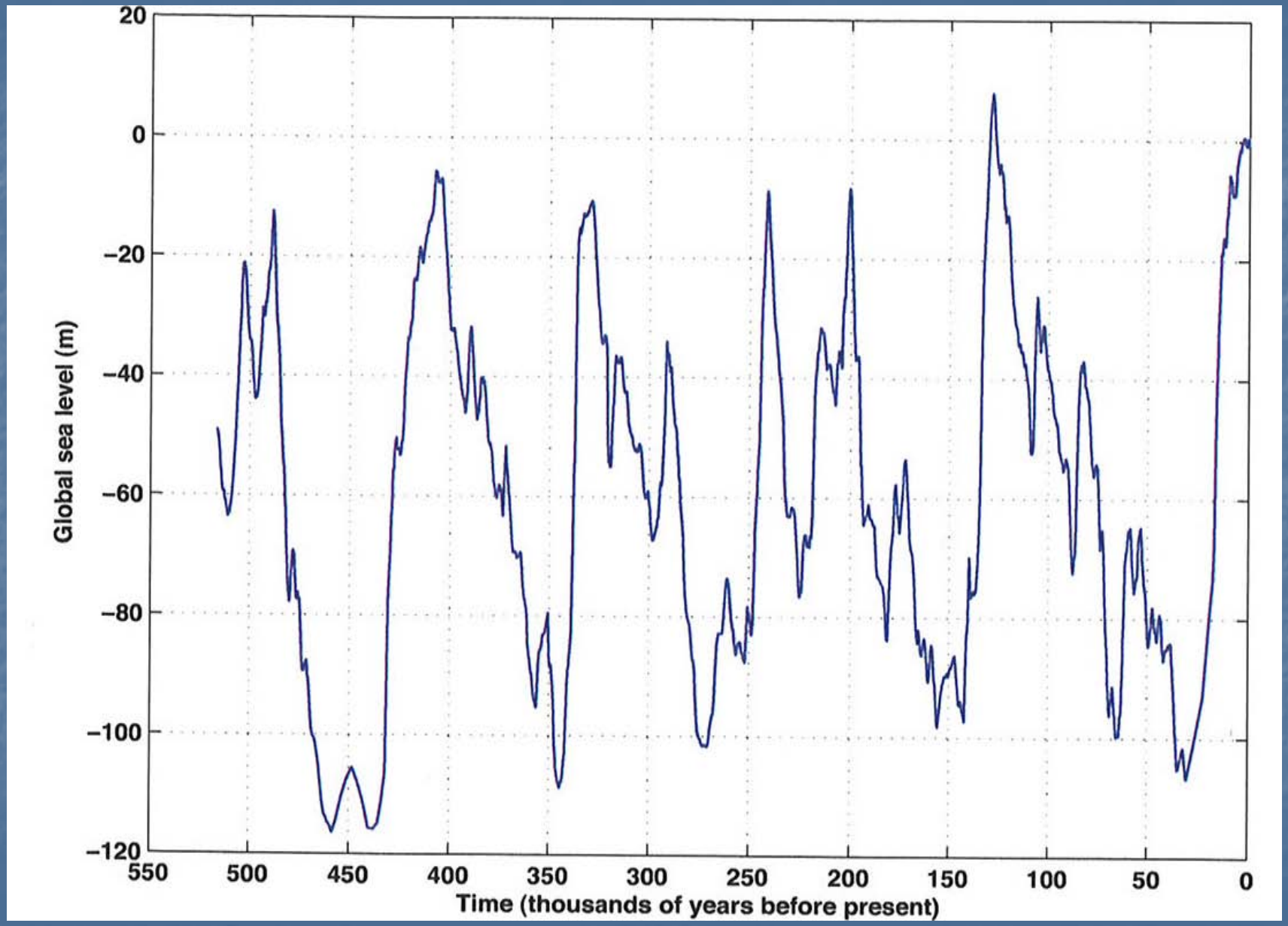
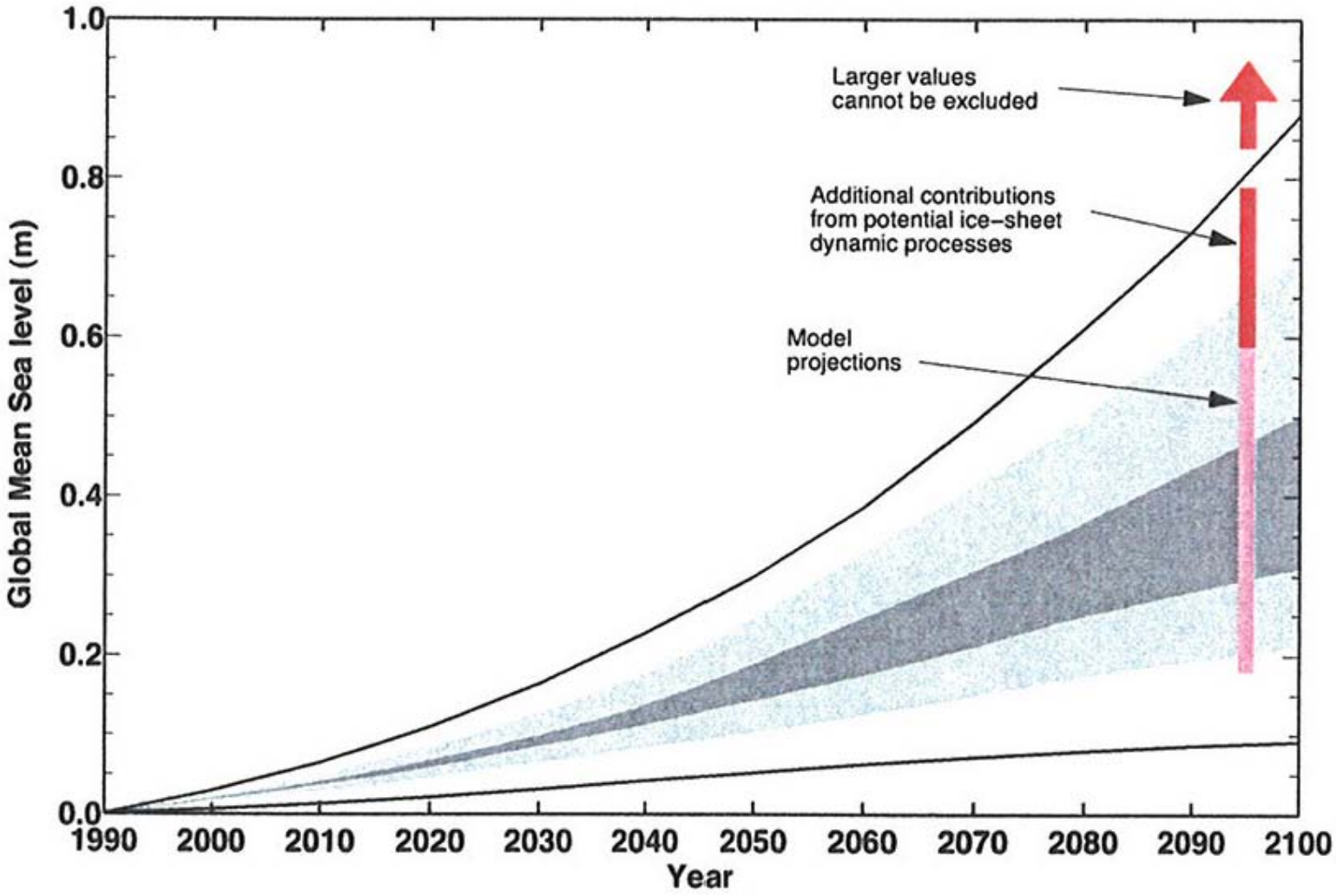
