

# **Predicting Sea Level Rise Impacts on Agricultural Production in Snohomish County Tidal Affected Floodplains**

**Nickname:** Sea Level Rise and Snohomish Agriculture

**Submitting Agency:** Snohomish Conservation District and Partners

**Project Period:** July 1, 2017 to June 30, 2019

**Total Project Cost:** \$200,917

## **Description of proposed work**

Snohomish Conservation District will lead a collaborative effort with The Snohomish Sustainable Lands Strategy, The US Geological Survey, UW Climate Impacts Group, and NOAA, to evaluate how climate change and sea level rise are likely to affect agricultural systems in the tidally influenced Lower Snohomish and Stillaguamish river floodplains. This information is anticipated to support estuary restoration as an appropriate response to protecting regional agricultural viability under sea level rise, by describing the value of a more strategic retreat from vulnerable low-lying areas, and a renewed focus of protecting agricultural lands and irrigation water resources at higher elevations.

## **Project Team**

Monte Marti – Snohomish Conservation District – Director – monte@snohomichcd.org  
Cindy Dittbrenner – Snohomish Conservation District – Project Manager – cindy@snohomishcd.org  
Eric Grossman – USGS, Pacific Coastal and Marine Science Center – egrossman@usgs.gov  
Guillaume Mauger – University of Washington, Climate Impacts Group – gmauger@uw.edu  
Paul Cereghino – NOAA – Coordinated investment lead – paul.r.cereghino@noaa.gov  
Josh Meidav (Prospective) – Tulalip Tribes of Washington – SLS collaborator - jmeidav@tulaliptribes-nsn.gov  
Gregg Farris (Prospective) – Snohomish County – SLS collaborator - GFarris@co.snohomish.wa.us

## **Related Project Work**

This analysis supports 1) ongoing restoration project development in the Snohomish and Stillaguamish floodplains, 2) ongoing efforts to reduce residential development pressure in Snohomish County floodplains, and 3) development of county agricultural sustainability objectives. The project follows a sea level rise symposium hosted by the Tulalip Tribes of Washington, and aims to integrate regional work by Washington Sea Grant, USGS, and the University of Washington Climate Impacts Group into an exemplary local sea level rise planning effort.

## **Technical Information**

**Problem Statement (<100 words)–Describe the specific problems faced by capital project sponsors that your work will resolve. Problems include our inability to efficiently select or design effective projects, or where stakeholder conflict stemming from lack of knowledge prevents implementation.**

Restoring fishery habitats in agricultural floodplains depends on collaboration between agencies and land managers in low-lying coastal landscapes. Sea level rise is anticipated to force retreat from these lands as maintaining groundwater drainage becomes increasingly difficult with 1 to 2 m of sea-level rise and increased river flooding by the year 2100. Government and private planners have no quantitative basis for considering these risks as we develop long range strategies for managing low-lying lands, either for habitat restoration or protection of agricultural productivity. Forecasting future groundwater impacts and flood risks helps decision

makers design strategies that protect agricultural production, reduce flood impacts, and recover salmon populations.

**Hypothesis Statement (<500 words)–Identify the ecological or social phenomena that you will study to solve the problem, and what we know or don't know. Make predictions about what you think is likely to be true, and identify what sources of uncertainty you will either control or explore.**

**H1. Extensive areas of the Snohomish lowlands currently used for agriculture will experience extensive groundwater ponding with sea-level rise over the next 50-100 years**

**H2. Predicted increases in groundwater levels will make agricultural drainage cost-prohibitive in some areas.**

**H3. Predicting flood and groundwater risk under sea level rise will increase the value of agricultural land protection in upland areas, and support buyout of at-risk lands in low-lying areas to prevent develop or for floodplain habitat restoration.**

This award would support an initial effort to work with land managers and agricultural community leadership to explore these three hypotheses. Sea level rise is an observed phenomena, and existing regional work will be used to describe a range of future sea level elevations. This effort will be supported by regional efforts to define the range of sea level rise risk, and to downscale climate change models to describe changes to river flood regime.

