

CRESCENT HARBOR SALT MARSH RESTORATION



Monitoring Plan

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The first incoming tide through an open channel at Crescent Harbor Salt Marsh in more than 90 years. Photo taken August 19, 2009.

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Introduction

Overview

This plan is intended to facilitate monitoring of physical and biological responses to habitat restoration implemented at the Crescent Harbor Salt Marsh Restoration site during 2008-2009. The monitoring program presented here includes baseline, implementation, effectiveness and validation monitoring. Our approach is structured to allow assessment of treatment- and site-level responses, as well as to allow the integration of site-level data into larger datasets that allow landscape-scale hypotheses to be addressed. The conceptual framework for this plan is based upon that outlined in the *Habitat Monitoring Strategy for the Tidal Skagit Delta* (Hood 2009). While many salmon habitat restoration projects in the Puget Sound region are directed towards the ultimate goal of restoring of Threatened Chinook salmon populations, the Skagit Delta strategy focuses on habitat-centered metrics. Such an approach enables consideration of the interactions of physical processes and biological responses from a systemic perspective, allowing restoration “success” to be evaluated in terms of benefits to a community of organisms rather than focusing solely on a specific management target. It is our belief that this strategy and the lessons learned from data collected under it will help lead to more robust, naturally functioning habitat restoration projects that will better serve Chinook salmon recovery goals over the long-term.

Project Background

Pocket estuary habitat for Puget Sound salmon has been defined as small, partially enclosed, non-natal bodies of water that are measurably less saline than adjacent nearshore habitat (SRSC and WDFW 2005). Such sites include salt marshes, lagoons, and tidal channels, and are important refuges for juvenile Chinook salmon and other species (SRSC and WDFW 2005). These habitats provide fry with a rearing and refuge opportunity as they migrate from their natal rivers toward the open ocean (Beamer et al. 2003). Restoration of pocket estuary habitat lowers the risk of mortality by reducing the time individual fish are exposed to nearshore or offshore hazards during this vulnerable phase of their life history (SRSC and WDFW 2005).

Covering around 300 acres, the Crescent Harbor Salt Marsh, located on Naval Air Station Whidbey Island (NASWI), near Oak Harbor, Washington (Figure 1), was

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historically the largest open barrier salt marsh on Whidbey Island (Philip Williams & Associates 2003, Collins and Sheikh 2005). The Skagit Chinook Recovery Plan (SRSC and WDFW) identifies this marsh as one of twelve priority restoration sites within one day's migration from the Skagit River Delta for juvenile Chinook salmon. Data collected in the Whidbey Basin indicate that juvenile salmon displaced from Skagit River delta habitat as a result of high population densities or flood events could reach these sites in as little as five or six hours (SRSC and WDFW 2005).

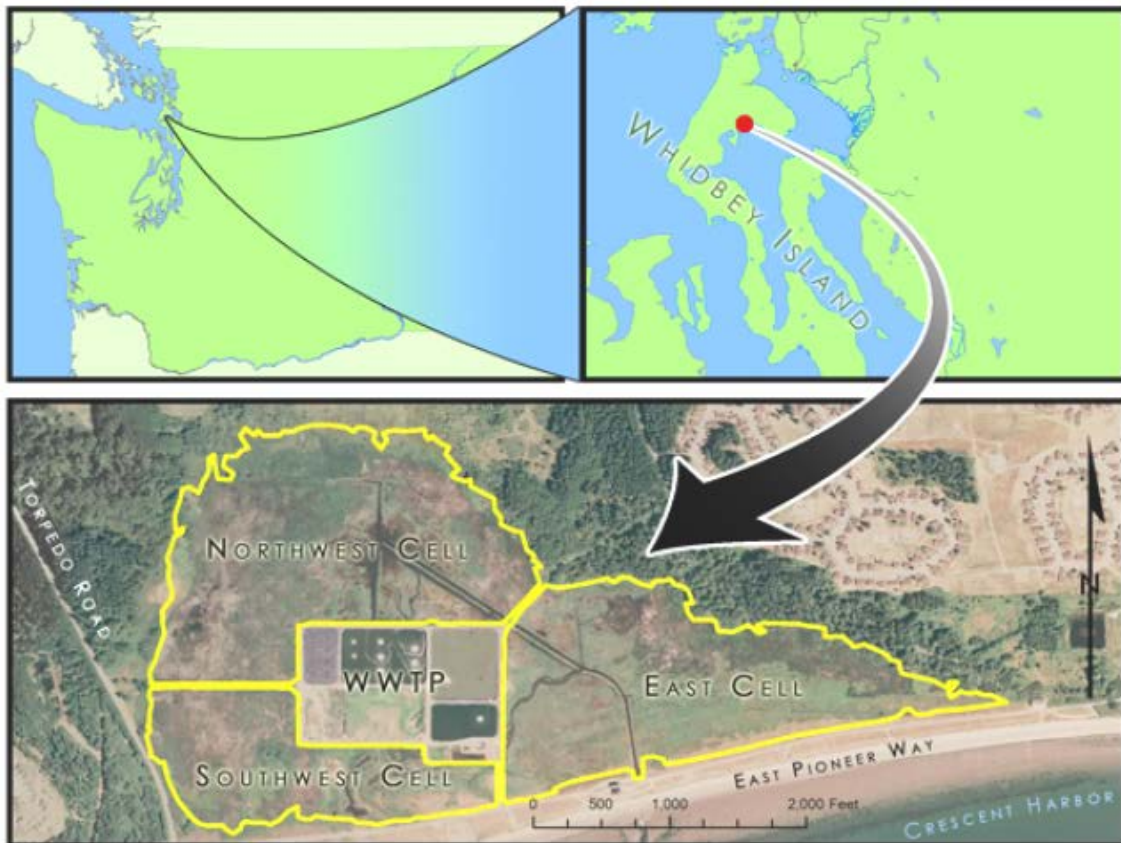


Figure 1: The Crescent Harbor Salt Marsh is located on Naval Air Station Whidbey Island, near Oak Harbor, Washington.

