for hydraulic model.

SURFACE TYPE	MESH SPACING (FT)
Logjam	3
Thalweg	7
Bank Top and Toe	10
Gravel Bar	15
Floodplain Channel	20
Valley Grade Break	50
Outer Boundary	50

The hydraulic model domain will extend throughout the study reach. Combined energy losses are represented in the model by Manning's roughness n-value coefficient. Using imagery and topography, surface features will be delineated and assigned n-values based on hydraulic literature (Chow, 1959). Refer to Table 9 for summary of initial roughness categories and n-values expected to be used in the model. These values may be refined after existing conditions results are reviewed.

Table 9. Summary of initial n-values defined in the hydraulic model.

SURFACE TYPE	MANNING'S N-VALUE
Main Channel	0.042
Side Channel	0.06
Gravel Bar	0.055
Gravel Bar Vegetated	0.07
Forest	0.1
Standing water	0.03
Road, gravel	0.035
Road, paved	0.016
Logs and Rootwads	0.15

6.3.2 CMZ Analysis

6.3.2.1 Analytical Framework

The work described in this QAPP will also primarily be focused on an analysis to delineate the channel migration zone for the Elwha River between RM 0 and 11.8, Little River between RM 0 and 7, and Indian Creek between RM 0 and 6. This analysis will follow the process described in "A Framework for Delineating Channel Migration Zones" (Rapp, Abbe 2003).

6.3.2.2 Analysis Setup and Data Needs

Key data will be the most recent LiDAR digital elevation model available (primarily 2018, with a small area of 2014 for the upper Elwha). CMZ delineation will begin with identifying distinct geomorphic subreaches of the study area based on physical characteristics such as topography (valley confinement), geology (e.g., bedrock, glacial deposits), land cover, artificial barriers to channel migration (i.e., revetments, state highways) and development. Surficial geology and historic channel mapping will inform current and future channel movement. Slope stability will inform geotechnical setbacks (per Rapp and Abbe 2003).

Analysis of historical aerial imagery and topography is a critical component of the CMZ to delineate the historical channel migration zone. Historic rates of erosion will be used to estimate erosion setback areas. We expect that some areas, particularly in the Indian Creek valley, the 100-year floodplain is likely to be greater in width than the historical channel migration zone (HMZ). Per WDOE guidelines, active alluvial fans are considered erosion hazard areas due to the frequent channel changes. All active alluvial fans will thus be mapped within the project area.

A limited, but targeted field investigation will be used to verify findings from the hydraulic analysis and initial CMZ delineation where site-specific conditions are not adequately explained by desktop methods.

6.4 Assumptions of study design

Assumptions include:

- Available lidar and imagery will be sufficient to represent channel and floodplain locations.
- Bank erosion and channel migration will be based on desktop interpretations of lidar and aerial photographs and will be validated with field observations.

6.5 Possible challenges and contingencies

6.5.1 Logistical problems

Field recon will be performed at low flow, to the extent possible. Unexpected higher than average flows could affect the fieldwork schedule. If questions about channel or erosion characteristics arise in areas of private property, field access may not be permitted, and analysts may need to rely solely on remotely sensed data and professional judgement.

6.5.2 Practical constraints

Clallam County has secured the necessary funding to cover desktop analysis, field data collection, hydraulic modeling, and the public outreach work included in this QAPP. Existing data to be used are publicly available or made available by Clallam County or the Elwha Klallam Tribe.

6.5.3 Schedule limitations

The review and approval process of the QAPP could delay desktop analysis and potentially delay the following field data collection. Field data collection is targeted for early fall low streamflow conditions, so delays could make field data collection challenging or less comprehensive.

7.0 Field Procedures

7.1 Invasive species evaluation

Study sites are not located within areas of extreme concern. The precautions and procedures outlined in SOP EAP070 (v.2.2, 2018) will be followed prior to and after all field activities. Field equipment and watercraft will be cleaned before and after use and checked for aquatic invasives prior to field efforts.

7.2 Measurement and sampling procedures

Eroding streambanks as well as other channel and floodplain features will be identified and mapped primarily using desktop analysis. Locations which provoke questions or uncertainty during analysis will be flagged to be visited in the field. Selected locations mapped from the desktop study will be assessed in the field for evidence of bank erosion, including exposed (unvegetated) banks, slope failure, recent large wood recruitment, and locations upstream of major sediment deposition in the channel. Relevant channel and floodplain feature locations will be recorded using an Apple iPad GPS with notes and photos to characterize the site. It is anticipated that one field day for two staff members will be adequate to address questions that arise during desktop analysis. A second field day will be added if necessary.

