Leque Island Estuary Restoration Monitoring and Adaptive Management Plan

Prepared For

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Prepared by

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1. INTRODUCTION

This monitoring and adaptive management plan provides guidance for implementing effectiveness monitoring for the Leque Island restoration project in Snohomish County, Washington being implemented by Washington State Department of Fish and Wildlife. The monitoring and adaptive management plan includes:

- A description of the restoration site and design;
- Monitoring approach which includes project objectives and hypotheses to be evaluated through monitoring;
- Metrics used to test the hypotheses;
- Values or performance criteria for defining success;
- Methods for data collection, analysis, and reporting; and
- Performance criteria and contingency actions to guide adaptive management.

The monitoring approach is designed to evaluate the effectiveness of the restoration actions relative to the stated objectives of the restoration project. This monitoring plan does not address the compliance of the project (i.e., was the project constructed as designed or specified in permit conditions). This monitoring plan incorporated recommendations from standard references for restoration monitoring in Pacific Northwest tidally influenced systems, including:

- Rice, C.A., Hood, W.G., Tear, L.M. Simenstad, C.A., Williama, G.D., Johnson, L.L., Feist, B.E. and Roni, P., 2005. Monitoring rehabilitation in temperate North American estuaries. Monitoring Stream and Watershed Restoration. American Fisheries Society, Bethesda, Maryland, pp. 167-207.

- Roegner, G.C., Diefenderfer, H.L., Borde, A.B., Thom, R.M., Dawley, E.M., Whiting, A.H., Zimmerman, S.A. and Johnson, G.E., 2008. Protocols for monitoring habitat restoration projects in the lower Columia River and estuary (No/ PMML-15793). Pacific Northwest National Lab, (PNNL), Richland, WA (United States).

- Koberstein, M., G.L. Slater, T. Bayard, T. Hass. 2017. Avian monitoring in support of the estuaries vital sign in Puget Sound: inventory and assessment. Final report to Puget Sound Partnership. Ecostudies Institute, Olympia, WA.

The adaptive management component of the plan is designed to address the inherent uncertainty in ecological restoration projects and seeks to minimize this uncertainty by learning about the system being managed (Thom and Wellman 1996; Thom 2000; Linkov et al. 2006). The basic process for adaptive management followed here includes five components:

1. A conceptual model of existing conditions and ecological processes affecting the restoration site that is used to predict the likely outcomes of individual restoration actions;
2. Clear statement of the goals and objectives for the restoration project;
3. Development of performance targets or criteria for evaluating outcomes relative to the objectives;

4. Monitoring the effects of the restoration actions relative to performance criteria; and
5. Adjusting restoration actions as needed—if performance criteria are not met, develop contingency plans or measures (decision framework) for adapting designs or implementing new actions.

This monitoring plan is organized in the following sections: (2) a description of the restoration site and project description; (3) overall monitoring approach; (4) discussion of the restoration objectives, and development of hypotheses and parameters for monitoring, and performance criteria; (5) monitoring schedule and reporting; and (6) a description of the adaptive management decision framework.

2. RESTORATION PROJECT

2.1 SITE DESCRIPTION

The Leque Island estuary restoration project intends to restore landscape processes and use by juvenile Chinook salmon and waterfowl and shorebirds on approximately 250 acres of former farmland at the meeting of the mouth of the Old Stillaguamish River channel and Port Susan Bay, adjacent to the zis a ba restoration project owned by the Stillaguamish Tribe. The project site is located on an island formed by the junction of the Old Stillaguamish River channel, the South Pass/West Pass channels, and Davis Slough near the town of Stanwood, WA. South Pass and West Pass to the east and Davis Slough to the west form a connection between Skagit Bay to the north and Port Susan Bay to the south. Highway 532, the only road onto Camano Island runs east-west on the northern most extent of the project area and separates Leque Island from the tidal wetlands to the north. The project site is about 2.9 miles from the mouth of the Stillaguamish River (aka Hatt Slough) and 3.5 to 5 miles from the major distributaries of the South Fork Skagit River (Fig. 1). The site's location makes it accessible to regional bird populations and juvenile salmon from the Skagit River, to the north, the Stillaguamish River, to the south and the Old Stillaguamish River Channel, to the east.

Leque Island was isolated from tidal inundation by levees, loss of historical tidal channels thru filling and excavation of linear drainage ditches, restriction of tidal exchange by tide gates, and agricultural development over the past 150 years. Pre-project site conditions include several infrastructural features that were removed in summer of 2019. Additionally, Washington Department of Fish and Wildlife pre-excavated several channels within the restoration area to prior for dike and levee removal. The result is a project site with a large tidal channel network with no to little tidal exchange due to the tidal dampening effects of dikes, levees and tide gates that was monitored as "pre-project" conditions (Fig. 2). Once breached, post project monitoring would occur across the same tidal channel network.

Fig. 1. Leque project area including the city of Stanwood, Skagit Bay and Port Susan Bay.

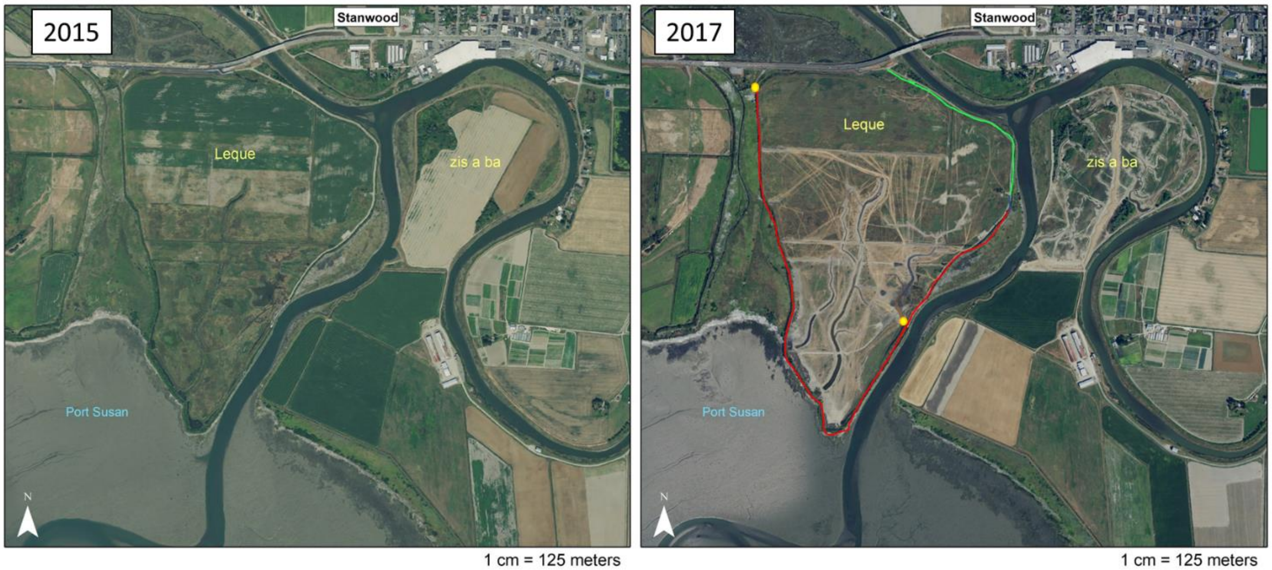

Fig. 2. Leque Island estuary restoration project in 2015 (no action) and 2017 with initial channels excavated. Red lines are existing levees that were removed in 2019; green lines represent the extent of new levee t built in 2019. Yellow and orange circles represent tide gates removed in 2019.

2.2 PROJECT DESCRIPTION

In general terms, the Leque Island estuary restoration project consisted of [1] removing the majority of the dikes and levees surrounding the site while constructing a new dike along the north-northwestern edge of the restoration site closest to the town of Stanwood, [2] removing the two existing tide gates, [3] filling most of the existing linear drainage ditches, [4] excavating new tidal channels in accordance with the conceptual design and connecting to existing mudflat channels on the exterior of the site, [5] using some excavation spoils to create marsh mounds, [6] removing the existing road and parking area within the site, and [7] allowing passive colonization of the site by native marsh vegetation once tidal inundation has been restored. Construction started on July 15th, 2019, when anthropogenic structures and trash were removed. Complete tidal inundation was restored to the interior of the site by October 14th, 2019. These elements are depicted in Fig. 2, showing the restoration area with the structures to be removed.

