Snohomish County Estuary Monitoring

Smith Island and Mid-Spencer Year 0-1 Project Monitoring, 2018-2019



Smith Island, Post-breach, 11 foot tidal elevation (MLLW), 11/6/2018. Photo: George White Location Photography.

June 2020

www.surfacewater.info

Snohomish County
Public Works
Surface Water Management

Acknowledgements

Department of Public Works
Kelly A. Snyder, MPA, Director

Surface Water Management (SWM) Division
Gregg Farris, Director
Dave Lucas, P.E., Floodplain Services Supervisor
Janell Majewski, Resource Monitoring Supervisor
Aaron Kopp, P.E., Smith Island Estuary Restoration Project Manager

Recommended Citation:

Snohomish County 2020. Snohomish County Estuary Monitoring; Smith Island and Mid-Spencer Project Monitoring, 2018-2019. Snohomish County, Public Works, Surface Water Management, Everett, WA.

Special Thanks for Monitoring Support:

Snohomish County thanks NOAA Restoration Center, Washington Department of Fish and Wildlife Washington State Estuary and Salmon Restoration Program, and Washington State Recreation and Conservation Office for their funding support to accomplish monitoring at Smith Island and throughout the Snohomish Estuary. We also thank Josh Chamberlain and Jason Hall (NOAA-Northwest Fisheries Science Center (NWFSC)) and Todd Zackey (Tulalip Tribes) for leading Snohomish Estuary monitoring, their expertise, planning and logistical support. Thanks to Casey Rice (NWFSC), *in memoriam*, for his years of dedication to Snohomish estuary monitoring and advancing the state of the knowledge to inform salmon recovery.

Other Smith Island and Mid-Spencer Island Partners are US Fish and Wildlife Service, Puget Sound Acquisition and Restoration Fund, Puget Sound Partnership, Pacific Coastal Salmon Recovery Fund.

Snohomish County contributions to this monitoring report were made by Frank Leonetti, Mike Rustay, Brett Gaddis, Luke Hanna, Scott Moore, Aaron Kopp, and Janell Majewski.

Report Inquiries: Frank Leonetti

Snohomish County Public Works
Surface Water Management Division
3000 Rockefeller Avenue, MS-607
Everett, WA 98201-4046
Phone: (425) 388-3464
Fax: (425) 388-6455
frank.leonetti@snoco.org

Table of Contents

Acknowledgements i

List of Tables and Figures iii

List of Appendices vi

Executive Summary 1

Introduction 6

Monitoring Strategy 9

Anticipated Outcomes and Results 10

Pre-Construction Monitoring 11

Implementation Monitoring 11

Post-Project Monitoring 11

Monitoring Results by Element 14

1. LiDAR and Ortho Imagery 15

2. Site Appearance and Change 17

3. Sediment 24

4. Tidal Prism - Hydrology/Water Quality 36

5. Channels and Habitat Area 48

6. Wood Complexes and Woody Material 61

7. Vegetation 63

8. Fish Use and Biota 78

Application of Monitoring Information and Recommendations 86

References 88

Appendices 90

List of Tables and Figures

Table 1. NOAA Grant award monitoring performance metrics. Unless otherwise noted, performance metric is included in this report. 4
Table 2. Snohomish Estuary monitoring communication objectives for monitoring elements and project sites; Smith Island (SI) and Mid-Spencer (MSp). 8
Table 3. Smith Island/Mid-Spencer monitoring for NOAA FY15 award, titled, "Restoring Resiliency in Puget Sound Snohomish River Delta," implemented as part of PRISM Record Number: 16-2152. These performance metrics support NOAA Coastal Resiliency Awards (#NA16NMF4630008 and #NA13NMF4630142). Also see Appendix B. 13
Table 4. Site appearance and change monitoring description from Snohomish County (2018). "D & I" refers to Data and Information Sharing outputs. 18
Table 5. Sediment accretion and loss monitoring description. 24
Table 6. Number of each SET, install date, latitude and longitude, final elevation of the top of the marker rod, number of rods used and approximate rod depth, and sample dates for each SET site in Mid-Spencer Island. 29
Table 7. Change in post elevation, average SET measurement change and standard error for each site, and average change in SET measurements for all sites. 29
Table 8. Average marker horizon change and standard error for each site, and average change in maker horizons for all sites. See Figure 13 for photo of accretion over marker horizon. 29
Table 9. Short-term monitoring of inferred sediment pin accretion at Mid-Spencer and South Spencer islands. . 33
Table 10. Hydrology and water quality monitoring description. 38
Table 11. Tidal channel and topographic monitoring description. 51
Table 12. Smith Island as-built (Snohomish County and City of Everett portions) and Mid-Spencer pre- and post-construction marsh characteristics for area, length, connections, and spacing typically summarized by Hood (e.g., Hood 2007). 53
Table 13. Description of vegetation monitoring. 64
Table 14. Smith Island pre-project vegetation frequency of occurrence by common species among 500 quadrat samples and by 100 macroplots, summer 2018. 69
Table 15. Deliverables for fish monitoring at Smith Island and Mid-Spencer project sites. 79
Table 16. Catch and date of first catch for sites inside and immediately outside of the Smith Island project, February-September 2019. 82
Table 17. Planned annual schedule of monitoring elements, pending funding. Yr0 is 2018. Grant funded years are italicized. 87

Figure 1. Locator map of the Snohomish River estuary, Smith Island and Mid-Spencer project sites, and the extent of 2019 LiDAR collection. Appendix A shows other Snohomish Estuary restoration projects. 3
Figure 2. Snohomish Estuary historic vegetated tidal marsh zones (from Haas and Collins 2001). Smith Island and Mid-Spencer locations are indicated with an open square. 7
Figure 3. Smith Island and Mid-Spencer general site boundaries showing selected features and generalized flow direction. 12
Figure 4. Examples of LiDAR and Ortho-imagery products suitable for topographic, vegetation, visualization and temporal analyses and comparisons. 16
Figure 5. Shaded relief of 2019 LiDAR elevations highlighting various Smith Island landmarks. 17
Figure 6. Locations of annual Primary and Secondary photo point monitoring. 20

Figure 7. Photo point documentation of Smith Island East Tidal Channel mouth, construction, dike breach, flood tide and drainage. Union Slough, connected to Puget Sound, is at left in photos. 21
Figure 8. Photo points of Starter Channel 9.3b (different bearings), pre-breach (2017) and post-breach (2018 and 2019). 22
Figure 9. 2019 high-resolution aerial image showing the excavated Starter Channel 7 draining to Union Slough (right) through a breach in the historical dike (1:500 scale). Constructed wood complexes are visible (circled) as is other woody material that has drifted into the site. 23
Figure 10. Basic schematic of a SET, including the rod SET, post, and SET measuring device (left), and the rod post and feldspar marker horizons (right). (Lynch et al. 2015). 26
Figure 11. SET Install and measure. Top right: Marker horizons set on corner of SET area with feldspar and PVC posts. Top left: crew uses pneumatic hammer to install SET rods into the ground. Bottom left: SET measuring devices and nine pins used to measure down the sediment surface. Bottom right: liquid nitrogen used to take freeze cores from each marker horizon which is then used to measure the amount of sediment accretion over the feldspar layer. 27
Figure 12. Location of four RSETs installed at Mid-Spencer Island and 64 sediment pins installed at Smith, Mid-Spencer and South Spencer islands. 2019 aerial photo. 28
Figure 13. Example of sediment accretion over the white feldspar marker horizon at the Qwuloolt restoration project in the Snohomish estuary. 30
Figure 14. Example of sediment pins (grey PVC) placed on sedge bench at Mid-Spencer in 2016. Tong Tran installs sediment pin (left). Scott Dirks (Snohomish County) surveys in the sediment elevation and top of pin with RTK-GPS (shown). 31
Figure 15. Sediment pin measure-down distance (y-axis) over time for four sediment pins at Mid-Spencer Island. Initial differences in measure-down distance reflects the difference in pin height above the marsh. 32
Figure 16. Unconsolidated sediment at Mid-Spencer Island over cattail marsh adjacent to Steamboat slough. Footprints highlight both the depth and lack of resistance in the recently deposited sediment. 32
Figure 17. Individual sediment pin accretion rates among six sites at Mid-Spencer and South Spencer islands over more than two years. 33
Figure 18. Analysis of elevation differences (legend categories) between 2009 and 2019 LiDAR elevations that illustrate sinuous channel formation and increasing elevation with marsh building at South Spencer Island (right panel). At Smith Island (left panel), decreasing elevation is associated with channel excavation and dike removal, whereas increases in elevation are associated with ditch filling. The minor gain in elevation at the outlet of Spencer Island is due to tidal elevation differences between 2009 and 2019 collection times. Otherwise surfaces are bare, except for Union Slough. 35
Figure 19. Smith Island water level, conductivity, and temperature monitoring locations. 37
Figure 20. Installation and water level data collection illustration from Diver Office© software, provided by Van Essen Instruments January (2016) Van Essen Instruments. All rights reserved. 39
Figure 21. Union Slough (left) and Smith Island interior tidal channel (right) water level, conductivity, and temperature logger installations. 40
Figure 22. Pre-project water level monitoring hydrograph at Smith Island. 41
Figure 23. Diurnal hydrograph snapshot of pre-project water level monitoring at Smith Island. 42
Figure 24. Post-breach water level hydrograph comparison between Union Slough and Smith Island East Tidal Channel. 43
Figure 25. Mid-construction, nine-day hydrograph comparison between Union slough tidal level and the interior East Tidal Channel of Smith Island. 43
Figure 26. Mid-construction, 1-day hydrograph comparison between Union slough tidal level and the interior East Tidal Channel of Smith Island. 44

Figure 27. Post-construction, 3-day hydrograph comparison between Union slough tidal level and the interior East Tidal Channel of Smith Island. 44
Figure 28. Relative difference in tidal elevation between Union Slough high tide water level and the Smith Island interior East Tidal Channel during the course of constructing additional starter channel breaches (SC7-ECC). ECC is the City of Everett Tidal Channel. 45
Figure 29. Water conductivity of Union Slough and the Smith Island Interior tidal channel. 46
Figure 30. Pre-project water temperature in Union Slough, Smith Island East Tidal Channel (ETC lower, ETC upper), and two interior ground wells (SW01 and SW02). 47
Figure 31. Post-project water temperature of Union Slough, and the Smith Island interior tidal channel. 48
Figure 32. Example of agricultural ditch at Smith Island re-connected to tidal inundation. 49
Figure 33. Mapped ditch network at Smith Island including re-connected and filled ditches. 50
Figure 34. Map of Smith Island and Mid-Spencer large and small tidal channels. 52
Figure 35. 2019 LiDAR-based elevations. Elevations that are less than 5 feet (within the Smith Island project area only) are predicted to become tidal flats (dark blue). Ground area west of the setback dike is protected from tidal inundation so will not become tidal flats. 54
Figure 36. Estimate of total marsh area in 2020 as compared to estimates for 1884 and 1996 estimated by Haas and Collins (2001). 55
Figure 37. Mid-Spencer Island, Smith Island, and Qwuloolt as-built channel connection data points (labeled) overlaying marsh island area and outlet channel count from Hood (2014). Mid-Spencer Island was included (circled) in Hood (2014) as a data point in the dike breach data set (grey circles). Open circles represent reference conditions. 56
Figure 38. 2019 Mid-Spencer Island channel count (breaches) per kilometer of dike overlaying Hood (2014) increase in passive breaching among restoration sites over time. Mid-Spencer Island is labeled from the original data set and in 2019 along with the potential trajectory associated with only passive breaching. . 57
Figure 39. Smith Island Everett channel, Smith Island County channels and Mid-Spencer Island surface area plotted against marsh island area and overlaying the Hood (2014) comparison of breach sites (grey circles) and reference locations (open circles) for Snohomish estuary locations. 58
Figure 40. Smith Island channel cross-sections, longitudinal profiles, dike breach sections and a vegetation delineation (profile) of *Carex* sedge grasses among large and small tidal channels. Mid-Spencer Island surveys will be included in future reporting. 59
Figure 41. Starter Channel 11 ground elevation along a thalweg profile of the constructed channel. Locations of cross-sections in Figure 40 are show in Figure 42. 60
Figure 42. Starter Channel 11 cross-section topographic elevations at positions corresponding to Figure 41. 60
Figure 43. Examples of wood complexes constructed at Smith Island including; A: Dike ends; B: Large wood complexes, and C: Small wood complexes. Fish were observed in small wood complex at bottom center. . 62
Figure 44. Smith Island pre-project landscape view of vegetation types including coniferous trees (background), deciduous trees, shrubs, grassland, and Himalayan blackberry (foreground). 63
Figure 45. Map of dominant pre-project vegetation prior to project implementation. Polygon labels are species common names. 66
Figure 46. 2016 one-meter high resolution, satellite-based land cover classification from NOAA (Office for Coastal Management 2020). 67
Figure 47. Smith Island vegetation macroplots established in 2018. Historical Snohomish Estuary vegetation survey transects are also shown. 68
Figure 48. Example 5-meter square macroplot for vegetation monitoring and 1-meter quadrat within. 69
Figure 49. Smith Island vegetation macroplot elevation distribution. Only 91 out of 100 plots were surveyed for elevation with RTK-GPS. 70

Figure 50. Initial 2018/2019 die-off of grasses in pastureland areas of Smith Island. 71
Figure 51. Example of line transect survey at Smith Island (2019) post-breach and cover classes used for characterization. 72
Figure 52. Green algae growth across bare soils. 73
Figure 53. Mats of algae growth up to 1-inch think on bare ground. Tidal action can lift and reposition mats leaving them in twisted mats like abandoned carpet. 73
Figure 54. Smith Island colonizing vegetation in 2019. 74
Figure 55. Existing Lyngbye's sedge (Carex Lyngbei) bench (left) next to bare soil of former dike footprint (right side of photo). A vegetation profile was captured here and is shown in Figure 40. 75
Figure 56. Vegetation height classes derived from LiDAR differencing model (surface height minus ground elevation) for 2014 (pre-project) and 2019 (post-breach). Visible color in lower right panel not masked by 2019 shading (grayed out) represents tree blow down 76
Figure 57. Invasive Scotch broom on the new set-back levee being treated with imazapyr (upper left), after die-back (upper right), mowing (lower left), and re-growth of hydro-seeded native grasses (lower right). 77
Figure 58. Setting a beach seine in Starter Channel 14, May 9, 2019. Union Slough is in background. 81
Figure 59. Setting a beach seine within the interior of Smith Island from the new setback dike. 81
Figure 60. Location of 2019 seine locations with catch of Chinook, coho and chum salmon. 83
Figure 61. Chinook salmon catch per unit effort by sample cycle for four locations. 84
Figure 62. Sub-yearling Chinook salmon average length among sites for cycle 10 sampling. Count (n= #) by site is also shown. 85

List of Appendices

Appendix A. Locations of Snohomish Estuary tidal marsh restoration projects and status. Diked locations actively or passively restored to tidal hydrology since 1996 are highlighted (yellow).

Appendix B. NOAA Award Special Conditions and RCO statement of Work.

Appendix C. Smith Island Photo Points.

Appendix D. Estuary-wide water quality sampling map (Figure 1 from Hall et al. 2018). CWS sites record water level, temperature, and conductivity (salinity). Snohomish County sites are labeled ETC (East Tidal Channel) and MSp (Union Slough at Mid-Spencer.

Appendix E. Smith Island cross-section and longitudinal profile data and figures.

Appendix F. NOAA high-resolution land cover classification and Snohomish Estuary projects.

Appendix G. 2019 Snohomish Estuary Fish Sampling Protocol (NOAA) and Site Map.

Appendix H. 2018-2019 Bird list.

Disclaimer Applies to Maps (as in Figure 1)

All maps, data, and information set forth herein ("Data"), are for illustrative purposes only and are not to be considered an official citation to, or representation of, the Snohomish County Code. Amendments and updates to the Data, together with other applicable County Code provisions, may apply which are not depicted herein. Snohomish County makes no representation or warranty concerning the content, accuracy, currency, completeness or quality of the Data contained herein and expressly disclaims any warranty of merchantability or fitness for any particular purpose. All persons accessing or otherwise using this Data assume all responsibility for use thereof and agree to hold Snohomish County harmless from and against any damages, loss, claim or liability arising out of any error, defect or omission contained within said Data. Washington State Law, Ch. 42.56 RCW, prohibits state and local agencies from providing access to lists of individuals intended for use for commercial purposes and, thus, no commercial use may be made of any Data comprising lists of individuals contained herein.

Executive Summary

Snohomish County implemented two estuarine restoration projects on neighboring areas – Smith Island and Mid-Spencer Island. The Smith Island restoration site, set across more than 300 acres in the Snohomish River estuary (Figure 1), was re-connected to tidal and river inundation in August 2018 after 85 years of floodplain isolation. Tidal marsh restoration is a critical Chinook salmon recovery action in Puget Sound (Cereghino et al. 2012), particularly in the lower Snohomish estuary (SBSRF 2005) where 85 percent of historical tidal marsh was lost due to industrial, urban and agricultural land uses (Haas and Collins 2001). The primary purpose of the Smith Island project was to re-establish a functioning and self-sustaining estuarine tidal marsh by restoring tidal hydrology, tidal channels, and multiple locations of tidal connectivity. As such, the project provides critical blind tidal channel rearing habitat for salmon species and other native fish. The primary purpose of the Mid-Spencer restoration project is to re-establish new tidal connections through the remnant dike to improve tidal connectivity and fish access to the marsh plane within the project site, which was naturally breached in the 1970's. These projects are among several important Snohomish Estuary restoration projects (Appendix A).

This Snohomish Estuary Monitoring Project was funded by NOAA Coastal Resiliency grant awards and was administered by Washington Department of Fish and Wildlife as an Estuary and Salmon Restoration Program (ESRP) Learning Project documented as RCO PRISM project (16-2152M). This report fulfills Task 4 (Appendix B) to complete a Final Data Report, that "will compile data gathered, analysis conducted and offer recommendations for further investigation and monitoring." Reporting will be uploaded to PRISM in Washington State and made directly available to stakeholders as part of implementing the Data Sharing and Information Plan (Snohomish County 2018).

This report includes key monitoring effectiveness metrics requested by NOAA and summarizes monitoring activities, level of effort, locations established/sampled, data collected, and initial results or findings. Monitoring effectiveness is also guided by project implementation objectives, monitoring questions, documenting as-built conditions, and formalizing expected outcomes. Table 1 includes the monitoring performance metrics by NOAA (Appendix B) for Smith Island with columns 1 and 2 published in the Snohomish County Estuary Monitoring Plan (Table 2 *in* Snohomish County 2018,). Year 0-1 information provided in this report is described in Column 3 unless, as noted, they are reported separately.

Monitoring data and observations collected to date support all of the following statements:

- Smith Island was built as designed and fully exchanges tidal cycles.
- Smith Island increases marsh area, channel connections, and blind tidal channel area, replacing historical loss of habitat area for juvenile salmon.
- Salmon were observed using all parts of Smith Island including the East Tidal Channel, constructed Starter Channels, Everett Channel, and the front of the new setback dike. In addition we observed most other typical estuarine rearing fish species.

- Temperature and salinity were as expected for this part of the estuary (Hall et al. 2018) and supportive of salmon rearing in throughout the majority of spring and early summer, prior to outmigration at the onset of warmer weather (Chamberlain et al., in review),
- Vegetation in Year 1 was, as expected, in a state of die-off and large trees began to blow over during the first winter storms. We anticipate die-off of upland plant species will continue for 2-4 years, but we have already observed emergent marsh species colonization and expansion.

It is anticipated that some data will be integrated with other regional monitoring and so may be contributed to NOAA-NWFSC, Tulalip Tribes or ESRP as part of tracking restoration project outcomes. For example, Snohomish estuary-wide analyses of fish data will be led by NOAA-NWFSC science staff. A cumulative summary of results and interpretation of longer-term changes and relevance to salmon recovery will, in most cases, require longer periods of time (3-5 years) from the project initiation and baseline characterization and are anticipated to be completed after 5 to 10 years.

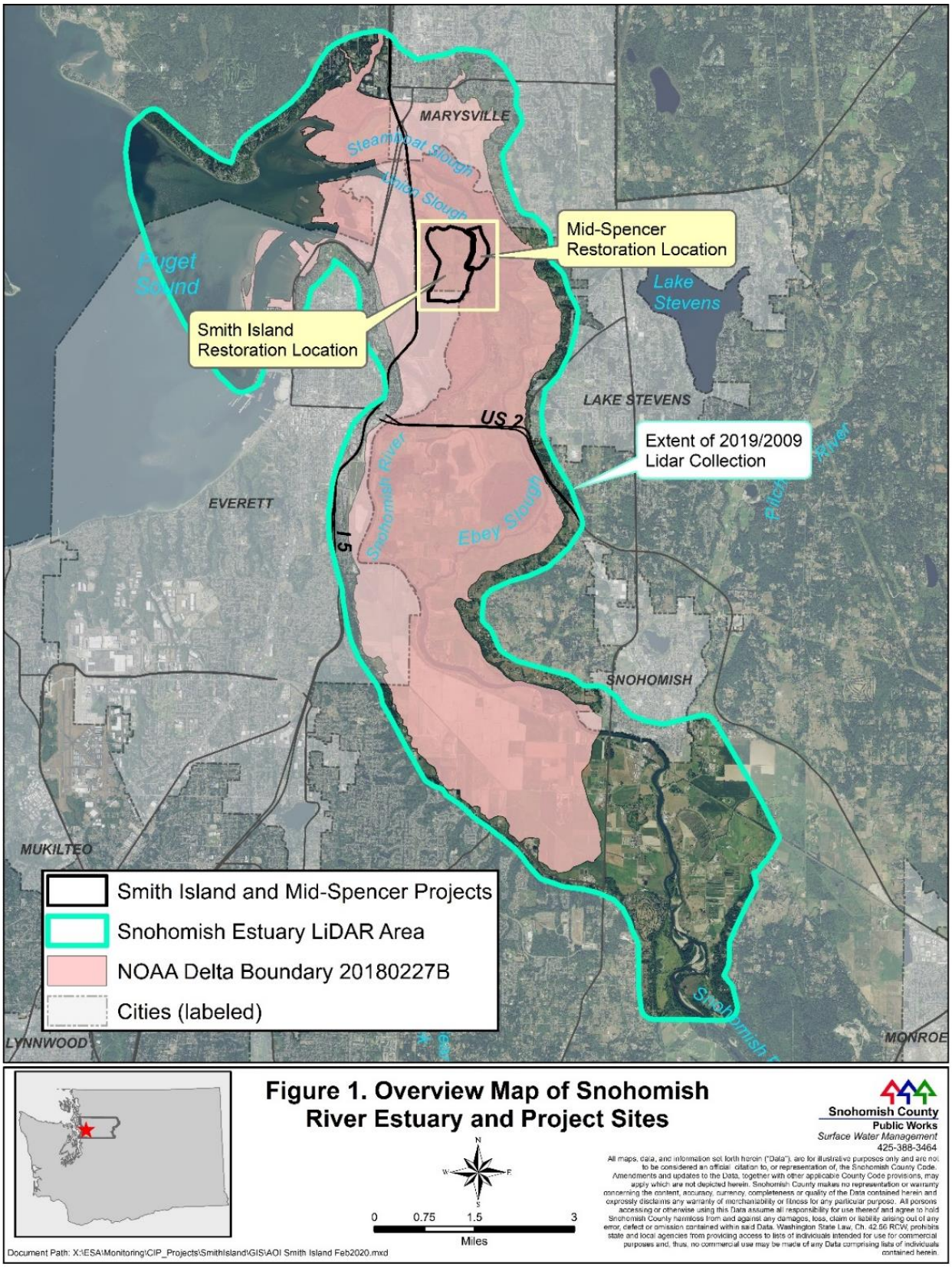


Figure 1. Locator map of the Snohomish River estuary, Smith Island and Mid-Spencer project sites, and the extent of 2019 LiDAR collection. Appendix A shows other Snohomish Estuary restoration projects.

Table 1. NOAA Grant award monitoring performance metrics. Unless otherwise noted, performance metric is included in this report.

Tier I Implementation Performance Metric		
Metric	**Units, Frequency, Products/Deliverable**	**Year 0-1 Reporting**
Land Elevations	Restoration designs and Post-construction as-built drawings - prepared and stamped by a licensed professional engineer/professional land surveyor, will show existing and proposed elevations and cross-sections for structures, channels, wetlands, and floodplains, final elevations and cross-sections of structures, channels, and land installed/altered by the project, and be surveyed into a known elevation benchmark and referenced to a standard geodetic datum.	Designs and as-built inventory were provided separately to grant and permit agencies under separate grant agreements - available at PRISM online for projects 16-1559 and 09-1279.
Hydrology - Water Levels	Pre- and Post-restoration hydrographs - generated by collecting water elevations using at least three data loggers (upstream and downstream of a removed tidal restriction, and one to correct for atmospheric pressure) surveyed into the same elevation benchmark/datum as the as-built drawings/project plans. Document the new flooding regime to determine consistency with restoration goals.	Pre- and Post-restoration hydrographs and supporting *Figure 22* and *Figure 24,* documentation, photos (and video) of water levels
Tier II Implementation Performance Metric		
Metric	**Units, Frequency, Products/Deliverable**	**Year 0-1 Reporting**
Photo points	Establish ≥ 10 photo points; Photograph twice per year, once in June/July and once in Nov/Dec until determined not necessary. Deliver GPS coordinates, bearings, map and annual winter/summer photos covering grant award period.	Maps of established photo point locations *(*Figure 6*)*. Pre-project and Year 0-1 photos at >50 sites.
Time-lapse photo/video	Establish at least one daily time-lapse camera/video at one large Smith Island breach location (prior to breaching) and maintain for ≥1 year post-breach. Provide video rendering of breach.	Description of video/time-lapse effort and products to date – Web links are at Smith Island project website.
Surface Elevation Tables/ Sediment Pins	Establish ≥4 Rod Surface Elevation Tables (RSETs). Measure RSET elevations semi-annually. Deliver GPS coordinates, RSET elevation benchmark, and elevation measurements covering grant award period (with NOAA & Tulalip Tribes). Establish ≥ 50 sediment pins based on channel proximity, elevation, and vegetation. Deliver GPS coordinates, initial sediment/pin elevations, and measure semi-annually covering grant award period.	Map of 4 RSET and 64 sediment pins *(Figure 12)*, description of installation, measurements, initial interpretation, and photos.

Table 1. Continued.		
LiDAR/ Aerial Photos	Acquire LiDAR (Light Detection And Ranging) at low tide post-breach. Provide LiDAR Digital elevation model, maps, and data collection report from vendor.	Completed data acquisition, processing, report and mapping examples *(Figure 4)*.
	Using available aerial photo imagery, establish baseline and biennial channel count, length, surface area calculations in GIS.	GIS based maps *(Figure 34)* and channel metrics *(Table 12)*.
Field Surveys (RTK-GPS)	Establish baseline cross-section and profile measurements at ≥ 5 channel locations. Measure annually. Provide plots of channel profile/cross-sections and changes covering grant award period.	Map of 84 cross-sections *(Figure 40)* and profiles and Appendix E of 25 cross-sections and profile plots.
Water level (above), Temperature, Salinity	Establish "upstream" (Smith Island-2018) and "downstream" (Union Slough-2016) water level, temperature, salinity and barometric sensors (15-minute recording interval downloaded quarterly); Provide map and daily pre- and post-breach data.	Reported observed year 0-1 salinity and temperature from tidal sensor location. *(Figure 29 and Figure 31)*.
Vegetation succession	Establish ≥20 5x5 m^2 random vegetation plots and 12 line-intercept transects across elevation gradient. Sample 1 m^2 random quadrat among plots/line transects in years 0, 1, 2, 3, 5, 7, 10. Provide vegetation locations (mapped) and results.	Map locations of 100 vegetation plots *(Figure 47)* and elevation data with initial results.
	Map major vegetation classes and mudflat to estimate composition as a percent of total area and change (based on 2-year NAIP aerial photos/vegetation plot data). Provide baseline map covering grant award period.	Pre-project vegetation community *(Figure 45)* for future comparison, potential marsh and mudflat areas *(Figure 35).*
Invasive vegetation	Perform annual post-breach invasive vegetation reconnaissance in restoration area. Map locations of invasive weeds and document treatment (type/area).	Invasive weed control effort *(Figure 57)* and other observations.
Beach seine to quantify fish use	Collect monthly (Feb-Sept) pre-project and post-project fish use data at Smith Island, Mid-Spencer, Union Slough and System-Wide sample locations with beach seine. Provide data to NOAA-NWFSC for database. Provide map of sample site locations and tables/figures of fish use by month by major site.	Maps of locations sampled in 2018 (pre-project and 2019 (Year 0-1) *(Figure 60)* and initial results of catch by location and month.
Reporting/ Communication	Create Data/Information Sharing Plan. Make data visible, accessible, independently understandable no later than 2 years post-data collection. Provide Snohomish County URL or other hosting URL (if NOAA Restoration Center/ NOAA-NWFSC).	This report fulfills reporting and communication for Year 0-1 implementation and monitoring.

Introduction

Snohomish County implemented two estuarine restoration projects in 2018 and 2019 on neighboring areas - Smith Island and Mid-Spencer Island. The Smith Island restoration site, set across more than 300 acres in the Snohomish River estuary (Figure 1), was re-connected to tidal and river inundation in August 2018 after 85 years of floodplain isolation. At the Mid-Spencer restoration site, remnant dikes were removed in 2019 to increase accessibility for juvenile salmon rearing. Tidal marsh restoration is a critical Chinook salmon recovery action in Puget Sound, particularly in the lower Snohomish estuary where 85 percent of tidal marsh was historically lost due to industrial, urban and agricultural land uses (Haas and Collins 2001).

Important objectives for estuarine marsh restoration, and salmon recovery in the Snohomish basin (SBSRF 2005) are to:

- Reestablish tidal hydrology with full inundation and evacuation;
- Renew sediment processes – transport to, deposition within, and accretion over time;
- Reestablish, reconnect and enhance lost delta area and increase tidal channel network;
- Recruit and store large woody material; and
- Reestablish and enhance native vegetation communities within the project wetlands and control invasive plants.

The primary purpose of the Smith Island project was to re-establish a functioning and self-sustaining estuarine tidal marsh by restoring tidal hydrology, tidal channels, and multiple locations of tidal connectivity to the isolated site. As such, the project provides critical blind tidal channel rearing habitat for listed salmon species and other native fish in the Snohomish River basin. Anticipated outcomes from this project are consistent with a conceptual model for estuarine delta restoration from Simenstad et al. (2006), where reintroduction of the full tidal prism is expected to restore processes, create structural changes, and lead to improved access, capacity, and functions for juvenile salmon and other fish and wildlife. The primary purpose of the Mid-Spencer restoration project was to re-establish new tidal connections through the remnant dike. The goal was to improve tidal connectivity and fish access to the marsh plain within the project site, which was naturally breached in the 1970's.

Historically, Smith Island and part of Mid-Spencer were predominantly located in the emergent/forested transition (EFT) zone (Figure 2) that contained preferred habitats for juvenile Chinook salmon, including blind tidal channels and distributary channel edge habitat. The lost marsh area affected the number and area of blind tidal channels, which were filled or isolated behind dikes. Haas and Collins (2001) found that 61 blind tidal channels and their drainage networks were lost across all marsh areas including the Estuarine Emergent Marsh (EEM) and Forested Riverine Transition (FRT) zones, representing about 75% of the blind tidal channel area in the lower Snohomish Estuary. The loss of this channel and habitat type disproportionately affected the rearing habitat capacity within the estuary which supports juvenile Chinook salmon smolt production in the emergent/forested transition zone. The reduction in blind tidal channels accounts for 62-98% of this estimated reduction in rearing capacity for Chinook salmon from 1884-1996 (Haas and Collins 2001). Now, the Smith Island and Mid-Spencer projects are among several

sites in the Snohomish Estuary (Appendix A) where the combined tidal marsh restoration area is anticipated to exceed 1700 acres, more than doubling the 1996 estimate of tidal marsh area.

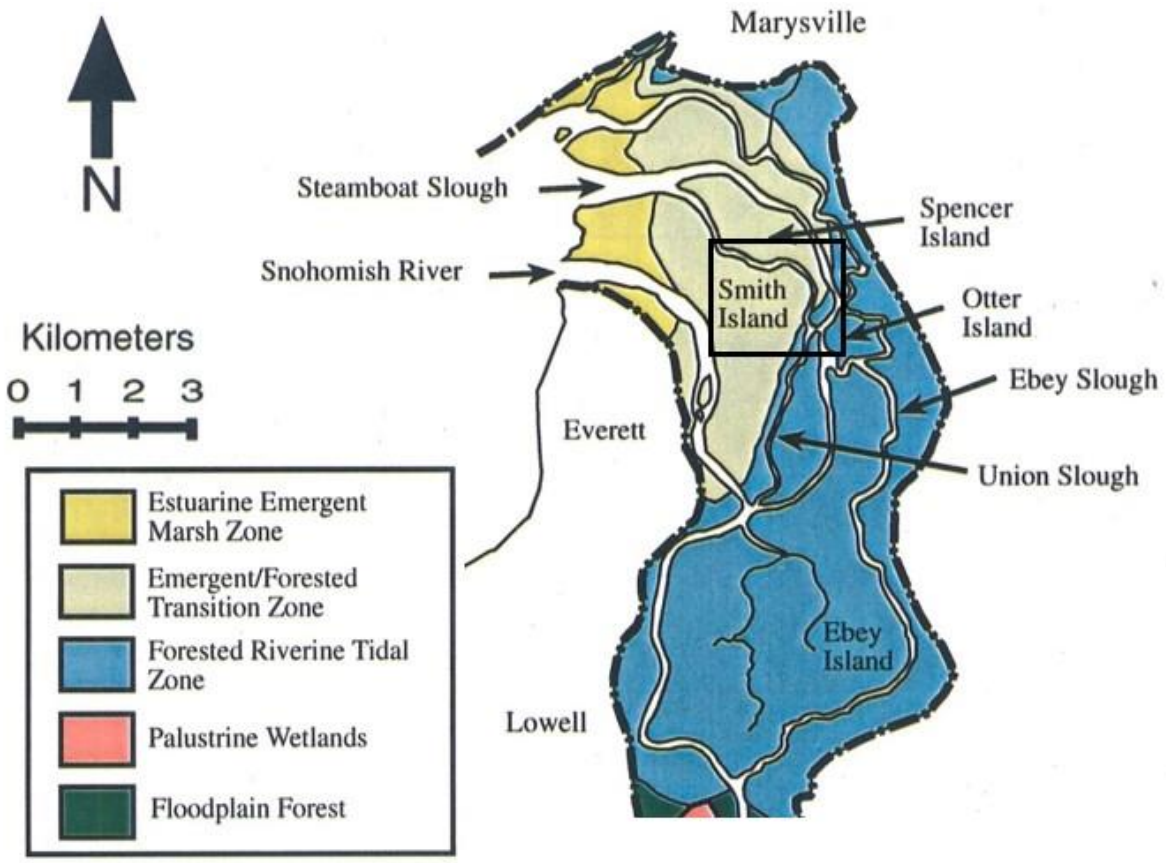


Figure 2. Snohomish Estuary historic vegetated tidal marsh zones (from Haas and Collins 2001). Smith Island and Mid-Spencer locations are indicated with an open square.

This report is a product of Snohomish County's Data and Information Sharing Plan (in Snohomish County 2018), supporting reporting and communication. Snohomish County objectives are to document implementation and progress by sharing data and information from four project phases; pre-construction, design, implementation, and post-construction effectiveness monitoring. Pre-construction and design phase information is already documented within PRISM, Washington State's Project Information System[1] . Snohomish County's initial implementation and effectiveness monitoring efforts in 2018 and 2019 for the Smith Island and Mid-Spencer restoration projects are reported here and completes obligations for the Snohomish Estuary Monitoring Project, funded by NOAA Coastal Resiliency grant awards (#NA13NMF4630142 and #NA16NMF4630008), administered by Washington Department of Fish and Wildlife as PRISM project 16-2152M (Appendix B). This report will also be archived in PRISM and made available at Snohomish County Surface Water Management's website for the Smith Island project[2] at:

www.surfacewater.info

[1] https://secure.rco.wa.gov/PRISM/search/ProjectSearch.aspx - Search "Smith Island" if other links are broken.
[2] https://snohomishcountywa.gov/1150/Smith-Island-Restoration-Project

It is anticipated that data and information sharing will also occur through presentation of project results to technical and non-technical audiences to fulfill project communication objectives. It is the policy of Snohomish County Department of Public Works to share and/or distribute, upon request, the project Geographic Information Systems (GIS) data collected by our department, when such requests are not made formally under the provisions of the Public Records Act (PRA), RCW 42.56. This policy is designed to both encourage transparency and open government with availability of project GIS data upon request. This report may describe some monitoring results or site conditions that overlap with information needs applicable to permit compliance or mitigation.

In order to tell the story about the changes and outcomes observed over time at Smith Island and Mid-Spencer and relate that to project goals and objectives, our project communication objectives based on initial monitoring reported below is included in Table 2. Note that not all communication objectives can be met after one year.

Table 2. Snohomish Estuary monitoring communication objectives for monitoring elements and project sites; Smith Island (SI) and Mid-Spencer (MSp).

Project Communication Objectives	Monitoring Elements
Show what restored tidal exchange at Smith Island looks like (photos and time-lapse video) and how Smith Island and Mid-Spencer appear to change over time.	Site Appearance & Change (SI, MSp)
Describe the maximum area of restored tidal hydrology. Show how the restored tidal hydrology matches that of tidal elevations in Union Slough, indicating full tidal exchange. Map and describe the number of tidal drainage basins created by the tidal prism and affiliated drainage connections to Union Slough.	Post-restoration Hydrology (SI)
Show the total tidal channel length, surface area, number of connected tidal channels, and branching order. Show the initial baseline and describe subsequent changes in profile and cross-sectional area that occur over time. Report results over time and use regional contexts/datasets described by Hood (2014) in comparison to other restoration sites.	Tidal channels (SI, MSp)
Describe the new tidal channel area, woody debris accumulation or change, low tide pond area, water temperature, salinity, dissolved oxygen levels in terms of suitability for rearing salmon.	Habitat/ Water quality (SI)
Show the magnitude of sedimentation post-construction and how elevation changes over time compares to estimates of sea level rise (SLR). Describe whether sedimentation rate is different at Smith Island compared to other sites.	Sedimentation (SI, MSp)

Project Communication Objectives	Monitoring Elements
Describe the fish species composition, size, origin (hatchery or wild) and density by date (migration timing). Provide an estimate of the salmon rearing capacity.	Fish use (SI, MSp)
Compared to the pre-construction vegetation community, map or show the die-off area (mudflat), and initial zonation (elevation, salinity, inundation) of the changing vegetation community. Describe changes in vegetation over time and how they are indicative of site trajectory or benefit for biota. In the long term (>10 years), describe changes in marsh vegetation that may interact with sedimentation and elevation.	Vegetation (SI)
Highlight whether small starter channels (breach and length) remain stable, expand, or fill? Document cover, scour and/or sediment storage functions from constructed wood treatments or naturally occurring woody debris.	Constructed habitat features (SI, MSp)

Monitoring Strategy

The monitoring strategy is informed by an interrelated set of pre-project conditions, assumptions from regional knowledge, project objectives and design choices, monitoring questions, and management information needs. Various monitoring efforts will cover three project phases; pre-construction, implementation (the baseline), and post-construction.

To restore tidal marsh access and function for juvenile salmon with the 326-acre Smith Island site, the dike was removed at three locations; a total of 4,340 linear feet of dike was removed. Smith Island is now bounded by a new set-back dike to the west and City of Everett to the south. At Mid-Spencer Island, 1745 feet of dike was removed to allow greater tidal exchange and enhanced connectivity for juvenile fish rearing at the site. In addition to dike removal at Smith Island, one remnant natural channel was reconnected to Union Slough, one large, sinuous, bifurcated channel was constructed (City of Everett Mitigation Channel), and 15 smaller channels were excavated and connected to Union Slough. These smaller channels are called “Starter Channels” as their length and area, among other channel metrics, are more likely to change over time due to tidal exchange, sediment dynamics, and flow partitioning among these channels or other factors. At Mid-Spencer, excavated channels were constructed across the former dike footprint. Other important project components at Smith Island include woody material installation, connection or filling of agricultural ditches, and retention of forested area that will die-off from tidal inundation. Woody material was also installed at Mid-Spencer.

The initial monitoring strategy and evaluation of the projects will focus on the as-built baseline of dike breach connections, restored tidal hydrology, tidal channel configuration and dimensions, vegetation baseline and invasive non-native plants, sedimentation, and fish use (site access). Long-term monitoring

will focus on tidal channel development, changes in topography and sedimentation, succession of marsh vegetation, changes in woody material, invasive non-native plants, and seasonal fish use, focusing on juvenile salmon. This monitoring strategy is partially informed by anticipated outcomes and results, as discussed below.

Anticipated Outcomes and Results

The projects anticipate restoring tidal inundation on at least 360 acres across the Smith Island site and more than 70 acres at Mid-Spencer. In the long term, the sites are likely to be comprised of mudflat, estuarine emergent marsh (EEM) and emergent shrub/scrub marsh according to these descriptions:

- Mudflats: A stretch of bare land that is inundated and is not vegetated except by microorganisms.
- Estuarine emergent wetlands: Areas dominated by erect, rooted, herbaceous hydrophytes and wetlands that occur in tidal areas in which the salinity is equal to or greater than 5% (EPA, 2007).
- Estuarine scrub-shrub wetland: A wetland where the dominant vegetation is less than 5 meters in height and wetlands where salinity is greater than or equal to 0.5%. Total vegetation coverage is greater than 20% (EPA, 2007).

It is anticipated that river sediments will be deposited in Smith Island and Mid-Spencer at an accelerated rate as a result of restored connectivity, but will be highly variable due to the complex hydraulics and range of flow velocities within the sites. It is unknown whether enough sediment will enter the site to keep up with predicted sea level rise due to climate change.

The sites will include branching, blind tidal channels. Some of these channels were constructed, some are historically remnant, and some will form post-restoration. Additionally, at Smith Island, some ditches behind the dike were filled as part of construction and will likely remain filled. The changes may include filling, narrowing or an increase in channel size (longer, deeper, and wider).

Woody debris complexes, a natural component of estuaries, were constructed and other complexes are expected to accumulate naturally from on-site tree death and from delivery from off-site sources. This will create areas of habitat cover and local scour in channels. Woody debris may help retain sediment on the marsh plain within Smith Island and increase elevation diversity, which would be expected to support more rapid and wider marsh vegetation re-colonization. The retention of existing conifer trees is unlikely at Smith Island due to tidal inundation across subsided elevations, so no forest stands are expected. However, tree saplings may survive on higher elevation areas or be supported by nurse logs, as is observed at Mid-Spencer.

Juvenile salmon will access the new habitats from Union Slough and are expected to use tidal channels, tidal flats, and remaining riverbanks. As such, Smith Island will add juvenile rearing capacity in the Snohomish estuary.

Pre-Construction Monitoring

Pre-construction monitoring included estuary-wide fish monitoring at long-term index sites within the Snohomish estuary, more intensive fish sampling in Union Slough adjacent to Smith Island and Mid-Spencer, and off-channel monitoring in Mid-Spencer Island. Other off-channel sites in the Snohomish Estuary are monitored by NOAA-NWFSC and Tulalip Tribes, which provides reference information for Smith Island and Mid-Spencer comparisons. Pre-construction monitoring also includes water level, salinity, and temperature monitoring in Union Slough. Other ground-water level and water quality monitoring has been implemented at well locations within Smith Island proper or at adjacent locations. Vegetation monitoring was implemented prior to construction in 2018 as was photo point documentation.

Implementation Monitoring

Basic implementation monitoring included as-built survey information, such as acres of estuary created, channel modification length and area, dike breach dimensions, tide gates removed, and habitat features installed (wood complexes). Photo point and time-lapse monitoring of implementation was also accomplished.

Post-Project Monitoring

Post-project monitoring will include the continued collection of data to help answer monitoring questions that derive from the goals, objectives, and anticipated outcomes. Initial evaluation of project effectiveness will focus on the as-built baseline of dike breach connections including locations and dimensions, restored tidal hydrology, tidal channel configuration and dimensions, vegetation baseline, and fish use. Figure 3 shows the restored sites including the as-built project boundaries.

Long-term (>5 years) monitoring will focus on tidal channel development, changes in topography, succession and die-back of marsh vegetation, and seasonal fish use by salmonids with a focus on Chinook. The fish use data will be used to estimate juvenile salmonid abundance, timing, size, species composition, and density at Smith Island. It is anticipated that these monitoring results will contribute to estimating salmon rearing capacity at Smith Island and Mid-Spencer Island and, in combination with other monitoring, within the Snohomish Estuary as a whole.

