Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by **Battelle** *Since 1965*

Using Inundation Modeling and Sum Exceedance Values to Predict Wetland Land Cover Distribution: Alternative Sea Level Rise, Terrain Modification, and Tide Gate Management Scenarios

HEIDA DIEFENDERFER[1], AMY BORDE[1] AND ANDRÉ COLEMAN[2]

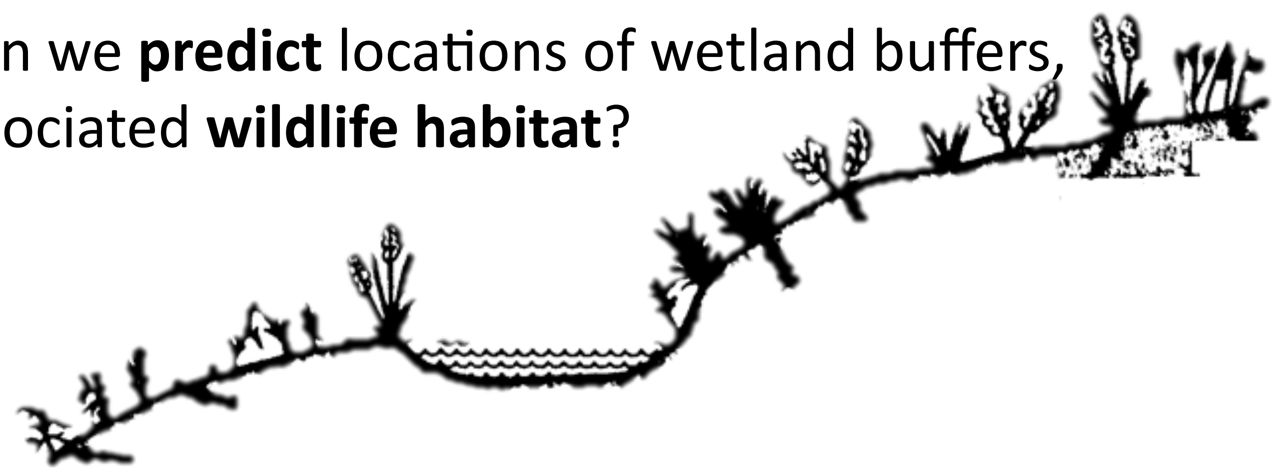
[1]Pacific Northwest National Laboratory, Marine Sciences Laboratory
[2]Pacific Northwest National Laboratory, Hydrology Group

Pacific Northwest Climate Science Conference
September 2014 – University of Washington, Seattle

Background-Global and National Research Needs

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

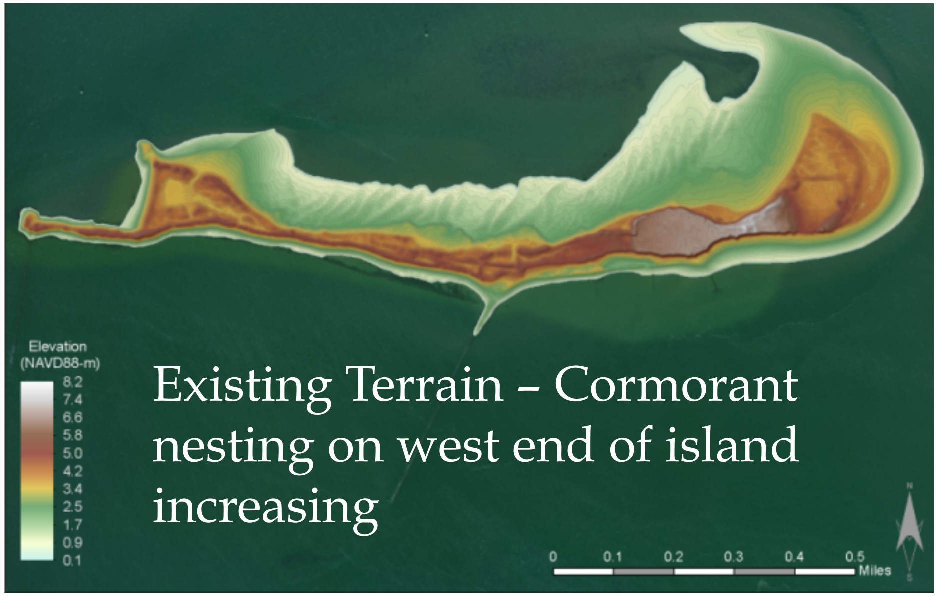
- The distribution and plant species composition of **coastal wetlands** changes with salinity and inundation dynamics (e.g., changes in relative sea level, evaporation, precipitation)
- Woody and herbaceous wetlands **buffer** coastal communities
- Wetland **migration** is limited by coastal development and species tolerances
- Are existing **data and models** sufficient for NEPA and federal climate adaptation requirements?
- How can we **predict** locations of wetland buffers, and associated **wildlife habitat**?