3. MONITORING APPROACH

Evaluating effectiveness requires a clear statement of restoration objectives and a set of hypotheses that allows testing of restoration outcomes relative to the objectives. The primary objectives for the Leque Island estuary restoration project are:

1. Restoring the tidal/riverine inundation that results in restored tidal wetlands function including sediment transport, channel formation and maintenance and establishment of tidal marsh vegetation;
2. Restoring tidal wetland habitat function (tidal channels and tidal marshes) for juvenile Chinook salmon rearing;
3. Restoring tidal wetland habitat function for shorebird and waterfowl.

Linkage of these objectives to hypotheses was guided by the following conceptual model: [1] historical tidal channel and tidal marsh were converted to agricultural use by limiting tidal and riverine inundation. The conversion to agricultural land resulted in a number of specific anthropogenic actions; excluding water with levees, filling in natural tidal channels, and excavating linear drainage ditches with two tidal gates thus dampening tidal exchange; [2] the consequences of these actions were loss of tidal wetland habitat for juvenile salmon rearing, including Chinook salmon, loss of shorebird and waterfowl presence, loss of tidal marsh vegetation (primary production), loss of secondary production (salmon prey such as copepods), and ground subsidence; [3] undoing anthropogenic impacts means removing the levees and tide gates to restore tidal/riverine inundation and fish access, and thereby restoring tidal inundation, natural sediment process, wood delivery and estuarine flora and fauna; [4] the quality of the restored channel network and vegetation will affect the value of the restored system for secondary production, that will influence juvenile Chinook salmon rearing and use by shorebird and waterfowl.

Once a conceptual model is described, the hypotheses can be formed based on the conceptual model. We have selected hypotheses that include processes (e.g., sedimentation rates), structure (e.g., channel form, vegetation structure), and functional responses (e.g., fish populations, bird abundance, plant communities) (Vallejo et al. 1996; Zedler 2001; Rice et al. 2005, Koberstein et al. 2017). Once hypotheses are established, we then select observations or parameters that will evaluate the stated hypotheses. We can then establish expected results (i.e. targets) given understanding of the system and restoration actions within tidal channel and tidal marsh habitat. Hypothesis related to the primary objectives are described in Section 4.

Objectives, hypotheses, parameters, and targets determine which monitoring methods and protocols are appropriate in this monitoring plan, and are defined as follows:

Objectives: Are what the project seeks to achieve— restore tidal wetland habitat to support juvenile Chinook salmon and the physical processes that maintain that habitat.

Hypotheses: Are testable suppositions regarding possible outcomes of restoration actions. Hypotheses are used to inform questions and can make future predictions regarding the restoration site. Hypotheses are statements based on the conceptual model from restoration actions that are thought to achieve the restoration objectives. Hypothesis should link parameters/attributes and targets with restoration objectives. In this monitoring plan, hypotheses will typically be stated as alternate hypotheses (difference) about the effect of restoration actions compared to null hypotheses (no difference). Many of these predictions have been described in detail in planning documents for the restoration project (Hood 2014a, b; WDFW and DU 2015). Monitoring results will be used to validate hypothesis and inform whether the project's objectives have been met or not. By testing the veracity of stated hypothesis, we can place the data collected within an adaptive management framework. Being able to adjust the parameters measure and the desired targets (defined below) with empirical data allow us to design restoration actions that are more biologically and ecologically meaningful.

Parameters/attributes: Are the characters that can be empirically measured to evaluate or test the hypotheses.

Targets: Are the values of the parameters that show that the alternate hypotheses have been supported and null hypothesis has been rejected- these are the performance criteria that indicate success.

3.1 STUDY DESIGN

The monitoring approach for Leque Island restoration project consists of a comparison between the project area and reference areas with limited before-after comparison. One question of interest is; do the restoration actions result in more juvenile Chinook salmon (and other fishes) at the site compared to before the restoration action? First, fish can possibly access the site before restoration through "leaky" tide gates and failures in the dike/levee system. This requires pre-restoration monitoring of the site to determine the temporal and spatial extent of fish use (Beamer et al. 2018). Second, the number of fish observed in the restored site is also influenced by the regional pool of fish available. For juvenile Chinook salmon, the regional pool is the number of fish emigrating from nearby Skagit River and Stillaguamish River systems and moving to the restoration project area. Reference locations can then inform temporal differences in regional pool of fish available to use the restoration site. Thus, fish monitoring will include a before-after monitoring element to document the net gain of fish access to the site that can inform before-after/control-impact (BACI) comparisons (Underwood 1994).

We are interested in site use by waterfowl and shorebirds. We will follow the BACI design as well, however evaluation of Leque Island restoration area is incorporated in evaluations of Fir Island Farm, Wiley Slough and Island Unit within the Skagit River delta and Leque Island and zis a ba restoration projects near the historical Stillaguamish River mouth (Slater et al. 2019, PRISM Record 18-2241). In addition, reference sites will be selected between the Skagit River delta and the current Stillaguamish River mouth. The broader spatial extent of the BACI design relates to the mobility of bird species so to account for regional bird species pool that might occupy Leque Island restoration.

The monitoring plan currently calls for monitoring the site for five years total (including pre-project) with some monitoring actions only occurring in some years (see Section 5). Monitoring will include one year of pre-project conditions and possibly up to four years of post-project monitoring to evaluate project hypothesis (Section 4).

3.2 DATA STORAGE AND MANAGEMENT

Data management and storage will follow standard protocols, using readily retrievable data formats. Raw data from automatic data loggers, fish surveys, vegetation and sediment monitoring will be stored in standard file formats (e.g., excel, shape files, jpegs) following downloads of field surveys. Post-processing data will be in standard file formats, maintained on the Skagit River System Cooperative (SRSC) network (backed up regularly). All electronic data files will be provided to WDFW with each monitoring report. Monitoring reports will be provided to WDFW in electronic (pdf) format.

Data collected by WDFW (e.g. bird counts and ground water monitoring) and given to WDFW will be stored on an agency-wide shared drive in readily available formats. Data and reports will be provided as deliverable to granting agencies and are available to share with others upon request.

4. HYPOTHESES, PARAMETERS, TARGETS, AND METHODS

Monitoring targets or performance criteria are developed in this section to provide benchmarks for evaluating the monitoring hypotheses. The hypotheses, parameters, and targets in turn determine which monitoring methods and protocols are suitable for monitoring restoration effectiveness. The relationship between objectives, hypotheses, parameters, targets, and protocols is as follows: Objective → Key Questions/Hypotheses Parameters/Attributes to Measure → Targets or Performance Criteria → Protocols for Data Collection and Analysis. Monitoring objectives and hypotheses are summarized in the following sections. The rationale for each of the four objectives, hypotheses, and parameters are summarized, and the performance criteria or restoration targets for each hypothesis are identified. These are summarized in Table 3 on page 24.

4.1 OBJECTIVE 1: RESTORE THE PHYSICAL PROCESSES THAT SUSTAIN TIDAL REARING HABITAT FOR CHINOOK SALMON

This objective contains the following sub-objectives: [1] restore tidal and riverine flooding and associated hydrological conditions, and [2] restore marsh aggradation through tidal/fluvial sediment delivery.

4.1.1.1 Hypothesis 1: *Tidal fluctuations inside the restoration site will be similar to those in reference marshes.*

In tidally influenced wetlands, tidal forcing or tidal exchange affects variation in water levels, which determine habitat suitability for wetland plants and animals. Tidal exchange determines numerous processes that are important for wetland structure and function, including sediment transport, erosion, and deposition; tidal channel development and complexity, vegetation distribution and composition; inundation periods, and salinity intrusion (Mitsch and Gosselink 2000). Because of the importance of water elevation to key processes, such as vegetation distribution, measuring the pattern of water level variation over time provides information to address a number of the project hypotheses. In addition, tidal exchange informs hydrologic connectivity of the site to external areas and often explains site accessibility for fish, for instance tidal muting limits densities of certain fishes within tidal wetlands (Beamer et al. 2017 and Greene et al. 2012).

