SPENCER ISLAND ECOSYSTEM RESTORATION
PUGET SOUND & ADJACENT WATERS

SNOHOMISH COUNTY, WASHINGTON

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Appendix B

Spencer Island Ecosystem Restoration

Draft Feasibility Report and Environmental Assessment

Engineering Appendix

January 2026

US Army Corps
of Engineers®
Seattle District

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Pertinent Project Data

Spencer Island Ecosystem Restoration Project Summary Data

General:	
County	Snohomish
River Basin	Snohomish
Location	approximately river mile 3.8 between Union and Steamboat Sloughs
Cost Share Sponsor	WDFW
Datum:	
Horizontal Datum	WA State Plane N Zone, feet, NAD83/2011
Vertical Datum	NAVD88
In-Water Work Window (Snohomish River)	June 1 to October 31
Hydrologic Data: Data for Snohomish River at Monroe USGS Stream Gauge, located 15 miles upstream of the project	
Drainage Area	1,665 sq mi
Annual Precipitation	90 in
Mean Annual Stream flow	9,800 cfs
Maximum Recorded Streamflow, November 1990	150,000 cfs
WSE`s (NAVD 88, feet):	
MHHW	9.02
MHW	8.15
MLW	0.49
NAVD88	0.0
MLLW	-2.34
2080 Sea Level Change Intermediate	+1.3
2080 Sea Level Change Intermediate-High	+2.32
OHWM	11.0
1% AEP Coastal WSE	12.43
1% AEP Riverine WSE	14.49 to 16.86

1% AEP FEMA Coastal WSE	13.0
1% AEP + SLC (Intermediate) WSE	14.72
In-Water Work Window (Snohomish River)	June 1 to October 31
Dike breach / lowering elevation	10.5
New tidal channel outlet invert elevation	-4
Jackknife Bridge Load Capacity	HL-93
HTRW	Phase I ESA complete December 2020; Phase II ESA completed December 2024

1. INTRODUCTION

The purpose of this design documentation report is to provide the rationale underlying decisions made in the course of developing the Spencer Island Ecosystem Restoration project in the Snohomish Estuary, in Snohomish County, Washington.

Engineering calculations and studies were undertaken to support the development and evaluation of alternatives; to inform cost estimates including schedules and evaluation of risk; to provide preliminary designs for Hazardous, Toxic, and Radioactive Waste, cultural resources, and real estate work; and to document the intended project performance. This appendix documents the results of the engineering work in accordance with USACE Engineering Regulations.

1.1 GENERAL PROJECT INFORMATION

Spencer Island is located between Union and Steamboat Sloughs near Everett, in the Snohomish River Estuary at approximately river mile 3.8, within the Whidbey Subbasin of Puget Sound (Figure 1). Spencer Island was diked in the early 1900s for agricultural purposes and was used primarily for grazing. During this period, drainage practices and lack of tidal inundation resulted in up to 4 feet of subsidence. The island was purchased in 1989 by Snohomish County Parks Department and the Washington Department of Fish and Wildlife (WDFW). WDFW owns the north portion of the island, managing the area for recreation, including waterfowl hunting. This ownership encompasses most of the proposed restoration site. The County manages the south half of the island for recreation. A series of designed breaches in the 1990s and the construction of a cross dike allowed tidal inundation to restore estuarine processes in the southern part of the island. In 2005, an accidental breach occurred in the northern part of the island, restoring muted tidal action to this area. Since those breaches occurred, many studies have highlighted the importance of removing dikes in estuary systems. Dike removal is intended to promote higher densities of tidal channels, increased edge complexity, alluvial sediment delivery and greater habitat diversity. Current conditions at the site are illustrated in Figure 2.

The Spencer Island site is one of the nine sites identified by the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP), authorized by the U.S. Congress in 2016, to protect and restore freshwater input and tidal processes where major river floodplains meet marine waters (river deltas). Other sites are in the following river deltas: Skagit (4), Nooksack (1), Big Quilcene (1), Duckabush (1); and Snohomish (1). For more information on PSNERP, see the integrated feasibility report and environmental assessment (FR/EA), available online here: https://www.nws.usace.army.mil/Missions/Civil-Works/Programs-and-Projects/Projects/Puget-Sound-Nearshore-Ecosystem-Restoration/

Target ecosystem processes for restoration at Spencer Island include the following:

- Tidal flow
- Freshwater input (including alluvial sediment delivery)

- Erosion and accretion of sediments
- Distributary channel migration
- Tidal channel formation and maintenance
- Detritus recruitment and retention
- Exchange of aquatic organisms

The proposed restoration includes dike breaching and dike lowering to restore estuarine processes and seasonal riverine flooding to the interior of Spencer Island. Breaching and lowering of dikes to suitable elevations are intended to allow tidal freshwater (low salinity) hydrology to support channel formation and the development of a tidal forested wetland community.

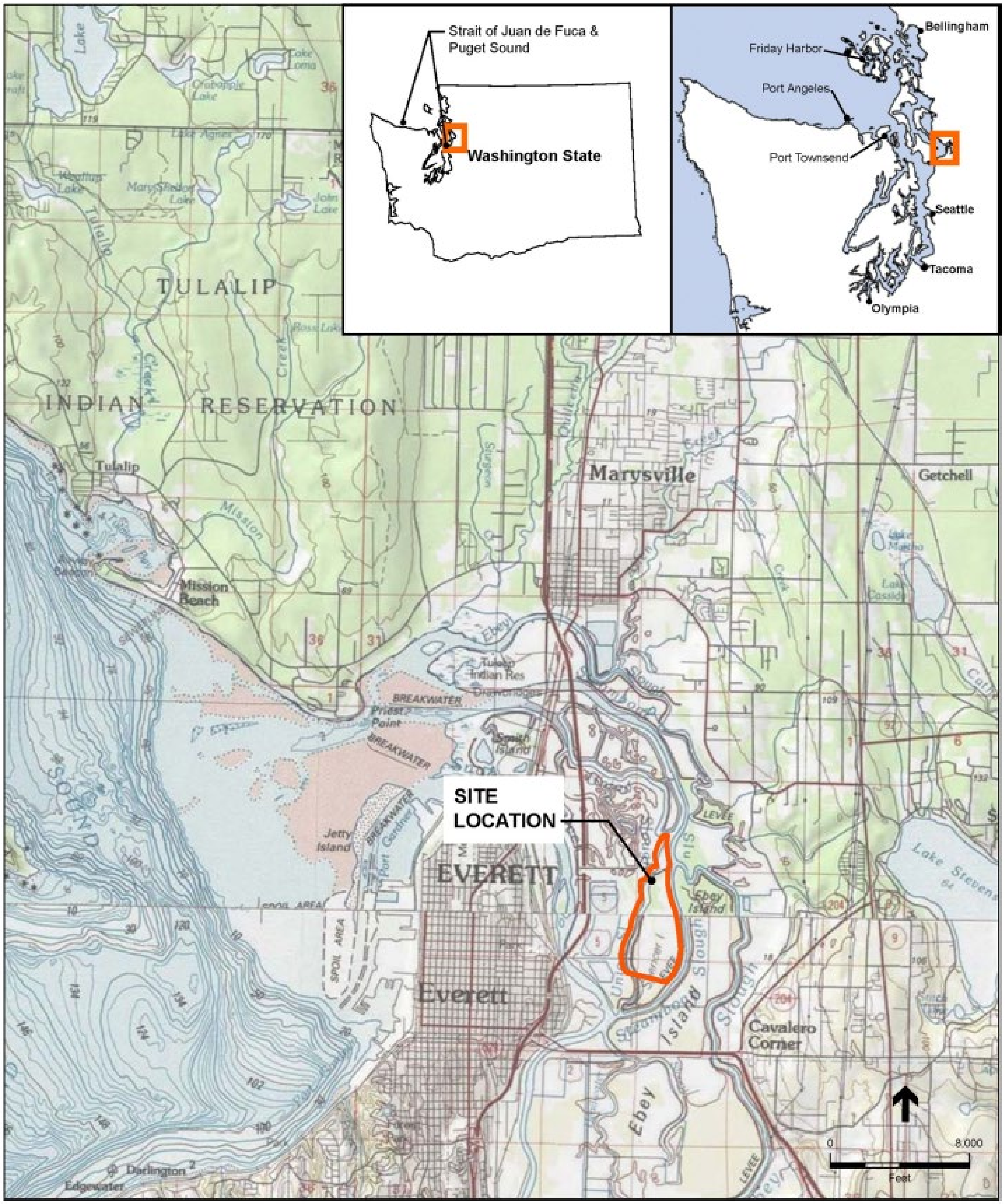


Figure 1. Spencer Island and Vicinity

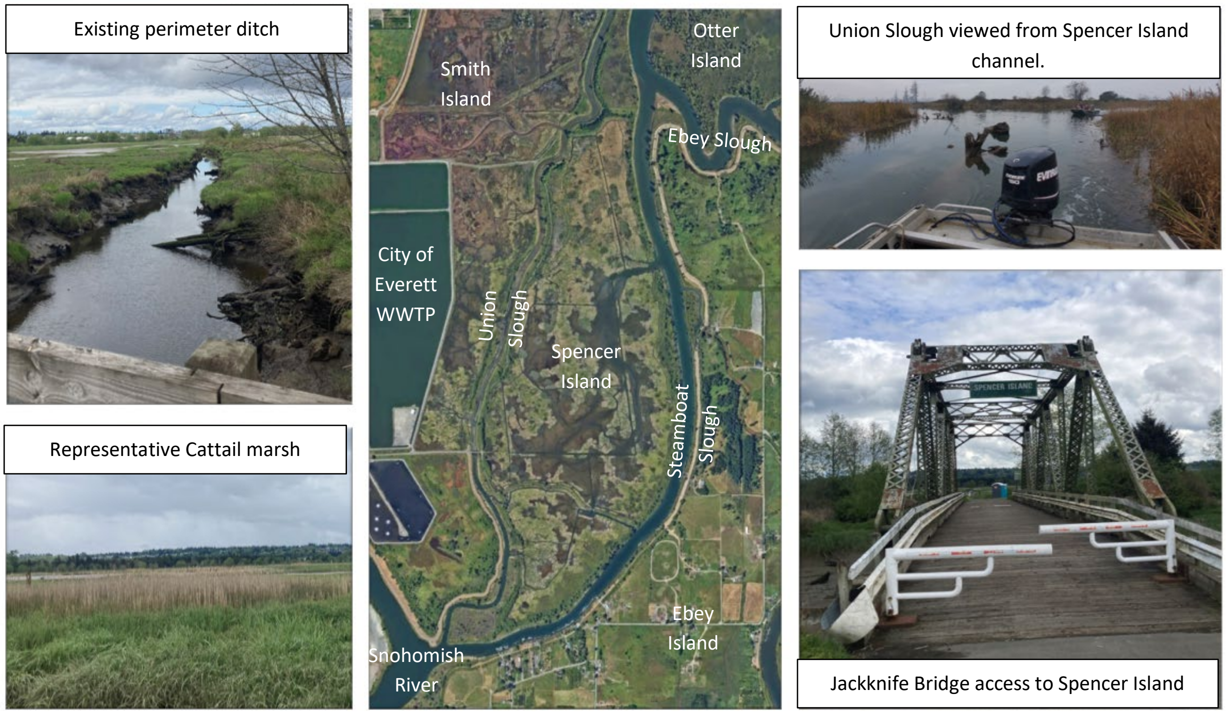


Figure 2. Spencer Island Existing Conditions

1.1.1 Major Project Component Summary

Key restoration elements at this site are shown in Figure 3 and include the following:

- Lowering of 11,500 lineal feet (lf) of existing dikes (27acres, 127,380cy) where at least 75% of the lowered levees are inundated during high tide events.
- Permanent trail improvements 1,830lf (2.4acres, 7,200cy)
- Removal of existing 4-ft diameter metal tide gate on Union Slough Dike
- Removal of two existing 60lf bridge at the South Cross Dike
- Filling of 8075 lf of existing ditches (5.4acres, 36,450cy)
- Excavation of 14 breach channels connecting the island to Steamboat Slough (2,700lf, 36,300cy) and 5 breaches to Union Slough (1,000lf, 14,100cy) where at least 75% of the breaches are inundated.
- Excavation of 1 breach channels through the North Cross Dike (222lf, 900cy) and 2 breach channels through the South Cross Dike (310lf, 2,200cy)
- Excavation of 12 new tidal channels (13,615lf, 14acres, 65,740cy) where at least 50% of the breaches will not have erosional features present.
- Constructing new marsh/upland planting benches (onsite dike spoil disposal) (28acres, 140,900cy)

- Onsite tree removal and in-channel woody material placement (Approximately 565 Total trees on site. Of this, approximately 46 trees are conifers. Total tree removal to be determined in later phases of design.)
- Revegetation with native trees and shrubs in upland areas with 80% survival of plants by the end of year 1 and 80% cover by year 10 in all planted areas. Two new permanent viewing areas (interpretive signage, benches, etc.)[1]
- One new hand-carried boat launch along Union Slough[1]

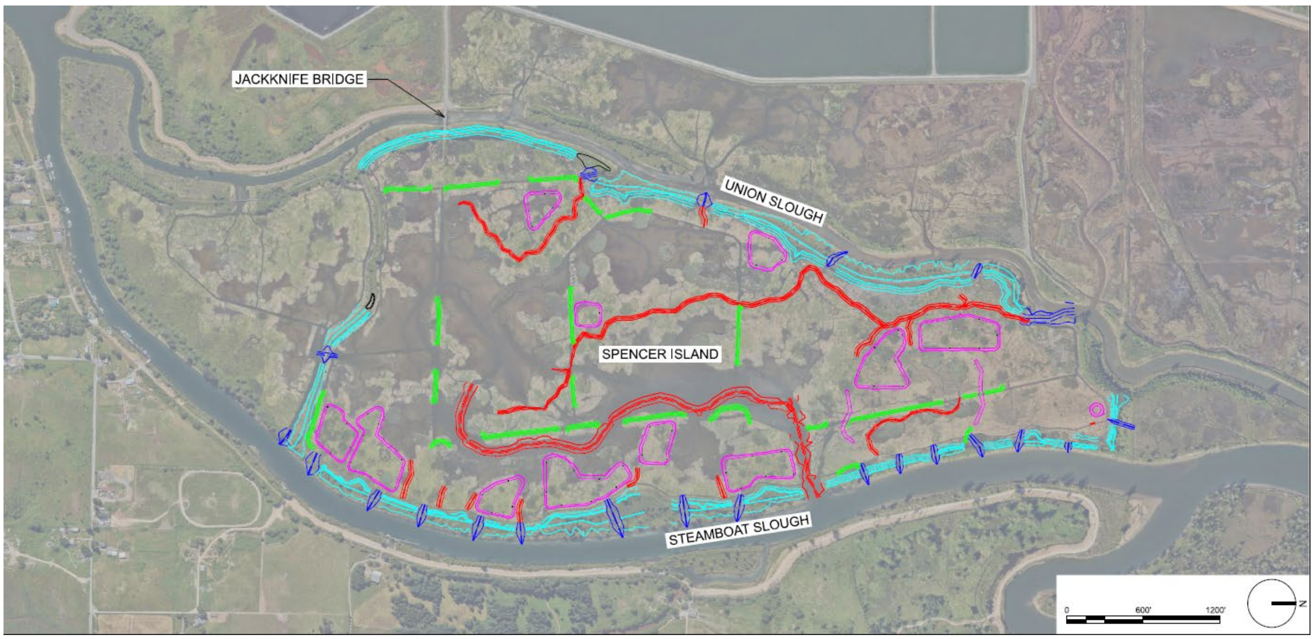


Figure 3. Spencer Island Ecosystem Restoration 35% Design Project Features

(NOTE: This design is not reflected in the drawing package. This design is represented in the quantities below.)

1.1.2 Partners

This project is a partnership between the USACE, WDFW, and Snohomish County. WDFW is the non-Federal Sponsor (NFS) and Snohomish County is a non-cost share sponsor and co-land manager. Other project partners could include Tulalip Tribe, Snoqualmie Wildlife Area Advisory Committee, and Technical Working Group.

[1] Note: Recreation improvement is not a project objective. These design elements represent opportunities to minimize overall recreation impacts of the restoration project (i.e. pedestrian trail lost). Recreation features are not expected to significantly impact costs. Trail widening will be a byproduct of access road construction. Areas cleared and graded for the viewing areas and boat launch, as well as the trail widening, will result in less acreage available for trees and other vegetation. These impacts would be offset by the greater area where existing levees will be lowered and allowed to revegetate.

1.1.3 Utility Relocations

An underground gas pipeline passes under the north end of Spencer Island (Figure 4) outside if the project footprint. The work footprint does not come closer than 400 feet from the pipeline. No other utilities are present on the island. No utilities will be disturbed or relocated.

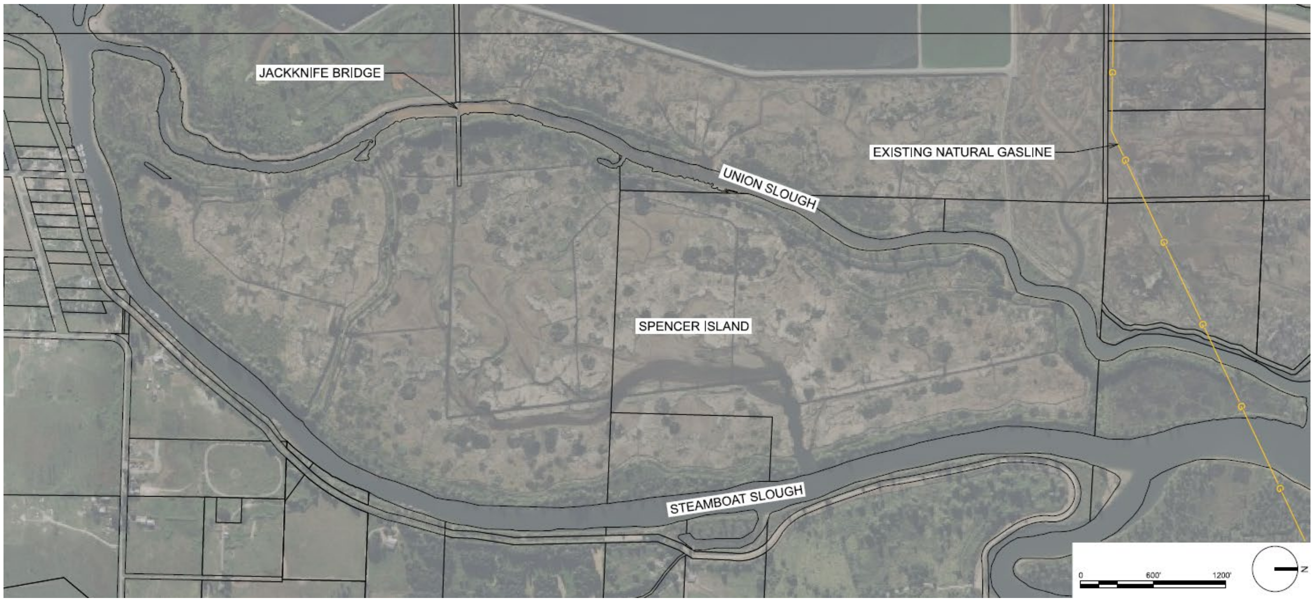


Figure 4. Spencer Island existing buried natural gas pipeline location

1.2 Survey

Projection Washington State Plane North Zone

Horizontal Datum NAD83

Vertical Datum NAVD88

Units US Survey Feet

Topographic LiDAR acquired July 31, 2019 by Quantum Spatial Incorporated (QSI LiDAR) Technical Report, October 25, 2019 for Washington Department of Natural Resources (DNR)

Bathymetric surveys of Snohomish River estuary sloughs: March 15-22, 2020 by SHI, report submitted to Tulalip Tribes May 2020

Bathymetric surveys of ditches: March 2023 by USACE Seattle District Hydraulic Engineering Section

Topographic survey of the existing levees was conducted by licensed land surveyors for WDFW in September 2025. This survey was conducted to support PED phase design work and to check the accuracy of the 2019 Lidar used in feasibility. The lidar data is higher than the ground survey by about 2 feet in most surveyed locations (see Annex C-4). Due to the large difference in elevation between the Lidar used in feasibility phase, USACE intends to entirely replace the lidar data along levees with ground survey data, however additional survey will be needed. The computed earthwork quantities (based on the artificially high lidar) were adjusted to account for the average error in the ground elevations.

1.3 CONCEPTUAL DESIGN DEVELOPMENT

The PSNERP feasibility study identified principles for nearshore restoration that support a process-based approach based on principles of landscape ecology and ecological restoration and are consistent with Corps planning guidance. The Project Delivery Team (PDT), in coordination with interested stakeholders and the public, refined a suite of projects along the Puget Sound shoreline that addressed basin-wide objectives. These objectives include the following:

- Restore the size and quality of large river delta estuaries.
- Restore the number and quality of coastal embayments.
- Restore the size and quality of beaches.

The Spencer Island / Snohomish River Estuary restoration project addresses the first objective. The site-specific goals and objectives for the Spencer Island project are these:

- Reconnect and restore lost tidally influenced areas including estuarine and freshwater tidal wetlands in the Snohomish River Estuary.
- Re-establish distributary channels in the Snohomish River Estuary to promote greater diversity of delta wetland habitats.
- Restore mudflats and salt marsh in the Snohomish River Estuary.

The PDT identified nine management measures to be used to formulate alternative plans for PSNERP. The PDT qualitatively determined which of the nine measures met the site-specific planning objectives and avoided site-specific planning constraints. The four management measures (not applicable to the Spencer Island / Snohomish River Estuary restoration project) not carried forward are armor removal, groin removal, hydraulic modification, and overwater structure removal. The following five management measures were carried forward for evaluation at this site (Figure 1 Project Plan):

- Remove existing dikes to restore the tidal prism of the delta, as well as reconnect freshwater and tidal flows to remnant and newly constructed tidal channels.
- Remove fill (existing dikes) from Spencer Island to reconnect the river to its intertidal floodplain and wetlands, restore floodplain and estuary wetland processes, and increase channel density.
- Reestablish tidally influenced distributary channels, replace a culvert at Union Slough with a bridge, and excavate channels within the marsh areas to restore tidal channel formation, exchange of aquatic organisms, and sediment accretion and erosion for greater habitat diversity, which increases biodiversity.
- Large wood placement for channel stability, which will increase habitat complexity.
- Riparian revegetation for shading, nutrient inputs, and complexity of bank habitat (non-structural measure)

1.4 Feasibility Phase Updated Design Guidance

During feasibility phase discussions with the NFS, PDT and project Technical Working Group (TWG) led to tailoring of these broad restoration objectives to local conditions present in the Snohomish Estuary. One of the first project meetings was a design charrette hosted by the NFS to elicit feedback from the local stakeholders and experts at the TWG based on their collective experience restoring and monitoring tidal marshes in the Snohomish estuary. The conceptual designs from the PSNERP feasibility phase (PSNERP 2011) were refined based on techniques being successfully utilized by other project partners in the estuary. The updated guidance is as follows (WDFW 2023):

1.4.1 Tidal Marsh Allometry and Channel Characteristics

- Recent research and modeling by others on predicting the number, orientation and spacing of dike breaches for tidal marsh restoration recommends adding more tidal channel openings than previously implemented on tidal marsh restoration projects. This recommendation is based on allometric analysis of reference tidal marshes in Puget Sound river deltas and the lower Columbia River estuary. Two papers by W. Gregory Hood were referenced by the study team: *Geographic Variation in Puget Sound Tidal Channel Planform Geometry*, published in the journal Geomorphology in 2015; and *Predicting the Number, Orientation, and Spacing of Dike Breaches for Tidal Marsh Restoration*, published in the journal Ecological Engineering in 2015.The Smith Island and mid-Spencer Estuary restoration projects incorporated Hood's tidal channel allometric model recommendations into the final designs for those projects, as well as several other recently completed and planned restoration projects throughout Puget Sound. Dr. Hood is a member of the project TWG.
- Other nearby projects results should be considered along with the Hood recommendation.
- Tidal prism can be used to determine the recommended breach sizes. One empirically derived equation for this comes from FitzGerald, D., Buynevich, I., Hein, C. (2012). Morphodynamics and Facies Architecture of Tidal Inlets and Tidal Deltas. Equation: Breach Area = 3.04 X (Tidal Prism)^1.05.
- Recommend looking at nearby restoration sites and reference marshes to see how channels have formed.
- Potential example: Several small islands to the northeast of Spencer Island—Otter Island, mid-Spencer Island—could be good candidates. Some existing channels on Spencer Island have the potential to be used to give an indication of shape and direction but these should be used sparingly as they are the result of a heavily manipulated system.

1.4.2 Topographic Diversity, LWM Placement, Vegetation, and Mounds

- Topographic diversity "affects abiotic and biotic components of vegetated ecosystems and has the potential to provide functions and services such as promoting floral and faunal biodiversity….The construction of mounds has been proposed to coastal restoration program reviewers on the basis of providing topographic diversity with the potential to reduce the impacts of subsidence behind dikes, accelerate the development of woody plant communities, control an invasive non-native plant (reed canary grass (Phalaris arundinacea)), produce a plant community mosaic, and generally increase habitat complexity at the restoration site." (Diefenderfer et al, 2018).

- Another study looking at topographic diversity for the Columbia Estuary Ecosystem Restoration Program (CEERP) looked at how "mounds or hummocks help defray costs of moving excavated material offsite and have been proposed in CEERP projects to provide topographic diversity with the potential to reduce the impacts of subsidence, accelerate the development of woody plant communities, control reed canarygrass, produce a plant community mosaic, and generally increase habitat complexity at the restoration site." (Diefenderfer et al, 2016).
- Mounds or other topographic features are important habitat features for waterfowl and other birds. The original Spencer Island restoration plan from the early 1990s suggested installing nesting islands on the northern portion of the Island, however it's unclear if they were constructed.
- Other restoration projects in the area, Smith Island in particular, have included large woody material (LWM) placement as a management measure. The Smith Island 90% Design Report notes that "LWM complexes will be constructed at strategic locations throughout the site to create edge habitat complexity and maintain tidal channel connections with Union Slough. The LWM structures will include driven piles, including a single driven pile that extends above high tide elevation for navigation purposes. The pile system will secure the LWM structure in place and also provide habitat for avian species. The extended piles are also unofficial navigational aids for boat traffic and tugs that use Union Slough to access Buse Timber near the I-5 Bridge."
- Greg Hood recently published research on designing large wood placement in tidal marshes, a project that was funded by WDFW ESRP learning program (Hood, 2022).

1.4.3 Effect of Intertidal Channel Velocity on Juvenile Salmonids

Water velocity is a key variable to consider for the Spencer Island restoration project. Because of the limited channel openings to the site, and to a lesser extent the ditch network, there are several pinch points where heightened water velocity may make it difficult for juvenile salmon to utilize the interior of the island. The main Steamboat Slough breach and the cross-dike breach are two spots where velocity is likely a problem for juvenile salmon; fish are presumably washed into the site on the flood tide and flushed out on ebb tide.

Recent work by WDFW and others has investigated intertidal structures' impact on estuarine fish, particularly juvenile salmonids. *The Effects of intertidal water crossing structures on estuarine fish and their habitat: a literature review and synthesis paper* has pertinent information for the Spencer Island Project:

> *Washington state law has required fish passage for dams and obstructions since 1890 and for all water crossing structures since 1949, although early application was restricted to highway*

culverts and larger stream and river systems (Barnard et al. 2013). As the understanding of fish passage needs evolved, the criteria and design for water crossing structures to meet fish passage requirements also evolved. Historically, fish passage rules and guidance were based on the hydraulic design approach to provide fish passage. This methodology involved applying design flow hydrology to the geometry of the road crossing structure and evaluating the resulting outfall drop, flow depth and velocity based on the swimming capabilities of the "target fish." The "target fish" defined by Washington state law are adult salmonids and a 6-inch trout, and were primarily focused on providing upstream movement to spawning grounds based on swimming ability criteria for adult salmonids. These early hydraulic design approaches emphasizing adult salmon swimming ability criteria ultimately resulted in fish passage and accessibility problems for weaker swimming aquatic organisms and fish, including juvenile salmonids…

Recognizing the need for juvenile and sub-adult fish to migrate both downstream and upstream, water crossing structure design guidelines were further modified to reflect an improved understanding of migratory and resident fish ecology.