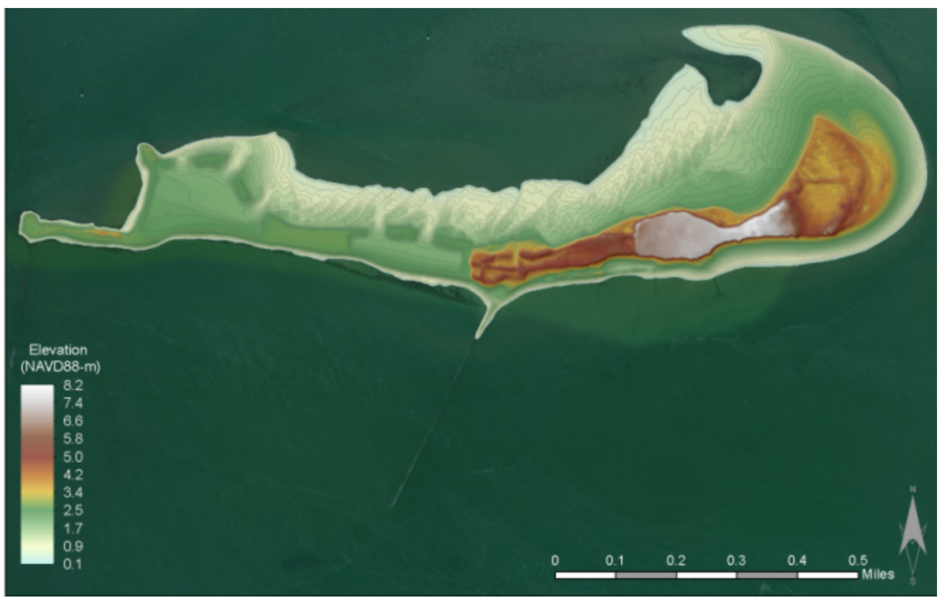


A Regional Research Need

- Home to largest North American colony of double-crested cormorants
- Habitat for 13 threatened and endangered salmon and steelhead (cormorant prey)
- Management Needs: NMFS Biological Opinion, Cormorant Management, USACE Environmental Impact Statement (EIS)

Local/Site-Scale Research Need: Proposed East Sand Island Terrain Modification





Proposed Terrain (left) - Design modifications on the west end, two potential marsh areas with terrain blocks and five channel openings. Emergent Goals: Deny cormorant nesting and increase shorebird roosting.

Research Approach

1) **current requirements** — Determine **current requirements** for climate change analysis in a U.S. Army Corps of Engineers EIS
2) Select/develop necessary **indicators** of avian habitats
3) **Assess existing data and models** relative to requirements
4) **Conduct analyses and modeling** for RSLR scenarios

Photo: HLD

Photo: Astoria-Warrenton Chamber of Commerce

Climate Change Policy Guidance for Federal Water Resource Projects: Key Documents

- President's Council on Environmental Quality (CEQ) *Interagency Guidelines for Federal Investments in Water Resources* (2013) Recommends incorporating climate change adaptation planning with NEPA processes to avoid parallel planning
- CEQ *Principles and Requirements for Federal Investments in Water Resources* (2013)
- U.S. Army Corps of Engineers (USACE) Climate Change Adaptation Plan and Report (2012, 2013)
- USACE Climate Change Adaptation Policy Statement (2011) "Mainstreaming climate change adaptation means that it will be considered at every step in the project lifecycle for all USACE projects, both existing and planned . . . to reduce vulnerabilities and to enhance the resilience of our water resource infrastructure."

USACE Policies for Sea Level Rise and Coastal Areas

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- USACE Engineering Regulation (ER) 1100-2-8162 *Incorporating sea-level change in Civil Works programs.* December 31, 2013
  http://www.publications.usace.army.mil
- The ER is based on **scenario-based planning** approach recommended in: National Research Council (1987) *Responding to Changes in Sea Level: Engineering Implications.*
- USACE and NOAA collaborated to produce the Sea-Level Change Curve Calculator: http://www.corpsclimate.us/ccaceslcurves.cfm
- Limitation: In general, national policies for project planning, regarding climate change effects on inland hydrology and effects on coastal storms, are less well developed than for sea level rise.

4-Step Quantitative Analysis on 2 Terrains X 3 Relative Sea Level Change Scenarios

1) Develop sea level rise scenarios that integrate global or eustatic change with the local change in land surface elevation at Astoria, according to the USACE regulation