4.1.1.2 Parameters

Tidal inundation can be evaluated by the changes in water surface elevations of the restored site compared to reference sites. In addition, measuring temperature and salinity can inform if the water is more riverine or marine in nature. Time series of water surface elevation (WSE measured in meters) from a reference gauge outside the restoration area. Time series of WSE, salinity (Practical Salinity Units-PSU) and temperature (^{o}C) measurements at two monitoring points within the restoration area.

4.1.1.3 Targets

Comparability of water levels between the restoration sites and the nearby reference sites. The target is similar water levels, salinity and temperatures over the restoration site with those of the nearby reference sites indicating that the natural tidal connectivity has been restored.

4.1.1.4 Methods

WSE will be measured with continuously recording submersible water level loggers tied to a known vertical elevation datum from February to August. WSE, temperature and salinity measurements will be obtained at three locations: [1] reference gage within the open channel near the Grand Junction, [2] within the restoration site in channel 1 (L1) and, [3] within the restoration site in channel 2 (L2) (Table 1, Fig. 4). These latter two loggers will be referred to as "restoration loggers" in the rest of this document.

The reference and restoration loggers will record WSE, salinity and temperature at 15-minute intervals for the duration of the monitoring period. The loggers will be placed in standpipes. Each logger will be suspended so that it remains submerged during low water periods (suspended in subtidal or below the lowest low water levels) and is not covered by more water than the stated range for the logger (overpressure). Sensors will be positioned slightly above the substrate (6 to 12 inches) to prevent sedimentation or abrasion at high flows. Locations (latitude, longitude and elevation) of the logger standpipes will be surveyed directly with with RTK-GPS (3-cm horizontal and vertical resolution) or from known benchmarks to the top of each level logger standpipe so that that water-level data is properly geo-referenced to local topographic data (e.g., North American Vertical Datum 1988 [NAVD88] and mean lower low water [MLLW] (Roegner et al. 2008). The restoration logger will be maintained, and the data downloaded by SRSC staff.

Logger data will be direct measure of pressure. We will convert and compensate for barometric pressure to estimate relative water depth. We will then used geo-reference to estimate NAVD88 elevation to compare WSE from different loggers.

Analytical Approach

The physical habitat determines the ability of juvenile salmonids to utilize the created habitat. Logger information will be used to 1) calculate the amount of wetted area within the restoration area and, 2) compare the physical habitat (temperature and salinity) in the two monitored channels. Using the logger data to obtain a WSE at the time of sample, the wetted area will be estimated in order to estimate the juvenile salmon abundance that use the restored area. Wetted area will be determined by digitizing elevation polygons from a high-resolution surface TIN (triangulated irregular network) provided by the Leque "AsBuilt" plan (i.e., dike and levee setback) condition and then artificially filling the channels. Using the as-built engineering plans and using the estimated tidal heights to "fill" each monitored channel, juvenile Chinook salmon abundance using the restoration area can be estimated. If the "AsBuilt" plan is unavailable then channel information collected to inform Hypothesis 4 will be used to estimate WSE for each channel.

To compare continuously monitored temperature and salinity, time series over the monitoring period will be graphed in a BACI framework. The reference logger and the restoration loggers will be compared visually to examine if there are variations in water chemistry across the spatial extent of the restoration area and compared to reference conditions both before and after restoration.

4.1.2.1 Hypothesis 2: *DO, salinity, and water temperature within the restoration site will be comparable to that of nearby reference marshes.*

DO concentrations, salinity, and water temperature are important determinants of habitat quality for aquatic organisms, including the distribution of wetland plants and other aquatic organisms (Thom et al. 2002). Dissolved oxygen concentration, salinity, and water temperature affect juvenile Chinook salmon, influences abundance in the local environment and provide a measure of the intrinsic quality of the habitat, restored or reference (Rice et al. 2005).

4.1.2.2 Parameters

DO (mg/L), salinity (practical salinity units-PSU) and water temperature (^{o} C).

4.1.2.3 Targets

Parameters within the restoration site and nearby reference sites will be similar.

4.1.2.4 Methods

Water quality parameters will be measured at each beach seine, stick seine and fyke trap using a multi-parameter sonde, YSI Professional Plus or YSI Professional 2030. In the reference sites, the water quality parameters will be collected after the seining event by wading to approximately hip deep (between 0.75m and 1.0 m) and taking a reading at both the top and the bottom of the water column. The two measures will then be averaged to produce an average water quality reading per sampling event. In the event of water levels < 0.3 m, only one water quality sample will be recorded.

In addition, water quality parameters will be measured continuously at two locations: within the restoration site and in a nearby reference tidal marsh. Continuous, automated data logging instruments, (equivalent to Aquistar® DO sensor, Instruments Northwest) will be placed at the locations where the water level loggers are installed. Water quality parameters will be measured at hourly intervals. Locations of the instruments will be surveyed relative to known benchmarks. Automated data loggers will provide a time series of water quality parameters that can be related to tidal cycles.

Analytical Approach

Boxplots will be created for the spot measurements of temperature, DO and salinity in each monitored channel in a BACI framework. We will compare if central tendencies and variation (95% Confidence Intervals) differ between Before/After and Control/Impact conditions. If needed Analysis of Variance can be conducted to evaluate significant differences between before and after restoration actions and between reference and restoration sites. Maximum values for temperature and salinity and minimum values for DO will be compared to reference values to determine if the restored habitat is suitable for juvenile salmonid rearing.

The following calculations and visual data displays will be used to evaluate restoration effects on water quality:

- Mean monthly (and standard deviation) values pre- versus post-project (all parameters).
- Mean (and standard deviation) daily maximum values before and after project (temperature).
- Mean (and standard deviation) daily maximum values before and after project (salinity).
- Mean (and standard deviation) daily minimum values before and after project (DO).
- Mean (and standard deviation) yearly values compared pre- versus post-project (all parameters).

4.1.3.1 Hypothesis 3: *The groundwater model developed for the project accurately predicted that reintroduction of tidal flows onto Leque Island and does not lead to saltwater intrusion into adjacent drinking water district.*

WDFW intends to monitor water levels and salinities in the lowland area between Leque Island and Camano Island during the background (design/engineering), construction, and post-project monitoring phases of the Leque Island restoration, contingent upon availability of funding. This lowland area was previously characterized by PGG (2012) and was selected to monitor for changes in groundwater elevations and salinities along the edge of Camano Island potentially associated with the restoration. In addition, monitoring will continue into the post-construction (post-restoration) phase, with duration to be determined based on review of natural data variability (noise) and expected groundwater flow dynamics.

4.1.3.2 Parameters
Water level (WSE measured in meters), temperature (^{o}C), specific conductance (uS/cm @ 25 ^{o}C)

4.1.3.3 Targets
Comparability between parameters in the monitoring stations before and after the project after taking changes beyond control of the project (ie: weather events, sea level change, changes in aquifer management) into account.

4.1.3.4 Methods
All five current monitoring stations (4 wells and a drainage ditch) are fitted with non-vented Van Essen CTD-Diver dataloggers that monitor water level, temperature and specific conductance ("SC"). SC is a common measure of salinity. The dataloggers have a maximum water-level range of 10 meters (33 feet) and are currently set at well depths intended to ensure representative measurement of aquifer salinity.

The dataloggers are programmed to collect data on a half-hourly basis, with PGG generally downloading dataloggers in the McIntyre Well, MW-4s, MW-4d and the Middle Ditch on a quarterly basis4. Immediately prior to download, PGG measures depth to water (DTW) in the monitored wells and records the surface- water stage from the staff gage. The manual DTW measurements allow us to calibrate the pressure transducer reading to the datalogger. PGG also calibrates the specific conductance (SC) probe on the CTD dataloggers periodically using standard calibration solutions. Island County incorporated the Oksendahl Well into their groundwater monitoring network and is responsible for all measurements and data collection.