The threshold at which drainage costs render agriculture unprofitable depends on a wide range of factors. This initial effort will depend on the models described below, and the best-professional judgement of agricultural producers and the managers of flood and drainage districts. This initial analysis will help define the risk posed by sea level rise that can inform the evaluation of drainage system viability under future scenarios. This risk assessment will support the identification of restoration projects that in turn support the strategic retreat of agricultural from more flood-prone low lying areas, to higher elevations that will sustain Snohomish agriculture into the future.

The greatest uncertainty is in the beliefs and perspectives of flood and drainage system managers. Speaking generally, this community has widely varied levels of confidence in sea level rise predictions, generally low opinion of the trustworthiness of restoration advocates, and a strong confidence in their ability to manage locally over time for drainage. The opportunity is that there is a shared interest among ecosystem managers and agricultural land advocates to protecting agricultural land stewardship across Snohomish county for future generations. An increasingly defined threat to low-lying lands may help galvanize broader land protection efforts in Snohomish County, while increase the viability of a strategic retreat from estuarine lands allowing for restoration.

**Methods (<1000 words) –Explain how you will collect measurements or evidence to test your hypotheses and solve the problem. Describe:**

Methods used to develop and implement groundwater analysis will occur at the same time as other community engagement activities as part of the Snohomish Sustainable Lands Strategy, including 1) agency coordination around the regulation of drained agricultural wetlands, 2) development of farmland protection priorities, and 3) development of methods for reducing housing development pressure on agricultural floodplains. Analysis of future groundwater levels is anticipated to inform and support these other efforts.

The methods proposed for this project aim to describe risk to farm viability from spring groundwater ponding, caused by higher future river water levels forcing up groundwater levels. Because we are extrapolating risk into the future using physical models, with the goal of supporting socially difficult decisions, we are proposing a modest and incremental approach, where “first order” estimates are coupled with intensive community

engagement to determine next steps. Therefore, these methods maximize the use of existing data, and interaction with land managers.

The results involve the extrapolation of observed groundwater dynamics into the future, based on river flood and sea level rise scenarios, and so will include some unavoidable uncertainty with limited ability to calculate statistical error. However, this effort and its results directly targets the kind of scientific investigation necessary to stimulate and inform public decision makers, and directly addresses the kinds of issues affecting large scale restoration design.

The project includes two complementary areas of work: 1) community engagement to scope analysis and present and discuss results led by SCD, and 2) completion of a first order GIS-based water level analysis of how rising sea and river levels will affect groundwater levels led by USGS.

### **Community Engagement**

**Community engagement is primarily reflected in ESRP Task 1, and Task 5-6, and will be used to both scope and frame analysis (Task 1), and to disseminate results (Tasks 5-6).**

Restoration of estuarine habitats in Snohomish County requires the creation of a community vision based on science, local knowledge and experience. It is critical that we engage private agriculture landowners and flood managers in this effort. They will help to inform the science and this will help to facilitate the dissemination of results.

The Snohomish Conservation District (SCD) will work with partners to effectively engage all parties concerned with floodplain management. The SCD will coordinate and facilitate both small group and large group discussions with key stakeholders. This multi-level engagement strategy will include:

- Meeting with dike/drainage district commissioners/board members at their regular meetings
- Meeting with flood managers at the Snohomish Coordinated Diking Council meetings
- Meetings with private landowners and agriculture producers that operate behind dike systems
- Meetings with federal and state agencies, tribes, and NGOs that are working within the watersheds
- Meetings with scientist and others researching the impacts of climate change, groundwater dynamics, sea level rise, agriculture systems, etc.

These outreach sessions will make proposed work by USGS and UW both transparent and responsive to local interests and concerns, and will set the stage for discussion of results. Following the study, we will conduct workshops to disseminate the results and work with farmers, dike and drainage districts, restoration practitioners and planners. This may include contracting with local flood managers or their consultants to estimate how increased groundwater volumes, or levee construction may affect costs of agricultural production, and identification of future steps to define a management plan for Snohomish lowlands.