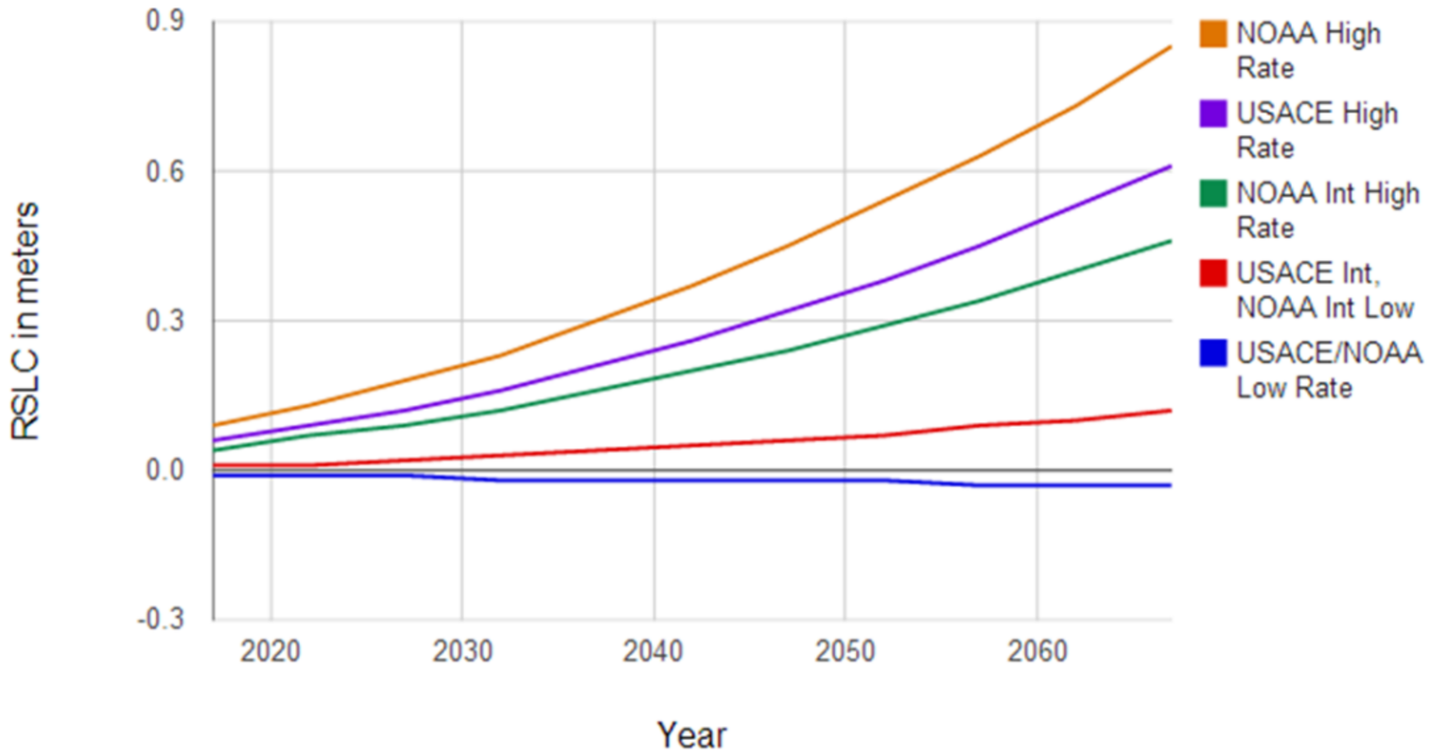
2) Interpolate existing USACE adaptive hydraulics model (AdH) runs corresponding to global sea level rise scenarios

3) Model changes to patterns of inundation on East Sand Island, under sea level rise scenarios, using existing Area-Time Inundation Index Model (ATIIM)

4) Project potential land cover/habitat distributions at East Sand Island for baseline and sea level rise scenarios using reference site data and sum exceedance values (SEVs)

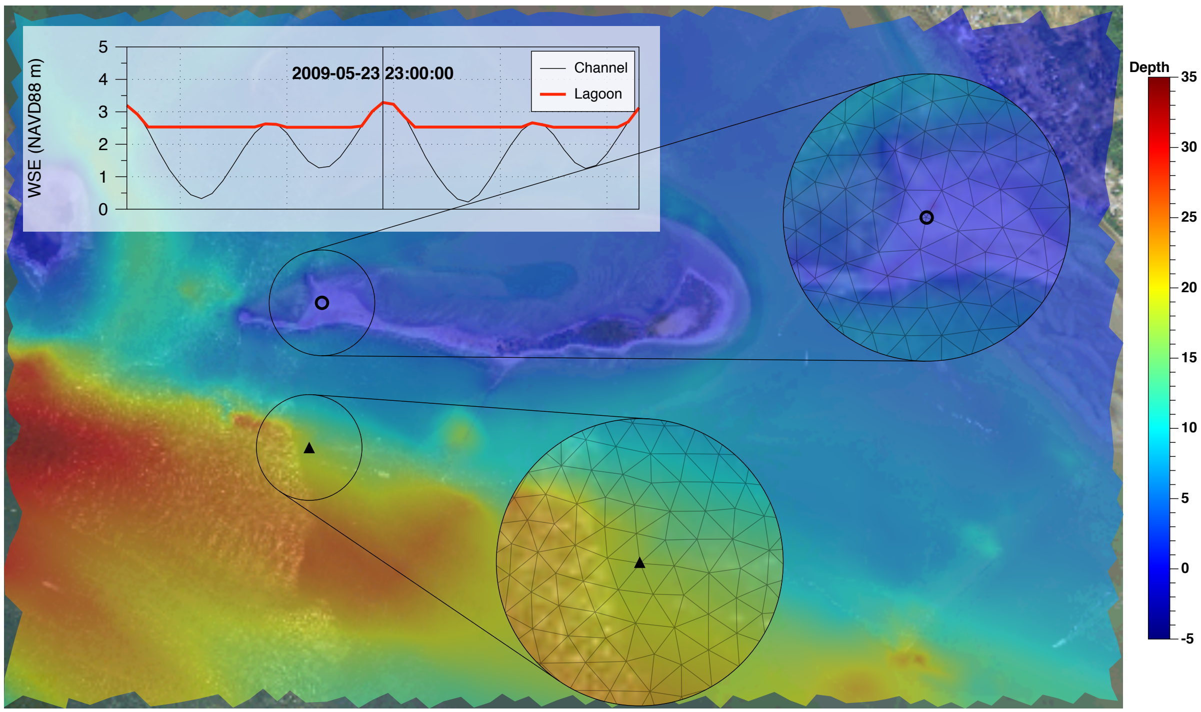
Step 1 – Sea Level Rise Scenarios for 50-year Planning Horizon

- The Sea-Level Change Curve Calculator produces NOAA Low, Intermediate Low, Intermediate High, and High rates; and USACE Low, Intermediate Low, and High rates, corresponding to IPCC scenarios.
- At Astoria, the USACE/NOAA Low Rate is Relative Sea Level **Fall**.
- Scenarios selected were +0.0, +0.12 and +0.5 m NAVD88, corresponding to recent runs of the USACE Adaptive Hydraulics Model (AdH).