The improvements to water crossing structure design and evaluation criteria were developed primarily for riverine crossings. Water crossing structures in tidally influenced areas such as bridges, causeways, culverts, and tidegates present unique challenges for design and assessment criteria. Target fish species, including all species of Pacific salmon, depend on tidally influenced channels for migration corridors between marine and riverine environments (e.g., juvenile migration to the ocean and adult migration to riverine spawning grounds). In addition, many species including some salmon depend on access to tidally influenced rearing habitat during juvenile life stages. The WDFW's most recent Water Crossing Design Guidelines provided some initial technical guidance for tidally influenced crossings in an appendix (Barnard et al. 2013, Appendix D), and recognized the importance of further developing these guidelines. (Excerpt from Greene et al. 2017)

The paper also provides information on key fish species potentially affected by intertidal water crossing structures:

> *Subyearling juvenile Chinook fry may avoid water velocities that exceed 0.3 m/s (Quinn 2005), prefer depths that are at least 1 meter (Beamer et al. 2005), and water temperatures cooler than 15°C (Brett 1952, Brett et al. 1982). Water velocities of up to 0.1 m/s will generally not impede juvenile salmonid movements (Wightman and Tayler 1976), although there are considerable variations in body sizes of juveniles due to the large variations in life history. Juvenile swimming speeds will vary greatly due to variations in size at migration among Chinook. Prolonged swimming speeds range from 0.14-0.50 m/s (Table A4), with speeds for fry migrants being 0.1-0.2 m/s, 0.2-0.5 for parr migrants, and 0.4-0.5 m/s for yearling migrants (Wightman and Tayler 1976, Smith and Carpenter 1987).*

1.5 Feasibility Phase Design Update Summary

Based on the updated design guidance several concepts were developed and evaluated by the NFS and USACE PDT members to identify a preferred alternative (see FR/EA). Hydraulic modeling was performed to evaluate the degree that velocities near the main dike breach and south cross dike approach desired conditions for juvenile salmon and to document additional area of inundation and connectivity (See

Annex D4). The NFS has agreements with Snohomish County related to continued pedestrian recreational access, and operations and maintenance at the site that present constraints and influence the final 35% design (WDFW 2023). As a result of the above guidance the design evolved as follows:

- Consideration of these additional design criteria resulted in the realization by the PDT that the existing large breach along Steamboat Slough is a fish barrier on a portion of the tide cycle, as is the bridge at the south cross dike, Inclusion of more channel outlets added along the island perimeter improves fish access, better mimics reference site conditions, and redistributes tidal flux to reduce velocities to a range that maximizes juvenile fish retention within the island. These additional channels create more diversity of habitat as well as redundancy to the uncertain effects of sediment and wood recruitment as well as natural successional processes and sea level rise.
- Degraded dikes and disposal areas with roughly graded surfaces constructed to elevations that allow high tide and river flow connectivity but also support wetland tree establishment and provide more habitat diversity. This required lowering the dikes further than in feasibility. Disposal areas are currently designed as mounds.
- Dikes degraded on both Union Slough, Steamboat Slough, and cross dikes to allow for cross-island connection (for water, wood, sediment, nutrients, and fish) with Smith Island in high flows and tides.
- The history of flood damage near the south cross dike and tendency of water and debris to flow from the SE to NW corner across the island led to the realization that preservation of access in the form of a loop trail and replacement bridges that met the latest design criteria for passage would be difficult and costly. For these reasons two existing bridges within the project footprint and one proposed bridge were removed from the project. Two new viewing platforms will be added as part of this project to offset these impacts. Along Union Slough the NFS intends to add pedestrian boardwalks to the north end of the island at a later date as part of a separate project.

In May 2024 the draft 35% design was presented to the Technical Working Group and NFS by the PDT. The TWG was helpful in making final refinements to the 35% design. No significant concerns were expressed with the current design as much of the feedback provided during the initial design charrette was incorporated.

1.6 Project Features and Information

Table 1 describes the project features developed in preparation of the design features which are quantified in Table 2 .

A general note for all civil quantity's tables shown below: The quantities reflect the current state of design, however the drawing package shows a prior version of the TSP that includes one fewer tidal channels and two fewer ditch fills. These features are included in the H&H models and cost estimates but not shown on the drawings. These refinements will be added to the Preconstruction Engineering and Design (PED) phase drawings.

Table 1. 35% Design Project Feature Descriptions

Doc. Reference	Project Feature	Description of Project Feature
1.6.1	Dike access improvement	Ensure vehicle and pedestrian access for portions of dikes needed for construction and those that will remain after construction.
1.6.3	Dike lowering	Lowering of existing dikes along Union Slough, Steamboat Slough, and North and South Cross Dikes to allow for natural tidal inundation.
1.6.4	Excavate dike breaches	Reconnect Spencer Island tidal marsh to adjacent sloughs to restore fish access with small perimeter breach channels.
1.6.5	Excavate interior tidal channels	Along ditches, excavate new sinuous channels to accelerate restoration of more natural marsh drainage network, tidal exchange, and fish accessibility.
1.6.6	Block and fill ditches	Use spoils from channel excavation to block and fill ditches to reduce short circuiting of marsh drainage network and improve fish accessibility.
1.6.7	Construct tidal marsh benches	Place spoils from excavation of dikes and breaches adjacent to lowered dikes to restore topography impacted by island subsidence and provide surfaces for colonization by marsh and upland vegetation.
1.6.8	Existing Parking Areas and Access	Maintain existing parking areas and access routes. No improvements planned. Temporarily restrict use during construction.
1.6.9	Recreational amenities	Widen trails to remain that are undersized, revegetate disturbed upland areas, interpretive signage, add two viewing areas to compensate for loss of loop trail and facilitate future work by others to add boardwalks. Add new hand launched boat access at Union Slough.
1.6.10	Demo existing bridges	Remove bridges that are located within the footprint of the South Cross dike, regrade adjacent channel to eliminate low tide fish passage barriers and long-term O&M issues.
1.6.11	Revegetation, Tree Salvage, & Large Wood Placements	Protect significant onsite vegetation, replant disturbed areas, reuse onsite large wood for habitat and erosion control.

Table 2. 35% Design Project Feature Quantity Summary

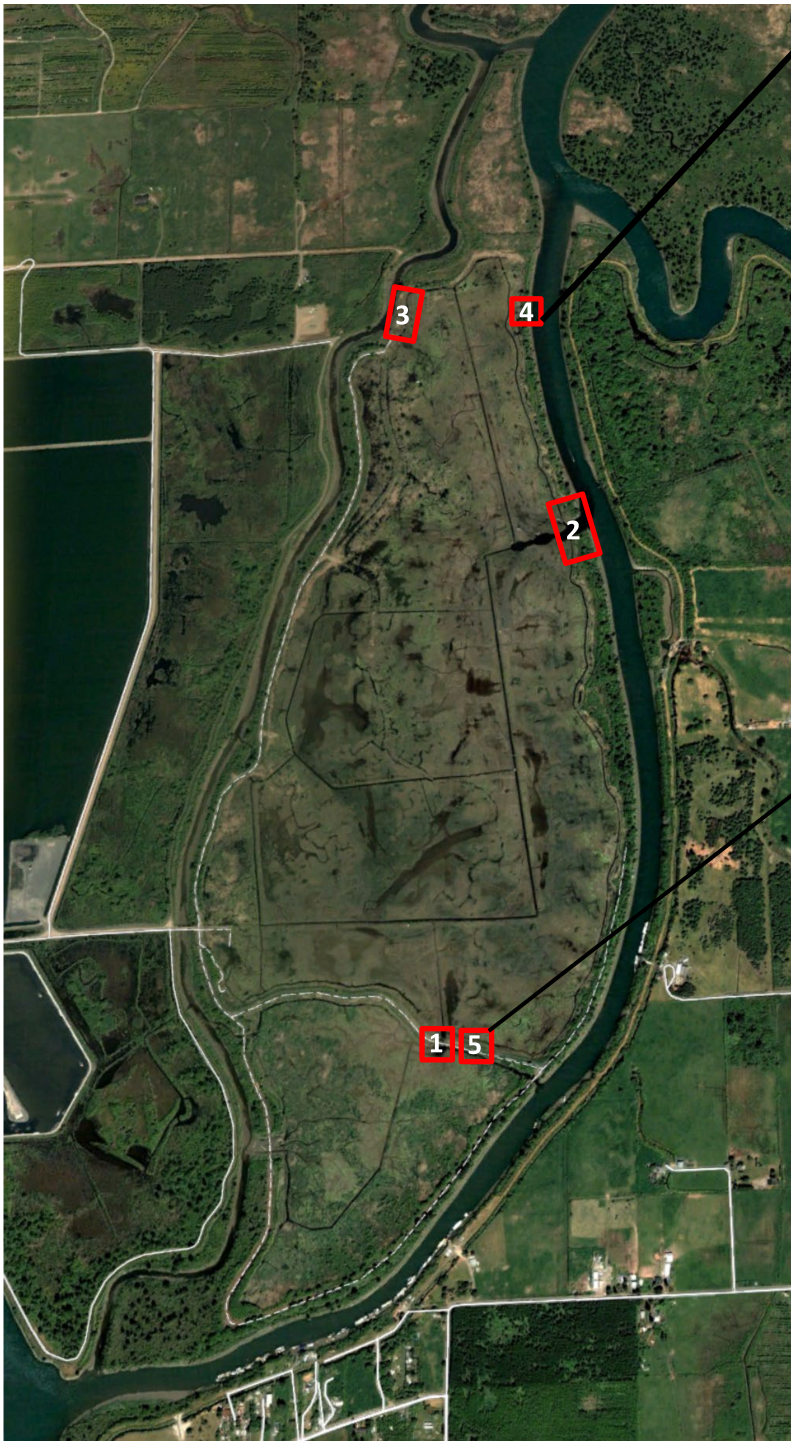
Feature of work	Location ids	Total length (FT)	Total footprint (AC)	Total volume	
				Cut (CY)	Fill (CY)
Dike lowering	Steamboat Slough	4760	10.5	35640	9110
	Union Slough	3380	11.0	49520	14660
	North cross dike	390	0.6	400	290
	South cross dike	1134	2.3	10300	260
Dike breaches	Steamboat Slough	2703	3.5	36300	0
	Union Slough	1003	1.9	14100	700
	North cross dike	222	0.2	900	0
	South cross dike	310	0.4	2200	0
Marsh benches	Steamboat Slough	0	13.3	0	63900
	Union Slough	0	5.1	0	30600
	North cross dike	0	0.2	0	1100
	South cross dike	0	2.1	0	9400
	Tidal channels	0	7.0	0	35900
Channel improvement	Smith Island	718	2.0	14100	200
Tidal channels	Channel 1-12	13613	14.1	60840	4900
Ditch fills	Ditch fills 1-19	8075	5.4	0	36450
Trail improvement	Union Slough	1830	1.7	1000	2700
Bridge removal	Bridge removal	0	0	0	0
Revegetation	Revegetation	0	0	0	0

1.6.1 Earthen Dike History and Performance

Spencer Island was initially cleared and dikes constructed in the 1930s to support agriculture and cattle. Supplemental modifications and improvements in the late 1960s and 1970s increased footprint and height of the dikes, averaging approximately 10 feet. These improvements were largely performed utilizing wooden detritus and chips or hog fuel. It is unclear if the crushed rock and soil fill placed over the hog fuel was placed at that time or during later maintenance and improvements.

Over the years the dikes encircling the site and the cross-dike (constructed in the 1990's) in the southern region of Spencer Island have had multiple breaches. Some locations have been repaired or bridges constructed while others were allowed to continue eroding and limiting access (Figure 5). From historical documentation of the project, failure modes of the dikes appear to have been related to the hog fuels relative instability and in at least one location combusting, catching on fire, as the organic material temperatures rose from the process of decomposition. In other locations where the native subsurface soils comprised of silts and clays were exposed from river erosion and slope failures, leading to breaches forming.

Based on the known history of the dike construction, material composition, and history of instability and breaches forming over the last 50 – 60 years, site conditions and dike performance are anticipated to worsen over the forthcoming 50 years or design life of the ecosystem restoration project.



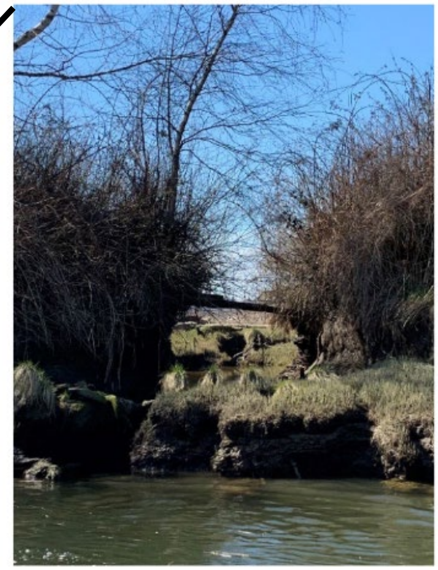


Figure 13: Smaller Steamboat Slough levee breach located on north end of Spencer Island, looking westward to interior of Spencer Island

Figure 6: Cross dike hole on north side. Seth for scale

Key: 1. South cross dike breach (2005). 2. Steamboat slough breach (2005). 3. Hogfuel spontaneous combustion breach (2007). 4. Natural dike breach (date unknown). 5. Actively failing area along south cross dike (2023).

Figure 5. Condition of Spencer Island dikes and recent breach history

1.6.2 DIKE ACCESS IMPROVEMENT

Existing trails along Union Slough and South Cross dike are overgrown with brush and non-native vegetation, hindering pedestrian access and site lines. Some areas are over-wide, some areas are very narrow. Along the Union Slough trail, existing vegetation will be cleared to a consistent width to reach the north end of the existing dikes. This will resolve access issues and improve site lines; however, some portions of the dike embankments will need to be partially rebuilt to withstand use by heavy equipment and trucks. Along the South Cross Dike trail, existing vegetation will also be cleared to a consistent width to reach the east end of the existing dike. Furthermore, variations in elevation along the dikes result in inconsistent overtopping frequency into the island from the Sloughs.

Along Union Slough, the dike would be graded to a more consistent height along the alignment by the placement and compaction of granular dike fill material. In addition, sections that are too narrow to support construction equipment will be widened. Once the grading work is complete, a temporary road will be placed along the Union Slough dike to facilitate construction access. The road material will be left in place and serve as trail bed post-construction. This will also facilitate future board walk construction along Union Slough by others. After construction is complete the temporary road will be replanted and the middle of the road converted to a permanent pedestrian trail.

The North Cross Dike is heavily overgrown, no access to the dike exists due to dike breaches. Temporary access via pontoons or amphibious heavy equipment will likely be needed from the north end of Union Slough dike to the North Cross Dike. A temporary access road would need to be developed along the alignment of the dike to be removed. The North Cross Dike work area would provide access to the north portion of the Steamboat Slough dike that is inaccessible due to the presence of a large existing breach. Approximately 1,100 linear feet will be used for access from the north end of Union Slough to the North Cross Dike. The contractor will have to pioneer an access road between trees to remain, and add any reinforcement material (geotextile, angular rock) necessary to support equipment that will also be removed upon completion of the work.

No permanent trail features are anticipated along the North Cross Dike.

Along Steamboat Slough the dike is heavily overgrown, and the dike is presently breached in at least two locations and will be breached in several more locations. No pedestrian access is available, and no permanent trail is anticipated. The contractor will have to pioneer an access road between trees to remain, and add any reinforcement (geotextile, angular rock) necessary to support equipment that will be removed upon completion of the work. No import of fill material is expected here because the existing dike is much higher than the final graded surface. Access to most of the dike will be from the South Cross Dike. Summary of dike access improvement work is provided below in Table 3.

Table 3. Summary of Temporary and Permanent Dike Access Improvement

Dike	Extents	Length (FT)	Typical Width (FT)	Cut (CY)	Fill (CY)	Notes
Union Slough Trail Improvement	Sta 00+00 to 18+30	1,830	20	2,700	1000	Portion that will remain for ped access. Fill includes Side casting and gravel pad.
Union Slough	Sta 21+00 to 52+80	3,380	VARIES	49,520	14,660	Portion that is lowered permanently
Steamboat Slough	Sta 02+40 to 41+60	3,050	VARIES	33,900	4,190	South of Historical Breach. Portion that is graded to elevation 10.5ft permanently. Fill volume is side casting.
	Sta 43+40 to 65+50	1,710	VARIES	1,740	4,920	North of Historical Breach Portion that is graded to elevation 10.5ft permanently. Fill volume is side casting.
North Cross Dike	Sta 00+00 to 01+90	190	25 to 90	350	160	Portion that is graded to elevation 10.5ft permanently.
	Sta 02+40 to 4+40	200	30	50	130	Portion that is graded to elevation 10.5ft permanently. Fill volume is side casting.
South Cross Dike	Sta 11+20 to 15+30	410	80	3,200	260	Portion that is graded to elevation 10.5ft permanently. Fill volume is side casting.
	Sta 16+80 to 24+04	724	45 to 115	7,100	0	Portion that is permanently graded to a variable elevation.

1.6.3 Dike/dike lowering/Channel improvement

Demolition involves removal of 4 existing dikes (Union Slough length 3,380lf, Steamboat Slough length 4,760lf, North Cross Dike length 390lf, South Cross Dike length 1,134lf), including 2 bridges and scour protection, and channel improvement along Smith Island (718lf) (Table 4). The Union Slough, Steamboat Slough and North Cross Dike will be graded to an elevation of 10.5-ft or to the natural ground elevation, whichever is higher. South Cross Dike will be graded to a variable elevation of 6.5-ft to 12-ft. The Smith Island channel improvement will be lowered to a typical elevation of 7ft. All the demolished material will be disposed of on-site in disposal areas that will be shaped to help bring up the elevation of the subsided marsh adjacent to the lowered dikes. At least 75% of the lowered levees will experience inundation to meet the success criteria for the project. The demolition will include felling approximately 565 trees, all of which can be used as habitat logs and erosion protection for ditch fill blocks. Dike lowering work will avoid existing standing spruce (and other significant native) trees wherever possible. Experience from other restoration projects nearby indicates hummocky disposal areas reestablish vegetation more successfully and provide more habitat diversity than smoothly shaped disposal areas. Design details will include roughened or hummocky finished surfaces for lowered dikes and onsite spoil placement. Landscaping plans will prioritize revegetation of the lowered dikes and onsite disposal areas.

Because the dikes are expected to be composed of lightweight wood chips (see WDFW Desktop Review, 2023) consolidation of soils under the dikes is not expected to be severe, and over-excavation of compacted soils in anticipation of rebound is not anticipated. The finished dike demolition cross section would excavate to the design removal profile which could leave some dike material in place if the natural ground is lower than the removal elevation (typically elev. 10.5 feet). If the natural ground elevation is higher than this elevation the dike removal would stop at a higher elevation. Elev. 10.5 feet corresponds to the adjacent Otter Island shoreline crest and is below the site Ordinary High-Water Mark (OHWM) (11.0 feet) and is exceeded several times per year during king tides or during riverine flooding. This indicates that the work area will be affected by tides daily and construction sequencing and equipment selection will need to anticipate working within the daily tidal range.

Because of the existing dike breach along Steamboat Slough and the bridge at the cross dike, working "in the dry" is limited to non-flood months and to elevations above the maximum expected tide elevation. At all other times or locations onsite, daily tidal inundation should be anticipated, and specialized equipment such as barges, marsh buggies and amphibious excavators may be the only practical means to complete restoration work.

Table 4. Summary of Dike Lowering Work

Dike	Length (FT)	Footprint (AC)	Volume (CY)	
			Cut (CY)	Fill (CY)
Union Slough	3380	1105	49520	14660
North Cross Dike	390	0.6	400	290
Steamboat Slough	4,760	10.5	35,640	9,110
South Cross Dike	1,134	2.3	10,300	260
Smith Island Channel improvement	718	2.0	14100	200

1.6.4 Excavate Dike Breaches

Twenty-two new breaches through existing dikes are proposed to connect the adjacent distributary channels to the interior of the island via existing and restored marsh channels (Table 5). At least 75% of the excavated breaches will experience inundation to meet the success criteria for the project The number of breaches was selected such that when all other existing connections between the island and the sloughs are accounted for, the restored island would have the same number of connections as would be expected for an undisturbed tidal marsh in the Snohomish Estuary based in its size.

It is anticipated that breaches would be excavated one by one during favorable tide cycles (summer spring tides) after dike lowering starting furthest away from the site access and working backwards as breach construction eliminates a primary access route for construction equipment. Excavation will follow tides down, staying above the elevation of the water surface to avoid excess turbidity generation. Once tides begin to reverse, excavation can continue below water as the incoming tide will wash the turbidity into the marsh. Work would stop once inundation prevented visual assessment of work progress or the ability of the equipment to move the excavated materials to the disposal area or if turbidity exceeds permitted levels. Once tides ebb, work would recommence. The work cycle will continue until the final design elevations, widths and slopes are achieved. Some breaches may take more than a day to complete. Long reach excavators will improve productivity by increasing the standoff distance between the cut slopes and excavator and excavator and spoil pile. This should effectively increase the number of work hours in a tide cycle. Use of marsh buggies and low ground pressure dump trucks (e.g., rubber tracked Marukas) will likely be necessary to move some spoils to disposal areas.

Table 5. Summary of Dike Breach Work

Dike	Number	Total Length (LF)	Footprint (AC)	Volume (CY)	
				Cut (CY)	Fill (CY)
Union Slough	5	1,000	1.9	14,100	700
North Cross Dike	1	220	0.2	900	0
Steamboat Slough	14	2,700	3.5	36,300	0
South Cross Dike	2	310	0.4	2,200	0

1.6.5 Excavate Interior Tidal Channels

The Spencer Island / Snohomish River estuary restoration project is reconnecting river delta distributary channels (Union Slough and Spencer Slough) to tidal marsh disconnected by agricultural dikes and an extensive network of drainage ditches that bisect the island north to south and east to west (Table 6). Ditches are also present along the landward side of perimeter dikes. Ditches along the periphery are distinguished from ditches within the interior of the site by the amount of shade they receive from adjacent riparian forest stands and the volume of in-channel woody material present. In general, ditches along the periphery have ample shade and woody material, and the project would be hard-pressed to construct channels of higher quality. For this reason, ditch blocks along the periphery are minimized. In contrast, ditches in the middle of the site, where subsidence is most pronounced, have no vegetative cover with very little instream wood. These ditches concentrate flow and create velocity barriers for juvenile fish.

The primary purpose of proposed channels constructed along the margins of the island is to connect water coming into the site via the new breaches to existing channels and the peripheral ditches. These channels are sized to blend the breach to the receiving channel and vary in width, extents, and elevation.

Channels constructed in the interior of the site are intended to restore the form and function of blind tidal channels. These channels are meandering and increase in width and decrease in elevation from the upstream to downstream ends (measured from receiving distributary channel). By increasing the width, and length (sinuosity) of the primary tidal channels in the marsh, water velocities are reduced, increasing the opportunities for juvenile fish to reside within the site throughout an entire tide cycle. There are presently locations near the primary breaches where velocities exceed the swimming speeds of juvenile fish for hours at a time, washing them out of the site.

Distributary channels are intended to remain permanently connected through tide cycles and will convey both fluvial discharge and tidal flux. Because of the presence of infrastructure (dikes for pedestrian access, Jackknife bridge and abutments) channel locations and dike lowering alignments partly reflect a desire to reduce the interaction of the river with these structures and to limit hindrances on natural processes.

Sizing of the channels depends on the expected flow conditions within the channels which are well within the capability of hydraulic modeling to capture. As described in the H&H annexes, channel locations and sizes were iteratively refined to achieve velocities, depths and shear stresses that can convey fine sediment to the tide flats. This is a physics based/analytical approach used commonly in alluvial channel design. Channels that are oversized will be prone to deposition. Conversely, channels that are undersized could be prone to erosion. Both deposition and erosion are desirable natural processes, restoration of which is the primary project goal. Thus, project success is unlikely to be jeopardized by slightly undersized or oversized channels that experience erosion and deposition. The same arguments can be made for decisions about constructed channel side slopes. While it is typical to design channels with trapezoidal cross sections for stability, most natural tidal marsh channels have near vertical side slopes, with frequent bank failures. This project uses a combination of trapezoidal and vertical side slopes depending on the proximity to infrastructure and need for stability.

Table 6. Summary of Interior Tidal Channel Work

Channel ID	Total Length (LF)	Footprint (AC)	Volume (CY)	
			Cut (CY)	Fill (CY)
CHANNEL 1	315	0.3	1,000	0
CHANNEL 2	174	0.2	510	0
CHANNEL 3	144	0.1	460	0
CHANNEL 4	184	0.2	520	0
CHANNEL 5	219	0.1	0	0
CHANNEL 6	187	0.2	500	0
CHANNEL 7	187	1.7	2,300	4,900
CHANNEL 7A	3,338	5.3	30,000	0
CHANNEL 8	1,054	0.5	1,200	0
CHANNEL 9	37	0.0	20	0
CHANNEL 10	5,096	3.7	17,200	0
CHANNEL 10A	117	0.1	220	0
CHANNEL 10B	237	0.2	510	0
CHANNEL 10C	340	0.3	800	0
CHANNEL 10D	141	0.1	0	0
CHANNEL 11	168	0.2	600	0
CHANNEL 12	1,678	1.1	5,000	0

1.6.6 Block & Fill Ditches

In concert with channel construction, key portions of large ditches that bisect the site will be filled to the elevation of adjacent vegetated marsh that was bisected when the ditches were constructed (Table 7). This effectively increases the flow path of water within the marsh, further increasing the residence time of both water and fish during a tide cycle. Woody material removed from the dikes will be placed at the ends of the ditch blocks to serve as erosion protection for the earthen fill and increase instream woody habitat.

Channel and ditch construction will generally occur below the elevation of the daily high tide and is expected to be difficult. Fortunately, underlying marsh soils are relatively dense silts and clays (cohesive) which will aid both channel construction and fill placement. Carefully planning and sequencing work with the tides as well as use of specialized crews and equipment (amphibious excavators, marsh buggies, barges) can avoid unnecessary delays, environmental disturbance, and cost overruns. Use of construction contract selection criteria targeting specialized contractors and/or performance-based specifications are strongly recommended.

Table 7. Summary of Ditch Block Work

Ditch ID	Total Length (LF)	Footprint (AC)	Volume (CY)	
			Cut (CY)	Fill (CY)
DITCH FILL 1	501	0.3	0	1,600
DITCH FILL 2	213	0.2	0	640
DITCH FILL 3	636	0.5	0	5,200
DITCH FILL 4	281	0.2	0	2,000
DITCH FILL 5	507	0.4	0	3,100
DITCH FILL 6	444	0.4	0	2,400
DITCH FILL 7	202	0.1	0	910
DITCH FILL 8	802	0.5	0	3,700
DITCH FILL 9	349	0.2	0	1,200
DITCH FILL 10	218	0.1	0	800
DITCH FILL 11	139	0.1	0	100
DITCH FILL 12	501	0.3	0	1,900
DITCH FILL 13	459	0.3	0	1,600
DITCH FILL 14	257	0.2	0	900
DITCH FILL 15	394	0.3	0	2,200
DITCH FILL 16	312	0.2	0	2,200
DITCH FILL 17	387	0.2	0	1,100
DITCH FILL 18	216	0.1	0	600
DITCH FILL 19	416	0.3	0	1,400
DITCH FILL 20	456	0.3	0	1,700
DITCH FILL 21	93	0.1	0	300
DITCH FILL 22	292	0.2	0	900

1.6.7 Construct Tidal Marsh Benches

Tidal marsh benches will be constructed from dike and channel excavation spoils adjacent to work areas to help restore topography of the island impacted by historical subsidence (Table 8). The top elevation of the benches will be equal to the adjacent dike lowering areas to increase the areal extents for establishment of salt tolerant riparian vegetation, to offset some of the losses of important vegetation communities present along natural dikes in the Snohomish estuary. A total of 148,140 cy of spoils will be placed, with the average fill height of 10.5 feet, and footprint area of 40.9 acres.