### **Water Level Analysis**

**After finalizing scope through community engagement, ESRP Tasks 3-5 will allow us to collect ground water data, and complete a “first order” analysis of the effects of sea level rise and river flooding on future groundwater levels.**

A combination of modeling and field data collection will be employed to establish and project groundwater response to surface water forcing and demarcate habitats and land uses vulnerable to sea-level rise and groundwater ponding out to the year 2100. In addition to spatially explicit mapping of the extent of projected groundwater ponding, estimates of the frequency distribution of ponding thresholds will be assessed and mapped. Today groundwater levels show tidal propagation below agricultural lands 1-3 km away from surface water in the unconfined coastal aquifers of the Skagit, Stillaguamish, and Grays Harbor river deltas. This dynamic behavior leads to periodic groundwater ponding today and we propose to exploit these relationships to

assess groundwater response to changes in stream flow under climate change, higher sea level, and storm surges. We anticipate these same forces are at work in the Snohomish.

Future river discharges associated with projected climate change are being developed by UW-CIG. Daily flow statistics will be scaled to sub-daily flow metrics for this study at 3 or 6 hour frequency based on historical data and daily-to-subdaily relationships to provide statistics and frequency distributions of projected changes in stream flow forcing. Models relating stream discharge to stream surface water elevations will be developed at approximately 5 stations along a longitudinal transect between Snohomish and Everett through cross-channel stage-area and discharge measurements over a range of low, medium and high stream flow and low/high tide conditions following USGS stream gaging methods (Levesque and Oberg, 2012). This sub-task is the same as found in a related 2017-2019 ESRP Learning Project (Snohomish Sediment Routing).

Scenarios of future sea-level position and storm surges that today elevate estuary water levels between 10-100 cm each year up to 10-15% of the time will be defined and parameterized using the most widely-accepted sea-level rise projections and historical storm surge anomaly statistics. The joint combination and probability of occurrence of stream flows, sea-level rise and storm surges will be integrated as surface water “forcings” to examine the likely response of groundwater across Snohomish marshlands.

Groundwater dynamics, particularly the spatial extent and gradient (or attenuation rate) of tidally-forced groundwater oscillations will be characterized today through field research of groundwater level behavior along a transects oriented away from the river channel. Three shallow groundwater level monitoring wells or piezometers along two transects, one in the Snohomish and the 2<sup>nd</sup> in the Stillaguamish River delta, will be sited each deployed with a continuous conductivity-temperature-depth (CTD) sensor. Water level data along with a time-series of barometric pressure will enable analyses of the tidal propagation in the groundwater across the coastal aquifers. Similar data from the Skagit, Camano Island and similar estuaries like Gray’s Harbor show tidal propagation in the groundwater reaching 1-2 km inland of tidally influenced surface waters and it is expected that similar attenuation rates characterize the Snohomish and Stillaguamish. These zones demarcate the region that groundwater below floodplain and estuary marshlands and diked/leveed farmland responds to tides today and will continue to respond in the future, under sea level rise.

Future groundwater levels and ponding extent will be evaluated by extrapolating today’s tidal driven groundwater level attenuation rates across the Snohomish estuary landscape under higher projected stream water surface elevations, sea level position and storm surge scenarios. Like in the Skagit, it is expected that a nominal 3-ft of sea level rise will give rise to significant ponding area and integrating the joint probability and occurrence of higher water surface elevations associated with projected increases in stream flows and non-tidal residuals (storm surge associated with the inverse barometer effect) common during passing low pressure storm events, will render a more complete picture of the extent and probability of vulnerability of currently diked and drained lands to groundwater ponding across the Snohomish and Stillaguamish. Results, including the spatial extent and change in frequency of groundwater ponding will be mapped in GIS for specific time frames (e.g. 2040, 2060, 2080, 2100) and used to calculate initial estimates of pumping (drainage) effort/costs.

These analyses will be translated in to language and images that can be understood by decision makers in our floodplains, and will be used as the basis for discussions about how these changes would affect ground water and flood management necessary for agriculture in our most productive low-lying areas.