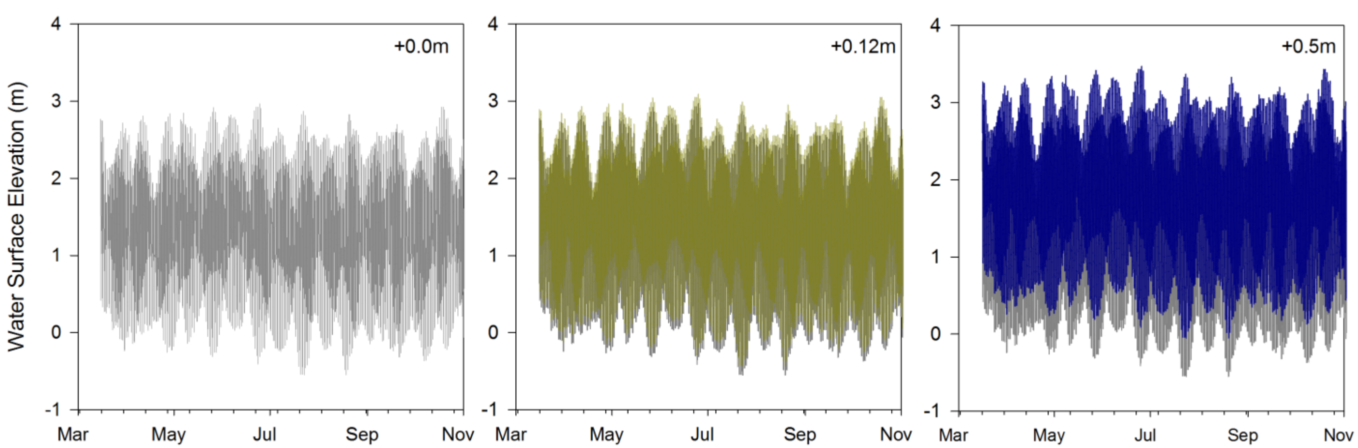


Step 2 – Interpolate USACE AdH Model, Water-Surface-Elevation Results, for ATIIM Model Input

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*



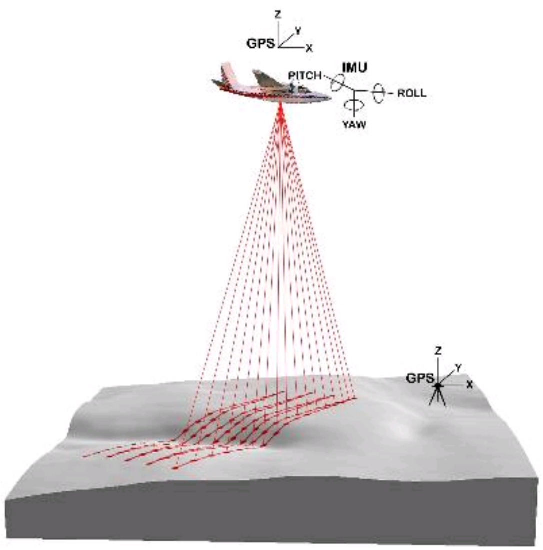
Compared three test AdH-derived WSE points around East Sand Island. Mean difference between the three locations was 1.5 cm for the entire study period; within the error of the LiDAR data.



Interpolated growing season water surface elevation outputs of AdH model for baseline (gray) and two locally corrected 50-year sea level rise scenarios (+0.12, +0.5)

Step 3 – Background: Area-Time Inundation Index Model Overview

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



- ATIIM Integrates in GIS;
  - Advanced terrain processing of high-resolution Light Detection and Ranging (LiDAR) elevation data suitable for very low relief tidal wetlands
  - Available bathymetry data
  - Water surface elevation data
    - In-situ, hydrodynamic or regression-based models, or synthetic
  - An inundated-area algorithm that enforces hydrologic connectivity and determines two- and three-dimensional inundation/volume extent over time
- ATIIM Produces 14 spatial metrics and 49 tabular metrics

Coleman AM et al. Spatially Based Area-Time Inundation Index Model, *Ecological Engineering, in review*.

Step 3 – ATIIM Model of Inundation Changes.

Four years of nesting data and LiDAR elevation data used to establish nesting zone elevation (2.7 – 4.8 m NAVD88) and provide nest frequency distribution. ATIIM maps/calculates values for scenarios.

	Total Available Nesting Hectares		**Nesting Hectares Denied**	
Sea Level Rise	*Existing Terrain*	*Alternative Terrain*	*Existing Terrain*	*Alternative Terrain*
+0.0	18.42	11.13	0.00	7.29
+0.12	17.65	10.70	0.77	7.72
+0.5	13.82	7.61	4.60	10.81