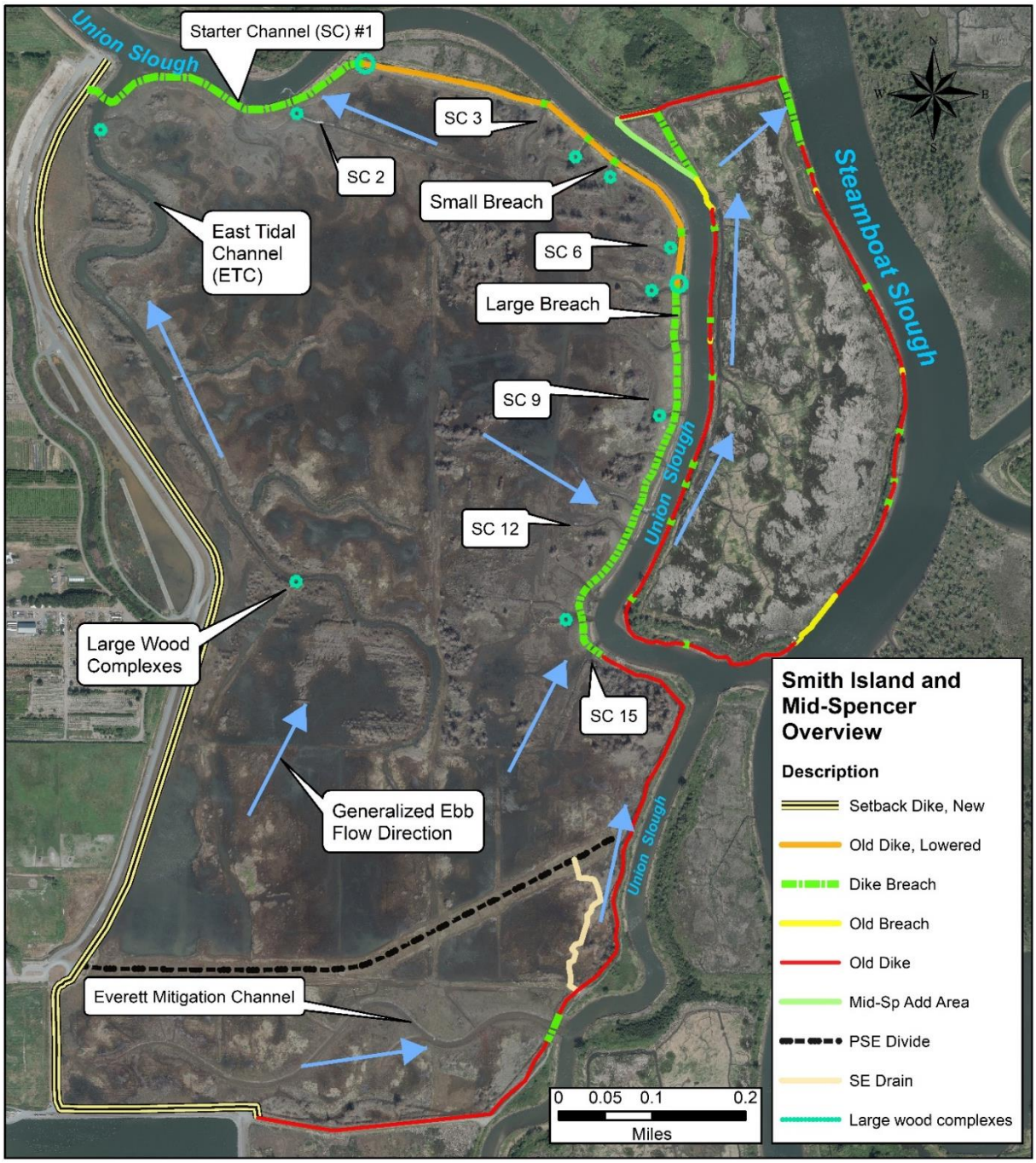


Figure 3. Smith Island and Mid-Spencer general site boundaries showing selected features and generalized flow direction.

Table 3 summarizes planned Smith Island and Mid-Spencer monitoring elements, tools or methods used and the measurement or data type created for interpreting project outcomes and supporting communication objectives above. These monitoring elements and associated deliverables are consistent with NOAA monitoring guidance and NOAA Special Conditions for Implementation and Effectiveness monitoring – named Tier I and Tier II by NOAA. These were incorporated as appropriate into progress reporting to grant agencies. More specific documentation of monitoring strategy, applicable monitoring questions, sampling methods and summary metrics are covered in the following report section.

Table 3. Smith Island/Mid-Spencer monitoring for NOAA FY15 award, titled, "Restoring Resiliency in Puget Sound Snohomish River Delta," implemented as part of PRISM Record Number: 16-2152. These performance metrics support NOAA Coastal Resiliency Awards (#NA16NMF4630008 and #NA13NMF4630142). Also see Appendix B.

Tier I Implementation Performance Metric	Units, Frequency, Products
Land Elevations	Restoration designs - prepared and stamped by a licensed professional engineer, will show existing and proposed elevations and cross-sections for structures, channels, wetlands, and floodplains. Post-construction as-built drawings - prepared by a professional land surveyor, showing final elevations and cross-sections of structures, channels, and land installed/altered by the project, and be surveyed into a known elevation benchmark and referenced to a standard geodetic datum.
Hydrology - Water Levels	Pre- and Post-restoration hydrographs - generated by collecting water elevations using at least three data loggers (upstream and downstream of a removed tidal restriction, and one to correct for atmospheric pressure) surveyed into the same elevation benchmark and datum as the as-built drawings and project plans. Pre- and Post-restoration photographs - document the new flooding regime to determine consistency with restoration goals.
Tier II Effectiveness Performance Metric	**Units, Frequency, Products**
Photo points	Establish ≥ 10 photo points; Photograph twice per year, once in June/July and once in Nov/Dec until determined not necessary. Deliver GPS coordinates, bearings, map and annual winter/summer photos covering grant award period.
Time-lapse photo/video	Establish at least one daily time-lapse camera/video at one large Smith Island breach location (prior to breaching) and maintain for ≥1 year post-breach. Provide video and rendering of breach.
Surface Elevation Tables	Establish ≥4 rod Surface Elevation Tables (RSETs). Measure RSET elevations semi-annually. Deliver GPS coordinates, RSET elevation benchmark, and elevation measurements covering grant award period. (planning/ installation with NOAA & Tulalip Tribes)
Sediment Pins	Establish ≥ 50 sediment pins based on channel proximity, elevation, and vegetation. Deliver GPS coordinates, initial sediment/pin elevations, and measure semi-annually covering grant award period.
LiDAR/ Aerial Photos	Acquire LiDAR (Light Distance And Ranging) at low tide post-breach. Provide LiDAR Digital elevation model, maps, and data collection report from vendor.
	Using available aerial photo imagery, establish baseline and biennial channel count, length, surface area calculations in GIS. Provide Table of channel characteristics and changes covering grant agreement period.

Table 3 Cont.	
Field Surveys (RTK-GPS) – also used for LiDAR ground control	Establish baseline cross-section and profile measurements at ≥ 5 channel locations. Measure annually. Provide plots of channel profile/cross-sections and changes covering grant award period.
Water level (covered above)	Establish "upstream" (Smith Island-2018) and "downstream" (Union Slough-2016) water level, temperature, salinity and barometric sensors (15-minute recording interval downloaded quarterly); Provide map of sensor locations and daily pre-breach and post-breach data.
Temperature	
Salinity	
Vegetation succession	Establish ≥20 5x5 m^2 random vegetation plots AND 12 line-intercept transects across elevation gradient. Sample 1 m^2 random quadrat among plots/line transects in years 0, 1, 2, 3, 5, 7, 10. Provide vegetation locations (mapped) and results covering grant award period.
	Map major vegetation classes and mudflat to estimate composition as a percent of total area and change (based on 2-year NAIP aerial photos/vegetation plot data). Provide baseline map covering grant award period.
Invasive vegetation	Perform annual post-breach invasive vegetation reconnaissance in restoration area. Map locations of invasive weeds and document treatment (type/area) covering grant agreement period.
Beach seine to quantify fish use (activity covered by NOAA-NWFSC/ Tulalip/ Snohomish County ESA 10A1a permit)	Collect monthly (Feb-Sept) pre-project and post-project fish use data at Smith Island, Mid-Spencer, Union Slough and System-Wide sample locations with beach seine. Provide data to NOAA-NWFSC for database. Provide map of sample site locations and tables/figures of fish use by month by major site. NOTE - data analysis to be performed by NOAA-NWFSC not covered by this grant award.
Reporting/ Communication	Create Data/Information Sharing Plan. Make data visible, accessible, independently understandable no later than 2 years post-data collection. Provide Snohomish County URL or other hosting URL (if NOAA Restoration Center/ NOAA-NWFSC).

Monitoring Results by Element

Each monitoring element described below reports, when applicable, monitoring goals and objectives, hypotheses, monitoring questions, monitoring methods and measurement, frequency and summary indicators, monitoring deliverable, analysis and interpretation, and communications. Several elements include remote sensing as a monitoring tool. Remote sensing primarily focuses on LiDAR acquisition and concurrent high-resolution ortho-rectified aerial photos.

1. LiDAR and Ortho Imagery

Figure 1 shows the location of the Smith Island and Mid-Spencer restoration sites within the lower Snohomish River and Estuary and the overlapping area targeted for 2019 LiDAR acquisition. LiDAR and high resolution aerial photos allow for remotely assessing the whole site or targeted areas for a suite of information including surface elevations, vegetation characteristics, and changing composition of channels, habitat, and vegetation, including deposition and erosion.

LiDAR data acquisition was completed in the summer of 2019 by Washington Department of Natural Resources (WDNR). Based on their expertise, WDNR developed specifications consistent with state-wide standards for pulse density, ground control, and aerial photo capture. WDNR now hosts the LiDAR on their Washington State LiDAR Portal (https://lidarportal.dnr.wa.gov/). The WDNR Vendor report is included in PRISM.

LiDAR collection occurred during a very low tide (-2.8 feet, MLLW datum) to capture the greatest extent of exposed ground surface. The collection area and specifications were the same as the geographic area sampled in 2009 (Figure 1, by the same vendor). Thus, this will facilitate some comparisons between the two collection events. High resolution (3-inch) 4-band (including near infrared) aerial imagery was also collected on nearly overlapping dates.

The primary (vendor deliverable) and derived products (Snohomish County post-processing) from the LiDAR and imagery collection are shown in Figure 4 and includes the following;

- Bare earth digital elevation model (DEM),
- First return (or highest hit) surface (a.k.a. digital surface model, DSM) which includes tree canopy or buildings,
- Vegetation height model which subtracts the bare earth elevation (DEM) from the first return (DSM) to estimate vegetation height,
- LiDAR intensity,
- Shaded relief model (Figure 5),
- A vegetation index called NDVI (normalized difference vegetation index),
- True color aerial imagery,
- False color aerial IR imagery, and
- Change analysis between 2019 and 2009 elevations – LiDAR differencing.

Various applications of the LiDAR data and imagery are included throughout this report. LiDAR and concurrently collected high-resolution aerial imagery will be obtained again within 5-10 years, if funding is available.

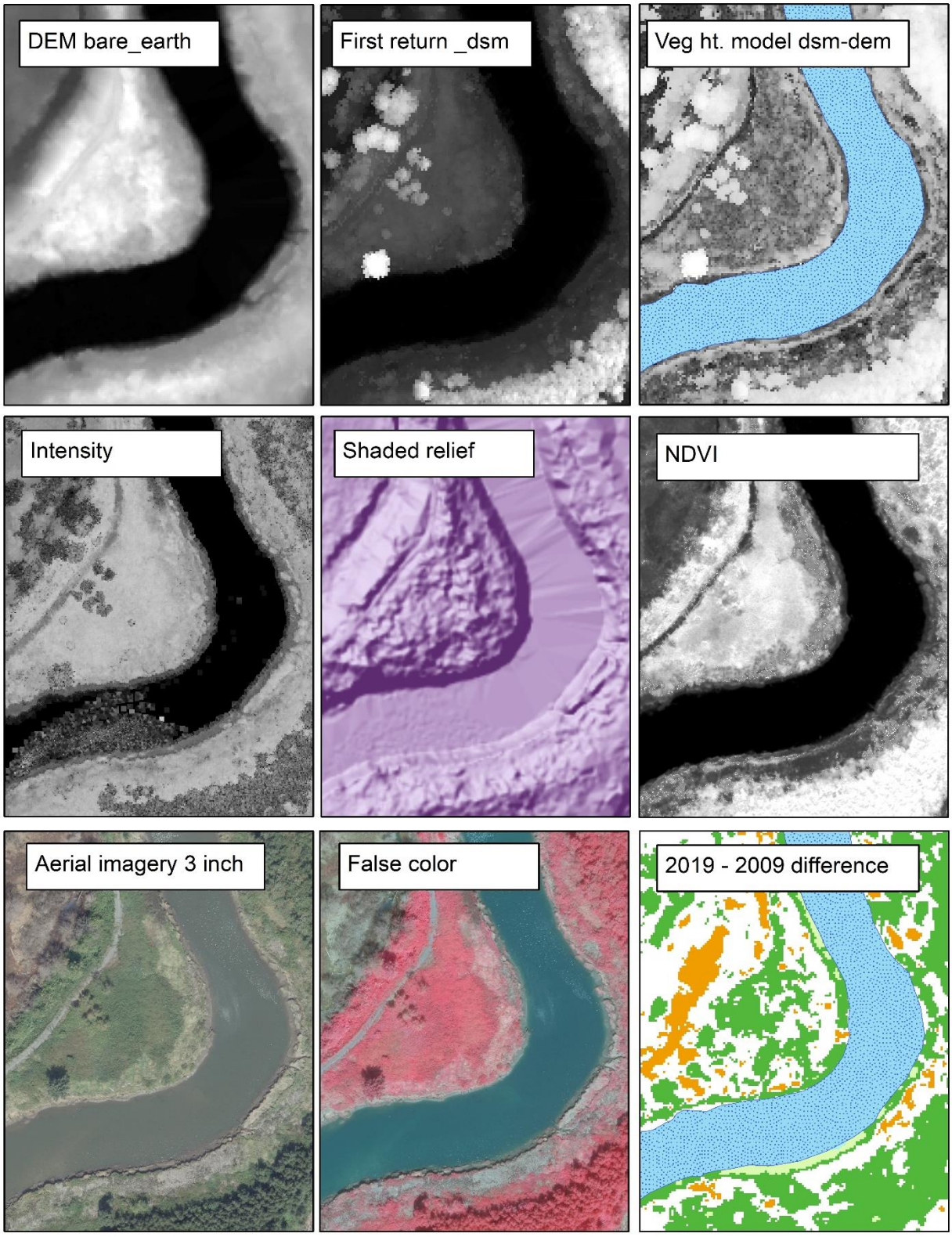


Figure 4. Examples of LiDAR and Ortho-imagery products suitable for topographic, vegetation, visualization and temporal analyses and comparisons.

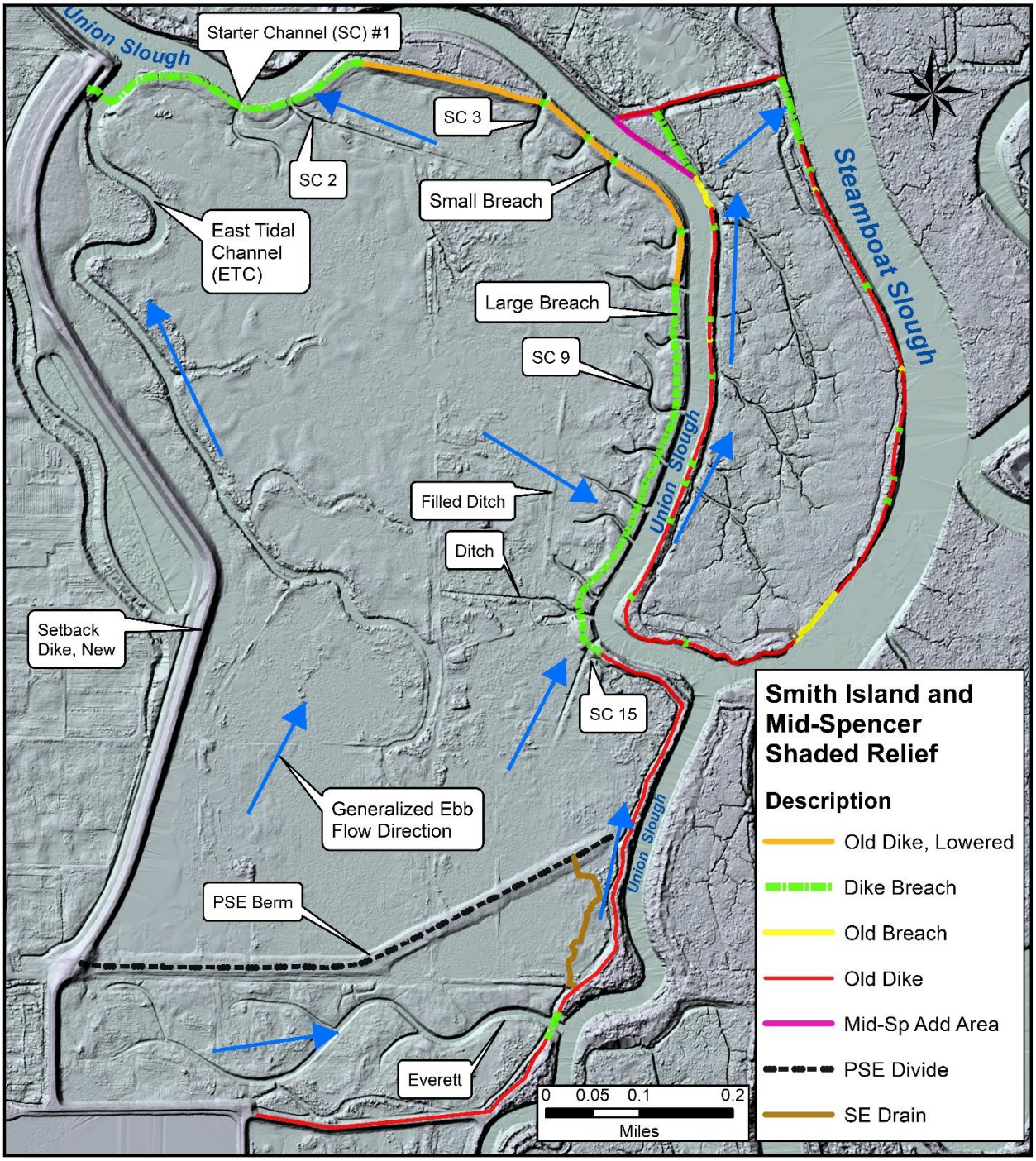


Figure 5. Shaded relief of 2019 LiDAR elevations highlighting various Smith Island landmarks.

2. Site Appearance and Change

As the sites change in appearance and function after restoration, an objective is to visually document changes and outcomes. Up until 2018, Smith Island was a mix of freshwater wetland and upland plant species with an abundance of reed canary grass, blackberries, and patches of willow, alder and conifer

trees. Additionally there were remnant nursery stocks of large trees. Mid-Spencer visually is an estuarine emergent tidal marsh with sedge grasses and cattails predominating. The remnant dikes or higher elevation marsh edge contain natural or planted Sitka Spruce trees.

Over time, Smith Island will change in appearance to resemble adjacent restoration locations where relatively recent tidal restoration has occurred, such as at Qwuloolt and Spencer Island. Over many decades, Smith Island will resemble Mid-Spencer Island in terms of vegetation and appearance of many complex channels and flow pathways. With this monitoring element, we will pictorially document many of the site changes and differences over time in vegetation, channel form, wood recruitment, and design features. This monitoring element is summarized in Table 4.

Table 4. Site appearance and change monitoring description from Snohomish County (2018). "D & I" refers to Data and Information Sharing outputs.

Element	**Photo/ Video -** **Permanent photo points/Time-lapse camera/ Ortho-rectified aerial photos**
Goal/Purpose	To pictorially document many of the site changes and differences in vegetation, channel form, and tidal exchange associated with restored processes, structural changes and functions.
Questions	Is Smith Island fully exchanging tidal sequences? Is the site storing sediment and/or is there erosion present within channels? Is the site showing die-off of canary grass and recruiting and growing natural marsh vegetation? Is the site forming channels? What is the changing composition of channel, habitat, and vegetation types?
Objectives	Obtain photo-documentation of the following site features: • Large dike breaches and lowered dike elevations, • Large tidal channels – east tidal channel, • Small tidal channels – natural, excavated, ditched, • Starter channel dike breaches, • Future mudflat expanse, • Lyngbye's sedge elevation, • Tidally flooded conifer stands, • Large wood structures, • New setback dike, and • Monitoring locations (Vegetation plots, sediment pins, fish sample sites) Dumping, vandalism, derelict vessels or other human disturbances will be recorded and reported to the site manager.
Methods	Digital photos with iPad, taken at 1.5 meter height on tripod/monopod; record bearing from digital compass, with date/time for tidal estimation; Assemble photo sequences throughout time. Aerial photos are described along with LiDAR collection. Time-lapse camera housing is secured in trees or atop large wood complexes. Time lapse interval is variously set between several hours or days.

Table 4 Cont.	
Number of units/ samples	Establish at least 10 photo point locations and 1 time-lapse camera location at one large Smith Island breach location prior to breaching.
Frequency/ Duration	Photograph twice per year, once in June/July and once in Nov/Dec until determined not necessary. Otherwise, years 0-as-built, 1, 2, 3, 5, 7, 10. Continuously recording time-lapse video during first year post-breach. High-resolution photos area anticipated to be available every 2-4 years, County-wide.
Deliverables **(D & I Sharing)**	Deliver GPS coordinates, bearings, map and annual winter/summer photos covering grant award period. Provide video rendering.
Evaluation/ Analysis **(D & I Sharing)**	Compile and compare photos over time to identify and highlight examples of conditions, process, and changes. Time-lapse shows full tidal exchange and range. Aerial photos qualitatively and quantitatively show areas of habitat/ channels/ vegetation types.

At Smith Island, 83 photo points were established in 2018-2019. Photos with multiple orientation were taken with a tablet computer and stored with the spatial position (GPS) in ESRI ArcCollector. Some earlier photos taken in 2016 or 2017 were suitable for use, as well. Locations were generally photographed in July and August 2018, prior to dike breaching and were after project completion in 2018 (August) and 2019 (April). Some photos do show construction activity at the time of dike breaching. Most (75 photo points) were established prior to breaching the dike. Some (8) were added post-breach and others may be added over time. Fifty points were designated as *Primary*, because of the number of pre- and post-breach photos obtained and photo capture of multiple directions. Others were designated *Secondary* due to the limited number of photos, replication of the type of condition, or potential for future exclusion or low value. Only time will tell which of the locations will be maintained. Locations are shown in Figure 6 and labeled (*Primary*, *Secondary)*. Eleven photo points were established at Mid-Spencer in 2019 (Figure 6). Post-constructions photos will be taken in 2020 and included in future reporting.

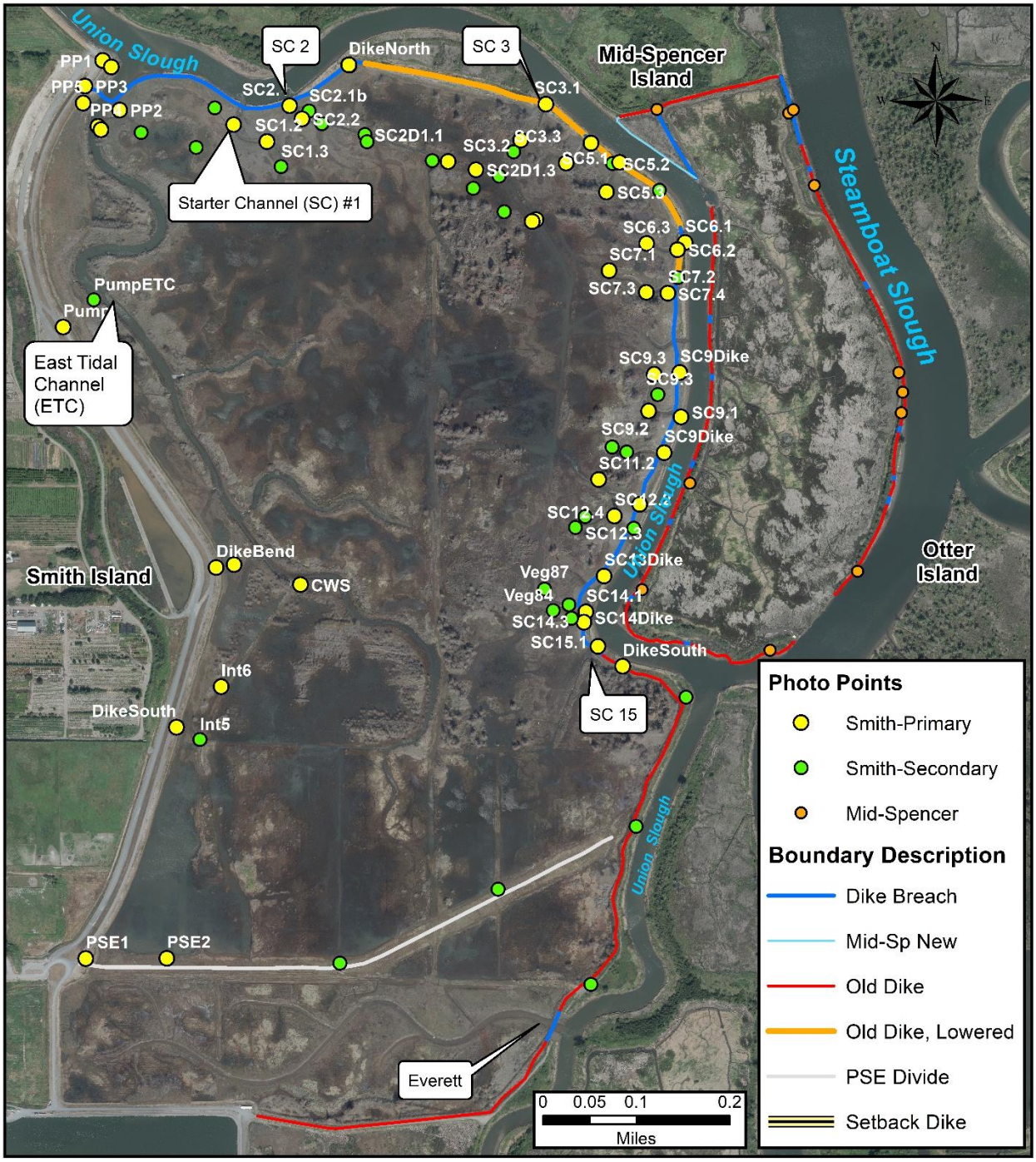


Figure 6. Locations of annual Primary and Secondary photo point monitoring.

Photos were almost exclusively taken at low tides in order to show the ground surface, channels, vegetation, sediment and differences with season. In 2019, the die off of vegetation within Smith Island was significant. Where the old dike was breached and lowered, some sedge benches along Union Slough appeared to colonize the former dike surface. A selection of photo points are shown in Figure 7 and Figure 8. All other photo points are included in Appendix C.



Figure 7. Photo point documentation of Smith Island East Tidal Channel mouth, construction, dike breach, flood tide and drainage. Union Slough, connected to Puget Sound, is at left in photos.



Figure 8. Photo points of Starter Channel 9.3b (different bearings), pre-breach (2017) and post-breach (2018 and 2019).

Other aerial photos obtained include ortho-rectified 3-inch high-resolution images accompanying 2019 LiDAR collection (Section 1). These aerial images capture significant detail and facilitate delineation of channel form and area and enumeration of tree blow down and large wood material (Figure 9). It is anticipated that future high-resolution aerial imagery will help to delineate changes in channel metrics, flow patterns, vegetation changes, and woody material, among other observations.



Figure 9. 2019 high-resolution aerial image showing the excavated Starter Channel 7 draining to Union Slough (right) through a breach in the historical dike (1:500 scale). Constructed wood complexes are visible (circled) as is other woody material that has drifted into the site.

Low elevation unmanned aerial vehicle (UAV) videography is featured at the Smith Island website. Additionally, time-lapse photography was used to generate a stop-motion video rendering of the initial dike breach (August 10, 2018) and construction prior to that date. Separately, time-lapse photography recorded subsequent dike removal and channel excavation at Starter Channel 9 and at Starter channels 13-15. Videography is featured here:

https://snohomishcountywa.gov/1150/Smith-Island-Restoration-Project

3. Sediment

Historical tidal marsh areas such as Smith Island and Mid-Spencer Island that were diked have subsided approximately 4 feet, partly because they have been isolated from river sediment supply. With restoration, the hydraulics of tidal exchange influences where river sediment is deposited or removed and, along with topographic elevation and vegetation changes, influences sediment accumulation. The rate and pattern of sedimentation, along with changes in subsidence, across Smith Island and Mid-Spencer Island will be a primary driving force behind future site conditions, including marsh development. Therefore, monitoring restored sediment processes is very important. Table 5 includes descriptions of the sediment monitoring effort.

Table 5. Sediment accretion and loss monitoring description.

Element	Sediment Accretion and Loss
Goal/Purpose	To document and understand future sediment dynamics from surface or sub-surface sediment processes after restoration, as these rates and patterns will affect marsh development and long-term site changes; also relative to predicted sea-level rise.
Questions	What is the magnitude and rate of sediment accretion among sample sites that vary by elevation, distance from Union Slough, and existing vegetation? When and where does newly accreted sediment or eroded surfaces support vegetation growth? Is the rate of sediment accretion equal to anticipated sea level rise? How does that compare to other estuary locations?
Objectives	The monitoring objectives are to measure sediment deposition (or loss) and ground elevation changes compared to baseline elevations, distance from Union Slough, and existing vegetation (or mud after initial die-off).
Methods	Up to four data sources may be used over time; RSETs, marker horizons (MH - feldspar and/or open plastic grids - 0.5 x 0.5 m^2), sediment pins, and topographic field survey using RTK-GPS. The baseline conditions will be established based on a combination of elevation information from RTK-GPS elevations of RSETs, Pins, and other as-built features at ground elevation such as ditches, cross-sections, and other ground points.
Number of units/ sample objectives	Establish 4 RSETs with 16 marker horizons. Establish ≥ 50 sediment pins based on channel proximity, elevation, and vegetation. Measurements will be made to nearest millimeter or tenths of inches. MH's and sediment pins may be re-placed over time.
Frequency/ Duration	RSETs/MH's and sediment pins are installed post-construction and field data is collected semi-annually after winter flooding and after summer vegetation growth. Semi-annual, seasonal sampling for up to the following duration – Year 0, 1, 2, 3, 5, 7, 10, and thereafter as feasible.

Table 5 Cont.	
Deliverables **(D & I Sharing)**	For RSETs, deliver GPS coordinates, SET elevation benchmark, and elevation measurements covering grant award period. For sediment pins deliver GPS coordinates, initial sediment/pin elevations, and measure semi-annually covering grant award period.
Evaluation/ Analysis **(D & I Sharing)**	Measure component elevation changes per time period (cm/yrs.); Evaluate net elevation change/ time (mm/yr.) including evaluation of shallow subsidence/expansion. Compare sediment accretion/erosion (cm/yrs.) by locations, vegetation type and elevation. Map sites and summarize deliverables. Note that changes in topographic measurement of elevations of profile, cross-section, cross-sectional area, thalweg elevation, channel slope, and channel length relative to established survey monuments may support interpretation of changes in sedimentation/erosion.

Rod-Surface Elevation Tables (RSETs) will help quantify site elevation changes due to both at-a-site sedimentation and a possible combination of shallow or deep subsidence or shallow or deep rebound in area-wide elevations at Smith Island and/or Mid-Spencer Island. An RSET involves very simple technology; it consists of a benchmark rod driven through the soil profile to resistance (typically 10-25 m depth; Figure 10 and Figure 11), Once established, a portable horizontal arm is attached at the fixed point anchored in concrete (Figure 10). Once attached, the RSET measuring device provides a constant reference plane that is used to measure down to the sediment surface using nine pins in four different orientations (Figure 11). Installation, maintenance and data collection followed methods described by the USGS (Cahoon D.R., and J.C. Lynch. 2003)[3] and was implemented in collaboration with the NOAA-NWFSC and Tulalip Tribes, who monitor other RSETs in the Snohomish Estuary and at the Qwuloolt restoration site (Rice et al. 2013).

[3] RSET Overview - https://www.usgs.gov/science/regions/northeast/maryland/science/surface-elevation-table
Mehods – https://pubs.er.usgs.gov/publication/70160049

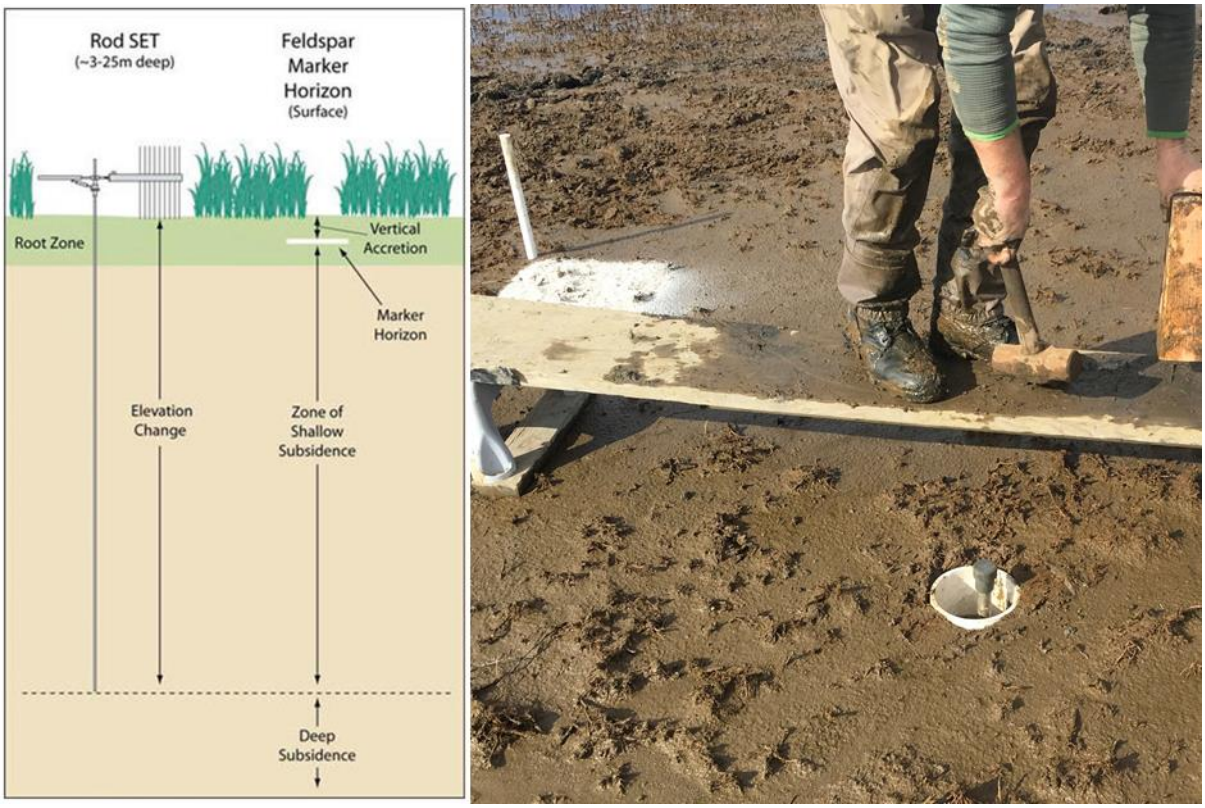


Figure 10. Basic schematic of a SET, including the rod SET, post, and SET measuring device (left), and the rod post and feldspar marker horizons (right). (Lynch et al. 2015).

RSET surface height measurements have confidence intervals of ±1.3 mm, a figure well within the annual rate of eustatic sea level rise (SLR). RSETs are the only tool that can capture surface elevation change with this precision. RSET data are usually complemented with shallow accretion monitoring using artificial soil marker horizons (MH – described below) typically made of feldspar, which simultaneously quantify rates of vertical surface accretion (i.e., sediment deposition). Surface marker horizons (MH - 0.5 x 0.5 m^2 of Feldspar clay) will be established using standard methods (Cahoon D.R., and J.C. Lynch. 2003) at each RSET location (3 per RSET site). These horizons will allow for measurement and visualization of sediment deposition as sedimentation depth above the MH is measured annually. MH's will be sampled using liquid nitrogen for freeze core sampling of cylindrical plugs or cylindrical plugs will be extracted using a transparent corer if depositional substrate is solid soil. The depth of sediment coverage over feldspar on each extracted freeze core plug will be measured at four locations around the plug with handheld calipers to obtain an average sediment deposition value per plug. The average sediment deposition value per monitoring event is based on an average from three plugs drawn from each separate MH. Over time, annual rates of sediment accretion will be estimated as the sediment depth to the feldspar marker horizon is repeatedly measured.



Figure 11. SET Install and measure. Top right: Marker horizons set on corner of SET area with feldspar and PVC posts. Top left: crew uses pneumatic hammer to install SET rods into the ground. Bottom left: SET measuring devices and nine pins used to measure down the sediment surface. Bottom right: liquid nitrogen used to take freeze cores from each marker horizon which is then used to measure the amount of sediment accretion over the feldspar layer.

The combined RSET/MH methods are necessary to identify the contribution of surface and shallow subsurface processes to surface elevation change at a specific site. Repeated measurements allow chronicling of net surface elevation change, which can be integrated with region-specific relative SLR (tide gauge data) to determine whether the surface elevation has kept pace with SLR over that time period. Initial SET elevations and changes will be compared to other Snohomish Estuary RSET sedimentation and accretion rates and locations (NOAA and Tulalip Tribes, un-published data).

In 2018 four RSETs were installed at Mid-Spencer Island (Figure 12) and initial baseline reading were made in November 2018. The total number of stainless steel rods used for each post was also recorded to provide an approximate rod depth (4-ft. rod sections). The top elevation and spatial location of each SET post and the four corners of the SET perimeter was recorded with an RTK-GPS receiver. Since installation, each site has been visited three times to make SET measurements (Table 6), though at this time only the first and last measurements are available. Because the first measurement was used as the baseline, there is only one data point to evaluate how sediment has accreted or eroded over time. In 2019, the amount of sediment accretion (deposit) overlying the feldspar marker horizon was measured

using liquid nitrogen to freeze a sediment core, which was then removed from the marsh for measurement (Figure 13). The amount (in mm) of the sediment layer covering the feldspar was measured with digital calipers.

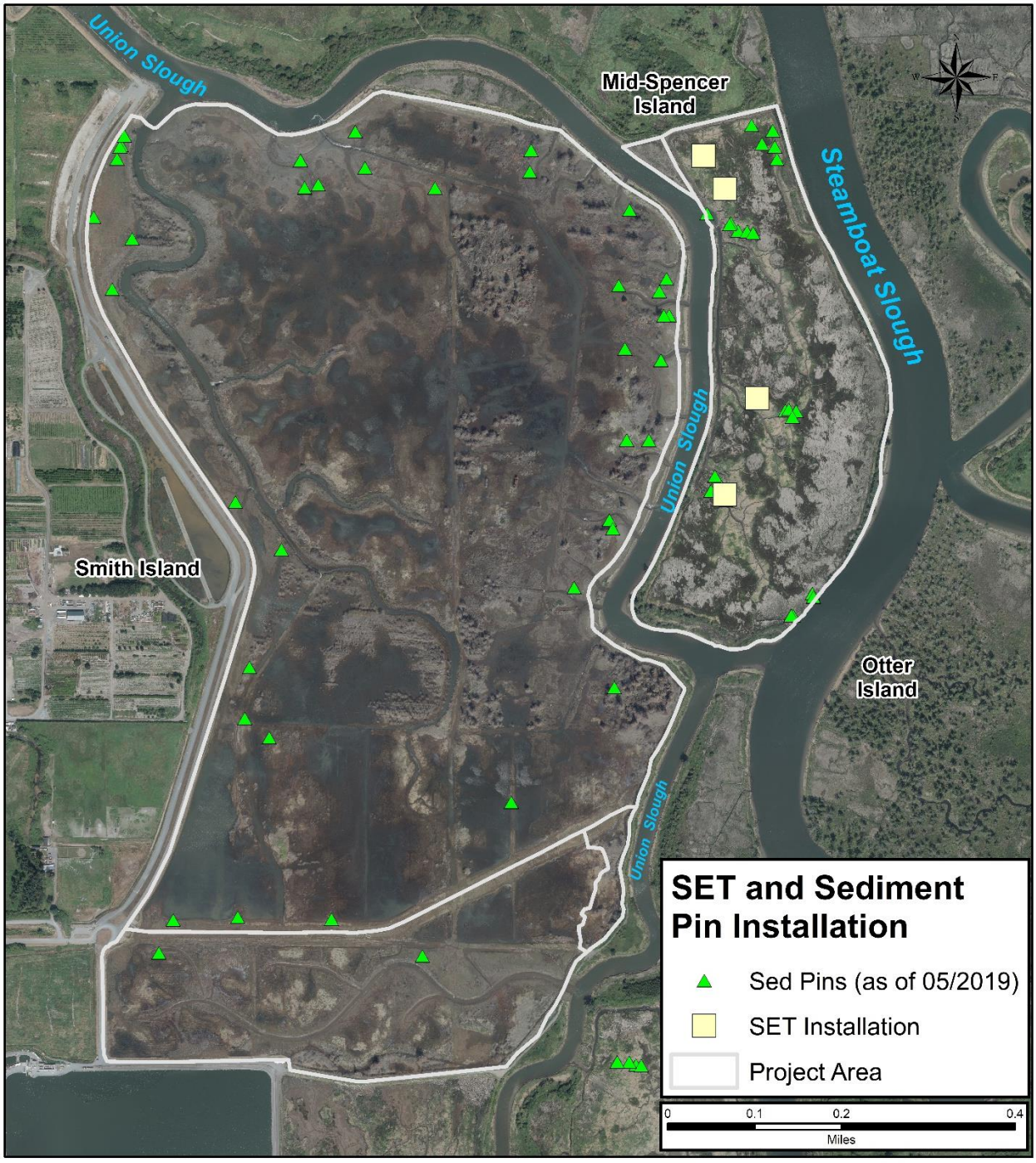


Figure 12. Location of four RSETs installed at Mid-Spencer Island and 64 sediment pins installed at Smith, Mid-Spencer and South Spencer islands. 2019 aerial photo.

Table 7 lists the average accretion of sediment at each SET site, the associated standard error, the total average accretion among all the sites, and the elevation difference for the top of the post at each site.

Table 8 lists the average accretion of sediment at the marker horizons for each site and the total average accretion for all the sites.

Table 6. Number of each SET, install date, latitude and longitude, final elevation of the top of the marker rod, number of rods used and approximate rod depth, and sample dates for each SET site in Mid-Spencer Island.

SET #	Install date	Latitude/Longitude	Marker rod elevation (NAVD 88 ft.)	Rods used	Rod depth, estimated	Sample dates
18.20	9/24/2018	48.020863/-122.156167	6.53	7	~28 ft.	1. 11/13/2018
18.21	9/24/2018	48.020345/-122.155577	6.89	8	~32 ft.	2. 05/09/2019
18.22	9/24/2018	48.016797/-122.154503	6.11	7	~28 ft.	3. 11/16/2019
18.23	9/24/2018	48.015239/-122.15433	5.84	5	~20 ft.	

Table 7. Change in post elevation, average SET measurement change and standard error for each site, and average change in SET measurements for all sites.

SET #	Post elevation change (NAVD 88 ft.)	Average SET measurement change (mm)	SET standard error
18.2	-0.031	8.03	0.79
18.22	0.087	7.53	1.59
18.23	0.018	11.25	2.77
Average	**N/A**	**8.94**	**1.11**

Table 8. Average marker horizon change and standard error for each site, and average change in maker horizons for all sites. See Figure 13 for photo of accretion over marker horizon.

SET #	Average Marker Horizon change (mm)	Marker Horizon standard error
18.2	19.15	2.03
18.22	22.08	2.51
18.23	12.65	1.59
Average	**17.96**	**2.79**

Due to the limited number of sampling dates since installation, it is difficult to draw any definitive conclusions. However, it appears that every SET location in Mid-Spencer Island has been accreting sediment over the 1.01 years between 11/9/2018 and 11/13/2019. The top elevation of the SET post at site 18.20 has subsided .031 ft. over the first year. This elevation change was not large enough to have an effect on the last SET measurements taken on 11/13/2019. It should be noted that the Mid-Spencer Island restoration project was constructed after the first two SETs measurements were taken. This may have caused minor disturbances to the surrounding area of some of the SETs which could have

influenced the latest measurement on 11/13/19. In coordination with NOAA and the Tulalip Tribes, these four SET sites will be visited at least annually to evaluate the sediment accretion and subsidence rates relative the other SET sites within the Snohomish Estuary network.



Figure 13. Example of sediment accretion over the white feldspar marker horizon at the Qwuloolt restoration project in the Snohomish estuary.

Finally, in 2020, up to 8 RSETs will be installed at Smith Island. Installation of RSETs was postponed until 2020, due to the uncertainty of tidal scour and hydraulics, ponding, vegetation die off, and irregular patterns of sediment mobilization and deposition. This is consistent with the timeframe of RSET installation at the Qwuloolt restoration site, which occurred 2 ½ years post-beach. RSETs at Smith Island will be sited at locations near dike breaches, existing channel networks and farther into the interior of the site to obtain greater spatial coverage.

Starting in 2016, sediment pins were placed at Mid-Spencer Island and thereafter at Smith Island in 2018 and 2019. Sediment pins are 1.5-2.5 inch PVC pipe (5-10 foot lengths) that are manually sunk into the marsh plain to a depth of 3-5 feet, depending on resistance (Figure 14). Approximately 3-5 feet of pipe is exposed above the marsh surface. The spatial position (*X, Y, and Z*) of the top of each post and marsh surface is acquired using RTK-GPS (Figure 14). The distance from the level top of the post to the marsh surface is vertically measured on 4 sides of the pin to the nearest centimeter using a stadia rod or metric measure tape graduated to 1 mm. The initial measure down height is recorded for each sediment pin. Pins are labeled in the field and GPS coordinates are collected for future tracking. The measure-down distance was measured semi-annually. The position of the top of the pin will be re-surveyed with RTK-GPS bi-annually to verify pin height and adjust the relative value of measure-down heights of earlier values if needed.



Figure 14. Example of sediment pins (grey PVC) placed on sedge bench at Mid-Spencer in 2016. Tong Tran installs sediment pin (left). Scott Dirks (Snohomish County) surveys in the sediment elevation and top of pin with RTK-GPS (shown).