### **Budget Narrative**

Total project cost: \$200,917

#### **1. Study Plan (\$28,750)**

The Conservation District will lead an extensive community engagement process to guide development of a study plan. This will include an estimated \$10,640 for Director-led consultation (140 hours) and \$16,240 in project management labor (280 hours) to conduct outreach interviews with the Snohomish Agricultural Advisory Committee, Snohomish Farm Bureau, Snohomish Sustainable Land Strategies, the Snohomish

coordinated diking council, and affected diking and flood control district managers; integrate project work with ongoing and related planning and modelling efforts; and to provide project management, billing, and financial oversight. An estimated \$1870 will be used to cover salary (20 hours) and travel (\$102) for Dr. Grossman to meet with watershed technical advisory groups (SLS, TAG), stakeholders, and resource managers to vet and develop the study plan.

## 2. Wiki Content Development (\$0)

Wiki Content will be developed by the NOAA Restoration Center as match.

## 3. Data Collection and Processing (\$39,984)

Data collection and processing (Task 3) will include inventory and synthesis of existing data required for the analyses (~\$2400) along with detailed field collection of time-series groundwater level and forcing water level data along select transects or sites of concern (\$35,904). Details of field data collection include equipment and supplies for shallow groundwater well installation and instruments that will be rented and deployed for the project duration (\$21,250). Salary and travel expenses for deployment, quarterly data download and equipment maintenance, and data handling, processing, and archiving totaling \$18,734 are needed.

## 4. Interim Results Analysis (\$61,041)

Analyses of field data collected and the modeling of resulting forcing water levels on groundwater levels across the landscape toward Task 4 is the largest cost totaling \$51,040. These expenses will be apportioned to salary for Dr. Grossman (12 hours) to advise methods for implementation, a post-doc level modeler (425 hours) to model the climate and resulting groundwater level scenarios, and a student technician/modeler assistant (480 hours) to merge model outputs into GIS and develop visualizations for results dissemination. This contracting budget also includes \$10,000 for sub-contracting with the UW Climate Impacts Group for development of scaled down river flow model outputs, and community engagement.

## 5. Final Project Report (\$6,582)

Analysis and writing (Task 5) will be apportioned for salary to Dr. Grossman (36 hours) and publication page costs (\$3400).

## 6. Final Project Presentation (\$64,560)

Final project presentation will include the representation of risk using existing web resources, and additional community engagement with the stakeholders used to develop the study plan. This will involve This includes an estimated \$12,160 of director-level outreach (160 hours), and \$17,400 of project manager labor (300 hours) to evaluate results with stakeholders, integrate findings with other planning efforts, grant and project management, and to translate groundwater level changes into operational cost estimates. This line includes an approximately \$5000 budget in consultancy fees to support contracting with special district staff to support cost management analysis (contracting), and a budget of \$30,000 for development of an interactive web tool that supports floodplain management among local stakeholders, based on past work develop ESRI-based interactive mapping tools in support of Sustainable Land Strategies project work in Snohomish County.

**Match** – Due to staff vacation schedule, we were unable to establish a final matching level at the time of submission. We have multiple efforts underway that will provide in-kind and cash match that may satisfy ESRPs matching goals including: 1) ongoing negotiations over management and regulation of diking and drainage systems in Snohomish County supported by local fees, 2) an existing grant and voluntary effort to develop an agricultural land protection strategy for Snohomish County including the study area, 3) a recent award to support Snohomish Conservation District in developing an agricultural resiliency plan. We cannot at this time however verify an exact matching level.

## Tasks and Deliverables (<500 words)

1. **Stakeholder Engagement** – we will contact local advisory and stakeholder groups, including the Snohomish Agricultural Advisory Board, and diking and drainage districts to refine the scope of the proposal and to insure that outputs provide information important for decision making.

**Deliverables** will include 1) a summary of interview findings, describing the interests and concerns of stakeholders, 2) a revised study plan reflecting the interests and questions of local flood managers, and 3) additional information about the status and vulnerability of drainage and diking systems.