Step 3 – ATIIM Model of Inundation Change Effects on Nesting Elevation Band

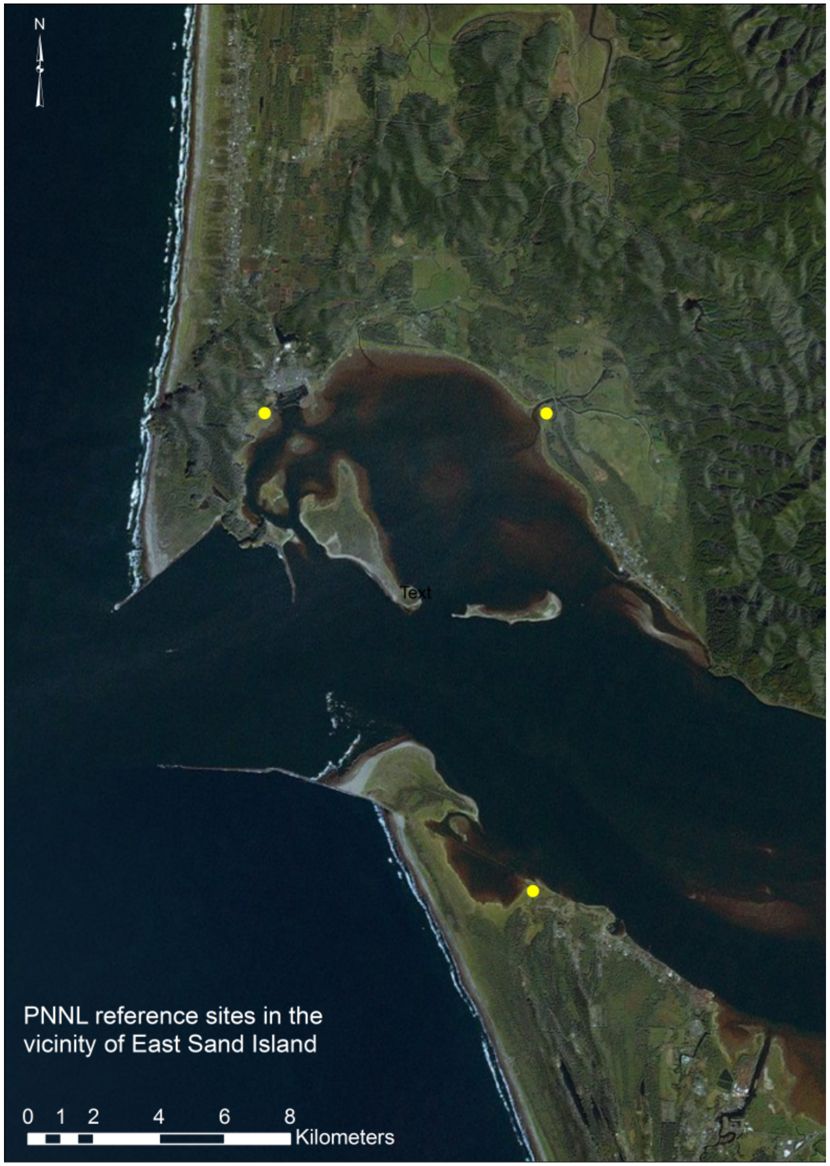
Existing East Sand Island Terrain +0.0 RSLR

Proposed East Sand Island Terrain +0.5 RSLR.

Note inundation (blue) covers the nesting band (yellow lines)

Step 4 – Background: Plant Community Data From Three Tidal Wetland Reference Sites