After each site visit, the digital datalogger data are uploaded into the project database and checked for equipment problems, drift (relative to manually measured water levels), and other errors. The data are assessed on an annual basis for observable and meaningful trends in water-level elevation or salinity throughout the monitoring period. Barometric correction is performed based on barometric data collected in Coupeville, WA by the Island-County Hydrogeologist. Where needed, the datalogger data are adjusted for instrument drift by applying a correction to the measurement associated with the field visit and linearly interpolating the correction back to the prior field visit (adjustments are typically within ±0.15 feet). A technical report is prepared on a near-annual basis to summarize findings derived from the monitoring data.

Table 1: Summary of monitoring points for ground water intrusion.

Monitoring Point	Ecology Well ID	Measuring Point Elevation (ft NAVD88)	Measuring Point (MP)	MP Stickup (ft als)	Well Completion Depth (ft bls)	Well Completion Elevation (ft NAVD88)	Static Water-Level Elevation Range (ft NAVD88)	Probe or Reference Elevation (ft NAVD88)	Probe Depth (ft bls)	NOTES
McIntyre Well	AHN-391	11.75	Top of steel casing	~3	23 to 33	~-14 to -24	6.5 to 8.0	~ -9.4	~ 21.2	Probe set for entire monitoring period (3/2015 thru present)
Middle Ditch	N/A	2.73	Zero on staff gage	n/a	n/a	n/a	4.3 to 7.3	~ 3.1	n/a	Installation disturbed between 4/2016-4/2017
		1.42						~ 2.7	n/a	New installation on 9/7/17
MW-4S	BIP-535	7.64	Top north side of PVC pipe	2.61	17 to 22	-12 to -17	5.3 to 7.9	~ -14.9	~ 19.9	Stable probe position from 11/2015 thru present. Probe lowered in 7/2015.
MW-4D	BIP-534	7.52	Top north side of PVC pipe	2.56	40 to 45	-35 to -40	5.5 to 8.1	~ -21.4	~ 26.4	Probe position from 7/30/15 to 9/7/17. Probe reads water level, SC and temperature.
								~ -37.5	~ 42.4	CTD probe lowered on 9/7/17. Probe reads only SC and temperature.
								~ -2.75	~ 7.7	Diver water-level probe installed on 9/7/17. Supplemental probe reads water level and temperature.
Oksendahl Well	AGA-505	74.32	Top of PVC Sounding Tube	0.9	85 to 90	-12 to -17	6.3 to 8.0	~ -2.57	~ 76.0	Stickup approximately 0.9 feet above concrete pad, with 0.19 feet associated with new sounding PVC sounding tube installed in March 2015.

Note: probe depths and elevations are considered approximate (typically +/- 0.15 feet) because they are calculated with each field calibration and thus incorporate potential instrument drift.

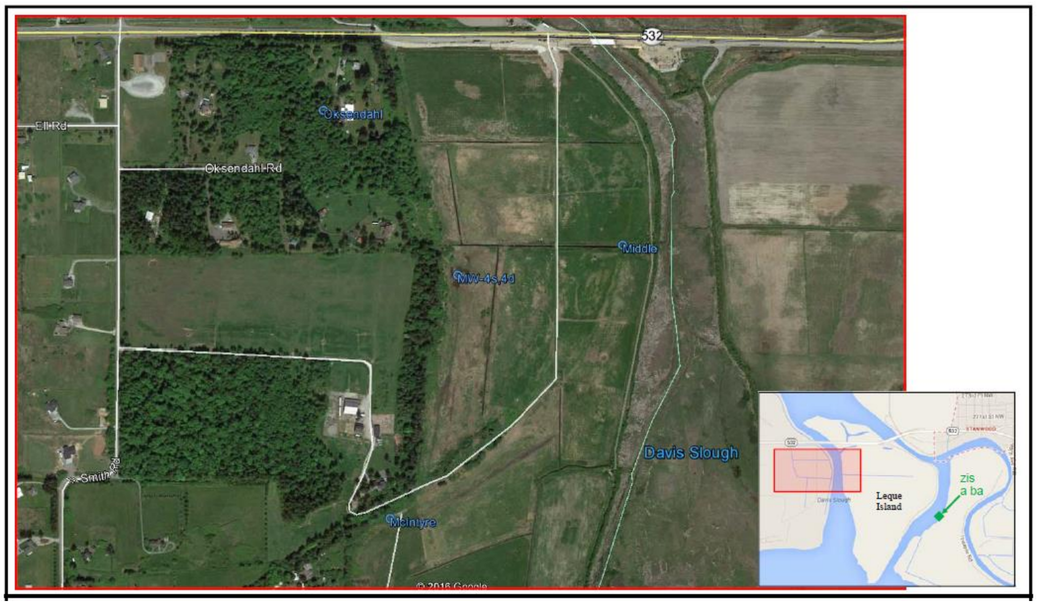

Figure 3. Approximate locations of monitoring locations for groundwater.

4.2 OBJECTIVE 2: RESTORE CHINOOK SALMON TIDAL REARING HABITAT

This objective contains the following sub-objectives: [1] restore natural tidal channel networks, [2] restore native marsh vegetation, [3] restore juvenile Chinook occupancy to the Leque Island site. Rearing habitat can be improved by increasing habitat opportunity and capacity (Simenstad and Cordell 2000). Greater channel area and complexity will increase the amount and quality of rearing habitat for Chinook by creating predator, flow and temperature refugia (channel complexity), and increasing availability and access to prey items from overhanging vegetation, detritus, and terrestrial insects/invertebrates contributed to channels from wetland and riparian vegetation.

4.2.1.1 Hypothesis 4: *Following initial excavation of a tidal channel network in accord with the conceptual design (Hood 2015a), the channel network will continue to elaborate to become increasingly complex and comparable to channel networks of reference tidal marshes.*

The planned restoration actions (levee and tide gate removal, channel excavation) are predicted to allow restored tidal prism to drive further channel network development from the initial excavated condition to a more complex and mature condition comparable to that of reference tidal marsh channels (Hood 2014a). The channel excavation proposed in the conceptual design (Hood 2015b) will accelerate this process. However, the rate at which the channel network will continue to elaborate following tidal prism restoration is unknown; tidal channel monitoring will not only confirm or falsify this hypothesis, it will also provide new information on the rate at which channel networks mature following excavation and tidal prism restoration. The nearly adjacent zis-a-ba restoration site is underlain by extensive and very thick clay soil, as is the adjacent North Leque dike failure site. Thus, similar occurrence of clay soils on the Leque Island restoration site will likely result in very slow channel network elaboration.

4.2.1.2 Parameters

Monitoring parameters will include: total tidal channel network length (m), total channel network surface area (m^2), and the lengths and surface areas of all individual tidal channels, i.e., planform metrics. Additionally, they will include tidal channel cross-section widths, depths, and areas for cross-sections at channel outlets and at the midpoints of the excavated mainstems of individual tidal channels. Channel profiles will be surveyed for channel mainstems and tributary channels that appear likely to experience head cutting.

4.2.1.3 Targets

The planform target is comparability with reference marshes to be assessed by allometric analysis of the type found in Hood (2015b). The cross-sectional target is the set of channel cross-section predictions made in the conceptual design report (Hood 2015a).

4.2.1.4 Methods

Channel planform will be digitized from aerial photographs in a GIS and compared to reference marshes through allometric analysis (Hood 2015b). Channel cross-sections and profiles will be surveyed with RTK-GPS (3-cm horizontal and vertical resolution). Channel cross-section endpoints will be marked with PVC pipes, set at least 1 m deep and at least 10 m from the channel banks where they will be unlikely to affected by channel erosion. Elevations will be recorded at 3-m intervals across the cross-section outside of the channel area and no more than 1-m intervals within channels, and/or at any clear break in topography—including at a minimum, left bank, right bank, and channel thalweg. Channel planform should be measured from aerial photos at least every two years. Channel cross-sections and profiles should be surveyed annually. Channel cross section calculations and reporting will include: [1] change in channel cross sectional area, width and depth; [2] visual display of changes in cross sections over time; [3] change in channel gradient.