2. **Water Level Analysis** – A first order quantitative analysis will identify risks and time frames, clarify adaptation questions, and identify areas where more intensive analysis could lead to project development.

**Deliverables** will include 1) maps and GIS data layers characterizing the extent and depth of groundwater ponding or depth to water table below the ground surface for a range of selected climate change (stream flow) and sea level rise scenarios for times of interest to managers and stakeholders (e.g. 2040, 2080, 2100). The GIS data layers will be attributed with the predicted frequency of groundwater level occurrence at each time step.

3. **Project Presentation** – The results of these analyses will be used to describe the risk of wide-scale groundwater ponding and the increasing operational costs over time under different climate change models.

**Deliverables** will include 1) presentations to disseminate findings that can be used by ESRP and other agencies to inform additional communities/regions of the issues and adaptive learning opportunities surrounding groundwater effects from sea level rise and its cross-cut with agriculture, ecosystem restoration and climate change adaptation planning. 2) a web-based representation of groundwater ponding risk in the lower Snohomish and Stillaguamish systems, 3) a concise report on findings and potential costs to agriculture of sea level rise in Snohomish County.

### **Policy Impact(<1000 words)**

The data, models and tools developed intend to help land use and resource managers identify impending changes and the timelines of those changes to lands and waters across floodplains and estuaries. The coastal squeeze projected to tidally-influenced Puget Sound rivers and estuaries from higher peak flows expected with more (and more intense) rainfall and the backwatering effects in streams and increase of groundwater levels in unconfined coastal aquifers associated with sea-level rise will profoundly change coastal ecosystems, restoration outcomes, and community capacity to maintain existing infrastructure and current land uses. The decision-support tools envisioned are important to inform of impending vulnerabilities and capacity thresholds (e.g. drainage pumping costs) that will be realized and helpful to identify alternative land use strategies that mutually benefit ecosystem restoration and function along with enhanced resilience for agriculture in systems like the Snohomish and Stillaguamish. Spatially explicit characterizations of impending risk and opportunities for resilience planning will help decision makers formulate policy to maximize capital expenditures where the project life-span is subject to large-scale adverse environmental change (e.g. farmland protection where it will steadily drown; estuary restoration where it will become increasingly saline). Ultimately, the work proposed will advance planning for cost-effective and more functional outcomes with more resilience (e.g. systems that can migrate as estuarine zones migrate or maximize function and lifespan within squeezed corridors) both within individual estuaries and among estuaries across Puget Sound and greater Pacific Northwest.

It is anticipated that integrating projected future stream flows and sea level rise to model and map areas that groundwater ponding will adversely impact agriculture and groundwater drainage will become cost-prohibitive will address ESRP Learning Objectives (D1 and D3) and help identify mutually beneficial strategies and priorities for maximizing floodplain ecosystem services, salmon recovery and resilient agriculture. SCD will lead a collaborative effort with The Snohomish Sustainable Lands Strategy, The US Geological Survey, UW Climate Impacts Group, and NOAA, to estimate how sea level rise scenarios may affect agricultural systems in the tidally influenced Lower Snohomish floodplain and estuary, in locations like Ebey

Island, Diking District 6, Marshlands, and French Slough. Modelling and analysis will examine the extent that groundwater ponding associated with sea level rise will affect agricultural operations and the cost over time that pumping will be required to drain lands, given subsidence, increasing sea level, and changing river flood regime. Modelling will integrate predicted river water level and sea level, as “forcing factors” on ground water ponding. Lower Snohomish agricultural systems depend on pumping groundwater and are therefore vulnerable to climate change. It is anticipated that characterization of impending risk to groundwater ponding through spatially explicit vulnerability maps and associated timelines depicting when drainage efforts will increase and become cost-prohibitive or ineffective (pumping to a higher sea level position) will address two ESRP Learning Objectives (D1 and D3) and help identify strategies and priorities for maximizing floodplain ecosystem services, salmon recovery and resilient agriculture.