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

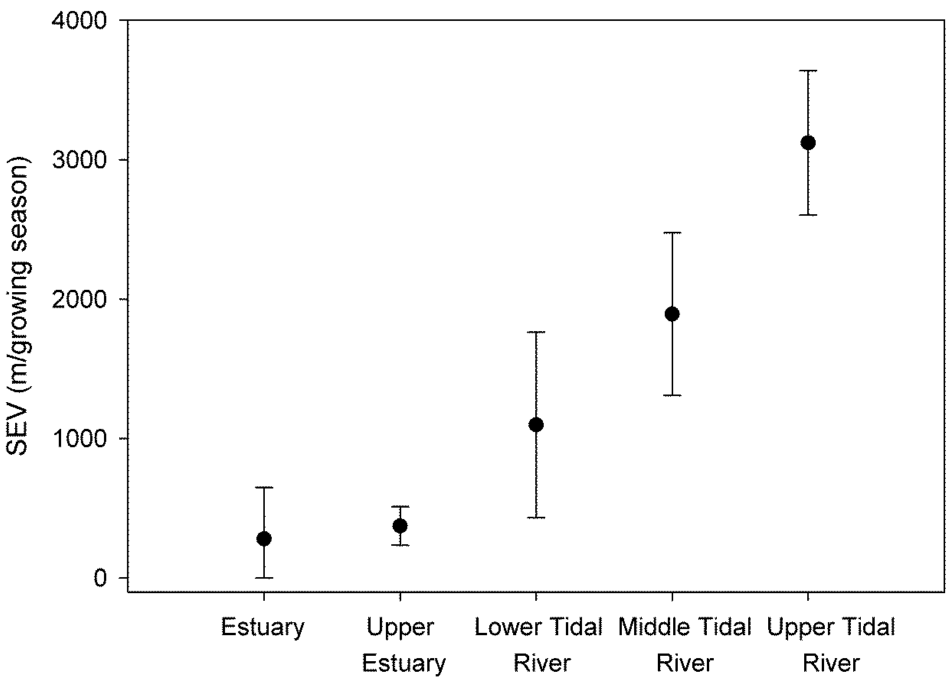


Baker Bay Marsh Reference Site

Step 4 – Background: Sum Exceedance Value Predicts Percent Cover; Location

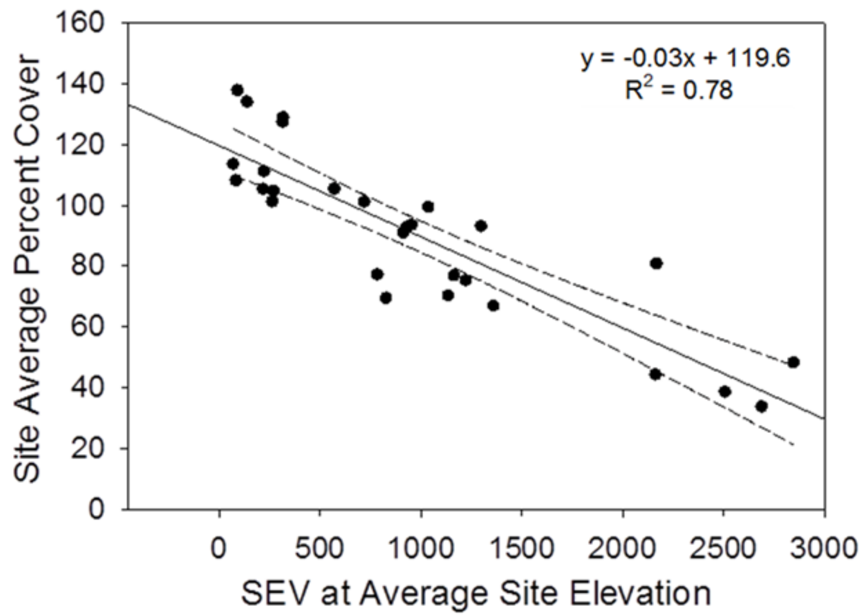
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

SEV: Index of hydrologic conditions during the vegetative growing season where the cumulative sum of the hourly difference between water surface elevation and land surface elevation during the growing season is calculated.



Jay, D. A et al. In Review. Tidal-fluvial and estuarine processes in the Lower Columbia River *Estuaries and Coasts*

Original citation: Gowing & Spoor 1998; Modified for the lower Columbia River by Borde et al. 2011, 2012.



Step 4 – Sum Exceedance Value Results

Existing East Sand Island Terrain – SLR +0.0

East Sand Island Proposed Terrain – SLR +0.5

Step 4 – Model Effects of Inundation Changes on Shorebird Habitat and Vegetation

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

Existing East Sand Island Terrain +0.0 RSLR.

Proposed East Sand Island Terrain +0.5 RSLR.

Potential herbaceous vegetation (tan) and shorebird roosting (white outline). Woody plants are expected to occur at higher elevations.

Other Applications: Tide Gate Management Scenarios for Chinook Estuary fish passage

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

These reference site/sum exceedance value modeling techniques also used for design elevations/planting plan behind tide gates on the Chinook River. SEVs were calculated from the outputs of FVCOM.