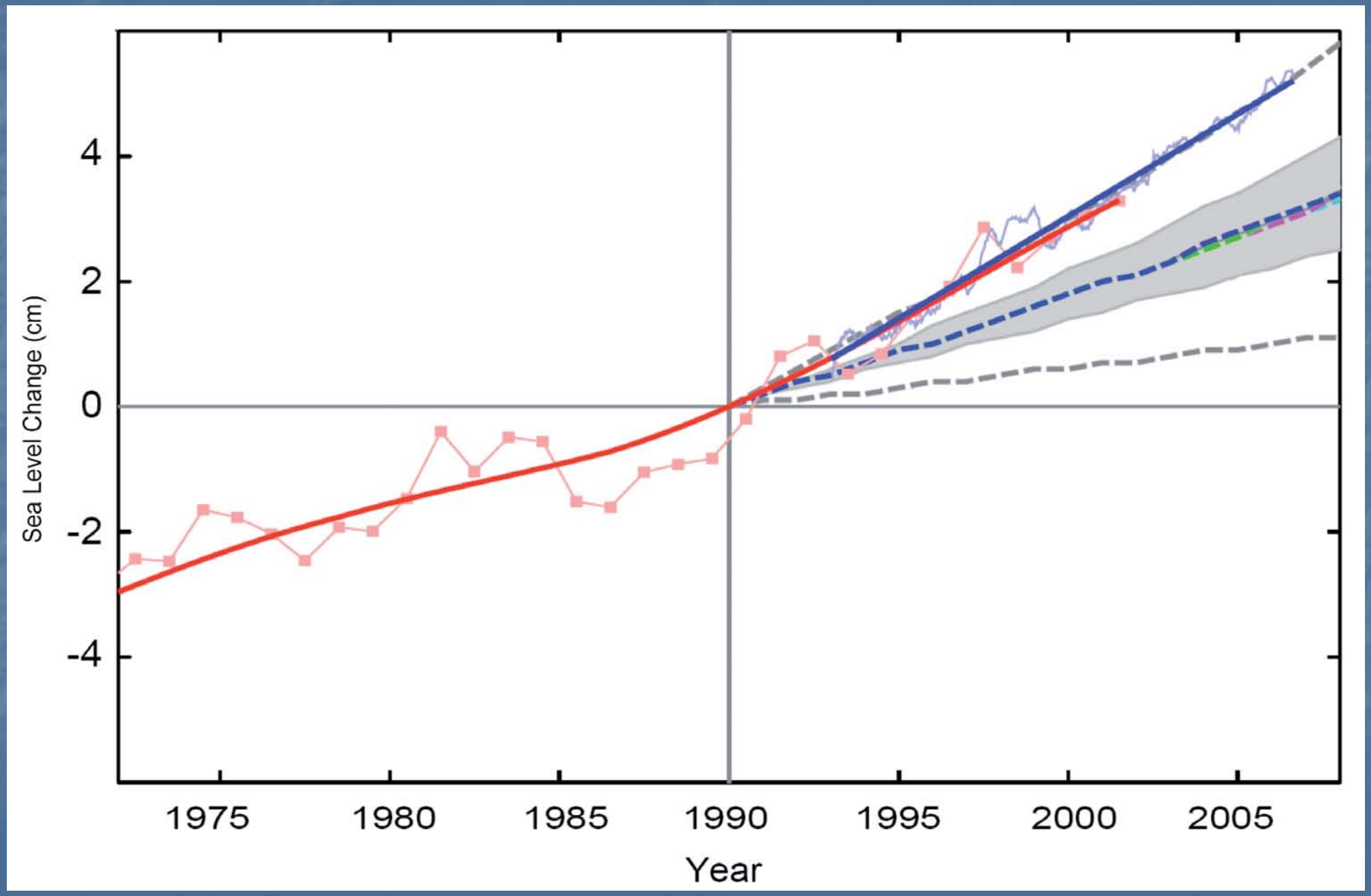
DUCKS UNLIMITED