## **References**

- Levesque, V.A., and Oberg, K.A., 2012, Computing discharge using the index velocity method: U.S. Geological Survey Techniques and Methods 3–A23, 148 p. (Also available at <http://pubs.usgs.gov/tm/3a23/>.)
- Savoca, M.E., Johnson, K.H., and Fasser, E.T., 2009, Shallow groundwater movement in the Skagit River Delta Area, Skagit County, Washington: U.S. Geological Survey Scientific Investigations Report 2009–5208, 22 p.



Figure 1. Maps showing groundwater monitoring array in the Marshlands of Snohomish Estuary (top) and Stillaguamish river-delta (bottom). Surface water monitoring sites will be sited in nearby estuary channels or nearshore along with barometer to develop the time-series forcing on groundwater levels observed in monitoring wells.

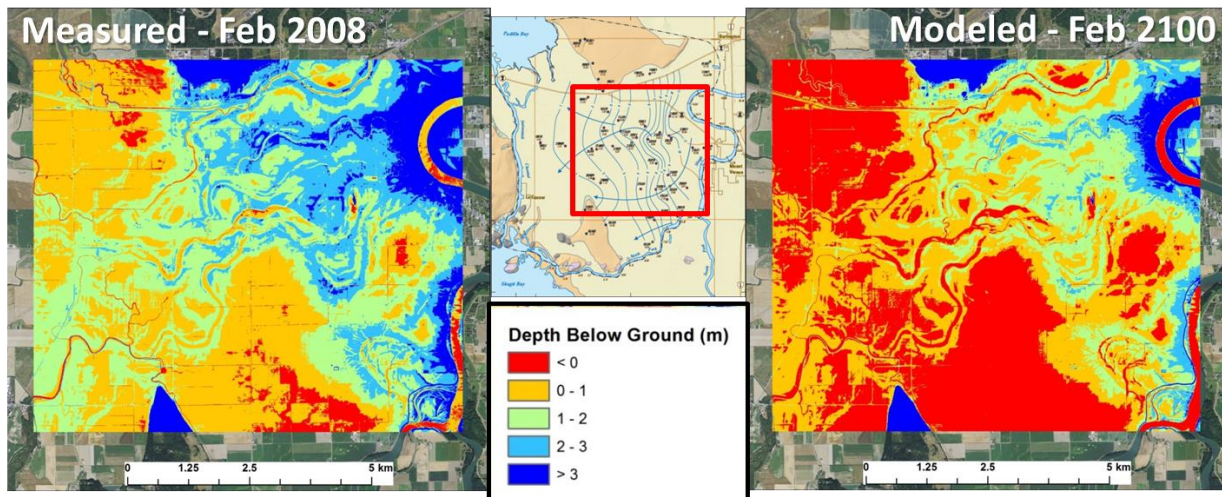


Figure 2. Example of measured depth to groundwater table across the central Skagit Delta immediately west of Mt. Vernon in Feb, 2008 (Left, after Savoca et al, 2009), and modeled depth to groundwater table for the same area given data in 2008 and extrapolated for 3-ft of sea level rise by the year 2100 (right). Red areas indicate water level above land surface elevation (ponding).