4.2.2.1 Hypothesis 5: *Native marsh vegetation will become established on the site through passive recruitment. The species distribution will be similar to that predicted in Hood (2014b), i.e., similar to that predicted and observed for the nearly adjacent zis-a-ba restoration site, which has similar elevation, salinity, and tidal range.*

Restoration of tidal inundation is expected to change the pasture grass vegetation community that characterized the project site, prior to disturbance by heavy machinery, into one of native tidal marshes. Native plant communities are a key factor in maintaining and supporting wetland function, creating habitat structure, shading tidal channels, stabilizing sediments and contributing to marsh accretion, contributing detritus and insects to aquatic food webs, and increasing salmon prey production. Additionally, many native species, particularly in the sedge family (Cyperaceae), are food plants for overwintering waterfowl.

4.2.2.2 Parameters

The parameter is ranked abundance (dominant and 2nd-4th most abundant) of vascular plant species at GPS-surveyed points.

4.2.2.3 Targets

The vegetation target is predominance of native tidal marsh species (particularly Cyperaceae) throughout the site, comparable to predicted and observed vegetation distributions in the zis-a-ba restoration site. An additional target is species richness comparable to that of reference marshes. Exotic species should be rare; any observed should be eliminated by physical control as soon as possible.

4.2.2.4 Methods

Vegetation on the restoration site will be monitored by point sampling with an RTK-GPS (3-cm horizontal and vertical resolution). The points will be distributed over a series of random transects that span the extent of the site, with a total of at least 300 points to be sampled, i.e., each point will be about 30-35 m apart. At each point the dominant and subdominant vascular plant species will be noted while the RTK-GPS simultaneously acquires the horizontal and vertical location of the point. Relative plant abundance at each point will be determined by visual estimation of aerial cover within a 1-m radius from the sample point. The GPS data will be transferred to a GIS for comparison of observed and predicted vegetation distributions similar to the method published in Hood (2013). Vegetation monitoring should occur annually during the first three years after restoration, and then again in years 5 and 7. Further monitoring might be deemed necessary depending on the observed vegetation colonization trajectory.

Supplementary monitoring will occur through analysis of aerial photographs in a GIS to map easily distinguishable patches of particular plant species, e.g., cattails, reed canarygrass. The aerial photo analysis will be ground-truthed with the data collected from the RTK-GPS point samples. Additionally, general changes in vegetation and channel development will be captured with annual, late summer, photo point monitoring. Permanent photo points will be established at strategic locations on the project site. Locations of the permanent photo points will be recorded with GPS, and compass headings for the photographs will be recorded. Photo points will be located in areas that provide views of portions of the site that are expected to undergo significant change following restoration.

4.2.3.1 Hypotheses 6: *Estuarine fish assemblages and juvenile Chinook salmon densities within the restoration site will be comparable to that of nearby reference marshes and similar inside and outside the site. Both Skagit River and Stillaguamish River salmon populations will be detected within the restoration site.*

4.2.3.2 Parameters

Identification and enumeration of all fish species captured at the site. Catch for all fish species will be recorded. Densities of juvenile salmonid species (fish/ha) within the restoration sites.

4.2.3.3 Targets

For the after-restoration period, we expect estuarine fish species consistent with other estuarine reference sites to be present within the restored area and to be similar to the assemblage outside of the old tidally restricted sites. We expect seasonal densities and abundance of juvenile Chinook salmon to be consistent between restored sites and reference sites and this an overall increase in Chinook salmon at the site.

4.2.3.4 Methods

Site selection, timing, and frequency

For the before-restoration period (2019), the sampling schedule will consist of two sampling events; a treatment sampling day and a reference sampling day. The treatment day will consist of nine small net beach seine sets in three sites (channels) and three stick seine sets at one site within the restoration area (Fig. 4, Table 1). A reference day will consist of nine small net beach seine sets made at three sites, one fyke trap at one site and three sticks seine sets made at one site (Fig. 5, Table 1) outside or adjacent to the project area. These five sites will be established as reference sites and will be sampled in years after restoration has occurred. Sampling will occur twice a month from March through July and once in August for a total of 22 sampling events per year (reference and treatment combined).

For the post-restoration period (2020 through 2023), the sampling events will take place at the same sites as 2019. After construction, the channels will be returned to tidal inundation and may require an expansion of the monitoring effort to include the newly formed habitat. Changes in the post restoration sampling plan will be recorded and the monitoring plan will be updated to take these changes into account.

Fig. 4: Location of the Leque Island fish sampling sites in 2019. Beach seine sites are shown as circles and stick seines are shown as squares.

Fig. 5: Location of the reference Leque Island fish sampling sites in 2019. Beach seine sites are shown as circles, fyke trap site are shown as triangles and the stick seine site is shown as a squares. Davis Slough was sampled with stick seines due to tidal constraints, as the slough only contained enough water to be sampled by small beach seine for an hour before and after high tide. Sampling schedule and crew availability did not permit sampling within this tidal window.

Table 1: Monitoring schedule by site, spatial location, gear type and number of sets for pre restoration monitoring.

Site	Type	Spatial	Gear Type	Comment
Leque 1 (L1)	(Restored Area) Treatment	Within project	Beach seine	Pre-restoration 3 sets in a tidal channel
Leque 2 (L2)		Within project	Beach seine	Pre-restoration 4 sets in a tidal channel
Leque 3 (L3)		Within project	Beach seine	Pre-restoration 2 sets in a tidal channel
Davis Tidegate		Within project	Stick seine	Pre-restoration 3 sets in a tidally restricted channel. The tide gate will be removed and the channel excavated in July 2019
West Pass Blind Channel	Reference Area	Adjacent to project	Fyke trap	Blind channel sampled by fyke trap Reference blind channel downstream of the project
South Pass		Downstream of project	Beach seine	3 sets along mainstem channel
Grand Junction		Adjacent to project	Beach seine	3 sets along mainstem channel
West Pass RB		Upstream of project	Beach seine	3 sets along mainstem channel
Davis Slough		Adjacent to project	Stick seine	3 sets within channel. Stick seine instead of small beach seine due to tidal constraints.

Field methods

We use a small net beach seine, stick seine and fyke trapping methods to sample sites. Small net beach seine methodology uses an 80-ft (24.4 m) by 6-ft (1.8 m) by 1/8-in (0.3 cm) mesh knotless nylon net. The net is set in "round haul" fashion by fixing one end of the net on the beach, while the other end is deployed by setting the net "upstream" against the water current, if present, and then returning to the shoreline in a half circle. Both ends of the net are then retrieved, yielding a catch. Average beach seine set area is 96 square meters (SRSC 2003).

Stick seine methodology uses a 25-ft (7.6 m) by 6-ft (1.8 m) by 1/8-in (0.3 cm) mesh knotless nylon net attached on either end to two 8-ft (2.4 m) by 2-in (5 cm) by 2-in (5 cm) posts to sample smaller order "branch" channels within a restoration area. The net is set in a "J-set" fashion by fixing one end to the beach and the second end crossing the channel downstream of the posted end. The net is then walked "upstream" by walking against the water current in a J-shape. The first end is then posted in an upstream location while the second end crosses back over the channel creating a "purse" in the net and closure. The lead line is then elevated up the side of the bank yielding a catch. Area sampled is estimated by measuring the length of the line walked and the wetted channel width.

Fyke traps are used to capture fish in small, blind tidal channel habitat. Fyke trap methodology uses nets constructed of 1/8-in (0.3cm) mesh knotless nylon with a 2-ft (0.6m) by 9-ft (2.7m) diameter cone sewn into a 40-ft (12.2 m) by 10-ft (3.05 m) net to collect fish draining out of the blind channel site during an ebbing tide. Fyke nets are deployed at high tides and block fish immigrating or emigrating from the channel. Fish are caught through the ebb tide until either the channel is dewatered, or low tide has occurred. Total time of the fyke net effort is recorded to estimate juvenile Chinook salmon catch per unit effort (# of fish/ unit time). To estimate total abundance in the blind channel catch is adjusted by trap recovery efficiency (RE) estimate that is derived from mark-recapture experiments using a known number of marked fishes released upstream of the trap at high tide. RE is usually related to hydraulic characteristics unique to the site (e.g., change in water surface elevation during trapping, or water surface elevation at the end of trapping). Multiple RE tests (several times per season) at each site are used to develop a regression model to convert the "raw" juvenile chinook catch to an estimated population within the habitat upstream of the fyke trap on any sampling day (SRSC 2003).