To date, a grand total of 64 sediment pins have been deployed (as shown in Figure 12). This exceeds our initial objective of placing 50 sediment pins. It is anticipated that some sediment pins will inevitably be lost, bent over, or otherwise compromised – hence the large array of pins. We anticipate placing more sediment pins in future years to obtain better spatial coverage and replace lost pins. A description of sediment pin methods from the USGS (USGS 2012) is available from tidalmarshmonitoring.org.[4]

Figure 15 provides an example of the measure down distance recorded for four pins geographically clustered on the east side of Mid-Spencer Island showing the initial (2016) and later measurements. Over time the measure down distance decreases at all pins indicating accretion of the sediment at the base of the pin. Often the delivery of sediment and accretion is visually obvious, as highlighted in Figure 16.

[4] http://www.tidalmarshmonitoring.net/monitoring-methods-sediment-pins.php
http://www.tidalmarshmonitoring.net/pdf/USGS-WERC-Sediment-Pin-SOP.pdf

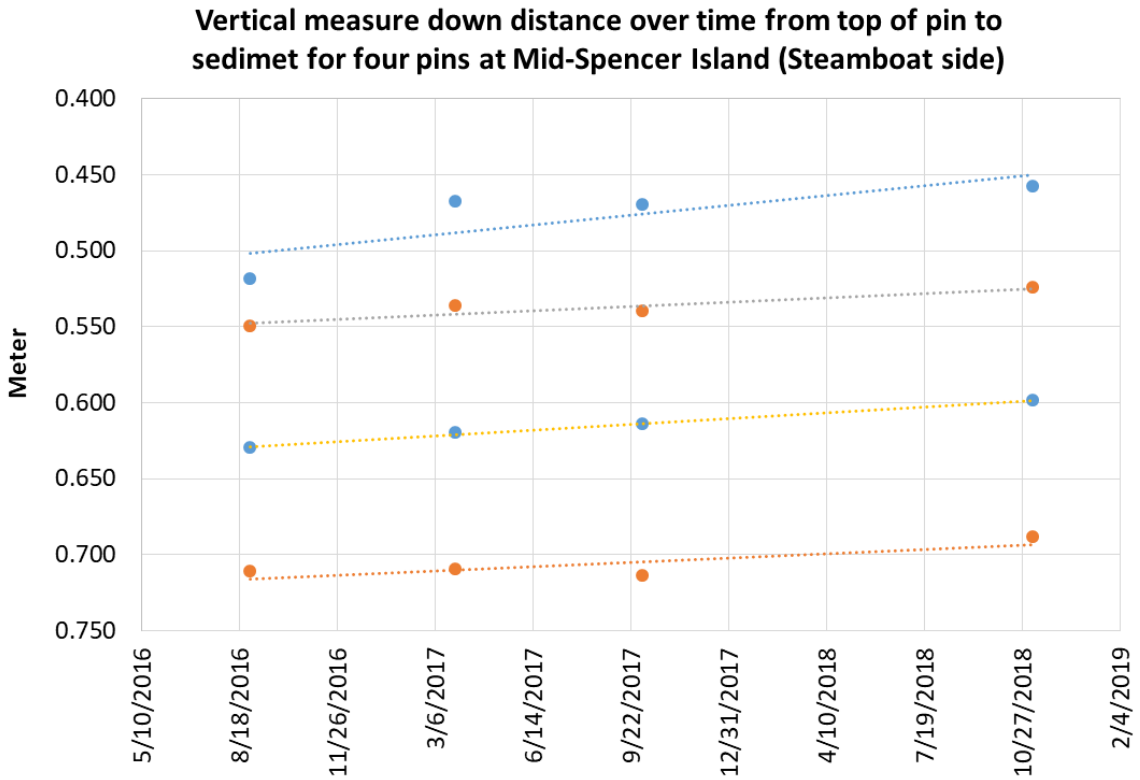


Figure 15. Sediment pin measure-down distance (y-axis) over time for four sediment pins at Mid-Spencer Island. Initial differences in measure-down distance reflects the difference in pin height above the marsh.



Figure 16. Unconsolidated sediment at Mid-Spencer Island over cattail marsh adjacent to Steamboat slough. Footprints highlight both the depth and lack of resistance in the recently deposited sediment.

The aggregate results to date of average total accretion and average rate are included in Table 9 and are shown in Figure 17 by individual sediment pins among sites for the time averaged accretion rate. The grand average among 26 sediment pins was 13 mm per year measured over a range of 565-994 days.

Table 9. Short-term monitoring of inferred sediment pin accretion at Mid-Spencer and South Spencer islands.

Location	Number of sediment pins	Number of observation dates	Days (last-first observed)	Average of total accretion (mm)	Average of rate (mm/yr.)
Mid-Spencer	**22**	**4.0**	**725**	**21**	**11**
Interior Mouth	5	2.8	580	19	9
Interior North	5	3.8	756	5	2
Interior South	4	4.5	756	10	5
Interior East (Steamboat side)	4	5.0	994	40	15
Mid-Island	4	4.0	565	38	25
South Spencer	**4**	**3.0**	**593**	**40**	**24**
NW-Island	4	3.0	593	40	24
Grand Total	**26**	**3.8**		**24**	**13**

In Figure 17, the most variable site is Mid-Spencer Mid-Island (MSM1-MSM4), where sediment pins were placed among the most varying individual locations, including bare marsh surface (MSM1), small tidal channel (MSM2), tidal channel bench (MSM3), and *Carex* marsh plain (MSM4). MSM4 was most similar to all other sites in terms of elevation and topography. Overall, it appears that the North and South sediment pin locations had the lowest accretion rates, whereas the sites closest to Union Slough (Mid-Spencer Mouth) and Steamboat Slough (Steamboat Side) had higher accretion rates.

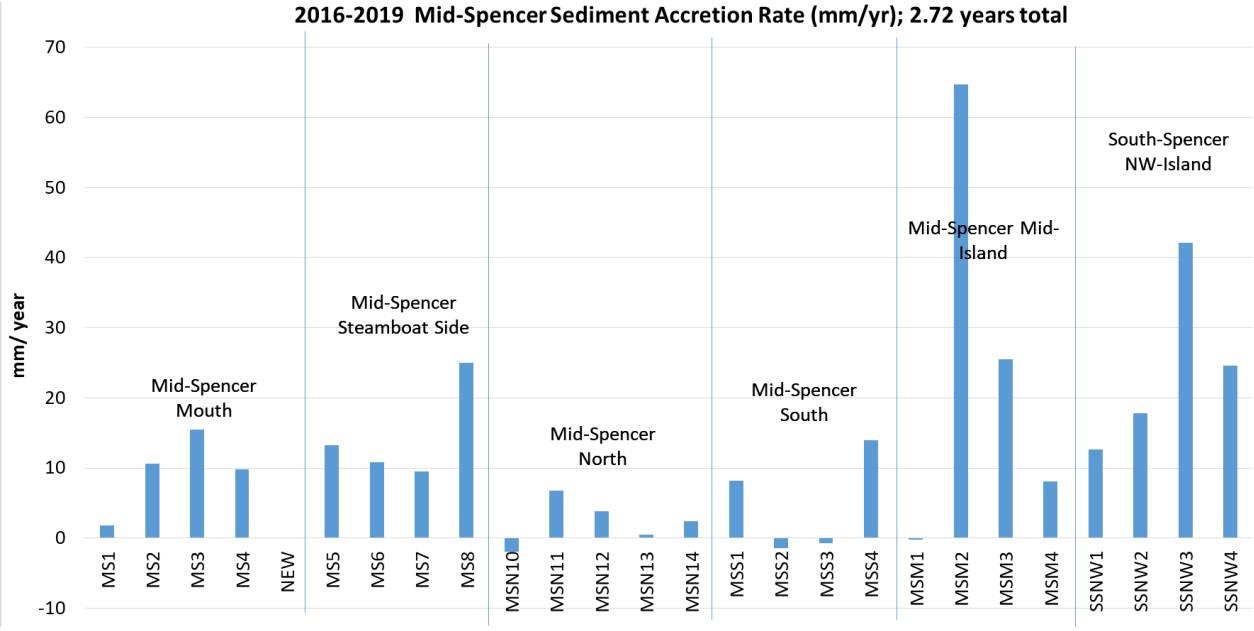


Figure 17. Individual sediment pin accretion rates among six sites at Mid-Spencer and South Spencer islands over more than two years.

The sediment pins placed at South Spencer Island also showed relatively higher accretion rate. These accretion rates will be updated over time and as more years pass, it may be possible to both differentiate seasonal rates of accretion (i.e., winter) and inter-annual variability.

Baseline LiDAR-derived elevation information was also obtained post-breach. These data primarily describe general elevation differences and channel form consistent with habitat-unit scales (1-10 m), but over time will also help describe differences in sedimentation or erosion across Smith Island. Illustrative of this are decadal elevation differences between baseline LiDAR (2019) and previously collected LiDAR from 2009; both collected at extreme low tide. Figure 18 shows both Smith Island (left panel) and Spencer Island (right panel). The Spencer Island site naturally breached prior to the 2009 LiDAR image. Since then, the main south-north ebb tidal flow has scoured (minor loss in blue) a sinuous flow path (white arrow), evident in the LiDAR differencing. Areas fringed with marsh vegetation have increased in elevation (orange and red) since 2009. Meanwhile, at Smith Island the primary differences between 2009 (pre-project) and 2019 (post-breach) are both the excavated channels (labeled) and breached (lowered) dike. Locations that have increased in elevation are primarily filled borrow ditches.

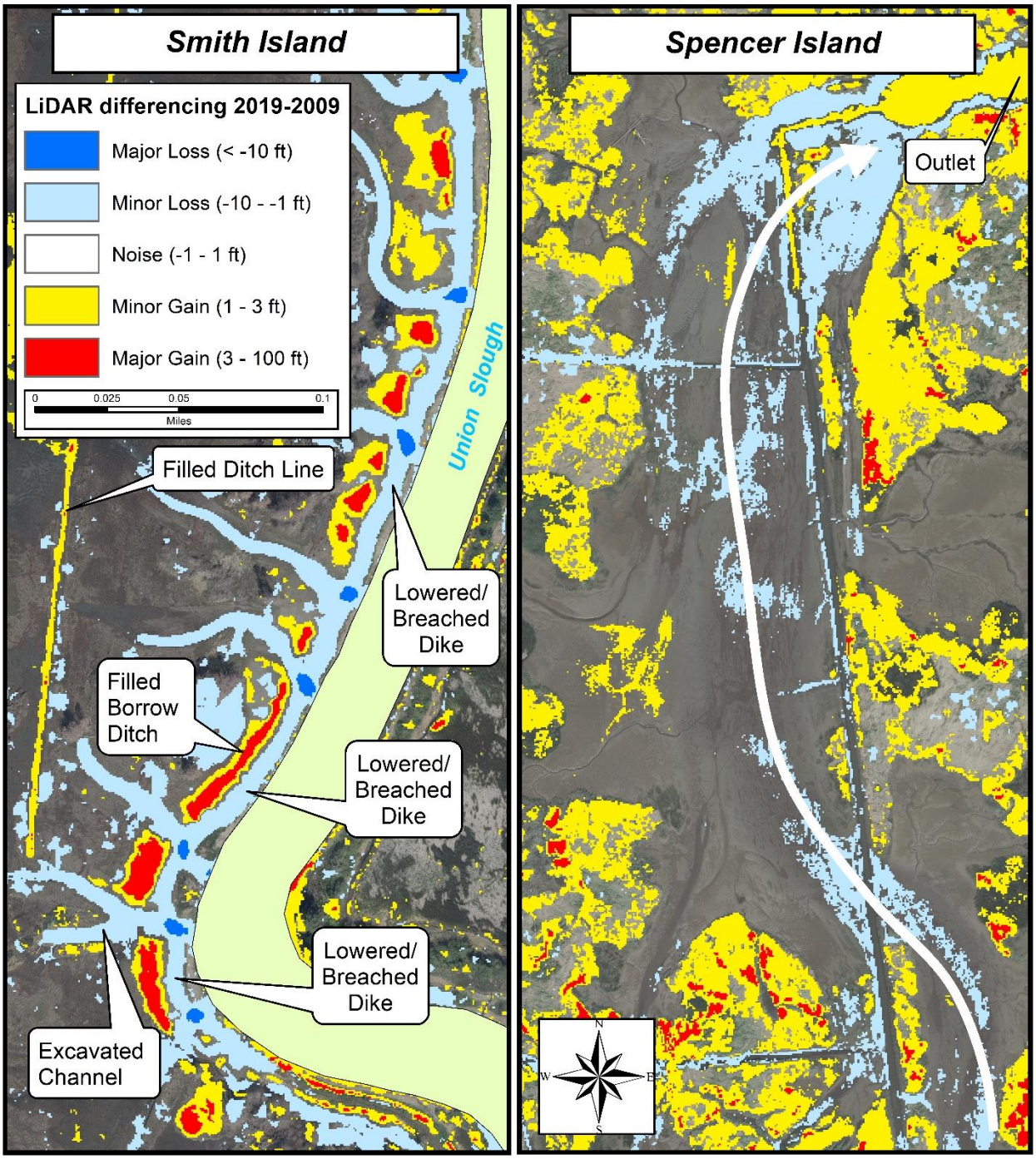


Figure 18. Analysis of elevation differences (legend categories) between 2009 and 2019 LiDAR elevations that illustrate sinuous channel formation and increasing elevation with marsh building at South Spencer Island (right panel). At Smith Island (left panel), decreasing elevation is associated with channel excavation and dike removal, whereas increases in elevation are associated with ditch filling. The minor gain in elevation at the outlet of Spencer Island is due to tidal elevation differences between 2009 and 2019 collection times. Otherwise surfaces are bare, except for Union Slough.

4. Tidal Prism - Hydrology/Water Quality

Marsh restoration and functional benefits for fish depends on restoring tidal hydrology. The restoration objective at Smith Island and Mid-Spencer Island was to create full tidal inundation and evacuation that tracks tidal exchange in Union Slough. Hydrology was monitored at Smith Island in order to describe the pre-project water level conditions and post-project restored hydraulic connectivity. Continuous water sensors (CWS) with water level, salinity and temperature were placed at fixed "upstream" (Smith Island, East Channel) and "downstream" (Union Slough) locations. One sensor measuring barometric air pressure and air temperature was also deployed on-site to provide compensation for tidal stage relative to air pressure. A map of sensor locations is provided in Figure 19. These sensors are part of a wider network of sensors deployed in the Snohomish Estuary and maintained by NOAA-NWFSC to document tidal exchange, temperature and salinity among main and distributary channels and at selected off-channel and restoration sites (Hall et al. 2018). Appendix D includes a map of estuary-wide sensor deployment locations. The data will be made available to NOAA-NWFSC to incorporate with the Snohomish Estuary-wide network of sensors used to calculate the proportion of time habitat conditions are in each of the mixohaline habitat types (Cowardin et al. 1979); polyhaline (18 – 30 parts per thousand; ppt), mesohaline (5 – 18 ppt), oligohaline (0.5 – 5 ppt), and freshwater (0 – 0.5 ppt (see Hall et al. 2018).

Pre-breach hydrology monitoring was conducted in Union Slough, the East Tidal Channel, and in groundwater wells. Pre-breach data was collected primarily for a year, July 2013 – October 2014. The pre-construction wells, Union Slough, and relic tidal channel sensor locations within the inundation area were removed prior to construction. Implementation (as-built) monitoring was conducted in the interior East Tidal Channel and on Union Slough as the project construction was being completed and for several months after. Post-construction monitoring has continued in the interior East Tidal Channel and on Union Slough.

For analysis and comparison between monitoring intervals, subsets of the data collected are shown below. Pre- and post-restoration hydrographs derive from water elevations generated from at least two sensors/data loggers (upstream and downstream of a removed tidal restriction, and one to correct for atmospheric pressure) surveyed into the same elevation benchmark and datum as the as-built drawings and project plans. Table 10 describes the monitoring goal, objectives, methods and more for hydrology and water quality.

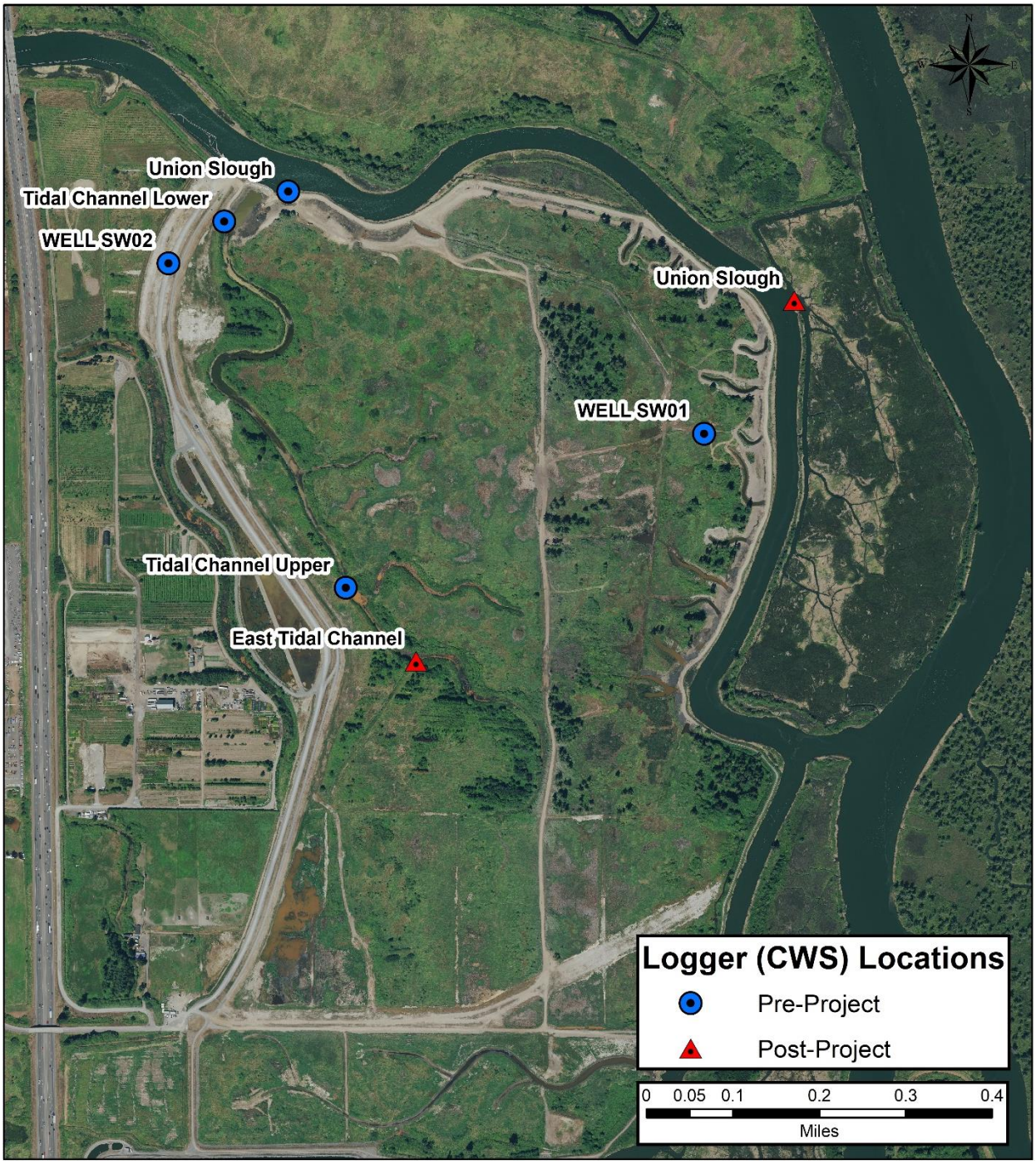


Figure 19. Smith Island water level, conductivity, and temperature monitoring locations.

Table 10. Hydrology and water quality monitoring description.

Element	Hydrology - Water Levels, Salinity, Temperature
Goal/Purpose	To document restoration of full tidal exchange and water quality characteristics.
Questions	Is Smith Island fully exchanging tidal sequences – flood and ebb? What is the maximum extent of tidal area? What is the range in water temperature? How does that compare to other restoration or reference locations? What is the range in bottom salinity? How does that compare to other restoration or reference locations?
Objectives	Establish Union Slough (downstream) and Smith Island (upstream) water level sensors to continuously record tidal elevation, temperature, and salinity
Methods	Deploy calibrated water level sensors to known elevation using slotted PVC well casing apparatus that is open to atmosphere and surveyed into the same elevation benchmark and datum as the as-built drawings and project plans. Sensors will be downloaded quarterly using manufacturer's software, sensors will be field checked for calibration and re-deployed.
Number of units/ samples	Establish three continuously recording pressure sensors (one of which is for collecting ambient barometric pressure) that also record temperature (Celsius) and conductivity (salinity). The words "sensor" and "logger" are used interchangeably.
Frequency/ Duration	Water surface elevations are continuously collected every 10 minutes, Years 1-3. In Year 1, GPS water edge at spring high tide.
Deliverables **(D & I Sharing)**	Pre- and Post-restoration hydrographs. Also supported by pre- and post-restoration photographs to document the new flooding regime in comparison to pre-project baseline.
Evaluation/ Analysis **(D & I Sharing)**	Document the new flooding regime to determine consistency with restoration goals. Inundation area; Tidal elevations in Union Slough and Smith Island; Estimate of Tidal Prism and volume exchange; Daily, monthly and seasonal min/max/average temperature and salinity. Seasonal salinity characteristics and relevance to vegetation changes and fish use.

The continuous water sensors (CWS) recording conductivity, temperature, and depth were the Schlumberger diver and Solinst brands. The method theory is the same between the sensors. The diver product manual[5] was used to establish installation and measurement guidelines. Figure 20 illustrates the installation and establishment of a baseline for the computational process and photo documents the installations.

[5] https://diver-water-level-logger.com/files/media/Downloads/m2-1111ediver.pdf

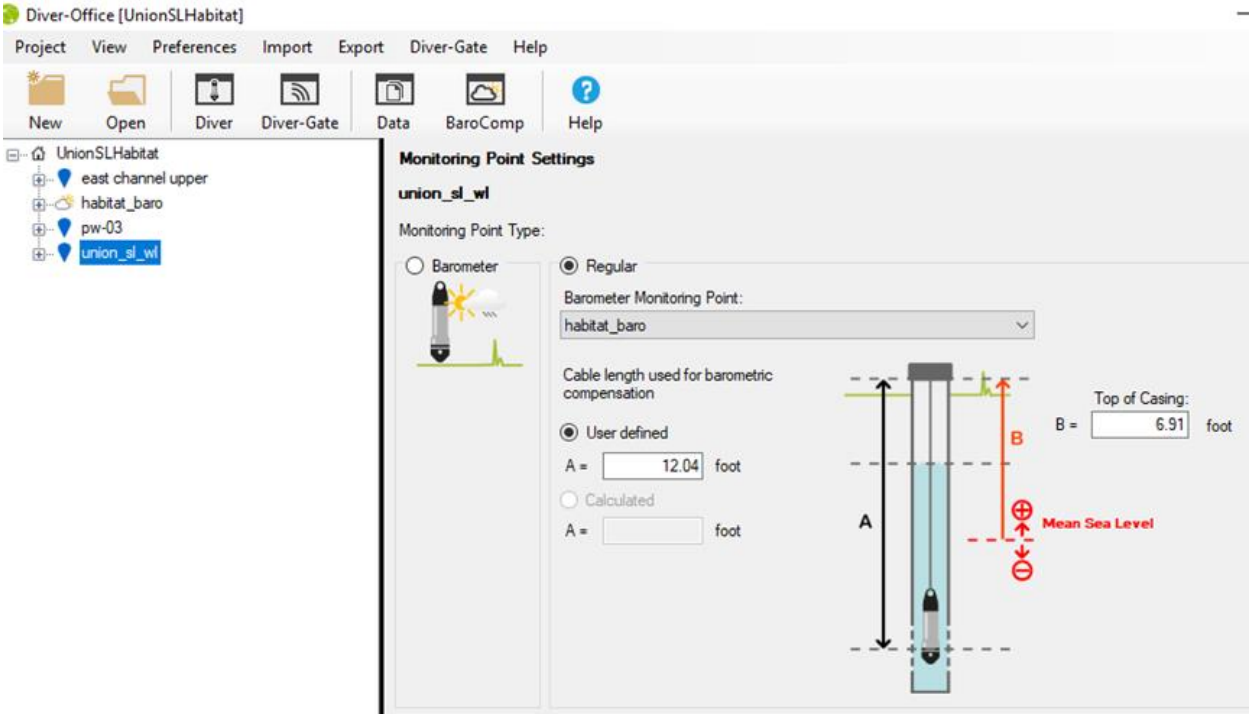


Figure 20. Installation and water level data collection illustration from Diver Office© software, provided by Van Essen Instruments January (2016) Van Essen Instruments. All rights reserved.

The sensor installation was accomplished by mounting a PVC pipe inside of a well casing below ground (pre-project) or onto a piling for a stable logger housing (Figure 21). Each water level logger was suspended from an attachment point on the well cap using braided fishing line and installed inside a 2 ½ inch PVC pipe sized appropriately for the height of tidal exchange. The PVC pipe had an open bottom and was perforated with holes drilled in the section the logger was suspended. The well pipes also had debris screening. The loggers were deployed with anti-fouling screens supplied and recommended by the manufacture. The manufacture's software and methods were used for calibration, compensation and data processing.



Figure 21. Union Slough (left) and Smith Island interior tidal channel (right) water level, conductivity, and temperature logger installations.

The fixed sensor elevation "measure down" was established by measuring tape from the sensor to the fixed survey location (cap top) to establish a staff elevation. A barometric pressure data logger was separately placed in a central location between Smith and Mid-Spencer islands. The barometric data was used to compensate for atmospheric pressure and pressure variations localized to the water logger locations. The logger software was used to compensate the water level pressure with barometric pressure and calculate the final water level elevation based off the fixed measure down length and surveyed staff elevation. Survey elevation data was collected with Trimble real time kinematic (RTK) R-10 antenna corrected to a local Virtual Reference Station (VRS).

Pre-project hydraulic monitoring was conducted concurrent with and in support of the project design phase. Ground-water level, the interior East Tidal Channel surface level and Union Slough tidal water level were collected in 2013 and 2014. The ground-water wells were removed prior to construction and dike breaching. The Union Slough logger was also moved due to its location within the dike breach area.

The baseline pre-project water level monitoring in Union Slough (Figure 22) is demonstrative of unimpeded tidal and river water level. Figure 22 shows several months of the pre-project hydrograph for Union Slough, the two groundwater wells and the two East Tidal Channel loggers. The two ground-water locations show tidal influence on the ground-water level throughout the interior of Smith Island behind the dike. The ground-water at each location was near the subsided ground-surface level. Although the tide did play a role on the diurnal water level within the disconnected Smith Island interior, the elevation range was muted and clearly disconnected from full inundation due to the perimeter dike. The tidal influence was also seen in the surface water within the relic tidal channel, which was connected to a tide gate that effectively drained the East Tidal Channel below the groundwater elevation.

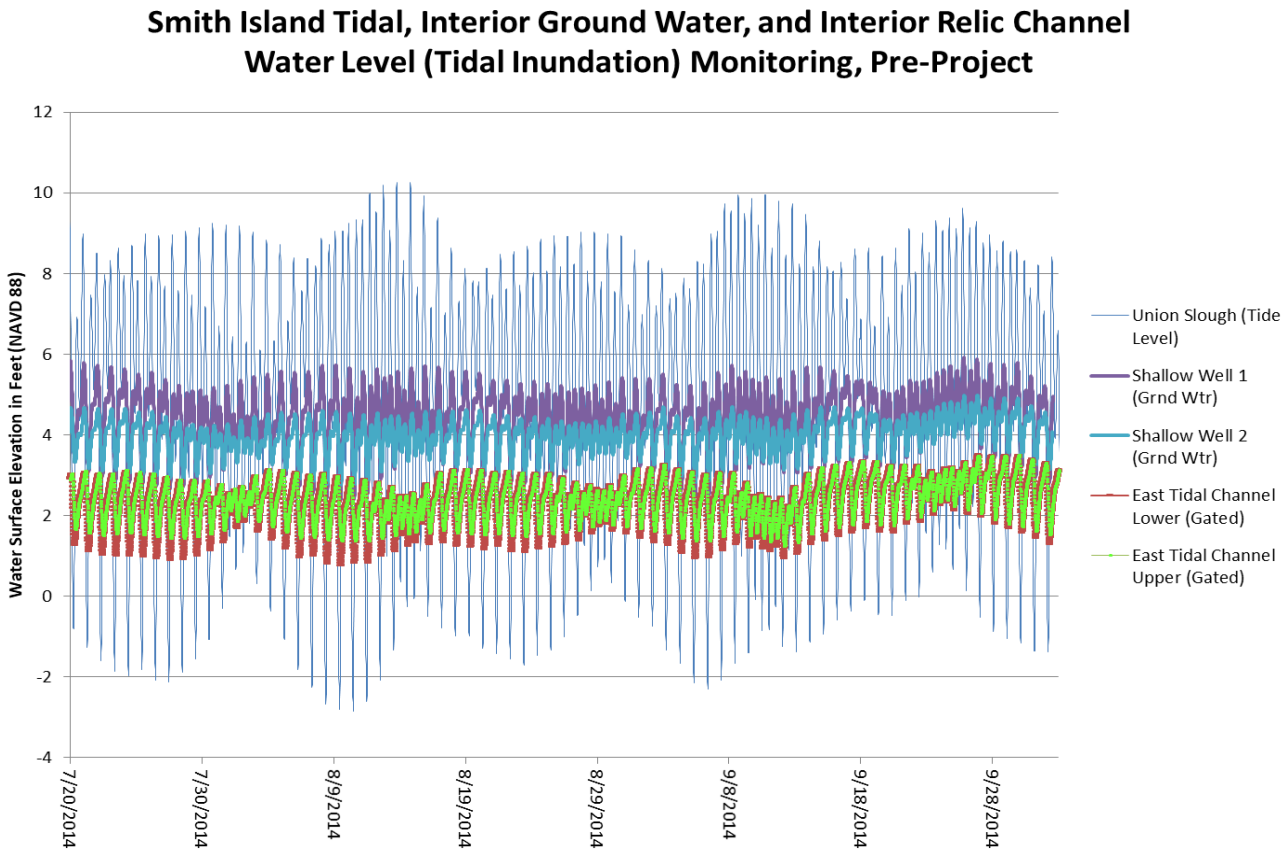


Figure 22. Pre-project water level monitoring hydrograph at Smith Island.

Figure 23 highlights an example of the diurnal (24-hour) tidal exchange in Union Slough and the tidally-influenced water level responses among the groundwater wells and East Tidal Channel. Relative to the high tide in Union Slough, the tidal influence on the groundwater wells is muted and the peaks are notably out-of-phase with Union Slough. Additionally, the water elevation in the East Tidal Channel is both muted and out-of-phase, as the influence on the upper logger was delayed relative to the lower logger which was closer to the tide gate and dike perimeter.

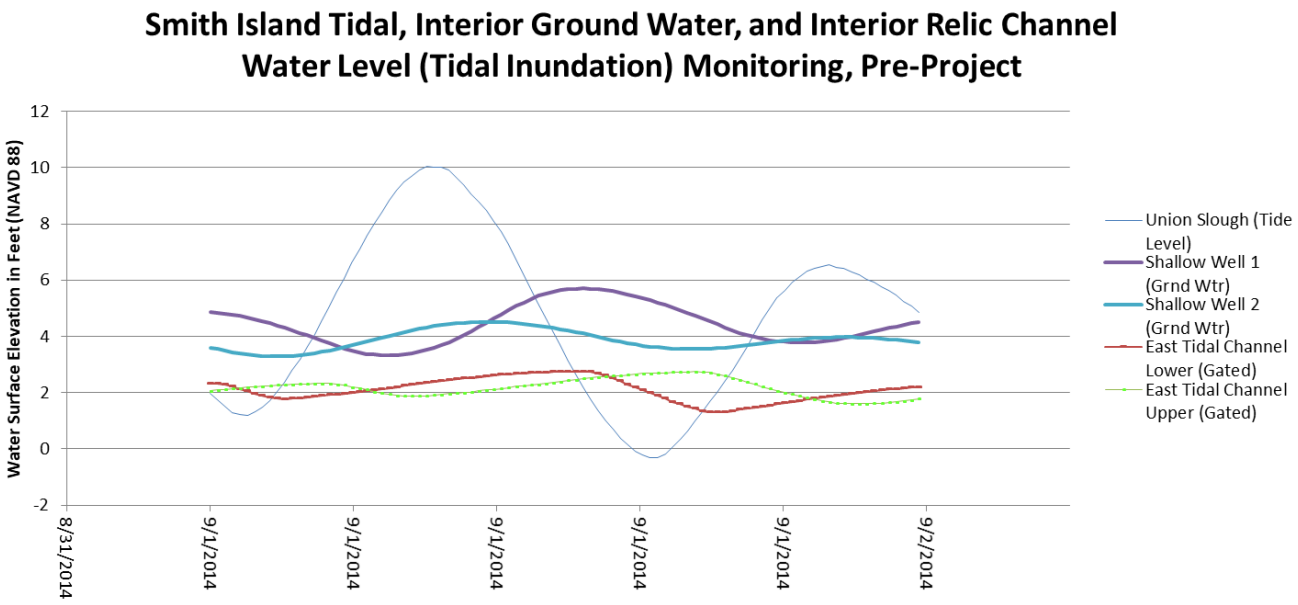


Figure 23. Diurnal hydrograph snapshot of pre-project water level monitoring at Smith Island.

Post-project hydraulic monitoring continued in Union Slough with a new logger location across Union Slough near Mid-Spencer Island (Figure 19). The interior area behind the removed dike and constructed channels was monitored near the pre-project upper East Tidal Channel location. In addition to the proximity (comparability) to pre-project monitoring, it was a location well within the interior of the breached site and with enough channel depth to detect water inundation lower in the tidal exchange sequence. The interior Smith Island logger was placed on September 5th, 2018 after the East Tidal Channel and first 5 starter channels (out of 15) were connected. The data representing the interior hydrograph during construction and approximately 3 months after construction, is graphed along with the Union Slough water level in Figure 24. The location of the interior water level logger was such that, as the water drained from the project area, the water level dropped below the sensor at tides below ~1.4' NAVD 88. This level indicates the bottom elevation of the interior tidal channel at the logger location. Overall, the East Tidal Channel water elevation tracks the water level in Union slough as tides are fully exchanged – though the lower tidal elevation in the upper East Tidal Channel does not match the lowest elevation of ebbing tides in Union Slough.

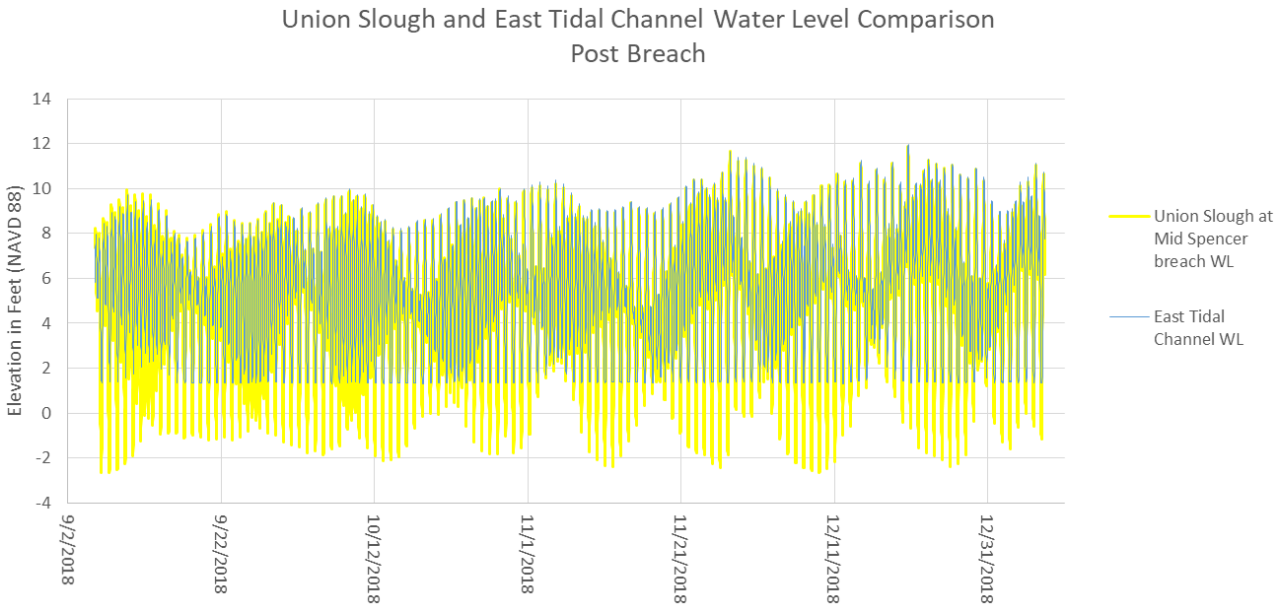


Figure 24. Post-breach water level hydrograph comparison between Union Slough and Smith Island East Tidal Channel.

Subtle changes are present in the tidal exchange mid-construction when the interior project tidal level was less than Union Slough by ~0.3 of a foot. This observation is shown in a 9-day hydrograph (Figure 25) and a single day hydrograph (Figure 26). These tidal differences in elevation, and with some lag time, between Union Slough and the East Tidal Channel occurred during construction prior to when all tidal breaches connecting to Union Slough were completed. Upon project completion, the flood tidal inundation levels were within ~0.1 foot elevation (Figure 27).

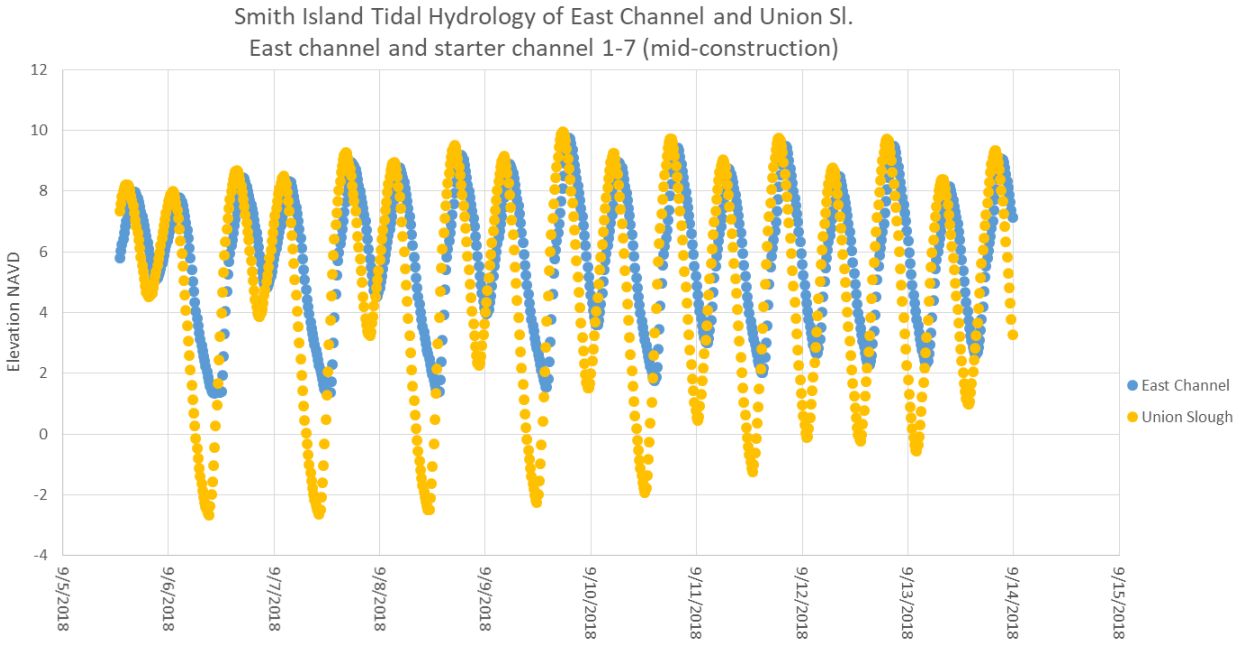


Figure 25. Mid-construction, nine-day hydrograph comparison between Union slough tidal level and the interior East Tidal Channel of Smith Island.

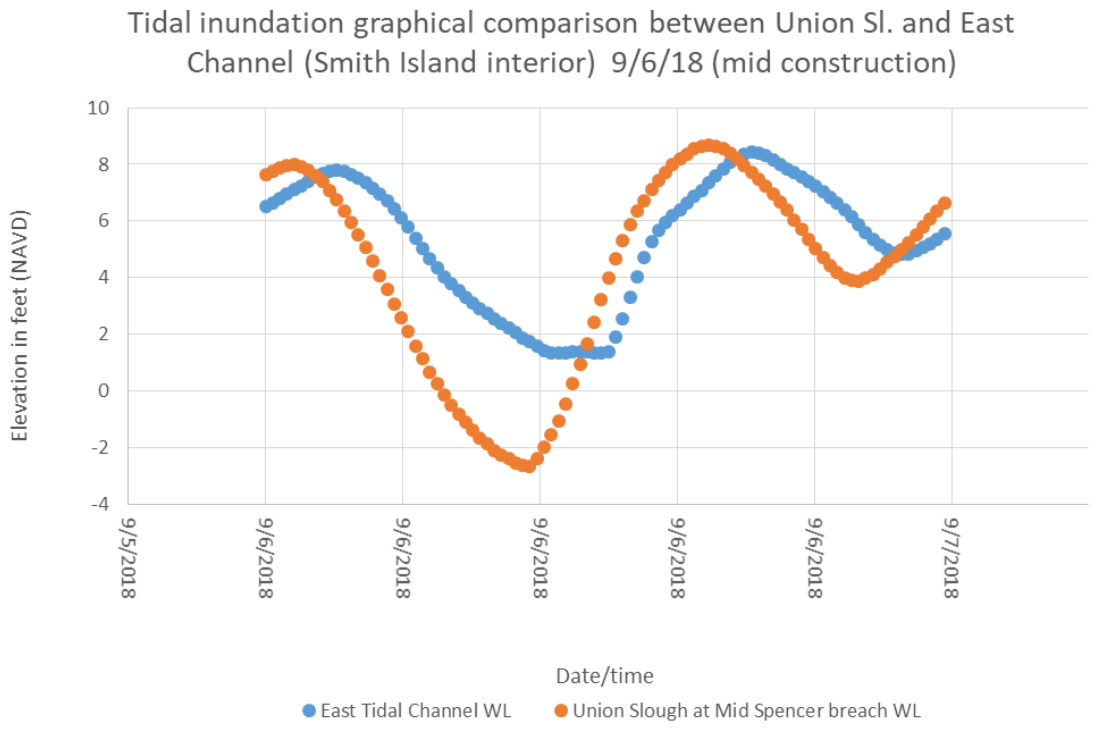


Figure 26. Mid-construction, 1-day hydrograph comparison between Union slough tidal level and the interior East Tidal Channel of Smith Island.

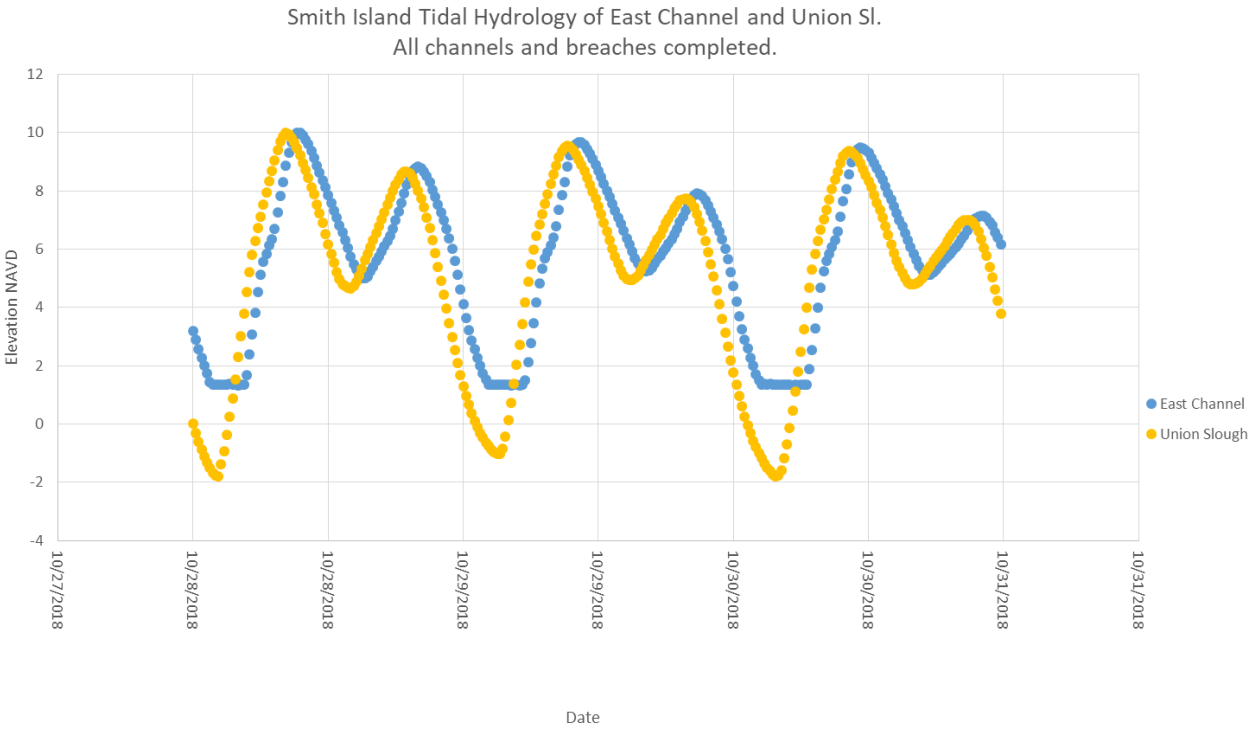


Figure 27. Post-construction, 3-day hydrograph comparison between Union slough tidal level and the interior East Tidal Channel of Smith Island.