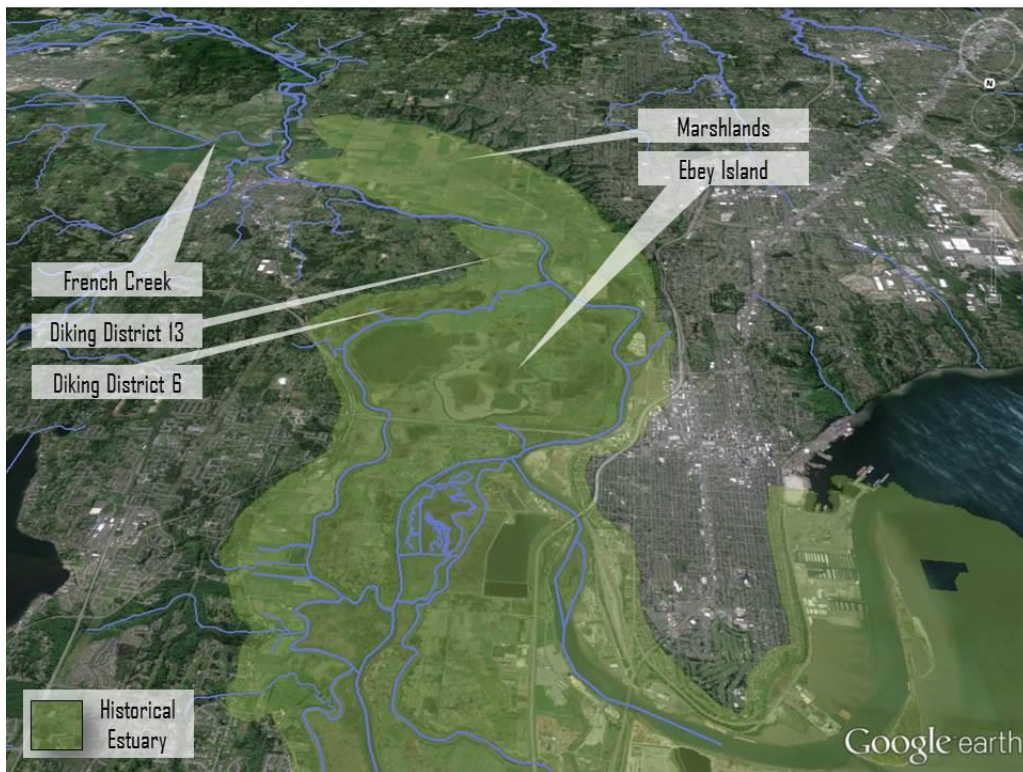


Figure 3. Historical Estuary and Tidally Influenced Areas of the Lower Snohomish

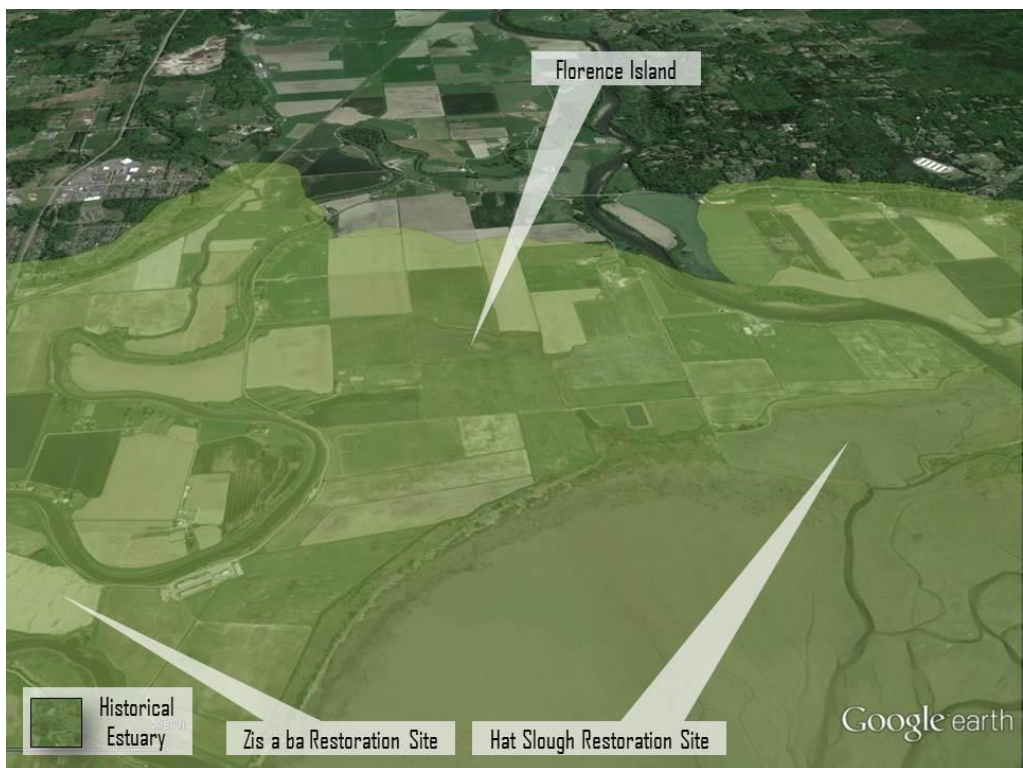


Figure 4. Historical Estuary and Tidally Influenced Areas of the Lower Snohomish

August 30, 2016

Dear Estuary and Salmon Restoration Program Manager,

The Nature Conservancy enthusiastically supports the ESRP learning proposal entitled '*Predicting sea level rise impacts on agricultural production in Snohomish tidal floodplains.*'

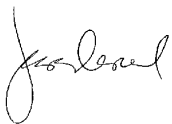
It is the Conservancy's goal in Washington to transform freshwater systems to support thriving rivers, salmon recovery, flood management, water quality and a healthier Puget Sound. The Conservancy is committed to supporting local communities develop an integrated set of goals, climate forecasts and actions that supports salmon recovery, flood control and agricultural viability. The proposed research to model how projected sea level rise will effect ground water levels and surface water ponding in Snohomish County coastal regions is a critical science gap that directly influences farmer's drainage choices today and in the future.

In a landscape where salmon populations and local farms are both struggling to survive, understanding how sea level rise will effect agricultural viability is a vital information need for delta and floodplain communities. The Snohomish Conservation District (SCD) is leading the way on developing an agricultural resiliency plan that integrates climate science and adaptation strategies for farmers in Snohomish County. No other coastal agricultural community in Washington has developed such a rigorous plan to adapt to future conditions. The new data generated under this grant will be incorporated into [The Nature Conservancy's Coastal Resiliency Tool](#) making the new information readily available and easily visualized by private landowners, flood managers and salmon recovery interests.

The Conservancy has committed \$50,000 this year to support SCD's Agricultural Resiliency Plan through a grant from NOAA's Community-Based Restoration Program. Our future outreach efforts will ensure the data generated in this learning project is readily accessible and is used to inform the development of integrated floodplain management goals, strategies and actions.