Refer to the revegetation plan for plant species and planting densities.

Table 8. Summary of Tidal Marsh Benches

Marsh Bench ID	AREA (AC)	VOLUMES (CY)	
		CUT	FILL
STEAMBOAT SLOUGH MARSH BENCH 1	3.6	0	16,000
STEAMBOAT SLOUGH MARSH BENCH 2	31.9	0	8,600
STEAMBOAT SLOUGH MARSH BENCH 3	2.9	0	13,900
STEAMBOAT SLOUGH MARSH BENCH 4	4.2	0	21,400
UNION SLOUGH MARSH BENCH 1	3.6	0	20,000
UNION SLOUGH MARSH BENCH 2	1.6	0	10,100
UNION SLOUGH MARSH BENCH 3	1.4	0	8,500
TIDAL CHANNEL MARSH BENCH 1	1.8	0	9,500
TIDAL CHANNEL MARSH BENCH 2	0.9	0	16,800
TIDAL CHANNEL MARSH BENCH 3	3.1	0	4,500
CONSTRUCTION BRIDGE MARSH BENCH 1	0.3	0	600
CONSTRUCTION BRIDGE MARSH BENCH 2	0.3	0	500
SOUTH DIKE MARSH BENCH	2.1	0	9,400
NORTH DIKE MARSH BENCH	0.2	0	1,100

1.6.8 EXISTING PARKING AREAS & ACCESS

Existing parking areas and access routes are outside the project footprint. There will be no impacts to existing parking or access. These areas will be temporally occupied by the contractor during construction. For safety of the public and contractors it is anticipated that WDFW and Snohomish County will restrict public access when construction activities are occurring. See Figure 6.

1.6.9 RECREATIONAL AMENITIES

Spencer Island is a popular Snohomish County and City of Everett recreation area. The site is co-managed by WDFW and Snohomish County. The site is used for walking, fishing, non-motorized boating, waterfowl hunting, bird and wildlife watching including other recreation activities. The process-based restoration reconnects and restores lost tidally influenced areas, re-establishes distributary channels and restores mudflats and salt marsh in the estuary. This is accomplished by removing the existing dikes to provide a free-flowing river and estuary.

This project will remove approximately 1,150 lf of an existing 1.4 mile loop trail that significantly hinders hydrologic processes and fish passage, and in the process remove two bridges on the Snohomish County owned portions of the site (one located at the South Cross Dike, one along Steamboat Slough). While these bridges are valuable recreational amenities, these bridges have failed in the past and are expected to be ongoing O&M issues for the County. To compensate for loss of the loop, a new earthen elevated platform will be installed at the east end of the restored South Cross Dike. This earthen viewing area will be at about the same elevation as the existing bridge but provide a larger area for people to gather. The oblong pad will be unobstructed and provide panoramic bird watching opportunities and allow for inclusion of picnic tables and interpretative signage.

As shown in Figure 3 the northern half of the Union Slough dike will be removed to allow for construction of several tidal channels. This will eliminate the need for the bridge that was part of the PSNERP conceptual design, and more importantly set the stage for significant improvement of pedestrian access to the north end of Union Slough, in the form of a new wooden boardwalk (to be designed and constructed by the NFS using separated funding sources). At the dike termination point a large viewing area will be created by clearing non-native vegetation, adding a gravel pad on existing dike fill, and restoration of the margins with plants that maximize viewing opportunities. This viewing pad will be connected by a short path to a hand-carried boat launch. This boat launch will be located at the location of the existing tide gate, which will be removed as part of this project. This will provide improved opportunities for the public to formally access both Union Slough and the restored Spencer Island tidal marsh. WDFW has long term plans to construct a board walk along the former path of the dike along Union Slough after this project is completed.

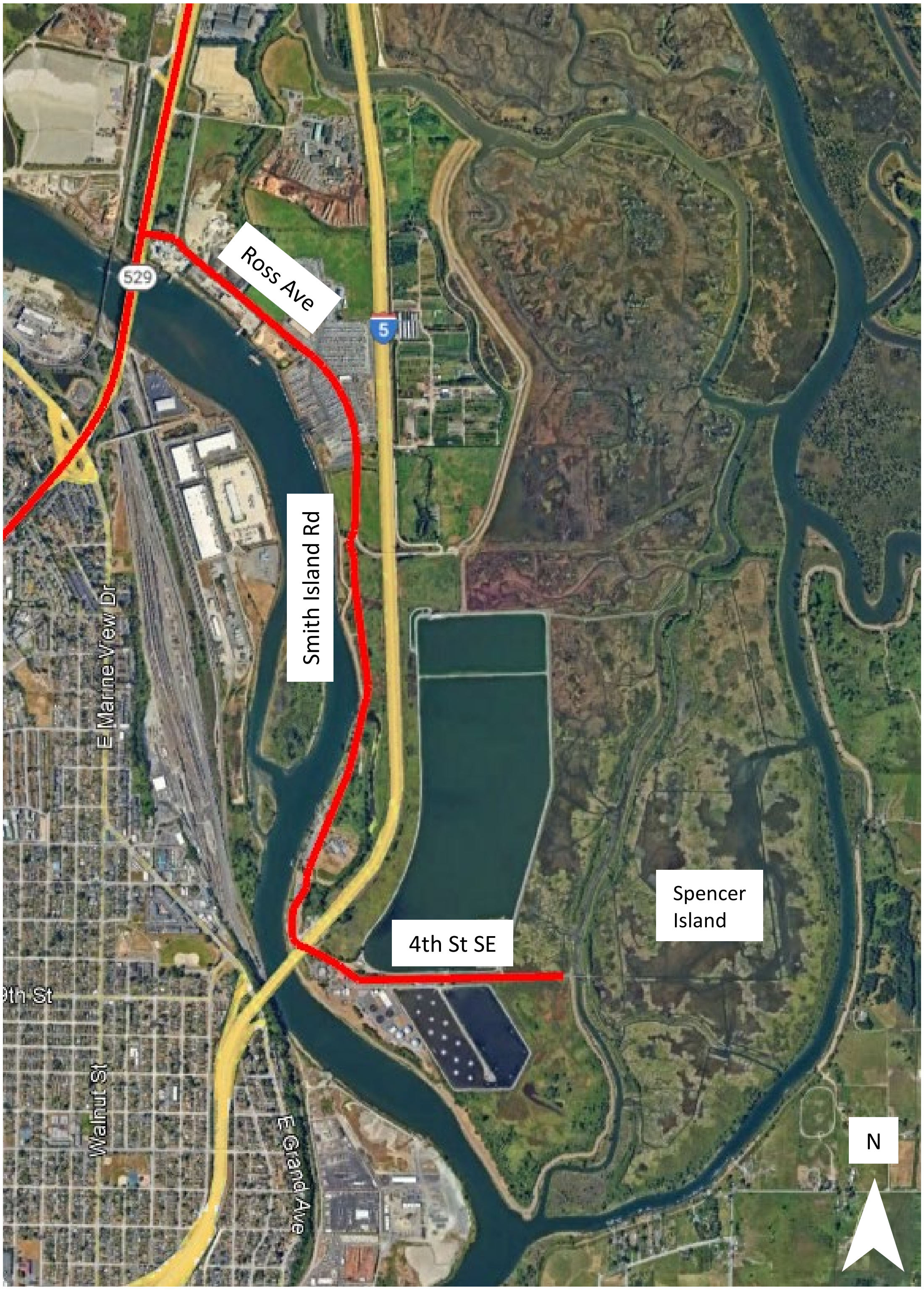


Figure 6. Proposed temporary construction access

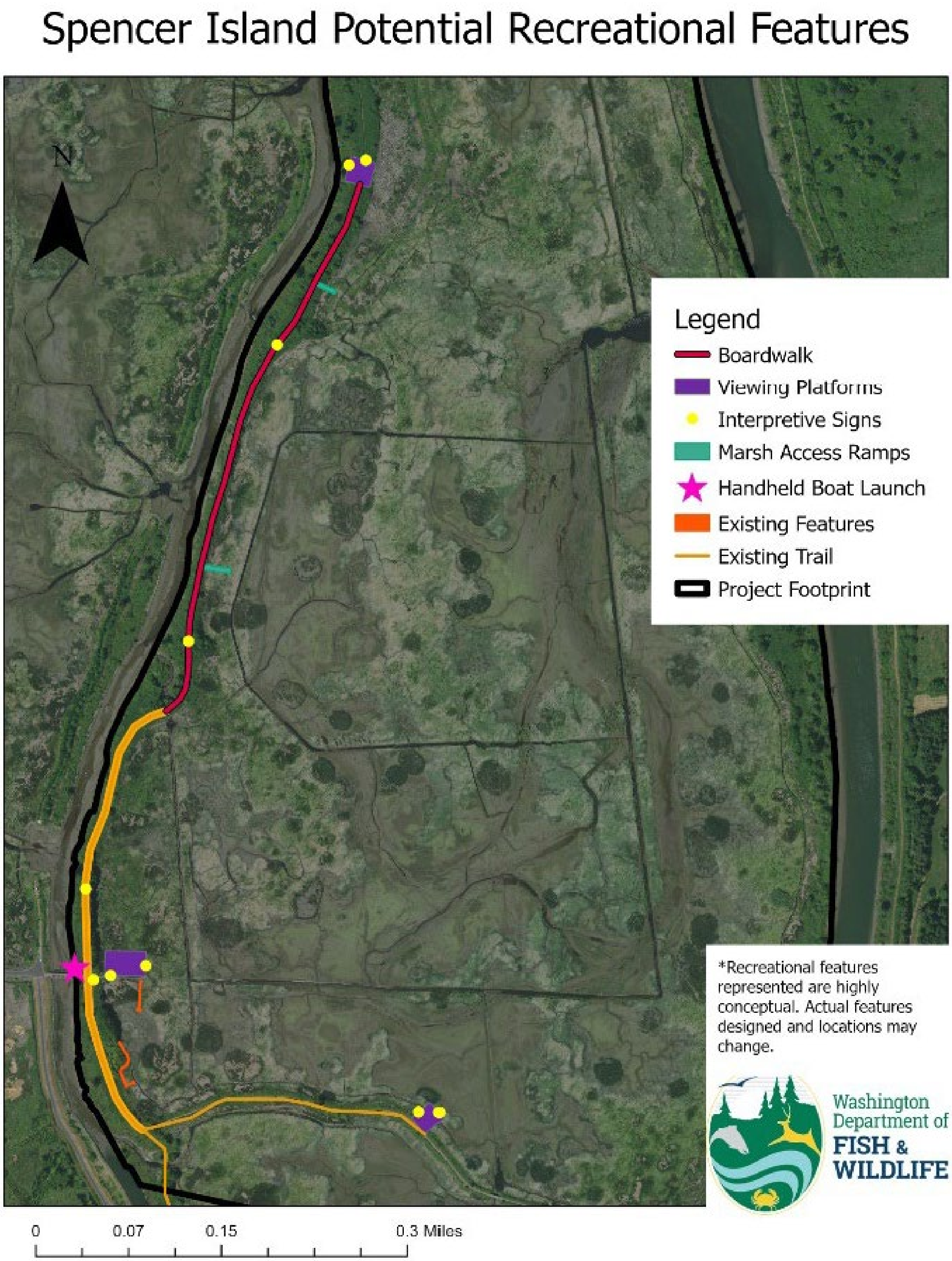


Figure 7. Potential Recreational Features

1.6.10 DEMO EXISTING CULVERT & BRIDGES

The Union Slough dike tide-gate and associated 48-inch corrugated metal culvert will be removed in the lowering in of the dike.

The eastern portion of the south cross dike will be lowered thus requiring the removal of two timber pedestrian bridges. The first is a single span timber bridge located at 47.991, -122.157, approximately 48’ long x 10’ wide. The second is a single span timber bridge located at 47.989, -122.154, approximately 67’ long x 10.5’ wide. Remove bridges in their entirety, including abutments and pile foundations.

1.6.11 Revegetation, Tree salvage, & Large Wood Placements

Approximately 85 acres will be temporarily disturbed as part of the project activities where most disturbance activities will occur below the high tide line (~12’ NAVD88). There will be an improved walkway that will be above the high tide line and is approximately 1.09 acres and will be revegetated with transplanted native vegetation (see Chapter 6 for additional info). All disturbed areas below the high tide line will be passively managed and native recruitment processes will be utilized. In upland areas, riparian trees and shrubs will be planted to deter recruitment of invasive plant species and to help offset removal of vegetation from construction. Refer to chapter 2 of this document for more information on vegetation management.

Based on current drawings, approximately 400 trees will need to be removed at areas where breaches in the dikes will be excavated and grading will be performed to lower the dikes, enhancing water connectivity at Spencer Island. The restoration project primarily focuses on enhancing aquatic habitat, with an emphasis on floodplain refuges and tidal channel habitats for ESA-listed salmonids, which are the target species. While riparian habitat is also important, and efforts will be made to minimize any negative impacts on it, priority will be given to aquatic habitat during construction. The number of trees was determined using Google Earth, and their morphology was assessed through field observations. The trees range in size from 10 to 50 feet in height and 4 inches to 3 feet in diameter. The approximate age of the trees are about 10 to 15 years old according to historic satellite imagery. Trees will be felled by toppling over with rootwads attached. Species to be removed from work areas include deciduous trees such as big leaf maple, black cottonwood, western red cedar, red alder, cascara, etc. Coniferous trees include Douglas fir, Sitka spruce, etc. Removal of conifer trees will be avoided if possible. Note that during the PED phase physical tree surveys will be conducted to identify significant trees that should be salvaged and left undisturbed.

Tree salvage work will generally require crews to mark trees to remove and remain prior to ground disturbance. Trees intended for ditch placements should be noted in the drawings (ID number, log length, location) to aid contractors in staging and decking of cleared materials near where they will be used. Tree removal will likely require use of an excavator with a thumb or a log loader to move trees. Excavators should be able to push trees over with the rootwads attached. Some trees will need to be topped and limbed first. Licensed forestry crews are recommended to avoid accidents in this sensitive location.

Where indicated, woody material (either existing down large wood or trees to be felled) will be placed at the heads ditch plugs to provide near-term stability to aid tidal channel and marsh rehabilitation. These placements will be anchored by burying with compacted soils used to fill ditches. All other woody material not used in ditch placements will be placed on site in a natural configuration (randomly, interspersed in standing trees and channels) near where it was generated, along the tops of spoil piles, lowered dikes, and the marsh plain, ditches, and channels.

Approximately 400 trees and 3,000 shrubs will be planted to offset for vegetation removal in upland areas of the project and will be monitored and adaptively managed for 10 years. At least 80% of the plants will survive by the end of year 1 and 80% cover by year 10 in all planted areas to meet the success criteria for the project. For areas outside permanent recreational trails, revegetation will consist of natural recruitment from local seed sources. This approach is based on recommendations provided by the project Technical Working Group and is based on locally developed best practices. Areas along trails and near interpretive rest areas will be seeded and revegetated. This treatment zone is located along the footprint of temporary access roads along Union Slough and the South Cross Dike. The revegetated areas will consist of the margins between the outside edge of the temporary access road and the edge of the new trail. The planting plan along these trails be developed in PED with input from Snohomish County parks and WDFW. See Section 6 for a more complete discussion of revegetation including invasives removal.

2. Hydrology, Hydraulics & Coastal Engineering

2.1 Overview

Relevant Hydrology, Hydraulics and Coastal (HH&C) data developed for detailed feasibility phase are presented in Annex D of the DDR, Hydrology, Hydraulics and Coastal Engineering. Annex D is subdivided into Annex D1 through D5. For pertinent data relevant to hydrology (river flooding, tides), inundation mapping, flood levels, and velocities refer to Annexes D1 and D2. For information specific to sediment transport and geomorphology, summaries of previous studies by others, metrics for the project area and reference site that inform the project design, refer to Annex D3. For information specific to hydraulic evaluations of the conceptual alternatives to support preferred alternative selection, see Annex D4. For a discussion of potential climate change impacts see Annex D5. Summary information from these Annexes is presented here.

2.2 Hydrology

Spencer Island is located between two Snohomish River distributary channels (Union Slough to the west, Steamboat Slough to the east). Union Slough reportedly forms the natural boundary between fresh water tidal wetland zone and the brackish tidal wetland zone (Collins and Haas 2001). The site and connected slough channels experience daily tidal fluxes from Puget Sound. Due to the difference in channel length and size between the mainstem and distributary channels, high and low tides occur at slightly different times. This results in dynamic conditions where upstream and downstream tidal fluxes can occur simultaneously in the mainstem and slough channels on incoming and outgoing tides depending on the location and phase of the tide cycle. Typical water levels are controlled by tidal fluctuations, and high-water levels controlled by river flooding. Tidal datums for Seattle are shown below in Table 9. Note that water levels recorded by WDFW at the north end of Spencer Island indicate high tides match the Seattle tide station, however low tides are highly influenced by the amount of freshwater being conveyed by the Snohomish River. Freshwater flows in the sloughs cause water levels in the south end of the Island at high tide to be higher than the north end by a foot or more. Thus, the tidal range at Spencer Island (difference between MHHW and MLLW) is about a couple feet less than at the Seattle tide gage.

Table 9. Seattle (NOAA #9447130) Tidal Datums Used for This Project

Datum	Value	Description
MHHW	9.02	Mean Higher-High Water
MHW	8.15	Mean High Water
MTL	4.32	Mean Tide Level
MSL	4.3	Mean Sea Level
DTL	3.34	Mean Diurnal Tide Level
MLW	0.49	Mean Low Water
MLLW	-2.34	Mean Lower-Low Water
NAVD 88	0	North American Vertical Datum of 1988

2.2.1 TIDAL FLOODING

Annual still-water tidal flood frequency data at the Seattle tide gage is shown below in Table 10 for the period of record using the peak-over-threshold method. Note that the 10-year recurrence interval, or 10% annual exceedance probability (AEP) tidal flood exceeds the elevation of the 10% AEP river flood at Spencer Island. Thus, tidal inundation (king tides plus storm surge) is the most common flood source at Spencer Island, with large riverine floods resulting in the greatest flood depths.

Table 10. Seattle (NOAA #9447130) extreme water level frequency curve*

% annual exceedance	Return period (year)	Total Water Level (feet, MLLW)	Total Water Level (feet, NAVD88)	±95% Confidence Interval (feet)
99	1.01	13.34	11.0	0.0354
50	2	13.6	11.26	0.0638
10	10	14.05	11.71	0.0954
2	50	14.54	12.2	0.1204
1	100	14.77	12.43	0.1307
0.2	500	15.37	13.03	0.1542

* Peak over threshold method.

2.2.2 SNOHOMISH RIVER FLOODING

Spencer Island is also subject to frequent fluvial flooding from the Snohomish River basin, which drains the combined flows of the Snoqualmie, Skykomish, Tolt, Sultan and Pilchuck. Real time stages and streamflows are measured at Monroe (river mile (RM) 20, 1,536 sq. mi.), upstream of the tidal backwater zone and on the Pilchuck River near Snohomish (129 sq. mi.). The total drainage area of the gaged proportion of the watershed tributary to the mainstem at the split to Union Slough and Steamboat Slough is 95% (1,665 sq. mi. of 1,749 sq. mi.). Tidal backwater extends up valley past the City of Snohomish (river mile (RM) 13). Annual runoff at the Monroe gage is 9,800 cfs, which equates to 6.4 cfs/sq. mi./year or an annual precipitation depth of about 90 inches.

Inspection of the annual (cyclic) hydrograph for the Monroe gage, based on the daily average streamflow period of record (Figure 8), indicates the presence of a typical fall and winter rain and rain on snow flood period, a modest decrease in late winter, followed by a May-June snowmelt freshet, and an August-

September low /base flow period. As shown in the monthly flow duration plot (Figure 9) May is typically the wettest month in terms of sustained high flows, with flows exceeding 7,000 cfs 90% of the time. August and September have the lowest runoff with baseflow less than 3,000 cfs more than 50% of the time. Because the mainstem Snohomish and Ebey Slough diverge upstream of where Union Slough and Steamboat Slough diverge, the flow present in the mainstem prior to the diversion toward Spencer Island is a fraction of that indicated below.

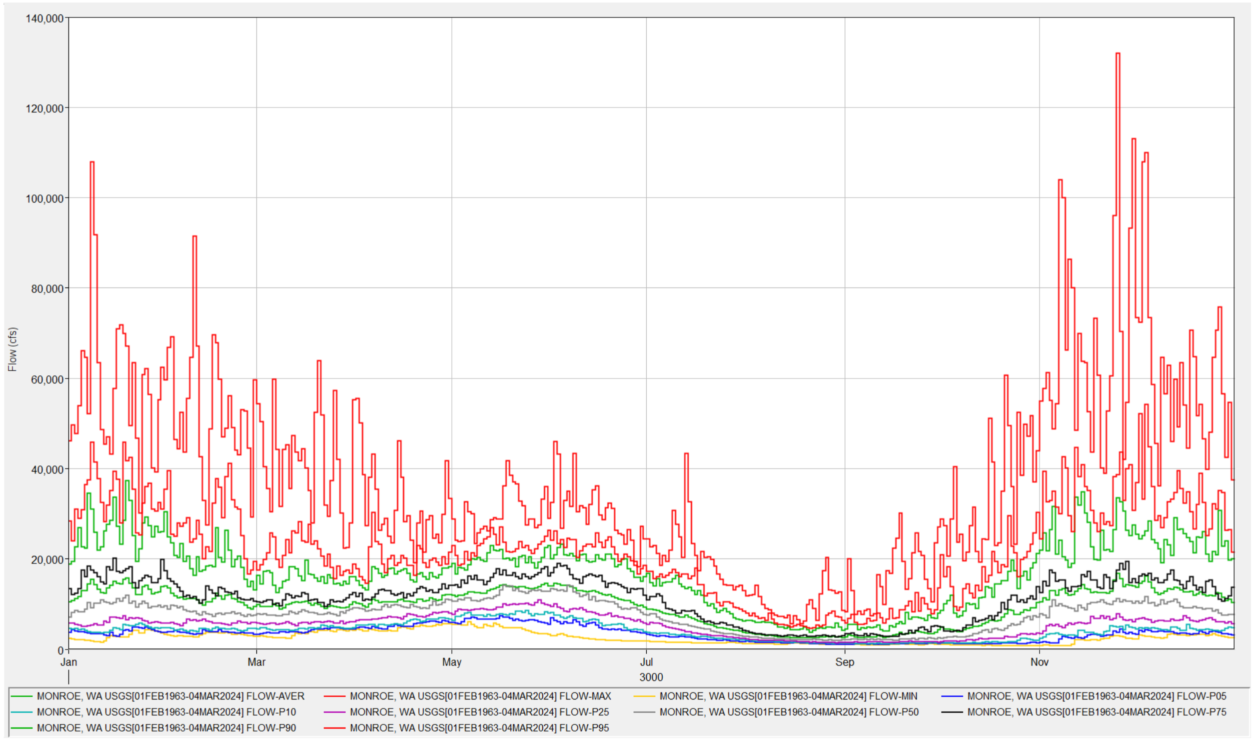


Figure 8. Snohomish River at Monroe daily discharge period of record cyclic analysis

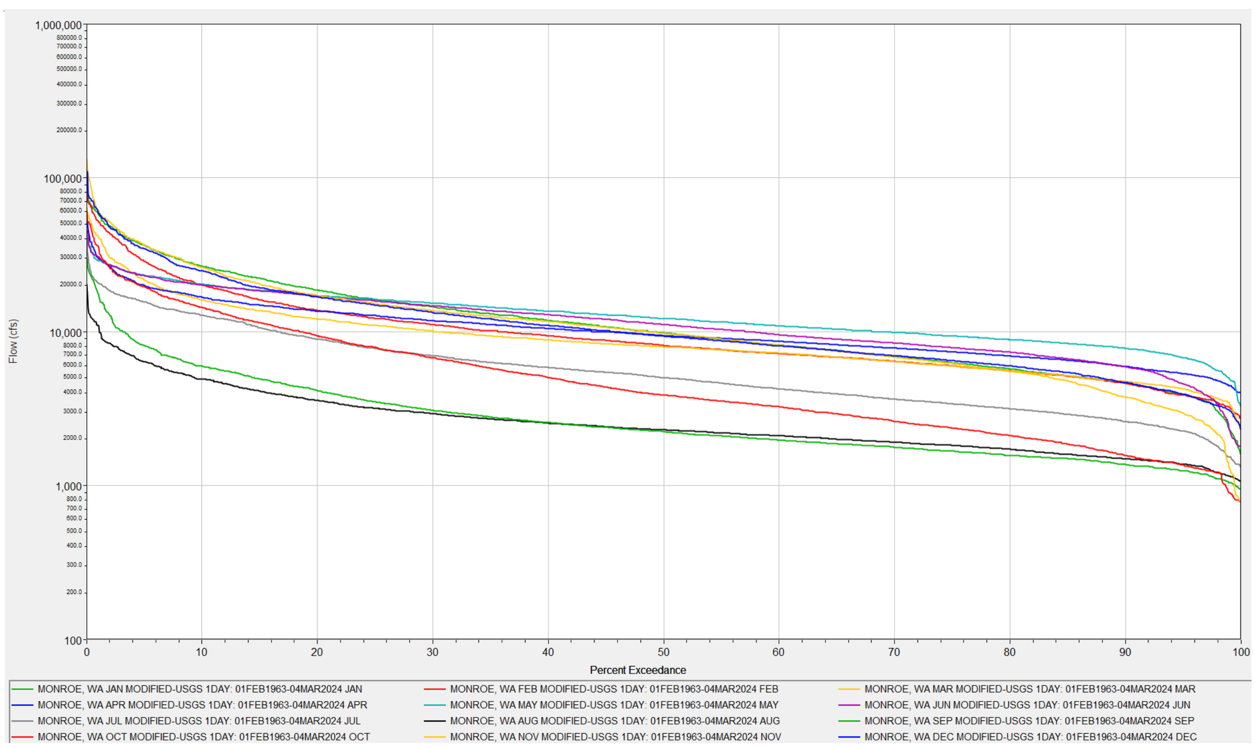


Figure 9. Snohomish River at Monroe, monthly flow-duration statistics

Damaging floods recorded by the Monroe have occurred in water years 1991, 2009, 1996, 2007, and 1976. The Snohomish gage was operational prior to the Monroe gage and recorded two large floods of comparable magnitude in 1951 and 1960. USGS published peak flood stages (without flows) for very large floods that occurred in 1905, 1916, 1920, 1932. As part of the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) historical floods for 1898, 1907, and 1918 were estimated by regression to build out the historical record which was then used to compute annual peak flow frequency statistics. There is considerable uncertainty in the methods and data used in the FIS, and 24 years have elapsed since that analysis was completed. Refer the FEMA flood insurance study and Annex D1 for more details. Peak flow frequency estimates are compared in Table 11..

Table 11. Current estimates for Snohomish River annual peak streamflows near Spencer Island

Flood Event		Snohomish at Monroe		Pilchuck River		Snohomish River + Pilchuck River	
Return Period (Years)	Annual Exceedance Probability (%)	WSE (cfs)	FEMA (cfs)	WSE (cfs)	FEMA (cfs)	WSE (cfs)	FEMA (cfs)
1	99%					*49,865*	*54,759*
2	50%	62200		5970		68,170	*77,561*
10	10%	101,700	120,700	10,300	8,900	112,000	129,600
50	2%	139,200	174,400	13,900	12,100	153,100	186,500
100	1%	156,100	196,800	15,400	13,300	171,500	210,100
500	0.2%	197,700	242,900	18,900	17,200	216,600	260,100

Computed routed unsteady flow hydrographs in the FEMA hydraulic model for the Snohomish were evaluated to understand the flow distribution between the various sloughs and to allow relating peak discharges at the gage upstream to the site. That analysis (see Annex D1 Table 8) shows that for the 10% AEP (10-year) flood event, when most flows are restricted to channels, the peak flow at the gage is 114,000 cfs, is attenuated as it moves downstream to 107,000 before 39,500 diverges into Ebey Slough (roughly 40%). At the mainstem split Steamboat/Union Slough, about 12,000 cfs diverts, with 8,800 cfs into Steamboat Slough, and 3,150 into Union Slough. Steamboat Slough receives about 8% of the peak at the gage, and Union Slough receives about 3%. Thus, the proportion of the flow at the gage passing by the project is roughly 10% for typical conditions, possibly higher when attenuation due to overbank flooding is not occurring. Note that as dikes overtop flows enter the sloughs from Ebey Island which can double the flood flow diverted from the mainstem. Tidal flux (daily flood and ebb tide discharges) can reduce or increase flows in the slough channels beyond what the simplified hydraulic model is estimating.