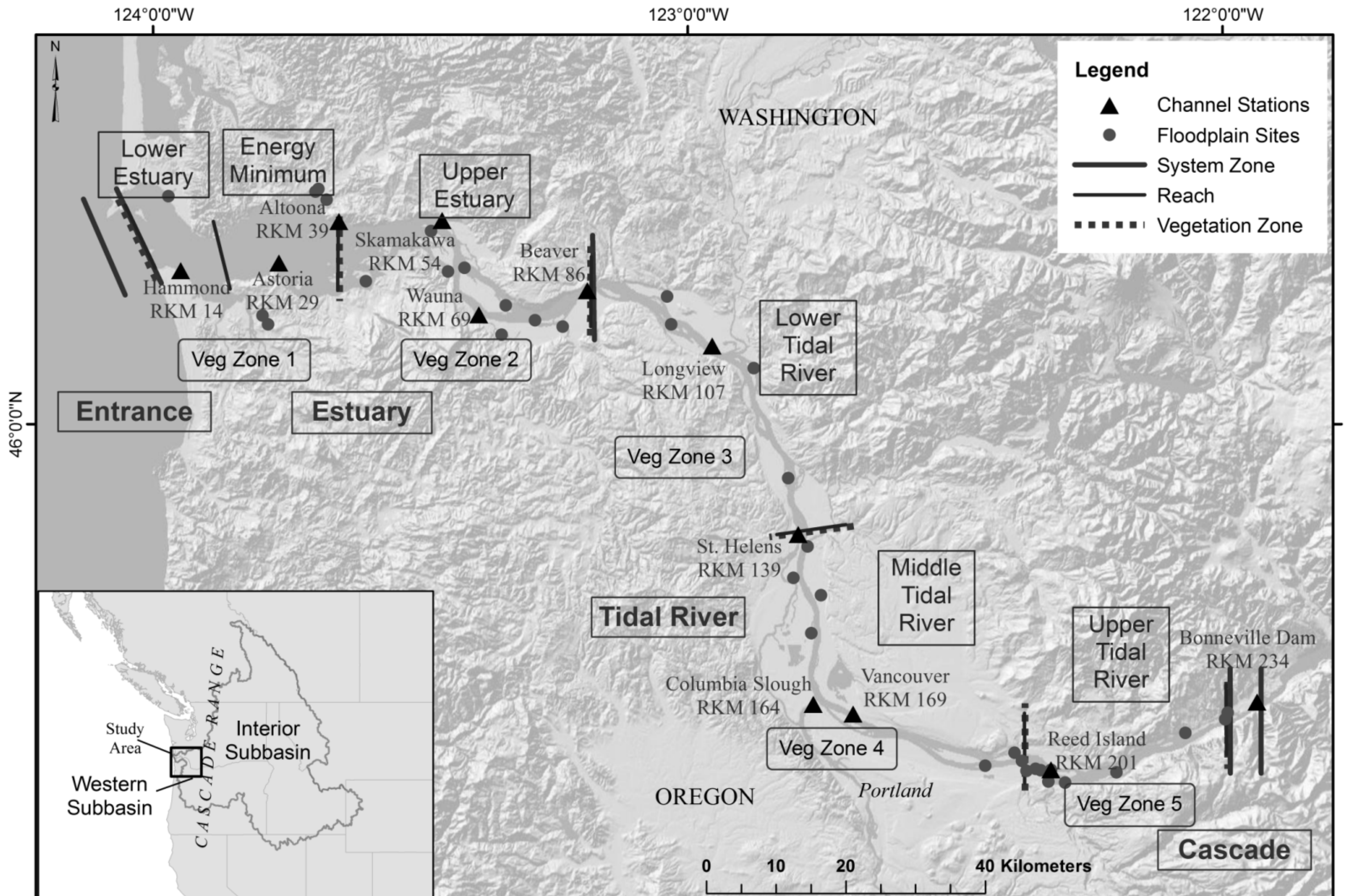
Conclusions

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by **Battelle** *Since 1965*

- The alternative design exposes more of the island to disturbance from tides and storm surge, reducing potential DCCO nesting.
- As sea level rises, the designed island surface will increasingly convert to mud flats suitable for shorebird roosting that would be unsuitable for DCCO nesting because of inundation.
- The ability to create tidal wetlands for juvenile salmon is possible but uncertain because of potential physical and biological disturbances, and the need for adequate sediment conditions. Sediment transport, morphology, & storm surge not modeled.
- Both mud flats and vegetated areas—possibly including marshes, dune grass, and woody plants at higher elevations—could persist on East Sand Island despite sea level rise for five decades.

Scale Limits: Dominant physical processes differ by river reach/distance from main stem

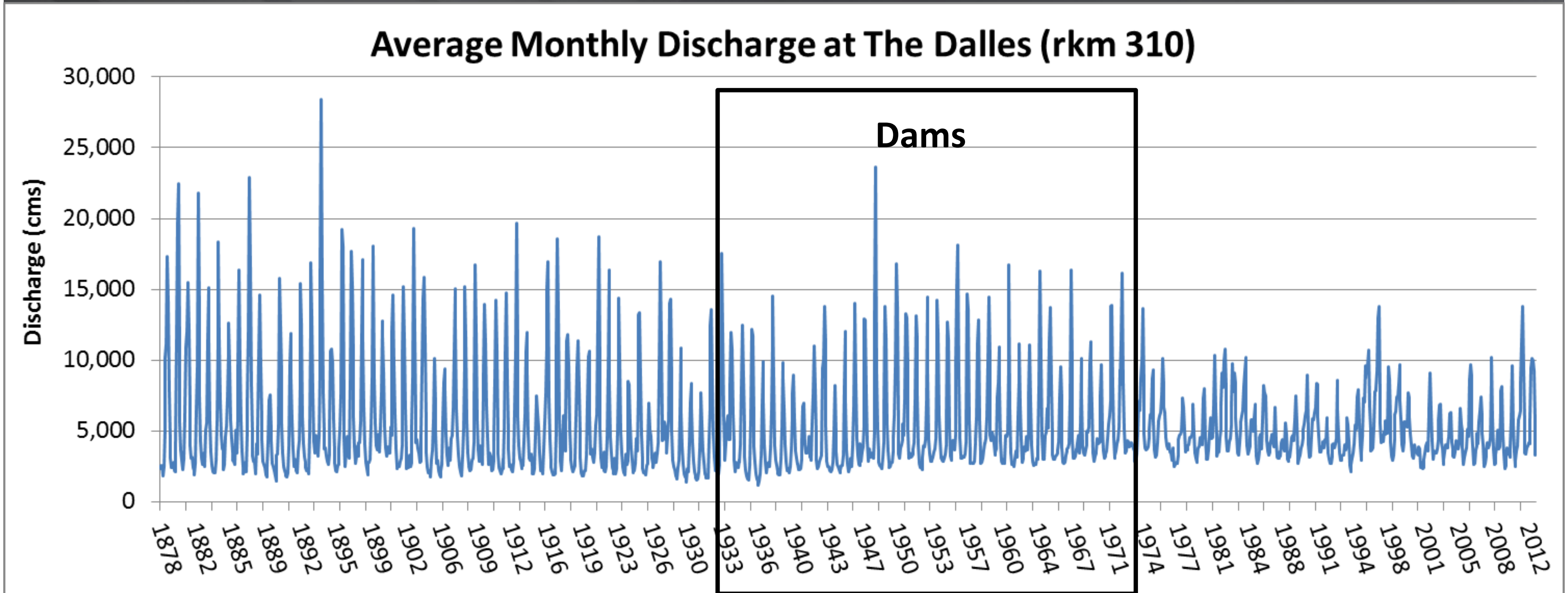
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

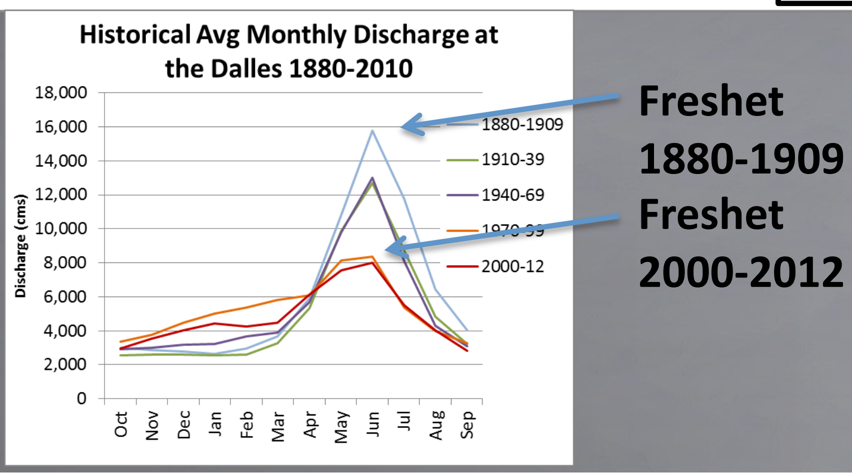


Jay, D. A., K. Leffler, H. Diefenderfer, and A. Borde. In press. Tidal-fluvial and estuarine processes in the Lower Columbia River: Part I and Part II. *Estuaries and Coasts*.