Historically, the site was hydraulically connected to Crescent Harbor by a channel located in the southwestern portion of the marsh. Around 1910, the marsh was diked and ditched for agricultural use, and the channel inlet was filled and replaced with a tide gate in the southeastern portion of the marsh. This allowed seasonal management of on-site water levels and blockage of flood tide flows. Site drainage was improved through ditching. Subsequently, muted tidal volumes and sediment transport has led to

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marsh surface subsidence to about three feet below natural marsh elevations due to soil decomposition and compaction. Although the Navy secured the tide gate partially open in 1993 to allow some tidal exchange, the small opening, undersized culverts, and blockage by mussels and barnacles have led to extremely muted tidal flow to marsh surfaces. A 30-acre wastewater treatment plant, with dikes associated with intake and outfall sewer lines, currently occupies the center of the site.

Although no fish usage data exist at this site for periods prior to modification, data from similar Puget Sound pocket estuary sites indicate that juvenile Chinook and other native salmonids were likely to have used habitats such as Crescent Harbor prior to diking and tide-gating. These habitats are thought to provide growth and survival advantages for juvenile salmon displaced from natal estuary habitat by flood events or high fry density (Beamer et al. 2003). Restoration of this large rearing habitat is anticipated to result in immediate use by juvenile salmonids, and nearshore habitat fish capacity will increase by an estimated 15,938 smolts annually through the restoration of approximately 206 acres of pocket estuary habitat.

Currently, the Crescent Harbor Salt Marsh is cut off from fish access and is largely disconnected from tidal exchange except through ground water. The site is diked and ditched, with minimal tidal exchange occurring through a tide gate. Much of the historic marsh, tidal channel, and freshwater tributary habitat at this site has excellent potential for restoration, except for an approximately 13-hectare (32 acre) wastewater treatment pond (WWTP) located in the center of the marsh and associated dikes for access and sewage pipes. The site has been divided into northwestern, southwestern, and eastern cells based on these cross-dikes (Figure 1). The marsh provides seasonally ponded habitat for waterfowl and other marsh wildlife. Limited tidal inundation occurs during extremely high spring tides. Crescent Creek, which enters the restoration site along its northwest edge, is an intermittent stream that supplies freshwater to the marsh. A large beach berm to the south of the site prevents direct inundation from Crescent Harbor except during the highest storm surges.

In 2003, Philip Williams & Associates (PWA) and the University of Washington Wetland Ecosystem Team, working for NASWI and Oak Harbor Public Works (OHPW), completed a feasibility assessment and restoration design for the site. In 2006, Navy SeaBees completed the first step indicated in this plan by removing an earthen berm of side-cast material along the main channel and constructing a bridge over what is planned to become the channel opening to the Harbor. After completing

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this action, permanent changes in deployment for the SeaBees led to postponement of restoration activities.

In 2007, SRSC restoration staff, working with NASWI Environmental Affairs personnel, picked up where the SeaBees left off, acquiring funding to continue restoration efforts at the site. The current restoration design is based largely on that put forth by PWA, but has been modified to increase tidal connectivity and fish access. Construction at the site will be completed during the summer of 2009, and includes the following actions:

1. Breaching a sewer intake dike connecting the east and northwest marsh cells to increase tidal volume and fish access.
2. Replacing an undersized culvert currently connecting the southwest and east salt marsh cells to improve fish access and tidal circulation.
3. Removing fill within the marsh at the southern edge of the WWTP to increase tidal prism and promote circulation and mixing of fresh and marine waters.
4. Creating a notched weir at the sewer intake dike separating the southwest and the northwest salt marsh cells to allow tidal circulation.
5. Breaching the remaining beach berm near the existing tide gate and reconnecting the existing channel network to Crescent Harbor through the Seabee bridge.

Key Processes at the Project Site

Introduction

Dikes and a non-functioning tidegate have isolated the project area from tidal influence, altering natural tidal hydrology in the project area. Diking has also interrupted the process of sediment transport and storage. Upland development has altered freshwater hydrology at the site. These processes are crucial in the formation and maintenance of a number of habitat conditions.

Tidal Hydrology

Tidal hydrology has been altered dramatically at the project site. The Crescent Harbor salt marsh is located along the shoreline of Whidbey Island. In such coastal regions,

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tidal hydrology is a very important process that shapes habitat conditions through the creation of blind channel networks. Additionally, increased mixing of tidal waters with freshwater entering the site from the surrounding uplands creates salinity gradients that are preferred by juvenile salmon and that can help to promote diverse vegetation communities. Diking has largely isolated the project area from tidal influence, altering natural tidal hydrology and the conditions depending upon it. While tidal hydrology functions naturally near the project area (i.e., outside of the beach berm), dikes and the non-functioning tidegate have largely prevented natural diurnal tidal inundation within their confines.

Freshwater Hydrology

Freshwater hydrology has been altered little within project site, though changes to drainage patterns of intermittent streams within the watershed surrounding the site have been dramatically altered (Mickelson, 2009). In general clearing of land for agriculture and straightening and ditching of natural channels have altered the magnitude and timing of stormwater flows that reach the site. With the lower infiltration rates that occur with increased development, stormwater flows tend to be larger and reach downstream points earlier in this system relative to historic conditions (Mickelson 2009). Such changes may impact water quality, sediment supply, and salinity gradients at the site.