For each set, we identify and enumerate all fish captured. A subset of individuals (up to 20) are measured for fork length or total length for fish with non-forked caudal fins. All the fish are returned alive to the water, except for hatchery-origin juvenile Chinook salmon with coded-wire tags embedded in their snouts. These fish are sacrificed in order to read the tags and the heads are stored in 90% ethanol until the coded-wire tags can be extracted and read (see Hypothesis 4, Section 4.2.1.1). Unmarked juvenile Chinook salmon will have a small tissue sample taken by caudal fin clip for DNA analysis to determine the natal origin of that fish. DNA samples will be stored by Stillaguamish Indian Tribe Natural Resources Department until funding has been secured for DNA analysis (see Hypothesis 7, Section 4.2.3.1).

We also record the time and date of each set, the percent of set area (the area that the net covers), and measure selected environmental conditions (salinity, temperature, dissolved oxygen (DO), water velocity, water depth, substrate class, and vegetation class) that are present within the seined area at the time of seining. Water temperature, salinity, and DO are measured using a YSI Professional Plus Model meter. Depth is measured with a stadia rod. Surface water velocity is measured using a JDC Electronics Flowatch flow meter. Velocity measurements are taken across the area seined after the set is made and the average value of these readings is reported for each site/date combination. Substrate and vegetation at each site are recorded according to criteria described in SRSC (2003).

To fully understand the utilization and effectiveness of the Leque Island restoration action to juvenile Chinook salmon, comparisons before and after and the between reference and treatment must include extrinsic variables such as potential seeding of outmigrants from the Skagit River, Stillaguamish River and to a lesser extent the Snohomish River or annual differences in weather (dry and hot vs. wet and cold years). The inclusion of juvenile Chinook salmon abundances emigrating from each neighboring rivers smolt trapping efforts will need to be included. In addition, river discharge will need to be included as well.

Analytical approach

At the conclusion, data will be collated and summarized by SRSC staff. The following tabular and visual products will be produced:

- Total fish captured
- Number of sets (beach seine, stick and fyke) made by month and year.

- All fish (estuarine and juvenile salmon) caught will be summarized as catch per unit effort (stick seine and small seine= # of fish/m^2, fyke net= # fish/ hr).
- Given that seine (stick and small) and fyke net methods do not have similar units, a way to equivocate the methodologies is required. In order to calculate a density over space from a fyke trap, the total channel surface area (m^2) behind the blind channel mouth will be calculated. The total juvenile Chinook salmon catch at each capture event will be adjusted by the recapture efficiency and divided by total channel surface area per site for all sampling events by year to estimate density (# of fish/m^2) within the blind channel. Seine sets that occur within the same channel will be averaged.
- Density of juvenile Chinook salmon by year will be estimated by dividing total catch by estimated area sampled at each sampling location. This will be each monitored channel for the restoration area and each site in the reference area.
- Juvenile Chinook salmon densities before and after restoration both inside and outside of the restoration area.
- Using estimated WSE and wetted channel area, abundance of juvenile Chinook salmon utilizing the restoration area before and after restoration.

Once the full suite of data is collected, a full BACI analysis can be implemented to assess the effectiveness of the Leque Island restoration actions compared to the objective. Traditional BACI's using ANOVA approaches are limited in their ability to assess non-linear effects and curvilinear seasonal pattern of the migration timing of juvenile Chinook salmon (Beamer et al in prep). For these reasons, we suggest using the entire dataset within a generalized additive models (GAMs) framework. GAMs are an extension of generalized linear models (GLM) that in addition to evaluating a suite of fixed effects, allow for the incorporation of non-parametric smoothers to account for non-linear relationships between the response variables and continuous explanatory variables such as time (Hastie and Tibshirani 1978).

To parameterize a GAM, the response variable is fish density within the Leque Island treatment. In this case, to account for the curvilinear seasonal pattern of the migration timing of juvenile Chinook salmon, a three-dimensional cubic regression spline smoother to sampling event for each year to account for potential annual variation in the shape of the relationship between juvenile Chinook salmon density and time should be applied. Possible covariates to include are listed in Table 2. Specific to these covariates are the annual estuarine seeding abundance of individuals emigrating from the river as smolt. Stillaguamish Tribe maintains a smolt trap and estimates total outmigration abundance as well as weekly catches. In addition, some information regarding natal origin of Chinook in Leque Island will be collected and analyzed by the Stillagumish Tribe. If large proportions of individuals caught in Leque Island were from the Skagit and or the Snohomish then aggregation of smolt abundance across basins will be addressed. Landscape connectivity estimates have now been made available (Beamer unpublished data). Landscape connectivity is important for describing fish use where sites closer to the river mouth tend to have higher densities than sites further away (Greene et al. 2016).

Table 2: Potential covariates to consider and their associated values.

Name	**Value**
Restoration	Before, after
Spatial	Treatment, reference
Year	2019, 2020, 2021, 2022

Month	3, 4, 5, 6, 7, 8
Week	Week numbers 9-32
Salinity	Practical Salinity Units (PSU)
Temperature	^oC
DO	mg/L dissolved oxygen
Depth	meters
Fish origin	Skagit, Stillaguamish, Snohomish
Stillaguamish Smolt trap catch	Fish/week
Reference juvenile Chinook densities	Fish/m^2
River discharge	ft^3/s (cfs)
Landscape Connectivity	Unitless metric

4.2.3.1 *Hypotheses 7:* Juvenile Chinook salmon utilizing Leque Island restoration area originated from Stillaguamish River and Skagit River and are similar to reference sites.

4.2.3.2 Parameters

Stock assignments for coded-wire tag identifiers and DNA assignments of juvenile Chinook salmon captured (funding dependent).

4.2.3.3 Targets

For the after-restoration period we expect estuarine juvenile Chinook salmon stock composition between Leque Island restoration area and reference sites to be similar. We also expect that juvenile Chinook salmon utilizing the Leque Island restoration area to have originated from Skagit River and Stillaguamish River.

4.2.3.4 Methods

We will have two methods of identifying river of origin for juvenile Chinook salmon. We will have coded-wire tags from some hatchery fish that will be retained and read by SRSC staff. Coded-wire tags will inform where the fish was reared and when it released. The second methods for determining natal origin will be from genetic analyses. Fin clips will be retained and stored for future analysis. Juvenile Chinook salmon can be differentiated by river basin by a genetic analysis (Ruckelshaus et al 2006).

When funding is available, genetic samples (fin clips) will be sent to a genetics lab to compare individuals to the established baseline for the Puget Sound. Individual juvenile Chinook salmon will be assigned to a natal river system, which will be used to estimate stock composition within restored areas and reference areas.

4.3 OBJECTIVE 3: INCREASE WATERFOWL AND SHOREBIRD USE WITHIN LEQUE ISLAND

This objective contains the following sub-objectives: [1] restore natural tidal channel networks, [2] restore native marsh vegetation, [3] restore waterfowl and shorebird occupancy to the Leque Island site while decreasing the upland bird occupancy. The latter sub-objective is conditional to the success of sub-objective 1 and 2.

4.3.1.1 *Hypothesis 8*: Return of tidal inundation will result in bird communities to be similar within the restored reach as compared to reference marshes.

4.3.1.2 Parameters
The abundance of migrating (spring and fall) and wintering shorebirds and waterfowl, including snow geese and abundance of breeding and wintering land birds (passerines and raptors) and secretive marsh birds.

4.3.1.3 Targets
Increase in of migrating (spring and fall) and wintering shorebirds and waterfowl presence and abundance after project implementation and similar to other reference locations.

4.3.1.4 Methods
Our proposed research has two main objectives; each requiring different survey methods to meet objectives. Bird survey methods suited for restoration monitoring include strip transects, area searches, and point counts (Ralph et al. 1995). One important consideration with avian sampling is estimating species detection probability during surveys. Bird detectability can vary for a variety of reasons, in particular due to changing habitat structure and composition as would be expected to occur with habitat restoration (Thompson 2002). Without correcting for detectability, comparisons of species abundance or density among sites (or over time) are likely to be inappropriate. There are numerous sampling techniques that allow for the estimation of detectability; we will consider multiple methods to meet each of our objectives, as suggested by Koberstein et al. 2017.