Hydrologic conditions at the site are complex necessitating use of advance models if accurate estimates of hydrologic conditions are desired, however, even with use of more sophisticated models, factors that are not typically accounted in the model such as variation in atmospheric pressure relative to the tide station, and wind setup effects on tides, can result in differences between computed and measured water levels even if the more sophisticated model is producing more physically realistic results. The underlying confidence in the statistical estimates of peak flows is higher than typical at this stie. Thus, uncertainty is an inherent part of the data and models used, and project designs should be developed accordingly by considering the potential for water levels to vary from those predicted by the models.

2.2.3 Long Term Hydrometeorological Conditions Assessment

This project incorporates considerations of future sea levels and inland hydrology in accordance with ER 1100-2-8162 and ECB 2026-1, and ER 1110-2-8159.

USACE estimated sea level change based on low (historical), and medium and high emissions scenarios are shown below in Figure 10. Presuming the project is constructed in 2027 sea levels/ tidal datums at the site could shift upwards from 0.8 to 3.6 feet by 2080 and will steadily increase thereafter. By 2063 the mean tide level could inundate the average island elevation daily (under high emission scenario) and by 2117 under the intermediate emission scenario. The proposed dike lowering elevation could be exceeded by the MHHW by 2045 under the high emissions scenario and 2081 by the intermediate emissions scenario. Given expected sedimentation within and along the island, this will extend the forecasted time for intersection between these reference elevations and datums, resulting in a project that is expected to provide intended benefits for the duration of the 50-year planning period.

The National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise Viewer tool was used to see how the changes in mean sea level could manifest near Spencer Island by 2080 (See HHC Annex D1, Fig. 11-14). Daily tidal inundation for nearly all conditions appears to result in inundation patterns resembling very large floods on the Snohomish River. It is unclear if landowners will adapt by increasing the height of dikes or abandon the low-lying floodplain areas allowing them to convert back to tidal marsh or tide flats.

NOAA estimates of sea level rise in Puget Sound range from a low of 0.4 feet to high estimates of 6.3 feet by 2080, which are notably higher than USACE forecasts. The restoration of natural functions of the floodplains and river deltas at the recommended sites will allow the sites to adjust to changing geomorphic conditions associated with changing sea levels, e.g., shifting landward as water rises and sediment accretes.

Qualitative impacts of changed future hydrometeorological conditions on temperature and streamflows are considered in HHC Annex D5. Expected changes are based on UW CIG modeling and affect the entire estuary (higher precipitation intensities, higher wintertime peak flows, lower summertime base flows, increased temperatures).

No significant differences are anticipated between future with and future without project precipitation or streamflows in the estuary, however restoration actions promote future resilience of tidal marsh at Spencer Island by allowing sediment laden freshwater to more easily enter Spencer Island. This will enhance sediment deposition rates, help maintain brackish conditions, promote native vegetation establishment, increase tidal channel shading, and reduce water temperatures in the summer. For these reasons, conditions should be qualitatively better than no action alternative.

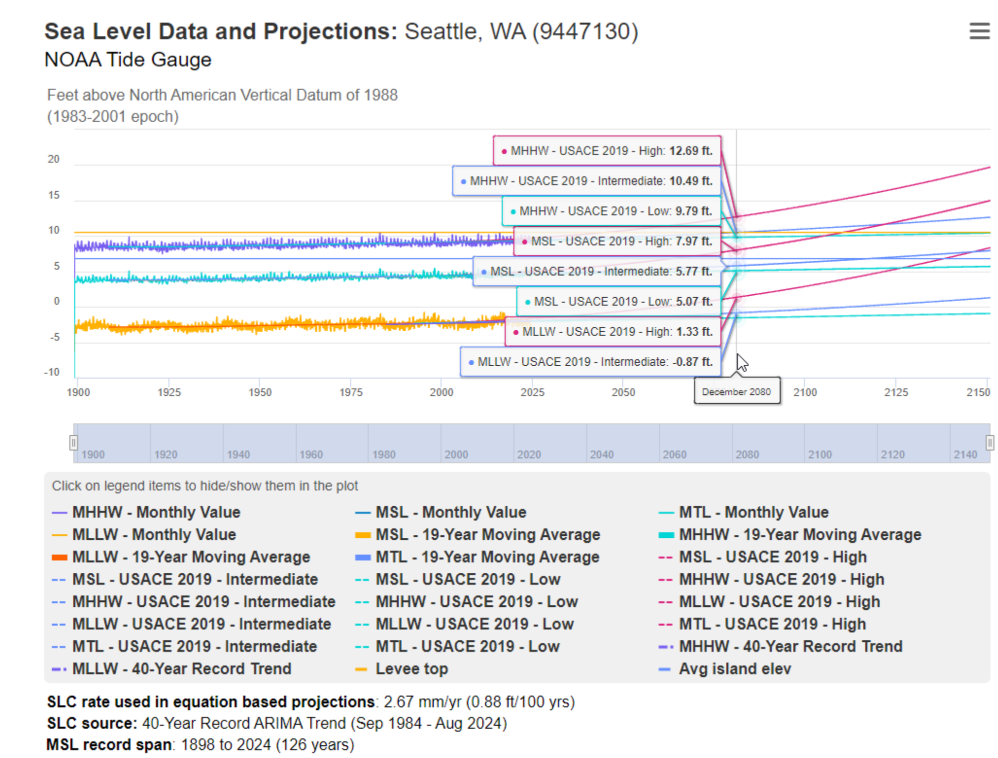


Figure 10. Sea level change forecasts at Seattle

2.3 Hydraulic Analysis

Hydraulic information (water levels, depths, velocities, etc.) were computed in an Hydraulic Engineering Center River Analysis System (HEC-RAS) model developed for the project that spans from the USGS gage at Monroe to the Puget Sound. The Snohomish River HEC-RAS model was developed to route streamflows from the gage through the project area. It is primarily used to estimate flood levels associated with various combinations of riverine and tidal high-water events and to aid in analyzing the potential effects of restoration.

Results of the 2D model described herein were checked with a HEC-RAS 1D/2D model that is anticipated to be used to support any FEMA flood map revisions. This model is much less computationally intensive and provides realistic inundation depths in overbank areas but does not capture 2-dimensional flow characteristics in distributary channels when they are present.

2.3.1 Scenarios

Because of the potential for coincident tidal and riverine flooding, several combinations of river floods and tidal floods were modeled for existing (E) and proposed (P) conditions. A total of 30 scenarios were analyzed. See Table 12 for a summary. Tides and river flows used in the analysis for scenarios 1E/P through 11 E/P are for 2020 (historical) conditions. Tides and river flows used in the analysis for Scenarios 12E/P through 15E/P are for 2080 conditions.

Table 12. Spencer Island 35% Design Modeling scenarios

Scenario	Coastal Boundary Condition	Riverine Boundary Condition	Source
1E/P	99% AEP / 11.0 feet	99% AEP / 54,533 cfs	WSE 2020, CIG 2014
2E/P	50% AEP / 11.26 feet	99% AEP / 54,533 cfs	“”
3E/P	10% AEP / 11.71 feet	99% AEP / 54,533 cfs	“”
4E/P	2% AEP / 12.2 feet	99% AEP / 54,533 cfs	“”
5E/P	1% AEP/ 12.43 feet	99% AEP / 54,533 cfs	“”
6 E/P	0.2% AEP/ 13.03 feet	99% AEP / 54,533 cfs	“”
7 E/P	MHHW + 1 feet (9.8 NAVD88)	50% AEP / 77,562 cfs	FEMA FIS estimates
8 E/P	MHHW + 1 feet (9.8 NAVD88)	10% AEP / 129,600 cfs	“”
9 E/P	MHHW + 1 feet (9.8 NAVD88)	2% AEP / 186,500 cfs	“”
10 E/P	MHHW + 1 feet (9.8 NAVD88)	1% AEP / 210,100 cfs	“”
11 E/P	MHHW + 1 feet (9.8 NAVD88)	0.2% AEP / 260,100 cfs	“”
12 E/P	MHHW + 1 foot 2080 (11.47ft NAVD88)	2080 50% AEP / 77,400 + 7,370 cfs	WSE 2020/CIG 2014
13 E/P	MHHW + 1 foot 2080	2080 10% AEP / 126,500 + 12,700 cfs	“”
14 E/P	MHHW + 1 foot 2080	2080 1% AEP / 194,200 + 19,000 cfs	“”
15 E/P	MHHW + 1 foot 2080	2080 0.2% AEP / 245,900 + 23,300 cfs	“”

2.3.2 Results

The HEC-RAS model setup, calibration, and results are presented in Annexes D1 and D2. Outputs from the existing conditions scenarios used in the FEMA FIS extracted from the locations shown in Figure 11 are summarized in Table 13 (1% AEP or 100-year river flood for existing conditions) and Table 14 (1% AEP or 100-year river flood for existing conditions). Water surface profiles along the mainstem Snohomish River between the Ebey Slough split and Puget Sound are shown in Figure 14. Mainstem Snohomish River water surface profiles from USACE HEC-RAS 2D model for historical and2080 river flood scenarios, along Steamboat Slough in Figure 15 and along Union Slough in Figure 16 . From inspection, the changes (increases and decreases) along the sloughs resulting from restoration are negligible to very small. Changes are essentially zero until widespread dike overtopping is occurring (2% AEP/50-year and greater floods). During these larger floods the removal of the dikes at Spencer Island potentially allows for more floodwater conveyance across Spencer Island, slightly reducing flood elevations in Steamboat Slough and increasing them in a short portion of Union Slough.

Computed changes in water levels for frequent floods (99% AEP to 10% AEP resulting from coastal inundation) show no change from existing conditions and are not shown here for brevity. During very large (1% to 0.2%AEP) floods when dike overtopping is widespread, changes are also negligible. Dikes near Spencer Island begin to overtop during the peak of the 1% AEP event. Redirection of floodwaters from Steamboat to Union Slough appears to cause some small, localized increases in flood levels for the 1% AEP event, however the depths are less than those indicated by the FEMA FIS. Refer to Annex D1 and D2 for a more complete comparison of model results by scenario.

Assuming a FEMA no-rise analysis will be necessary in PED, water surface elevations (WSE) from the USACE 2D models are compared with effective FEMA FIS values at the lettered FIS cross sections in Table 15 and Table 16. In general, the HEC-RAS modeling indicates minimal to no change in flood risk associated with removal of existing (already breached) dikes.

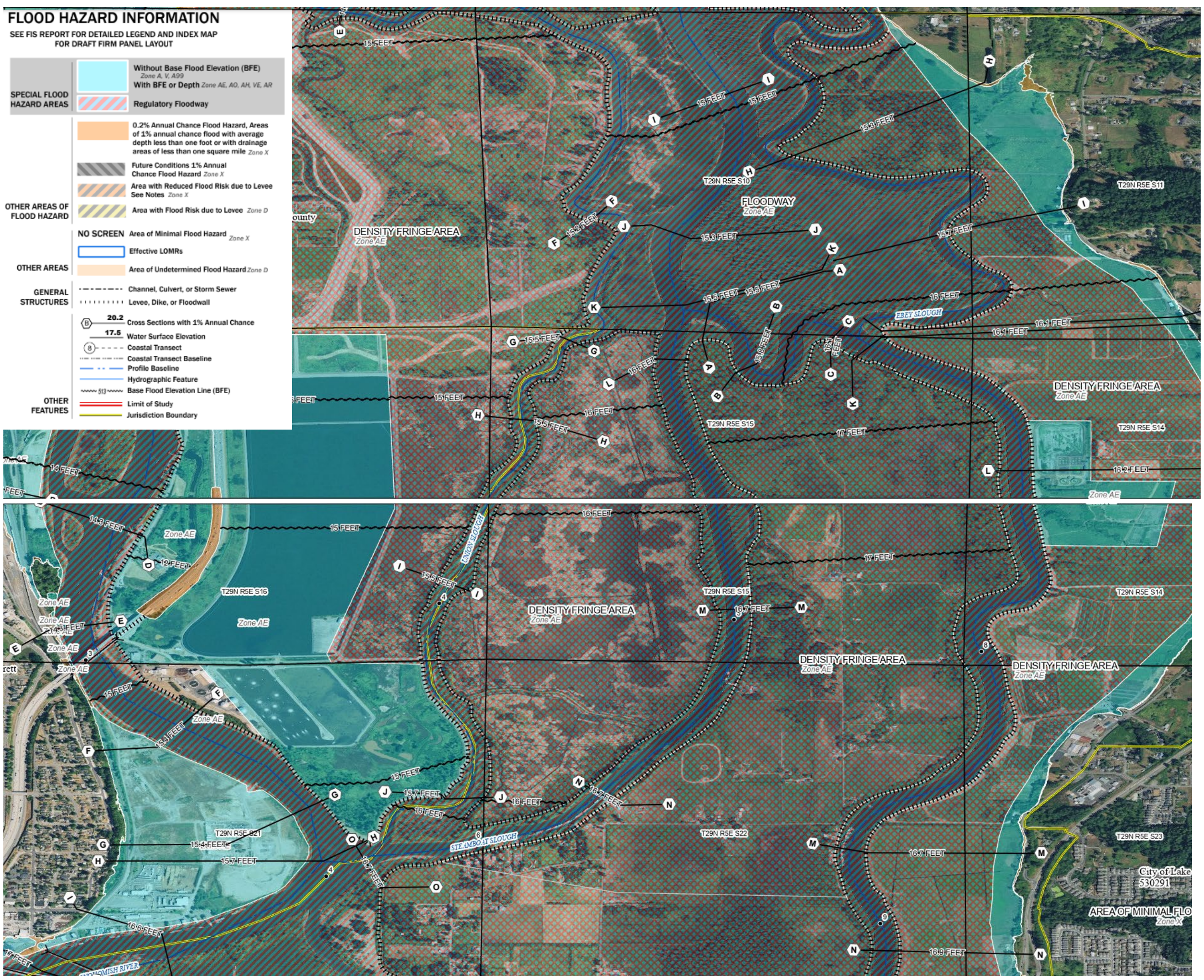


Figure 11. Effective FEMA Flood Insurance Rate Maps (FEMA Flood Hazard Viewer, 2023)

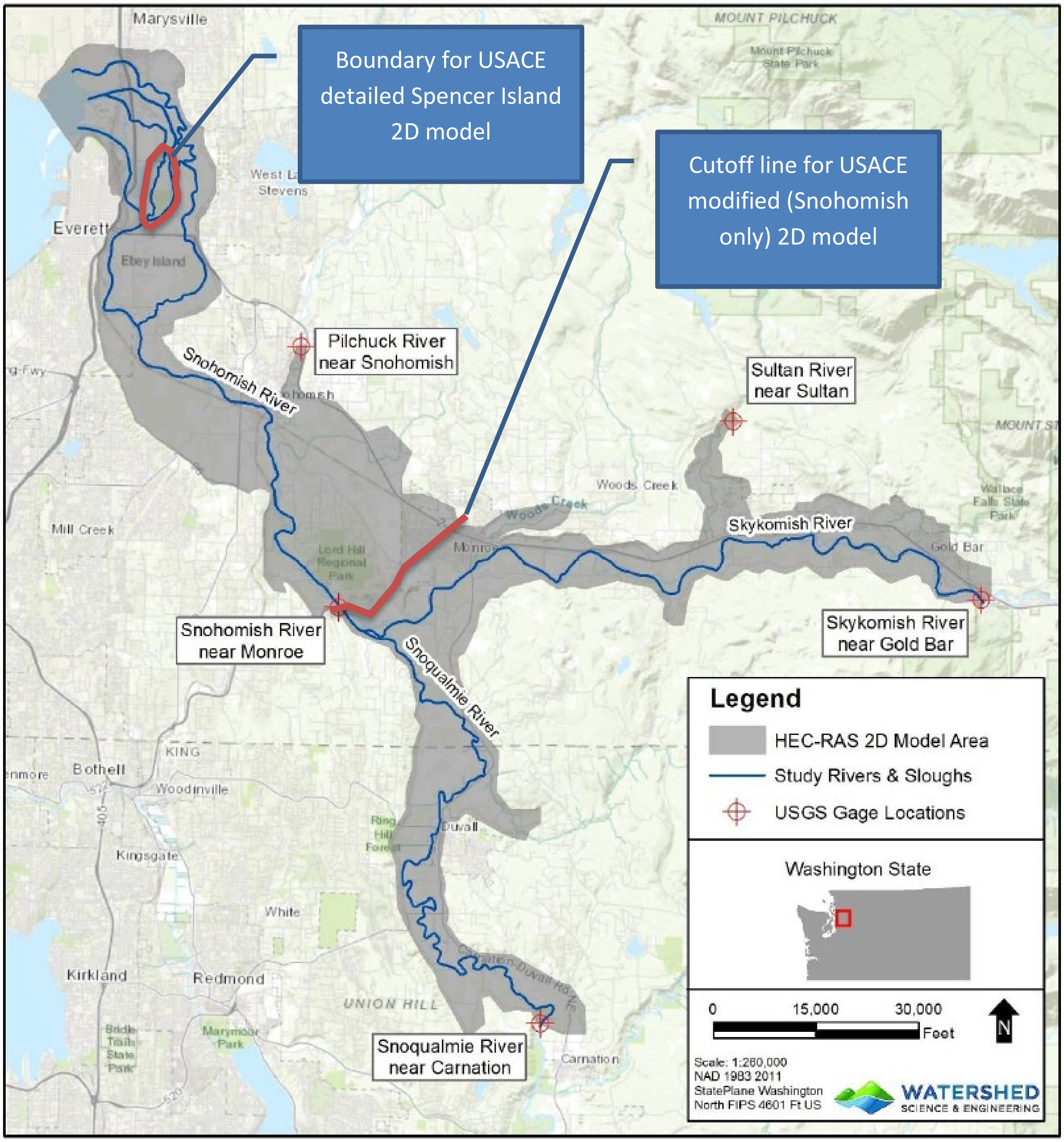


Figure 12. HEC-RAS 2D model extents and stream gage locations

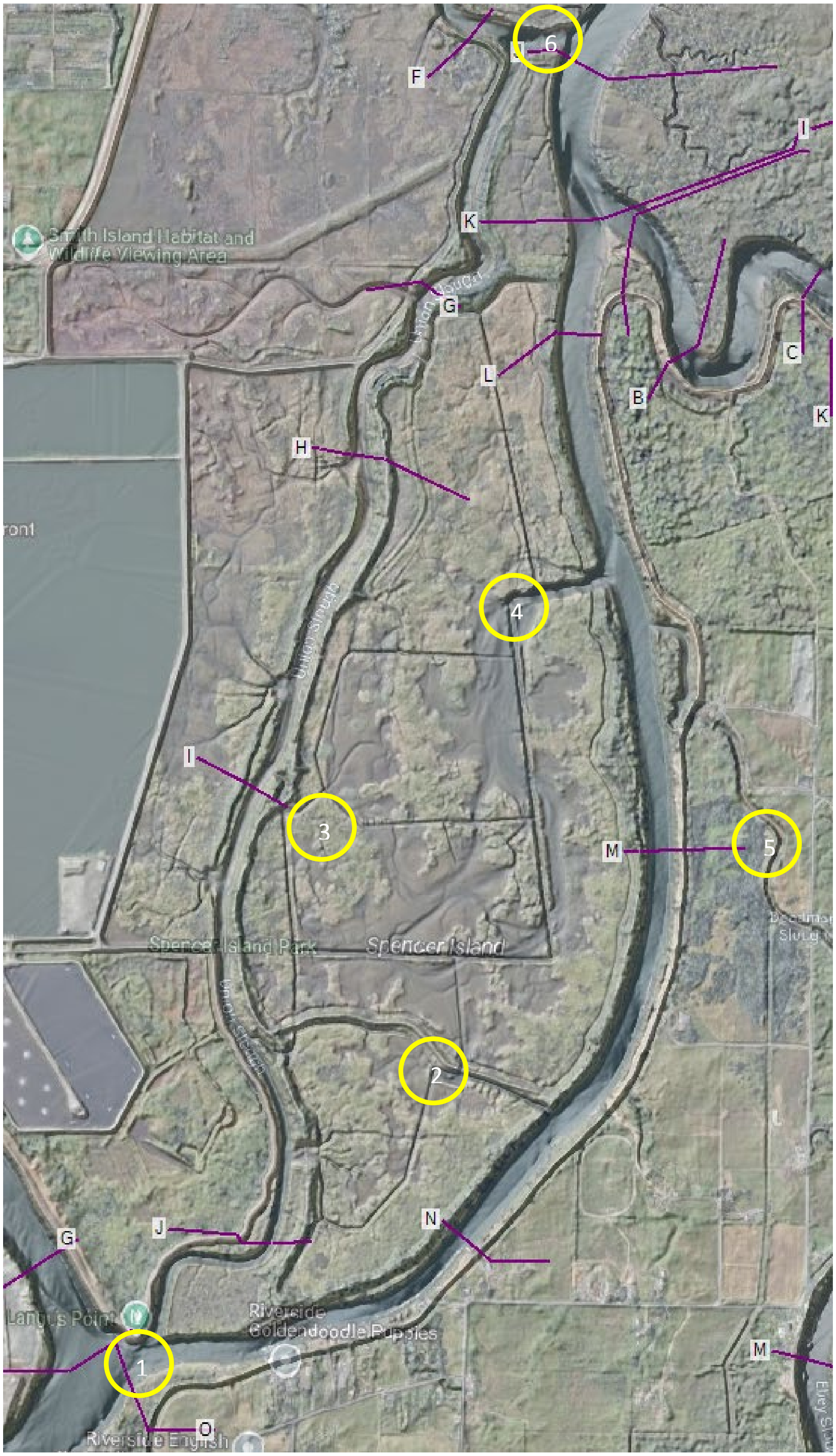


Figure 13. Output locations for peak water surface elevations showing FEMA FIS lettered cross sections.

Table 13. Peak Water Surface Elevations – Existing, Historical (Observed) Conditions

(NAVD 88, feet. Computed in USACE 2D model.)

AEP	Flood Event R.I. (year)	Steamboat/Union Slough - XS O	Bridge S. of Cross Dike	Union Slough XS I	North End of main ditch	Steamboat XS M	Buse Cut - Steamboat XS J
0.5	2	11.74	10.93	10.63	10.51	10.68	10.31
0.1	10	12.39	11.33	10.95	10.80	11.02	10.51
0.02	50	15.51	14.14	13.85	13.93	14.88	12.95
0.01	100	16.86	15.74	15.10	15.51	15.96	14.49
0.002	500	19.48	18.39	17.77	18.07	18.39	17.22

Table 14. Peak Water Surface Elevations - 35% Design, Historical (Observed) Conditions.

(NAVD 88, feet. Computed in USACE 2D model)

AEP	Flood Event R.I. (year)	Steamboat/Union Slough - XS O	Bridge S. of Cross Dike	Union Slough XS I	North End of main ditch	Steamboat XS M	Buse Cut - Steamboat XS J
0.5	2	11.65	10.72	10.65	10.63	10.70	10.34
0.1	10	12.29	11.07	10.98	10.95	11.05	10.55
0.02	50	15.44	14.20	14.03	13.99	14.83	12.95
0.01	100	16.76	15.62	15.44	15.35	15.81	14.43
0.002	500	19.43	18.31	17.98	17.93	18.27	17.14

Table 15. Comparison of FEMA Regulatory & Base Flood Elevations (BFEs) to USACE Existing Condition (2D 1% AEP flood stages near Spencer Island.)

Location	FEMA XS ID	UNET Station (RM)	FEMA regulatory WSE (ft)	FEMA BFE (NAVD88, ft)	USACE 2D 1%AEP Exist. WSE (ft)	FEMA regulatory minus USACE 2D (ft)	FEMA BFE minus USACE 2D (ft)
Snohomish River	G	3.68	15.4	16.1	14.7	0.7	1.4
Steamboat Slough	O	6.23	16.7	17.2	16.5	0.2	0.7
Steamboat Slough	N	5.7	16.7	17.2	16.4	0.3	0.8
Steamboat Slough	M	4.96	16.7	17.2	15.8	0.9	1.4
Steamboat Slough	L	4.2	16	16.6	15.1	0.9	1.5
Steamboat Slough	K	4.04	15.5	16.1	14.7	0.8	1.4
Steamboat Slough	J	3.76	15.3	15.9	14.3	1.0	1.6
Union Slough	J	4.5	15.7	16.3	15	0.7	1.3
Union Slough	I	3.79	15.5	16.1	15.1	0.4	1.0
Union Slough	H	3.24	15.5	16.1	15.2	0.3	0.9
Union Slough	G	2.91	15.5	16.1	14.3	1.2	1.8
Union Slough	F	2.49	15.2	15.7	13.9	1.3	1.8
All Cross Section Average			15.8	16.4	15.1	0.7	1.3
Spencer Island	SA#11		Not published	16.0	15.6	NA	0.4

Table 16. Comparison of FEMA Regulatory & BFEs to USACE 35% Design Conditions

(2D 1% AEP flood stages near Spencer Island.)