Sediment Supply

The amount and rate of sediment supplied to the site has changed greatly relative to historic conditions. Whereas tidal flows historically facilitated sediment import and export at the site, the current isolated system undergoes little sediment transport. With little new sediment inputs, the current marsh surface has subsided about three feet relative to historic conditions.

Conditions and Biological Responses at the Project Site

Vegetation Communities and Salt Marsh Habitats

Vegetation communities and non-open water salt marsh habitats have likely been altered from historic conditions due to changes in salinity and site elevation resulting

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from alterations to tidal hydrology. Current vegetation communities at the site vary with elevation, which ranges from about 2.5 feet (NGVD29) on the marsh surfaces to 12 feet (NGVD29) and greater on dike tops and uplands surrounding the salt marsh. A 2004 study documented more than 80 plant species, dominated at lower elevations by salt-tolerant plants such as *Salicornia virginica* (pickleweed), *Distichlis spicata* (seashore saltgrass), and *Atriplex patula* (spear saltbush). Higher elevations within the marsh surface were populated by moderately salt-tolerant species such as *Typha latifolia* (cattail) and non-native *T. angustifolia* (Heatwole 2004).

Other salt-tolerant species common to reference sites were not present at the Crescent Harbor site. These included *Triglochin maritimum* (sea arrow-grass), *Jaumea carnosa* (fleshy jaumea), driftwood, *Cuscuta* spp. (dodders), *Puccinellia* spp. (alkali grass), *Plantago maritima* (sea plantain), and *Grindelia integrifolia* (entire-leaved gumweed) (Heatwole 2004). Shrubby species such as *Rosa nutkana* (Nootka rose) and non-native *Rubus discolor* (Himalayan blackberry) are present along dikes and higher elevations within the site. The upland areas surrounding the restoration site are covered with mixed conifer-deciduous forest.

Fish and Wildlife Use

Native salmonids and many other native resident fish species currently have only extremely limited access to the site; though these species are not common, it is likely that some have gained occasional access via the greatly muted flows passing through the tidegate. Shore crabs and mussels are common in the vicinity of the tidegate. Several genera of invertebrates, including Acari, Araneae, Diptera, Hemiptera, and Homoptera, were observed frequently at the project site during pre-project surveys, with Dipterans observed most frequently (Heatwole 2004).

Wildlife use of this site is extensive, particularly by waterfowl. Casual observations indicate that several species of ducks as well as Canada Geese occupy the site for large portions of the year. A variety of neotropical migrant songbird species are commonly found in upland habitats surrounding the site, and several resident species such as Northern Harriers can be found year-round. Rabbits are commonly observed occupying the shrubby and grassy habitat patches surrounding the site. Overall, the mammal species composition and distribution at the site is unknown. Reptile species have not been observed on the site, though no formal survey has taken place.

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Project Goals and Objectives

The restoration actions described in the *Overview* section above are being carried out to accomplish the following goals and objectives:

Project Goals

1. Restore natural processes, conditions, functions, and biological responses to the Crescent Harbor salt marsh
2. Restore critical pocket estuary rearing habitat for ESA-listed juvenile Chinook salmon
3. Restore estuarine habitat for other fish and wildlife species.

Project Objectives

1. Restore tidal flow, natural channel development, and biological functions to the Crescent Harbor salt marsh. This will be accomplished by breaching the beach berm, modifying interior dikes, removing artificial fill, and limited channel excavation
2. Restore fish passage to the Crescent Harbor salt marsh

Monitoring Objectives

Our monitoring strategy at the Crescent Harbor salt marsh restoration site follows a baseline, implementation, effectiveness, and validation monitoring approach, and is intended to allow project planners and land managers to assess the degree to which the restoration goals and objectives, listed above, have been achieved. *Baseline* monitoring documents the conditions at the site prior to implementation of restoration activities. *Implementation* monitoring is intended to determine whether the project was constructed as design. *Effectiveness* monitoring helps to determine whether or not the restoration actions were successful in achieving the desired effect on landscape- and site-level processes. *Validation* monitoring allows assessment whether changes to process resulting from restoration was successful in achieving the desired ecological effects on habitat for fish and other species.

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This information will allow adaptive management of the project as well as inform the design of future projects. Measures of treatment- and site-level project success follow directly from project goals and objectives and are considered in terms of restoration of natural habitat processes and biological functions to the project site, and the subsequent responses of biological communities. This will be quantified in several ways:

1. *The proportions of the restored sites that are exposed to daily tidal inundation.*
2. *Development and persistence of blind tidal channel habitat.*
3. *Seasonal occupation of the blind tidal channels by juvenile Chinook, other salmonids, and other native fish species.*
4. *Colonization of restored marsh surfaces by native salt marsh vegetation and invertebrate communities.*
5. *Seasonal occupation of the restored marshes by shorebirds, herons, ducks, and other marsh bird and animal species.*

In addition to allowing characterization of individual project success, monitoring will allow researchers to assess a variety of treatment-, site-, and landscape-level questions that apply pertain to ecosystem function at these various scales. This information will assist with future project planning, developing restoration strategies for the Skagit Bay nearshore, and understanding the roles and interactions of processes and biota within the ecosystem.