The results also show that the tidal exchange is delayed within the Smith Island interior compared to Union Slough by approximately 1.25 hours on an incoming tide and nearly 2 hours on an outgoing tide. The slight flattening of the incoming tide level observed within each of the hydrographs likely indicates the point at which the water level rises above the interior tidal channel banks and then, more slowly, fills the reconnected floodplain.

Lastly, a comparison was made of the difference in daily maximum water levels between Union Slough and the Smith Island interior tidal channel. Figure 28 shows the elevation difference, in feet, of the daily maximum water level. A positive measurement indicates that Union Slough had a higher maximum water level than the Smith Island interior channel for that day. Conversely, a negative (<0) measurement indicates that the daily maximum water level within the Smith Island Project was higher than within Union Slough. The vertical accuracy of the survey equipment is generally +/- 0.07 feet. This plot of tidal elevation difference by date shows that as more of the breaches were completed (tidal starter channels 6 – 15, as labeled by date of completion) from September 5 to September 30, the tidal elevation difference between Union Slough and the East Tidal Channel became less over time as the site became fully connected. There is some indication that higher river flow further raises water level within the site (more negative value) compared to Union Slough.

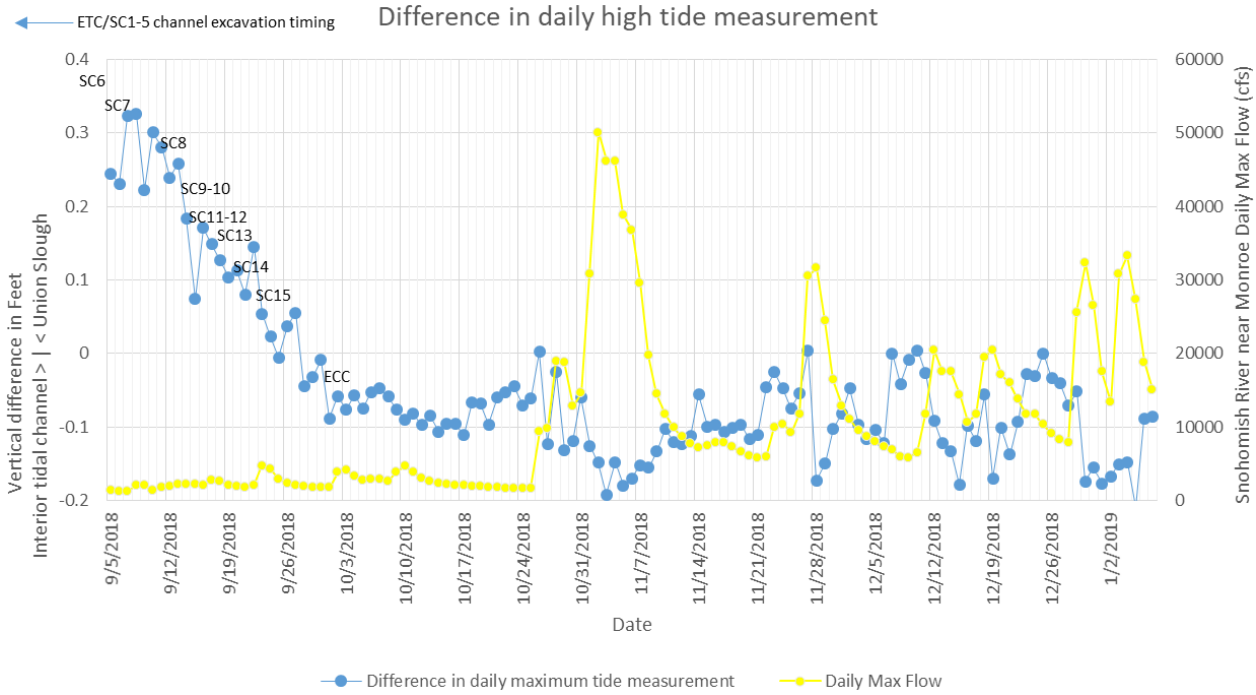


Figure 28. Relative difference in tidal elevation between Union Slough high tide water level and the Smith Island interior East Tidal Channel during the course of constructing additional starter channel breaches (SC7-ECC). ECC is the City of Everett Tidal Channel.

Water conductivity data was collected and compared between Union Slough and the Smith Island interior tidal channel, as shown in Figure 29. Conductivity levels are used to detect the tidal water versus fresh water influence in the restored tidal interior compared to the Union Slough channel. The East Tidal

Channel sensor was subject to dewatering each tide cycle below ~1.4' NAVD, consequently. The conductivity within the interior tidal channel follows closely the tidal- and river-water influenced conductivitiy readings found in Union Slough. Also because the sensor within the East Tidal Channel was located at a higher tidal and absolute elevation than the sensor in Union Slough, the salinity intrusion to Union Slough at the sensor elevation (bottom of channel) would be expected to be slightly higher at the peak of tidal elevation, which is the case. There are also periods of reduced conductivity during river flow events that effectively displace tidal (more saline) water.

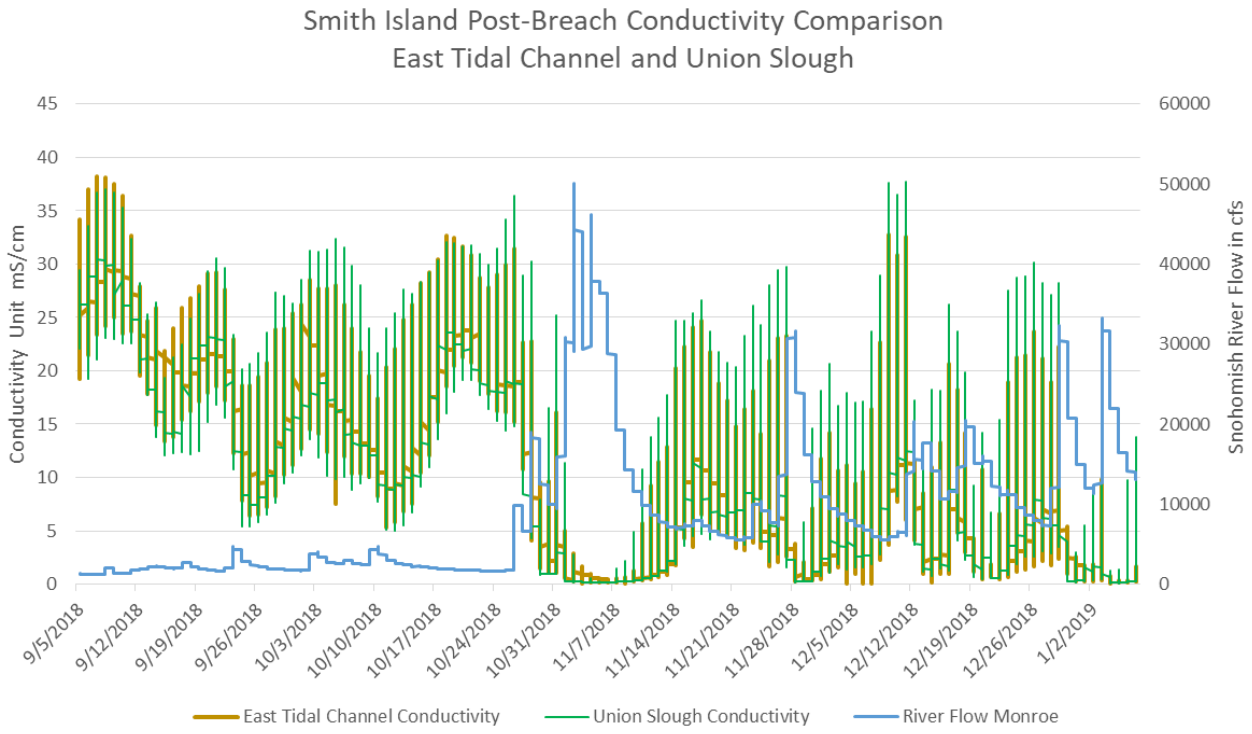


Figure 29. Water conductivity of Union Slough and the Smith Island Interior tidal channel.

Water temperature data from pre-project monitoring is displayed in Figure 30. The interior tidal channel temperature weakly tracks the summer seasonal temperature within Union Slough. The upper interior channel is generally warmer than the Union Slough temperature and the lower channel location. The lower interior tidal channel may have been influenced by ground-water. The ground-water wells remained around 10° C.

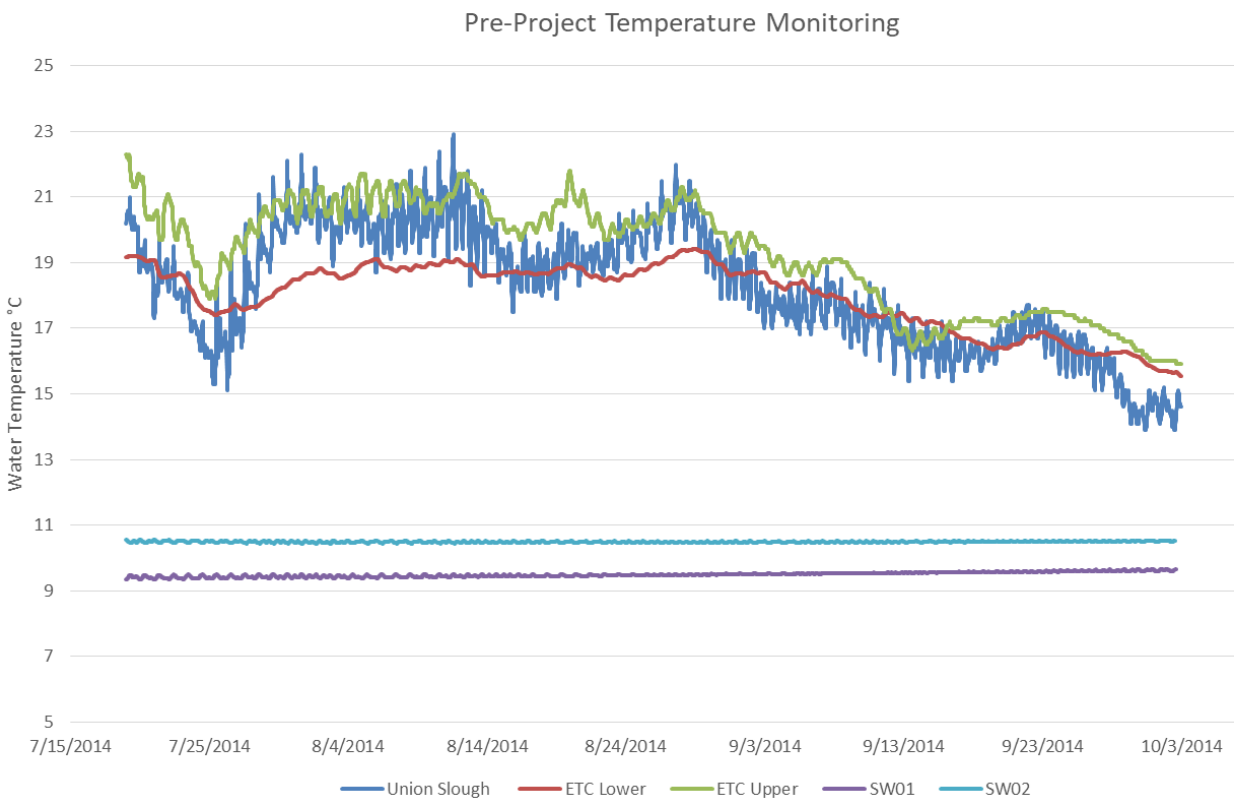


Figure 30. Pre-project water temperature in Union Slough, Smith Island East Tidal Channel (ETC lower, ETC upper), and two interior ground wells (SW01 and SW02).

Post-restoration, the reconnected interior East Tidal Channel and Union Slough water temperatures are shown in Figure 31. The interior tidal channel logger was subject to dewatering each tidal level below ~1.4 feet NAVD. The temperature during these periods of exposure to air was not graphed. The temperature within the interior channel location closely followed Union Slough temperature, other than in the summer when the interior channel location temperature was elevated. The interior East Tidal Channel drains almost every tidal cycle, and has a relatively shallow depth across a large area that is exposed to summer heating. The onset of the warmest temperatures potentially affecting fish behavior and survival are generally after June, when the cumulative juvenile salmon outmigration is mostly completed (Chamberlain et al. in review).

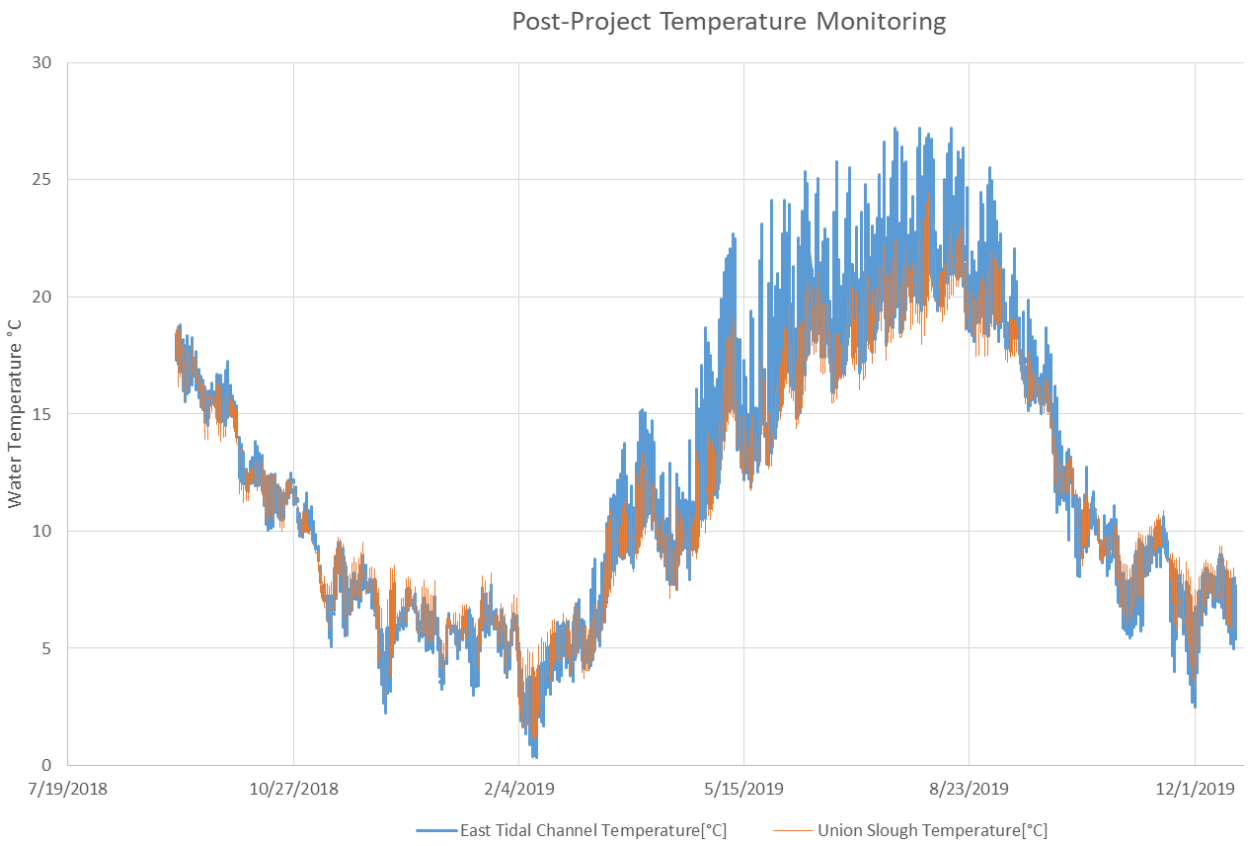


Figure 31. Post-project water temperature of Union Slough, and the Smith Island interior tidal channel.

5. Channels and Habitat Area

The number, geometry (depth, width, length) and scaling of tidally-formed channels in estuarine environments has been described in terms of hydrodynamic influences that affect response variables such as sediment organic content, and biotic community structure that support habitat functions for juvenile salmonids (Hood 2002a, 2007). Natural tidal channels have highly correlated characteristics of channel length, outlet width, outlet depth, ebb velocity, surface area, and perimeter, all scaled to a tidal prism covering a marsh area or "island" (Hood, 2002a, Hood 2007). These characteristics are important considerations for evaluating outcomes at restoration sites (Hood 2002b). At estuary restoration sites where connectivity to tidal inundation is re-established, altered elevations, ditches (Figure 32), remnant channels, channelized tidal flow, and altered vegetation all contribute to significant modification from natural tidal geometry (Hood 2014). As a consequence, trajectories of tidal channel change over time and the restoration of functions naturally important to juvenile salmon, in particular, may be uncertain (Hood 2002b).

Figure 33 shows the mapped ditch network at Smith Island prior to site restoration and shows which were filled and which were retained and connected to the restored channel network. The original ditch length within the Smith Island project footprint was 32,805 ft. (9,999 m). Of these, 21,519 ft. (6,559 m)

were filled and graded to design elevations, while 10,646 ft. (3,245 m) feet were retained and connected to (or reshaped and incorporated into) starter channels, the City of Everett mitigation channel, or the historic East Tidal Channel. Many, but not all, limits of ditch fill have been surveyed with RTK-GPS. Changes in ditch extent due to future channel erosion/incision or accretion will be evaluated.



Figure 32. Example of agricultural ditch at Smith Island re-connected to tidal inundation.

In the Snohomish estuary, there are un-diked historical reference locations such as Otter Island, levee systems that naturally breached and eroded decades ago on South Spencer Island and Mid-Spencer, and intentional breaches at restoration projects such as Qwuloolt and Smith Island. For Smith Island, comparative conditions are considered to be other previously diked and breached locations, such as Mid-Spencer and South Spencer islands, which have multiple points of connectivity to distributary sloughs, but also include remnant dike length surrounding a subsided base elevation within these sites. Hood (2014) found that some restoration locations in the Snohomish estuary had channel characteristics distinctly different from reference sites (tidal channel number and surface area), but that breached sites also evolved over time to form more tidal channel connections like natural reference sites. This expectation suggests that the juvenile salmon rearing capacity (quantity and quality) in tidal channels will increase over time at Smith Island as channel network length, area and connectivity are increased. Accompanying changes in vegetation and structure will create more complex habitat conditions, like more woody debris, low tide pools, greater sinuosity, and possible beaver-formed pools. At Mid-Spencer, enhanced connectivity to an already-beneficial site, should result in immediately higher benefit now.

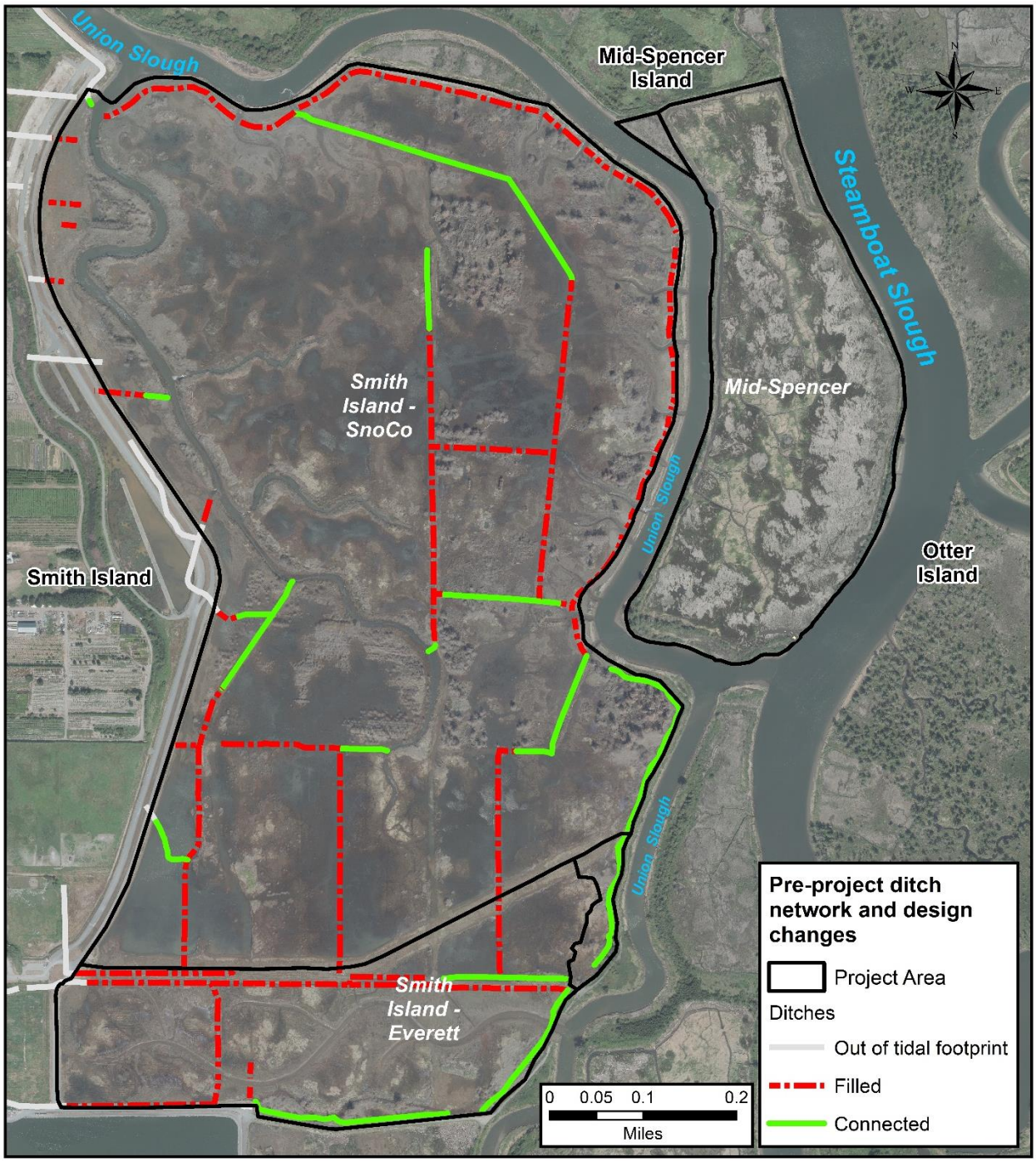


Figure 33. Mapped ditch network at Smith Island including re-connected and filled ditches.

It is anticipated that metrics describing tidal channel attributes for the entire Snohomish estuary will be updated over time as part of the Puget Sound Status and Trend Monitoring Project (Beechie et al. 2017). Therefore, the same methods were followed for identification and delineation of tidal channels and tidal flats (un-vegetated) at Smith Island and Mid-Spencer Island. Table 11 includes descriptions of our tidal channel and topographic monitoring goals, objectives and methods.

Table 11. Tidal channel and topographic monitoring description.

Element	Tidal Channels (Topography) / Habitat Areas
Goal/Purpose	To document the restored channel connections, length and areas as well as habitat areas and how tidal channel characteristics and habitat types change over time.
Questions	Do remnant (or excavated) channels enlarge, deepen, lengthen, add branching order or contract? What is the change in edge/perimeter habitats? Do filled ditches remain filled where shallow sloping banks are constructed? Does woody debris placement, drift or storage influence tidal channel formation or tidal partitioning? Does tidal erosion connect low-lying areas that do not drain at low tide?
Objectives	Establish baseline and biennial channel count, length, surface area calculations/estimates from available aerial photo imagery for large (2-5 m) and small (1-2 m) channels. Establish baseline cross-section and profile measurements at remnant channels, ditches and excavated channels. Identify limits of ditch filling. Acquire Smith Island/Mid-Spencer LiDAR at low tide post-breach. Delineate and estimate areas of major tidal flat habitat types including mudflat, emergent marsh, shrub, forest or other subtypes, as feasible for tracking.
Methods	Channel count, length, and surface area of channels and non-channel wetland habitat types will be manually digitized in a GIS using available aerial photos from pre- and post-construction years using methods consistent with Beechie et al. (2017) as originated by Hood (2007) and adopted by the Puget Sound Partnership for tracking estuary extent and restoration in Puget Sound (Ramirez and Simenstad (2018). Channel cross-sections and long profiles will be field measured using RTK-GPS. Survey coordinates will be used repeat surveys. Channel cross-sections will extend across the marsh plain for five meters to detect out-of-channel topographic changes. The headward extent of existing/newly excavated channels will be located in the first year to evaluate future headward changes. Use LiDAR to estimate surface elevations (0.1 m) – calibrated to survey control/measured elevations.
Number of units/ samples	Smith Island and Mid-Spencer are separate units. Five channel cross-sections and 5 longitudinal profiles. Aerial photos, as available.
Frequency/ Duration	Field and aerial photo survey completed of pre-project, as-built channels, and in years 1, 2, 3, 5, 10 and then every 5 years, if feasible. LiDAR in year 1, then once every 5-10 years, as feasible. Aerial photos, as available.
Deliverables **(D & I Sharing)**	Table of channel characteristics and changes covering grant agreement period. Plots of channel profile/cross-sections and changes covering grant award period. Maps and figures for final reporting. Provide LiDAR digital elevation model, maps, and data collection report from vendor.
Evaluation/ Analysis **(D & I Sharing)**	Quantify changes in channel count, lengths, area, profiles, sinuosity, and channel volume, if feasible from combination of aerial photos and field surveys. Quantify changes in site edge lengths relevant to fish use. Quantify the frequency distribution of elevations and change between years using LiDAR differences.

The pre-construction Smith Island project site contained disconnected tidal channels, a network of ditches and two tide gates. Aerial photos obtained in 2019 during low tide were used to delineate the post-construction large tidal channels (remnant natural and constructed) as polygon features (Figure 34). Small tidal channels and extents were identified using field observations, field topographic locations or GPS locations, as-built information and were mapped as polyline features. In most cases, the line feature was delineated to a known upstream channel limit based on LiDAR, GPS ground points, limit of as-built excavation (or fill), or observed site conditions.

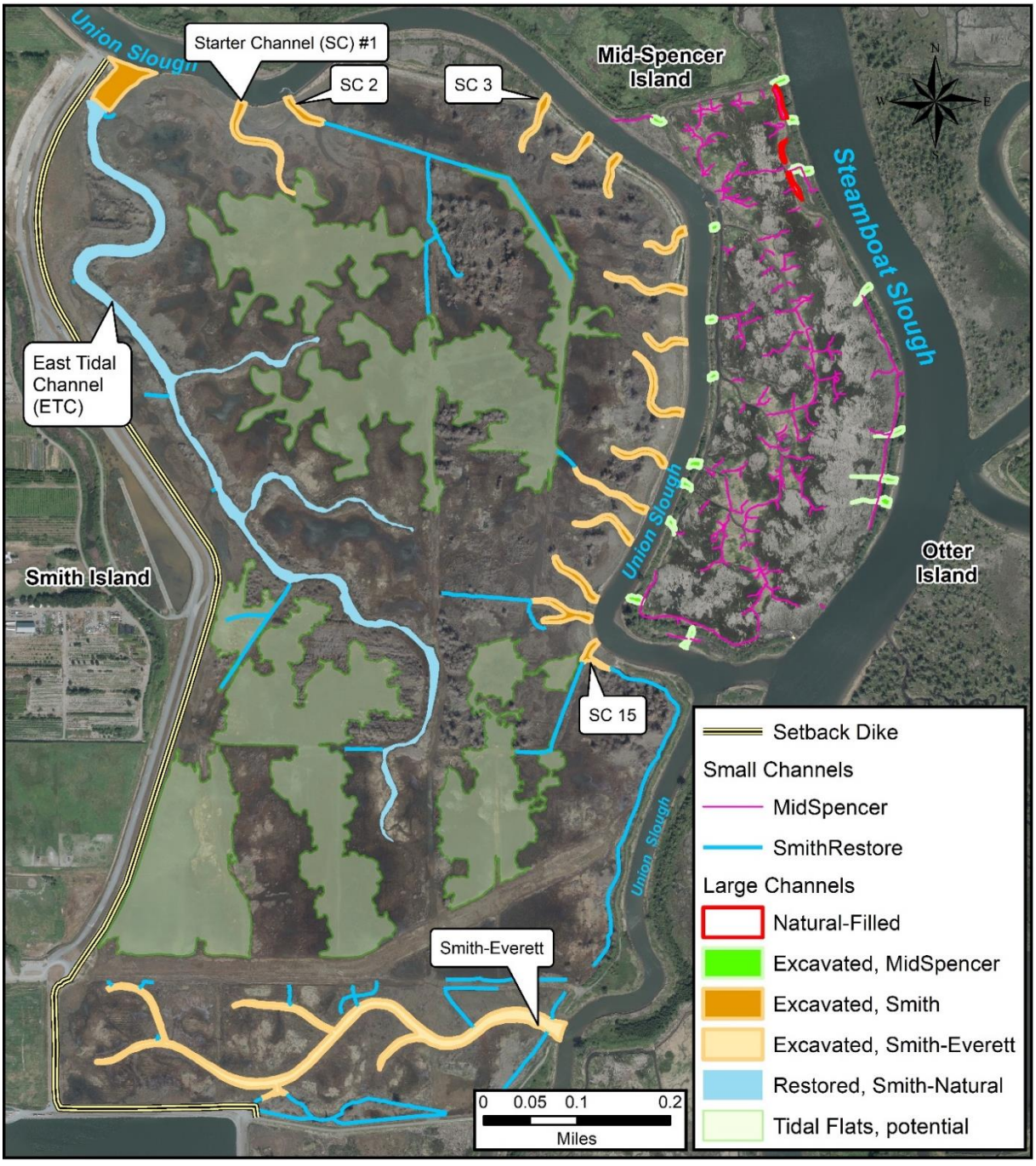


Figure 34. Map of Smith Island and Mid-Spencer large and small tidal channels.

The length of remnant channels that were re-connected after dike breaching are now summarized together with all existing channel characteristics in Table 12.

Table 12. Smith Island as-built (Snohomish County and City of Everett portions) and Mid-Spencer pre- and post-construction marsh characteristics for area, length, connections, and spacing typically summarized by Hood (e.g., Hood 2007).

	Smith Island - As-Built		Mid-Spencer	
Metric	**Snohomish**	**Everett**	*Pre-project*	*Post-project*
Project/Marsh Area (Ha)	129.7	24.9	28.2	28.7
Hood (2007) - Marsh Area (Ha) - [1]	123.5	22.4	25.4	25.5
Island Perimeter (m) - [2]	2,700	264	2,554	2,665
Channel Connections - total (new)	16 (15)	1 (1)	7	23(16)
Distance (Avg.) between outlets (m)	169	NA	365	116
Breaches per km dike	5.9	3.8	2.7	8.6
Existing Channel Area (m2) - [3]	**29,741**	**0**	**13,239**	**12,368**
Ditch-Filled (m)	5,299	1,897		137
Excavated Channel Area (m2)	**18,766**	**15,722**		**3,832**
Small tidal channel length (m)	3,693	2,231	7,584	7,694
Small tidal channel area (m2)-estimate	**13,823**	**9,590**	**15,168**	**15,389**
Grand Total Channel Area	**62,330**	**25,312**	**28,407**	**31,589**
Total New/Reconnected Channel Area		**90,824 (9.1 ha)**		

[1] - Total island area minus channel area.

[2] - Length of island perimeter fronting Union Slough. Does not include length of new setback dike.

[3] - Delineation and calculations based on NOAA PSSTMP (2017) and Ramirez and Simenstad (2018).

One channel feature type included in Figure 34, but not formally delineated or included in Table 12 is tidal flats. These are un-vegetated mud flats, where established channel networks with vegetated edges have not yet formed (Ramirez and Simenstad 2018). Haas and Collins (2001) excluded these areas in their estimate of total marsh area, though at the time tidal flats were present only in the EEM zone at lower elevations of the delta front facing Port Gardner. Today, tidal flats have also typically formed in areas with substantial land subsidence where tidal connections have recently been restored (i.e., formerly diked locations) in the EFT and FRT zones (see introduction). For example, at South Spencer Island, a location naturally breached in 2003-2006, tidal flats have been mapped by NOAA (Beechie et al. 2017). At this location, tidal flats typically occur at a ground elevation less than 5 ft. (NAVD 88). For Smith Island we classified the 2019 LiDAR digital elevation model to that specific surface elevation (as dark blue in Figure 35) to represent the potential surface area likely to become un-vegetated tidal flats after die-off and decay of upland vegetation occurs. This interpretation only applies to the Smith Island project boundary waterward of the setback dike. In future years, tidal flats will be delineated relative to newly established marsh vegetation and updated over time as marsh elevations and associated extents of vegetation change.

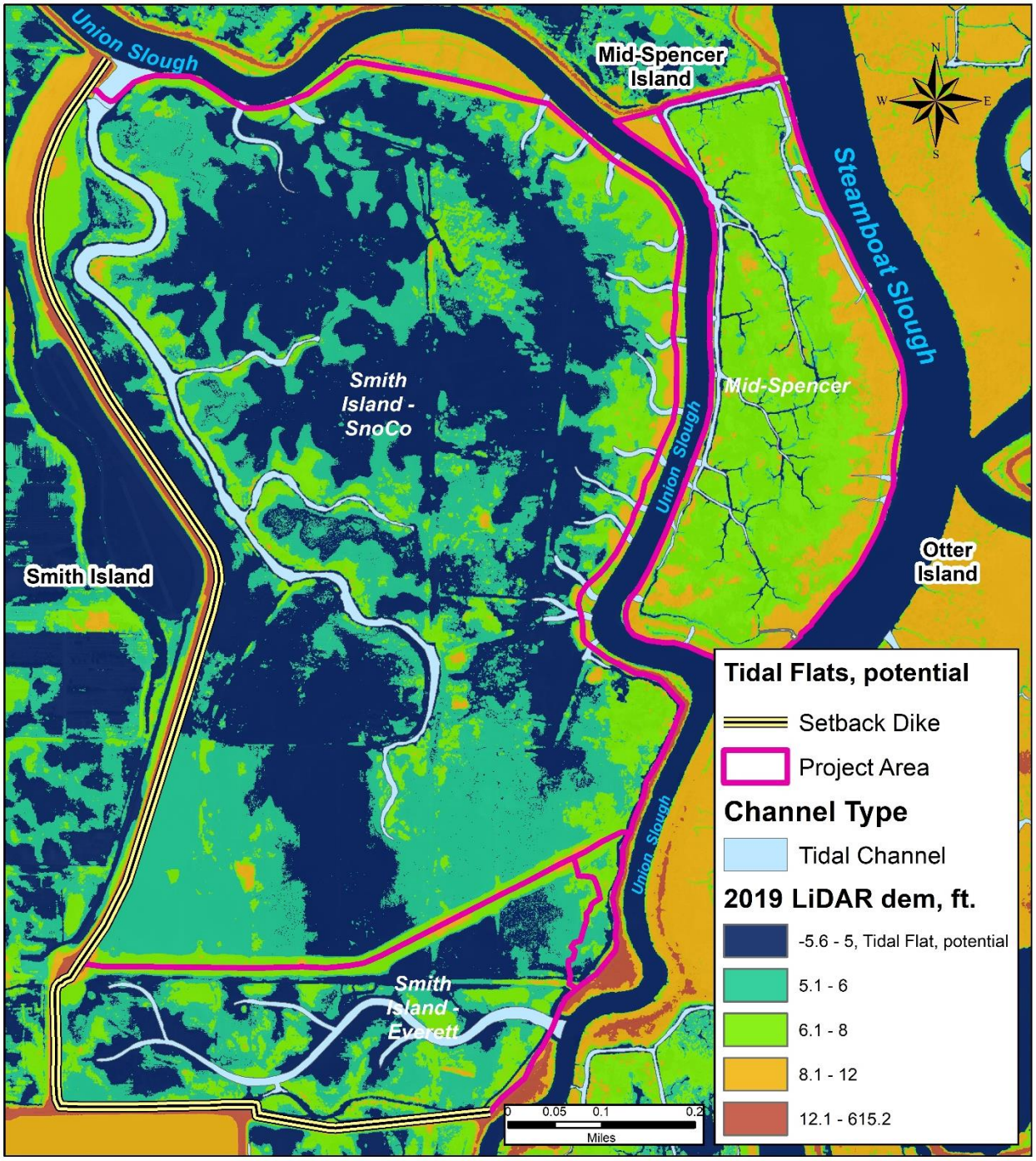


Figure 35. 2019 LiDAR-based elevations. Elevations that are less than 5 feet (within the Smith Island project area only) are predicted to become tidal flats (dark blue). Ground area west of the setback dike is protected from tidal inundation so will not become tidal flats.

In summary, with the re-connection of the marsh area at Smith Island and other natural and constructed changes, the total marsh area in the Snohomish Estuary has increased notably since 1996, when Haas and Collins (2001) last estimated the total marsh area accessible to juvenile salmon. Today, total area of tidal marsh has increased by 577 hectares, a 93% increase in area (Figure 36), due to tidally re-

connected marshes, including Spencer Island, Qwuloolt, Upper Union Slough, Lower Union Slough, and the Everett Riverfront. This total estimate does include tidal flats as described above which have formed in the EFT and FRT zones since 1996. If these tidal flats were excluded, the total increase would be less, but a substantial increase nevertheless.

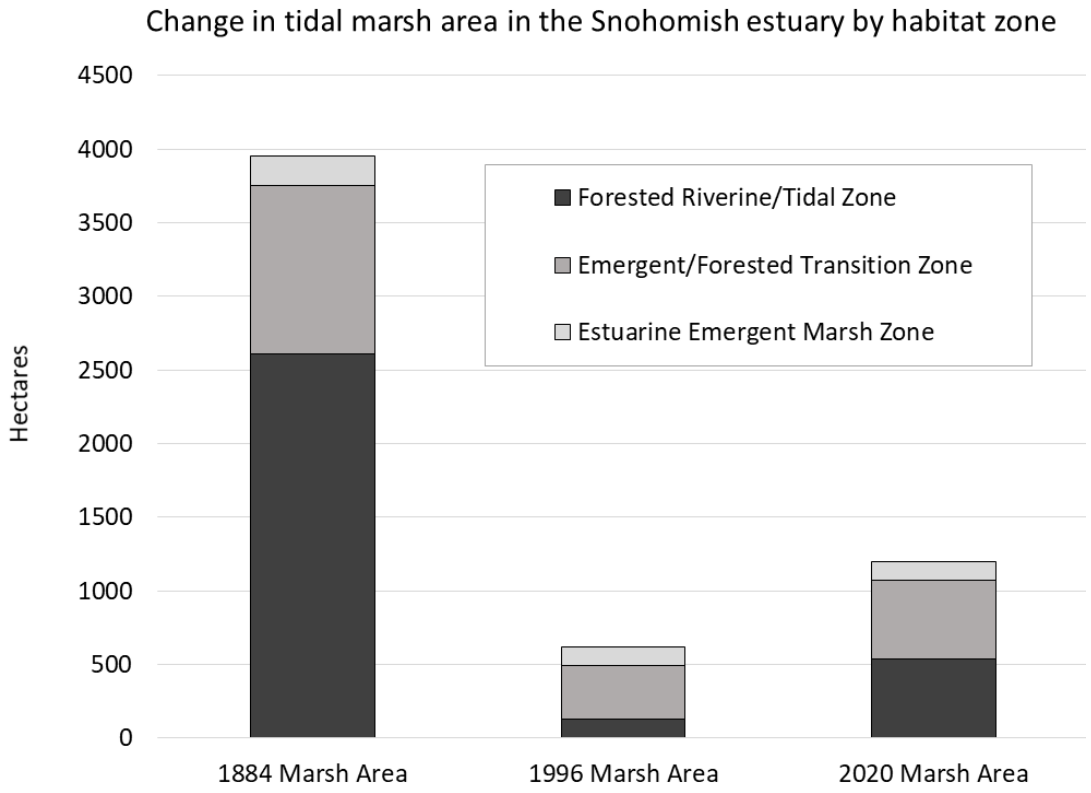


Figure 36. Estimate of total marsh area in 2020 as compared to estimates for 1884 and 1996 estimated by Haas and Collins (2001).

With project completion a number of channel characteristics have changed due to excavation and new channel connections. These conditions can be evaluated based on illustrating these changes in channel metrics relative to those reported by Hood (2007, 2014), which includes analyses of Snohomish estuary sites. With dike breaching, channel count increased at both Smith Island and Mid-Spencer. Figure 37 shows the channel count plotted against island area (hectares), as shown in Hood (2014). Overlaying the original plot of natural sites (open circles) and restored sites (filled circles) are the pre-project channel count for Mid-Spencer Island and the post-project (as-built) count of levee breaches for Mid-Spencer and Smith Island. The number of channels now present at Mid-Spencer Island plots in alignment with other natural marsh islands. On the other hand, the total number of channels constructed and re-connected at Smith Island plots in alignment with other restoration sites and has a relatively lower channel count than would be expected for a natural marsh island of the same size. In contrast, the Qwuloolt restoration site has one breach opening.

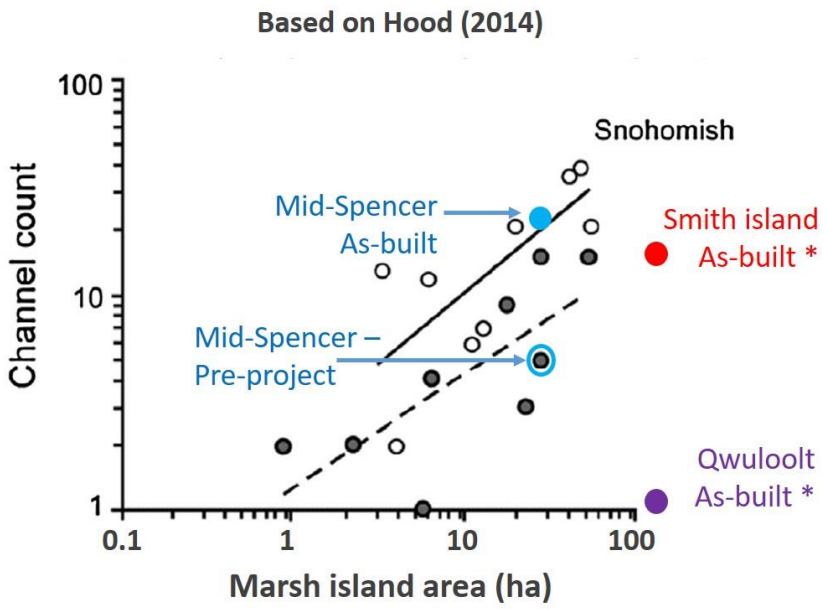


Figure 37. Mid-Spencer Island, Smith Island, and Qwuloolt as-built channel connection data points (labeled) overlaying marsh island area and outlet channel count from Hood (2014). Mid-Spencer Island was included (circled) in Hood (2014) as a data point in the dike breach data set (grey circles). Open circles represent reference conditions.

For Mid-Spencer Island and other restoration sites, Hood (2014) evaluated the change in the number of passively-formed channel connections over time as remnant dikes failed and became naturally breached. He concluded dike breaches and new connections to tidal exchange occurred on the order of ½ to 1 breach per decade per kilometer of dike. Although simplistic in calculation, we estimate the time saved in constructing additional dike breaches was 138 years relative to the rate of passive breaching (Figure 38).

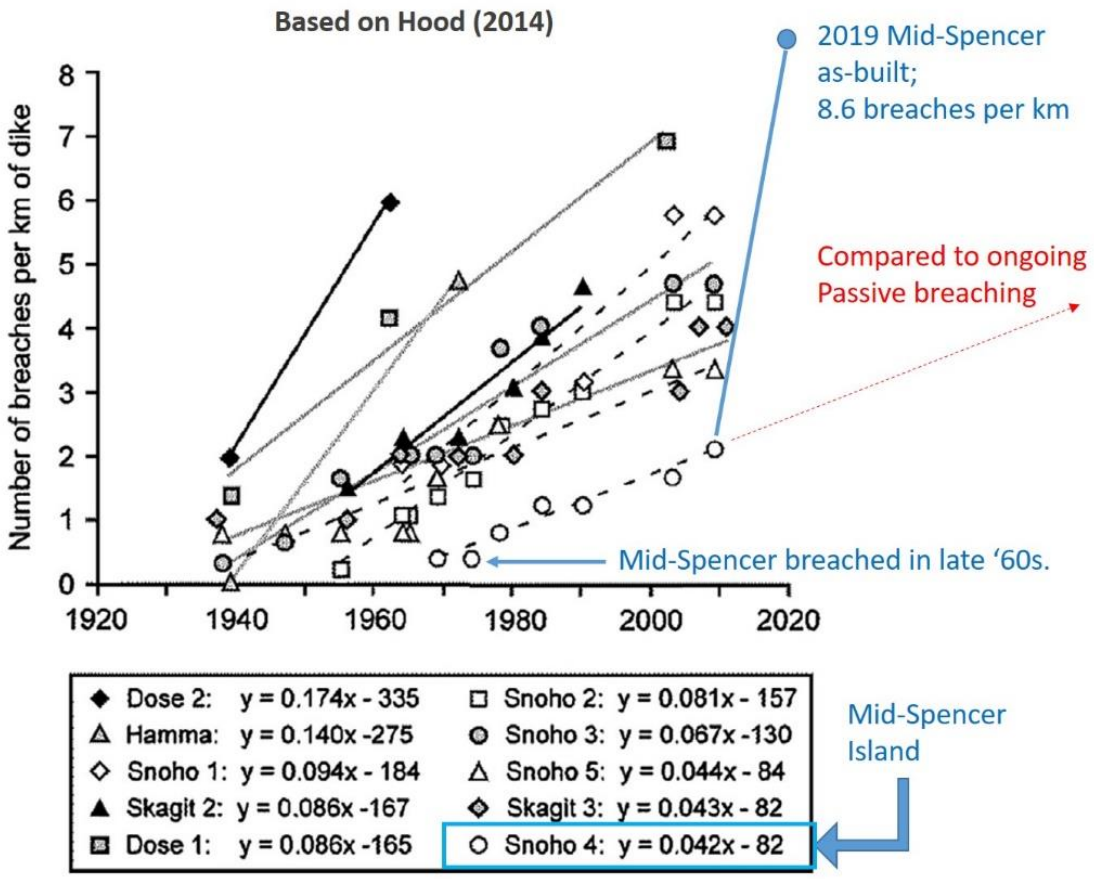


Figure 38. 2019 Mid-Spencer Island channel count (breaches) per kilometer of dike overlaying Hood (2014) increase in passive breaching among restoration sites over time. Mid-Spencer Island is labeled from the original data set and in 2019 along with the potential trajectory associated with only passive breaching.