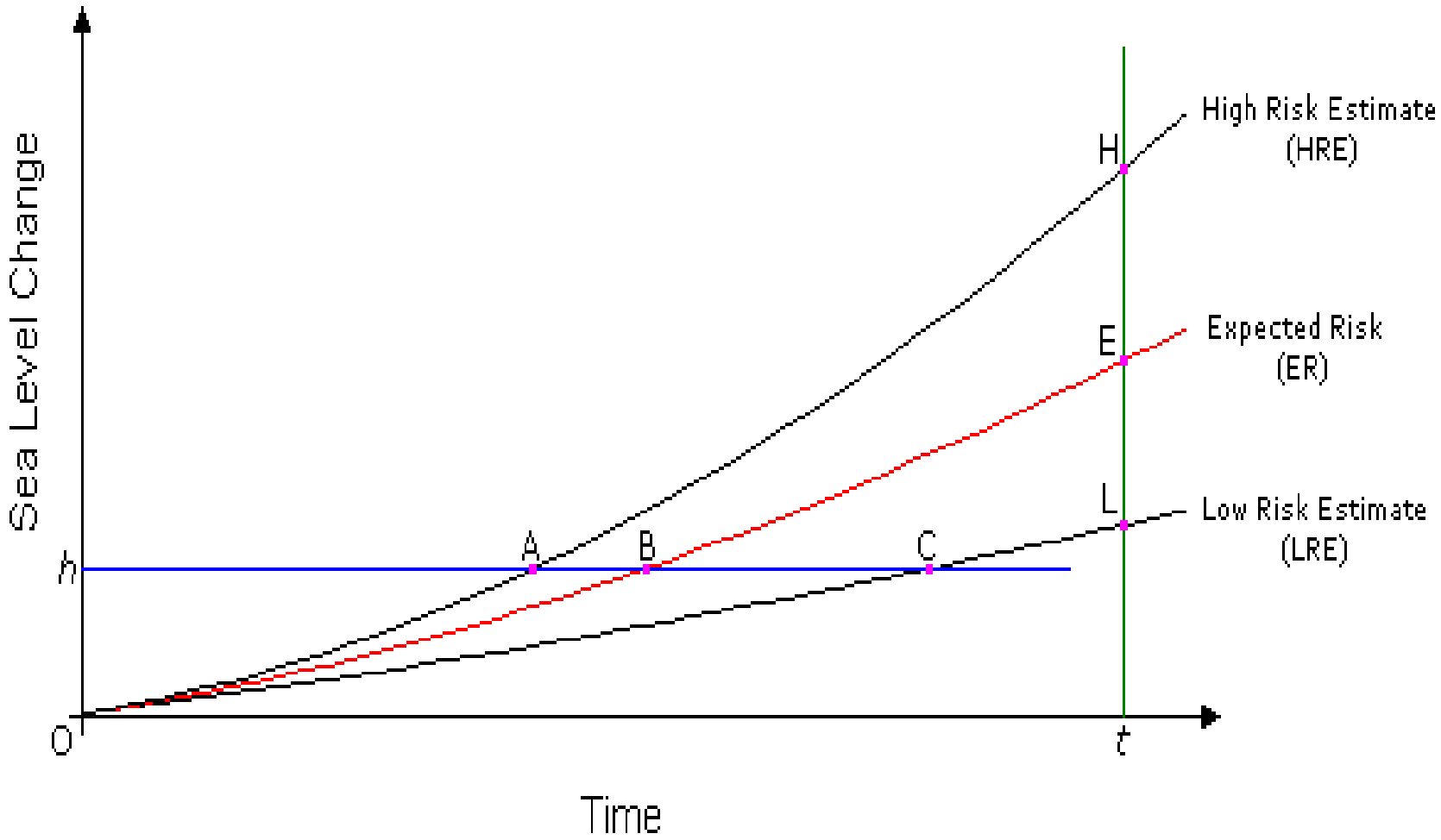
Sea Level Rise

Providing Nature A-Right-of Way


Global sea level (m)
20
0
−20
−40
−60
−80
−100
−120
550
500
450
400
350
300
250
200
150
100
50
0
Time (thousands of years before present)


Larger values
cannot be excluded
Additional contributions
from potential ice-sheet
dynamic processes
Model
projections
Global Mean Sea level (m)
1.0
0.8
0.6
0.4
0.2
0.0
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year


Sea Level Change (cm)
4
2
0
-2
-4
1975
1980
1985
1990
1995
2000
2005
Year


Sea Level Change
Time
O
h
t
A
B
C
H
E
L
High Risk Estimate
(HRE)
Expected Risk
(ER)
Low Risk Estimate
(LRE)

Coastal Areas will be Impacted During 21st Century

- Pattern of long-term sea-level rise
- Extreme sea-level events caused by storms and waves

The Problem

- Loss of coastal wetlands due to submergence
- Wetlands cannot migrate upslope because of human infrastructure or geomorphology