Monitoring Framework

Skagit Delta Framework

The conceptual framework for this monitoring plan is grounded in the *Habitat Monitoring Strategy for the Tidal Skagit Delta* (Hood 2009). This strategy was developed to provide a structure for approaching the design of monitoring programs in tidally influenced regions of the Skagit River delta. Though the Crescent Harbor salt marsh restoration site is not a part of the Skagit River delta, many of the same processes, biota, and interactions are present within salt marshes in both areas, so many of the concepts and questions presented in the Skagit Delta Strategy are applicable at the project site. Furthermore, the Skagit Delta Strategy is not intended to provide specific monitoring

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prescriptions, but rather indicates a habitat-centric conceptual approach to designing individual monitoring plans that is based firmly in ecological community and process theory. This makes the Skagit Delta Strategy a flexible tool under which a variety of monitoring protocols can be designed.

The goals of the Skagit Delta Tidal Habitat Monitoring Strategy are:

1. *Produce and evaluate design, planning, and engineering tools for restoration.*
2. *Evaluate success of individual restoration sites.*
3. *Evaluate reference conditions and landscape context of restoration sites.*
4. *Evaluate system trends, e.g., effects of climate change, cumulative effects of restoration.*
5. *Evaluate success of a suite of restoration sites collectively (i.e., interactions, synergies, indirect effects, cumulative effects).*
6. *Evaluate system resilience.*
7. *Improve understanding of ecosystem patterns and processes (Hood 2009).*

The Skagit Delta Monitoring Strategy takes a pragmatic view of ecosystem restoration, recognizing that it is not likely feasible or indeed possible to restore habitat on a large scale to a pre-Anthropocene reference condition given human influence on global climate and ecological processes coupled with socio-economic limiting factors. Focus is instead placed on sustainably recovering valued ecosystem functions through the restoration of ecosystem processes and structure (Hood 2009).

Conceptual Ecosystem Model

Central to the Skagit Delta Monitoring Strategy is an ecosystem model that provides a generalized synthesis of our current understanding of the ways in which processes and biota interact and are linked at a landscape scale (Hood 2009, Figure 2).

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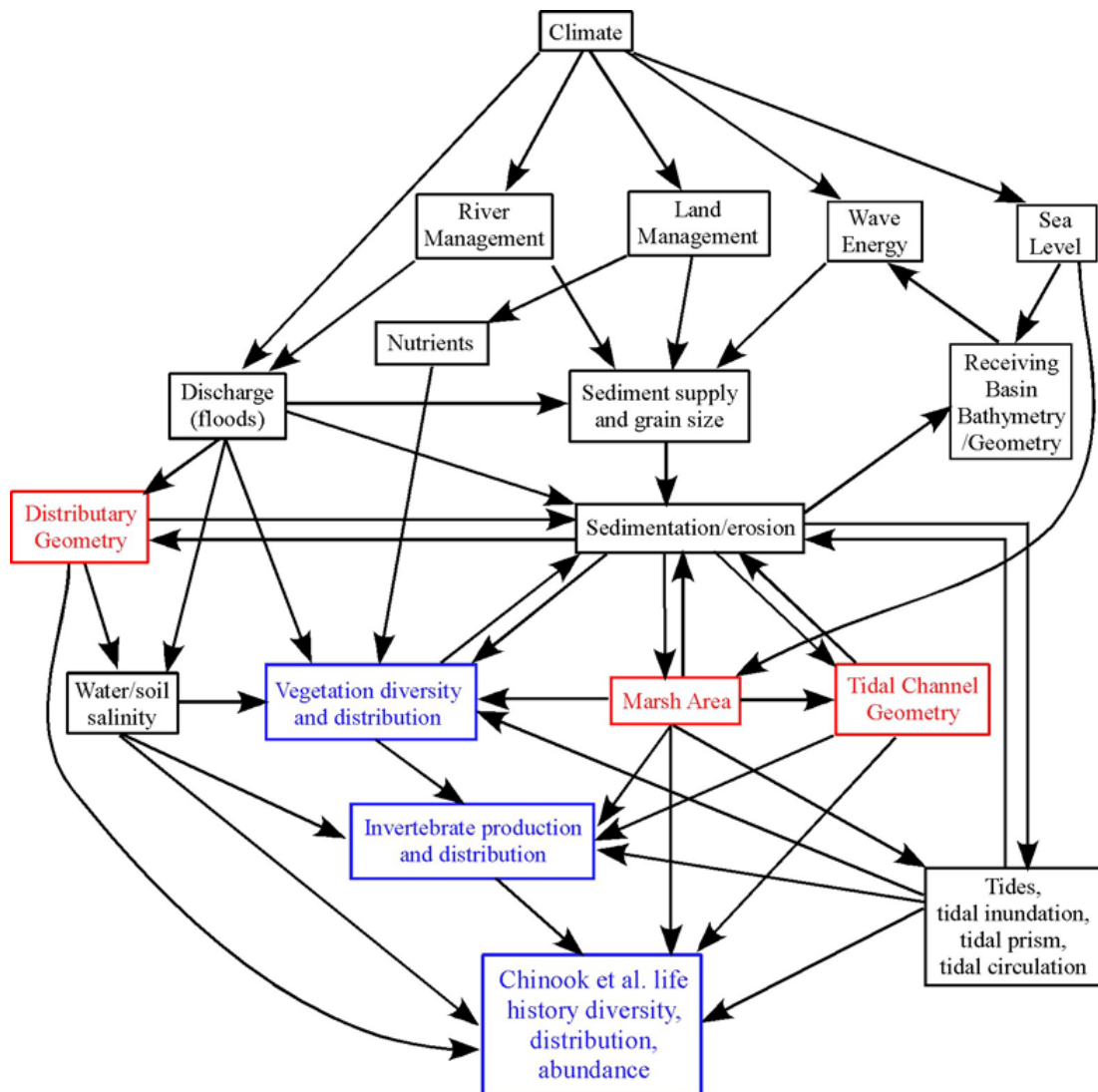


Figure 2. Simplified representation of Skagit Delta system network. Arrows are cause (base) and effect (arrowhead) linkages between system components. Red boxes are components that are often directly modified by estuarine habitat restoration actions through dike breaching/removal or channel excavation. Blue boxes are often ecological management objectives. Reprinted from Hood 2009.