Lastly we considered the quantity of channel surface area due to constructed excavation and re-connection of formerly isolated channels based on analyses by Hood (2014), (Figure 39). Filled circles represent restoration sites, whereas open circles represent natural marsh islands within the Snohomish estuary. We added Mid-Spencer and Smith Island channel area values from Table 12 as shown in Figure 34. Prior to construction, Mid-Spencer Island had a greater channel surface area than would be expected for a similarly sized natural tidal marsh. The addition of new breaches through the remnant dike and the excavation of connected channels has further increased the channel area at Mid-Spencer. For Smith Island, separate calculations were made for the Snohomish County and the City of Everett portions of the site. As can be seen in Figure 34, the City of Everett designed one large sinuous channel with minor branches that empty out of one breach location. The majority of the Snohomish County portion drains through the East Tidal Channel and two large dike breaches containing 15 starter channels. As a result, both Mid-Spencer and the City of Everett channel area plot in alignment with natural tidal marshes (filled circles in Figure 39), whereas the Snohomish County (SnoCo) channel area (Smith-SnoCo, in Figure 39) plots below the extended trend line for natural tidal marshes and is more in alignment with the other restoration sites (open circles). Total channel area is likely to adjust in the future decades.

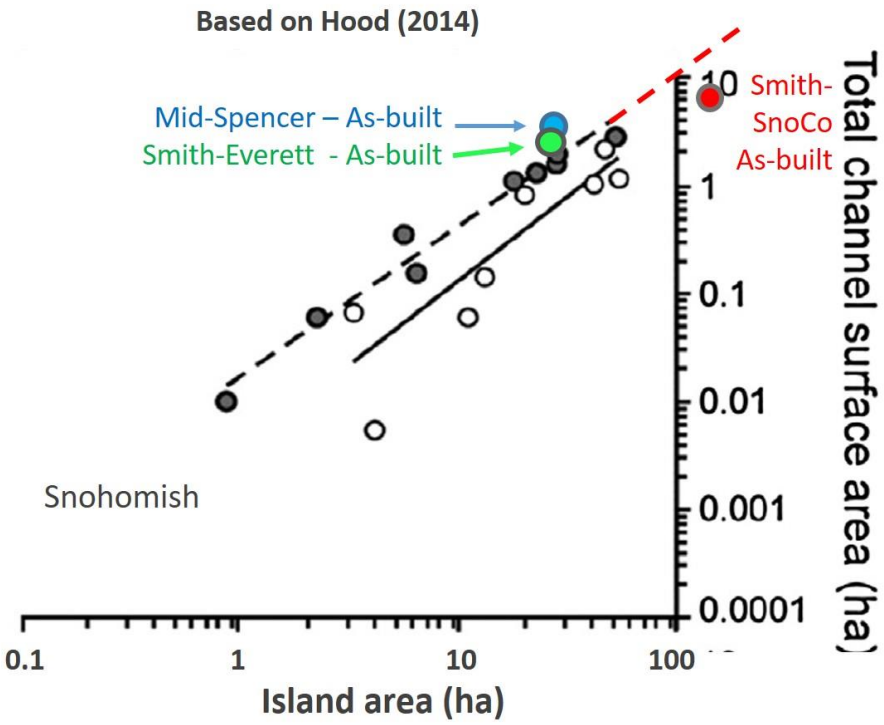


Figure 39. Smith Island Everett channel, Smith Island County channels and Mid-Spencer Island surface area plotted against marsh island area and overlaying the Hood (2014) comparison of breach sites (grey circles) and reference locations (open circles) for Snohomish estuary locations.

The geomorphic response of tidal channel cross sectional area is proportional to channel discharge. The partitioning of the tidal prism discharge among the channels is visibly observed to be highly variable. Hence, though starter channels generally have very similar cross-sectional areas, their velocity and total discharge vary significantly. A few channels have large water volume exchange, relatively higher water velocities, and persistent ebb flow throughout the tidal cycle. Other starter channels have much less water volume exchange, low velocity, and cease to flow through the tidal cycle.

An indication of channel adjustment is likely to be observed in channel cross-sections and longitudinal profile surveys. As-built channel cross-sections and longitudinal profiles (obtained with RTK-GPS) were measured for many locations in 2018 prior to, and immediately after dike breaching (Figure 40). These field-based spatial positions were also used to guide the delineation of large and small channel boundaries (polygons and line features, respectively). In all, 84 cross-sections or profiles were established in 2018. For example, the map inset in Figure 40 shows numerous cross-sections established in Starter Channel (SC) #11 along with a longitudinal profile. This profile is plotted in Figure 41 and shows the longitudinal distance/position of the labeled cross-sections in Figure 42. Appendix E includes 25 cross-sections and longitudinal profiles, including Starter Channel 11. Processing of cross-section and longitudinal profile data continues in 2020. The hydraulics of the channels will be explored over time by monitoring channel characteristics and adjustment and whether this has influence on fish use.

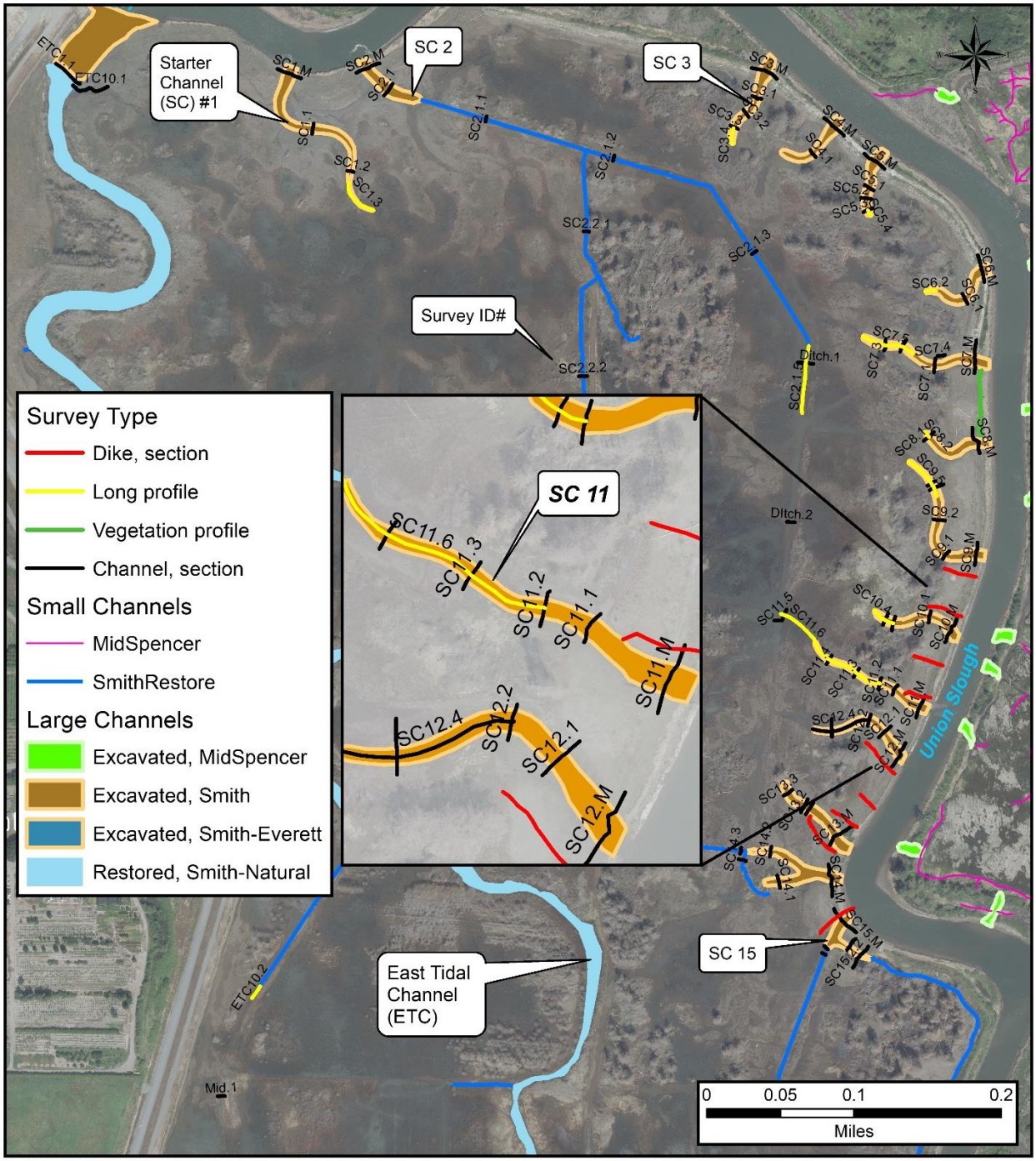


Figure 40. Smith Island channel cross-sections, longitudinal profiles, dike breach sections and a vegetation delineation (profile) of *Carex* sedge grasses among large and small tidal channels. Mid-Spencer Island surveys will be included in future reporting.

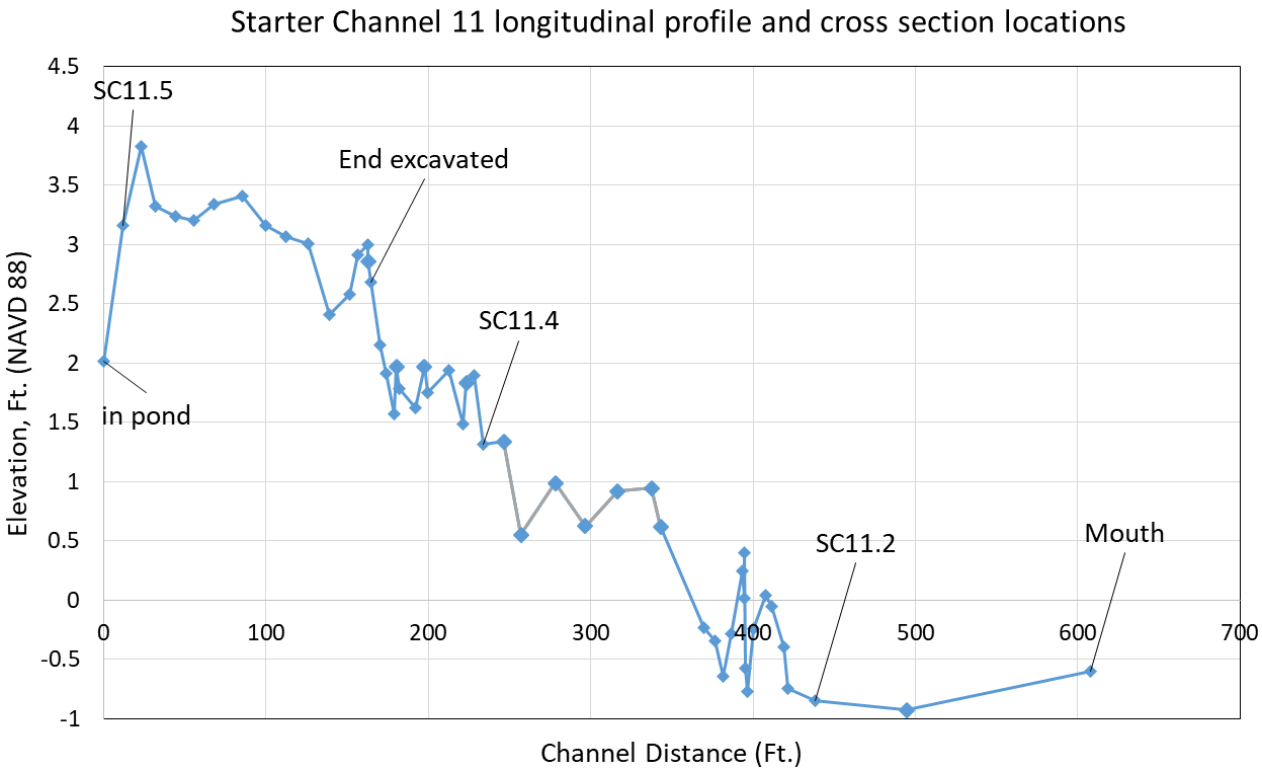


Figure 41. Starter Channel 11 ground elevation along a thalweg profile of the constructed channel. Locations of cross-sections in Figure 40 are show in Figure 42.

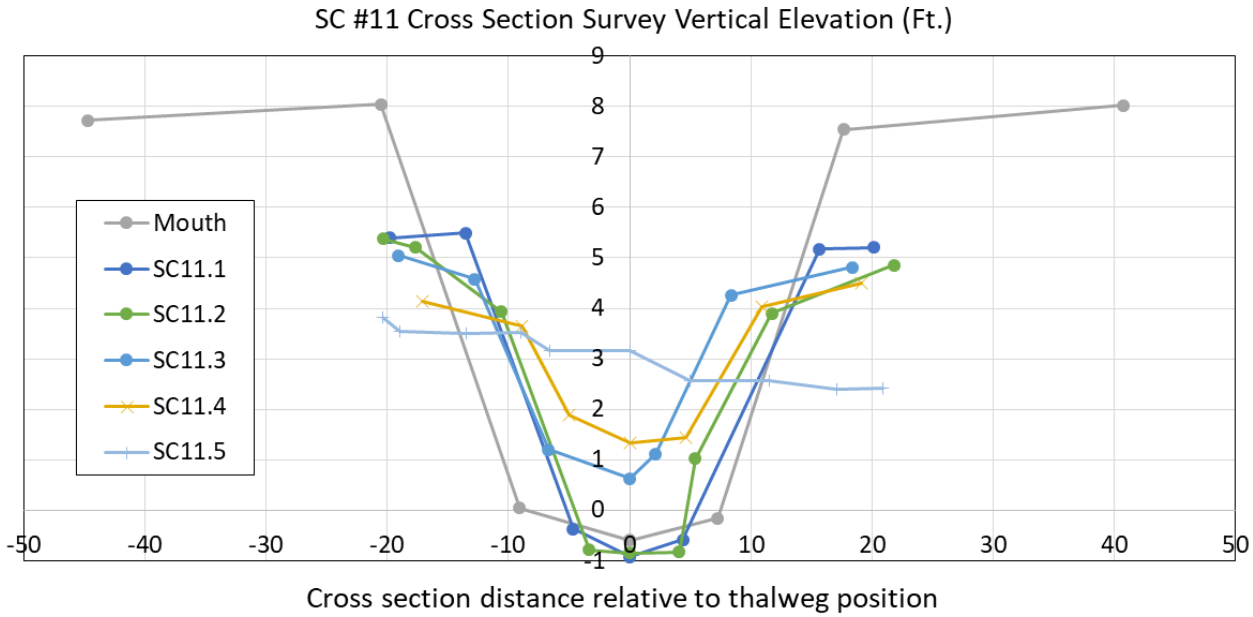


Figure 42. Starter Channel 11 cross-section topographic elevations at positions corresponding to Figure 41.

The long term monitoring of the tidal channels will help describe the geomorphic responses to variables such as tidal hydrology, sediment dynamics, and vegetation. It's uncertain whether future channel

geometry at restoration sites will follow hydraulic geometry relationships that are evident in other natural or reference restored locations (Hood 2007), though future changes will be evaluated relative to this body of work.

6. Wood Complexes and Woody Material

The Smith Island and Mid-Spencer projects include designed channel or habitat features including wood complexes. These project treatments are expected to be stable and persistent over time but may become altered and change in shape and/or function as influenced by tidal exchange, sediment dynamics, vegetation colonization or new woody material deposition. Mid-Spencer wood complexes are described at the project website and will be evaluated in future years.

At Smith Island, three designs of wood complexes were constructed. The first design used at the remnant ends of the old dike (two locations), wrapped the end of the dike with large wood material in an overlapping rootwad configuration that was secured to vertical pilings (panel A, Figure 43). As these wood structures are the closest to Union Slough, they may wrack and store additional large wood drifting through Union Slough and may develop a higher density of woody material per length of the project boundary. The second design (nine locations) is for large channels and consists of 3-5 pieces of anchored large wood material with rootwad cross members placed at the ground surface elevation and secured to vertical driven pilings (panel B, Figure 43). The third design, which is the most numerous (31 locations), is low profile, small diameter wood material placed vertically at excavated starter channel edges (panel C, Figure 43) or within remnant ditches (panel C, right photo, Figure 43).

For constructed wood complexes, we will evaluate for the following conditions over time:

- Are they stable and retained,
- Do they trap and retain more woody material or sediment,
- Do they create more scour or channel deformation, and
- Are they used by fish for cover compared to non-cover locations of starter channels?

Natural wood complexes may form over time as on-site trees die and blow down and/or as more woody material is deposited on-site from upriver sources. For example, using the 2019 high-resolution aerial ortho-imagery, we identified 46 pieces of large wood with rootwads[6] and 53 pieces of large wood without rootwads. In addition, approximately 116 trees were blown down in 2018-2019 and now contribute to the woody material on Smith Island. As new blow down occurs, which is expected to diminish over time, these trees will be quantified with other natural wood that drifts into the site.

[6] Large wood size is a minimum 7.6 meters length and 30 cm diameter, consistent with Snohomish County wood inventory in mainstem rivers (Snohomish County 2004). Rootwads are 1 meter in diameter.

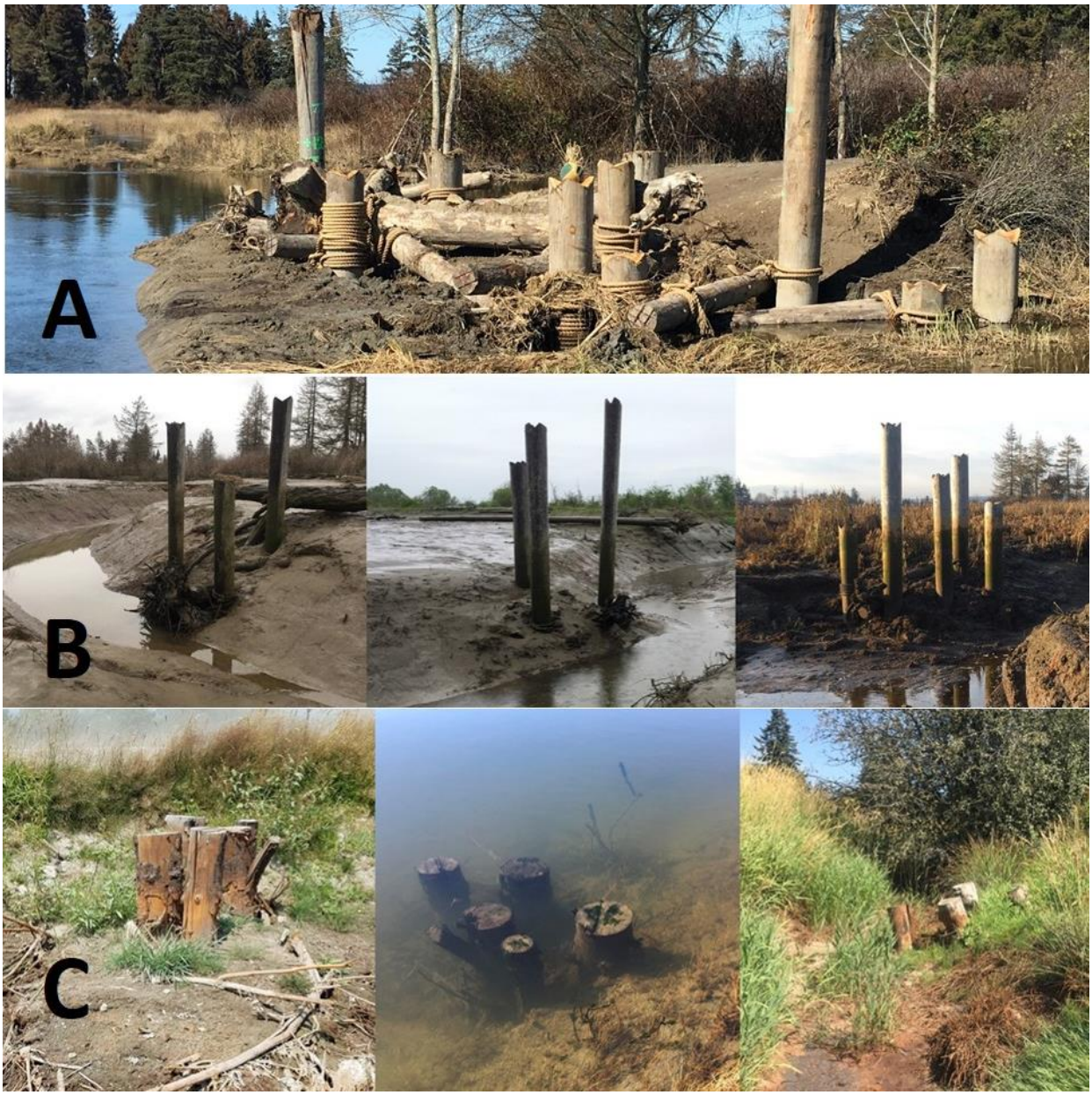


Figure 43. Examples of wood complexes constructed at Smith Island including; A: Dike ends; B: Large wood complexes, and C: Small wood complexes. Fish were observed in small wood complex at bottom center.

Although there are no project performance requirements or objectives for woody material abundance and functions, information summarized from these monitoring data can be compared to other project sites and natural reference locations. This information can be used to inform site adaptive management, specifically whether more wood should be added. In addition, the data can help answer whether placed wood structure matters to the performance of estuary restoration projects.

7. Vegetation

Before dike breaching and for decades prior, Smith Island was managed primarily as pasture land, but contained patches of native and non-native conifer forest and large nursery tree stock. Non-native and invasive species were widespread across the site, in particular reed canarygrass and Himalayan blackberry. Figure 44 shows a typical pre-project view from the breached dike of the Smith Island site. Mid-Spencer Island, on the other hand, is dominated by a variety of emergent marsh species.



Figure 44. Smith Island pre-project landscape view of vegetation types including coniferous trees (background), deciduous trees, shrubs, grassland, and Himalayan blackberry (foreground).

An overall goal of the Smith Island restoration project is to recover natural tidal marsh vegetation across the site. Because the Smith Island site has subsided by 4-6 vertical feet, the site elevation is less reflective of the historical emergent/forested transition (EFT) zone (Figure 2) and more like the elevations of remaining estuarine emergent marsh (EEM) zone father downstream. As a result, the restored Smith Island site is more likely to support emergent marsh species, a very limited shrub-scrub area, and mud flat (refer to as highlighted in section 4 for a broader discussion on marsh plain elevation). New tidal marsh vegetation at Smith Island will be influenced by the following factors based on certainty of effect;

- Depth, duration, and frequency of tidal inundation,
- Surface water salinity,
- Mortality rate of salinity intolerant species,
- Micro-topography and tidal channel evolution,

- Seed sources and recruitment,
- Invasive species,
- Soil/sediment texture (native as compared to newly deposited),
- Soil compaction and cohesion,
- Relic conditions (compaction, re-worked soil, fill, haul roads influence micro-topography), and
- Retention of woody debris

Vegetation monitoring will focus on answering questions related to factors that are most certain to influence vegetation response. Monitoring questions, along with descriptions of the monitoring element are in Table 13.

Table 13. Description of vegetation monitoring.

Element	Vegetation
Goal/Purpose	Document the development of tidal marsh vegetation, community composition and species change over time at Smith Island and Mid-Spencer Island. Identify invasive species and control them so that a native plant community is established.
Questions	• What is the area of coverage and elevations occupied by vegetation communities/assemblages? What changes are evident over time? • What species make up vegetation communities in different spatial or elevation areas? Are there losses and/or gains by species or community? • What is the legacy (retention and extent) of the pre-breach vegetation community on recruitment and establishment of new, post-breach plant assemblages? • What biotic and abiotic factors are driving the observed plant attributes on the Smith Island site? • Do wood accumulations (treatments, legacy forest, or new recruitment from off-site) foster woody vegetation growth in locations that otherwise are below critical tidal elevations? • What invasive species and regulated classes are present and what area(s) are initially colonized? In particular, purple loosestrife (*Lythrum salicaria*), yellow-flag iris (*Iris pseudacorus*), non-native knotweeds (*Polygonum cuspidatum, P. polystachyum, P. sachalinense, and P. bohemicum*), and similar related species and hybrids. • How do vegetation attributes at Smith Island and Mid-Spencer compare to other breached or reference sites? After year 3, year 5, year 10?
Objectives	Quantify plant community areas and species composition over time, including die off areas, eventual mudflat delineation and wood storage. Confirm emergent marsh development as anticipated and scrub/shrub vegetation. Identify locations of noxious weeds. Provide spatial and species information for Stewardship and Maintenance implementation which includes noxious weed control.

Table 13 Cont.	
Methods	Aerial photo delineation and interpretation of vegetation communities and field surveys of vegetation (species and cover) with quadrats/ line transects. Annual invasive vegetation reconnaissance with GPS and camera. Measure or estimate size of target species area.
Number of units/ samples	Establish ≥20, 5 x 5 m^2 random vegetation plots AND 12 line-intercept transects across elevation gradient at Smith Island. Sample 1 m^2 random quadrat among plots/line transects for species and cover in years 0, 1, 3, 5, 10.
Frequency/ Duration	Field surveys in years 1, 3, 5, 10 and every 5 to 10 years if necessary. Aerial photos schedule noted above.
Deliverables **(D & I Sharing)**	Provide vegetation locations (mapped) and results covering grant award period. Map locations of invasive weeds, provide to site manager, and document treatment (type/area).
Evaluation/ Analysis **(D & I Sharing)**	Map major vegetation classes and mudflat to estimate composition as a percent of total area and change (based on 2-year NAIP aerial photos/vegetation plot data). Determine if vegetative cover is <50%.

The pre-project vegetation was classified and mapped using aerial photos and ground-truthing and was comprised of many upland species. Figure 45 shows past mapping of dominant vegetation areas, most of which will die-off over time with tidal inundation.

In addition to pre-project vegetation mapping, a 2016 satellite-based high-resolution (1-meter) land cover classification was completed by NOAA's Coastal Change Analysis Program (Office for Coastal Management 2020) for Snohomish County (Figure 46). As the extent is much larger than Smith Island and the imagery was acquired prior to Smith Island restoration, the 2016 classification will be useful for comparing future land cover classification (types and extents) within the Snohomish Estuary as a whole (Appendix F) and for individual restoration sites because the resolution is one meter. Within the Smith Island project boundary, for example, the pre-project classification shows the predominance of grassland, cultivated crops, upland forest, some estuarine emergent wetland, and less shrub/scrub vegetation. In contrast, Mid-Spencer Island, which was already influenced by tidal exchange was dominated by estuarine emergent wetland. At more recently restored sites, we note the presence of unconsolidated shoreline (tidal flats) where vegetation establishment has not occurred to date due to the subsided elevations. Similar classification types would be expected at Smith Island in the future.

Finally, other pre-project vegetation information includes Snohomish County's Snohomish Estuary Vegetation Survey (un-published data) that implemented vegetation surveys by line-transects across the estuary (shown in Figure 47). Repeat sampling of historical transects and/or establishment of new transect profiles at Smith Island and Mid-Spencer Island will support the objective of identifying vegetation change and resilience with respect to elevation and changes over time.

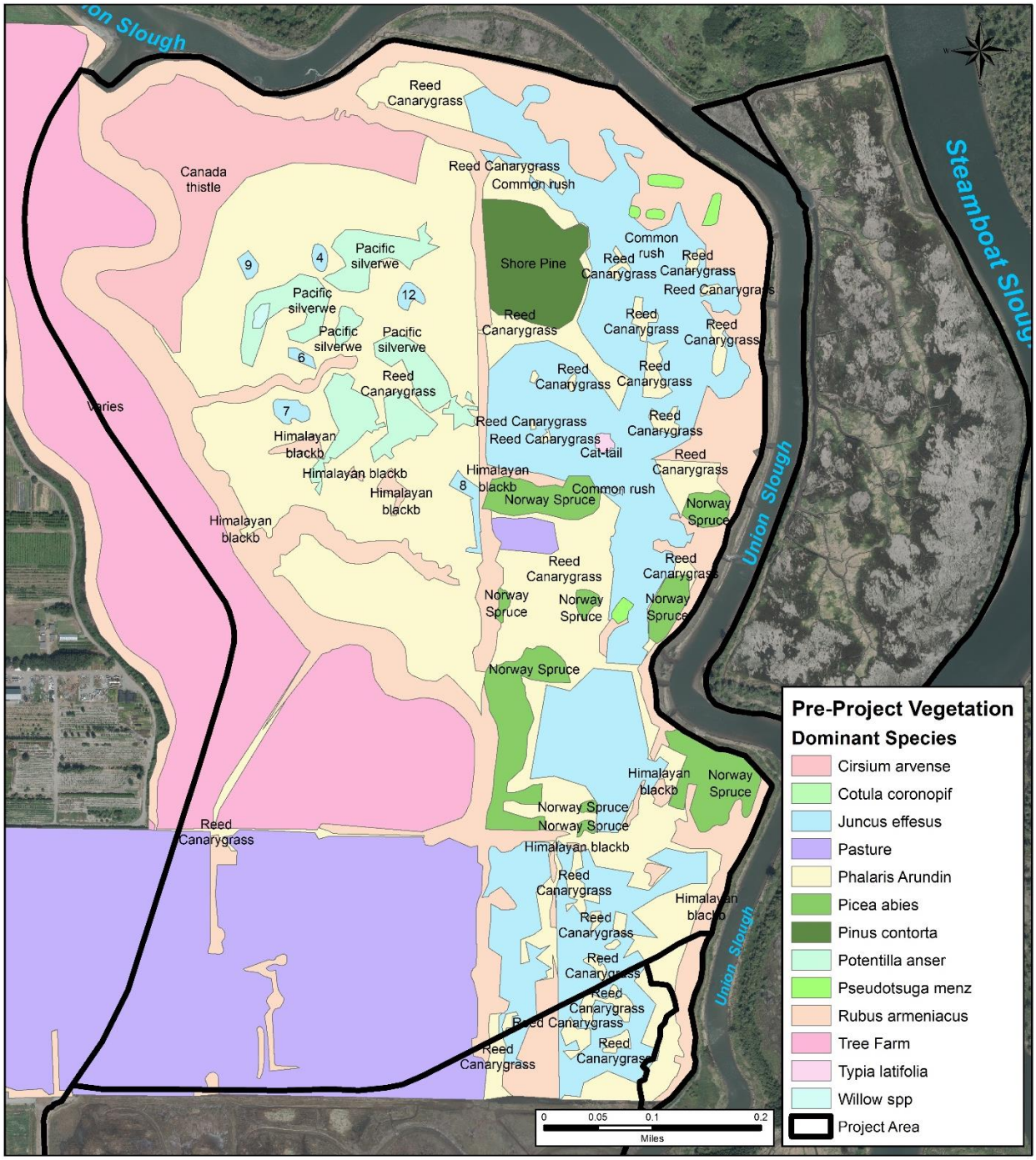


Figure 45. Map of dominant pre-project vegetation prior to project implementation. Polygon labels are species common names.

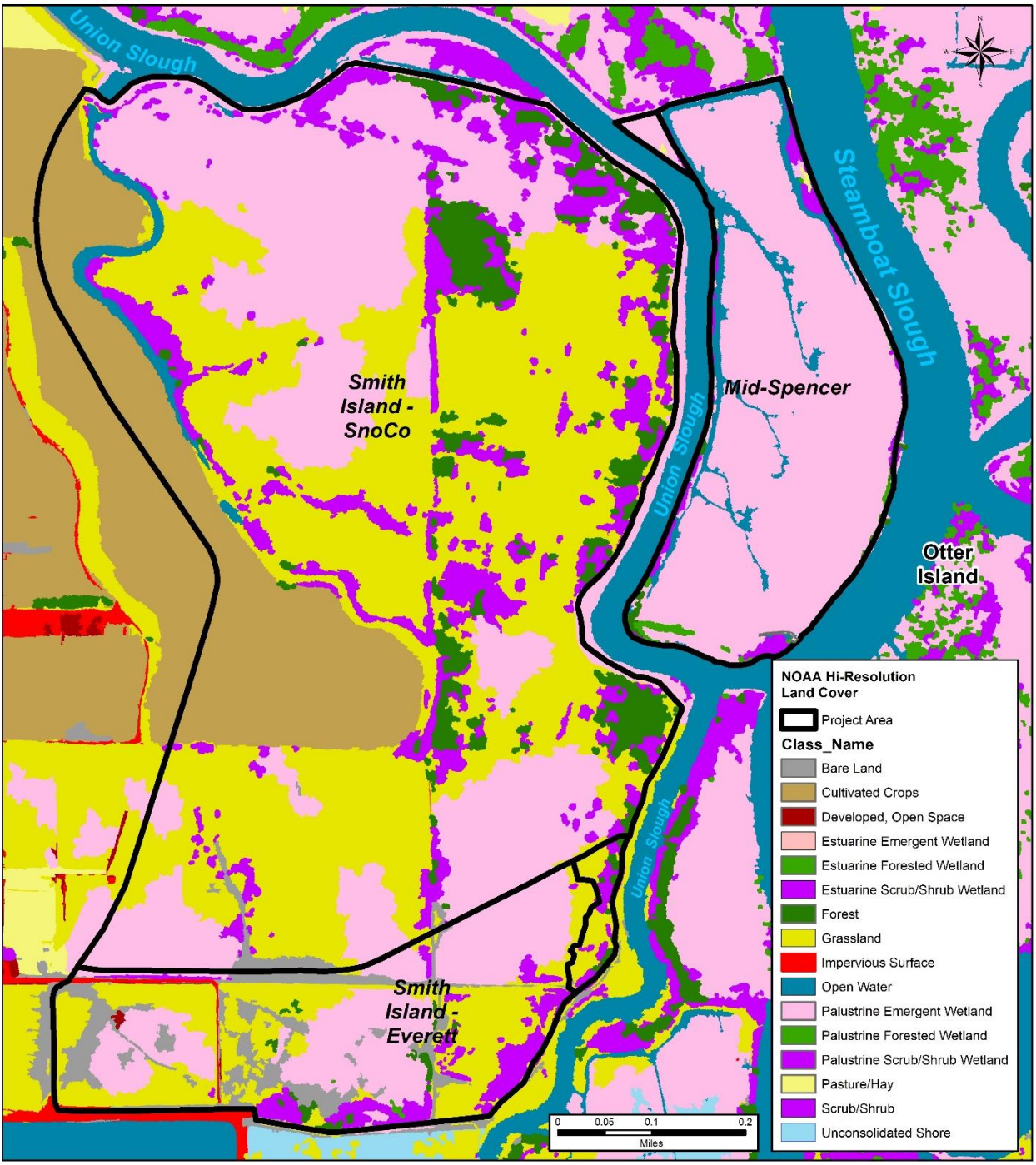


Figure 46. 2016 one-meter high resolution, satellite-based land cover classification from NOAA (Office for Coastal Management 2020).

In summer 2018, area-wide vegetation mapping and land cover classification of pre-project conditions was supplemented with field-based vegetation monitoring prior to dike breaching. Macroplots were established across the restoration site among variable elevations to monitor the coarse community assemblages (Figure 47). Vegetation monitoring was implemented later in the growing season to make sure all vegetation had demonstrated active growth.

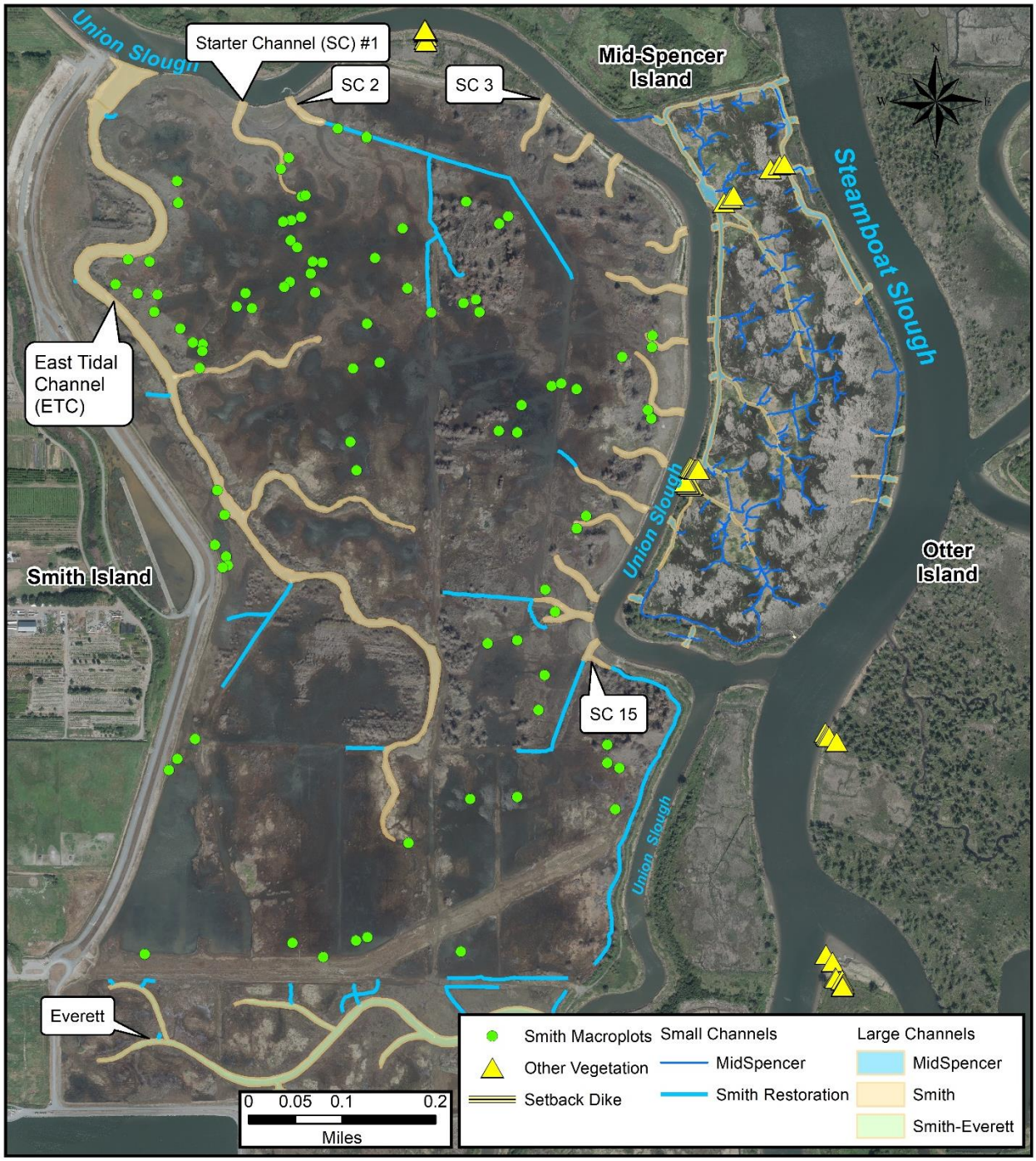


Figure 47. Smith Island vegetation macroplots established in 2018. Historical Snohomish Estuary vegetation survey transects are also shown.

In all, 100, 5-meter by 5-meter macroplots (Figure 48), were established across the Smith Island project site based on aerial photography, landscape position, and elevation range. Each macroplot was divided into 25 1-meter subplots. Five subplot locations were selected by random number generator for frequency analysis. A 1-meter square quadrat was placed at each of the 5 selected subplots. All plants within each subplot were identified to species and recorded. No cover data was collected.



Figure 48. Example 5-meter square macroplot for vegetation monitoring and 1-meter quadrat within.

A total of 500 subplots were assessed. Nine commonly observed species were ranked by frequency of occurrence (Table 14). However, the vegetation monitoring team documented 67 species of plants in total. Photo points were also established to observe qualitative changes in vegetation.

Table 14. Smith Island pre-project vegetation frequency of occurrence by common species among 500 quadrat samples and by 100 macroplots, summer 2018.

Species code	Common name	Status	Frequency of Occurrence	
			Quadrats (n=500)	Macroplots (n=100)
PHAR	reed canarygrass	Introduced	0.37	0.50
AGST	creeping bentgrass	Introduced	0.33	0.48
JUEF	soft rush	Native	0.21	0.36
HOLA	velvet grass	Introduced	0.19	0.29
RARE	creeping buttercup	Introduced	0.17	0.22
ALPR	meadow foxtail	Introduced	0.11	0.15
JUBU	toad rush	Native	0.11	0.15
CIAR	Canada thistle	Introduced	0.10	0.12
POAN	Pacific silverweed	Native	0.18	0.21

Reed canarygrass (*Phalaris arundinacea*) and creeping bentgrass (*Agrostis stolonifera*) were the most abundant species, each occurring in approximately 50% of all macroplots. Other commonly occurring species in this pasture matrix included velvet grass (*Holcus lanatus*), creeping buttercup (*Ranunculus repens*), soft rush (*Juncus effusus*), toad rush (*Juncus bufonius*), and Canada thistle (*Cirsium arvense*).

Depressional areas commonly hosted soft-stem bulrush (*Schenoplectus tabernaemontani*), common cattail (*Typha latifolia*), pacific silverweed (*Potentilla anserina*), common spikerush (*Eleocharis palustris*), and water foxtail (*Alopecurus pratensis*). Narrow-leafed cattail (*T. angustifolia*) was also present on occasion, sometimes in a mixed stand with common cattail, or other times alone. Edges of formerly managed areas were occupied by blackberry (*Rubus bifrons, R. laciniatus*), hardhack (*Spiraea douglasii*), red elderberry (*Sambucus racemosa*) and occasionally alder (*Alnus rubra*).

Overall, there appeared to be little correlation between vegetation and elevation differences within the Smith Island project site prior to restoration relative to vegetation differences by elevation observed in the tidal estuary. However, depressional areas hosted more typical native wetland species regardless of situational elevation. In these areas, hydrology and conditions for this assemblage of plants are tied to combinations of groundwater fluctuations, underlying hydric soils, and effects from compacted soils from prior land uses. Plot elevations across the project site were captured from the center of each macroplot by RTK-GPS and ranged predominantly from 3.0-6.6 feet (Figure 49). Few of the species above (Figure 45 and Table 14) are expected to persist post-breach and after the return of tidal inundation. However, other species will colonize and establish within Smith Island.

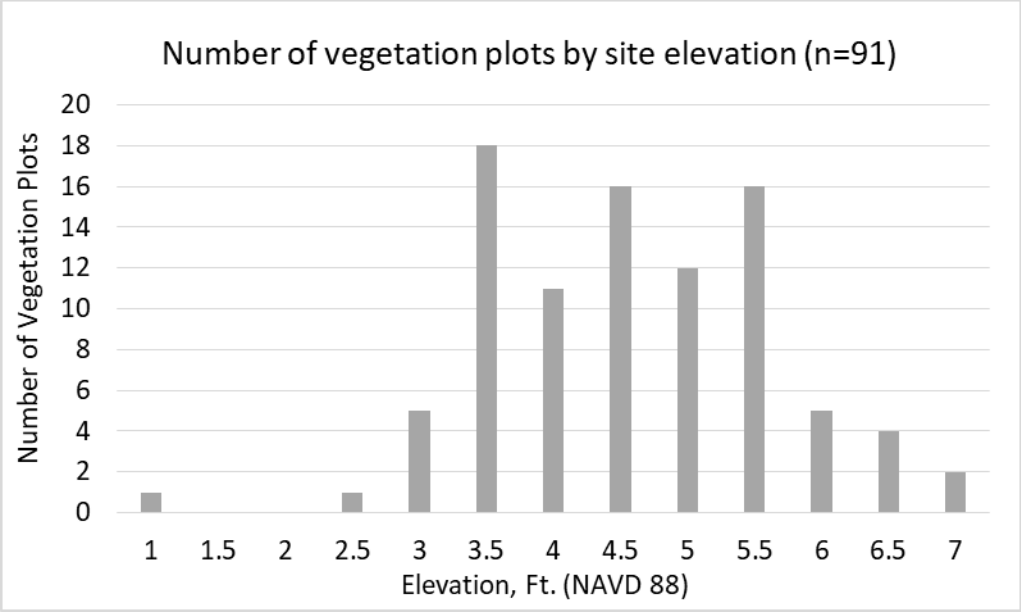


Figure 49. Smith Island vegetation macroplot elevation distribution. Only 91 out of 100 plots were surveyed for elevation with RTK-GPS.

In August 2019, one year after dike breaching, initial random walking observations were used to evaluate on-the-ground conditions, scope accessibility, and determine whether there was enough new vegetation to merit a full monitoring effort in Year 1. No recordable live vegetation was observed in any

of the 2018 vegetation plots we encountered and plots were not re-surveyed. Additional informal observations (August 30, 2019) were of mostly dead reed canarygrass (Figure 50). However, we did observe spike rush (*Eleocharis parvula*) and brass buttons (*Cotula coronopifolia*), primarily on bare mudflats.