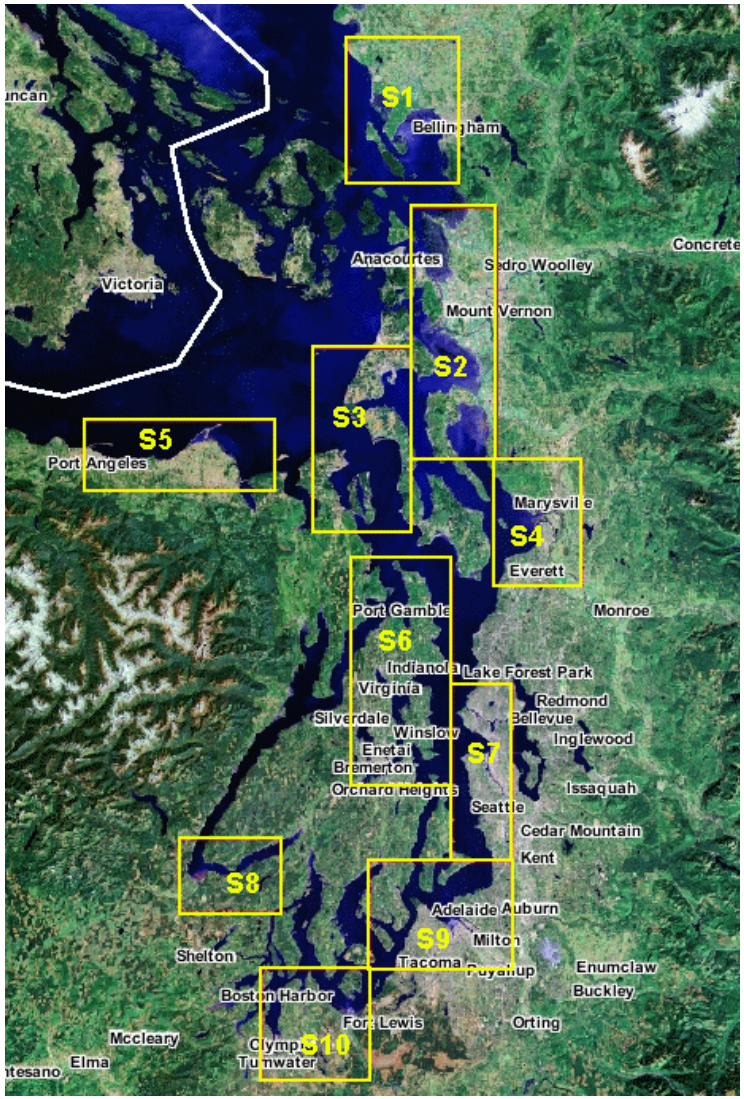
NATIONAL WILDLIFE FEDERATION

Sea-level Rise and Coastal Habitats in the Pacific Northwest

An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon

NATIONAL WILDLIFE FEDERATION

Study Area


S1
Bellingham
Concrete
Anacortes
Sedro Woolley
Victoria
Mount Vernon
S2
S3
S5
Port Angeles
Marysville
S4
Everett
Port Gamble
Monroe
S6
Indianola
Lake Forest Park
Virginia
Redmond
Silverdale
Bellevue
Winslow
Inglewood
Enetai
S7
Bremerton
Issaquah
Orchard Heights
Seattle
Cedar Mountain
Kent
S8
Adelaide
Auburn
S9
Milton
Shelton
Tacoma
Puyallup
Enumclaw
Buckley
Boston Harbor
Fort Lewis
Orting
Mccleary
S10
Elma
Tumwater

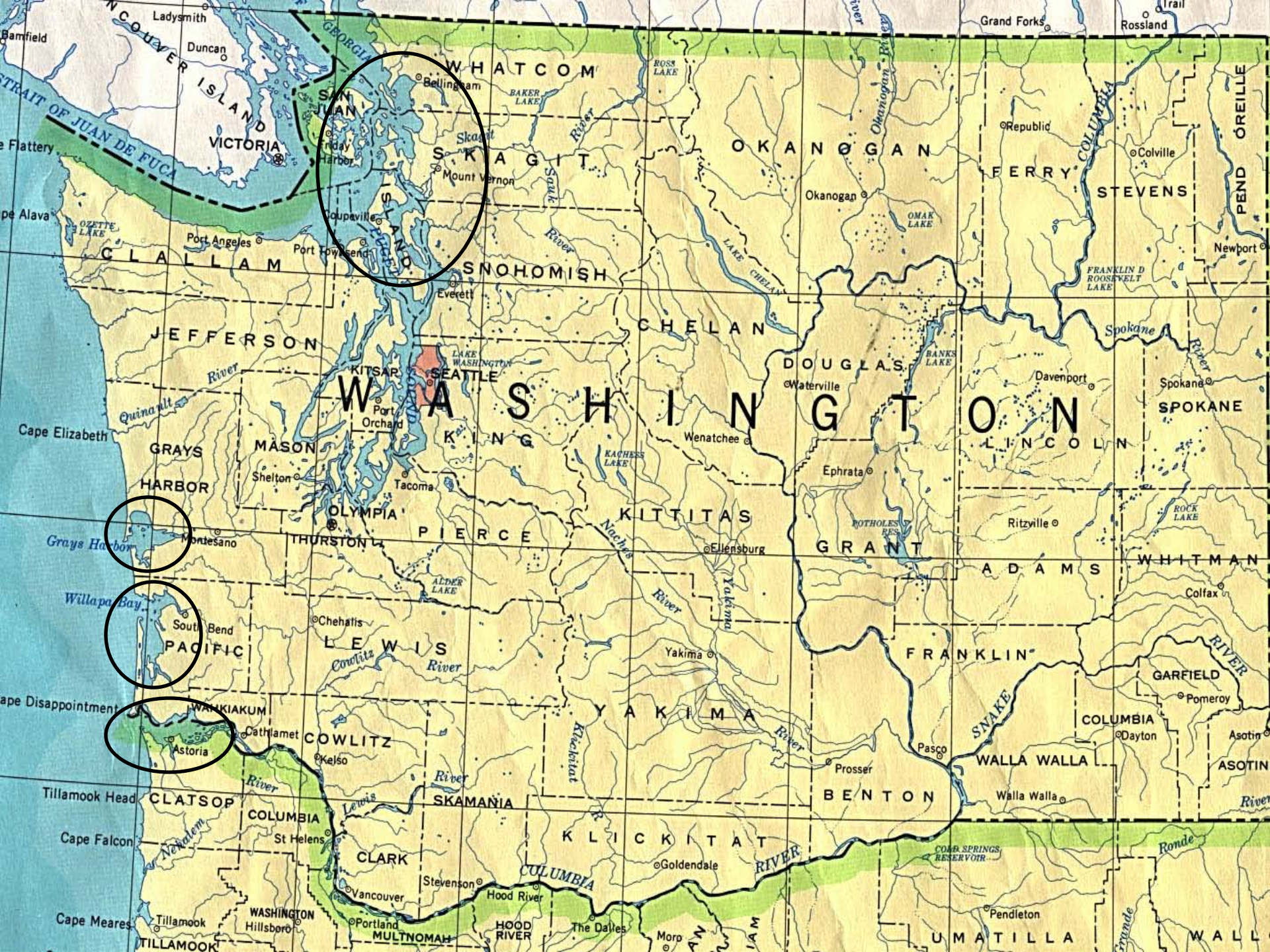
Raymond
South Bend
Pe Ell
WASHING
Long Beach
Astoria
Cathlamet
Gearhart
Seaside
UNITED
Cannon Beach
Arch Cape
Manzanita
OREGON
Rockaway
Garibaldi
Bay City
Tillamook