The conceptual model presented above omits for clarity significant components of the system. Furthermore, the relative contributions of the components and linkages illustrated in the model are likely different for the Crescent Harbor watershed than for the much larger Skagit River. For example, freshwater flooding potentially plays a smaller role in sedimentation and erosion at the Crescent Harbor salt marsh than in Skagit River salt marshes. The limitations of the model are discussed in more detail in

the Skagit Delta Monitoring Strategy (Hood 2009). Nonetheless, this model still gives a general overview of the conceptual connections between various components in the system, providing a framework from which to strategize monitoring given the monitoring objectives and constraints of individual projects.

Baseline Monitoring

Monitoring Approach: Baseline monitoring at the site consists of biological surveys (vegetation and invertebrates) conducted in 2004 as part of Heatwole's UW master's thesis that was described previously, historical reconstructions from US Coast and Geodetic Survey mapping and reference marshes, and physical surveys conducted by PWA and SRSC as part of the project design process. These surveys documented distribution and composition of vegetation and invertebrate communities, site elevations, and site features such as inlets, dikes, culverts, or other control structures. These data will be used as a baseline for evaluation of project success.

Implementation Monitoring

Monitoring Approach: Implementation monitoring at the site will consist of post-construction total station surveys and a set of post construction drawings that will allow assessment of how closely the as-built project matches the as-designed project. An accompanying report will describe any changes to project design.

Effectiveness Monitoring

Restoration actions at Crescent Harbor Salt Marsh were designed based upon the hypothesis that a series of dike breaches would lead to a re-establishment of the processes of tidal inundation, sedimentation, and erosion that would in turn establish habitat that would be utilized by juvenile Chinook salmon and other native salt marsh species. The effectiveness of restoration activities in restoring natural tidal processes will be quantified in the following ways, outlined in the Monitoring Goals and Objectives:

1. *The proportion of the restored site that is exposed to daily tidal inundation.*

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Monitoring Approach: The proportion of the site exposed to daily tidal inundation will be measured and mapped in a GIS by using aerial photos and digital elevation data or by using on-the-ground elevation surveys. For monitoring purposes, this will be defined as MHW, which is the average height of all high tides at the site. The proportion of the site exposed to daily tidal inundation will be measured on a yearly basis for three years following project construction.

2. The development and persistence of blind tidal channel habitat.

Monitoring Approach: The development of persistent blind tidal channel habitat will be measured and mapped in plan, profile and cross-section form using a GIS, aerial photos, and elevation and GPS surveys. Tidal channel evolution will be measured on a yearly basis for five years following the completion of project construction.

Validation Monitoring

The validity of the assumptions underlying our major hypothesis that the restoration of habitat-forming processes would lead to use by juvenile Chinook and other native salt marsh vegetation will be evaluated in the following ways, which stem directly from the Monitoring Goals and Objectives:

1. Seasonal occupation of the blind tidal channels by juvenile Chinook, other salmonids, and other native fish species.

Monitoring Approach: Seasonal occupation of blind tidal channels by juvenile Chinook, other salmonids, and other native fish species will be quantified via beach seine sets at several tidal channel locations with the salt marsh. Sampling effort will be equal between the three marsh cells with two paired sets within each cell. Sampling within the marsh will be compared to beach seine sets on the Crescent Bay beach faces just outside the project inlet. Two sets will be conducted on either side of the inlet.

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2. *Colonization of restored marsh surfaces by native salt marsh vegetation and invertebrate communities.*

Monitoring Approach: Colonization of restored marsh surfaces by native salt marsh vegetation and insect communities will be quantified via repeated visits to permanent transects. Species composition, diversity, richness, and colonization rates will be determined and compared to baseline monitoring data. Data will also be compared to reference salt marsh sites in the Skagit Bay ecosystem.

3. *Seasonal occupation of the restored marsh by shorebirds, herons, ducks, and other marsh bird and animal species.*

Monitoring Approach: Seasonal occupation of the restored salt marsh by shorebirds, herons, ducks and marsh bird and animal species will be recorded through point count surveys at several intervals throughout the year in order to characterize utilization of the site by both migratory and resident species of birds and animals.

Additional validation monitoring at the site will be used to investigate the accuracy of three-dimensional tide models (Battelle/PNNL 2008) that were used during the project design process to predict the effects of various restoration scenarios.

1. *How close were the model predictions to the actual conditions observed on the site?*
 - a. *Flow Velocity*
 - b. *Duration/depth of inundation*
 - c. *Bed Stress*
2. *What is the relationship between the tidal elevation within the marsh to the tidal elevation in Crescent Harbor?*

Monitoring Approach: Gaging stations that measure tide level and velocity will be set up at several points within the restoration site and in Crescent Harbor. Data will be collected throughout a wide tidal range to allow evaluation of tidal relationships at both normal and extreme tides. These data will then be compared to model predictions for an assessment of accuracy and precision.

Research Questions

Based upon the conceptual framework outlined in the Skagit Delta Monitoring Strategy, the following monitoring parameters have been prioritized based upon their utility in helping resource managers, scientists, and others plan and design future habitat restoration projects. Parameters which can be used as model inputs or outputs have also been prioritized. Monitoring priorities for the Crescent Harbor Salt Marsh Restoration project are listed here in the form of questions about which hypotheses have been made about the outcome of restoration actions at the site.