Figure 50. Initial 2018/2019 die-off of grasses in pastureland areas of Smith Island.

These observations were primarily on areas of bare ground associated with excavated starter channels, the former (now lowered) dike footprint, and areas filled (usually former borrow ditches) with soil from the dike along Union Slough.

Also in 2019, we conducted 20 non-random, non-monumented 30-meter long transects that were perpendicular to excavated channels and the dike footprint. Locations were selected to maximize encountering measurable vegetation along each transect. Each transect started at either the water edge (of Union Slough or a starter channel) or at the top of bank, whichever was accessible and safe. A 1-meter square quadrat was placed every 5-meters on the transect, starting with a random point between 0 and 10 meter marks on the transect meter tape. Within each quadrat, all vascular plant species present and rooted within the quadrat were identified and listed. Daubenmire cover classes (values shown in Figure 51) were used to estimate amount of occupied space by each species. Each transect had 5 to 6 plots. Overall, the new pioneering vegetation was sparse, with less than 10% total cover on any one quadrat.

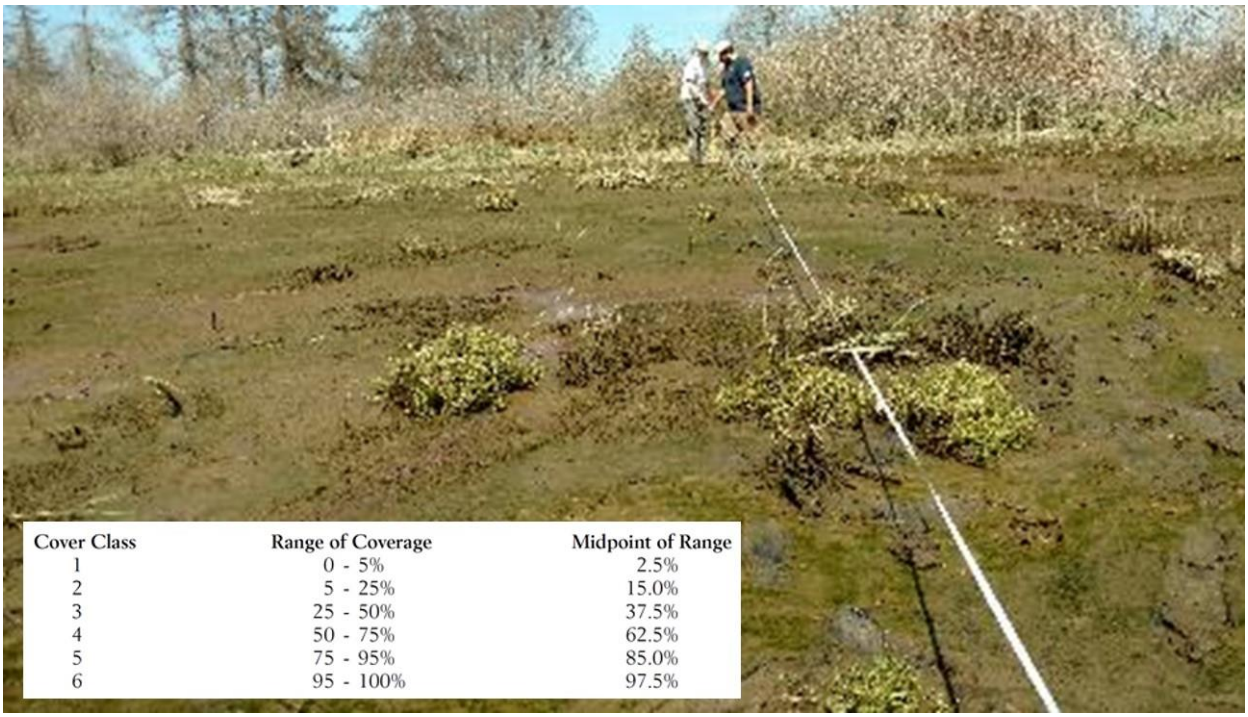


Figure 51. Example of line transect survey at Smith Island (2019) post-breach and cover classes used for characterization.

Species commonly encountered included brass buttons (*Cotula coronopifolia*), small spikerush (*Eleocharis parvula*), Lyngbye's sedge (*Carex lyngbyei*), reed canarygrass (*Phalaris arundinacea*), goosefoot (*Atriplex patula*), and creeping bentgrass (*Agrostis stolonifera*). On tidally influenced bare ground, filamentous bluegreen and green algae (*Enteromorpha sp.*) were the most common cover type (Figure 52). In some places these algal mats were over an inch thick (Figure 53) while in other areas it forms a thin green veneer.



Figure 52. Green algae growth across bare soils.



Figure 53. Mats of algae growth up to 1-inch think on bare ground. Tidal action can lift and reposition mats leaving them in twisted mats like abandoned carpet.

On bare mineral soil, circular patches of small spike rush are expanding outwards, contributing more cover and capturing fine sediments (Figure 54). The centers become sparser over time and may support establishment of other estuarine and floodplain adapted species.



Figure 54. Smith Island colonizing vegetation in 2019.

Lyngbye's sedge is rapidly colonizing disturbed bare ground created in dike removal, grading, and channel excavation. While some spread is from newly arriving seed, much of the sedge is expanding into the site (left to right in Figure 55) through rhizomes from the extant sedge benches outside the original dike footprint. Finally, we observe that remnant riparian shrubs and emergent vegetation that were situated on the outside of the old levee faces and adjacent to tidal shelves are colonizing landward into the bare mineral soil within the old levee footprint.



Figure 55. Existing Lyngbye's sedge (Carex Lyngbei) bench (left) next to bare soil of former dike footprint (right side of photo). A vegetation profile was captured here and is shown in Figure 40.

Following the collection of new LiDAR data and high-resolution imagery in summer 2019, the die-off of vegetation in terms of tree death and blow down was also evaluated. There were limited patchy extents of conifer trees at Smith Island, comprised of Douglas fir, Western red cedar, Shore pine, and Norway spruce, all of which were growing at elevations subjected to tidal inundation and salinity intrusion. LiDAR was used to detect blow down by creating a vegetation height model based on the difference between a bare earth elevation and the first return (tree top) elevation. The same vegetation height model was also created for the 2014 LiDAR collection. Figure 56 shows the 2014 first return hillshade used to create the model (top left panel, Figure 56), the 2014 classified vegetation height (>12 feet; top right panel), the 2019 post-breach classified vegetation height (>12 feet; lower left panel), and the trees that have blown down represented as the visible color in the lower right panel (Figure 56). In this panel, the 2019 tree height is greyed out and masks the 2014 tree height, except where trees were no longer standing in 2019. Only the 2014 former tree height shows through. These downed trees will decay over time, may float and move position, and could form other habitats. In all, using the 2019 high-resolution ortho-imagery, a total of 116 trees are estimated to have blown down in 2018-2019. As more trees die and lose root strength in saturated soils, more trees will blow down, adding to the stock of downed woody material that is part of natural estuarine habitats.

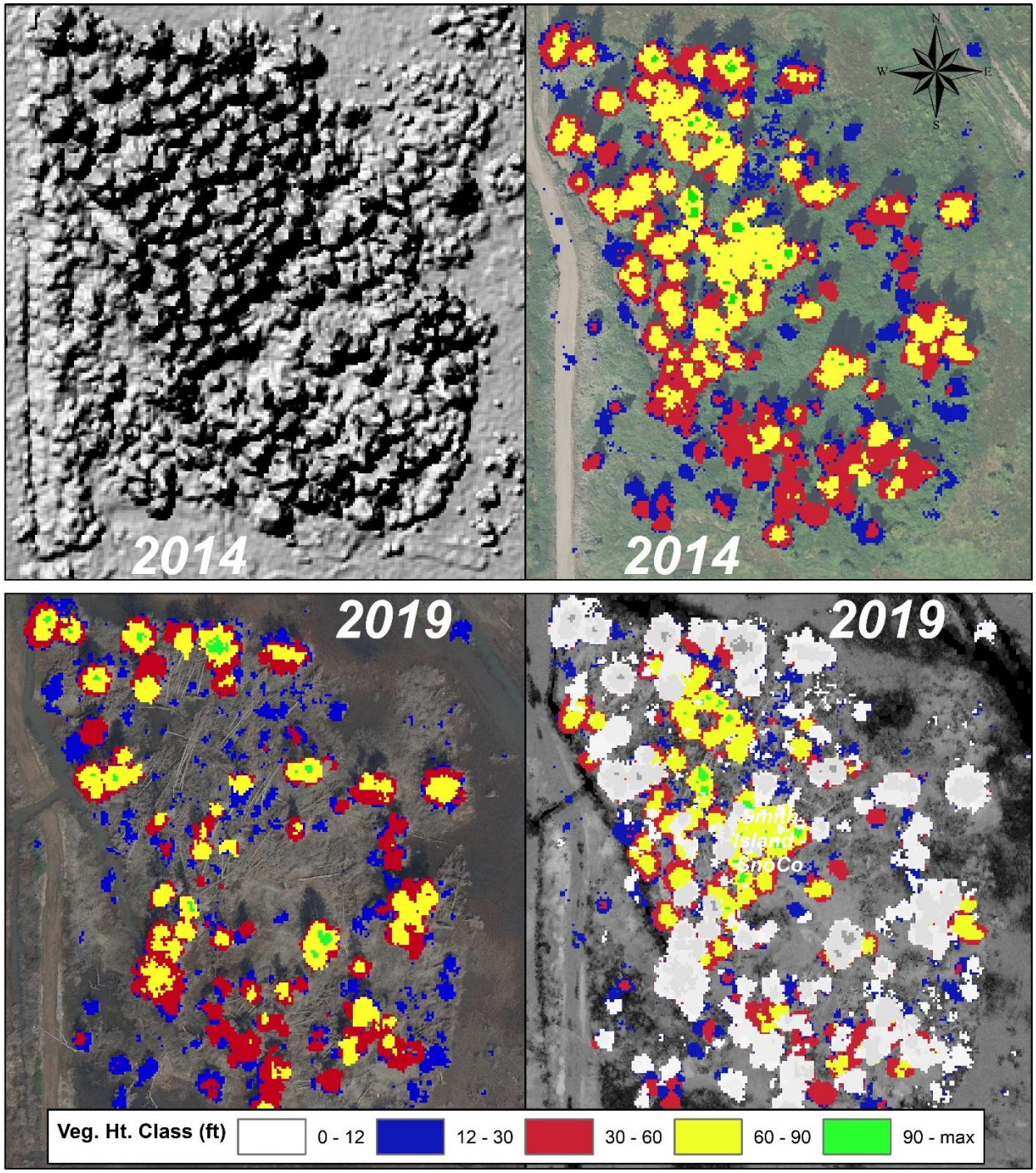


Figure 56. Vegetation height classes derived from LiDAR differencing model (surface height minus ground elevation) for 2014 (pre-project) and 2019 (post-breach). Visible color in lower right panel not masked by 2019 shading (grayed out) represents tree blow down.

In addition to tracking the types of vegetation lost and gained by area at Smith Island, noxious weed presence will also be determined to ensure they can be eliminated or controlled. Identifying noxious weed control options and implementation of control measures is an objective of vegetation monitoring.

In April 2019, the face of the new cross levee was surveyed for the extent of Scotch broom infestation. On May 1, Scotch broom was treated with imazapyr over two consecutive days (upper left, Figure 57). The effectiveness of the herbicide application and resurgence of original hydro-seeded grasses was observed during multiple visits in June-August (upper right), after which the standing dead Scotch broom and other vegetation was mowed (lower left). By October 2019, the original hydro-seeded native grasses had rebounded (lower right, Figure 57). The treatment also controlled other undesirable non-native plants such as clover and thistles.



Figure 57. Invasive Scotch broom on the new set-back levee being treated with imazapyr (upper left), after die-back (upper right), mowing (lower left), and re-growth of hydro-seeded native grasses (lower right).

Other non-native invasive species observed in limited areas within the interior of the Smith Island site (in summer 2019) included Purple loostrife, thistle, a nightshade and patches of Himalayan blackberry still persisting at a few higher elevation areas. These locations will be observed in 2020 to determine their persistence, if any.

In future years, coarse vegetation community types will be delineated from aerial photos to document changes in aerial extents of tidal flats, emergent marsh, and scrub/shrub. In the near-term, vegetation die-off will be observed as new colonization and expansion occurs. These changes will be documented among macroplots, photo points, and line transect surveys to characterize species composition and cover within these coarse community assemblages. Though, re-visits to the numerous macroplots in tidal flat areas may not be needed.

8. Fish Use and Biota

While the Smith Island and Mid-Spencer projects will have long-term benefits to plants and animals that rely on intact estuary process, the primary purpose for these restoration actions was to improve rearing habitat for listed Chinook salmon. As such, the project goals are to restore fish access to Smith Island and Mid-Spencer Island, improve salmon habitat quality and quantity, and thereby increase fish rearing capacity. It is assumed that restoration sites in the Snohomish Estuary, including Smith Island, will offer rearing opportunity, capacity and functions over time that are similar to unaltered (or previously restored) tidal marsh and natural edge habitats. Estimates of juvenile salmonid fish use and site capacity for rearing will be dependent in part on the extent of dispersal within a network of accessible restored tidal channels, presence of fish in Union Slough and connectivity to adjacent waters. Other indicators of benefits accruing to rearing salmon are fish size, length of seasonal site use, and diet.

For these project sites, we were interested in evaluating the following questions pertaining to fish use and more specifically juvenile salmon rearing.

- Which species are present and what parts of the project sites do salmon access for rearing?
    - Does use vary within-site (channel, flats, and dike face)?
    - Does use vary by wild and hatchery types?
- When do salmon use the project sites during the spring/summer outmigration season?
    - Does seasonal use vary among project habitat types or compared to other natural or reference sites?
- Are there differences in indicators of benefit, such as size and rearing timing compared to other sites?
- How does use at project sites compare to other sites sampled nearby or across the estuary?
    - Do salmon densities and distribution inside Smith Island and Mid-Spencer resemble those in other restoration sites?
    - Does the multiple large breach design of Smith Island and Mid-Spencer increase connectivity and lead to higher and more well distributed salmon use compared to restoration sites with single breaches?

Monitoring for salmon and other fish use of the new projects will answer key questions about their success and can provide insights for other important salmon recovery adaptive management actions. However, fish use will also be dependent upon up-river seasonal and annual outmigration patterns (e.g., Chamberlin et al., in review) and watershed abundance of salmon that will vary by year. Therefore estimating and interpreting the observed fish use and reconciling annual differences will require data on fish use for restoration sites, estuary-wide fish use, and up-river fish use - the estimates of juvenile salmon abundance from Skykomish and Snoqualmie river smolt trapping (e.g., Kubo et al. 2013). Therefore, a thorough understanding of the benefits of Smith Island and Mid-Spencer Island will take some years to evaluate. For Smith Island and Mid-Spencer Island, Snohomish County's Fish Use monitoring element is described in Table 15.

Table 15. Deliverables for fish monitoring at Smith Island and Mid-Spencer project sites.

Element	Fish Use
Goal/Purpose	Document and demonstrate fish access and use of the project sites (Smith Island and Mid-Spencer) in manner similar to other restored sites and/or comparable off-channel habitats.
Questions	• Are juvenile salmon present at the project sites confirming accessibility and connectivity? • If so, when (seasonal timing), where (East Tidal Channel, excavated starter channels, edge/bank habitats within the sites), and how many (catch per unit effort or density)? • What proportion are hatchery vs. wild origin? • How much new salmon rearing habitat capacity exists at Smith Island and Mid-Spencer Island? • How does fish use at Smith Island and Mid-Spencer Island compare to fish use at other accessible index sites (main channels), and other restored or natural off-channel locations? • Is the abundance, timing, or locations of fish use influenced by environmental factors unique to or reflecting differences at Smith Island and Mid-Spencer Island (e.g.; water quality, habitat quantity and quality) relative to other estuary-wide locations? • Is the level of fish use influenced by relative level of fish use in Union Slough? Is the level of fish use in Union Slough similar to Steamboat and Ebey sloughs?
Objectives	Collect pre-project and post-project fish use data at Smith Island, Mid-Spencer, Union Slough and System-Wide sample locations with beach seine. Provide data to NOAA-NWFSC for their database. For this study, fish use refers to data describing species, sample location, abundance/catch per unit effort, fish size, timing, and origin (hatchery or wild). This activity was covered by a NOAA-NWFSC/ Tulalip/ Snohomish County ESA 10A1a permit.
Methods	Small modified Puget Sound beach seine (measuring 36 meters length and 1.8-3.0 meters in height (wings to bag) made of 3mm (wings) to 1.5mm (bag) knot-less nylon mesh) standardized among Tulalip Tribe, NOAA-NWFSC, and Snohomish County. All fish species are identified, counted, and measured (fork length or total length, up to 25 individuals/species/location). Fish sample processing protocols for 2018 are included in Appendix G as well as a map of index and random sample locations. For each fish sampling site, temperature, dissolved oxygen, and salinity are also measured at the water surface and bottom, as is tidal current velocity. All required biological sampling permits will be obtained.
Number of units/ samples	20 long-term index sites throughout 9 zones in the Snohomish Estuary, 12 random sites within Smith Island and Mid-Spencer and 3 random sites within Union Slough.

Table 15 Cont.	
Frequency/ Duration	Monthly (Feb-Sept) pre-project and post-project beach seine sampling. Duration – Year 0, 1, 2, 3, 5, 7, 10, pending funding.
Deliverables **(D & I Sharing)**	Provide map of sample site locations and tables/figures of fish use by month by site. NOTE - data analysis will primarily be performed by NOAA-NWFSC.
Evaluation/ Analysis **(D & I Sharing)**	For preliminary analysis of fish data, descriptive statistics, simple graphical analysis, and multivariate techniques will be used. For Smith Island and Mid-Spencer, the summary of field effort and basic patterns of fish use of the sites in space and time will confirm use, timing, species composition, and size. Other analyses and reporting of the fish data will be provided by NOAA-NWFSC and/or Tulalip Tribes (e.g. Rice et al. 2013), focusing on estuary-wide patterns of fish use and a comparison to multiple restoration sites, off-channel locations, channels, and habitat zones.

Estuary-wide fish monitoring has been implemented since 2012 in collaboration with NOAA Northwest Fisheries Science Center and Tulalip Tribes Natural Resources. This effort has typically been implemented at approximately 20 long-term index sites and at six or more off-channel locations which are similar to the restored tidal marsh locations adjacent to the mainstem or distributary channels (Steamboat, Union, or Ebey sloughs). Moreover, NOAA and Tulalip Tribes are also monitoring fish use at the Qwuloolt restoration site (Rice et al. 2013). There is an abundance of pre-project data for these comparison and long-term index sites in a database managed by NOAA. This database will provide the estuary-wide context to evaluate fish use by restoration sites, by site connectivity metrics (NOAA) and relative to watershed-wide smolt production estimates. Results from pre-project and system wide studies will be published in Chamberlin et al. (in review) and subsequent publications. Snohomish County fish monitoring information has been and will continue to be incorporated into the NOAA database, though this report documents initial fish monitoring results from 2019 random and index sites in the immediate vicinity of the projects.

In 2019, the first year post-restoration, Smith Island intensive fish sampling generally occurred once every two weeks (a cycle) between February and September. For each sample cycle approximately 24 sites (random and index) were sampled including nine inside Smith Island channels, seven in Union Slough, three each in neighboring Mid-Spencer and Port of Everett off-channel sites and two additional sites in Steamboat Slough. Random sample locations were generated by NOAA for all off-channel and restoration sites among the entire Snohomish Estuary. Within the Smith Island project site, a total of 123 net sets were conducted between February and September. Including these sets and others near Smith Island, Snohomish County completed 326 net sets in 2019. 2019 sampling of Mid-Spencer Island occurred prior to project construction.

Monitoring methods are adapted from Chamberlin et al. (in review). At each site, fish were sampled using a 125-foot long nylon beach seine that tapered from 10-feet deep at the center to 6-feet deep at the wings. At off-channel locations that have tighter working dimensions, a smaller 80 ft. x 6 ft. net was

used. The beach seine was normally set during an outgoing tide. At each site, the sample team deployed the seine in a semi-circle from the bow of a boat or floating tote moving in a downstream direction among different habitat types (a starter channel in Figure 58 and on the setback dike and marsh plain Figure 59). Then the net was pulled into the shore, concentrating the catch into the bag at the center of the net. Fish and other macro-organisms were placed in buckets, identified by species, measured and released. Chinook and coho salmon were additionally identified as hatchery or natural origin based on visual identification of external marks (adipose fin clip) or detected presence of a coded-wire tag.



Figure 58. Setting a beach seine in Starter Channel 14, May 9, 2019. Union Slough is in background.



Figure 59. Setting a beach seine within the interior of Smith Island from the new setback dike.

Within the Smith Island restoration site, 16 species of fish and one species of cnidarian medusa (water jelly) were caught. Table 16 lists each species by total number netted within Smith Island and outside the project in Union Slough and the date of the first catch per species both inside the project and out. Salmon were first caught inside the Smith Island project site in March and continued to be caught until August. Specifically, chum salmon were caught between March 12th and June 19th, Chinook were caught between March 26th and July 2nd and coho between May 8th and August 20th. Figure 60 displays the location and general number of the three salmon species caught in and near the site.

Table 16. Catch and date of first catch for sites inside and immediately outside of the Smith Island project, February-September 2019.

Common Name	Scientific Name	Smith Island Interior Catch (123 seine sets)	First Date Caught	Exterior Union Slough Catch (52 seine sets)	First Date Caught
Blackeye Goby	*Coryphopterus nicholsii*	11	8/20	0	-
Chinook (Hatchery)	*Oncorhynchus tshawytscha*	36	4/9	6	5/22
Chinook (Wild)	*Oncorhynchus tshawytscha*	181	3/26	93	2/27
Chum	*Oncorhynchus keta*	923	3/12	1088	2/27
Coho (Hatchery)	*Oncorhynchus kisutch*	1	5/21	0	-
Coho (Wild)	*Oncorhynchus kisutch*	72	5/9	5	5/9
Large Scale Sucker	*Catostomus macrocheilus*	36	6/11	0	-
Coastal Cutthroat	*Oncorhynchus clarki*	3	6/4	0	-
Pacific Herring	*Clupea pallasii*	0	-	3	7/3
Brook Lamprey	*Lampetra planeri*	0	-	2	5/9
Peamouth Chub	*Mylocheilus caurinus*	338	3/12	5	4/10
Pile Perch	*Rhacochilus vacca*	1	7/12	0	-
Prickly Sculpin	*Cottus asper*	100	2/26	18	3/27
Redside Shiner	*Richardsonius balteatus*	1	6/4	0	-
Saddleback Gunnel	*Pholis ornata*	1	5/21	0	-
Shiner Perch	*Cymatogaster aggregata*	309	6/11	73	5/9
Staghorn Sculpin	*Leptocottus armatus*	543	2/26	49	2/27
Starry Flounder	*Platichthys stellatus*	649	3/12	232	3/14
Threespine stickleback	*Gasterosteus aculeatus*	3324	2/26	357	2/27
Water Jelly	*Aequorea spp.*	5	5/8	3	5/9
Longnose Dace	*Rhinichthys cataractae*	1	5/8	2	5/9

Sampling from 2019 demonstrates that fish were utilizing new channels and connected habitats within the Smith Island project with multiple fish species documented throughout the site over the sampling period. Ubiquitous estuary species such as starry flounder and staghorn and prickly sculpin were observed in the site very early in the sampling effort.

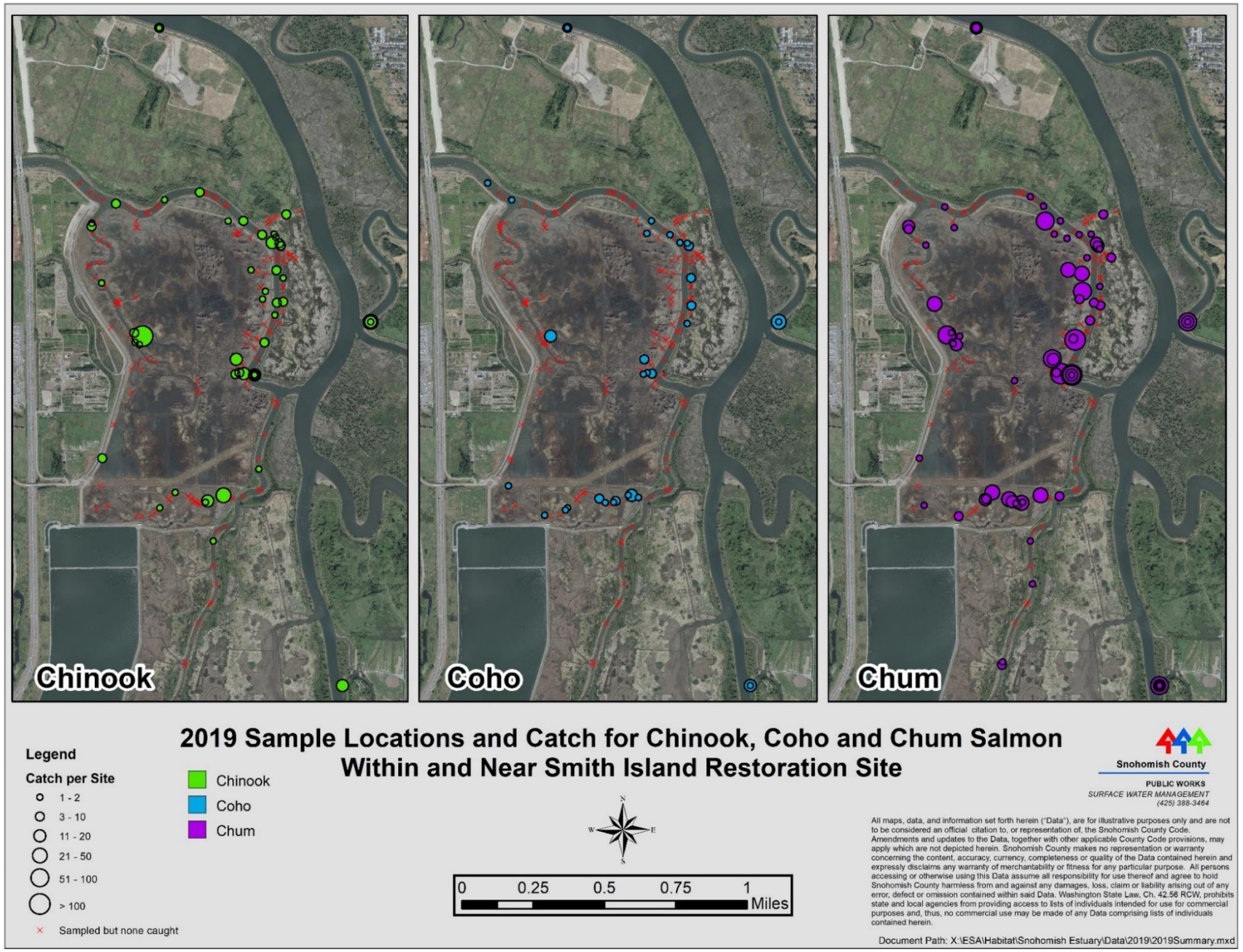


Figure 60. Location of 2019 seine locations with catch of Chinook, coho and chum salmon.

Initial results not only reveal that juvenile salmon have adequate access through multiple breach openings on incoming tides but that, in at least some instances, salmon remained in wetted areas of the Smith Island project through the outgoing tidal cycle. For Smith Island, the peak catch of Chinook salmon was during cycle 10 in late May, which is typically toward the end of cumulative fish outmigration (Figure 61). Particularly interesting was the abundance and size of juvenile Chinook and chum salmon using the restored site. Chum are thought to move quickly through the estuary to rear in nearshore areas but the abundance and size of chum found deep within the project site suggests a longer residence time when habitat is available.

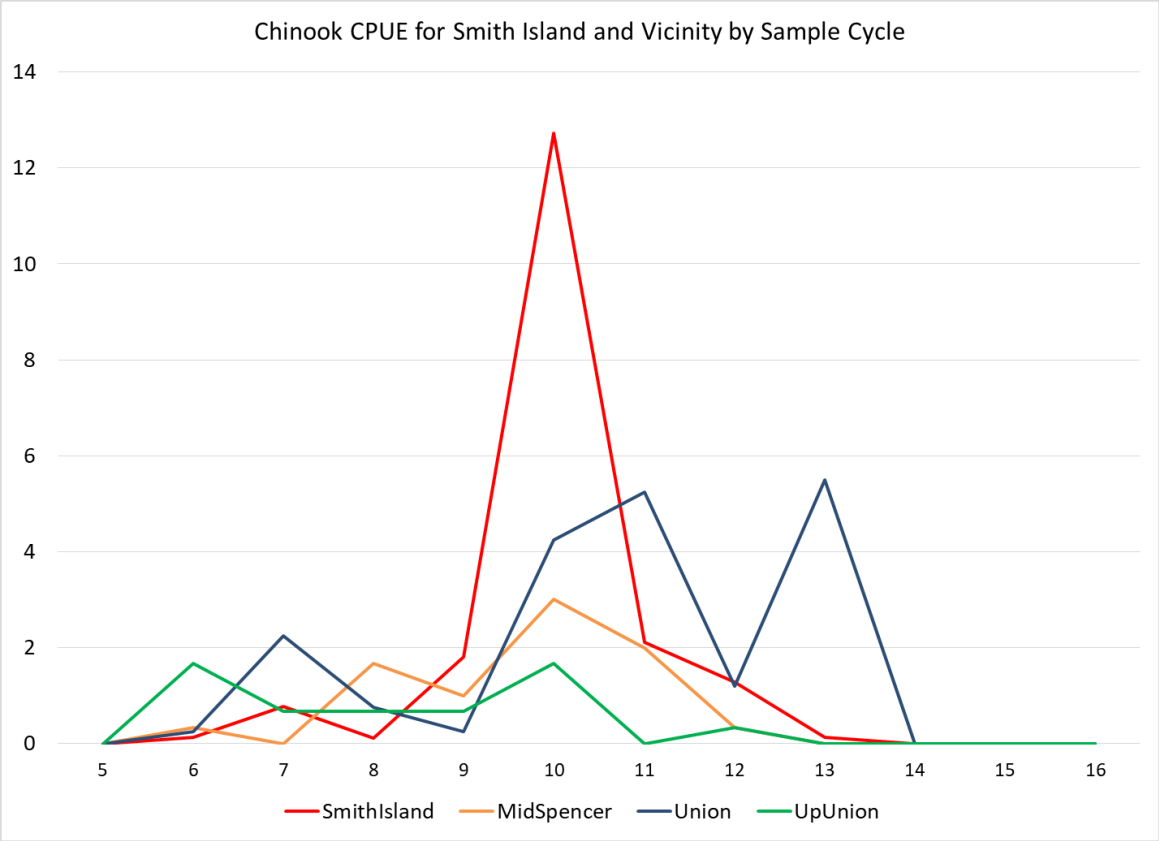


Figure 61. Chinook salmon catch per unit effort by sample cycle for four locations.

For sub-yearling Chinook, we compared the lengths of fish sampled among several sites during cycle 10, in part due to the larger catch and our anecdotal observation of larger sized Chinook being found in Smith Island. Chinook salmon caught in the East Tidal Channel were larger than those caught elsewhere among nearby sites. Other Smith Island starter channels (SC's) also held larger fish on average (Figure 62). Elsewhere, smaller Chinook were observed at Mid-Spencer Island, in the adjacent Union Slough and especially in upper Union Slough.

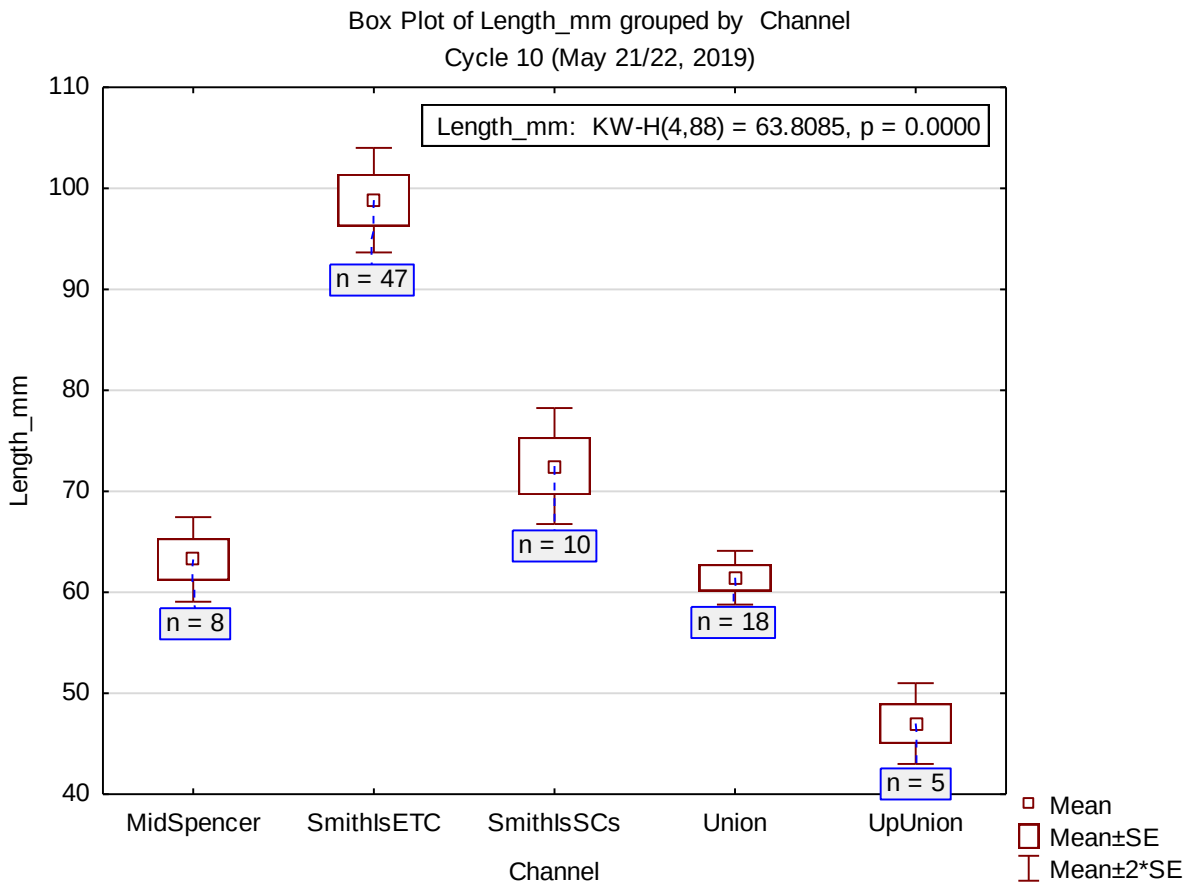


Figure 62. Sub-yearling Chinook salmon average length among sites for cycle 10 sampling. Count (n= #) by site is also shown.

In future years we plan to monitor fish use at Smith Island and Mid-Spencer Island to:

- Characterize species use, timing, and size,
- Document differences among restored and nearby marsh sites,
- Estimate capacity for rearing at Smith Island,
- Compare results with other intensively monitored sites (e.g., Qwuloolt), and
- Evaluate potential differences in fish use among distributary channels, starter channels, Mid-Spencer Island, and the East Tidal Channel.

Other biota including birds, mammals and macroinvertebrates (small bugs), present at Smith Island, will also be observed, though not formally monitored. Estuaries are very valuable habitats for migrating and resident birds so observing their use of the newly created habitat is important. To date, we have generated a species list of birds observed at Smith Island and Mid-spencer Island (Appendix H). Any use of or colonization by beaver will also be noted. Macroinvertebrates that provide forage for juvenile salmon may be collected in the future to better understand how Smith Island supports the juvenile salmon diet. However, collection of this type of data will only be implemented if part of an estuary-wide scope of work led by either NOAA or Tulalip Tribes. Inclusion of Smith Island and Mid-Spencer Island in that potential study would be welcomed.

Application of Monitoring Information and Recommendations

Outcomes, observed or measured at the Smith Island project site to date are consistent with the goals, objectives and design of the project. It is too early to make conclusions that would lead to adaptive actions needed to reinforce outcomes or address unanticipated outcomes. As Mid-Spencer Island was constructed in 2019, no monitoring information is relevant yet to conclusions or recommendation. Monitoring data and observations collected to date support all of the following statements about the Smith Island restoration project;

- Smith Island, as-built, meets the design objectives and fully exchanges tidal cycles.
- Smith Island increases Snohomish estuary habitat area, channel connections, and blind tidal channel area, replacing some historically lost capacity for juvenile salmon.
- Salmon were observed using all part of Smith Island including the East Tidal Channel, constructed Starter Channels, Everett Channel, and the front of the new setback dike. In addition we sampled 12 other typical estuarine rearing fish species within the Smith Island project site.
- Temperature and salinity were as expected for this part of the estuary (Hall et al. 2018) and supportive of the majority of salmon rearing in spring and early summer (Chamberlain et al., in review).
- Vegetation in Year 1 was, as expected, in a state of die-off and large trees began to blow over during winter storms. Emergent marsh species colonization and expansion is occurring.

Applying future monitoring information gained from the Smith Island and Mid-Spencer Island projects will assist with the following categories of adaptive decision-making:

- Evaluating salmon rearing capacity and functions at estuary restoration sites to inform future updates to Salmon Plan recovery targets.
- Evaluating salmon rearing capacity at restoration sites in the context of system-wide salmon rearing to estimate and prioritize additional future restoration, if needed.
- Informing future estuary restoration project designs.
- Informing decision-making appropriate to Smith Island stewardship and maintenance.
- Informing mitigation compliance objectives and performance.
- Correcting or maintaining project conditions from un-anticipated outcomes,
- Planting intervention to promote marsh scrub-shrub or forest development.

Smith Island and Mid-Spencer Island are only a small part of the Snohomish Estuary. On an estuary-wide scale, as multiple restoration actions, like Qwuloolt, Smith Island, Mid-Spencer and Blue Heron Slough, occur in relatively short sequence, it may be difficult to differentiate changes or outcomes that only reflect restoration at Smith Island and Mid-Spencer Island and not interacting effects from other actions. Therefore, some of the data collection for system-wide fish use will be continued to better interpret observations at Smith Island and Mid-Spencer Island in the context of the whole estuary and other sites. Estuary-wide changes will be analyzed in collaboration with NOAA, the Tulalip Tribes, and other restoration partners. Due to the number of variables that affect salmon populations in freshwater,

estuaries, Puget Sound and the North Pacific Ocean over multiple years, there will likely be ongoing uncertainty regarding the individual site effects of restoration at Smith Island and Mid-Spencer Island on salmon population abundance, productivity, diversity and spatial structure – the viable salmonid population parameters.

Stewardship Recommendations

These actions are recommended to improve site conditions at Smith Island and/or Mid-Spencer Island:

- Remove metal fence posts, and other fencing.
- Remove tires and other large trash.
- Treat invasive weeds after additional die-off in 2019- 2020, and reconnaissance in summer 2020.
- Remove one remaining culvert in re-connected ditch. This has plugged occasionally.
- Improve flow connectivity of a remnant historical natural at the end of the East Tidal Channel that is bisected by road fill.
- Improve drainage connections from haul road compaction/ depressions to adjacent ditches/channels.

Monitoring Recommendations

Continue implementation of the Snohomish County Estuary Monitoring Plan according to planned effort, with limited exceptions. For example, hydrologic monitoring was conducted primarily to demonstrate full tidal cycle inundation and drainage as part of documenting implementation effectiveness. Other data collected included water temperature and salinity, which also confirmed tidal exchange. Therefore hydrologic monitoring for implementation effectiveness will be discontinued in future years. Table 17 highlights planned monitoring work by year. Ideally over time we will make more use of un-manned aerial vehicles for low-elevation imagery and mapping.

Table 17. Planned annual schedule of monitoring elements, pending funding. Yr0 is 2018. Grant funded years are italicized.

Monitoring Element	***Monitoring Years (Calendar and Project Yr.)***							
	2018	***2019***	**2020**	**2021**	**2023**	**2025**	**2028**	**2030**
	Yr0	***Yr1***	**Yr2**	**Yr3**	**Yr5**	**Yr7**	**Yr10**	**Yr12**
Photo/video points	*X_PP*	*X*	X		X		X	
Topography (channels and LiDAR-*L*)	*X_P*	*X*	X		X -*L*		X -*L*	
Hydrology	*X_PP*	*X*	X					
Sediment monitoring	*X_PP*	*X*	X	X	X	X	X	
Vegetation composition	*X_P*	*X*	X	X	X	X	X	
Wetland Rating					X		X	
Fish Monitoring	*X_P*	*X*	X	X	X	X	X	
Large Woody Material	*X*	*X*	X	X	X	X	X	
Invasive species	*X_PP*	*X*	X	X	X	X	X	
Analysis and reporting			***Yr0-1***	**Yr2**	***Yr3***	***Yr5***	***Yr7***	***Yr10***

P- Pre-breach; PP – Pre- and Post-breach

References

Beechie, T. J., B. Timpane-Padgham, O. Stefankiv, J. Hall, G. Pess, M. Liermann, M. Rowse, K. Fresh, and M. Ford. 2017. Monitoring habitat status and trends in Puget Sound: development of sample designs, monitoring metrics, and sampling protocols for nearshore, delta, large river, and floodplain environments. NOAA Technical Memorandum.

Cahoon D.R., and J.C. Lynch. 2003. Surface Elevation Table Website, Patuxent Wildlife Research Center, Laurel, MD. U.S.A. http://www.pwrc.usgs.gov/set/

Cereghino, P., J. Toft, C. Simenstad, E. Iverson, S. Campbell, C. Behrens, J. Burke. 2012. Strategies for nearshore protection and restoration in Puget Sound. Puget Sound Nearshore Report No. 2012-01. Published by Washington Department of Fish and Wildlife, Olympia, Washington, and the U.S. Army Corps of Engineers, Seattle, Washington.

Chamberlin, J., J. Hall, T. Zackey, F. Leonetti, M. Rustay, C. Rice. In review. Broad scale spatial and temporal variability in Chinook salmon distribution reflects important life history distinctions in an estuarine landscape.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79-31.

Haas, A., and B. D. Collins. 2001. A Historical Analysis of Habitat Alteration in the Snohomish River Valley, Washington since the mid-19th Century: Implications for Chinook and Coho Salmon. Report for Snohomish County.

Hall, J. E., T. P. Khangaonkar, C. A. Rice, J. Chamberlin, T. Zackey, F. Leonetti, M. Rustay, K. Fresh, A. Kagley, and M. Rowse. 2018. Characterization of salinity and temperature patterns in a large river delta to support tidal wetland habitat restoration. Northwest Science 92(1):36-52.

Hood, G.W. 2002a. Landscape allometry: from tidal channel hydraulic geometry to benthic ecology. Can. J. Fish. Aquat. Sci. 59:1418-1427.

Hood, G.W. 2002b. Application of landscape allometry to restoration of tidal channels. Restoration Ecology 10 (2): 213-222.

Hood, W.G. 2007. Scaling tidal channel geometry with marsh island area: a tool for habitat restoration, linked to channel formation process. Water Resour. Res. 43, W03409.

Hood, W. G. 2014. Differences in tidal channel network geometry between reference marshes and marshes restored by historical dike breaching. Ecological Engineering 71 (2014) 563–573.

Kubo, J., K. Finley, and K. Nelson. 2013. 2000-2012 Skykomish and Snoqualmie Rivers Chinook and Coho Salmon Out-migration Study. Tulalip Tribes Natural Resources Department Report. Tulalip Natural Resources Division 6406 Marine Dr. Tulalip, WA 98271.

Lynch, J. C., P. Hensel, and D. R. Cahoon. 2015. The surface elevation table and marker horizon technique: A protocol for monitoring wetland elevation dynamics. Natural Resource Report NPS/NCBN/NRR—2015/1078. National Park Service, Fort Collins, Colorado.

Office for Coastal Management, 2020: C-CAP Land Cover, Snohomish County, Washington, 2016, https://inport.nmfs.noaa.gov/inport/item/53263.

Ramirez, M and Simenstad, S. 2018. *DRAFT* Protocol Recommendations for Tracking Estuary Extent and Restoration in Puget Sound. Designed for reporting on Chinook Salmon Recovery Common Indicators and Puget Sound Vital Sign Indicators. Supported with Puget Sound Partnership Assessing Recovery Funds for the 2017-2019 biennium under Interagency agreement IAA 2018-29. 26 pages.

Rice, C., Chamberlin, J., Hall, J., Zackey, T., Schilling, J., Kubo, J., Rustay, M., Leonetti, F., Guntenspergen, G. 2013. Monitoring ecosystem response to restoration and climate change in the Snohomish River estuary - Field operations and data summary. Prepared for Tulalip Tribes. December 31, 2013.

Simenstad, C, M Logsdon, K. Fresh, H. Shipman, M. Dethier, J. Newton. 2006. Conceptual model for assessing restoration of Puget Sound nearshore ecosystems. Puget Sound Nearshore Partnership Report No. 2006-03. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington. Available at http:// pugetsoundnearshore.org.

Snohomish Basin Salmon Recovery Forum (SBSRF). 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works, Surface Water Management Division, Everett, WA.

Snohomish County 2018. Snohomish County Estuary Monitoring. Snohomish County, Public Works, Surface Water Management, Everett, WA.

VanEssen Instruments (2016). Product Manual, Diver. Eijkelkamp Soil and Water. P.O. Box 4, 6987 ZG Giesbeek Nijverheidsstraat 30, 6987 EM Giesbeek, The Netherlands.

Appendices

Appendix A. Locations of Snohomish Estuary tidal marsh restoration projects and status. Diked locations actively or passively restored to tidal hydrology since 1996 are highlighted (yellow).

Appendix B. NOAA Award Special Conditions and RCO statement of Work.