Location	FEMA XS ID	UNET Station (RM)	FEMA regulatory WSE	FEMA BFE (NAVD88, ft)	USACE 2D 1%AEP 35% WSE (ft)	FEMA regulatory minus USACE 2D (ft)	FEMA BFE minus USACE 2D (ft)
Snohomish River	G	3.68	15.4	16.1	14.8	0.6	1.3
Steamboat Slough	O	6.23	16.7	17.2	16.4	0.3	0.8
Steamboat Slough	N	5.7	16.7	17.2	16.3	0.4	0.9
Steamboat Slough	M	4.96	16.7	17.2	15.7	1.0	1.5
Steamboat Slough	L	4.2	16	16.6	15	1.0	1.6
Steamboat Slough	K	4.04	15.5	16.1	14.6	0.9	1.5
Steamboat Slough	J	3.76	15.3	15.9	14.3	1.0	1.6
Union Slough	J	4.5	15.7	16.3	15.3	0.4	1.0
Union Slough	I	3.79	15.5	16.1	15.3	0.2	0.8
Union Slough	H	3.24	15.5	16.1	15.1	0.4	1
Union Slough	G	2.91	15.5	16.1	14.4	1.1	1.7
Union Slough	F	2.49	15.2	15.7	14	1.2	1.7
All Cross Section Average			15.8	16.4	15.1	0.7	1.3
Spencer Island	SA#11		Not published	16.0	15.4	NA	0.6

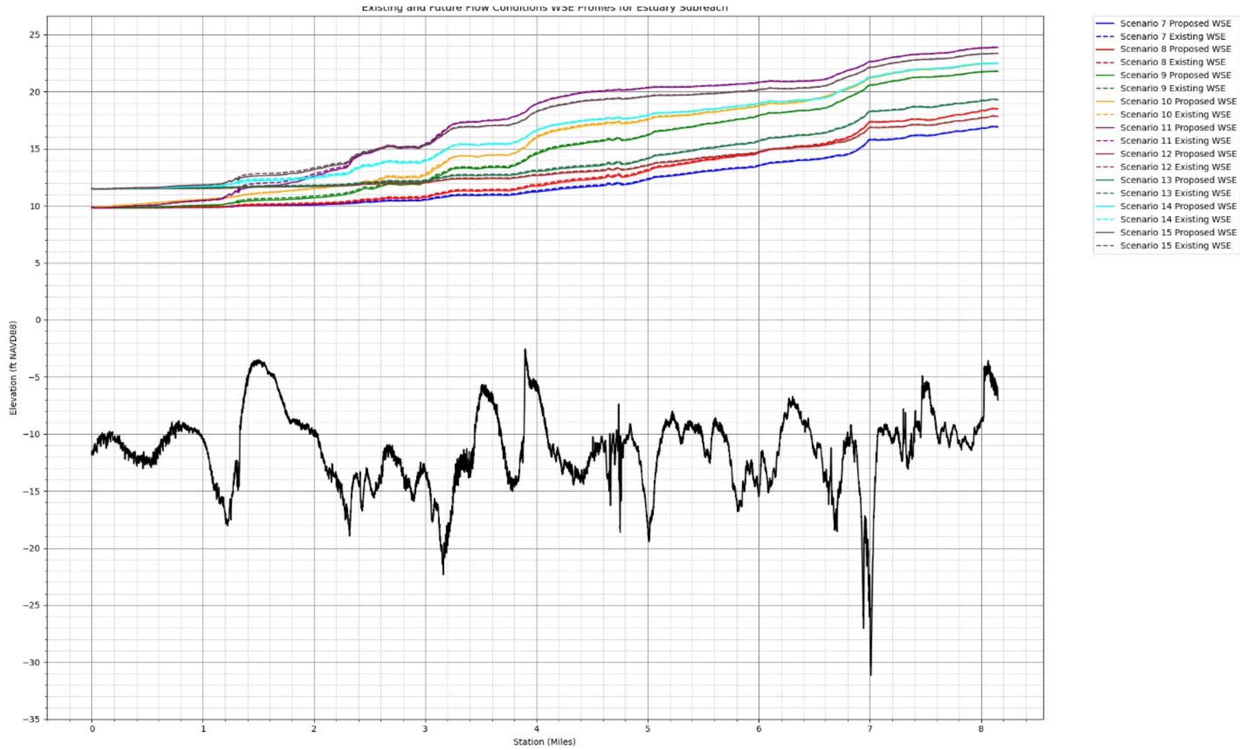


Figure 14. Mainstem Snohomish River water surface profiles from USACE HEC-RAS 2D model for historical and2080 river flood scenarios

Along Steamboat Slough between Puget Sound and upstream connection with the Snohomish River flooding scenarios (Figure 15) show larger changes (decreases) in maximum water surface profiles than in other distributary channels. The decreases are caused by dike removal at Spencer Island which allows for diversion of more floodwater from Steamboat Slough across Spencer Island toward Smith Island and Union Slough, which is one of the goals of the project (to improve connectivity between Steamboat and Union Slough restoration projects). Spencer Island spans from RM 4.5 to 6.6 in the plot below.

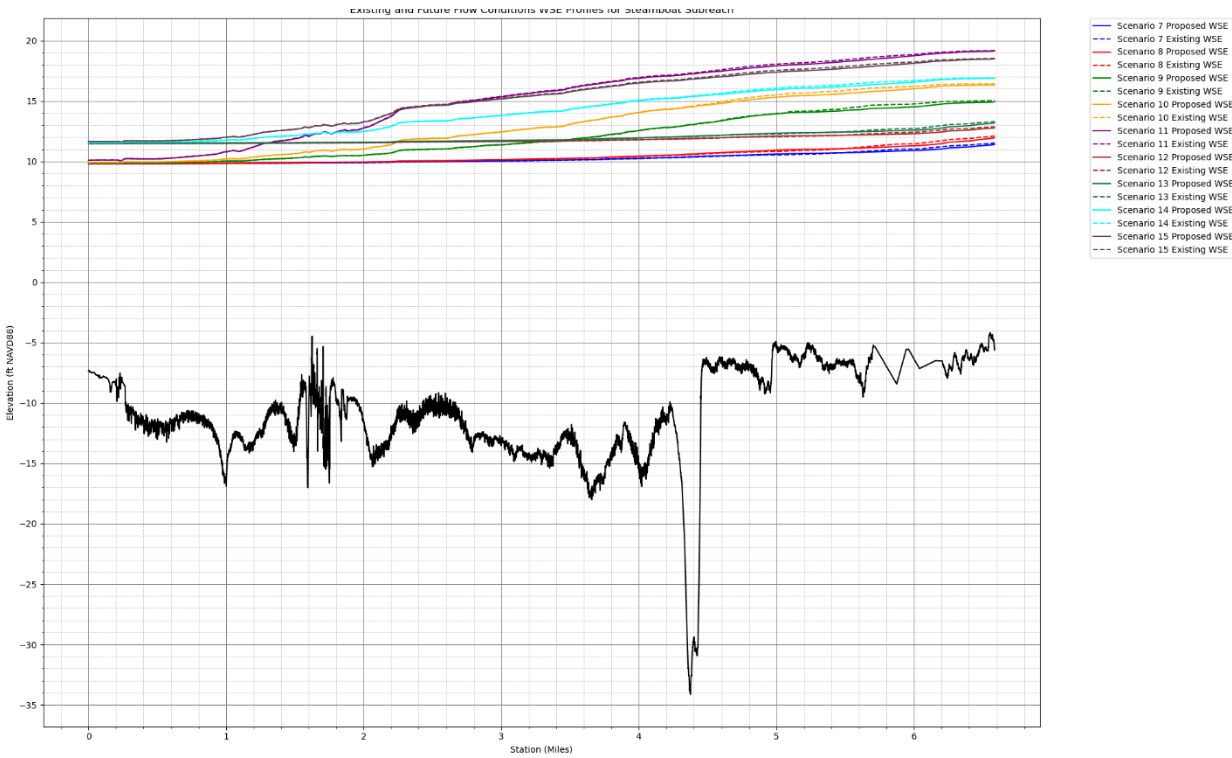


Figure 15. Steamboat Slough water surface profiles from USACE HEC-RAS 2D model for historical and 2080 river flood scenarios

Along Union Slough between Puget Sound and upstream connection with the Snohomish River flooding scenarios show small changes (both increases and decreases) in maximum water surface profiles. Decreases in water surface occur in the upstream most part of Union Slough, immediately after the junction where Steamboat and Union sloughs branch off the mainstem Snohomish. This slight decrease is observed in Scenarios 7, 8, 9, 12, and 13. Increases in water surface occur around stations miles 1.25-1.75. The increases occur for Scenarios 9, 10, 11, 14, and 15 and are caused by dike removal at Spencer Island which allows for diversion of more floodwater toward Smith Island and Union Slough, which is one of the goals of the project (to improve connectivity between Steamboat and Union Slough restoration projects).

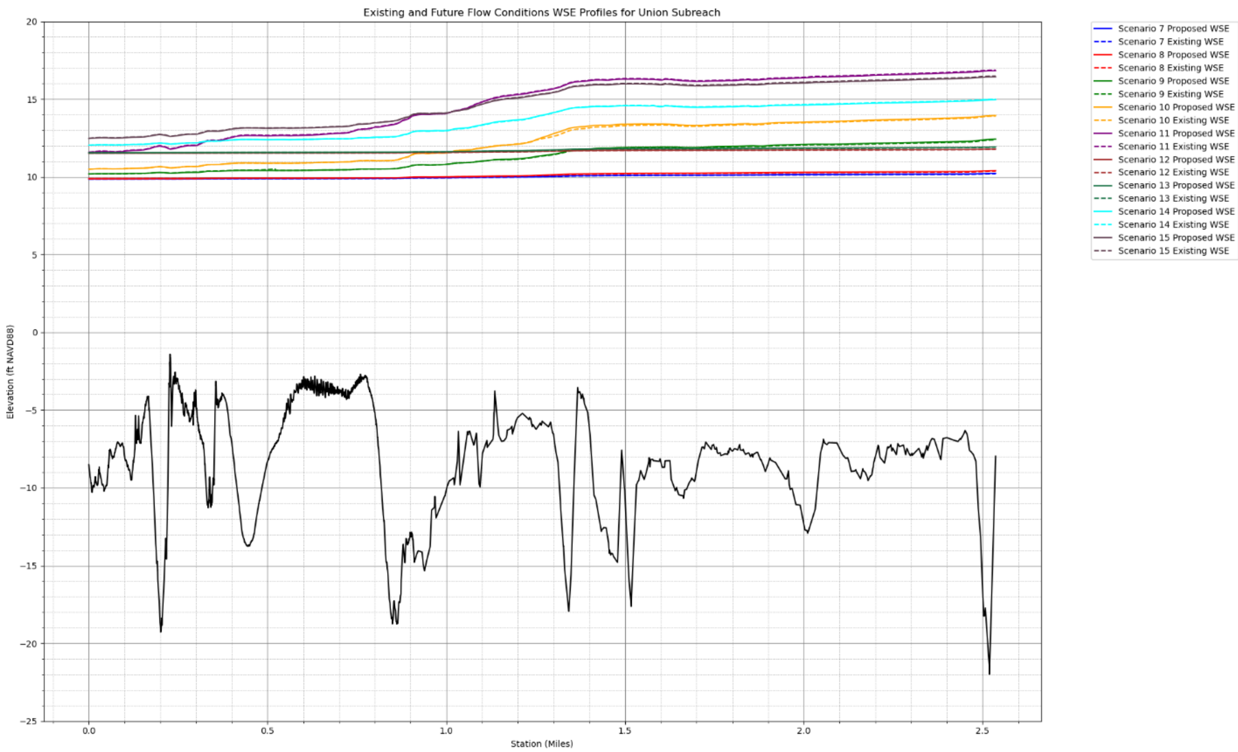


Figure 16. Union Slough water surface profiles from USACE HEC-RAS 2D model for historical and 2080 river flood scenarios

Velocity inundation maps for the existing and proposed conditions for the 50% AEP and 1% AEP river flood events are shown in Figure 17 through Figure 20. Velocities in Spencer Island are much lower than adjacent sloughs and the Snohomish River for existing and proposed conditions. Differences in velocities between existing and proposed conditions are small and localized to Spencer Island and adjacent distributaries, and not increasing or decreasing significantly. Refer to the HH&C Appendix Annexes D.1 and D.2 for more information on the Riverine H&H Modeling and Calibration.

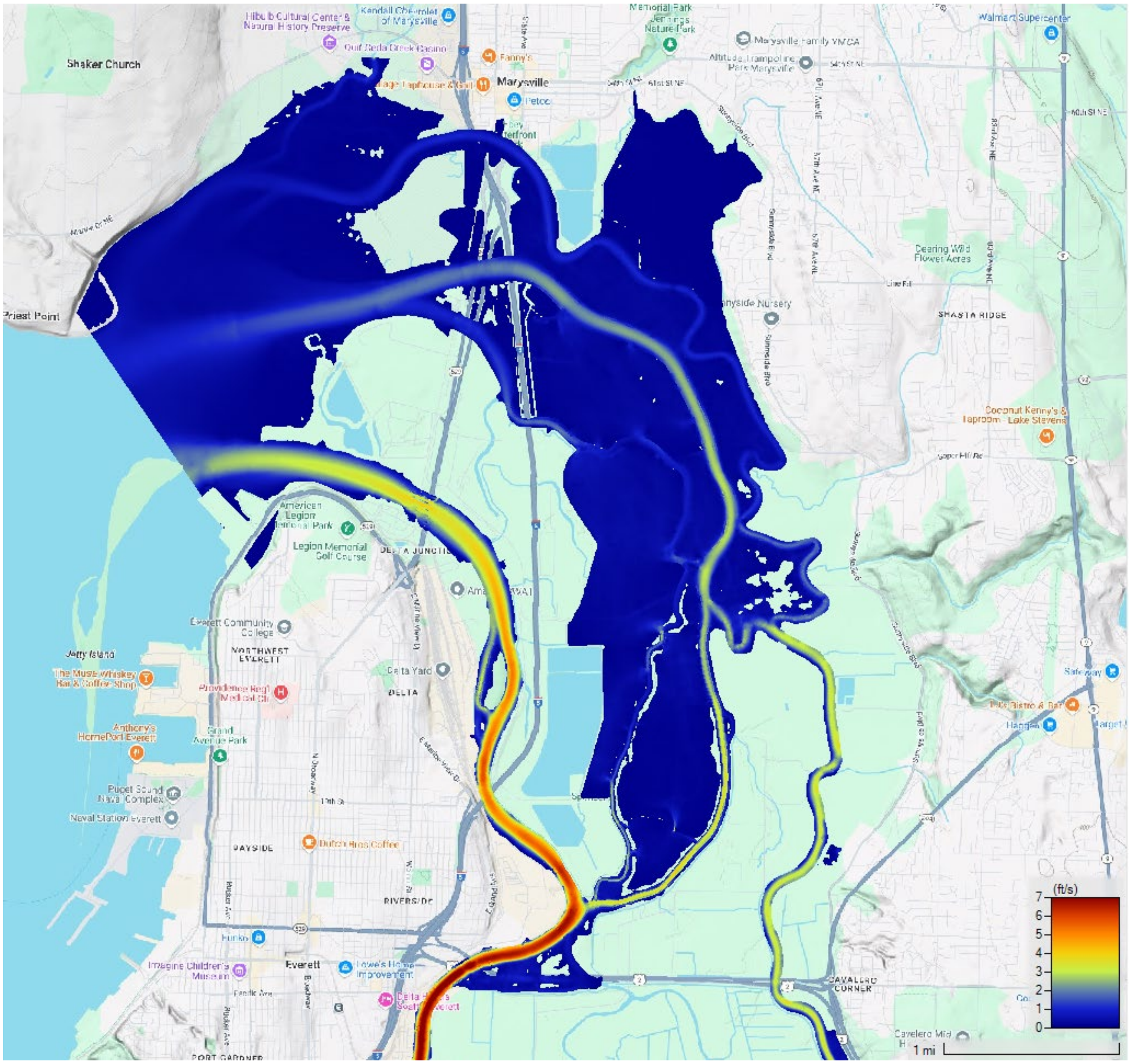


Figure 17. 50% AEP velocity inundation map with coincident MHHW+1' tide – existing conditions

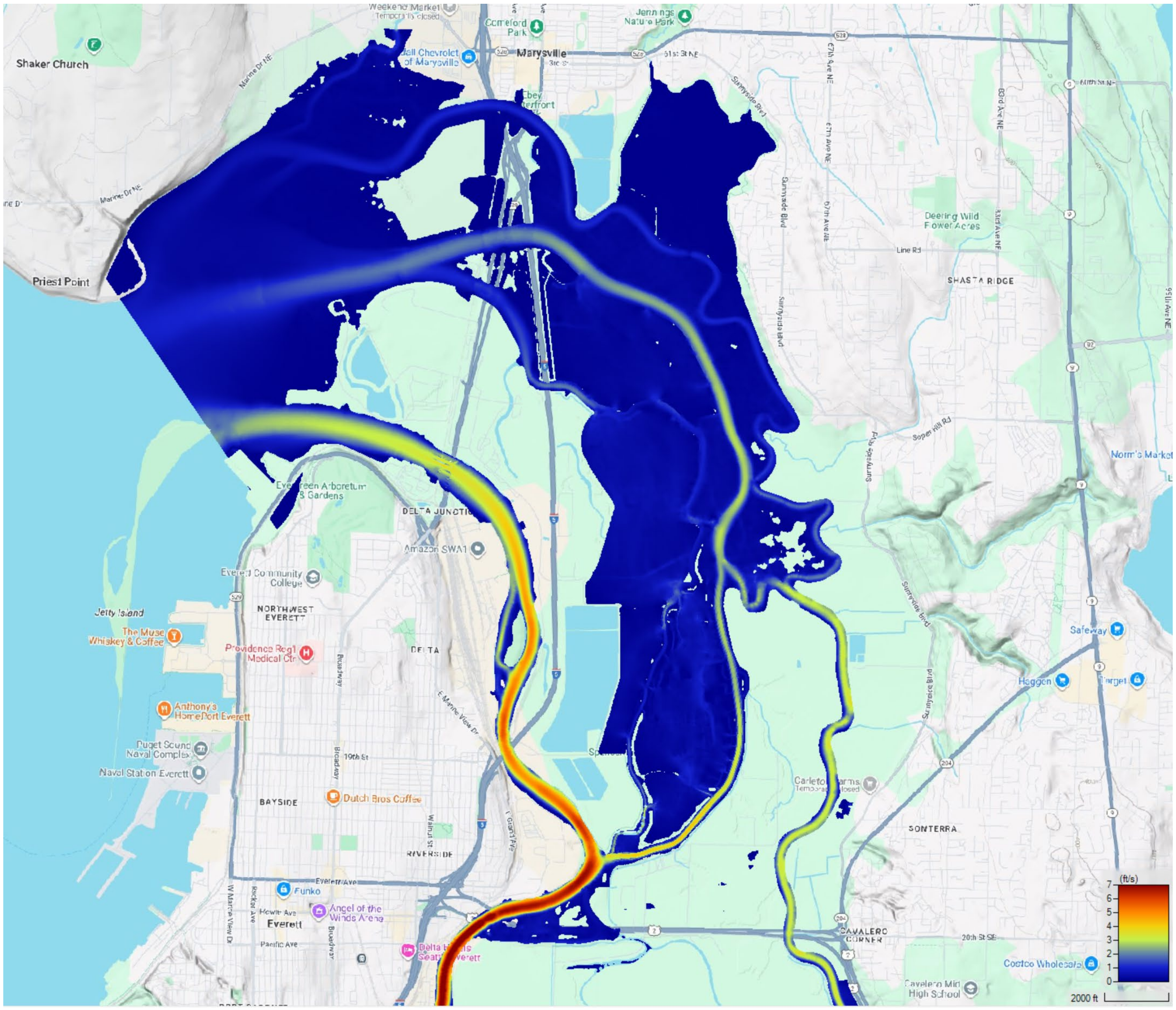


Figure 18. 50% AEP velocity inundation map with coincident MHHW+1' tide – proposed conditions

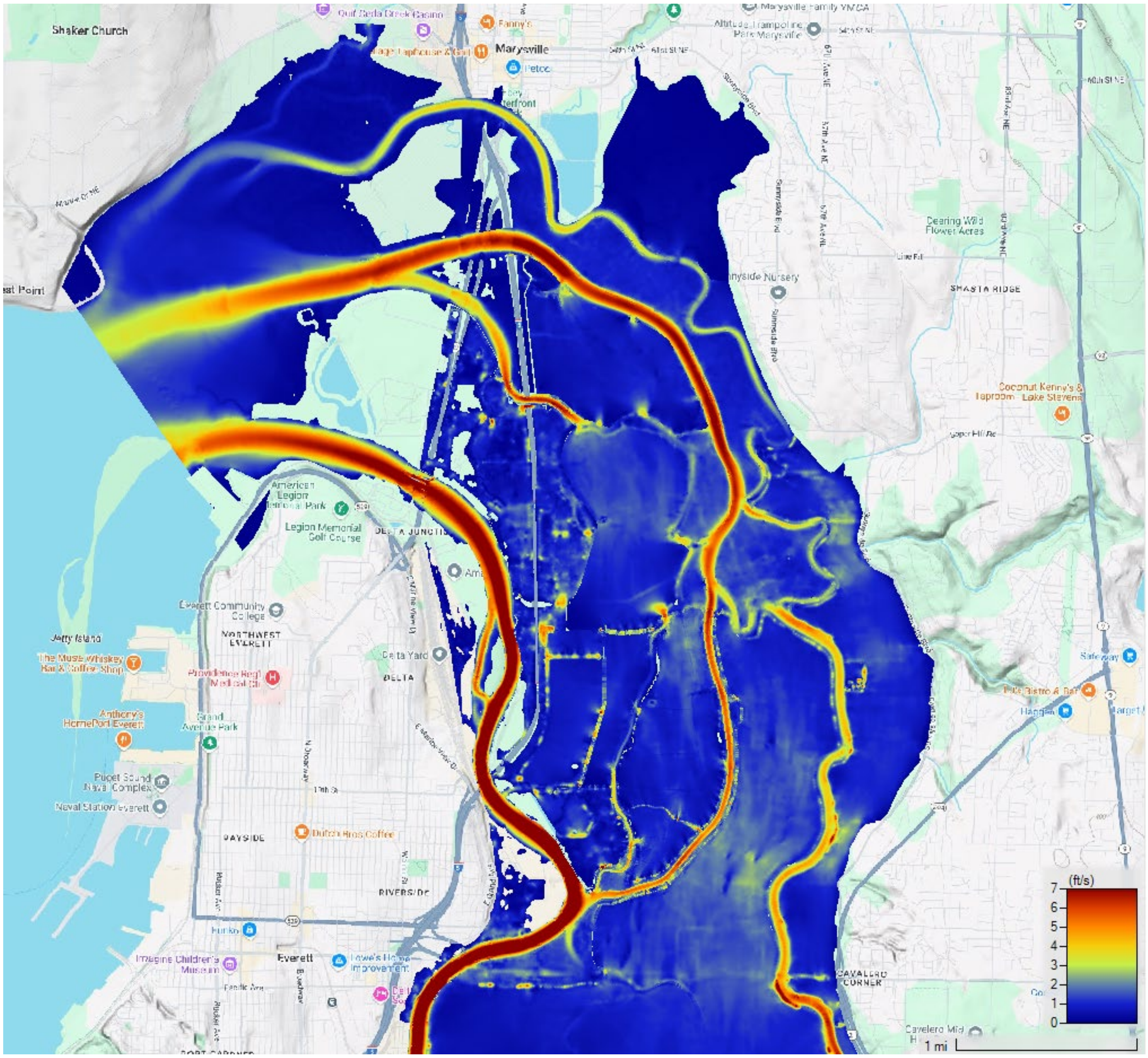


Figure 19. 1% AEP velocity inundation map with coincident MHHW+1' tide – existing conditions

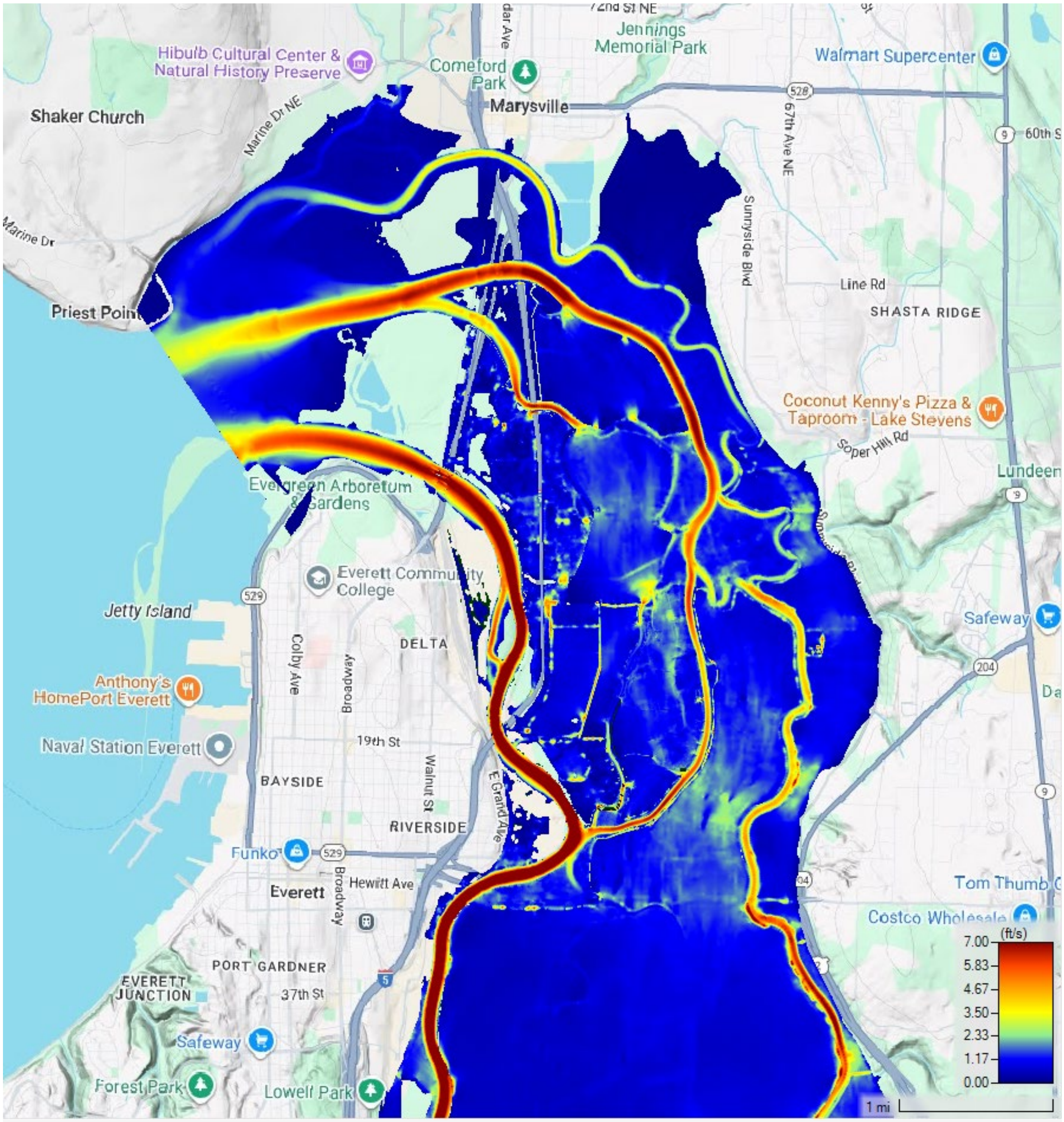


Figure 20. 1% AEP velocity inundation map with coincident MHHW+1' tide – proposed conditions

2.3.3 FLOODPLAIN MANAGEMENT IMPLICATIONS

As shown in Table 17 the average change in the FEMA cross sections near Spencer Island are 0.0 feet, and the USACE computed WSE are on average 0.7 feet lower than published regulatory WSEs, despite use of the same hydrologic boundary conditions. Within Spencer Island 1% AEP water surface elevations could increase 0.2 feet (wholly within project footprint). Nearby on Union Slough the increase in water surface elevations could approach 0.3 feet if mitigation of induced flooding (expansion of conveyance on Smith Island, see section 2.3.4) is not included.

Table 17. Comparison of USACE 35% Design Conditions to USACE Existing Conditions

(2D 1% AEP flood stages near Spencer Island.)

Location	FEMA XS ID	UNET Station (RM)	USACE 2D 1%AEP 35% WSE (ft) (w/o flowage on Smith Island)	USACE 2D 1%AEP Exist. WSE (ft)	35% minus Existing (ft) (w/o flowage on Smith Island)
Snohomish River	G	3.68	14.8	14.7	0.1
Steamboat Slough	O	6.23	16.4	16.5	-0.1
Steamboat Slough	N	5.7	16.3	16.4	-0.1
Steamboat Slough	M	4.96	15.7	15.8	-0.1
Steamboat Slough	L	4.2	15	15.1	-0.1
Steamboat Slough	K	4.04	14.6	14.7	-0.1
Steamboat Slough	J	3.76	14.3	14.3	0.0
Union Slough	**J**	**4.5**	**15.3**	**15**	**0.3**
Union Slough	**I**	**3.79**	**15.3**	**15.1**	**0.2**
Union Slough	H	3.24	15.1	15.2	-0.1
Union Slough	**G**	**2.91**	**14.4**	**14.3**	**0.1**
Union Slough	**F**	**2.49**	**14**	**13.9**	**0.1**
All Cross Section Average			15.1	15.1	0.0
Spencer Island	SA#11		15.6	15.4	0.2

For context it should be noted that the CLOMR modeling report (Otak, 2015) no-rise analysis for the nearby Smith Island restoration project constructed by Snohomish County, indicated potential rises of 0.7 feet at the outlet of the primary tidal channel near I-5. The effects of Spencer Island are considerably less because the dikes are already breached, and the reconnected marsh area is much less than at Smith Island.