Standard operating procedure EAP112 (Assessing Bank Erosion Vulnerability, 2019) is not being used because this project is a reconnaissance-level assessment and is limited by private property access to select locations. Also, we want to capture continuous data instead of discrete transects and want data on mechanisms and length of bank failure rather than bank angles.

7.3 Containers, preservation methods, holding times

Not applicable.

7.4 Equipment decontamination

Not applicable.

7.5 Sample ID

For the field visit, sampling IDs will be in the following format: YYYY-MM-DD-ER/LR/IC-Sample ##, Elwha River (ER), Little River (LR), Indian Creek (IC), (e.g. 2024-05-15-ER-01). Unique site IDs will be assigned to each measurement location within each reach. Sample IDs will be recorded with field measurements (e.g., large wood jam, wetland) on an iPad with a GPS location and stored in a database.

7.6 Chain of custody

Not applicable.

7.7 Field log requirements

Data will be recorded in ESRI Field Maps on iPads with waterproof protective cases. Waterproof field notebooks will be used as back-up field data collection. For both digital and written field notes, the following information will be recorded:

- Name and location of sample site
- Unique sample ID
- Field personnel
- Any changes or deviations from the QAPP or SOPs
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Field measurement values and notes (e.g., channel width, vegetation cover)

7.8 Other activities

Not applicable.

8.0 Laboratory Procedures

8.1 Lab procedures table

Not applicable.

8.2 Sample preparation method(s)

Not applicable.

8.3 Special method requirements

Not applicable

8.4 Laboratories accredited for methods

Not applicable

9.0 Quality Control Procedures

Field data will be collected by a single team working together, so potential issues caused by personnel calibration of visual estimates will be minimized, and duplicate sampling will not be required.

9.1 Table of field and laboratory quality control

Not Applicable

9.2 Corrective action processes

Field crews will review the QAPP prior to field data collection. The contractor's quality assurance manager will ensure that data are collected following methods approved in the QAPP and SOPs referenced in the QAPP (particularly Rapp and Abbe 2003). Field data will be reviewed for potential errors or quality control issues at the end of each field day. Outliers will be reviewed and discussed with field crews. Data unable to be corrected will be omitted. If needed, an additional field day will be added to re-collect omitted data points. The contractor's quality assurance manager will review all data following desktop and field data collection and analyses.

10.0 Data Management Procedures

10.1 Data recording and reporting requirements

All data from the field will be recorded on an iPad using ArcGIS Field Maps software, which includes attributes for date, GPS location, field measurements, and photos of sampling locations. Field notebooks will also be used as back-ups in the case of iPad failure. Data from the iPad will be synced to an online database each day during sampling, or field data input to a geodatabase if paper notebooks are used in the field. All data will be checked for accuracy and transcription errors at the end of each day. If there are any discrepancies in data entries, the contractor will check the field datasheets and discuss them with the field sampling team. Field notebooks, if used, will be stored in the contractor's office for 2 years after completion of the project. Existing publicly available data that is going to be integrated into this project will be added to an electronic database with documentation about how to retrieve the data again from the public source if needed. Data collected in the field will be backed-up in the cloud and on the contractor's server.

10.2 Laboratory data package requirements

Not applicable.

10.3 Electronic transfer requirements

All data in the field will be acquired on an iPad using the ESRI Field Maps software. Data will be automatically stored in digital format and easily converted into text or Excel format for distribution. Where data is collected via field notebook instead of the iPad, data will be scanned and transferred to an electronic format immediately following the field visit.

10.4 Data upload procedures

All final versions of geospatial data produced throughout the analysis will be included as an appendix to the Channel Migration Zone delineation report and linked within the Clallam County website and the websites of other stakeholders. The data produced throughout this project is not applicable for the Environmental Information Management (EIM) data system or compatible with the EPA's Water Quality Exchange (WQX) portal.

10.5 Model information management

The contractor will document the development of hydraulic models throughout the full project life, noting all model iterations in the Model Tracking and QAQC excel document. Tracking document templates are included as Appendix B of this QAPP. Models will be stored on the contractor's server and backed-up to the cloud. Model files will be shared with Clallam County upon completion with a portable USB device. It is anticipated that model files and result data files will be 4 – 10 GB in size.

11.0 Audits and Reports

11.1 Audits

No audits are planned for this data collection effort.

11.2 Responsible personnel

Not applicable.

11.3 Frequency and distribution of reports

Desktop, field data, and hydraulic model output will be compiled and analyzed into a comprehensive channel migration zone assessment technical report, which will include:

- A reach scale channel migration zone map showing the delineation of the historical migration zone, avulsion hazard zone, erosion hazard area, disconnected migration area, relative risk of erosion hazards, and the full channel migration zone.

- A hydraulic model scenario of a 100-year flooding event will be used to help inform the channel migration zone mapping and the results will be displayed and described in the report.