Our previous shorebird and waterfowl research in estuarine and agricultural habitats in the Skagit-Stillaguamish estuary provide the basis for proposed methods (Slater 2004, Virzi et al. 2017). Survey methods will include strip transects with distance sampling (Buckland et al. 2001) for upland and marsh habitats, and area searches for tidal flats and created freshwater wetland habitats. We will use existing survey sites at Fir Island Farm, Leque Island and Wiley Slough, established in 2016 (Fig. 6). An identical study design is proposed for Zis a ba, Island Unit and new reference marshes.

At Fir Island Farm, six transects were randomly established inside the restoration area and adjacent marsh. At Leque Island, eight transects were established. At the Wiley Slough reference marsh, two transects were established. At Zis a ba, three transects are proposed. All transects are > 250m apart and 150m from site boundaries. Observers walk along each transect recording birds seen or heard and estimate their distance from the transect line. Observers do not count birds farther than ½ the distance between transects to reduce the likelihood of double-counting.

In general, our methods will continue those implemented by Virzi et al. (2017), and implemented at the Qwuloolt and TNC Port Susan Preserve restoration projects (Rice et al. 2011; Woo et al. 2011), if possible. The use of distance sampling techniques allows us to estimate density, abundance and detection probabilities for all species encountered during surveys (Buckland et al. 2001).

Tidal flat surveys will be conducted with an area search. The survey area at restoration sites borders the ecotone between the tidal flat and diked upland extending 250 m onto the tidal flat (250 m width). At reference marsh sites it borders the ecotone between the tidal flat and emergent marsh. The survey time is 20 minutes. Observers record the maximum number of birds counted for each species detected. If created freshwater wetlands are part of the final design for any restoration site, they will also be surveyed using this method from fixed locations along the wetland boundary.

Three survey periods include: spring migration (Mar-May), fall migration (Aug-Sep), and winter (Feb-Mar), reflecting the periods when shorebird and waterfowl populations are prominent in this region. Winter surveys will be conducted upon cessation of the hunting season (Jan 31), as hunting pressure likely forces waterfowl to make decisions on habitat use relative to safety rather than to preference. In each season, we will conduct > 3 repeated surveys at both high and low tides. Density estimates for species and taxa will be determined for each habitat type in each season.

Landbirds and secretive marshbirds are surveyed using point counts (Ralph et al. 1995), incorporating call-broadcast surveys to increase detection probability of secretive marshbirds (Conway 2011). Survey points at our existing study sites at Fir Island Farm (n=8), Leque Island (n=10) and Wiley Slough (n=2) are distributed systematically > 250m apart over the sites and 150m from the site boundary. At Zis a ba, Island Unit and reference marshes, we propose to add > 3 additional points. Observers conduct 9-min surveys at each point, recording all aural and visual detections of all species encountered during each minute of a 5-min passive listening period, followed by a 4-min call-broadcast period for focal species. Observers broadcast 30 seconds of calls followed by 30 seconds of silence for focal species: Virginia Rail, Sora, Wilson's Snipe, and American Bittern.

At least 3 repeated surveys will be conducted during the 6-week breeding season (May-Jun), as recommended in the Standardized North American Marshbird Protocol (Conway 2011). We will also conduct 3 repeated surveys during winter (Feb-Mar). While the Marshbird Protocol allows for surveys in the morning or evening, we will restrict our surveys to within 3 hours of sunrise so that breeding season surveys will capture singing landbirds on territories. We will use distance sampling and time-of-detection models to estimate density, abundance and detection probability for all species encountered (Buckland et al. 2001; Alldredge et al. 2007).

Analytical Methods

Not all avian taxa will likely respond to restoration actions in a similar manner. For example, we expect shorebird and waterfowl abundance will increase after restoration while many landbirds (e.g., passerines and raptors) currently using upland habitats at restoration sites will likely decrease in abundance as these habitats are restored to wetland habitats. We recognize that our ability to accurately and precisely estimate species abundance will have some uncertainty due to changes in habitats at restoration sites over time that may affect detectability. In order to deal with this uncertainty, we will incorporate measures of detectability shown to address this statistical noise into our survey methods (e.g., distance sampling, time-of-detection sampling) so that abundance estimates are more comparable over time allowing better interpretation of trends in response to restoration actions (Buckland et al. 2001; Alldredge et al. 2007).

Statistical analyses will be conducted using program DISTANCE (Thomas et al. 2010). We recognize that data limitations could affect our ability to precisely estimate abundances since > 60 detections are generally considered necessary to produce reliable estimates of detection probability. However, for most species we expect to reach this number of detections with repeated surveys. We will also explore additional techniques for estimating detectability, such as N-mixture (Royle et al. 2004) and occupancy (MacKenzie et al. 2006) using a grid system over the study area. Detectability is a critical issue in bird monitoring that has often been ignored in previous bird restoration monitoring (Koberstein et al. 2017). Both Koberstein et al. (2017) and Virzi et al. (2017) identified this problem, recognizing that estuarine restoration is a very dynamic process where habitat (and hence detectability) is expected to change substantially over time as conditions at restoration sites stabilize. Both authors recommended using a combination of techniques to collect the highest quality data possible and allowing researchers the ability to deal with changing field conditions and any restrictions placed on certain techniques that may arise.

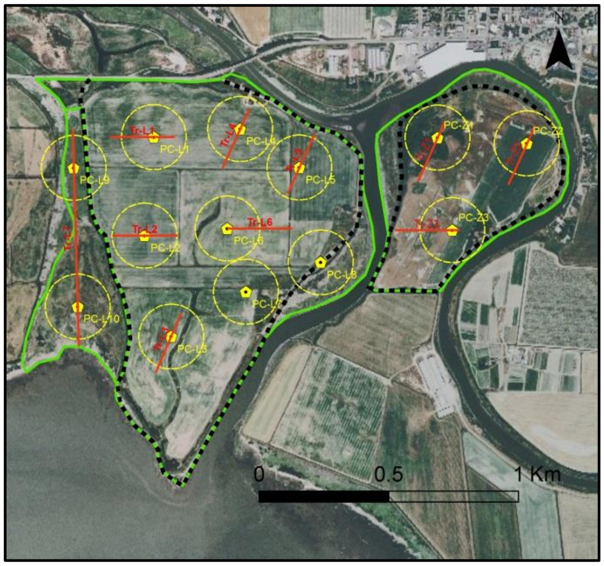

Figure 6. Map of bird survey design at Leque Island restoration site (pre-restoration surveys began winter 2016/17) and proposed survey design at Zis a ba restoration site. Study designs follow the design described for the Fir Island Farm restoration site. Surveys at Leque Island include surveys in an adjacent reference marsh; no such reference marsh is available at the Zis a ba site. Solid green lines mark the study site boundaries and black dashed lines mark the dikes that will (Leque) or were (zis a ba) breached.

4.4 PERFORMANCE TARGETS

The performance targets are the parameter values used to evaluate whether or not the restoration site is meeting the stated project objectives. For each hypothesis and parameter, a value, or range of values, indicates that the site is performing as desired or predicted by the conceptual models that guided the restoration design. Parameter values falling outside those ranges may indicate the restoration actions have not had the predicted effect on processes, structures, or functions, and contingency measures may need to be implemented.

Table 3. Summary of targets associated with objectives, hypotheses and parameters for Leque Island restoration monitoring.