SEA-LEVEL AFFECTING MARSHES MODEL

- SLAMM 6 Version
- Simulates the processes involved in wetland conversion and shoreline modification under long-term sea-level rise
- uses changes in sea-level with inundation, erosion, overwash, saturation, and accretion to predict changes from one wetland type to another
- 0.39 m (11.2 inch), 0.69 m (27 inch), 1 m and 1.5 m rise by 2025, 2050, 2075 and 2100
- Performs analysis at current diking conditions and without dikes in place
- A complex decision tree incorporating geometric and quantitative relationship is used to represent transfers among coastal wetland classes

Improvements to NWF Analysis

- **Used LIDAR data**
- **Better ‘dike layer’ definition**
- **Separate analysis of major estuary systems**
- **Added analysis of Gray’s Harbor**
- **Simpler wetland classification**
- **Examining uncertainty in SLAMM**



WASHINGTON
WHATCOM
SKAGIT
SNOHOMISH
CHELAN
OKANOGAN
FERRY
STEVENS
PEND OREILLE
CLALLAM
JEFFERSON
KITSAP
SEATTLE
KING
DOUGLAS
LINCOLN
SPOKANE
GRAYS HARBOR
MASON
OLYMPIA
THURSTON
PIERCE
KITTITAS
GRANT
ADAMS
WHITMAN
PACIFIC
LEWIS
YAKIMA
FRANKLIN
GARFIELD
COLUMBIA
WALLA WALLA
ASOTIN
BENTON
CLATSOP
COWLITZ
SKAMANIA
KLICKITAT
CLARK
WASHINGTON
MULTNOMAH
HOOD RIVER
UMATILLA
TILLAMOOK
VICTORIA
SAN JUAN
Friday Harbor
Bellingham
Mount Vernon
Coupeville
Port Angeles
Port Townsend
Everett
Port Orchard
Tacoma
Shelton
Montesano
South Bend
Chehalis
Cathlamet
Kelso
Astoria
St Helens
Vancouver
Portland
Hillsboro
Tillamook
Stevenson
Hood River
The Dalles
Goldendale
Moro
Prosser
Pasco
Walla Walla
Pendleton
Ellensburg
Yakima
Wenatchee
Ephrata
Waterville
Okanogan
Republic
Colville
Newport
Davenport
Spokane
Ritzville
Colfax
Pomeroy
Dayton
Asotin
Bamfield
Ladysmith
Duncan
Grand Forks
Rossland
Trail
Cape Elizabeth
Cape Disappointment
Tillamook Head
Cape Falcon
Cape Meares
Grays Harbor
Willapa Bay
Quinault River
Cowlitz River
Lewis River
Nehalem River
Skagit River
Sauk River
Okanogan River
Spokane River
Naches River
Yakima River
Klickitat R
Columbia River
Snake River
Ronde River
Grande River
Lake Chelan
Lake Washington
Kachess Lake
Alder Lake
Potholes Res
Franklin D Roosevelt Lake
Cold Springs Reservoir
Strait of Juan de Fuca
Georgia
Puget Sound