Appendix C. Smith Island Photo Points.

Appendix D. Estuary-wide water quality sampling map (Figure 1 from Hall et al. 2018). CWS sites record water level, temperature, and conductivity (salinity). Snohomish County sites are labeled ETC (East Tidal Channel) and MSp (Union Slough at Mid-Spencer.

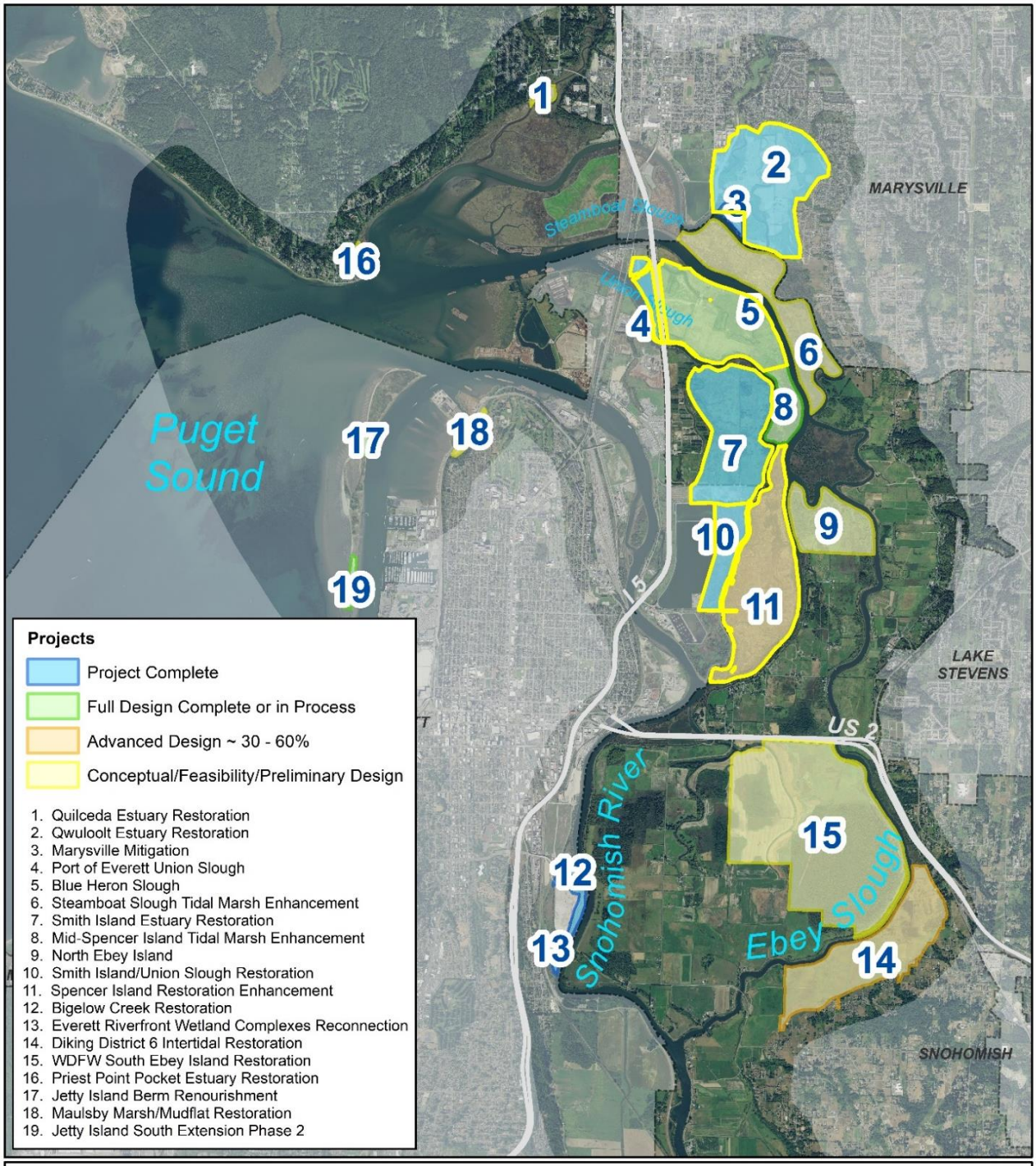
Appendix E. Smith Island cross-section and longitudinal profile data and figures.

Appendix F. NOAA high-resolution land cover classification and Snohomish Estuary projects.

Appendix G. 2019 Snohomish Estuary Fish Sampling Protocol (from NOAA) and Site Map.

Appendix H. 2018-2019 Bird list.

Appendix A. Locations of Snohomish Estuary tidal marsh restoration projects and status. Diked locations actively or passively restored to tidal hydrology since 1996 are highlighted (yellow).



Special Award Conditions

Award Number: **NA16NMF4630008**
Amendment Number: **0**

1) New Award SAC
This award number NA16NMF4630008, to Washington Department of Fish and Wildlife, supports the work described in the Recipient's proposal entitled "Restoring Resiliency in Puget Sound Snohomish River Delta" dated 7/1/2015, and revisions dated 11/6/2015, which are incorporated into the award by reference. Where the terms of the award and proposal differ, the terms of the award shall prevail.

2) Outstanding NEPA Documentation and Restricted Availability of Funds
By accepting this award, the Recipient agrees to assist and cooperate with NOAA Fisheries in the preparation of any outstanding National Environmental Policy Act (NEPA) compliance documentation. For purposes of NEPA compliance, Phase 1 of the project includes project design, permitting, outreach, and baseline monitoring. The activities for which work can proceed (as described above) will have no significant individual or cumulative adverse effects on the environment. The Recipient will not expend any funds for Phase 2 project implementation which includes levee removal construction and associated engineering until impacts have been assessed, and NEPA compliance documentation has been completed by NOAA. At this time, $1,492,277 of the total award funds are available to the Recipient to complete Phase 1 tasks outlined above that have no adverse impacts on the environment. The remaining award funds will be available after the NOAA Program Officer provides NEPA clearance by confirming in Grants Online that this award condition has been satisfied.

3) Monitoring Implementation and Basic Effectiveness for Hydrologic Reconnection Projects
NOAA's Restoration Center will use the following products to evaluate whether restoration techniques have been implemented as designed, and whether those designs show a basic level of effectiveness at meeting project goals: 1) Restoration Designs; 2) Post-construction As-Built Drawings; 3) Pre- and Post-restoration hydrographs.

Restoration designs will be prepared and stamped by a licensed professional engineer and will show all relevant existing and proposed elevations and cross-sections of structures, channels, wetlands, and floodplains. The as-built drawings will be prepared by a professional land surveyor and shall show the final elevations and cross-sections of the structures, channels, and land installed or altered by the project. As-built drawings will be surveyed into a known elevation benchmark and referenced to a standard geodetic datum.

Pre- and post-restoration hydrographs will be generated by collecting water elevations using at least three data loggers (upstream and downstream of a removed tidal restriction, and one to correct for atmospheric pressure) surveyed into the same elevation benchmark and datum as the as-built drawings and project plans. Each monitoring period will occur over a 28-day tidal cycle, and measurements will be taken every 15 minutes.

Washington Department of Fish and Wildlife is required to submit these products no later than the final report. A separate monitoring report is required as part of the final report. The monitoring report must include:
• As-built drawings and a description of any deviations from original design plans, along with explanations for any such deviations;

• Descriptions of the methods and equipment used, including the location and elevation of all gages/ data loggers on a map;

• Pre- and Post-restoration hydrographs and a discussion and interpretation of the information captured during monitoring, referenced to tidal and geodetic datums; and

• Recommendations for further investigation and monitoring.

4) Cost Sharing or Matching Requirement
The Recipient is providing matching funds in the amount of $1,100,000 of project-related costs from non-federal sources. The Recipient must maintain its official accounting records for the entire award Federal share and match in the amount of $1,100,000. Cost sharing or matching requirements of 2 C.F.R. Sec. 200.306 and Department of Commerce Financial Assistance Standard Terms and Conditions Sec. B.04 apply to this award. Per Sec. B.04, the Recipient should contact the Grants Officer if it seeks an exception to the policy requiring cost share to be paid out at the same general rate as the Federal share.

5) Contact Information
Contact information for NOAA and the Recipient is maintained in the NOAA Grants Online award management system.

In addition:

The Federal Program Officer for this award is: Jessica Berrio; 301-427-8654; jessica.berrio@noaa.gov

The Technical Monitor for this award is: Jason Lehto; 206-526-4670; jason.a.lehto@noaa.gov

6) Project Scope of Work
This National Oceanic and Atmospheric Administration (NOAA) award, number NA16NMF4630008, to Washington Department of Fish and Wildlife (the Recipient), supports the work described in the Recipient's proposal entitled "Restoring Resiliency in Puget Sound Snohomish River Delta" dated 07/01/2015, and revisions dated 11/06/2015], which are incorporated into the award by reference. Where the terms of the award and proposal differ, the terms of the award shall prevail.

7) Performance Progress Reports
Reporting requirements are described in 2 C.F.R. Sec. 200.327-.329, 200.211, and 200.300(b); Department of Commerce Financial Assistance Standard Terms and Conditions Sec. A.01, A.02, B.02, D.02(c), D.03, and K.03.n.; and Bureau-Specific NOAA Administrative Standard Award Conditions, with the following supplement.
Progress reports must be submitted using the NOAA Community-based Restoration Program's Performance Progress Report (PPR) reporting form approved by OMB under control number 0648-0472, or a successor form. The NOAA Federal Program Officer will provide this form to the Recipient. Interim semi-annual progress reports are due no later than 30 days after the semiannual reporting periods ending March 31 and September 30 for the entire duration of the award.

These follow the same frequency and have the same due dates (April 30 and October 30, respectively) as the SF-425 Federal Financial Reports, which also must be submitted as a condition of this award.

A comprehensive final report covering all activities during the award period is required and must be received by the NOAA Program Officer within 90 days after the end date of this award, but a final semi-annual report is not required.

8) Cooperative Agreement

This award is a cooperative agreement as described in 2 C.F.R. Sec. 200.24, meaning that NOAA is "substantially involved" in the project. NOAA Fisheries' participation will be crucial to ensuring the timely implementation of the most beneficial habitat restoration project. NOAA may participate in one or more of the following ways:

• collaboration on the scope of work through participation in meetings and review of documents

• providing assistance with technical aspects of the habitat restoration project such as assistance with permitting or development of detailed work plans and monitoring plans;

• review and comment on design plans at the beginning of the award, at various stages throughout any portion of the design process that occurs during the award (e.g. conceptual, 30%, 60%, and 90% completion), and at the final completion stage

• review of procurement materials to the extent authorized by 2 C.F.R. Sec. 200.324;

• tracking the progression of the restoration from planning through implementation and post-construction monitoring, with particular emphasis on tracking Recipient achievement of targets for major milestones and performance metrics and sharing results, as described further in the Special Award Condition on Monitoring and Data Sharing;

• other involvement consistent with Office of Management and Budget Guidance on Substantial Involvement. See 43 Federal Register 36860 (Aug. 18, 1978).

9) Monitoring and Data Sharing

To evaluate project implementation quality and effectiveness, and learn from this restoration project(s), the Recipient will execute appropriate project monitoring with guidance from NOAA. As the project proceeds, NOAA's substantial involvement will include further coordination to execute implementation, basic effectiveness monitoring, and potentially more detailed effectiveness monitoring, if applicable. The Recipient will collaborate with NOAA to identify monitoring elements such as parameters, methods, sampling duration and frequency, and post-implementation targets. NOAA's involvement will also include ongoing coordination on data management, analyses, and dissemination of results. The Recipient will develop a data/information sharing plan, and submit appropriate monitoring information with progress reports, as well as at other appropriate times. Templates for the data/information sharing plan and other monitoring related guidance are provided at http://www.habitat.noaa.gov/funding/applicantresources.html.

Environmental data and information collected and/or created under this grant/cooperative agreement will be made visible, accessible and independently understandable to users in a timely manner (typically no later than two (2) years after the data are collected or created) free of charge or at minimal cost that is no more than the cost of distribution to the user, except where limited by law, regulation, policy or by security requirements.

* The data/information sharing plan (and any subsequent revisions or updates) will be made publicly available by NOAA on our website at time of award and, thereafter, will be posted by the Recipient with any published data.

* Environmental data and information produced under this award and made available to the public must be accompanied by the following statement: "These environmental data and related items of information have not been formally

disseminated by NOAA, and do not represent and should not be construed to represent any agency determination, view, or policy."

* NOAA may at its own discretion, use information from the data/information sharing plan to produce a formal metadata record and include that metadata in a catalog to indicate the pending availability of new data.

* Failing to share environmental data and information in accordance with the submitted data/information sharing plan may lead to disallowed costs and be considered by NOAA when making future award decisions.

10) Verification of Permits and Consultations
Verification of permits and regulatory compliance related to this project must be presented to the NOAA Technical Monitor prior to project implementation. The Recipient should provide a list of Federal, tribal, state, and local permits acquired for this project by email or letter to the NOAA Technical Monitor.

11) Acknowledgement of Project Contributors
The Recipient must display, where appropriate and practical, publicly visible signs indicating that the project has received funding from the NOAA Restoration Center. These signs should also identify other contributing partners. These contributions should also be acknowledged in all communications with the media and the public and in all outreach related to the projects, consistent with Department of Commerce Financial Assistance Standard Term and Condition K.03.i.

12) Project Safety
The Recipient must have a written safety plan for management of the project, which should specifically address safety of project personnel, associates, visitors, and volunteers. The Recipient must conduct a safety briefing for volunteers immediately prior to their participation in hands-on restoration activities under this award. In addition, for any Self-Contained Underwater Breathing Apparatus (SCUBA) diving activities in a project, it is the responsibility of the Recipient to ensure that SCUBA divers are certified to a level commensurate with the type and conditions of the diving activity being undertaken. Furthermore, it is the responsibility of the Recipient to ensure that any SCUBA diving activities under this award meet, at a minimum, all applicable Federal, State, and local laws and regulations pertaining to the type of SCUBA diving being undertaken.

13) Compliance with Applicable Laws, Obtaining Permits, and Consultation Requirements
The Recipient is required to comply with national policy requirements consistent with 2 C.F.R. Sec. 200.300 and Department of Commerce Financial Assistance Standard Terms and Conditions, Section K. The Recipient will ensure that implementation of the project will meet all Federal laws and regulations by obtaining all Federal, state, and local permits and consultations applicable to the project prior to expenditure of award funds for those activities requiring permits and consultations. This includes, but is not restricted to, consultations required under the Endangered Species Act, Magnuson-Stevens Fishery Conservation and Management Act (Essential Fish Habitat), National Historic Preservation Act, and Coastal Zone Management Act. The Recipient will be cognizant of all conditions and restrictions required by their permits

and consultations, and will immediately halt activities and contact their NOAA Technical Monitor if events occur that threaten to violate the conditions or restrictions required by their permits and consultations.

14) Project Files

The Recipient must maintain project files for all restoration activities taking place under this agreement consistent with 2 C.F.R. Sec. 200.333. These files must contain, at a minimum, project work plans and copies of all federal and state permits/consultations associated with project implementation.

15) Outreach and Communications

Department of Commerce Financial Assistance Standard Term and Condition K.03.i. is supplemented as follows consistent with NOAA's collaboration on this project. The Recipient will coordinate with NOAA on outreach plans, events, products, and media coverage associated with the project, so that NOAA Communications staff may assist with the development of outreach communications and messaging. Recipients should provide drafts of any outreach plans to NOAA staff for review and input. In particular, all press releases should be shared with NOAA in draft at least one week in advance of release to allow NOAA the opportunity to provide comments, and a quote if requested. Please coordinate with the Federal Program Officer listed under the Contact Information award condition. Grantees will provide copies of final outreach products, website mentions, press materials, photos, etc. via the standard progress reports to NOAA, or when available throughout the award period. Grantees will provide NOAA with high-resolution before, during, and post-implementation photos of the project. Photos of the site prior to construction and during project implementation should be submitted with progress reports or as requested by NOAA. Further outreach and communications guidance on can be found at: http://www.habitat.noaa.gov/funding/applicantresources.html under 'Outreach Resources.'

16) Invasive Species Control

Pursuant to Executive Order # 13112, Recipients of NOAA funding cannot implement any actions that are likely to cause or promote the introduction or spread of invasive species, and should provide for restoration of native species and habitat conditions in ecosystems that have been invaded. NOAA Recipients are expected to take positive steps to prevent the introduction of invasive species, provide for control of invasive species, and minimize the economic, ecological, and human health impacts that invasive species cause. Where possible and/or practicable, Recipients should also respond rapidly to and control populations of invasive species in an environmentally sound manner, promote public education on invasive species, and conduct post-construction monitoring to ensure that impacts on native species did not occur (as applicable). NOAA can provide additional guidance on the detection, control and prevention of invasive species impacts upon request.

Attachment A – Statement of Work

LEARNING PROJECT TITLE: Snohomish Estuary Monitoring Project

Project Contacts

Project Manager:
Frank Leonetti
Frank.leonetti@snoco.org
425-388-3464 x 4249
Snohomish County SWD
3000 Rockefeller Ave MS 607
Everett, WA 98201

Budget Contact:
Laura Brown
Laura.brown@snoco.org
425-388-6675
Snohomish County
3000 Rockefeller Ave MS 610
Everett, WA 98201

PRISM Record Number: 16-2152

Whole Project Scope
The Snohomish Estuary Monitoring Project is one of four elements funded in part by NOAA Coastal Resiliency Award #NA16NMF4630008. Other elements are contracted separately and include Smith Island Estuary Restoration Project (RCO #09-1279), Mid-Spencer Island Estuary Restoration Project (RCO #16-1559), and WDFW technical and science support. A time extension request is being processed with NOAA to extend the period of performance from December 31, 2018 until December 31, 2019 to accommodate a deferral of NOAA-funded post-breach monitoring work as a result of construction schedule delays.

Snohomish Estuary Monitoring Project funds are subawarded to Snohomish County by ESRP and are administered by RCO as project #16-2152. Activities include pre- and post-breach monitoring associated with the Smith Island and Mid-Spencer Island estuary restoration projects, and monitoring of immediately surrounding areas of the Snohomish River estuary. This project is part of an ongoing federal-state-local-tribal collaborative evaluating Snohomish estuary fish use, rearing capacity, and estuary restoration project implementation outcomes and effectiveness.

Agreement Scope
Snohomish County Public Works Resource Monitoring staff will provide project site and associated estuary monitoring, technical support, and supervision during the grant period. Activities include data collection, analyses, and reporting in collaboration with NOAA Northwest Fisheries Science Center/Restoration Center estuary-wide monitoring efforts and applying consistent protocols. The County is collaborating on an on-going basis with NOAA to identify monitoring elements such as parameters, methods, sampling duration and frequency, and post-implementation performance. NOAA involvement will also include coordination on data management, analyses, and dissemination of results.

This project involves NOAA-defined Tier I implementation monitoring plus collection of select data that will contribute toward longer-term project and estuary-wide Tier II effectiveness monitoring. Related monitoring work by NOAA-NWFSC, USGS and Tulalip Tribes is underway outside the scope of this grant award.

Tier I implementation monitoring products will help evaluate whether restoration techniques applied at the Smith Island and Mid-Spencer restoration sites have been implemented as designed, and whether those designs show a basic level of effectiveness in meeting project goals. These metrics will be reported with the following deliverables for the Smith Island and Mid-Spencer restoration projects.

Table 1.

Tier I Implementation Performance Metric	Deliverable
Land Elevations	Restoration Designs - prepared and stamped by a licensed professional engineer, will show relevant existing and proposed elevations and cross-sections for structures, channels, wetlands, and floodplains. Post-construction As-Built Drawings - prepared by a professional land surveyor, will show final elevations and cross-sections of structures, channels, and land installed or

	altered by the project, and be surveyed into a known elevation benchmark and referenced to a standard geodetic datum.
Water Levels	Pre- and Post-restoration hydrographs - generated by collecting water elevations using at least three data loggers (upstream and downstream of a removed tidal restriction, and one to correct for atmospheric pressure) surveyed into the same elevation benchmark and datum as the as-built drawings and project plans. Pre- and Post-restoration photographs - document the new flooding regime to determine consistency with restoration goals.
Annual Operating and Maintenance Costs	Pre- and Post-restoration O&M costs - document the estimated change in operations, maintenance and/or liability costs associated with restoration for a five year period to avoid annual variability.
Public Safety	Document improved public safety through reduction or elimination of hazard(s) as a result of the restoration.
Community Enhancement	Document improved civic improvement as a result of the restoration (e.g. infrastructure, utilities, recreation access or facilities).
Recommendations	Monitoring Report – compilation of data gathered, analysis conducted and recommendations for further investigation and monitoring. This is also the Final Data Report deliverable.

Tier II effectiveness monitoring products will help evaluate whether restoration techniques applied at the Smith Island and Mid-Spencer are demonstrating a basic level of effectiveness in meeting project goals. Although much longer time-frames will be needed to assess long term effectiveness and quantify outcomes and success, many of the elements included below establish the much needed baseline that will make future evaluation possible. These metrics will be reported with the following deliverables for the Smith Island and Mid-Spencer restoration projects.

Table 2.

Tier II Effectiveness Monitoring Performance Metric	Deliverable
Photo points	Establish ≥ 10 photo points; Deliver GPS coordinates, bearings, map and annual winter/summer photos covering grant award period.
Time-lapse photo/video	Establish one web-enabled daily time lapse camera/video at one large Smith Island breach location (prior to breaching) and maintain for ≥1 year post-breach. Provide video rendering from vendor; MP4 format.
Sediment Elevation Tables (coordinated plan and install with USGS, WWU, NOAA, Tulalip Tribes)	Establish ≥4 Sediment Elevation Tables (SETs). Measure SET elevations semi-annually. Deliver GPS coordinates, SET elevation benchmark, and elevation measurements covering grant award period.
Sediment Pins	Establish ≥ 50 sediment pins based on channel proximity, elevation, and vegetation. Deliver GPS coordinates, initial sediment/pin elevations, and measure semi-annually covering grant award period.
LIDAR/ Air Photo	Acquire Smith Isl./Mid-Spencer LIDAR at low tide post-breach. Provide LIDAR DEMs, maps, and data collection report from vendor.
	Establish baseline and biennial channel count, length, surface area calculations from available air photo imagery. Provide Table of channel characteristics and changes covering grant agreement period.
Field Surveys (RTK-GPS) – also used for LIDAR ground control	Establish baseline cross-section and profile measurements at ≥ 5 channel locations. Measure annually. Provide plots of channel profile/cross-sections and changes covering grant award period.
Water level (covered above)	Establish "upstream" (Smith Island-2018) and "downstream" (Union Slough-2016) water level, temperature, salinity and barometric sensors (15-minute recording interval
Temperature	
Salinity	

	downloaded quarterly); Provide map of sensor locations and daily pre-breach and post-breach data.
Vegetation succession	Establish ≥20 5x5m^2 random vegetation plots AND 12 line-intercept transects across elevation gradient. Sample 1m^2 random quadrat among plots/line transects in years 0,1,3,5,10. Provide vegetation locations (mapped) and results covering grant award period.
	Map major vegetation classes and mudflat to estimating % areal composition and change over time (based on 2-year NAIP air photos/vegetation plot data). Provide baseline map covering grant award period.
Invasive vegetation	Perform annual post-breach invasive vegetation reconnaissance in restoration area. Map locations of invasive weeds and document treatment (type/area) covering grant agreement period.
Beach seine to quantify fish use (activity covered by NOAA-NWFSC/ Tulalip/ Snohomish County ESA 10A1A permit)	Collect monthly (Feb-Oct) pre-project and post-project fish use data at Smith Island, Mid-Spencer, Union Slough and System-Wide sample locations with beach seine. Provide data to NOAA-NWFSC for database. Provide map of sample site locations and tables/figures of fish use by month by major site. NOTE - data analysis to be performed by NOAA-NWFSC not covered by this grant award.
Reporting/ Communication	Create Data/Information Sharing Plan. Make data visible, accessible, independently understandable no later than 2 years post data collection. Provide Snohomish County URL or other hosting URL (if NOAA Restoration Center/ NOAA-NWFSC).

NOAA-funded monitoring activities will be undertaken by County staff and through County contract with WA Conservation Corps program (WCC) support, subject to WCC availability, and/or from other programs (e.g. County summer internship, etc.). Contracted support will be used to help coordinate field work, scheduling with partners (NOAA and Tulalip Tribes) and volunteers, and assist with data collection and input. Additional project support will be available from WDFW science staff identified to contribute best-available science information, education and reporting support.

Project Budget

Budget Category	ESRP	Match	Subtotal
Personnel (Project Lead)	$55,744	$19,720	$75,464
Contractual Services	$56,000		$56,000
Project Total	$111,744		$131,464

Task Summary

TASK 1 – Data Collection
Description: In accordance with the Smith Island Monitoring Plan and NOAA Northwest Fisheries Science Center/Restoration Center (NOAA-NWFSC), field data will be collected on average 7 days per month during the eight month monitoring season with increased winter and summer seasonal field day for the first year post-breach. Data collection, analysis, and distribution will be undertaken in coordination with WDFW science staff identified to contribute best-available science information, education and reporting support, Tulalip Tribes Natural Resources Monitoring staff, and NOAA Northwest Fisheries Science Center/Restoration Center staff.

Deliverable: A final Monitoring Report will be submitted following project completion (also the Task 4 deliverable). This report will compile data gathered, analysis conducted and offer recommendations for further investigation and monitoring. Environmental data (raw files and or spreadsheets/databases) will be made available to NOAA and to the public upon request.

TASK 2 – Project Management
Description: Supervise all project activities, including data collection and analysis, schedule, budget, project staff and contractor work, reporting, and QAQC of deliverables.

Deliverable: Project management updates included with progress and final reporting deliverables and through communications with RCO and ESRP grant mangers, as needed.

TASK 3 – Progress Report

Description: Report interim project achievements to RCO and ESRP through the PRISM progress reporting module. Updates for each of the NOAA Coastal Resiliency Award elements will be incorporated into a single NOAA Performance Progress Report and submitted two times per year to this RCO #16-2152, RCO #09-1279 (Smith Island), and RCO #16-1559 (Mid-Spencer). ESRP staff will add WDFW technical and science support updates to these reports for submittal to NOAA in accordance with NOAA Coastal Resiliency Award #NA16NMF4630008 reporting requirements.

Deliverable: NOAA Performance Progress Report are submitted two times per year using forms provided by NOAA for this purpose. Table 2 illustrates monitoring performance measures tracked as part of this periodic progress reporting.

Table 2.

Project Name	Award or Sub-Award Number
Restoring Resiliency in Puget Sound: Snohomish River	NA16NMF4630008

B. Performance Measures

Click to Add New Performance Measure

1. Objective/Goal Description	2. Measure (Unit)	3. Baseline	4. Target Year	5. Target	6. Actual To Date (cumulative)	7. Explanation
Wetland Habitat Restored	# Acres	381	2018	381		307 - Smith Island (revised based on survey and permitted design) 74 - Mid-Spencer Island estimate based on preliminary design
Habitat Made Available or Stream Habitat Restored	# Miles	3.7+	2018	3.7+		3.7 miles - Smith Island (based on survey and permitted design) __ miles - Mid-Spencer estimate based on preliminary design
Volunteer Involvement	# Hours					During summer field monitoring seasons volunteers are accepted.
Volunteer Involvement	# Participant s					During summer field monitoring seasons volunteers are accepted.
Maintenance and Operations Cost	$/5 years	N/A		N/A		Funded by Snohomish County
Built as designed	Y/N					Standard surveyed elevations and cross section of structures (setback dike, drainage facilities), channels, wood structures, and land alterations (remnant dike, pipeline berm).
Flood storage capacity	# Acre/ Feet					For both sites, pre- and post-breach hydrographs will be generated using at least three data loggers (downstream and upstream of water constrictions, and to correct for atmospheric pressure).
Land protected by upgraded levees	# Acres	700	2018	700		Smith Island setback dike is protecting $80 million in agricultural and commercial land development and public infrastructure, including a section of Interstate 5 and the City of Everett Water Treatment Facility.

TASK 4 – Final Data Report

Description: The Final Data Report will include documentation of selected deliverables from Table 1 (Water level and Recommendations) and Table 2 based on performance objectives and initial interpretation of effectiveness monitoring. This report will compile data gathered, analysis conducted and offer recommendations for further investigation and monitoring.

Deliverable: The final Monitoring Report, also the Task 1 deliverable, is due as an attachment to the final PRISM project report (see Task 5).

TASK 5 – Final PRISM Project Report

Description: Report final project achievements and metrics through the PRISM final reporting module. Necessary attachments, project metrics accounting, and a detailed narrative are major components of this final report.

Deliverable: Final report submitted no later than 90 days from the project agreement end date.

#	Task List	Target Date	ESRP	Match	Total Cost
1	Data Collection		**$106,000**	**$9,000**	**$115,000**
2	Project Management			**$3,000**	**$3,000**
3	Progress reports	2 annually		**$2,000**	**$2,000**
4	Final data report	December 31, 2018	**$5000**	**$5,000**	**$10,000**
5	Final PRISM Report	December 31, 2018	**$744**	**$720**	**$1,464**
	TOTAL		**$111,744**	**$19,720**	**$131,464**
				Retainage %10	**$13,146**
				Total Agreement	**$131,464**

Appendix C. Smith Island Photo Points.



SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

East Tidal Channel PP2

Pre-breach







Post-breach



SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

East Tidal Channel PP3



2017 2018
Post-breach
2018 2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

ETC PP4 North

Pre-breach







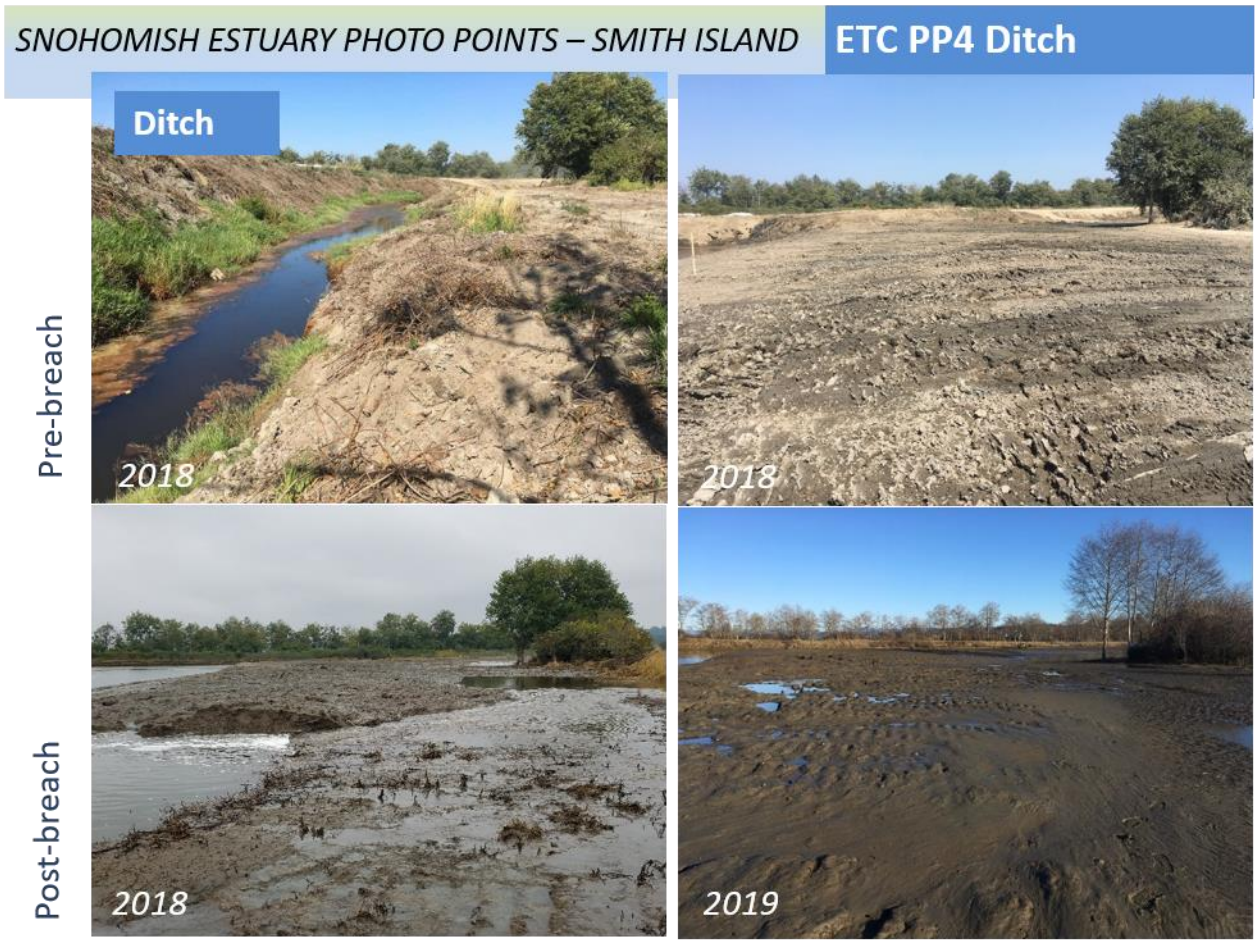


Post-breach








SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND
ETC PP4 Ditch
Ditch
Pre-breach
Post-breach
2018
2018
2018
2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

ETC PP5 Dike South

Pre-breach





Post-breach







SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Dike_Pumphouse

Pre-breach





Post-breach









SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Pumphouse ETC

Pre-breach



2017

Post-breach





Pre-breach



2018

Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

East Tidal Channel CWS

CWS – continuous water sensor location

Pre-breach



Post-breach







SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

New Dike Bend

Pre-breach

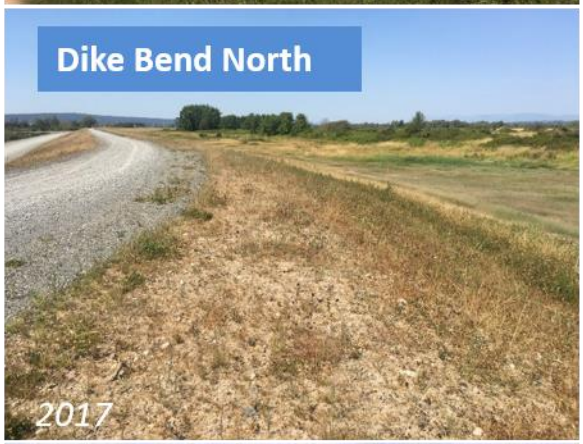


Post-breach





Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

New Dike South

Dike Interior

Pre-breach



Post-breach





2017
2018
Post-breach
2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

New Dike South

Pre-breach



Post-breach





Post-breach

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Interior Points

Pre-breach



Post-breach





Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Entry/ PSE Alignment

Pre-breach





Post-breach





Pre-breach



Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Old Dike North

Pre-breach







Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Old Dike North

Pre-breach





Post-breach







SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Old Dike North

Pre-breach





Post-breach







SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 1

SC1.2

Pre-breach



Post-breach





SC2.1 Dike

Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 1



Pre-breach
2017
2018
Post-breach
2018
2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 2

Pre-breach





Pre-breach







Pre-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 2

Pre-breach





Post-breach





2017 2018

Post-breach

2018 2019


SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND
Starter Channel 2
SC2.2
SC2.1 Dike East
Pre-breach
Post-breach
2018
2018
2018
2018
2019
2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 3

Pre-breach





Post-breach





Post-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 3

Post-breach





Post-breach



Post-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 5

Pre-breach





Post-breach





Pre-breach





Post-breach





Starter Channel 5

Post-breach







Post-breach





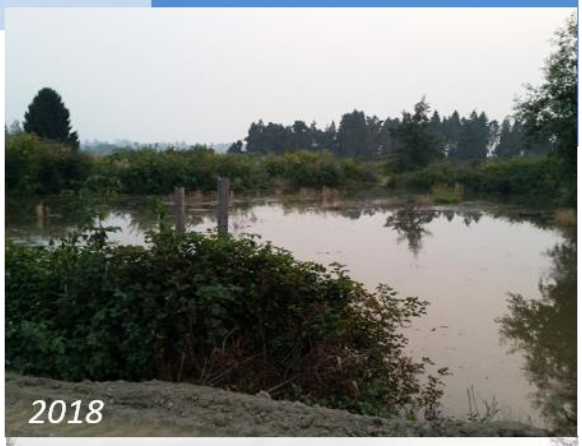


Starter Channel 6

SC6.1

Pre-breach





Post-breach





SC6.1 Dike

Pre-breach





Post-breach






SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND
Starter Channel 6
SC6.2
SC6.3
Pre-breach
Post-breach
2018
2018
2018
2019
2019

Starter Channel 6

Post-breach



Pre-breach



Post-breach



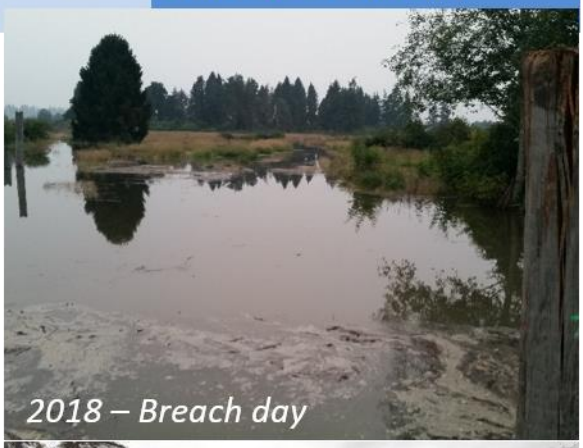


SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 7

Pre-breach





Post-breach





Pre-breach



Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 7

SC7.1 dike south

Pre-breach



Post-breach





SC7.2a

Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 7



Pre-breach

Date



Post-breach





Post-breach



Post-breach

Date

Date

Starter Channel 7



SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 9 Dike

SC9_Dike South

Pre-breach





Post-breach





SC9 interior

Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

SC9 Dike Location

SC9 to Union Sl.

Pre-breach



Post-breach





SC9 Dike North

Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 9

SC9.1





Pre-breach



Post-breach





Date

Date

Starter Channel 9

Pre-breach



Post-breach





Pre-breach





Post-breach





Starter Channel 9

SC9.2c Veg Plot 88

Pre-breach



Date

Post-breach





SC9.3a to dike

Pre-breach



Date

Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 9

Pre-breach





Post-breach





Pre-breach





Post-breach



Date



Pre-breach
Post-breach

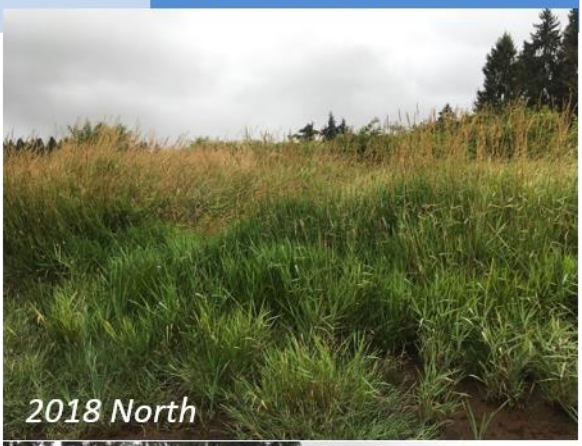

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND
Starter Channel 12
SC12.2 up
SC12.2 down
Pre-breach
Post-breach
2018
2018
2018
2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND **Starter Channel 12**

SC12.3 VegPlot 89

Pre-breach









Post-breach

Pre-breach

2017 2018

Post-breach

2018 2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND **Starter Channel 12**

Pre-breach





Post-breach



Starter Channel 13

Pre-breach





Post-breach



2019

Pre-breach



2019

Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 14

SC14.Dike

Pre-breach





Post-breach





SC14.1 to dike end

Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 14

Pre-breach

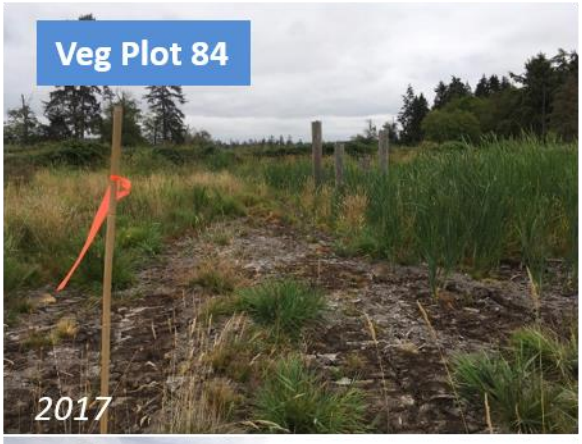




Post-breach



Pre-breach





Post-breach





SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND **Starter Channel 14**

Post-breach - 2019

SC14.3









Post-breach - 2020

SC14.3

2017 2018

Post-breach

2018 2019

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Starter Channel 14

Pre-breach

Veg Plot 87









Post-breach

XX.xx

SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Old Dike South

Pre-breach





Post-breach



Pre-breach



Post-breach



SNOHOMISH ESTUARY PHOTO POINTS – SMITH ISLAND

Old Dike near SC15

Pre-breach





Post-breach





Pre-breach

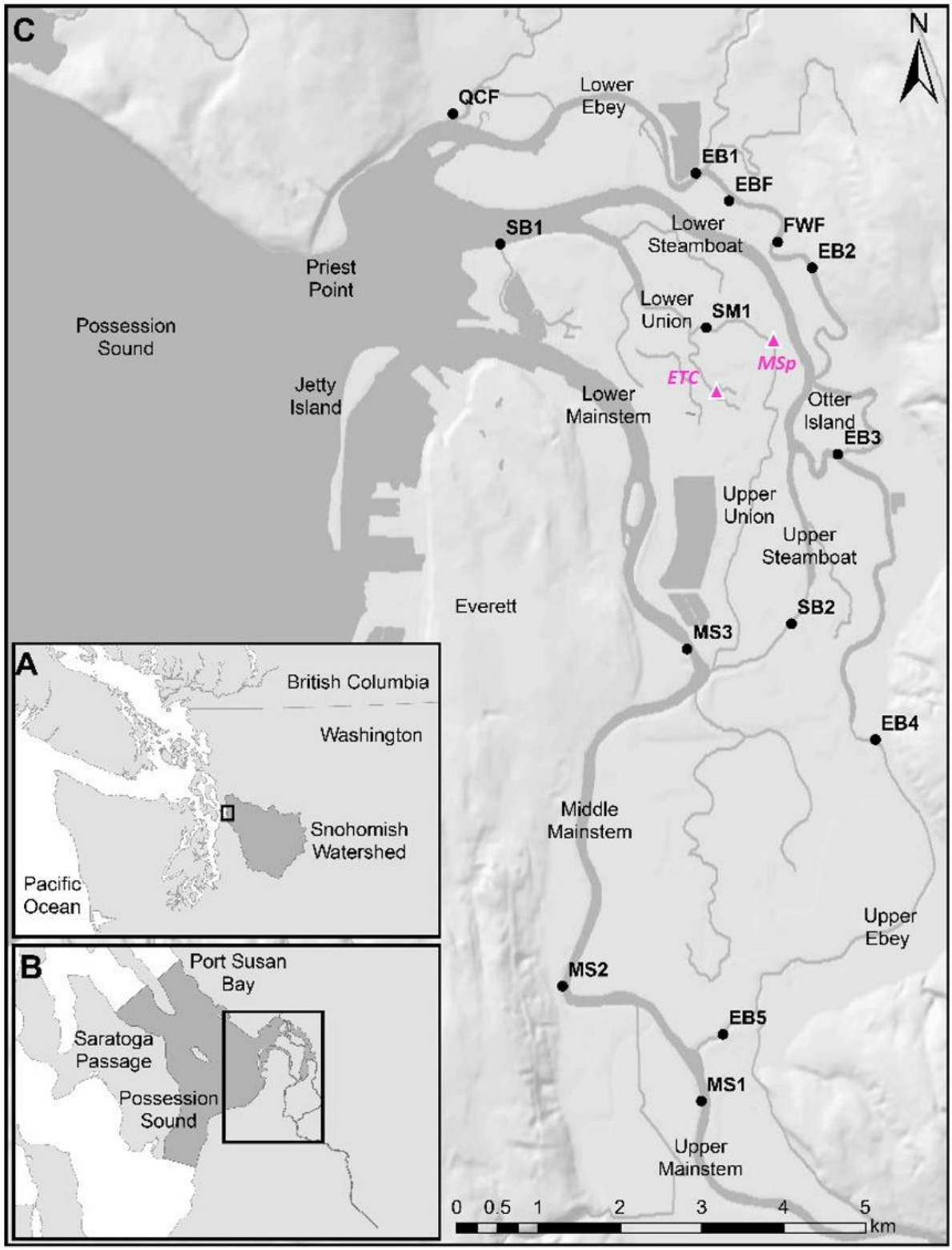


Post-breach



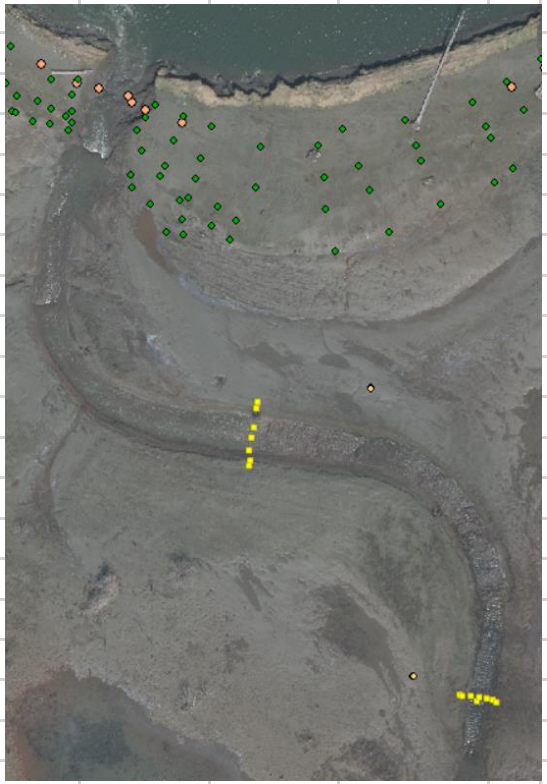


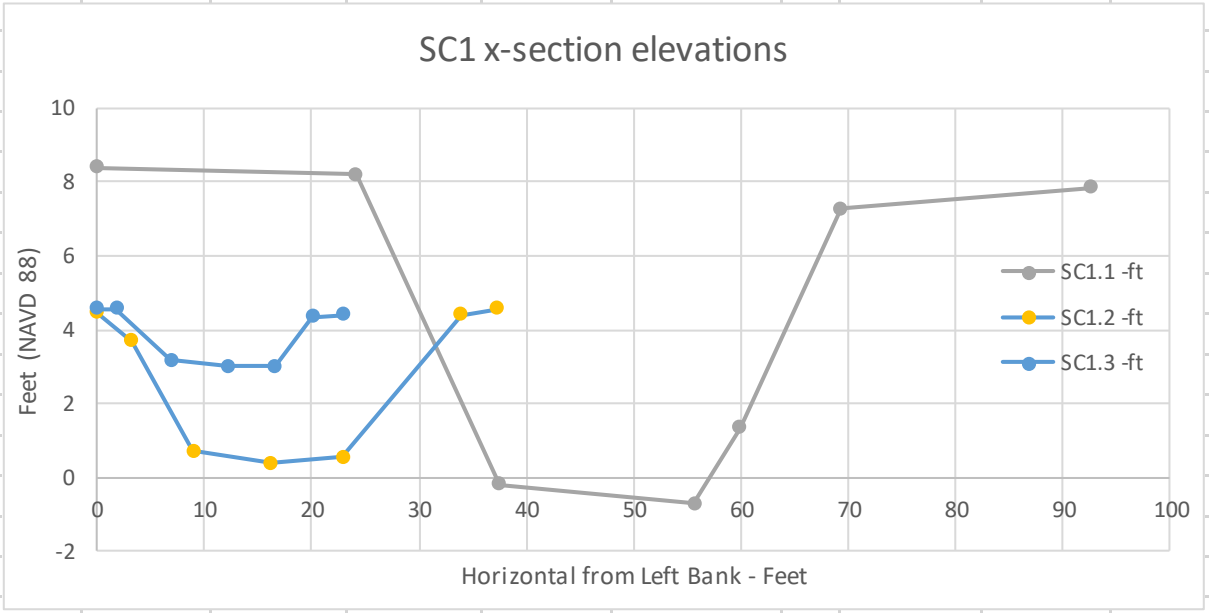
Appendix D. Estuary-wide water quality sampling map (Figure 1 from Hall et al. 2018). CWS sites record water level, temperature, and conductivity (salinity). Snohomish County sites are labeled ETC (East Tidal Channel) and MSp (Union Slough at Mid-Spencer.