Objective	Hypothesis	Parameters	Pre-project Condition	Restoration Target
1. Restore the physical processes that sustain tidal rearing for juvenile Chinook salmon	H1: Tidal fluctuations inside the restoration site will be similar to those in reference marshes.	Time series measures of water surface elevation across tidal exchanges.	Water exchanged muted by dikes and tide gates.	Similar water levels over the restoration site as over nearby reference tidal marshes.
	H2: Dissolved oxygen, salinity, and water temperature of tidal waters within the restoration stie will be comparable to that of nearby reference marshes.	Spot measures of dissolved oxygen, salinity and water temperature.	Water exchanged muted by dikes and tide gates.	Dissolved oxygen, salinity and water temperature are similar between restoration site and reference sites.
	H3: Restored tidal exchange and fluvial inundation will result in sediment accretion within the restoration site.	Time series measures of marsh surface elevations.	Limited sediment accretion and sediment compaction for agriculture practices resulted in marsh surface at lower elevation.	Increase sedimentation from pre-restoration condition that are similar too reference marsh sedimentation rates within the first few years of restoration.
	H4: The groundwater model developed for the project accurately predicts that the reintroduction of tidal inundation onto Leque Island and does not lead to saltwater intrusion to adjacent drinking water wells.	Water level (WSE measured in meters), temperature (o C), specific conductance (uS/cm @ 25 o C)	Limited tidal inundation at the site and adjacent drinking water wells are not affected by marine water.	Tidal inundation is increased at the stie and adjacent drinking water wells are similar to pre-project water level, salinity and temperatures.

2. Restore tidal rearing habitat for Chinook salmon and other estuarine fishes.	H5: Following initial excavation, the tidal channel network will continue to elaborate and become comparable to reference marsh tidal channel networks.	Total Channel network length and surface area; individual channel length and surface area; and channel cross-sectional area.	Excavated drainage ditches present; no tidal channels.	Channel networks are complexity is increased and similar to reference tidal marsh channel networks.
	H6: Native Marsh vegetation will passively establish in a distribution similar to that predicted in the project design documents.	Ranked abundance from dominant, 2nd, 3rd and 4th most abundance GPS survey points.	Agricultural pasture covers most of the site with small area occupied by upland trees and shrubs.	Marsh vegetation distributed as predicted in the conceptual design and similar to nearby reference tidal marshes.
	H7: Juvenile Chinook salmon abundance will increase, and fish community will be become more diverse, and each will be similar to reference marshes.	Chinook salmon abundance, length of time Chinook salmon are present and species richness.	Fish access is restricted by dike walls and tide gates limiting Chinook salmon abundance and access to some estuarine fishes.	Chinook salmon abundance and fish species richness increases at the site becoming similar to reference marshes.
	H8: Return of tidal inundation will result in bird communities to be similar within the restored reach as compared to reference marshes.	The seasonal abundance of shorebirds and waterfowl, and land birds (passerines and raptors) and secretive marsh birds.	Lack of tidal inundation at the site reduces the total wetted area for shorebirds and waterfowl and land is occupied more by upland bird species.	Increase in of migrating (spring and fall) and wintering shorebirds and waterfowl presence and abundance after project implementation and similar to other reference locations.

5. MONITORING SCHEDULE

Monitoring of the Leque Island restoration project includes one year of pre-project data collection and four years of post-project monitoring.

5.1 Pre-project Monitoring

Pre-project data were collected in 2019 up until levee removal in August-October 2019. These data included response variables:

1. Fish community structure and salmonid densities
2. Vegetation mapping
3. Channel structure
4. Sediment

5.2 Post-project Monitoring

This monitoring plan calls for the site to be monitored for a total of five years, with four years of monitoring following completion of the Project. Not all monitoring tasks will occur in each year. The following summarizes the data collection and fish monitoring schedule:

- Year 1, 2019 (Phase I- setback levee, flood control structure, tidal channel excavation, and marsh mound construction. Pre-project from a fish, vegetation and sediment monitoring standpoint.
- Year 2, Post-Project 1, 2020: vegetation and sediment monitoring continued. Start Water quality and channel monitoring.
- Year 3, Post-project 2, 2021: Continued fish/sediment monitoring.
- Year 4, Post-project 3, 2022: Continued fish/sediment monitoring. Finish vegetation monitoring.
- Year 5, Post-project 4, 2023: Finish fish/sediment monitoring.

Future monitoring and reporting will only be completed if funding can be secured to complete identified tasks. As of October 2019, funding has been secured for monitoring activities for 2020. No additional funding for 2020-2023 has been secured at the time of writing.

5.3 Monitoring Products

Annual monitoring reports that contain the results of all data collected from January 1 through December 31 of each year will be completed for each year that funding is available.

Final report can be drafted to evaluate the success of the project based on the stated objectives. By including all years an overall effect to juvenile Chinook abundance can be estimated for the project while controlling for annual variation.

5.4 Data Storage and Management

Data management and storage will follow standard protocols, using readily retrievable data formats. Raw data from automatic data loggers and site surveys will be stored in standard file formats (e.g., excel, shape files, jpegs) following downloads of field surveys. Post-processing data will be in standard file formats, maintained on the SRSC network (backed up regularly). All electronic data files will be provided to Washington Department of Fish and Wildlife with each monitoring report. Monitoring reports will be provided to Washington Department of Fish and Wildlife in electronic (pdf) format.

Data collected by WDFW and given to WDFW by SRSC will be stored on an agency-wide shared drive in readily available formats. Data and reports will be provided as deliverable to granting agencies and are available to share with others upon request.

6. ADAPTIVE MANAGEMENT PLAN

The adaptive management component of the plan is designed to address the inherent uncertainty in ecological restoration projects and seeks to minimize this uncertainty by learning about the system being managed (Thom and Wellman 1996, Thom 2000, Linkov et al. 2006). The basic process for adaptive management followed here includes five components:

1. A conceptual model of existing conditions and ecological processes affecting the restoration site that is used to predict the likely outcomes of individual restoration actions;
2. Clear statement of the goals and objectives for the restoration project;
3. Development of performance targets or criteria for evaluating outcomes relative to the goals and objectives;
4. Monitoring the effects of the restoration actions relative to performance criteria; and
5. Adjusting restoration actions as needed – if performance criteria are not met, develop contingency plans or measures (decision framework) for adapting designs or implementing new actions.

6.1 POTENTIAL CONTINGENCY MEASURES

Natural systems are highly variable and there is significant uncertainty surrounding predictions about how the project site will respond to restoration actions. Restoration actions may have unexpected or unanticipated effects and/or conditions and factors external to the restoration may cause the site to respond in an unexpected way. Due to this uncertainty, when the project targets and objectives are not met, there are three basic alternatives (Thom and Wellman 1996; Rice et al. 2005):

- No action
- Maintenance
- Modification of goals or performance criteria

No action means no corrective action will be taken and no change in goals or targets is needed. For example, elevation ranges of native vegetation at Leque Island may not match those found elsewhere in the Stillaguamish or Skagit delta marshes. However, if native vegetation is establishing successfully and contributing to habitat function, differences in elevation between the project site and other sites in the Stillaguamish or Skagit deltas may result in new hypotheses, but do not require any action.

Maintenance is the most common response to project targets not being met and includes any physical actions that are taken to maintain the progress or course of changes desired on the restoration site. Examples include invasive species management and re-planting with native species if the abundance of non-native invasive is greater than specified in project targets.

A simple decision framework should be used to determine appropriate contingency actions if project targets are not met. The framework includes the following steps and questions:

- Performance criteria is not met during a given monitoring year;
- Is the trend in the right direction, but the target has not been met? – No action; continue to monitor;
- Is the trend in the wrong direction and the target has not been met? – determine the likely cause and select among possible contingency actions;
- Have controlling factors or influences external to the project site changed and may be contributing to site performance?
- Are other site conditions not performing as expected and may be contributing factors?
- What contributing factors can be affected on the project site to correct the problem?

At Leque Island, based on the site conditions, landscape setting, uncertainty surrounding the hypotheses, and the combination of active and passive restoration being proposed, the following targets have the most likelihood of not being met in the early stages of monitoring:

- Presence and abundance of invasive plants.
- Elevation/vegetation correlations.
- Rate of channel formation and channel geomorphology.
- Changes in surface elevation or sedimentation rates.

Potential contingency measures most likely to be available for maintenance at Leque Island:

- Invasive plant species management measures, e.g., manual control and/or herbicide treatment to eradicate small patches and control the spread of larger areas.
- Re-planting of areas with native shrubs and/or trees if reed canary grass begins establishing in high marsh or riparian areas.
- Re-grading/re-contouring of site to establish desired elevations and inundation conditions.
- Adding channel habitat features and/or riparian plantings to influence habitat conditions for salmon and/or water quality parameters.

7. REFERENCES

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