The assessment will synthesize findings to delineate the channel migration zone of the Lower Elwha River, Little River, and Indian Creek in order to inform the county and other stakeholders of potential hazards and impediments to development. Project deliverables related to the actions covered by the QAPP are listed in Table 10.

Table 10. Project deliverables.

DELIVERABLE	FORMAT	DATE
QAPP	document (.docx / .pdf)	June 2024
Public and Stakeholder Meeting #1	presentation / slides	September 2024
Hydraulic model outputs	raster file (.geotiff)	Early October 2024
Hydraulic map exhibits	maps (.pdf)	Early October 2024
Geodatabase of field data collections	geodatabase (.gdb)	Early November 2024
Draft CMZ delineation report	document (.docx)	May 2025
Public and stakeholder meeting #2	presentation / slides	May 2025
Final CMZ delineation report	document (.docx /.pdf)	June 2025
Final CMZ delineation GIS files	geodatabase (.gdb)	June 2025

11.4 Responsibility for reports

All NSD staff listed in Table 3 will co-author the report, along with additional technical staff as needed. The project manager will be responsible for submitting the QAPP and delivery of the final report and documents to the county and other stakeholders. Licensed geologists listed in Table 3 will provide senior review and approval required for the Channel Migration Zone delineation.

12.0 Data Verification

12.1 Field data verification, requirements, and responsibilities

Field data will be reviewed by the contractor’s quality assurance manager before delivery to Clallam County. Clallam County’s project manager will also review data deliverables prior to approval and project completion.

12.2 Laboratory data verification

Not applicable.

12.3 Validation requirements, if necessary

Not applicable.

12.4 Model quality assessment

The QAPP and other QA/QC supporting materials will be distributed to all NSD project staff involved with this project. The quality assurance manager will ensure that all tasks are carried out in accordance with the correct quality control procedures. NSD will review project deliverables throughout each phase of development to ensure adherence to model protocols.

The quality assessment will conform to the following guidelines:

- Modeling activities including data interpretation, hydrologic and hydraulic input data, and other computational activities are subject to peer review. All modelers will maintain careful electronic records for all aspects of model development.
- If historical data are used, the source of the data and any information regarding the quality of the data will be documented in the CMZ report.
- The quality assurance manager lead will periodically review the modeling work, through work group meetings.

Model Tracking and QAQC Document

The hydraulic modeler will document the development of the models through the full project life, noting all model iterations in the Model Tracking and QAQC excel document. The tracking document is included as Appendix B of this QAPP. The Model Tracking and QAQC excel document includes the following list of QA/QC checks that will be filled out at the project onset and updated as necessary throughout the project.

Topography:

- Review input surface (look at surface hillshade for abnormalities, compare to design drawings to confirm all elements have been incorporated).
- Verify model geometry is in correct projection.
- Confirm that correct surface is associated to geometry.
- Is the surface resolution fine enough to capture areas of interest?
- Is node spacing adequate in areas of interest? Does node spacing capture key topographic features?

Roughness:

- Are Manning's n-values reasonable?
- Confirm roughness polygons and values are correctly assigned.

Boundary Conditions:

- Does mesh boundary fully encompass flow extent?
- Is the size of boundary outflow appropriate for flow extents?
- Are outflow boundary condition location(s) and type(s) reasonable? Check for backwater or abnormal velocity near boundary. Check slopes.
- Review hydrologic analysis. Are inflow values reasonable?
- Is inflow boundary condition location(s) and type(s) reasonable? Is it far enough away from area of interest? Check slopes.

- If quasi-steady state, does the model have time to fully equilibrate at each flow? (Confirm with mass balance in output review below)

Model Parameter Data:

- Is timestep reasonable?
- Is the choice of full momentum v. diffusion wave appropriate?

Output Review:

- Check Froude number raster - does it make sense?
- Check computation log - any significant errors?
- Are there any oscillations in the result rasters through time? (i.e., cells blinking off and on)
- Any unexpected patterns in spatial velocity, depth, shear results? Are depth/velocity/shear values reasonable?
- Are model structures (culverts, bridge, weirs) behaving as expected?
- Is the mass balance comparison acceptable, with net discharge roughly equivalent for inflow vs outflow?

These parameters will all be tracked and documented for all hydraulic model iterations, in addition to file locations, dates, and source information.

12.4.1 Calibration and validation

The hydraulic model for the study area will not be calibrated. The 100-year flow simulation will be compared with effective base flood elevations and floodplain extents in current FEMA flood maps, but it is acknowledged that effective data is outdated and should not be used for calibrating hydraulic models of contemporary conditions. Model roughness and mesh parameters may be edited and refined to achieve the objectives of the hydraulic model.