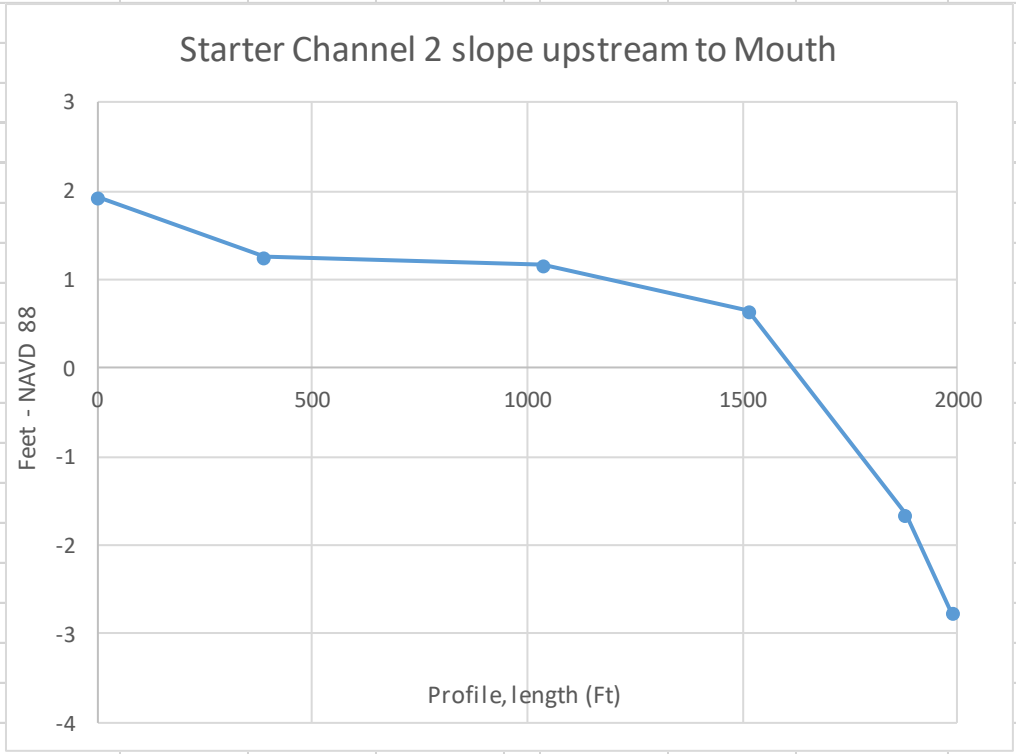
Starter Channel 1 - Mouth (SC1.1); Middle SC1.2; End SC1.3 - correspond to photo points.

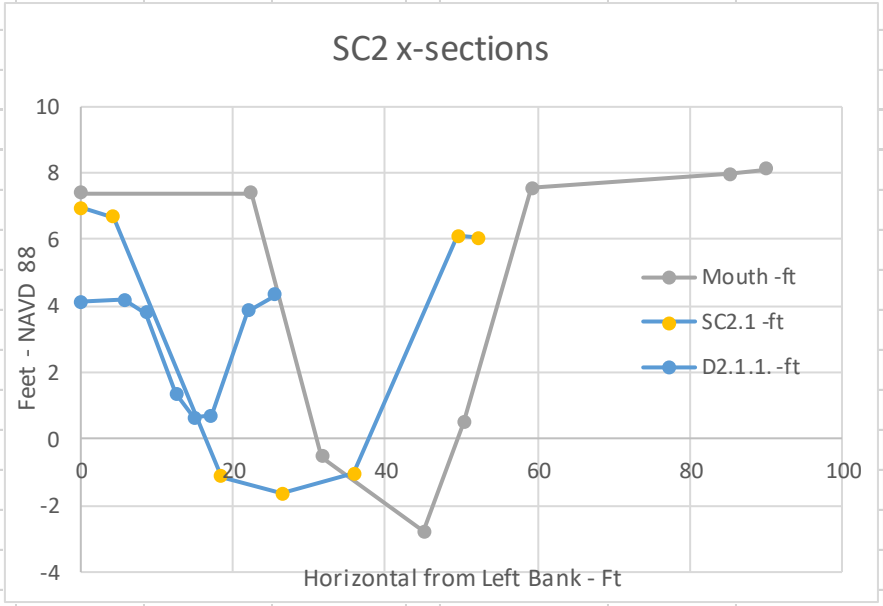
Mouth	Post-brea	2018	OTAK		Middle	SC1.2	pre-breach				Top	SC1.3	
			10/17/2018		7/31/2018			7/20/2019			7/31/2018		
Distance (m	Feet	CumDist	SC1.1 -ft		Distance	CumD	SC1.2 -ft	Distance	CumD	Elevation (ft)	Distance	CumD	SC1.3 -ft
0	0	0	8.392		0	0	4.46	0	0	4.9	0	0	4.566
7.34	24.08136	24.08136	8.199		3.25	3.25	3.692	3.3	3.3	3.8	1.832	1.832	4.552
4.08	13.38583	37.46719	-0.196		5.72	8.97	0.711	5.9	9.2	0.9	5.055	6.887	3.184
5.55	18.20866	55.67585	-0.699		7.25	16.22	0.381	7.9	17.1	0.5	5.24	12.127	3.01
1.28	4.199475	59.87533	1.341		6.68	22.9	0.549	6.4	23.5	0.65	4.446	16.573	3.01
2.87	9.41601	69.29134	7.266		10.96	33.86	4.394	12	35.5	4.4	3.457	20.03	4.349
7.1	23.29396	92.5853	7.845		3.46	37.32	4.556	4	39.5	4.7	2.837	22.867	4.394
								3	42.5	4.9			





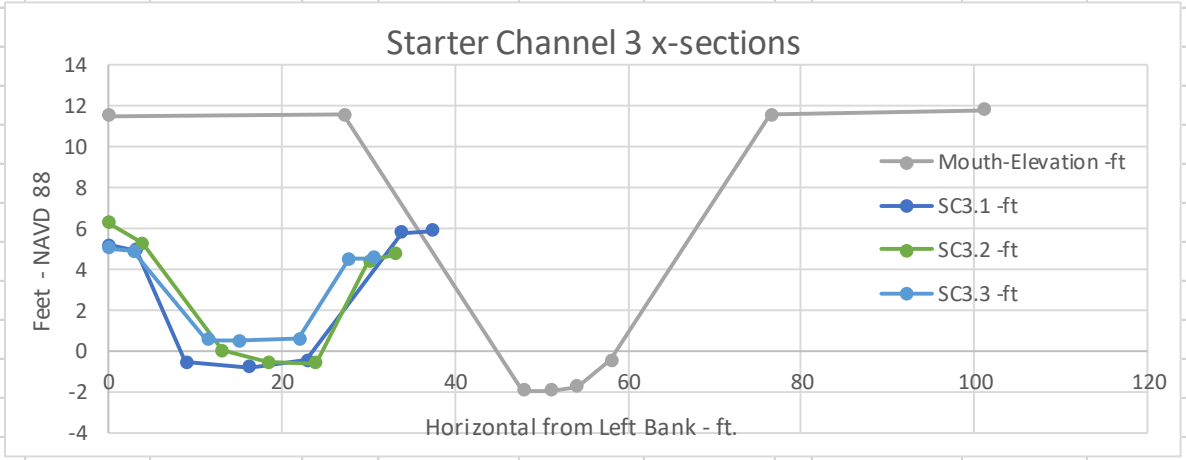
Starter Channel 2														
Slope				**Mouth**	Post-brea	10/17/2018	OTAK	**2.1**		7/31/2018	**Ditch 2.1.1**		7/31/2018
Feet	CumD	Section (u	Elev	Feet	CumD	Mouth -ft		Distance	CumD	SC2.1 -ft	Distance	CumD	D2.1.1. -ft
0	0	End	1.931	0	0	7.396		0	0	6.934	0	0	4.116
388.9	388.9	2.13	1.258	22.33	22.33	7.383		4.224	4.224	6.679	5.71	5.71	4.176
647.19	1036.09	2.12	1.165	9.37	31.7	-0.533		14.27	18.494	-1.124	2.85	8.56	3.781
478.98	1515.07	2.1.1	0.641	13.37	45.07	-2.771		7.979	26.473	-1.652	4.03	12.59	1.365
363.66	1878.73	Middle (2.	-1.652	5.23	50.3	0.499		9.357	35.83	-1.034	2.32	14.91	0.641
108.97	1987.7	Mouth	-2.771	8.9	59.2	7.54		13.68	49.51	6.088	2.18	17.09	0.695
				26	85.2	7.965		2.82	52.33	6.031	4.847	21.937	3.841
		Diff total	4.702	4.9	90.1	8.107					3.638	25.575	4.338
		Slope	0.002366										





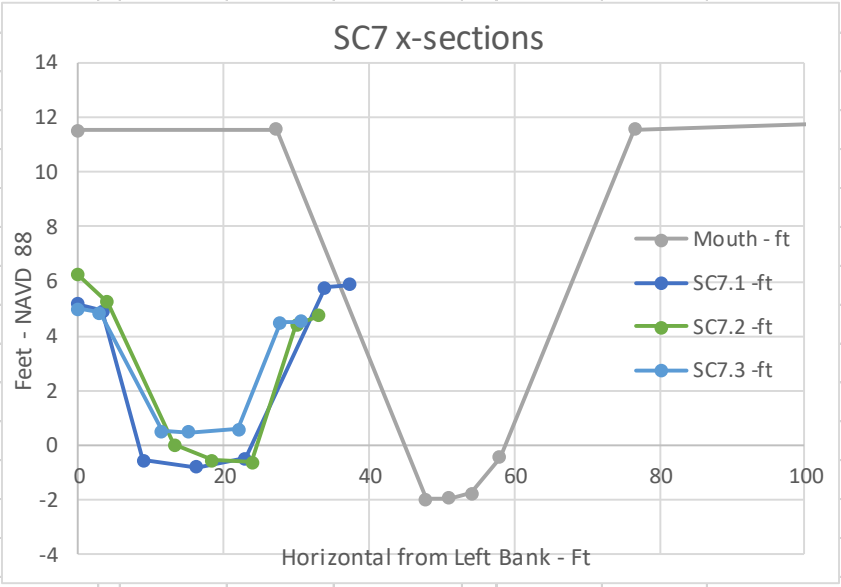
Starter Channel 3						OTAK							
Slope				**Mouth**	Post-brea	2018	**SC3.1**			**SC3.2**			
						10/17/2018	7/31/2018			7/31/2018			
Feet	CumD	X-sec mar	Elev	Feet	CumD	Mouth-Elevation -f	Distance	CumD	SC3.1 -ft	Distance	CumD	SC3.2 -ft	
0	0	End	3.885	0	0	11.513	0	0	5.169	0	0	6.235	
60.9	60.9	3.13	0.475	27.179	27.179	11.554	3.25	3.25	4.917	3.93	3.93	5.25	
66.2	127.1	3.12	-0.625	20.66	47.839	-1.978	5.72	8.97	-0.556	9.225	13.155	0.006	
69.2	196.3	3.1	-0.794	3.24	51.079	-1.934	7.25	16.22	-0.794	5.299	18.454	-0.548	
103.1	299.4	Mouth	-1.978	3.016	54.095	-1.772	6.68	22.9	-0.495	5.483	23.937	-0.625	
57.7	357.1	Union		3.9	57.995	-0.464	10.96	33.86	5.761	6.116	30.053	4.411	
			Diff1	18.52	76.515	11.56	3.46	37.32	5.863	3.08	33.133	4.725	
			5.863	24.475	100.99	11.793							
			Slope				**SC3.3**			**End**			
			0.016418				7/31/2018			7/31/2018			
							Distance	CumD	SC3.3 -ft	Dist	Elev		
							0	0	5.001	End	3.885		
							2.88	2.88	4.862				
							8.51	11.39	0.517				
							3.74	15.13	0.475				
							6.817	21.947	0.587				
							5.845	27.792	4.497				
							2.876	30.668	4.528				

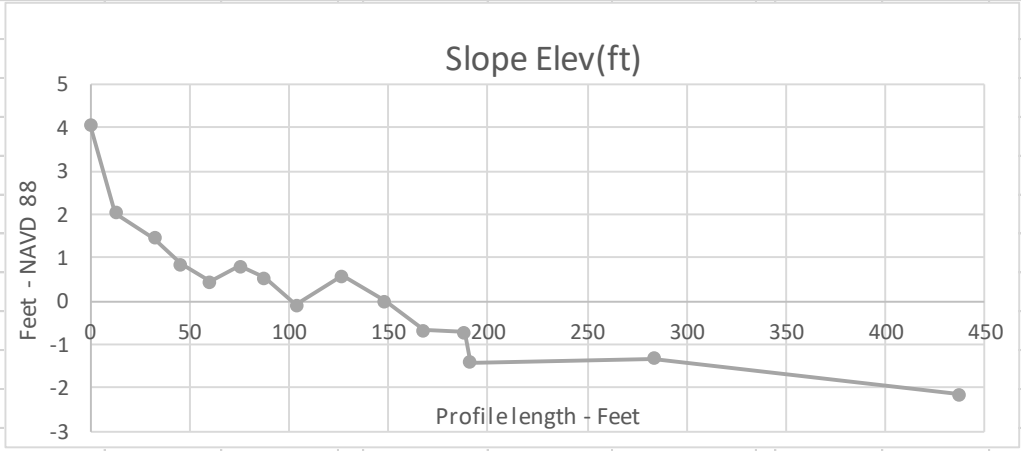




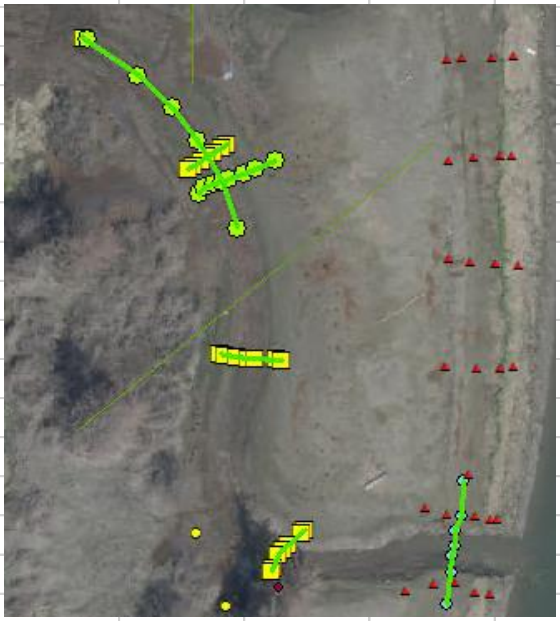
Starter Channel 7															
Slope			**Mouth**	Post-brea	10/17/2018	**SC7.1**		7/31/2018	**SC7.2**		7/31/2018	**SC7.3**		7/31/2018
Feet	CumD	Elev(ft)	Feet	CumD	Mouth - ft	Distance	CumD	SC7.1 -ft	Distance	CumD	SC7.2 -ft	Distance	CumD	SC7.3 -ft
0	0	4.066	0	0	11.513	0	0	5.169	0	0	6.235	0	0	5.001
12.81	12.81	2.021	27.179	27.179	11.554	3.25	3.25	4.917	3.93	3.93	5.25	2.88	2.88	4.862
19.31	32.12	1.434	20.66	47.839	-1.978	5.72	8.97	-0.556	9.225	13.155	0.006	8.51	11.39	0.517
13.45	45.57	0.845	3.24	51.079	-1.934	7.25	16.22	-0.794	5.299	18.454	-0.548	3.74	15.13	0.475
14.65	60.22	0.446	3.016	54.095	-1.772	6.68	22.9	-0.495	5.483	23.937	-0.625	6.817	21.947	0.587
14.82	75.04	0.792	3.9	57.995	-0.464	10.96	33.86	5.761	6.116	30.053	4.411	5.845	27.792	4.497
12.2	87.24	0.528	18.52	76.515	11.56	3.46	37.32	5.863	3.08	33.133	4.725	2.876	30.668	4.528
16.176	103.416	-0.104	24.475	100.99	11.793									
23.116	126.532	0.578												
21.415	147.947	-0.005												
19.75	167.697	-0.689												
20.59	188.287	-0.727												
2.68	190.967	-1.427												
92.376	283.343	-1.322												
153.24	436.583	-2.165												

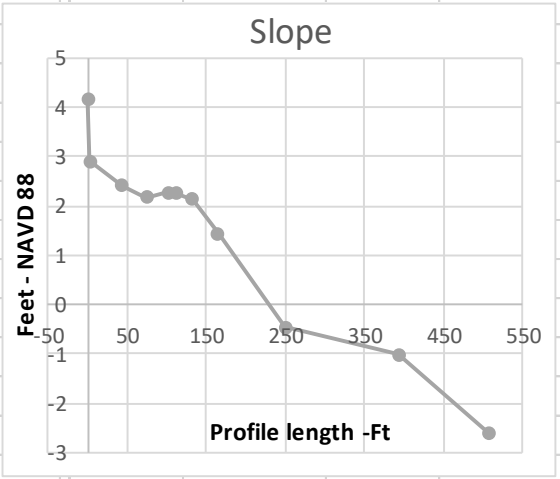


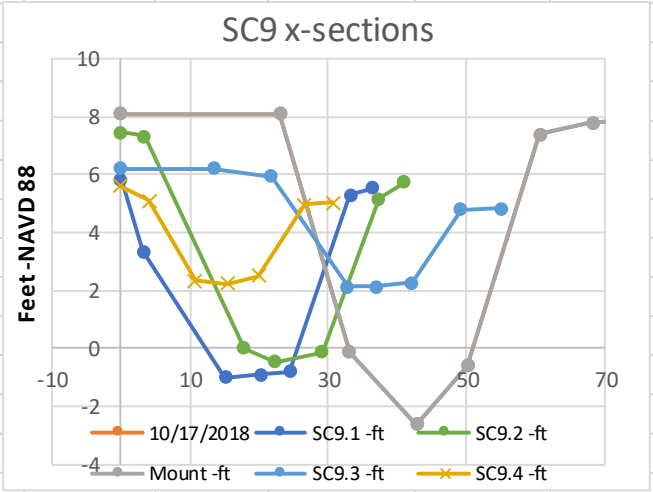




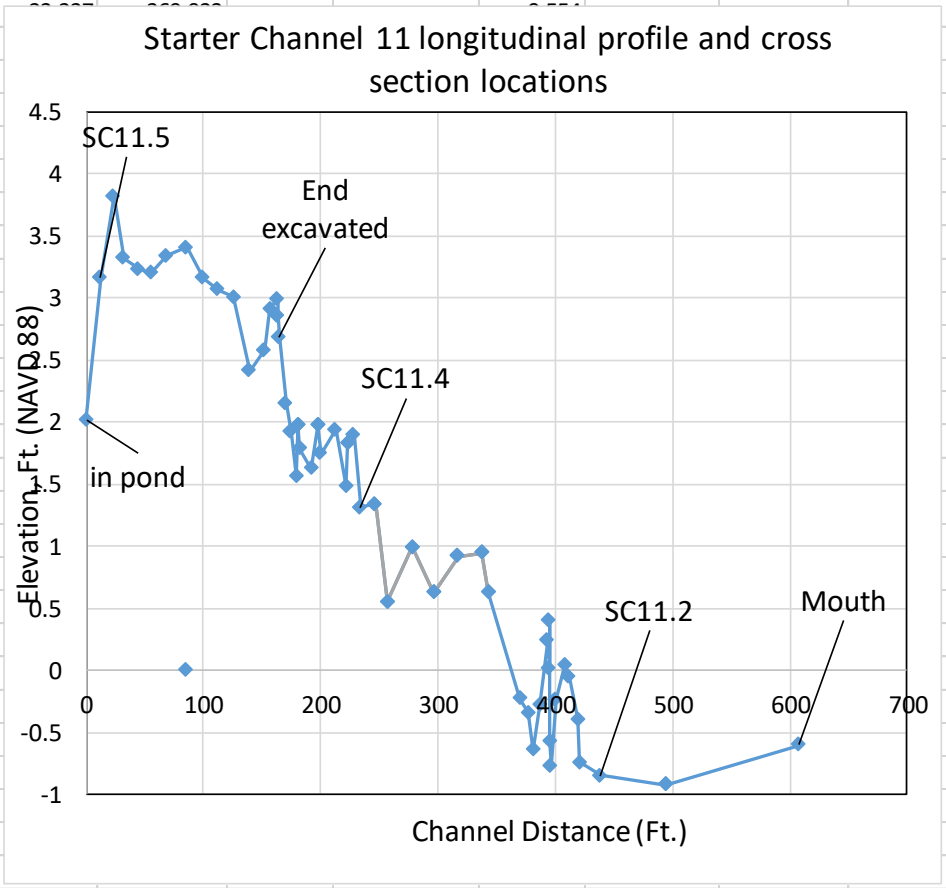
Starter Channel 9													
Slope					**Mouth**	10/17/2018		**SC9.1**	7/31/2018		**SC9.2**	7/31/2018	
Feet	CumD	Field	Elev (ft)	xsec ID	Feet	CumD	Mount -f	Distance	CumD	SC9.1 -ft	Distance	CumD	SC9.2 -ft
0	0	upper enc	4.174		0	0	8.095	0	0	5.831	0	0	7.463
3.326	3.326	Field4	2.902		23.03	23.03	8.107	3.34	3.34	3.342	3.422	3.422	7.333
39.878	43.204	Field4	2.416		9.97	33	-0.108	11.77	15.11	-1.008	14.363	17.785	0.003
30.93	74.134	Field4	2.167		9.807	42.807	-2.613	5.3	20.41	-0.887	4.619	22.404	-0.452
27.12	101.254	Field4	2.269		7.378	50.185	-0.6	4.008	24.418	-0.788	6.657	29.061	-0.106
11.828	113.082	Field4	2.246	9.4	10.479	60.664	7.403	8.798	33.216	5.297	8.298	37.359	5.178
19.384	132.466	Field4	2.139	9.3	7.514	68.178	7.801	3.226	36.442	5.552	3.669	41.028	5.755
31.891	164.357	Field4	1.451		21.278	89.456	7.929						
85.65	250.007	Field4	-0.452	9.2			**SC9.3**	7/31/2018		**SC9.4**	7/31/2018		**Top**
143.09	393.097	Field4	-1.008	9.1			Distance	CumD	SC9.3 -ft	Distance	CumD	SC9.4 -ft	Elev (ft)
114.6	507.697	Field4	-2.613	Mouth			0	0	6.228	0	0	5.599	3.885
151.6	659.297	end chan at carex ed		Carex			13.46	13.46	6.199	4.165	4.165	5.108	
							8.317	21.777	5.958	6.548	10.713	2.322	
							10.949	32.726	2.141	4.683	15.396	2.246	
							4.16	36.886	2.139	4.601	19.997	2.508	
							5.26	42.146	2.259	6.63	26.627	4.958	
							6.959	49.105	4.793	4.011	30.638	5.044	
							5.788	54.893	4.842				



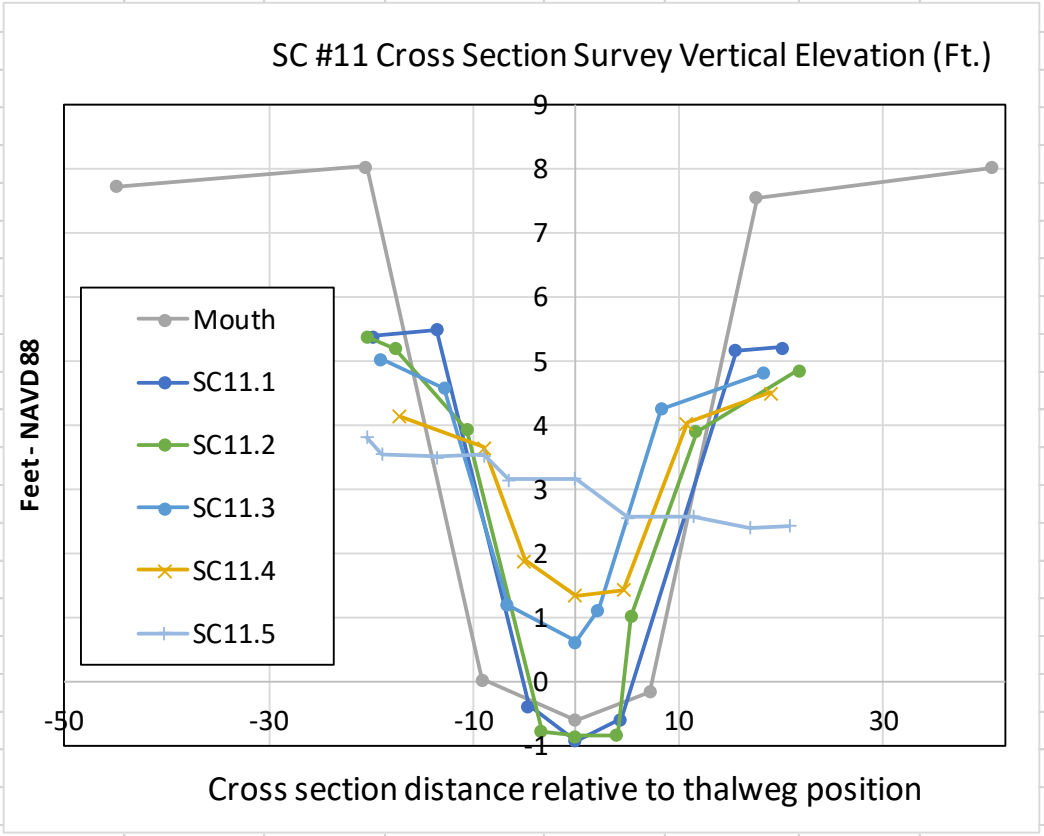




Starter Channel 11												
Slope				X-sec Elev	Mouth	10/17/2018			SC11.1	7/31/2018		
Feet	**CumD**	**Field**	**Elev**		Feet	CumD	Adjusted	Elev	Distance	CumD	Elev	Adjusted
0	0	upper enc	2.017		0	0	-44.757	7.728	0	0	5.396	-19.768
12.356	12.356	SC11.5	3.163		24.24	24.24	-20.517	8.043	6.198	6.198	5.496	-13.57
11.098	23.454		3.825		11.41	35.65	-9.107	0.035	8.9	15.098	-0.377	-4.67
8.746	32.2		3.324		9.107	44.757	0	-0.6	4.67	19.768	-0.924	0
12.21	44.41		3.236		7.263	52.02	7.263	-0.162	4.413	24.181	-0.588	4.413
11.08	55.49		3.2		10.381	62.401	17.644	7.549	11.24	35.421	5.17	15.653
12.98	68.47		3.342		23.065	85.466	40.709	8.027	4.475	39.896	5.21	20.128
17.218	85.688		3.411	**Slope Cont.**	**Feet**	**CumD**	**Field**	**Elev**	**X-sec Elev**			
14.15	99.838		3.162									
12.82	112.658		3.067									
13.506	126.164		3.009									
13.295	139.459		2.412									
12.297	151.756		2.578									
5.18	156.936		2.912									
6.028	162.964		2.996									
0	162.964		**2.858**	**2.858**								
1.805	164.769	End excav	2.684									
5.656	170.425		2.155									
4	174.425		1.917									
4.93	179.355		1.569									
1.266	180.621		**1.972**	**1.972**								
1.898	182.519		1.784									
9.38	191.899		1.623									
5.769	197.668		**1.971**	**1.971**								
2.256	199.924		1.747									
13.01	212.934		1.942									
8.592	221.526		1.485									
1.94	223.466		**1.835**	**1.835**								
5.067	228.533		1.9									
5.278	233.811	SC11.4	1.314									
12.885	246.696		**1.34**	**1.34**								
23.227	257.038		**0.554**	**0.554**								
21.396	278.434		**0.989**	**0.989**								
18.346	296.78		**0.626**	**0.626**								
20.02	316.8		**0.918**	**0.918**								
20.878	337.678		**0.944**	**0.944**								
5.48	343.158	SC11.3	**0.622**	**0.622**	235.158							

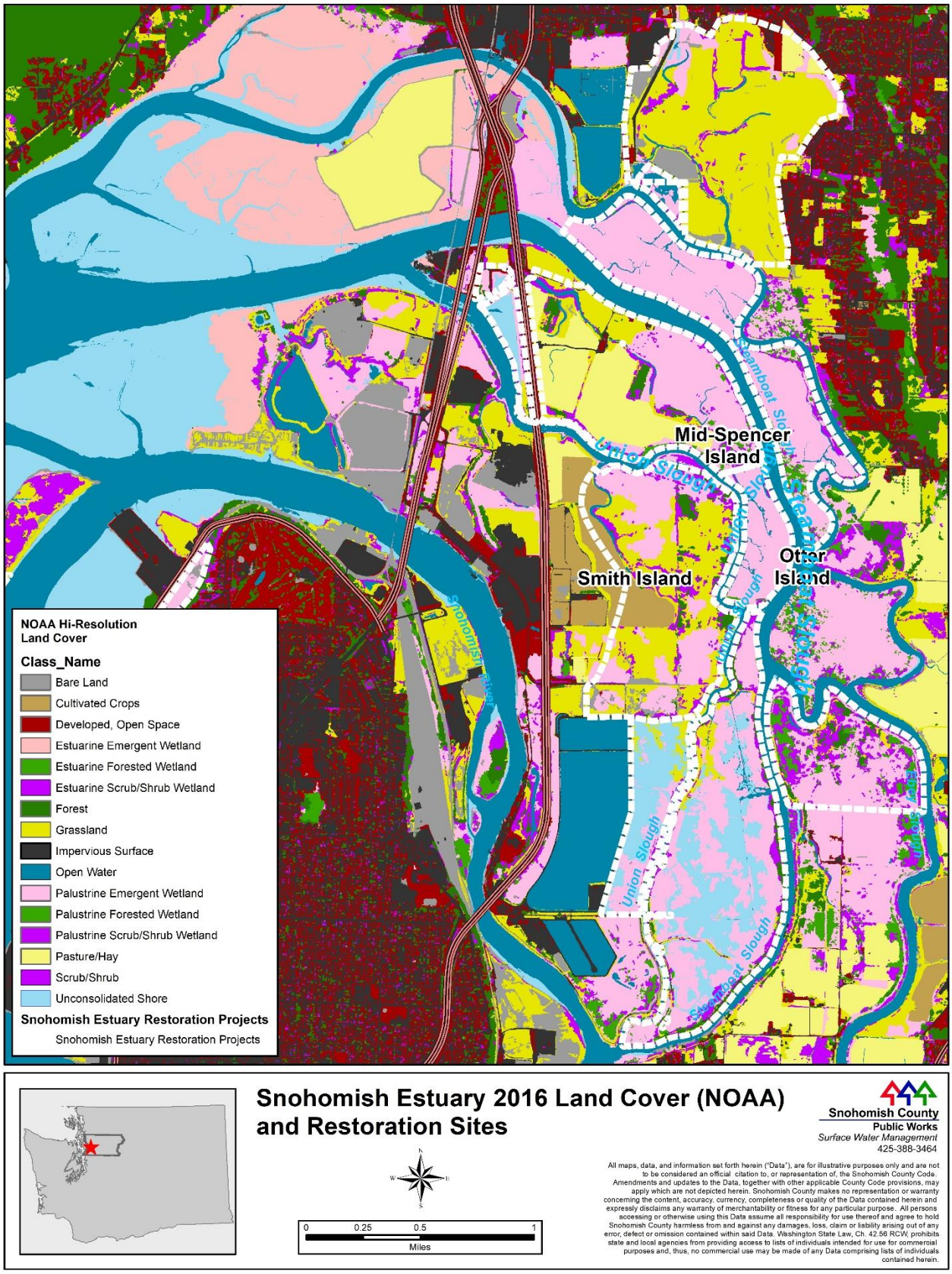


Starter Channel 11												
SC11.2	7/31/2018			**SC11.3**	10/4/2018			**SC11.4**	7/31/2018			
Distance	CumD	Adjusted	Elev	Distance	CumD	Adjusted	Elev	Distance	CumD	Adjusted	Elev	
0	0	-20.336	5.378	0	0	-19.065	5.043	0	0	-17.126	4.135	
2.683	2.683	-17.653	5.207	6.256	6.256	-12.809	4.578	8.2	8.2	-8.926	3.648	
7.079	9.762	-10.574	3.931	6.111	12.367	-6.698	1.2	3.9	12.1	-5.026	1.882	
7.214	16.976	-3.36	-0.786	6.698	19.065	0	0.622	5.026	17.126	0	1.34	
3.36	20.336	0	-0.85	2.147	21.212	2.147	1.116	4.659	21.785	4.659	1.431	
4.077	24.413	4.077	-0.833	6.227	27.439	8.374	4.26	6.213	27.998	10.872	4.03	
1.35	25.763	5.427	1.014	9.972	37.411	18.346	4.817	8.225	36.223	19.097	4.51	
6.302	32.065	11.729	3.903									
10.08	42.145	21.809	4.855									



SC11.5	In pond	7/31/2018		Top
Distance	CumD	Adjusted	Elev	Elev
0	0	-20.415	3.819	3.885
1.47	1.47	-18.945	3.552	
5.479	6.949	-13.466	3.499	
4.53	11.479	-8.936	3.532	
2.329	13.808	-6.607	3.157	
6.607	20.415	0	3.163	
5.032	25.447	5.032	2.563	
6.507	31.954	11.539	2.571	
5.521	37.475	17.06	2.402	
3.832	41.307	20.892	2.425	

Appendix F. NOAA high-resolution land cover classification and Snohomish Estuary projects.



Appendix G. 2019 Snohomish Estuary Fish Sampling Protocol (from NOAA) and Site Map.

1) Sites and methods

a) *Sites types (System, Intensive, Off-Channel*):
   i) System: Systems sites are comprised of Index sites and are sampled with the standard PS beach seine (39m) set from the bow and with the current
   ii) Intensive: Intensive sites are associated with the Qwuloolt and Smith island project sites and are comprised of a series of random sites (n=6 and n=3, respectively) located adjacent to each project site. Sites sampled using the same methods as for System with the exception of the Qwuloolt intensive sites that occur within the project site which will use the small Beamer beach seine (24m).
   iii) Off-Channel: OC sites are comprised of random sites selected within a given "channel" (see list below). Initially we will sample 3 sites within each channel but effort may be scaled back after review. These sites are fished with the smaller Beamer net set off the bow.

b) *Moving sites*:
   i) Check the "Site Moved" box on the data sheet
   ii) Rename the site using the intended/closest site number that occurs in the same zone and append with "new"
   iii) Record the lat./long. for the new site on the data sheet (in decimal degrees if possible). Handheld GPS/phone/tablet coordinates are fine.
      (1) If using the tablet ensure you are recording the position of the boat/tablet and not the cursor. (follow drop down: GPS>>GPS position).

c) *Site responsibilities*:
   i) Tulalip/NOAA: Marysville Rest Index, Qwul Intensive, MR Off, Otter Is, Deadwater, Nearshore
   ii) SnoCo: All System index (excl. lower Ebey), Smith Intensive, Spencer Off, Fields Off, DD6

2) Fish processing procedures:

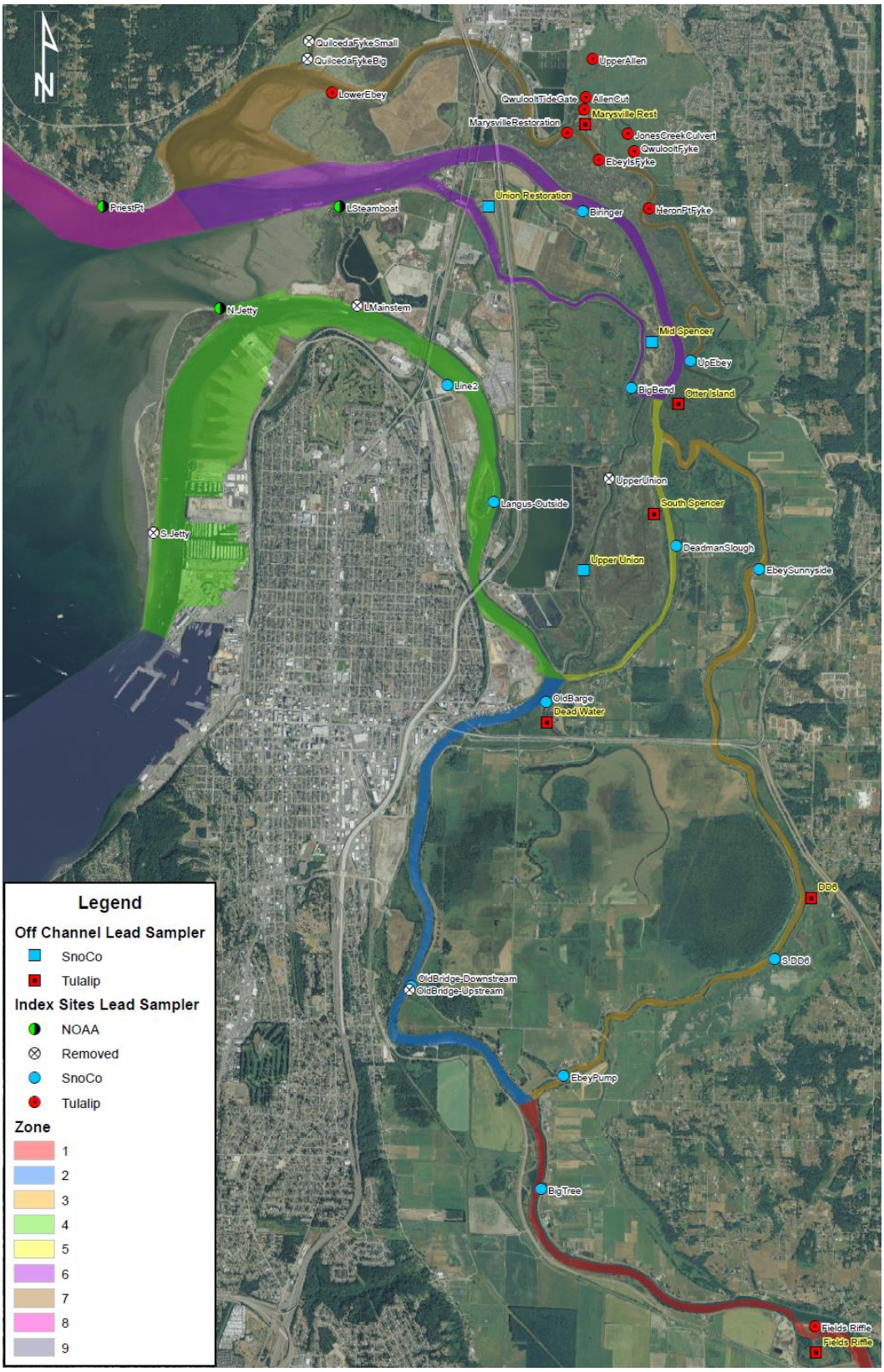
a) *Take: (Unintentional morts should be used before killing any fish; For marked fish prioritize CWTs.)*
   i) System & Intensive: **5 each**, Marked and Unmarked, Chinook from each zone.
   ii) Off-Channel: **3 each**, Marked and Unmarked, Chinook from each channel.
      (1) Fill out tag info (tags to be provided) and bag individual fish. Place immediately on ice and transfer to freezer at end of day.
      (2) Mark the "Take" box for each fish lethally sampled, Number sequentially from 1-n for each site and record under "sample #". Fill out "mort/take" boxes in lower right corner. M and UM as separate spp.

b) *Subsampling*: (only to be used when necessary, not as a normal sampling tool)
   i) When?
      (1) Catches are sufficiently large and conditions (water temp, DO) would make it dangerous to process fish in usual manner (high degree of unintentional mortality)
      (2) If catches are large and uniform (i.e. thousands of surf smelt or shiner perch)
   ii) Note "Subsample" very clearly in the Comments; At a minimum remove 2 uniform units (i.e. scoops, buckets, etc.) from the total catch; use the same unit to count and remove the remaining fish from the catch; record number of units "sampled" (to be processed) and number of units "released" in the Comments
   iii) Process "sampled" units per normal
   iv) **Remove and process individually all salmonids other than chum and pink**

3) Data management

a) Make every effort to fill out each data sheet completely. Important to note “recorder” in case of questions.

b) After each DCE, scan and create pdf of datasheets and place in drive folder
   i) Snoh_Estuary_NOAA > *20__ (yr)* Working Folder > Datasheets
   ii) Name each file using the following convention: yyyymmdd(last day you have data for)_SnoCo or Tul/NOAA (e.g. 20170201_SnoCo)
   iii) Please also email pdf to Josh & Jason



Map F-1. Snohomish Estuary fish monitoring zones (1-9), long term index sites, and sampling lead (from NOAA).

Appendix H. 2018-2019 Bird list.

Bird observations at Smith Island and Mid-Spencer (2018-2019)	* Estuary-wide includes Smith Island observations	
Common name	Location	Photo Confirmed
Canada Goose	Smith Island	yes
Northern Pintail	Union Slough / Smith Island	yes
Lesser Scaup	Union Slough	yes
Northern Shoveler	Smith Island	yes
Ringneck Duck	Smith Island	yes
Mallard Duck	Smith Island	yes
Green-winged Teal	Smith Island	yes
Bufflehead	Smith Island	yes
Western Grebe	Steamboat Slough	yes
Red-necked Grebe	Steamboat Slough	yes
Pied-billed Grebe	Union Slough	yes
Green Heron	Steamboat Slough	yes
Great Blue Heron	Estuary Wide	yes
Greater Yellowlegs	Smith Island/Mid-Spencer	yes
Long-Billed Dowitcher	Smith Island	yes
Killdeer	Smith Island	yes
Belted Kingfisher	Estuary Wide	yes
Caspian Tern	Estuary Wide	yes
Glaucous-winged Gull	Estuary Wide	yes
Mew Gull	Estuary Wide	yes
American Crow	Estuary Wide	
Bald Eagle	Estuary Wide	yes
Northern Harrier	Mid-Spencer/ Smith Island	yes
Osprey	Estuary Wide	yes
Turkey Vulture	Estuary Wide	yes
Red-tailed Hawk	Estuary Wide	yes
Merlin	Steamboat Slough	yes
Barn Owl	Estuary Wide	
Cooper's Hawk		
Sharp-shinned Hawk		
White-necked Swift	not confirmed	possible
Barn Swallow		
Bank Swallow	Smith Island	yes
Red-winged Blackbird	Smith Island	yes
Cedar Waxwing	Steamboat Slough	yes
Black-capped Chickadee	Mid-Spencer	yes

Dark-eyed Junco	Mid-Spencer	
Winter Wren	Smith Island	yes
Savannah Sparrow	Smith Island	yes
Eastern Kingbird	Steamboat Slough	yes
Robin	Estuary Wide	yes
Varied Thrush		
Fox Sparrow	Estuary Wide	yes

This page left intentionally blank