Detailed SLAMM Land Categories

- **23** Categories derived from National Wetlands Inventory

Dry Land: Developed and Undeveloped

Swamp: General, Cypress, & Tidal

Transitional Marsh: Occasionally Inundated, Scrub Shrub

Marsh: Salt, Brackish, Tidal Fresh, Inland Fresh, Tall Spartina

Mangrove: Tropical Settings Only

Beach: Estuarine, Marine, Rocky Intertidal

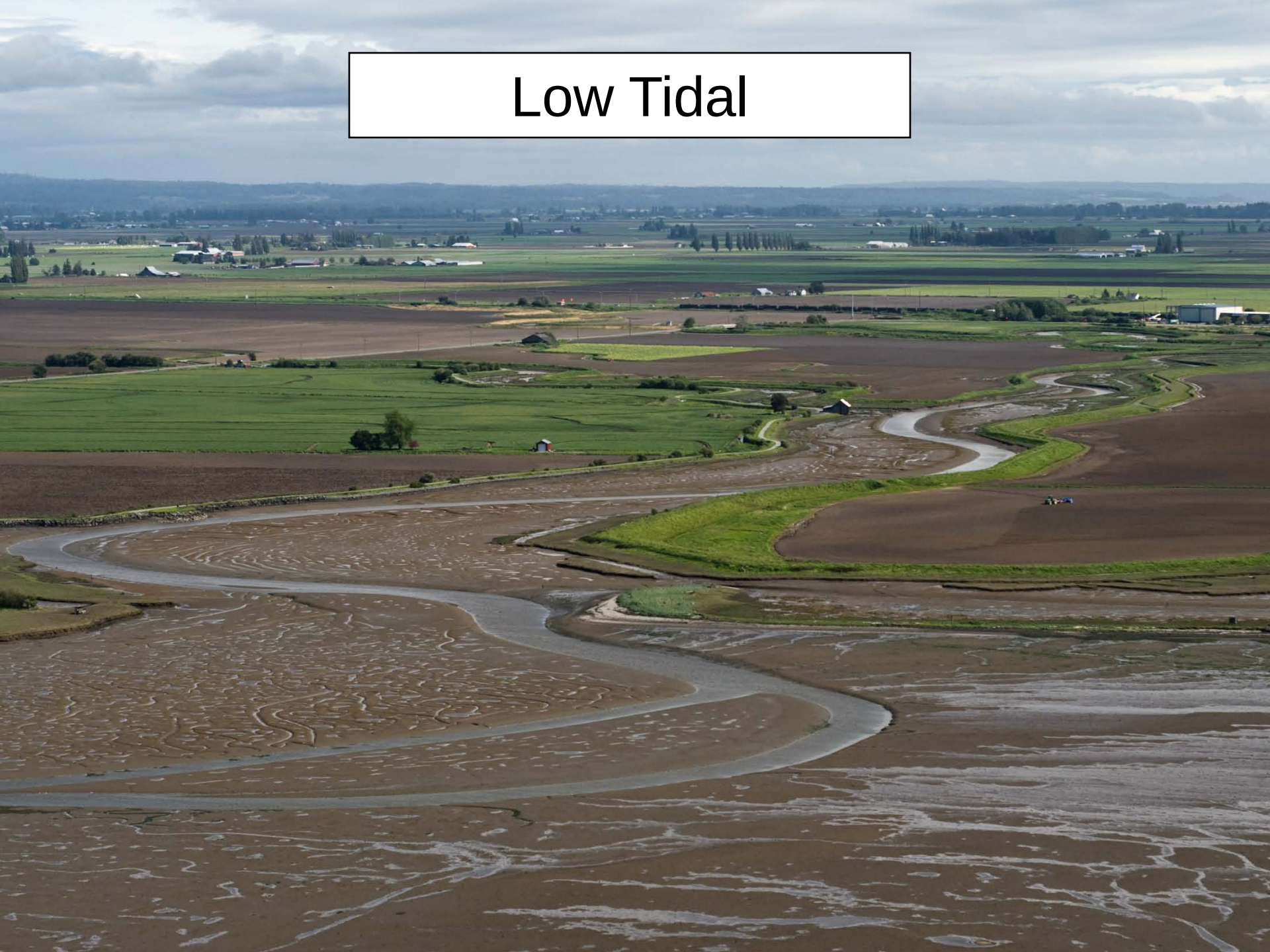
Flats: Tidal Flats & Ocean Flats

Open Water: Ocean, Inland, Riverine, Estuarine, Tidal Creek

Nearshore Zones

Habitat Type in NWF Report	Cowardin et al. (1979) Classification	Nearshore Zone
Estuarine Beach	Estuarine intertidal unconsolidated shore (sand)	Low Tidal
Tidal Flat	Estuarine intertidal unconsolidated shore (mud)	
Saltmarsh	Estuarine intertidal emergent	Saltmarsh
Transitional Marsh	Estuarine intertidal scrub shrub	Transitional
Brackish Marsh	Estuarine intertidal emergent	
Tidal Swamp	Palustrine forested or scrub shrub (tidal modifier)	Freshwater Tidal
Transitional Fresh Marsh	Palustrine emergent (tidal modifier)	
Riverine Tidal	Riverine aquatic bed (tidal modifier)	