2.3.4 Mitigation of Potential Induced Flooding

To address the potential for induced flooding impacts on developed portions of Smith Island, USACE has expanded the project footprint to include an adjacent portion of Smith Island just across from the main breach with Union Slough (referred to in section 1.6.3 as Smith Island Channel Improvement). This expanded footprint allows for demolition of a remnant dike that was previously breached by the City of Everett and Snohomish County to restore tidal hydrology to former farmlands purchased as wetland mitigation sites. This dike and an adjacent cross dike (North Levee) hinder free passage of floodwaters during high flow events. Expansion of the Smith Island breach reduces this hindrance for floodwaters along Union Slough. The expanded breach redirects floodwater away from upstream levees into these tidal wetlands, moderately increasing elevations/depths near the breach. See Annex D.1 for a hydrologic analysis of the potential effects on these wetlands (negligible to beneficial) and Annex D.2 for flood inundation changes.

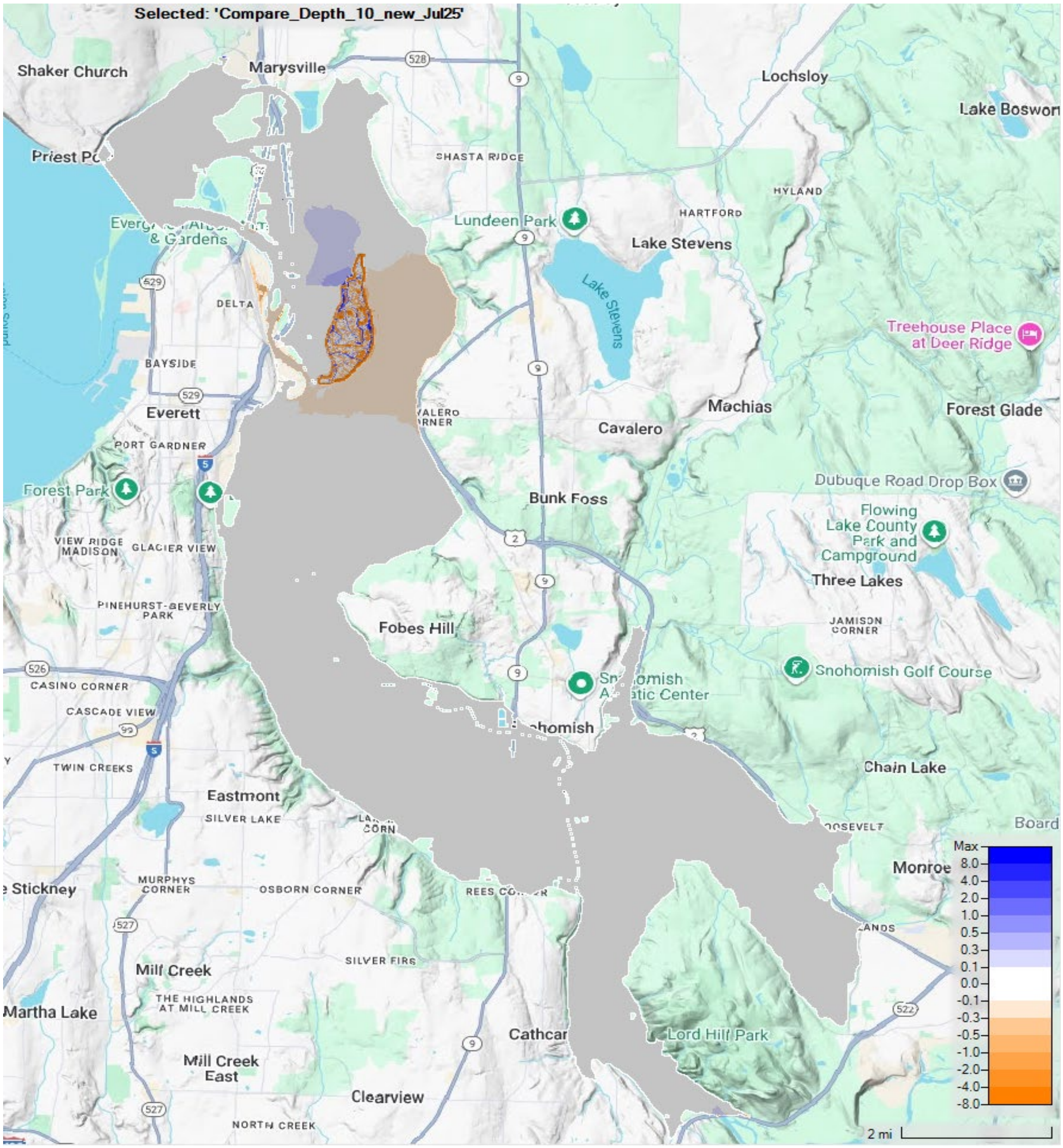


Figure 21. 1% AEP depth changes near Spencer Island (with project + channel improvement (mitigation)) on Smith Island levee

2.4 HYDRAULIC DESIGN

2.4.1 DIKE LOWERING AND SPOILS PLACEMENT

Hydraulic design for this feature is quite minimal. The top elevations of the dike lowering are targeting a WSE reference line that is consistent with natural topographic divide between upland and marsh vegetation. As shown in Figure 22 and Figure 23 below, this elevation band (orange solid line) ranges from 12 to 9.5 feet along Steamboat and Union Slough and slopes downward from south to north. At the north end of the island this reference line is 0.5 feet higher than the tidal MHHW elevation. Along Steamboat Slough this line nearly matches the linear slope between the maximum tide measured at two tide gages installed by WDFW (data recorded mid-March 2023 to July 2023) indicating it is consistent with a king tide or seasonal high flow. The increase in elevation in the divide is caused by fresh water from the Snohomish River in the sloughs.

For purposes of assuring natural processes associated with tidal and fluvial flooding are restored to Spencer Island the upland artificial fill needs to be removed to an elevation that corresponds to natural high ground. For 35% design purposes the elevation 10.5 was selected for all lowering locations, as this appears to be above the elevation of high tides frequently experienced but at or below the onset of tidal or fluvial flooding. Marsh benches where spoils will be side cast will be no higher than this elevation. Areas with significant established riparian vegetation will be left intact. USACE estimates that the OHWM for the site is about 11.0 feet, representing an average between the south and north sides of the island.

PED phase design refinements will use calibrated hydraulic data to slope the crest of the lowered dikes to allow the same frequency of overtopping along the restored banks. In addition, the tolerances for final grading will have looser tolerances than typical to allow for topographic variability which is believed to aid in vegetation reestablishment.

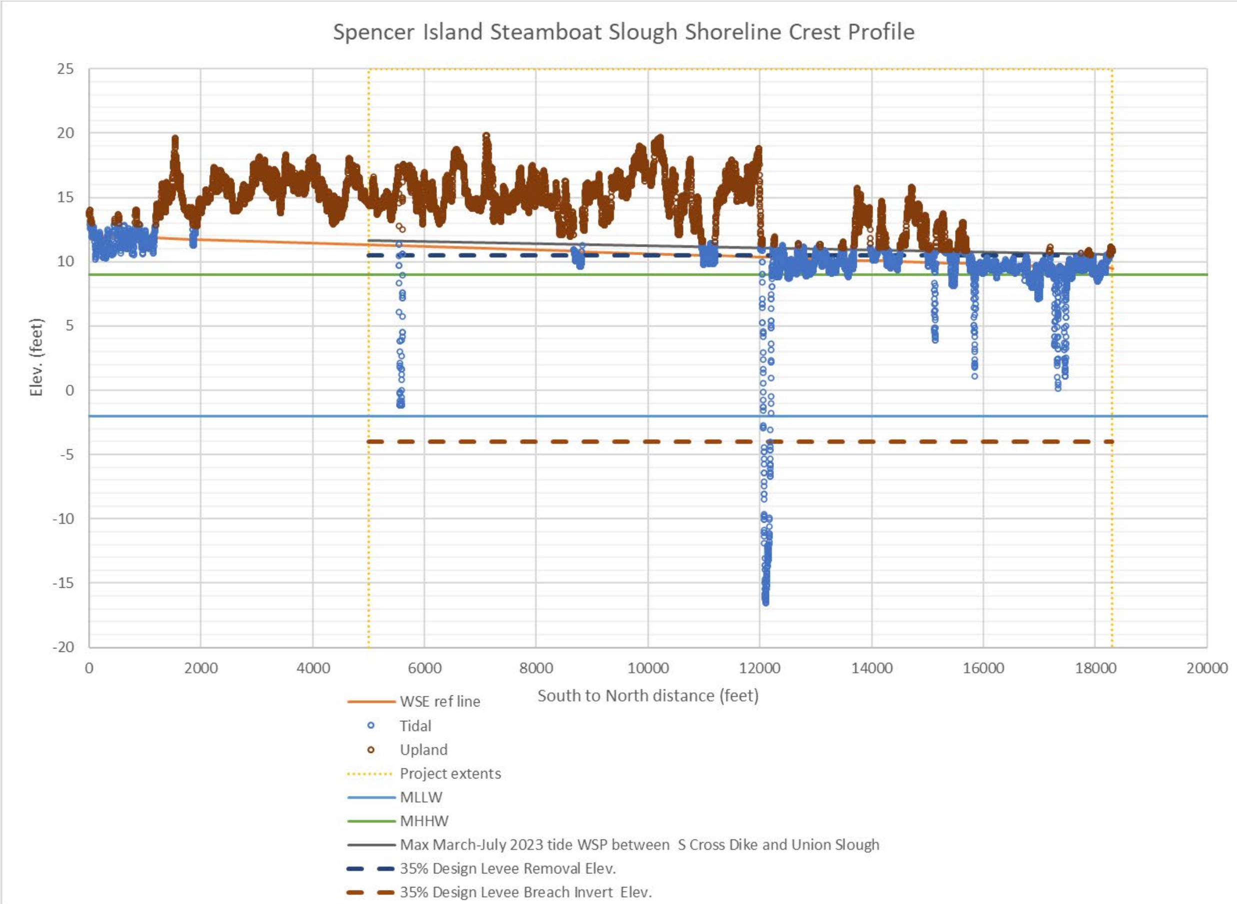


Figure 22. 35% dike removal crest profile along Steamboat Slough and dike invert breach profiles relative to existing ground and tidal datums, and water surface profile that aligns with natural marsh elevation.

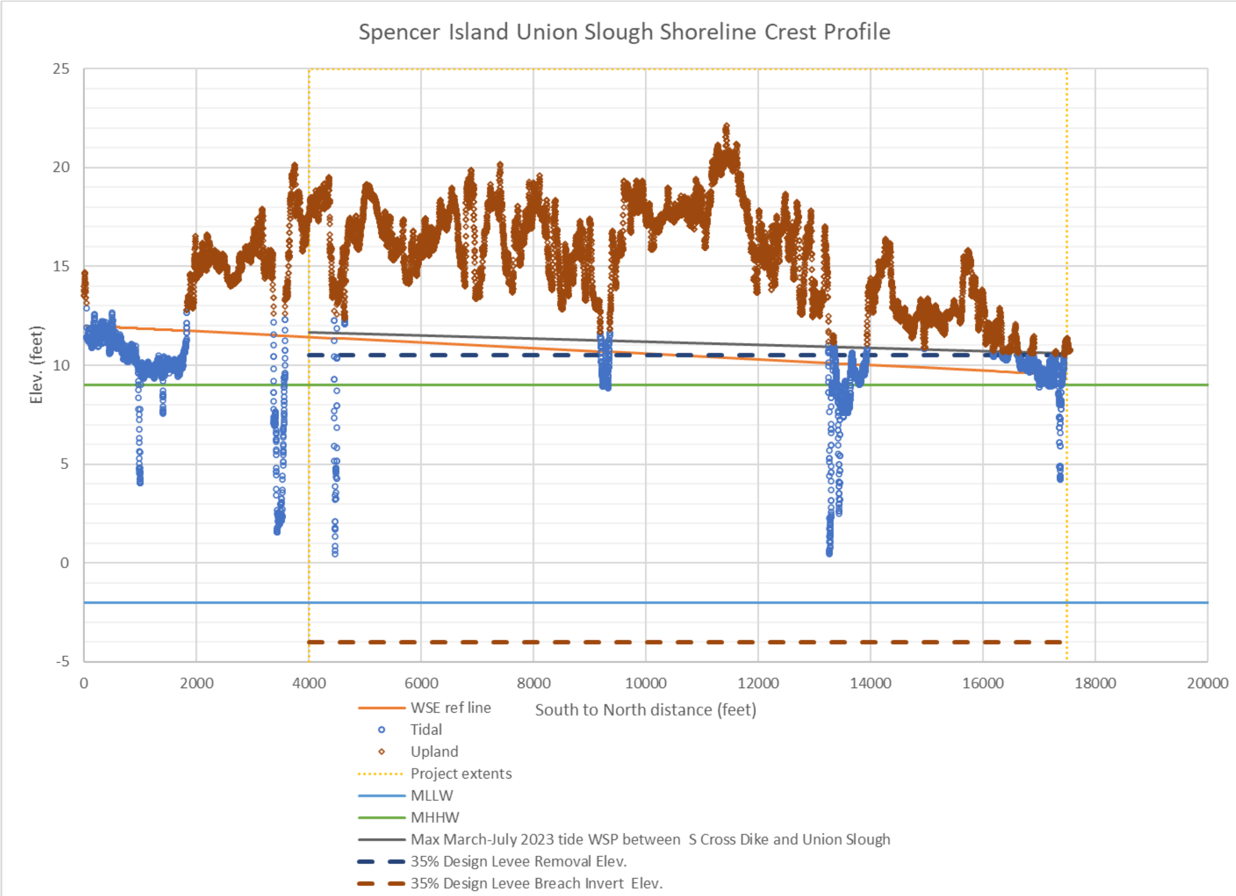


Figure 23. 35% dike removal crest profile along Union Slough and dike invert breach profiles relative to existing ground and tidal datums, and water surface profile that aligns with natural marsh elevation.

Note that the Union Slough dike will be improved up the point of the existing tide gate, which will be removed (near station 9300 in Figure 23). Up-station from this location the dike will be lowered to elevation 10.5 feet. Because Union Slough has higher invert elevations than Steamboat Slough, invert elevations may be adjusted upwards in PED phase.

A cross dike is present near the southern property line and the northern tip of the island (Figure 24). The south cross dike was installed in 1994 to help maintain ponded conditions for waterfowl habitat. Between 2004 and 2005 both the Steamboat Slough dike and the south cross dike breached, resulting in installation of a pedestrian bridge by the County at the south cross dike. The cross dike increases both flood elevations south of the dike and velocities in the vicinity of the existing bridge. The removing of some or all the cross dike reduces flood elevations and normalizes velocities, improving fish passage.

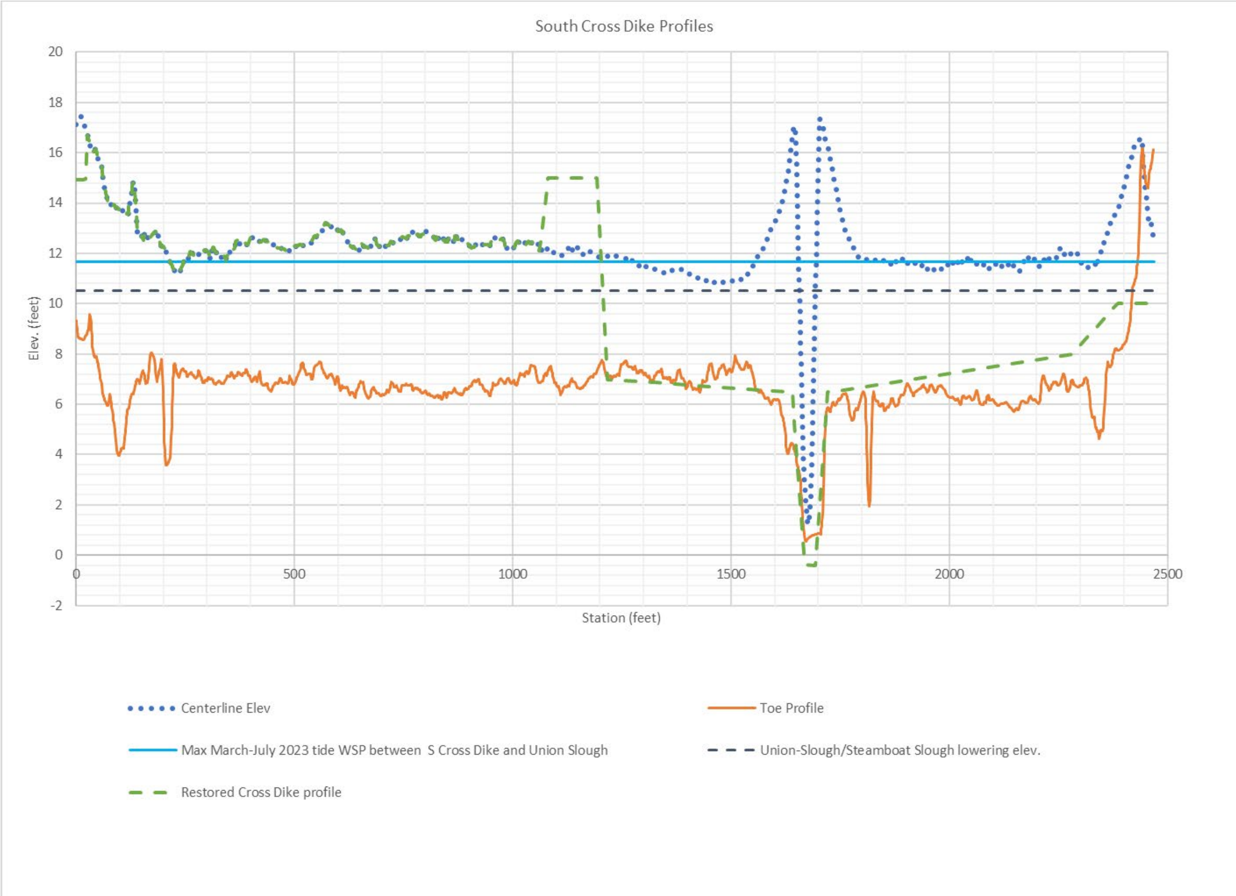


Figure 24. South cross dike profiles.

2.4.2 Ditch Fills

Existing ditches concentrate marsh drainage into deep linear channels and short circuit the natural marsh drainage network, resulting in excessively high velocities and erosive conditions that are hindering marsh habitat development and fish use. Filling ditches will reduce flow concentration in ditches (by forcing flow in dispersed natural and constructed channels) and is a primary method to reduce unnaturally high velocities that are inhibiting fish use in the site. Ditches will be filled up the elevation of adjacent marsh with soil excavated nearby to construct new tidal channels. Conserved onsite large wood will be embedded in the upstream and downstream ends of filled ditch segments to protect the fill from erosion. Because compaction will be somewhat difficult given in-the-wet construction methods, ditch fill elevations may include an overburden allowance for consolidation.

A total of 9,945 feet representing 48% of the 20,745 of the total interior ditch length are proposed for fill or restoration as part of a new channel. The top elevation for ditch fills (once consolidation has been completed) is about equal to 7 feet (adjacent marsh elevation).

2.4.3 New Tidal Channel - Distributary Channel Connections (Dike Breach Channels)

In the absence of dikes, Spencer Island would more closely resemble Otter island, and have several dozen small channels connecting the island to Union Slough and Steamboat Slough. Recent Snohomish River estuary scientific research conducted by Dr. Greg Hood (2015a) resulted in several regression equations that can be used to estimate the number of tidal channel outlet connections (outlets) for a given area of tidal marsh to be restored. For Spencer Island (139 ha), a total of 50 channel outlets of varying size and length would be expected (Table 18). At present the existing island has at least 31 outlets, however, only 12 of the 31 identified connected channels extend through the island shoreline crest into the interior of the island, the remainder are draining small catchments present between the existing dikes and the adjacent sloughs. The proposed (35%) design adds 13 new outlets, getting the island much closer to Hood's linear regression prediction for outlet number. The total length of channels on Spencer Island is less than the regression prediction, possibly due to presence of ditches that short circuit the marsh drainage network, loss of historical channels, and incomplete development of the marsh channel network post-dike breach. The total area (wetted, measured at mean tide) represents 24% of the island area - this is nearly 5 times greater than the regression prediction (5%) due to several feet of subsidence, which has resulted in substantial inundation at low tide. Restoration does not significantly alter this condition but provides substantially more opportunity for sediment and LWM to deposit within the island. Combined with side casting of spoils along constructed channels the site will more closely resemble reference conditions after construction.

After restoration, 13 new outlet channel connections will be distributed along the east shoreline of the island along Steamboat Slough, and existing outlet channels along Union Slough where dike lowering occurs will be widened and improved. Because more tidal and river flow are present in Steamboat Slough adding more outlet channels on that side of the island is more effective at restoring natural processes. This also helps redistribute the tidal flux presently entering the site through the large existing breach, reducing excessive velocities that hinder fish passage.

Table 18. Hood regression allometric predictors for Spencer Island

		Regression parameters			Outputs				
Metric	Reference Site	a	b	X (ha)	Y	upper 95% CL	lower 95% CL	Existing	Proposed (35%)
Outlet count	Snohomish	0.394	0.61	138.7	**50**	271	9	**31**	**44**
Total length (m)	Snohomish	1.931	1.24	138.7	**38647**	382306	3907	**27408**	**29560**
Total area (ha)	Snohomish	-2.398	1.52	138.7	**7**	99	0.5	**34**	**35**
Largest length (m)	Snohomish	1.657	1.07	138.7	**8891**	139506	567	**160**	**1909**
Largest area (ha)	Snohomish	-2.66	1.4	138.7	**2**	23	0.2	**0.6**	**8.5**
Largest outlet width (m)	Snohomish	-0.33	0.84	138.7	**29**	174	5.0	**44**	**44**

Hood (2015b) also analyzed the spacing of outlets along marsh islands in Puget Sound including the Snohomish estuary. Hood's data (see section 5, HHC Annex D3) appear to show a weak trend of decreasing distance with island size. Data for Spencer Island and Otter Island (reference site) were reviewed relative to the Snohomish data. Outlet spacing at Otter Island (87m) is well below that of Spencer (241 m) and falls on Hood's regression curve, while Spencer Island under existing and proposed conditions is still well above the regression prediction. After restoration the outlet spacing would drop significantly, to 170 m, closer to Hood's regression prediction for undisturbed sites.

2.4.4 Bridge & Culvert Removal

Spencer Island has two bridges that are proposed for removal, associated with the south cross-dike. The cross-dike prevents a significant amount of exchange of water between the north and south sides of the island that cannot be compensated with dike breaching alone. The cross-dike bridge has a riprap sill that is one of the largest hydraulic barriers for fish present on site. Removing this sill normalizes tidal flux at this location, significantly improving accessibility for fish to the portion of Spencer Island north of the cross-dike. The bridge located at the exit of a large ditch on the east side of the island, which was damaged and replaced during the 2006 flood, would be removed, because the cross-dike removal would eliminate the need for the bridge.

2.4.5 Interior Tidal Channels

New/restored interior tidal channels will be sized to match the eroded widths of the primary breach channels to accelerate the channel development occurring at the site. Marsh sediments are heavily consolidated due to subsidence, cohesive and hold near vertical slopes. Side slopes during construction will be angle of repose (1:1) but design slopes are flatter (4:1). Sinuosity observed within the existing marsh will be emulated where possible to reduce short circuiting, create a more natural appearance, and restore hydraulic conditions. Note that as-built reports by Otak (2019) for the Mid-Spencer project illustrate expected site conditions at Spencer Island. Channel cuts there had steep banks generally, with little to no caving observed.

2.4.6 Large Wood & Large Wood Structures

Large wood and logjams are persistent features of healthy Pacific Northwest rivers including the Snohomish. The temperate forests of the central Cascades produce very large trees, which can create abundant, large logjams that have distinct forms and functions within river valleys including flow deflection, pool formation, bar building, organic and inorganic material sequestration (Abbe and Montgomery 2003), promotion of stable forest patches, and anabranched channel types (Collins et al. 2012). Large wood and logjams are present in the Snohomish estuary slough channels, primarily in the form of submerged snags or drift jams deposited during large floods. Data by Hood (2022) indicates large wood jams are *infrequent* features of tidal marshes. As such, large wood placement at Spencer Island is not a focus of restoration. No anchored large wood structures are proposed, however trees and large wood that must be moved as part of construction will be placed in ditches to help armor the ditch plugs from erosion and to create aquatic habitat. Excess woody material will be randomly scattered on top of and around work areas (tide flats, marsh plain, and riparian). Shrubs, branches, and woody material not suitable for habitat construction will be mulched and spread along trails as part of landscaping work.

2.4.7 Coastal Design

Not applicable.

2.5 Geomorphology and Sedimentation

2.5.1 Overview

This section presents a summary of historical and existing geomorphic conditions and expected future with and without project conditions related to channel migration, erosion, deposition, and habitat types at Spencer Island. Refer to Annex D.3 for full analysis.

2.5.2 Current and historical conditions

US Coast and Geodetic Survey (USC&GS) maps (T-sheets) and interpretations of the pre-development wetland conditions are shown below in Figure 25 (Collins and Haas, 2001). Spencer Island, Union Slough, Steamboat Slough and the mainstem Snohomish River are generally in the same locations and orientations as the T sheet. The most dramatic changes evident when comparing the T-sheet map to modern conditions include the truncation of several large Smith Island channels including a former distributary that connected the “Old River” to Union Slough, (located near the Buse lumber mill, and present through the 1930s), the Buse cut, which connected Steamboat Slough to Union Slough, presumably to make transport of logs to the Buse Mill easier, and the connection of Ebey Slough with Steamboat Slough near the Buse Cut. The mapped distributary channel widths and orientations are very similar to present day conditions, except for the portion of Ebey Slough north of the connection with Steamboat Slough, which appears to have narrowed, likely in response to diversion of flow to Steamboat Slough.

A study mapped land cover types for marsh islands that include salt marsh/pine west of Steamboat Slough and salt marsh/mixed forest east of Steamboat Slough (Collins (2002)). A large tidal channel is mapped that spans the northern half of the island connecting to Union Slough at the northwest corner of the restoration site where an enlarged tidal channel is proposed. A small tidal channel is mapped at the location of an existing restored tidal channel on the Snohomish County parcel, restored in the 1990s. No other large tidal channels are indicated. Small channels are indicated at two locations at Ebey Island and one location at Otter Island.