Scale Limits: Tidal Wetland Distribution Affected by Changes to the Hydrograph

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

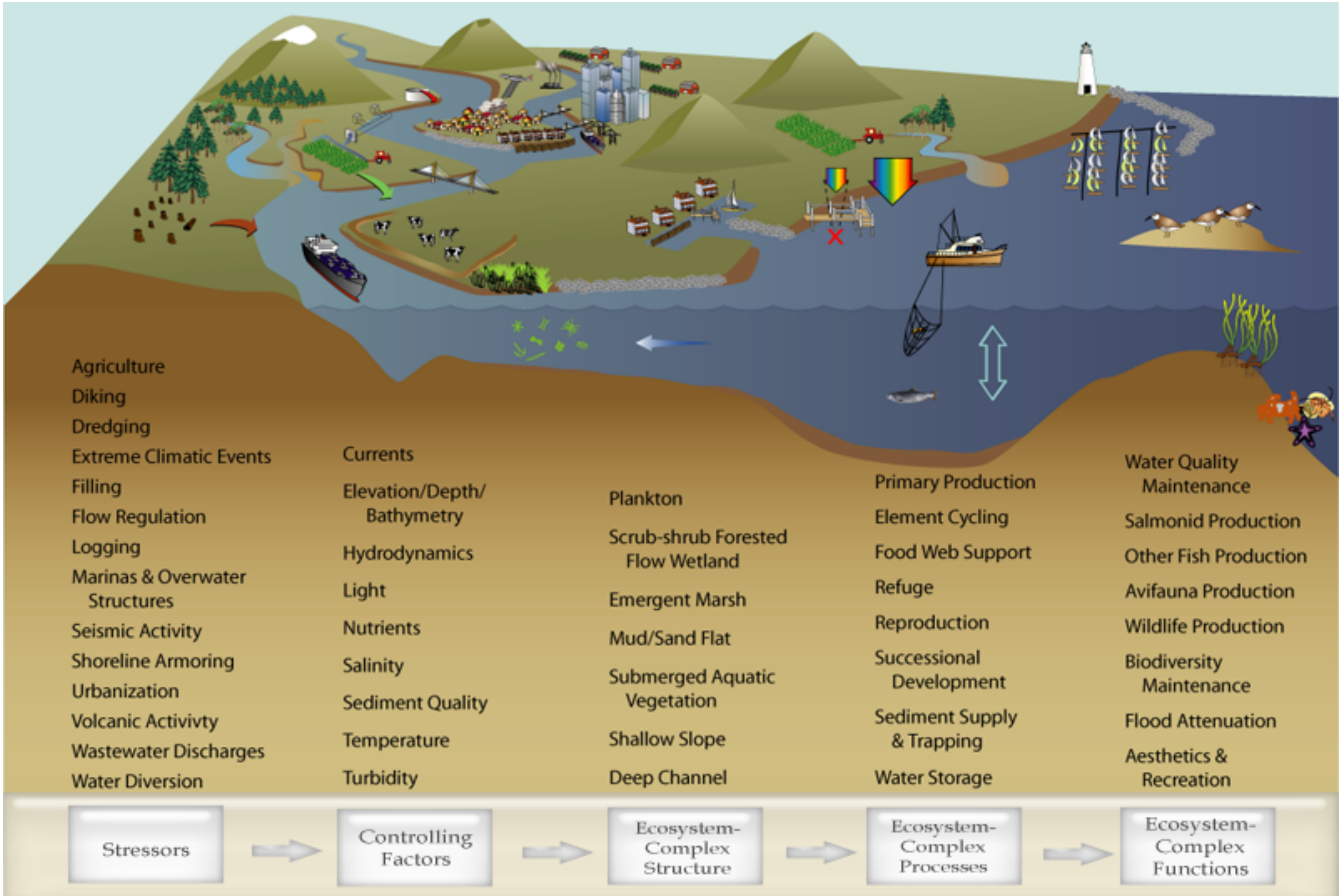




Flow Trends 1878-2012: Decrease and Interannual Variability

http://nwis.waterdata.usgs.gov/nwis

Dynamics Limits: Not All Interactions in the Ecosystem Conceptual Model Considered



Acknowledgements

Research funded by the U.S. Army Corps of Engineers, Portland District—Cindy Studebaker, lead.

Rod Moritz, PE, USACE, led development of alternative terrain.

Other biologists contributing to new inundation metrics for cormorant nesting, shorebird roosting, and juvenile salmon habitat: Dan Roby, Oregon State University; Michelle McDowell, USFWS; and Nichole Sather, PNNL.

Contact Information:
heida.diefenderfer@pnnl.gov
andre.coleman@pnnl.gov
amy.borde@pnnl.gov

This study was fully reported in Diefenderfer et al., April, 2014. PNNL-23300. Available from: Cynthia.A.Studebaker@usace.army.mil