We applaud this interdisciplinary science team and enthusiastically support this proposal to estimate how sea level will effect agricultural systems in Snohomish County. This learning project will serve as a model approach for other floodplain communities in Puget Sound and beyond.

Sincerely,



Jessie Israel  
Puget Sound Conservation Director



UNITED STATES DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
NATIONAL MARINE FISHERIES SERVICE  
Damage Assessment Restoration Center NW  
7600 Sand Point Way N.E., Bldg 1, Seattle, WA 98115

August 30, 2016

**RE: Sea Level Rise Effects of Snohomish Agriculture**

Dear Evaluation Committee,

NOAA Restoration Center has been supporting reach-scale restoration in the Snohomish Watershed and Whidbey Basin. We are excited to support this proposal for the ESRP Learning Program. NOAA has actively and financially supported work to downscale climate change predictions so that it becomes relevant to county-level planners and project developers. This proposal is the necessary next step to bring climate change planning to bear on the stewardship of our floodplain resources.

Snohomish Conservation District is taking a leadership role in Puget Sound Floodplain management, by integrating salmon recovery, agricultural protection and flood protection. This proposal supports NOAA's regional and national strategic planning, including substantial investments through the President's Resilient Lands and Waters Initiative, and our regional efforts in Coordinated Investment. This proposal also reflects a tremendous investment by Snohomish County staff and leadership through their ongoing Sustainable Lands Strategy.

Success in Snohomish County depends on the ability of the county to deliver integrated projects that support salmon recovery, agriculture, and flood management. These efforts are neither simple nor easy. I think you will find that the projects herein reflect a robust and earnest effort to realize the potential of integrated planning. ESRP is critically positioned to support this effort.

We commit our technical expertise and influence toward accelerating integrated floodplain planning that recovers trust resources and furthers salmon recovery. Thank you for considering this proposal for funding.

Sincerely,

Jennifer Steger  
Northwest Region Supervisor  
NOAA Restoration Center



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