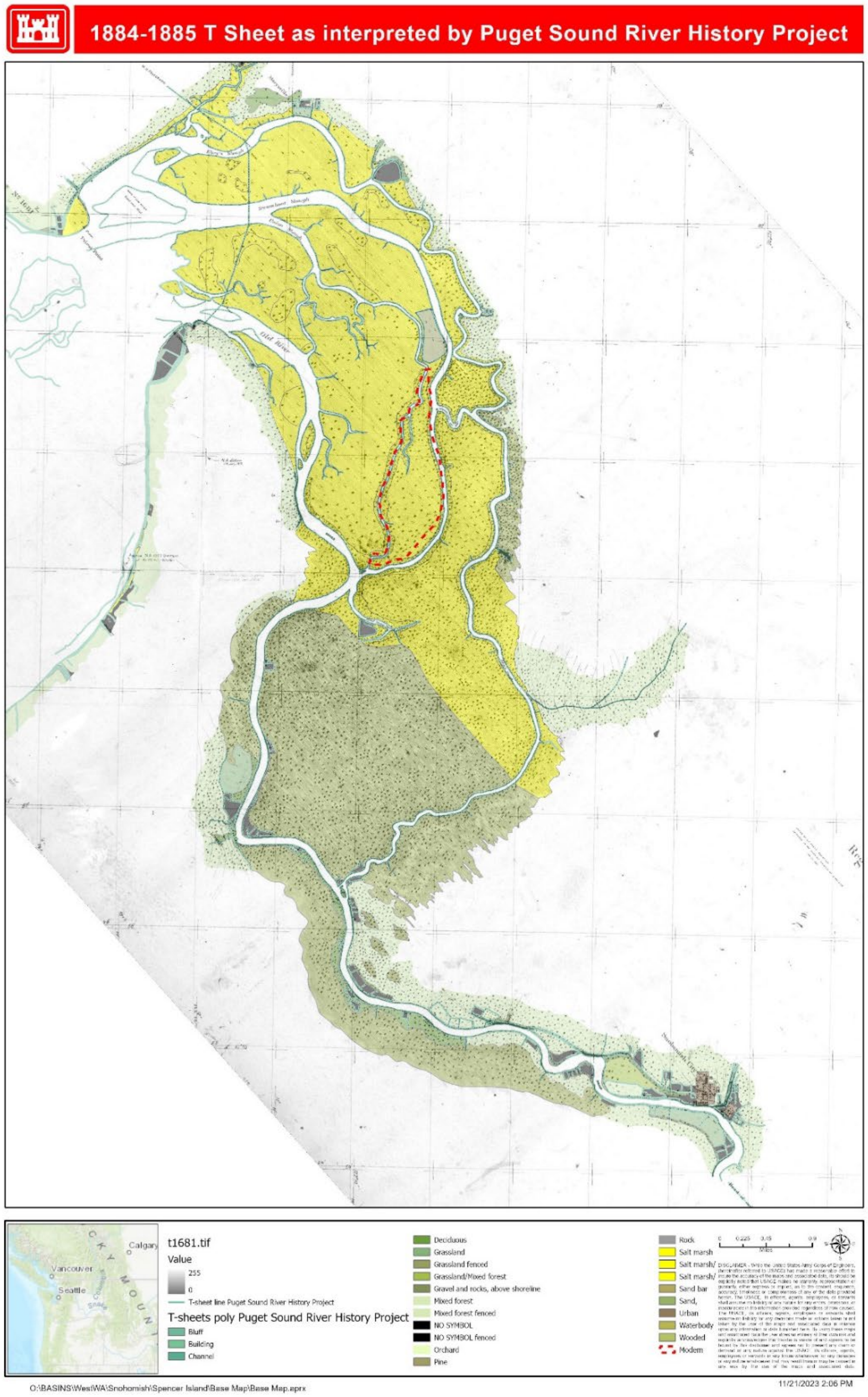


Figure 25. Puget Sound river history project interpretation of USC&GS T sheet in the vicinity of Spencer Island

It was estimated that prior to settlement, 3,950 hectares of tidal marsh existed in the estuary (excluding tide flats) (Haas and Collins (2002)). The cartographers interpreted landcover types from General Land Office survey bearing tree records and government maps and identified three primary tidally influenced habitat types in the vicinity of Spencer Island including estuarine emergent marsh, emergent/forested transition, and forested riverine/tidal zone. Using the 1996 maps from the Haas and Collins 2001 study, 600 hectares of remaining tidal marsh habitat were delineated, a loss of 3,350 ha (85%). With that, sixty-one blind tidal channel networks greater than 6-m wide at the mouth were lost. Only 25% of the blind tidal slough remained intact and connected to the distributary channel network. Distributary channel margins were heavily modified by development, but the channel network changed little, otherwise.

The T sheet map shows a higher density of tree symbols along the shoreline than along the interior of the marsh islands and at the upstream head of Spencer Island near the Snohomish mainstem. Currently areas with higher concentrations of trees correlate with areas that have ground elevations at or above high tide elevations. Mature conifers are present along the Union Slough for the full length of the island and from the existing large breach channel northwards along Steamboat Slough in the 1938 air photo (Figure 26). Scrub shrub conditions are present in the southern portion of the island along Steamboat slough suggesting trees there had been logged. Mature trees are also present along the margins of the relict tidal channel (and all other nearby marsh island major tidal channels).

As shown in Figure 26, by 1938 agricultural development (for grazing) had cleared large portions of the interior of the island. Dikes were constructed to their modern extents except for the cross dike at the south end of the island that was built in the mid-2000s. The large tidal channel in the T sheet is present but the width appears to decrease in the northern direction suggesting ditches were conveying drainage to the Sloughs and the old channel was cut off and in the process of filling in. A large ditch is visible in the 1938 photo at the south end of the site, near the location of the cross-dike bridge. This ditch is the present location of the channel connecting the south end of the island to Steamboat Slough. The air photo resolution is too poor to identify other ditch locations. The large ditches present on site today were constructed in response to subsidence of the interior caused by pumping of local drainage. Subsidence is common throughout many agricultural sites in the estuary.

2.5.3 Recent historical conditions

Review of overlays of existing Lidar data and 1938 air photos (Annex D3 - Figure 2) indicates that shoreline positions (and channel widths) of the lower Snohomish River distributary channel network are remarkably consistent around Spencer Island and adjacent distributary channels suggesting there has not been large enough changes in the tidal, streamflow or sediment transport characteristics to initiate dynamic behavior such as bar building, active erosion, avulsion, etc., which are processes present on upstream tributaries.

Dike construction reportedly began in the late 1800s and was largely complete by the 1930s. Dikes and revetments are present along both banks of Union and Steamboat Slough in the project footprint, as well as adjacent distributaries and the mainstem Snohomish. Historical air photo review indicates channel positions are remarkably consistent over time, in the tidally influenced portion of the river (from Snohomish to Puget Sound), where bars are largely absent, and banks are relatively high.

As shown in Figure 26, two observable changes to the distributary channel shoreline that have occurred since 1938 include the “Buse Cut” between Steamboat Slough and Union Slough (dividing Spencer Island in two) and northward migration of a small portion of Otter Island where Ebey Slough first connects with

Steamboat Slough, likely in response to the effects of the cut. Large scale changes to topography in the vicinity of the project include construction of Interstate 5 in the 1960s and construction of the City of Everett WWTP lagoon dikes. These projects filled tidal channels and disconnected flood and sheet flows across Smith Island.

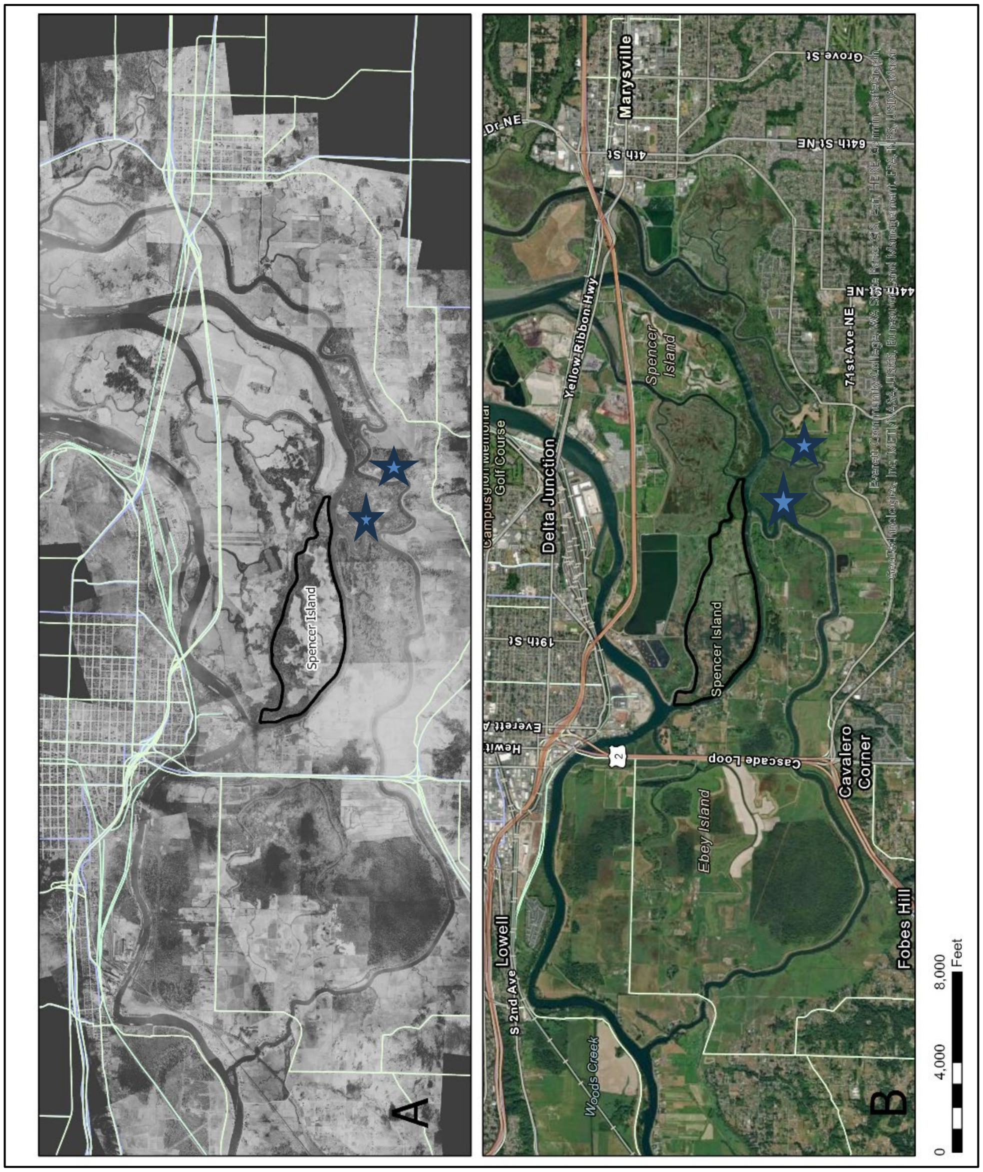


Figure 26. Snohomish estuary 1938 air photo (A) and current conditions (B)

Arguably the largest topographic and hydrologic changes that have occurred in the last 20 years are construction of restoration projects on former agricultural lands along Ebey Slough (Qwuloolt), Union Slough (Union Slough 1135, Spencer Island, Smith Island Phase 1 and 2) and Steamboat Slough (Mid-Spencer Island, Blue Heron Slough). These projects breached portions of existing dikes and constructed starter channels to reconnect marshes to distributary sloughs representing hundreds of acre-feet of new tidal prism and over a thousand acres of restored tidal marsh habitat.

Vertical land motion data suggest the mouth of the Snohomish River is stable vertically (constant base level). Sedimentation is present in the form of sand dunes and small bars, primarily along the mouths of sloughs (tide flats), within the channel of the mainstem Snohomish, Steamboat Slough, and Union Slough, and along the lower portion of Ebey Slough. Upstream of Otter Island Ebey Slough is generally deeper than the mainstem and Steamboat Slough.

Multibeam data show that thick deposits of sand are present on top of smooth erosion resistant bed materials in deep scour pools. Pool depths exceed 25 feet in many locations. Scour pools are most common at the downstream confluences of major distributaries, tight bends, at armored obstructions, and at the confluence with major tidal channels. Sediment budget data derived from repeat cross section surveys suggest net long-term deposition causing a slow rate of vertical aggradation on the mainstem, Union Slough, and Steamboat Slough in the vicinity of Spencer Island.

Natural dikes are widespread along the banks of the mainstem Snohomish, all sloughs, and most tidal channels. Scrub shrub and water tolerant trees are present along these elevated ridges, likely enhancing sedimentation. Scarps and slumps of emergent and herbaceous marsh vegetation are common along banks however the presence of vegetation rootmats appears to limit erosion. Ongoing dredging of the mouth of the river and the upstream navigation channel has an unknown effect on conditions near Spencer Island, but the effect is presumably small as the dredging is downstream of the split with Steamboat Slough.

Design of nearby Snohomish estuary marsh restoration projects has typically been focused on creation of a small number of large breaches through dikes. Breaches are often but not always at the locations of historical channels. Starter channels and ditch blocks are constructed in the interior of the site to aid in reestablishment of a dendritic tidal channel network.

Common changes observed after prior restoration projects include a daily tidal flux, die-off of upland vegetation and non-native wetland herbaceous plants, formation of tidal flats and establishment of tidal channel networks, reestablishment of wetland plant communities tolerant of tidal inundation and salinity, and deposition of large wood within channels and along shorelines. Erosion and deposition patterns in the restored areas indicate a flux of sediment and geomorphic equilibrium.

At some of the restoration sites (Qwuloolt, Smith Island) reconnection has resulted in rapid evolution of constructed channels in response to daily tidal flux. In the case of the Qwuloolt project the primary breach channel was undersized initially, but erosion and scour enlarged the channel to the point where equilibrium conditions were reached within a few years at the primary outlet. Some channels within the site were constructed at elevations higher than the equilibrium channel elevation and headcutting is occurring. The erosion is confined to the tidal channels. Headcutting is also observed at some of the tidal channels at Smith Island. This erosion is difficult to predict but is a desirable outcome as it helps redistribute sediment within the site and promotes reestablishment of a dendritic channel network.

The accidental dike breach at Spencer Island in 2005 has initiated the same change in vegetation conditions. The presence of narrow, deep ditches throughout the site however has hindered reestablishment of the dendritic channel network, as the ditches cut across natural drainage divides, and the straight deep channels short circuit relicts of natural channels. The remnant dikes along Steamboat and Union Slough limit tidal exchange with Steamboat Slough to one very large channel and to Union Slough with one medium sized channel. This condition concentrates flow in the ditches connected to these channels as there are no other pathways to disperse tidal flow. At very low outgoing tides it is possible that velocities in portions of these ditches present barriers for fish that might otherwise want to enter the marsh. Presumably natural erosion and sedimentation will adjust these ditches to an equilibrium condition that resolves this issue, however the lack of perceptible changes to these ditches since the dike breach occurred suggests this process is likely to span several decades, if not longer.

2.5.4 Future With and Without Project Conditions and Changes

Recent trends detected by others related to altered estuarine hydrodynamics and salinities (Hall 2024, Nugraha and Khangaonkar 2024) are likely to continue. This project is expected to permanently reestablish dynamic tidal channels in these locations and associated natural processes. Slow changes to the width, depth, cross sectional shape, and planform of all constructed channels is a desired and expected outcome that will indicate the system is moving toward a natural geomorphic equilibrium. Some channels will enlarge, and some will silt in or close off entirely. New channels forming around the constructed channel will help form a dendritic channel network and microtopography formation near the breaches. Dike breaching and spoils placement areas that have appropriate elevation (9.5 feet or higher) will revegetate and convert what is largely cattail marsh to riparian forested wetlands.

Hydrodynamic patterns during daily tide cycles as well as major floods will be modified. Flood flows will cross the island from Steamboat Slough to Union Slough relatively unhindered, which should increase the amount of water, sediment and large wood flowing across the island. Large wood accumulates on the island now due to the presence of dikes along Union Slough that trap wood within Spencer Island. Removal of dikes will allow free passage of wood into and out of Spencer Island during floods. It is uncertain if the volume of woody material retained on the island will increase or decrease as a result of levee lowering. Dike lowering will allow more sediment to flow into the island during floods. As sediment deposits around hummocks, standing trees and large wood, the elevation of the marsh plain will increase, promoting dynamic conditions within the marsh tidal channel network,. Portions of connected sloughs will likely deepen in some areas where tidal flux into/out of the island is enhanced, and shoal in others. The density and length and complexity of marsh channels will increase due to the construction of new outlets and filling of ditches that presently cause short circuiting.

Given that Spencer Island is already connected to Steamboat and Union Slough by multiple large breaches, and the project seeks to remove perimeter dikes and construct new outlet channels, increasing connection with the nearby sloughs, nearly all the future changes expected under existing conditions should be expected to materialize in the future with project conditions. The wetlands present on site would still convert to salt marsh due to sea level change in the 50-year planning period (Figure 27 through Figure 29), however, it is reasonable to assume that the island wetland vegetative community would remain in its present state for a longer period of time, due to the greater connectivity provided by the dike removal and breaches, which would promote dispersion and deposition of sediment and large wood that is presently bypassing the island interior along the sloughs. Thus, the resiliency of the low-salinity (oligohaline) tidal marsh (i.e. longevity) could be enhanced as a result of the project.

Given that current salinities are low (oligohaline), and that the tidal prism of the site is not going to be affected significantly by restoration, increasing the number of side channels connecting distributaries should provide more opportunities for fish to access what should be high quality habitat (in terms of wetted usable area, water temperatures, and salinities). While sea level change could increase salinities, any increase would occur slowing over several decades, so reconnecting with this large oligohaline wetland remains beneficial.

The conversion of expansive vegetated wetland areas to unvegetated tideflats upon an increase in sea level could reduce forage opportunities for salmonids, so projects such as Spencer Island that preserve or enhance the longevity of wetlands accessible to salmonids should remain beneficial for decades.

The remarkable lateral stability of existing distributary and primary (highest order) tidal channels despite historical levee construction and over two decades of large-scale tidal marsh restoration throughout the Snohomish estuary (increased tidal prism) strongly implies that there will not be large scale changes to the estuarine distributary channel network that result from construction activities on Spencer Island. The potential increase in tidal prism at Spencer Island has already been realized by the existing dike breaches. Since the existing remnant dikes and ditches will continue to hinder tidal hydrology and river flooding, removal of these dikes and ditches will primarily affect conditions on Spencer Island. Anticipated geomorphic changes would likely include formation of low-order tidal channels; widening, shoaling, and abandonment of existing tidal channels; natural levee formation along the margins of distributary and high-order tidal channels; sedimentation within the tideflats and marshplain; and vegetation establishment and succession. During floods, dike lowering will allow unhindered sheet flow across the island. This will more easily convey sediment and large wood into Spencer Island and to adjacent tidal marshes.

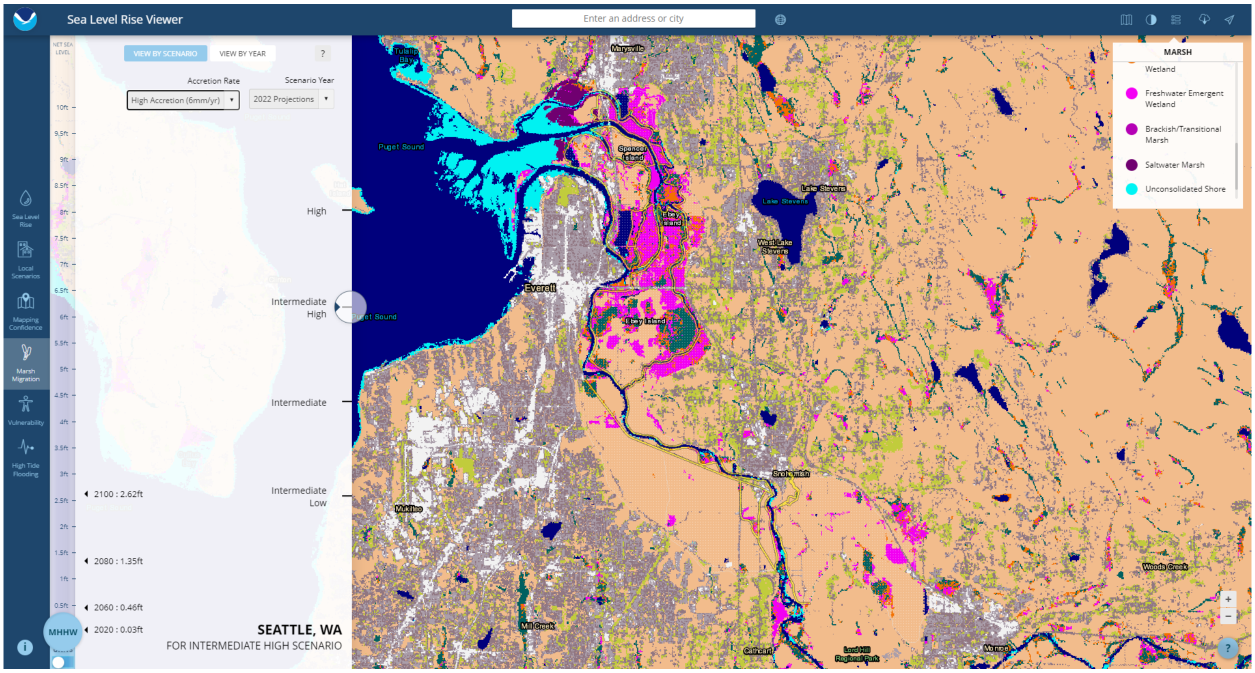


Figure 27. Marsh wetlands, existing conditions baseline, Spencer Island mapped as freshwater emergent marsh

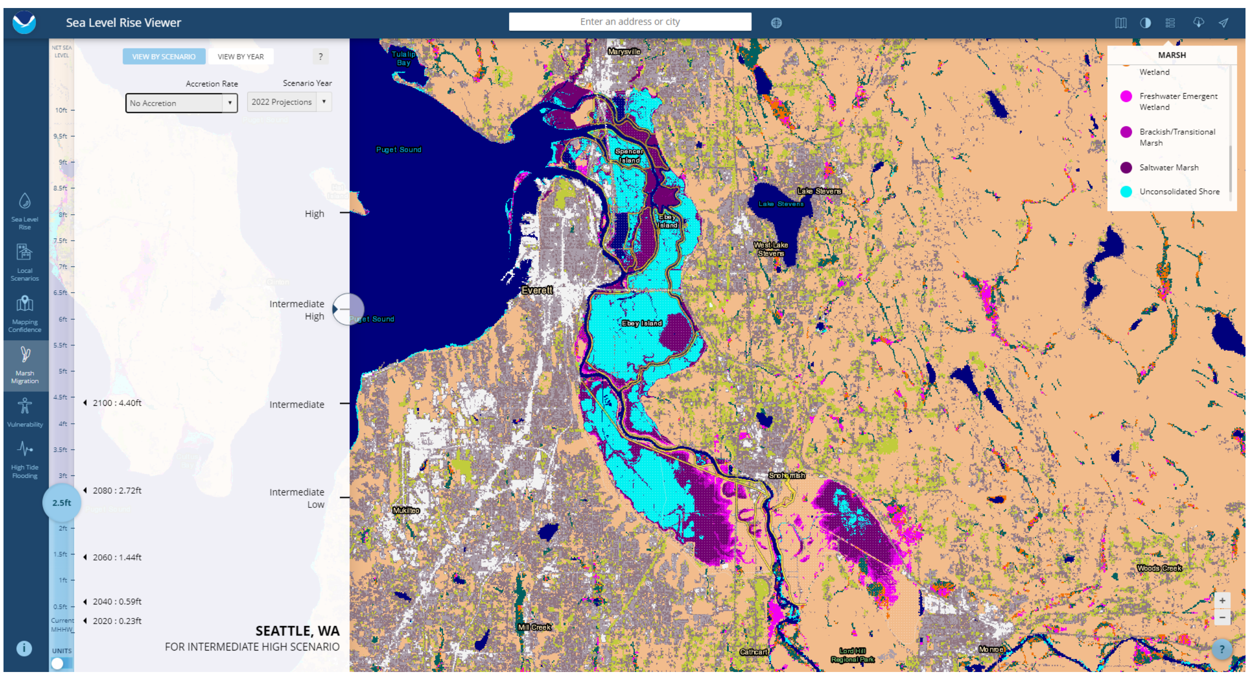


Figure 28. 2080 Int-high emissions scenario + no accretion. Island converts to salt marsh with some tide flats.

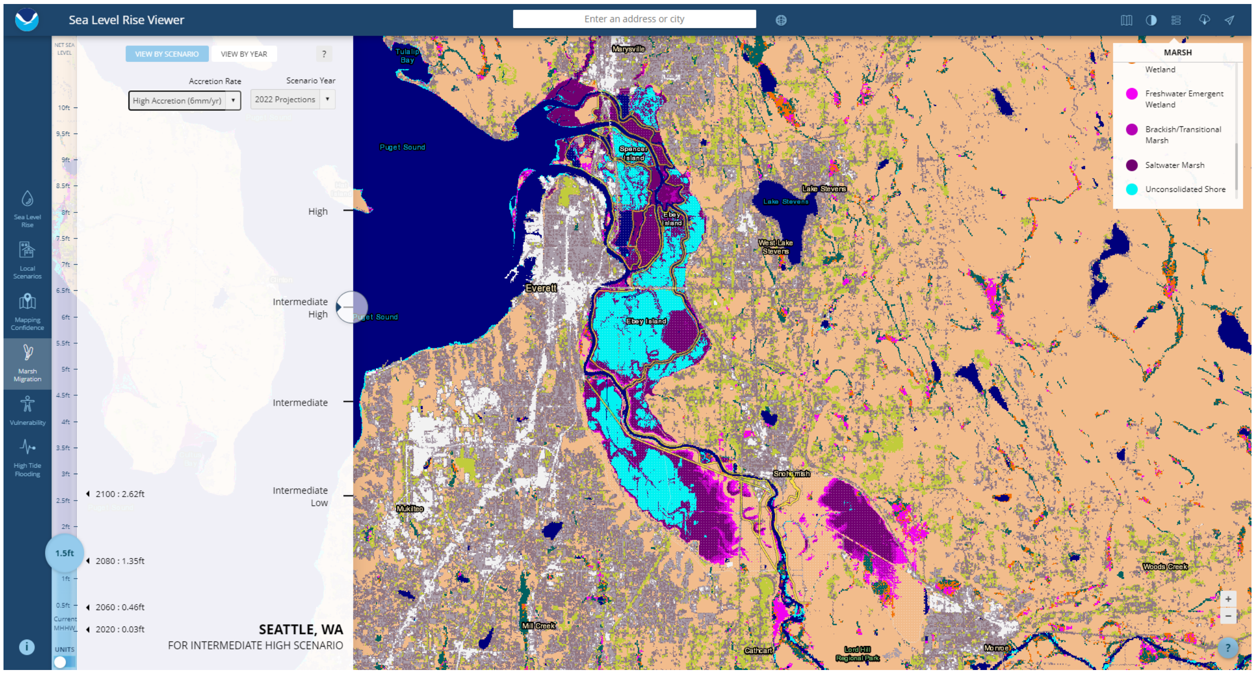


Figure 29. 2080 Int-high emissions scenario + high rate of accretion. Island converts to salt marsh.

3. Civil Design

This section discusses the key elements of the civil design and determines the gross volumes associated with each feature. The discussion includes the major components, construction, access, and staging considerations.

3.1 Topography

Topography was obtained by LiDAR (DNR, 2019) and supplemented with multibeam bathymetric surveys performed by Tulalip Tribes contractors (SHI 2020) as well as ad-hoc Spencer Island ground and bathymetric surveys performed by WDFW and USACE crews.

Vegetation present during the 2019 LiDAR flight obscures the dike ground elevation, resulting in a Digital Elevation Model (DEM) that is artificially high. During PED phase a full topo survey of the dike removal areas will be conducted, and any other work areas that where the accuracy of survey could impact construction cost estimates. As seen at adjacent restoration projects, the primary effect of this error is to reduce the amount of spoils generated in construction, reducing availability of materials available for fills. Additional survey should allow for cost reductions in PED associated with dike removal and channel construction, however fill areas and mounds may be less extensive as a result.

3.2 Staging and Access

Refer to the Civil Annex for staging and access details.

Access to the site will be primarily via I-5, Highway 529, existing surface streets (28th Pl NE, 35th Ave NE, Ross Ave, Smith Island Rd, 4th St SE), the Jackknife bridge across Union Slough, and remnant earthen dikes and trails on Spencer Island. Because there are no large wide open lay down areas on Spencer Island, staging on the island will likely be opportunistic and occur in any flat area within the work footprint that is above the high tide elevation and allows for two-way access. The City of Everett and Snohomish County have open space nearby that could accommodate a larger laydown area, however these would be for the convenience of the contractor and are not required to complete this project. Because this project does not need large quantities of imported material to complete, and all excavated materials will remain on site, equipment will primarily be excavators that will be staged and serviced near work areas. No large lay down areas for material storage or processing are needed.

With some clearing and isolated regrading excavator and dump truck access can be provided along the southern remnant of the Union Slough Dike, South Cross Dike, and southern remnant of the Steamboat Slough Dike.

A bridge owned by Snohomish County is present on the South Cross Dike that must be crossed to access the Steamboat Slough Dike work area. This bridge is supported by steel pilings and will be demolished as part of the South Cross Dike lowering work. If the deck is not wide enough for heavy equipment access the contractor will likely remove the railings and place a railcar or other temporary bridge on top of the existing deck.

In areas subject to tidal inundation, heavy equipment will have to work with tides, rely upon mats to reduce ground pressure, construct temporary roads above the tides, or use movable floating platforms to access work areas. To access the north end of the site and the remnant dike north of the existing Steamboat Slough breach channel, contractors will have to either use small tugs with barges and spuds, landing craft, or install small pontoon bridges from the Union Slough Dike, or rely upon amphibious equipment. Small temporary movable bridges will be needed to span small tidal channels and ditches when working along the northern portion of the Steamboat Slough remnant dike and within the spoil's placement areas.