Objectives of hydraulic model analysis activities:

- What are the existing hydraulic conditions in the Elwha River, Little River, and Indian Creek study areas at the 100-year recurrence interval flow?
- How do 100-year flood extents correspond to floodplain terrace elevations and extents, as represented in the best available terrain dataset?
- Where are flood and erosion risks to stream banks, property, and infrastructure under current flooding conditions at the 100-year event?

To answer these questions, the model must be able to provide credible representations of the movement of water. Model calibration is not typically performed at high-magnitude flood events such as the 100-year event since comprehensive elevation and spatial data is rarely available at this recurrence interval. A sensitivity analysis may be performed to address the potential range of uncertainty with n-values on computed base flood elevations or 100-year floodplain extents.

12.4.1.1 Precision

Model precision will be determined by comparing the relative difference in modeled water surface elevation (WSE) with surveyed WSE points collected in the field, and with FEMA mapped flood elevations. Precision will be determined by determining the root mean square error (RMSE). A precision of ± 0.1 feet is desirable to accurately assess existing hydraulic conditions and risk and is consistent with FEMA floodplain regulatory requirements.

12.4.1.2 Bias

Bias will also be determined primarily by comparing modeled inundation extents with FEMA mapped floodplains. Model roughness may be adjusted to reduce bias.

12.4.1.3 Representativeness

The model will be developed to represent hydraulic conditions in the Elwha River between RM 0 to 11.8, Little River from 0 to 7, and Indian Creek from RM 0 to 6. Inflow conditions are based on the 100-year recurrence interval event to assess risk to existing habitat, property, and infrastructure – consistent with the resolution required for CMZ delineation. Boundary conditions anticipated for the hydraulic model include:

- A 100-year flood flow for the Elwha River at RM 11.8, Little River at RM 7, and Indian Creek at RM 6.
- Tidal boundary at the Strait of Juan de Fuca consistent with the 100-year recurrence interval event.

12.4.1.4 Qualitative assessment

Modeled versus effective-mapped inundation boundaries will be compared to view model bias across the model domain.

12.4.2 Analysis of sensitivity and uncertainty

Model sensitivity to boundary conditions, roughness parameters, and computational parameters will be assessed by reviewing changes in mass balance, WSE, and inundation patterns relative to field observations and FEMA mapping. Uncertainty in modeled outputs following sensitivity may be assessed with RMSE based on modeled versus observed WSE.

13.0 Data Quality (Usability) Assessment

All field measurements will follow protocols in this QAPP and SOPs referenced herein. Measurements not conforming to data quality standards (e.g. excess duplicate measurement error) will be recorded and flagged for review.

All data issues identified will be discussed with the Project Manager and Quality Assurance Officer to determine data usability. All decisions to allow data that did not fully comply with quality control criteria or QAPP requirements will be explained, and any limitations on data use will be fully discussed in the final project report.

13.1 Process for determining project objectives were met

The objectives for this project will be met if data were collected using the scientifically defensible protocols described above and presented to Ecology in the final document.

Documentation will be prepared under the direction of the quality assurance manager and the hydraulic model supporting the model calibration and the ability to meet the specified acceptance criteria. If the model does not meet the acceptance criteria, the project team will direct efforts to bring it into compliance. If the model still fails to meet acceptance criteria, a thorough review of the problem and potential corrective actions will be performed and provided to Clallam County.

13.2 Treatment of non-detects

Not applicable.

13.3 Data analysis and presentation methods

No specialized statistics are anticipated for this project. Specialized software includes HEC-RAS hydraulic modeling software. Hydraulic model outputs will be in Geo TIFF format. CMZ delineation will be in geodatabase and map figure format.

13.4 Sampling design evaluation

Not applicable.

13.5 Documentation of assessment

The channel migration zone assessment report will document the usability of the data collected during this study. The project will be considered successful if all the objectives listed in section 3.2 are achieved and if the parameters described in this QAPP are characterized using the data collected.

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APPENDICES

Appendix A: Glossaries, Acronyms, and Abbreviations

Appendix B: HEC RAS 2D Model Tracking and QAQC Spreadsheet

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Streamflow: Discharge of water in a surface stream (river or creek).

Thalweg: The deepest and fastest moving portion of a stream.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

DQO	Data quality objectives
CMZ	Channel migration zone
e.g.	For example
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
GPS	Global Positioning System
HUC	Hydrologic Unit Code
i.e.	In other words
MQO	Measurement quality objective
QAPP	Quality assurance project plan
NHD	National Hydrography Dataset
SOP	Standard operating procedures
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
m	meter

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* (USEPA, 2014).

Bias: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

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, 2014; USEPA, 2020).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 2014; USEPA 2020).

Data quality objectives (DQO): 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).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

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 (USEPA, 2001).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

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

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).

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).

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