These questions, which concern the effects of restoration on biota (salmon and other fish, vegetation, invertebrates, etc) and on the physical landscape (sedimentation, accretion, tidal channel development, are separated here by the scale at which they occur. The Skagit Delta Monitoring strategy identifies three spatial scales at which monitoring can address questions about restoration-related changes:

1. *Treatment-scale* questions are related to the effects of various restoration techniques used within the project site.
2. *Site-scale* questions concern processes that influence local habitat development and function.
3. *Landscape-scale* questions are concerned with overall restoration strategy and often require long-term monitoring efforts (Hood 2009).

Many of the questions listed here have been selected directly from the Skagit Delta Monitoring Strategy. Each question is accompanied by a hypothesis that represents a prediction that can be tested through monitoring. A brief description of how data will be collected to allow testing each hypothesis is then presented. This list of questions is by no means exhaustive, but is intended to highlight ways in which data will be collected that may help researchers move closer to answering some of these important questions.

Vegetation Monitoring

Treatment-scale Questions:

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1. *Does vegetation need to be planted on a restoration site or can natural (passive) colonization be successful?*

Hypothesis: Vegetation through passive colonization will result in effective restoration of native salt marsh plant communities to surfaces within the project site.

Monitoring Approach: Vegetation will be monitored before and after restoration via repeated visits to permanent transects to determine whether species composition, diversity, richness, and colonization rates change following implementation of restoration activities. Previous vegetation monitoring efforts will be incorporated into the analysis, and data will be compared to nearby reference sites.

2. *How can non-native plant species be best controlled?*

Hypothesis: Control of non-native species will require different approaches for different portions of the site depending on species, elevation, and salt tolerance. For large portions of the site currently dominated by Himalayan blackberry (*Rubus armeniacus*), exposure to marine waters will effectively control this species. Some mechanical or chemical control will be necessary for this species where it is located at higher elevations within the site or is otherwise protected from salt exposure. Other portions of the site which are densely populated by narrow-leaf cattail (*Typha angustifolia*) and hybridized cattail (*T. angustifolia* x *T. latifolia*) will require mechanical control such as mowing to create more favorable conditions for colonization by native species.

Monitoring Approach: A model will be developed that predicts the response of non-native plant species at the site to changes in tidal hydrology, incorporating elevation and salinity as predictors of species presence. Model predictions will be tested by monitoring vegetation before and after restoration via repeated visits to permanent transects to determine whether changes to tidal hydrology resulting from restoration efforts lead to a decrease in the proportion of non-native species.

Site-scale Questions:

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1. *If tidal hydrology is restored to a site, will vegetation colonize the site, or will the site be an unvegetated tidal flat?*

Hypothesis: Colonization of the site by vegetation will be controlled by factors including inundation frequency and duration, salinity, and flow velocity.

Monitoring Approach: Spatially explicit predictions about the distribution and composition of plant species (Heatwole 2004), which were based upon salinity and elevation, will be tested by monitoring post-restoration vegetation colonization via repeated visits to permanent transects to determine the ways in which changes to tidal hydrology resulting from restoration activities influence colonization of the site by individual species.

2. *What species of vegetation will colonize? What determines which species will colonize and their spatial distribution?*

Hypothesis: Colonization of the site by individual vegetation species will be controlled locally by factors including inundation frequency and duration, salinity, elevation, and flow velocity.

Monitoring Approach: Spatially explicit predictions about the distribution and composition of plant species (Heatwole 2004), which were based upon salinity and elevation, will be tested by monitoring post-restoration vegetation colonization via repeated visits to permanent transects to determine the ways in which changes to tidal hydrology resulting from restoration activities influence colonization of the site by individual species.

3. *Will vegetation persist in the face of anticipated sea-level rise?*

Hypothesis: Sea-level rise will increase the depth and duration of tidal inundation on marsh surfaces within the site, which will lead to changes in vegetation distribution and relative abundance. The effects of sea-level change on vegetation community structure will be buffered by sediment accretion on marsh surfaces.

Monitoring Approach: Sedimentation rates will be measured at several locations within the site; these will be used model changes in site elevation due to sedimentation. This model will be coupled with estimates of eustatic sea-level

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rise and the vegetation models described above to predict changes in vegetation community composition and species relative abundance.

Salmon Use Monitoring

The Crescent Harbor Restoration Project is expected to achieve two fish related objectives: (1) increase tidal delta habitat area for juvenile salmon rearing and (2) improve fish access to that habitat. Our proposed fish use monitoring is essentially a before/after restoration design. We expect changes in fish use within the treatment (restored) area following restoration. Unfortunately, we understand that pre-project data was limited. This will restrict our ability to speak to temporal variation.

Nonetheless, we hypothesize there is an increase in tidal delta juvenile salmon rearing capacity because previously existing habitat would now be available for colonization by fish through improved access and increase in tidal influence. If the restoration project is successful at increasing the nearshore non-natal rearing capacity for juvenile Chinook salmon, then we would expect the density of juvenile Chinook salmon within the project area to be similar to juvenile Chinook salmon densities in other non-natal estuaries of Skagit Bay. We can directly compare Chinook salmon densities from other monitored sites throughout Skagit Bay to those within Crescent Harbor.

Comparison of Crescent Harbor to other monitored sites must keep in focus that data reported in Beamer et al. (2005) showed that differences in landscape connectivity and annual Chinook smolt outmigration population size strongly influence the densities of juvenile Chinook salmon at any site within the Skagit River delta and its nearshore environs. Results from Skagit Intensively Monitored Watershed (IMW) sites are critical for doing this analysis. Because these sites are located throughout the Skagit estuary, we can analyze results from the Crescent Harbor restoration project over a wide range of landscape connectivity and determine whether results from Crescent Harbor are consistent with what is observed throughout the Skagit Bay nearshore. Each year's monitoring results are compared separately, because each year represents a unique Chinook salmon outmigration.