Because excavated materials will be side cast the need for dump trucks is limited. Use of long reach excavators can minimize need for ferrying excavated materials, however some spoil areas will be far enough from work areas that the contractor will likely need low ground pressure tracked dump trucks to ferry material. Within the center of the site, contractors will need to rely on floating platforms or amphibious equipment as there is no way to isolate these work areas from tides.

3.3 Stormwater Best Management Practices

Construction stormwater features are contractor designed. In addition to those stormwater controls expected in the stormwater management plan the following should be included.

- Fish Exclusion
- Turbidity Monitoring
- Washouts
- Outlet Controls

3.4 General Construction Methodology

Specific timing restrictions will be required for in-water work (1 June to 31 October) to protect fish and wildlife, and other measures may be required under site-specific permit requirements to protect downstream infrastructure. Construction would be in the drier summer months to facilitate access and construction and to comply with regulated in-water work windows to protect sensitive fish species. Cultural resources monitoring will occur on this project (See 1.8.2 Cultural Resources). Any excavated materials would be re-used on-site as much as possible. The erosion and water quality control plan and best management practices will include the following (See Figure 18):

- Existing roadways or travel paths will be used whenever possible and stream crossings minimized.
- The number of temporary access roads will be minimized, and roads will be designed to avoid adverse effects like creating excessive erosion and avoiding crossing slopes greater than 30%.
- All temporary access roads and staging areas (currently unimproved) will be covered with geotechnical fabric and rock during construction.
- All temporary access routes will be removed (including gravel surfaces) and planted after project completion.
- As much as practicable, any large wood, native vegetation, weed-free topsoil, and native channel material displaced by construction will be stockpiled for use during site restoration.
- When construction is finished, the construction area will be cleaned up and rehabilitated (replanted and reseeded) as necessary.

- A Work Area Isolation Plan will direct work for all water crossing requiring flow diversion or isolation.
- Within seven calendar days of project completion, any disturbed bank and riparian areas shall be protected using native vegetation or other erosion control measures as appropriate.

Construction sequencing will be left to the construction general contractor; however, the proposed sequencing below is anticipated based on ease of access with work performed from the existing causeway or with it in place to be used as access and/or protection of the site.

i. Dikes
   a. The dikes will be lowered to a typical elevation of 10.5ft or to the natural ground elevation, whichever is higher and have a 2% cross-slope towards the river to allow for stormwater runoff. During construction the contractor might decide to partially remove the dikes to maximize access throughout the site and leave final grading to only when necessary. As the dike is being demolished the material will be side casted on the landward side of the dike to create a bench of 10ft to 50ft width and varying slope. The toe of the side cast will maintain a min 3ft offset from the nearest shoulder of the existing interior channel. This will create a varying slope.
   b. Contractors will have to either use small tugs with barges and spuds, landing craft, or install small pontoon bridges from the Union Slough Dike, or rely upon amphibious equipment to access the northern end of Steamboat Slough (STA 43+43 to STA 65+53) and North Cross Dike. The northern portion of Steamboat Slough shall be demolished beginning at 43+43 and working northbound to STA 65+53. From this point, the North Cross Dike shall be demolished beginning at STA 4+39 and working westbound to STA 0+00. The Southern portion of Steamboat Slough shall be demolished beginning at STA 41+70 working southbound to STA 0+00. Along Steamboat Slough, from STA 41+70 to STA 43+43 there is an existing breach, and from STA 29+00 to 31+20 there is a No Work Area/Environmental Resources Avoidance Zone.
   c. South Cross Dike shall be demolished in two sections. The first section will begin from STA 24+04 and working westward to STA 16+43. The elevation shall vary from 6.5ft to 10ft with proposed grades ranging from 0.00% to 1.86%. The second section will begin from STA 15+85 and working westward to STA 10+83. The elevation shall vary from 6.5ft to 12ft with proposed grades ranging from 0.12% to 16.42%. Between these two degrades is a proposed breach.
   d. Union Slough shall be demolished working southbound from STA 58+65 to STA 20+82. At STA 20+30 is a proposed breach and a proposed Tide Gate.

ii. Smith Island Channel Improvement
   a. The Smith Island channel improvement will be graded at the beginning and the end of the improvement a 5H:1V slope form grade to Elevation 7ft. The improvement will have a 0% cross slope.

iii. Union Slough Trail Regrade/Temporary Construction Access
   a. The current condition of the Union Slough walking trail is in poor condition. Widening the trail will improve both construction access and pedestrian access to the island. The walking trail along Union Slough shall be cleared of vegetation. The Union Slough Trail shall be regraded in two directions. First, beginning at the Jackknife Bridge STA 7+69 working northbound to STA 19+65 with an elevation change of 14.05ft to 15ft. Second,

beginning at the Jackknife Bridge STA 7+69 working southbound to STA 0+00 with an elevation change of 14.05ft to 15ft. The trail shall be widened to 20ft and be covered with 6in of gravel. The side slopes of the trial will be sloped at 1.5H:1V. Excess material cut from the widening and the Union Slough Dike lowering will be used to create a 20ft bench landward of this trail repair. The bench will have a 2% cross-slope towards the interior of the site to allow for stormwater runoff. The toe of the bench will maintain a min 3ft offset from the nearest shoulder of the existing interior channel. This will create a variable slope.

iv. Breaches

a. 22 breaches will be cut through the exterior dikes and dikes. As the dikes are being lowered, the dikes will be breached. The breaches will be excavated beginning from the slough side into the upland. This work will be conducted with the use of a long arm excavator from a barge. Table 19 describes the typical breach sections.

Table 19. Summary of Dike Breach Sections

Breach	Number	Typical Bottom Width (FT)	Typical Side Slope	Typical Beginning Elevation (FT)	Typical Ending Elevation (FT)
Union Slough	5	5	2H:1V	-4	-2
North Cross Dike	1	20	4H:1V	0	2
Steamboat Slough	14	2	5H:1V	3	3
South Cross Dike	2	15	4H:1V	0	-4

v. Viewing platforms

a. 2 viewing platforms will be constructed. One located on Union Slough from STA 18+40 to STA 19+65 and is roughly 0.4 acres, and the second located along the South Cross Dike at STA 9+80 to STA 11+20 and is roughly 0.3 acres. These viewing platforms will be created with the use of the excess cut from the dike lowering of Union Slough and South Cross Dike respectively. The Union Slough viewing platform will be contracted to a top elevation of 15ft and have a 6in thick gravel surface. The South Cross Dike viewing platform will be constructed to a top elevation of 12ft and have a 6in thick gravel surface.

vi. Channels

a. 18 Channels will be constructed in the interior of the site. Table 20 describes the typical channel sections. The channels are intended to restore the form and function of the tidal marsh land. The channels will be constructed beginning from the upstream working to the downstream end.

Table 20. Summary of Channel Sections

Typical Bottom Channel Width (ft)	Typical Side Slopes	Typical Beginning Elevation (ft)	Typical Ending Elevation (ft)

5	4H:1V	3	3
10	2H:1V	2.5	2
20	5H:1V	-3	-8

vii. Ditch Fills

a. Ditches located internal to the site are to be filled to the elevation of the existing adjacent vegetated marsh. To protect the filled areas from erosion, woody materials will be placed at both ends of the dich fills to serve as erosion protection for the earthen fill. This will also increase the instream woody habitat. The proposed work will be challenging due to the tidal conditions. To minimize delays, costs, and environmental impact, specialized equipment and contractors experienced in working in wetland conditions are required. Careful planning and scheduling around tides is crucial.

viii. Marsh Bench/Spoil Pile

a. Excess soil from the dike and channel excavation/grading will be repurposed into constructing tidal marsh benches. A total of 140,900 cy of soil will be used to create these benches, with a height of 10.5 feet, and will cover a total area of 27.8 acres. These benches shall be constructed near their respective excavation work to minimize the travel of the contractor’s heavy equipment. Care will be taken to not mix respective types of excavated spoil material.

4. Geotechnical Engineering

This section provides background information on the geotechnical design and construction of the proposed environmental restoration features for the Spencer Island Ecosystem Restoration project. The geotechnical design features include improvements at Union Slough, North Dike, South Dike, and Steamboat Slough, with dike lowering, trail upgrades, and the removal of outdated structures. Additional reports that assisted in providing the project site background and assumptions are provided in Annex B – Geotechnical Appendix

4.1 Geologic Setting

The geology of Spencer Island is characterized by its location in the Snohomish River estuary, where riverine and tidal forces shape its landscape. The island is primarily composed of alluvial deposits—sediments like silt, sand, and clay—brought by the river, forming a marshy and wetland-rich environment. Glacial till from past glaciations lies beneath these surface deposits, a common feature in the Puget Sound region. Tidal activity and freshwater flows contribute to the dynamic estuarine system, while ongoing processes like erosion and subsidence continuously influence the island’s structure. This geologic setting creates a unique blend of wetland and estuarine ecosystems.

4.1.1 Local Geology

The geology of Spencer Island and the wider Snohomish Quadrangle is characterized by distinct layers formed through glacial, fluvial, and estuarine processes. According to Minard, J.P. (1985) in the Geologic

Maps of the Marysville and Everett Quadrangles, Snohomish County, Washington, the primary geological layers in this area include:

Alluvial Deposits (Holocene): These are surface layers composed of sediments like silt, sand, and clay deposited by the Snohomish River. These materials are the result of riverine flooding and tidal actions within the estuarine environment.

Estuarine Deposits (Holocene): Mixed with alluvial materials, estuarine deposits include organic-rich sediments formed in the tidal flats and wetlands of the island. They reflect the interaction between fresh and saltwater influences.

Glacial Outwash (Pleistocene): These sands and gravels were deposited by meltwater streams during the retreat of the Vashon Glacier. They are stratified and form the higher ground areas in the region.

Glacial Till (Pleistocene): Dense, unsorted materials deposited directly by glaciers, composed of clay, sand, gravel, and larger rocks. This layer typically lies beneath the outwash and is a defining feature of Puget Sound lowlands.

Lacustrine Deposits (Pleistocene): Fine-grained sediments (silts and clays) deposited in glacial lakes that formed as the glaciers retreated. These can be found in some low-lying areas, contributing to the wetland formation.

Figure 30. Composite Geologic Map of Site and Adjacent Area

4.2 Subsurface Investigations

Based on the geologic mapping of the region and the previous site investigations highlighted below, the surficial 10 feet is anticipated to be comprised of soft organic silt to clayey silt, with interbed sand lenses becoming more predominant at greater depths. Medium dense sands and silts were generally encountered in the region from 20 to 40 feet in depth and layering of dense sands and soft to stiff clay and silt extending to a depth of approximately 80 to 90 feet (maximum boring depths documented).

4.2.1 Nearby Investigations

Less than ¼ mile from the project site at Smith Island, Shannon & Wilson conducted a subsurface investigation and developed recommendations for the design and construction of a setback levee. This is summarized and presented in the *Geotechnical Engineering Report, Smith Island, Snohomish County* (see Annex B). The report includes historical data and explorations as well as those to support design of the setback levee. Conditions presented within the report assisted in the development of assumptions and planning for the feasibility level at Spencer Island.

4.2.2 Preliminary Site Investigation

On July 13, 2023, USACE conducted a preliminary site investigation for the Spencer Island Ecosystem Restoration project to assess the immediate underlying subsurface conditions. Three locations were assessed advancing a 3-inch sampling barrel via hand auger to depths ranging from 5 to 7 feet. Disturbed samples were collected while advancing to the final depth of the augured holes. In addition to the samples collected, dynamic cone penetrometer (DCP) tests were performed to assess the relative in situ density of the materials encountered. See Annex B "Preliminary Site Investigation Memo" exploration logs for description and photographs of the materials encountered. The hand augers were performed at the slope toes of the access dikes along Union and Steamboat Slough.

Subsurface soils encountered can be summarized as 6 to 12 inches of sod/grass and turf underlain by 2 to 4 feet of fill (predominantly hog fuel/mulch) before encountering the native estuarine silt. DCP tests conducted recorded blows of between 2 to 4 blows per 1.75-inch increment indicating that the in situ density of shall soils are very soft to soft.

4.3 Disposal Sites

All excavated materials will be reused as marsh benches or along existing dikes. No off-site disposal sites have been identified at this stage.

4.4 Groundwater

No groundwater studies have been performed or wells installed in support of the project. Given the project site is bound by the Union Slough and Steamboat Slough, which are fed by the Snohomish River, groundwater elevations are anticipated to closely match the river stage elevations, which are also tidally influenced. As the river stage changes, groundwater conditions within the project site will not respond immediately and may reflect a typical average or mean depth reflective of the local hydraulic conditions. See *Section 2 Hydrology, Hydraulics & Coastal Engineering* for additional discussion of the site hydraulic conditions. A groundwater study was conducted nearby the project site (see the *Geotechnical Engineering Report, Smith Island, Snohomish County* included in Annex B) and may provide additional insight on impacts to groundwater elevations from riverine and tidal influences. No further analysis or consideration on groundwater variance was included as part of the feasibility study.

4.5 Large Woody Material

Not applicable. No anchored wood placements are proposed that require geotechnical properties or engineering to stabilize.

4.6 Earthquake Studies

No earthquake studies were available in support of the project, however, a review was conducted of nearby faults and data available from recorded seismic events.

Spencer Island, located in Snohomish County, Washington, lies within a complex geological setting characterized by multiple fault lines. The Snohomish River delta, where Spencer Island is located, is particularly susceptible to liquefaction during seismic events, which could exacerbate damage to structures.

4.6.1 Geologic Faults

Southern Whidbey Island Fault (SWIF): This is the most significant fault near Spencer Island, characterized as a right-lateral strike-slip fault. This fault cuts diagonally through Puget Sound and is known to have produced a significant earthquake approximately 2,700 years ago. Located approximately 10 to 15 miles west of Spencer Island, this fault zone runs northwest from Whidbey Island toward the mainland. It is characterized by its potential for generating large earthquakes, with paleoseismic studies indicating that it has produced at least four significant seismic events in the past 3,000 years, including a major quake estimated to be between magnitudes 6.5 and 7.0.

Spencer Canyon Fault: This fault is situated even closer to Spencer Island, approximately 3 to 5 miles to the northeast. This fault is part of a complex fault system in the region. It has been studied in relation to the broader tectonic framework of the Pacific Northwest, which is influenced by both the SWIF and the Cascadia Subduction Zone

Cascadia Subduction Zone: Approximately 50 to 60 miles offshore from Spencer Island, this subduction zone is a crucial geological feature that influences the seismic activity across the Pacific Northwest. It marks the boundary where the Juan de Fuca Plate is being subducted beneath the North American Plate, generating significant tectonic stress. The potential for large megathrust earthquakes, estimated to occur every 300 to 600 years, poses a significant threat to the entire Pacific Northwest.

4.6.2 Seismic History and Seismic Conditions

A review was conducted of available from recorded seismic events available publicly through the Pacific Northwest Seismic Network which can be accessed at the website https://pnsn.org/

Based on a review of this information from the past 50 years, three seismic events have occurred within the project site boundaries; two of which (near the southwest project boundary) are likely associated with the same earthquake given that the time of occurrence was within 15 minutes of each other and a distance of 500 feet. See the tables below for a summary of the data reviewed for the seismic history near the project.

Table 21. Seismic Review

Region	1 mile	5 miles	25 miles
Events	5	76	6675
Average Depth	11.2 miles	1.4	9.8
Average Magnitude	1.3	1.0	1.3
Most Recent	2024/08/09 21:42:55	2/26/2021 – 07:44	3/30/2021 – 18:06

4.7 Seismic Site Class

A site-specific assessment to determine the seismic site class was not conducted in support of this project, however, the *Site Class Map of Snohomish County, Washington* by Stephen P. Palmer, et al that was published September 2004, maps the project site as Site Class D to E. In Shannon & Wilson's report for Smith Island, the Seismic Site Class was determined to be Site Class E in accordance with AASHTO LRFD Bridge Design.

4.8 Design Phase Recommendations

The Tentatively Selected Plan does not currently include any proposed structures and is instead focused on the degrading existing dikes, excavation of breach and tidal channels, ditch filling, marshland plantings, and non-structural recreational sites (viewing areas, benches, hand carried boat launch). Based on the current scope, additional geotechnical investigations or analysis are not anticipated as being necessary during the design phase. Listed below are some considerations for what may warrant additional investigations or analysis

- Additional soil classification for reuse of materials onsite.
- Settlement of trails or embankments from site improvement
- Development of foundation designs and recommendations. Any added permanent structures would likely require deep foundations.
- Development of seismic design parameters if permanent structures are added to the project.

4.9 Geotechnical Construction Considerations

The greatest geotechnical challenges that will be present for construction will be access to build and construct or excavate for the site development and features. Located in a marshland, the surficial soils are highly organic and compressible, specialized construction equipment with low bearing pressures may be required. Construction access routed will utilize the existing embankments which are predominantly constructed with hog fuel/mulch. These embankments may require some improvements and widening to accommodate the construction traffic.

5. Structural Design

5.1 Bridges

The existing Jackknife bridge located at the east end of 4th Street SE and owned by Snohomish County is a historic steel truss girder bridge with timber decking built in 1914 (Figure 31). It originally spanned Ebey Slough before it was removed and stored in an Everett boat yard before being repurposed in 1993 in its current location. According to grant records, “The bridge is primarily for pedestrian use but is engineered for legal loads to allow for emergency and maintenance vehicles (Snohomish County, 1994).” The plans for the Ducks Unlimited restoration project in 2008 list the bridge capacity as follows, “SOLO TRUCK: 20 TONS; TRUCK W/SEMI-TRAILER: 31 TONS; TRUCK/TRAILER COMBO: 38 TONS” (Ducks Unlimited, 2008). Plans are stamped by a Washington State Professional Engineer, dated 10-23-06.

Figure 31. Jackknife Bridge

Two existing timber pedestrian bridges owned by Snohomish County will be removed along the east end of the south cross dike. The first is a single span timber bridge located at 47.991, -122.157, approximately 48’ long x 10’ wide (Figure 32). The second is a single span timber bridge located at 47.989, -122.154, approximately 67’ long x 10.5’ wide (Figure 33). Bridges are to be entirely removed, including abutments and pile foundations.

Figure 32. Existing Bridge to be Removed

Figure 33. Existing Bridge to be Removed

There are no new bridges anticipated as part of the project.

6. Vegetation Management – Invasive Plant Removal, Planting Plan, and placement of Large woody Material

Invasive plant removal:

Invasive plant species were identified during site visits and will be removed prior to any construction activities (Table 22). The invasive plant species have different requirements for how they are managed and will be removed and properly disposed of according to the rules and regulations outlined in RCW 17.10 and WAC Chapter 16-750. Invasive plant species that exist below the high tide line will be passively managed. Restored hydrologic conditions and natural recruitment will help limit invasive plants which have been successful in adjacent restoration projects (ICF International 2014). Invasive plant species above the high tide line will be actively managed through mechanical removal, herbicides, or any other methods approved by Snohomish County Noxious Weed Control Board.

Table 22. List of invasive plant species that will be removed.

Invasive Plant Species
Himalayan blackberry (*Rubus spp*)
Cordgrass (*Spartina spp*)
Reed canarygrass (*Phalaris arundinacea*)
Scots broom (*Cytisus scoparius*)
Knotweed (*Fallopia spp & Persicaria wallichii*)
Tansy ragwort (*Senecio jacobaea*)
Purple loosestrife (*Lythrum salicaria*)

Vegetation Removal:

Trees and shrubs will be removed prior to cutting breaches and lowering dikes. Native trees and shrubs will be planted upland to offset for vegetation removal, GHG emissions, and to deter colonization of invasive plants. We identified a list of trees and shrubs based on observations during previous site visits of well-established native plants (Table 23). The native plants will be planted along the constructed trail on the southwest portion of Spencer Island, where approximately 1.09 acres of planting area is available. Based on the recommended tree spacing outlined below, around 378 trees and 3,008 shrubs will be interplanted. The trees and shrubs will be evenly distributed across species, resulting in approximately 63 trees of each species and 430 shrubs of each species. At least 80% of the plants will survive by the end of year 1 to meet the success criteria for the project. These native plant species are typical of Puget Sound lowland floodplains and will be planted according to the following:

1. Vegetation plantings will be located on all disturbed areas above the high tide line to limit recruitment of invasive plant species and to help offset vegetation removal from construction, Pacific willows will be planted closest to the high tide line,
2. Bare root plants will be installed at the end of fall or winter to limit the plants' exposure to dry periods and will be watered if needed,
3. Trees will be spaced approximately 12 feet on center,
4. Shrubs will be spaced approximately 4 on center,
5. Erosion control measure will be taken, if necessary.

Table 23. List of tree and shrub species to plant.

Tree Species	Shrub Species
Western redcedar (*Thuja plicata*)	Red-osier dogwood (*Cornus stolonifera*)
Sitka spruce (*Picea sitchensis*)	Hardhack (*Spiraea douglasii*)
Black cottonwood (*Populus trichocarpa*)	Sweetgale (*Myrica gale*)
Red alder (*Alnus rubra*)	Nootka Rose (*Rosa nutkana*)
Cascara (*Frangula purshiana*)	Salmonberry (*Rubus spectabilis*)
Pacific willow (*Salix lasiandra*)	Oso-berry (*Oemleria cerasiformis*)
	Sitka willow (*Salix sitchensis*)

A monitoring and adaptive management plan will be implemented to ensure that plantings will survive 10-years after construction is complete. Further details are outlined in Appendix E in the draft FR/EA.

Placement of Large Woody Material:

All trees removed for construction of breaches and lowering dikes will remain on site as LWM for structural habitat. The preferred location for placing LWM is within tidal channels at the ends of new ditch plugs. Trees will be cut into pieces suitable for machine placement, generally lengths greater than 25-feet, with rootwads attached. Trees may also be placed near breaches and/or on top of lowered dikes whenever practicable. The intention of keeping LWM on site is to promote natural LWM recruitment, provide structural habitat for salmon, and to provide additional shade over water within Spencer Island, and create a source of nurse logs for spruce seedling establishment.

7. Cost Considerations

Cost estimates have been developed for the project. Please refer to Appendix H of the FR/EA for additional information.

At March 2026 price levels, the estimated first cost of this project is $13M.

Feasibility level cost estimates are likely conservative due to several factors:

i. Bare earth LiDAR data at this site includes vegetation, resulting in a basemap that is biased high in terms of elevation. The primary project activity is excavation of dikes and channels and placement of these materials in ditches and mounds. Thus, the amount of excavation of earthen material (and onsite fill placement) will be less than calculated in CAD. Survey data collected during completion of feasibility to support design phase work was reviewed to confirm that the lidar used is indeed higher than actual ground elevations. To account for the over estimation of earth work the feasibility design earth work volume estimates provided in the Engineering Appendix have been adjusted by subtracting the elevation bias from the average cut height within a work area. See Civil Annex C-4 for more discussion of this procedure.

ii. During feasibility it was assumed that the perimeter/exterior ditches would not be filled due to the presence of functional habitat. The PDT and NFS conducted further evaluations with stakeholders after the design was completed and determined that these ditches could be filled. Filling these ditches will allow for significantly reduced handling of excavated materials and an increase in productivity rates for disposal area construction.

iii. Invert elevations for new tidal channels (in the feasibility design) may be modestly deeper than necessary to reestablish desired connectivity. As a cost saving contingency measure, higher invert elevations may be considered for some new proposed breach channels.

iv. All trees along dikes are presumed to be cleared. After evaluations by project staff, it has been determined that significant trees should be protected. This is likely to reduce or eliminate some excavation and backfill work. The length of dike where significant trees are present is estimated to be about 8% of the total dike length.

8. Schedule for Design and Construction

Design phase work will officially start once the decision document and project partnership agreement are signed. Currently this is anticipated for winter 2025 and expected to continue into 2027. Design, modeling, and floodplain management coordination will be necessary throughout the design phase to ensure the project is compliant with policy. Before the project is physically complete work will likely entail a conditional letter of map revision (CLOMR) for the effective FEMA flood insurance rate maps due to anticipated changes in base flood elevations and removal of dikes at Spencer Island.

The general schedule is based assumption of one in-water work season (2027), with work occurring upland before and after the in-water work to prepare and clean up the site.

Construction will likely be completed in three phases over one or two years (all contracts solicitated at approximately the same time):

- Phase I: mobilize, prepare work areas (upland clearing, dike improvements for access), stockpiling as needed.
- Phase II: In-water work – dike removal along exterior of island, with simultaneous channel construction and disposal area grading, bridge removal, viewing platform construction.
- Phase III: Surfacing for dikes/trails to remain, revegetation as required, install signage, demobilize.

All in-water work will occur within the designated fish window of June 1 to October 31 for the lower Snohomish River. There may be work that occurs out of water or behind an isolation device outside of the in-water work window. USACE will work with WDFW to determine the exact work window and which project elements fall within the Snohomish River prior to finalizing construction sequencing. Note that a late award, issues with submittals, or inadvertent discovery could force the project into a two-season duration.

Use of specialized heavy equipment rated for work in wetlands and marshes will be necessary and prior experience should be part of the selection criteria. An industry day is recommended to alert potential bidders.

No known utilities are present on Spencer Island and no utility relocations are anticipated.

9. Outline of Specifications

The following information outlines the specifications (job no 21009) that will be included in the contract documents:

DIVISION 0 PROCURMENT AND CONTRACTING

LIST OF DRAWINGS

BID SCHEDULE

DIVISION 01 - GENERAL REQUIREMENTS	
01 14 00	WORK RESTRICTIONS
01 22 00.00 10	MEASUREMENT AND PAYMENT
01 30 00	ADMINISTRATIVE REQUIREMENTS
01 32 01.00 10	PROJECT SCHEDULE
01 33 00	SUBMITTAL PROCEDURES
01 35 26	GOVERNMENTAL SAFETY REQUIREMENTS
01 42 00	SOURCES FOR REFERENCE PUBLICATIONS

01 45 00.00 10	QUALITY CONTROL
01 45 00.15 10	RESIDENT MANAGEMENT SYSTEM CONTRACTOR MODE (RMS CM)
01 50 00	TEMPORARY CONSTRUCTION FACILITIES AND CONTROLS
01 56 00	CARE AND DIVERSION OF WATER
01 57 19	TEMPORARY ENVIRONMENTAL CONTROLS
01 57 19-A	WATER QUALITY MONITORING PLAN
01 57 19-B	FISH CAPTURE AND HANDLING DURING WORKSITE ISOLATION
01 57 19-C	GUIDELINES FOR ELECTROFISHING
01 57 19-D	ARCHAEOLOGICAL MONITORING PLAN
01 57 20	ENVIRONMENTAL PROTECTION
01 57 20A	WATER QUALITY CERTIFICATION
01 57 20B	GENERAL PRESCRIPTIONS THAT APPLY TO ALL PROPOSED RESTORATION ACTIONS
01 74 19	CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT
01 78 00	CLOSEOUT SUBMITTALS
DIVISION 02 - EXISTING CONDITIONS	
02 41 00	DEMOLITION AND DECONSTRUCTION
DIVISION 03 – CONCRETE	
DIVISION 31 - EARTHWORK	
31 00 00	EARTHWORK
31 05 19	GEOTEXTILE
31 11 00	CLEARING AND GRUBBING
31 23 00.00 20	EXCAVATION AND FILL
DIVISION 32 - EXTERIOR IMPROVEMENTS	
32 90 00	PLANTING
DIVISION 33 UTILITIES	
33 40 00	STORM DRAINAGE UTILITIES
DIVISION 35 - WATERWAY AND MARINE CONSTRUCTION	
35 31 19	STONE, CHANNEL, SHORELINE/COASTAL PROTECTION FOR STRUCTURES
35 44 00	IN-STREAM AND FLOODPLAIN HABITAT CONSTRUCTION

10. ANNEXES

Available electronically as separate documents.

A – Engineering Drawings Annex

B – Geotechnical Annex

C – Civil Design Annex

D – Hydrology, Hydraulics and Coastal Engineering Annex

E – Structural Annex – Reserved