The restoration action at the site involved breaching a barrier dike thereby re-establishing tidal influences to the isolated marsh. The primary fish monitoring question is about whether fish are utilizing (changes in present/absence, density, size, and timing) habitat within the formerly isolated marsh differently than when the old tide gate and barrier dike were in place. We propose to answer these questions by

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comparing fish use results in a pair-wise manner from sampling sites downstream and upstream of selected non-random locations within the restored marsh (Figure 1) using available data collected in years before and after installation of the new gates.

Juvenile salmon and other tidal delta fishes are hypothesized to colonize habitat restored by the Crescent Harbor Restoration Project. Chinook salmon do not spawn in the small watersheds upstream of the restoration project area. Thus, fry sized Chinook salmon are hypothesized to colonize the restored area from sources downstream of the project area. Juvenile Chinook salmon are expected to use the area between February and August, however timing may vary year to year depending on overall Chinook population size and Skagit River flows.

Other Monitoring Variables and their Integration

Habitat is formed and maintained as a function of natural processes and stressors acting on the site. Fish response to the habitat conditions that result. Juvenile salmon carrying capacity for a tidal delta rearing life stage is primarily a function of wetted area available. However, other habitat variables such as water depth, velocity, temperature, salinity, and DO also influence habitat conditions that fish respond to. We measure these variables for each fish sampling site on each sampling event. Our fish monitoring methods are described in SSC (2003) (Exhibit B and at http://www.skagitcoop.org/documents/EB1592_SSC_2003.pdf).

In addition to the data collection described above, dissolved oxygen (DO) will be documented at fish sampling sites on each sampling date as close to high and low water as possible. Water temperature will also be recorded for each DO measurement.

Tidal Channel Monitoring

Treatment-scale Questions

1. *Should tidal channel networks be excavated or can they carve themselves through tidal erosion?*

Hypothesis: Tidal channel networks can carve themselves naturally through erosion, although the rate at which tidal channel networks develop can be increased through the excavation of ‘starter’ channels, particularly where the marsh surface is densely vegetated prior to restoration of tidal inundation. Selection of appropriate locations and geometries for these excavated channels is

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likely challenging and must be informed by site morphology and existing hydrology; improper siting and sizing can produce unanticipated results.

Monitoring Approach: This hypothesis is best tested experimentally, but there is no way to achieve truly independent control and experimental treatments, much less replication, within our project site. The pre-restoration condition at the Crescent Harbor Salt Marsh consists of a network of excavated tidal channels (ditches) which were likely situated to accommodate only muted tidal flow. Furthermore, although the site can be divided into three cells based on cross-dikes, each cell likely exhibits different tidal hydrology due to the muting effects of flow-control structures. Within each cell, the tidal channels are interconnected hydraulically and are thus not independent.

Monitoring can, however, produce some site-specific and anecdotal information about the development of natural versus excavated channels. Tidal channels, both excavated and naturally developing, will be monitored via periodic planform mapping from aerial photos as well as via elevation profiles and transects to characterize tidal channel development following restoration activities. Substrate composition, flow velocity, and overlying vegetation density will be documented for each channel monitored. This may contribute towards answering the following treatment-scale questions:

- a. *What size should the channels be if excavated? What size will they become if allowed to erode to a point of dynamic equilibrium?*
 - b. *Will excavated tidal channels persist or will they fill with sediments?*
 - c. *Should borrow ditches and drainage ditches be filled during site restoration to promote natural channel formation and channel geometry?*
2. *How quickly can tidal channels develop through tidal erosion?*

Hypothesis: The rate of development of tidal channels through tidal erosion depends on tidal velocity, substrate composition, and the density of overlying vegetation. Channels forming in areas of greater flow velocity, having more unconsolidated substrate, or having less dense vegetative cover will develop more quickly than channels forming elsewhere.

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Monitoring Approach: Newly developing channels will be monitored via periodic planform mapping from aerial photos as well as via elevation profiles and transects to determine the rate of tidal channel development through tidal erosion. Substrate composition, flow velocity, and overlying vegetation density will be documented for each channel monitored.

Site-scale Questions:

1. *How many channels should one excavate or expect to develop through erosion?*

Hypothesis: An allometric relationship exists between the number of channels expected to develop and marsh area, so the number of channels that can be expected to develop can be estimated for the project site.

Monitoring Approach: The number of channels expected to develop will be estimated using an existing model developed for the south fork of the Skagit River. The south fork of the Skagit River is located some distance from the project site, so the allometric relationship between channel geometry and marsh size likely differs somewhat from that of the Crescent Harbor Salt Marsh. However, few other appropriate reference marshes exist from which to better parameterize the model, so an attempt will be made to generalize the model results to the project site. Channels that develop within the site will be counted and measured, and will be compared to model predictions.

2. *What size distribution of tidal channels should one expect or excavate?*

Hypothesis: An allometric relationship exists between the size distribution of channels expected to develop and marsh area, so the size distribution of channels that can be expected to develop can be estimated for the project site.

Monitoring Approach: The size distribution of channels expected to develop will be estimated using an existing model developed for the south fork of the Skagit River. The south fork of the Skagit River is located some distance from the project site, so the allometric relationship between channel geometry and marsh size likely differs somewhat from that of the Crescent Harbor Salt Marsh. However, few other appropriate reference marshes exist from which to better

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parameterize the model, so an attempt will be made to generalize the model results to the project site. The geometry of channels that develop within the site will be measured and compared to model predictions.

Sedimentation and Accretion Monitoring

Treatment-scale Questions:

Several treatment-scale questions regarding sediment and accretion monitoring are listed in the Skagit Delta Monitoring Strategy. Hypotheses about these questions could be generated using 3-D hydrodynamic modeling and tested through relatively simple data collection. Although it is beyond the scope of this monitoring project to employ such models, basic sedimentation monitoring will be carried out. Minor adaptation of the original 3-D hydrodynamic model used in the project design process could allow prediction of sedimentation and marsh accretion rate and distribution, which could then be tested using the monitoring data. This model was parameterized prior to project construction, it could reasonably be used to generate ‘a priori’ scenarios. Some potential questions are listed below:

- 1. How does dike breaching versus dike removal affect sediment routing and spatial patterns of marsh accretion? How does it affect on-site sedimentation and how does it affect off-site sedimentation?*
- 2. What are the consequences of excavating or not excavating tidal channels on site accretion patterns and rates?*
- 3. How does channel density influence accretion rates? How much channel should one excavate?*

Site-scale Questions:

- 1. How do inorganic sedimentation rates vary by vegetation species – after accounting for elevation/hydroperiod and channel network effects?*
- 2. How do organic sedimentation rates and in situ organic production and accumulation vary by vegetation species?*

Landscape-scale Questions:

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In addition to treatment- and site-level questions that can begin to be addressed through modeling and data collection at individual restoration sites, other landscape-scale questions can only be addressed through synthesis of data from other monitoring efforts in nearby salt marsh reference sites. Some of the potential questions that data from this monitoring effort may contribute to are listed below:

1. *What ecological function has been lost as a consequence of reduced habitat diversity, abundance, and connectivity?*
2. *Are there local or regional differences in tidal channel geometry (allometry)?*
3. *If there are local or regional differences in tidal channel allometry, what causes these differences? Can differences be diagnostic indicators of anthropogenic impacts?*

Reporting, Responsibility, and Use

Monitoring Responsibility

The overall responsibility for monitoring at Crescent Harbor lies with the Skagit River System Cooperative. To effectively monitor the restoration project monitoring team will be established comprised of SRSC staff, US Navy Environmental Affairs Personnel, invited scientists, and local volunteers from qualified monitoring programs such as WSU Beachwatchers. This team will include a project coordinator along with trained restoration, fisheries and botanical scientists. The team has taken on approval of this monitoring plan, will finalize plan details, coordinate monitoring tasks, ensure that monitoring is completed and will collectively prepare a monitoring report for each of the monitoring years and a final report at the end of project monitoring.

Reporting Requirements

An SRSC staff member will synthesize the monitoring report. This synthesis will consist of developing a format for the report which each section, combining the sections into a coherent single report, and, based on biological responses, conditions, functions and

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processes, developing/recommending adaptive management measures as part of each annual report and the final report.

Use of Report

Intent

The intent of monitoring this project and of reporting the monitoring results is twofold: First, gathering and synthesizing information that allows land managers to objectively evaluate project success will enable adaptive management; Second, collecting data that helps researchers and managers to understand the ways in which processes shape habitat allows the creation of tools in the form of models that can be used to guide future restoration planning and to evaluate additional hypotheses.

Adaptive Management

The Crescent Harbor restoration site is owned/managed by the US Government and managed by the US Navy Whidbey Island Naval Air Station Command for the purpose of fish & wildlife conservation, with the exception of those areas still being managed as waste water treatment facilities by the City of Oak Harbor under contract with the US Navy. The restoration area will be managed/maintained by the US Navy Whidbey Island Naval Air Station indefinitely for conservation purposes. SRSC and the Swinomish Tribal Community will continue to provide technical and cultural support in stewardship and monitoring of the property through Cooperative Agreement with the US Navy.

To facilitate and coordinate monitoring and maintenance activities a project monitoring team will be established and comprised of appointed representatives from The US Navy and SRSC, and other organizations deemed appropriate by the US Navy. The project monitoring team will use this report and its recommendations to guide adaptive management at the project site. Upon implementation, adaptive management measures will then be incorporated into the monitoring plan for the following years, in order to assess the effectiveness of these measures.

Report Availability and Future Use

The monitoring report will be made readily available to project stakeholders and other interested parties.

Monitoring Tasks

Category	Task	Scientist Time (weeks/year)	Tech Time (weeks/year)
Vegetation	Establish and Sample Transects	1	1
Vegetation	Map current vegetation communities	1	1
Tidal Channel	Plan, profile, and section mapping of new and existing tidal channels	2	2
Fish Use	Assess fish access and densities	3	3
Reporting	Report preparation and synthesis	2	2

Reporting Tasks

Report Preparation and Synthesis

Some reporting is covered within the scope of each task. An annual report for each task will be completed and the reports for each individual task will be synthesized into a comprehensive annual monitoring report. Money is also budgeted for report publication.

Monitoring Schedule

1. Draft Plan: February 2010; Final Plan: March 2010.
2. Baseline Monitoring: Collected 2002-2003, 2007-2009.
3. Implementation Monitoring: Immediately post-project
4. Post-Project Monitoring: Years 1, 2, 4, 7,10

Monitoring Quality assurance/Quality Control Measures

The following are project QA/QC guidelines (from Shreffler and Thom, 1994):

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1. A thorough review of relevant field sampling and mapping methodologies is being conducted during the monitoring planning phase. Actual protocols used will be described thoroughly.
2. All sampling procedures will be tested in the field prior to actual sampling.
3. Where applicable (i.e., for vegetation plots), if more than one field crew is used for any discrete monitoring task, comparability of crew data collection will be assured by reviewing procedures and repeating measurements on the same plots until estimations are within 10% for each team.

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