Low Tidal

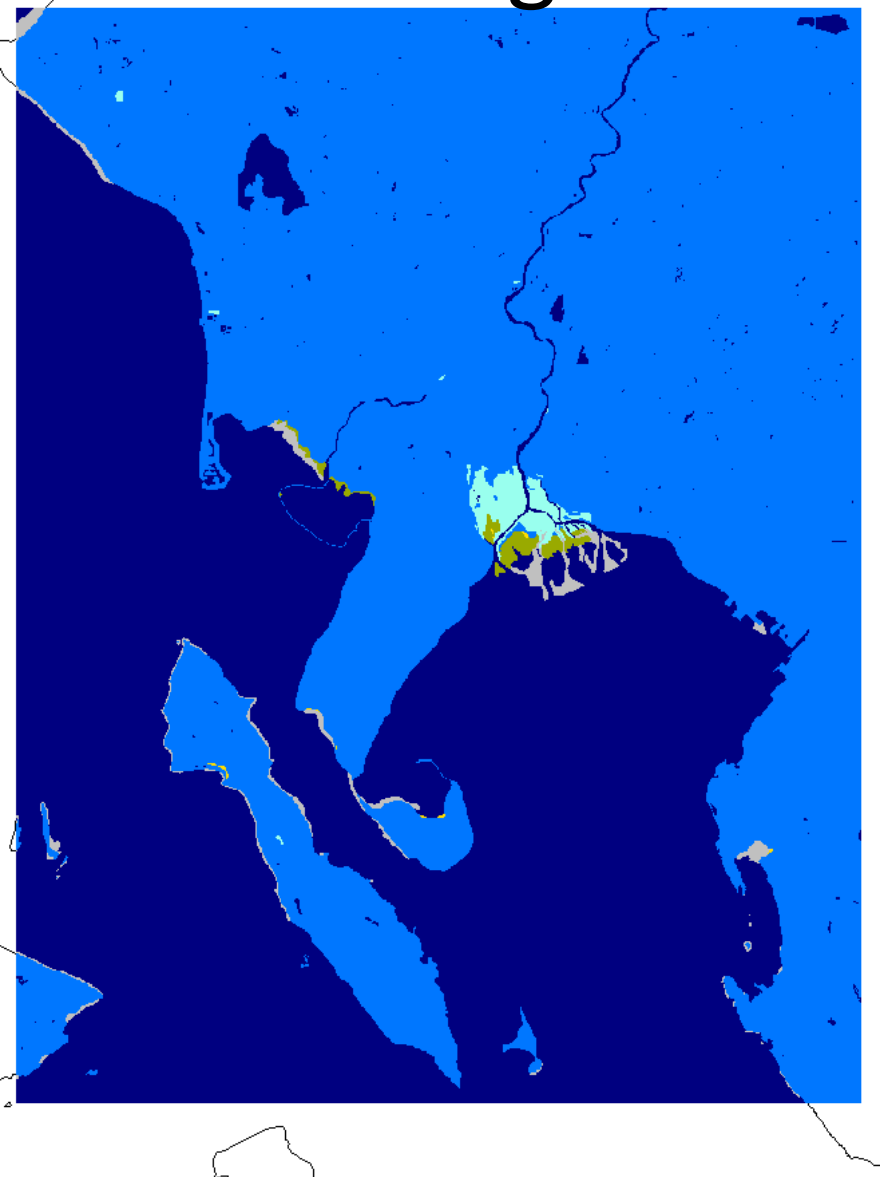


Saltmarsh

Transitional

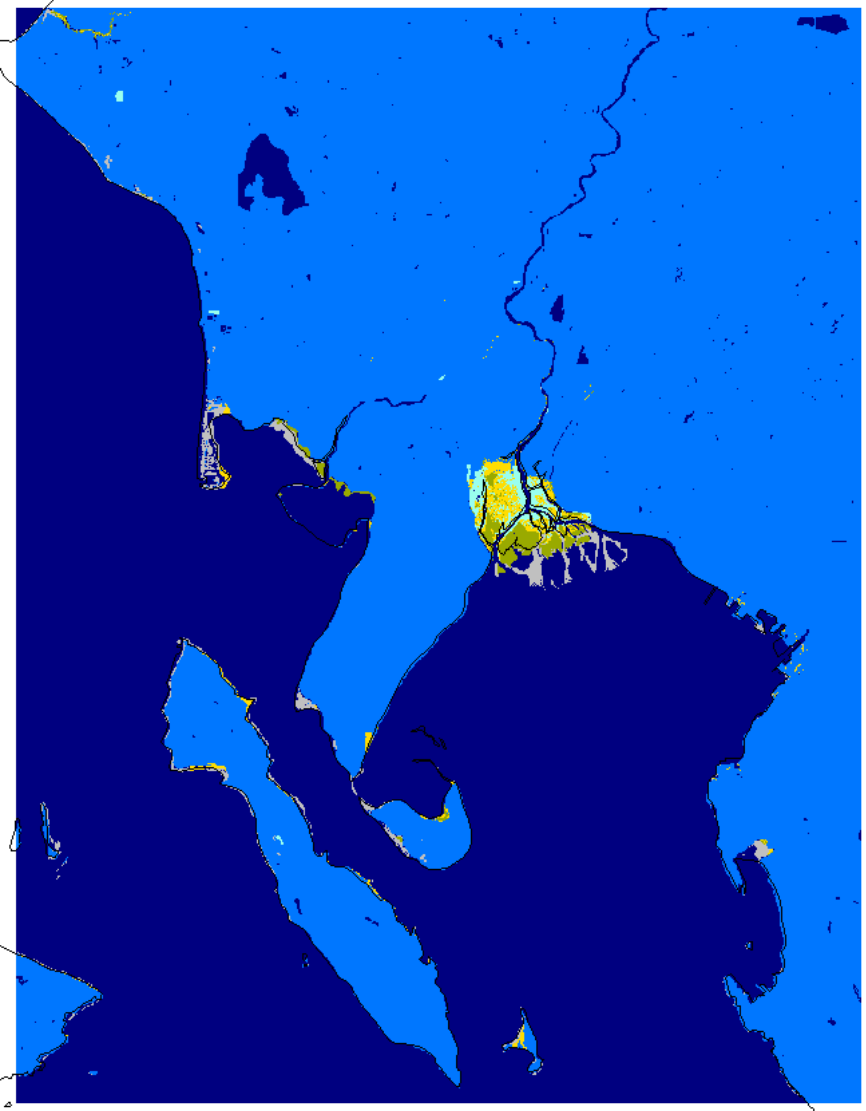
Freshwater Tidal

Bellingham Bay ,Initial Condition

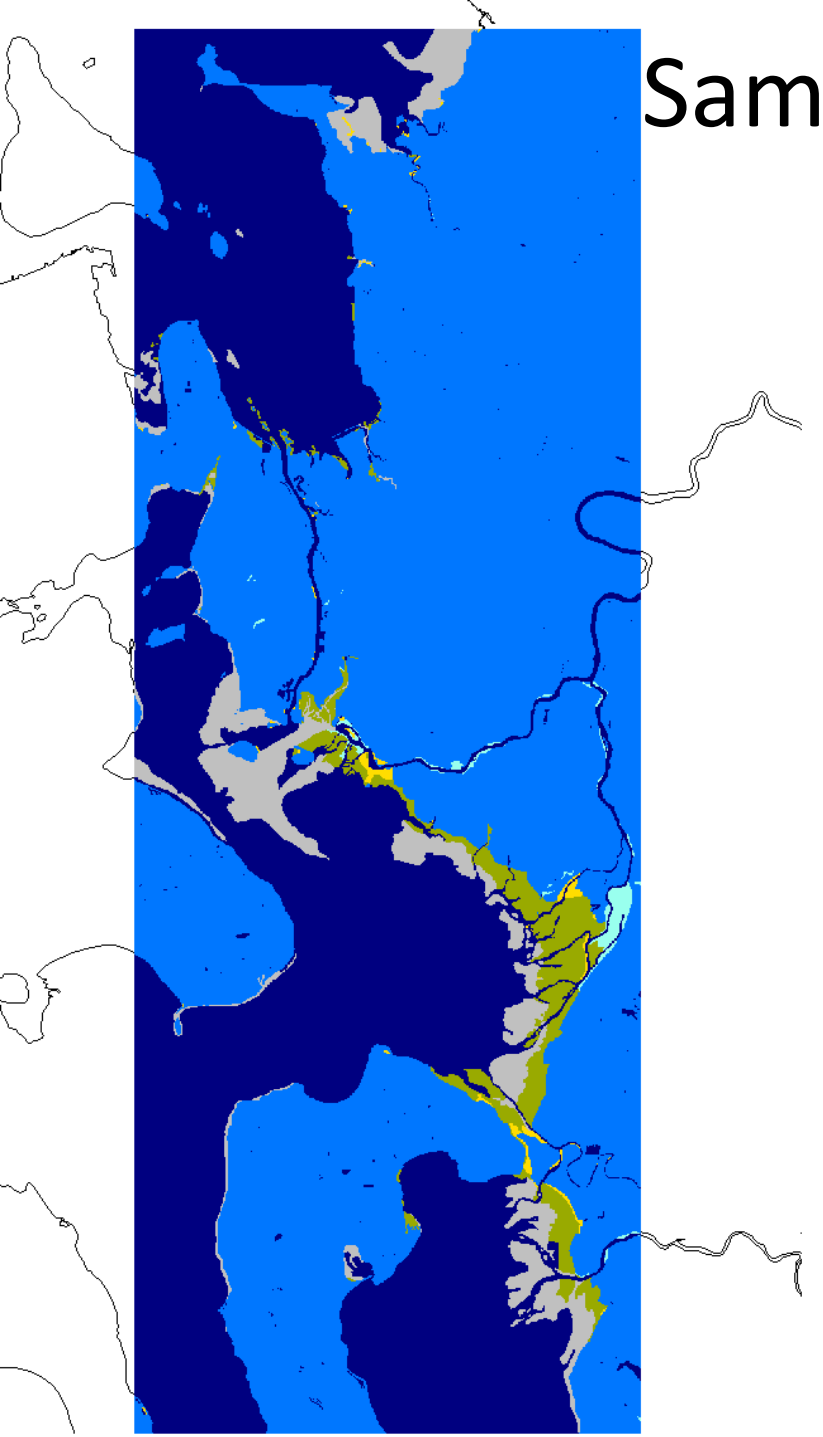


Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	

Bellingham Bay, 2100 A1B Max Dikes

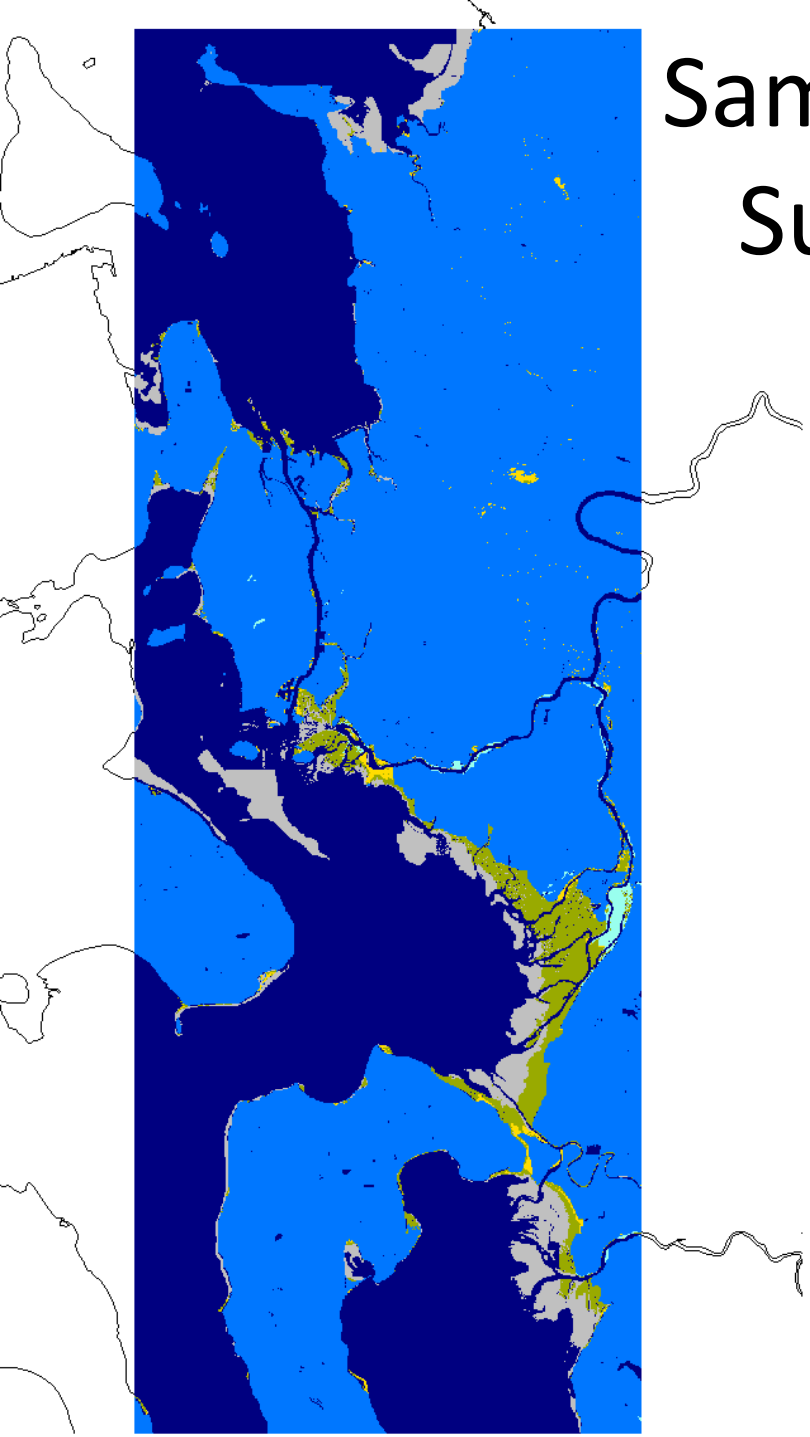


Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	



Samish, Padilla, Skagit, Port Susan Bays, Initial Condition

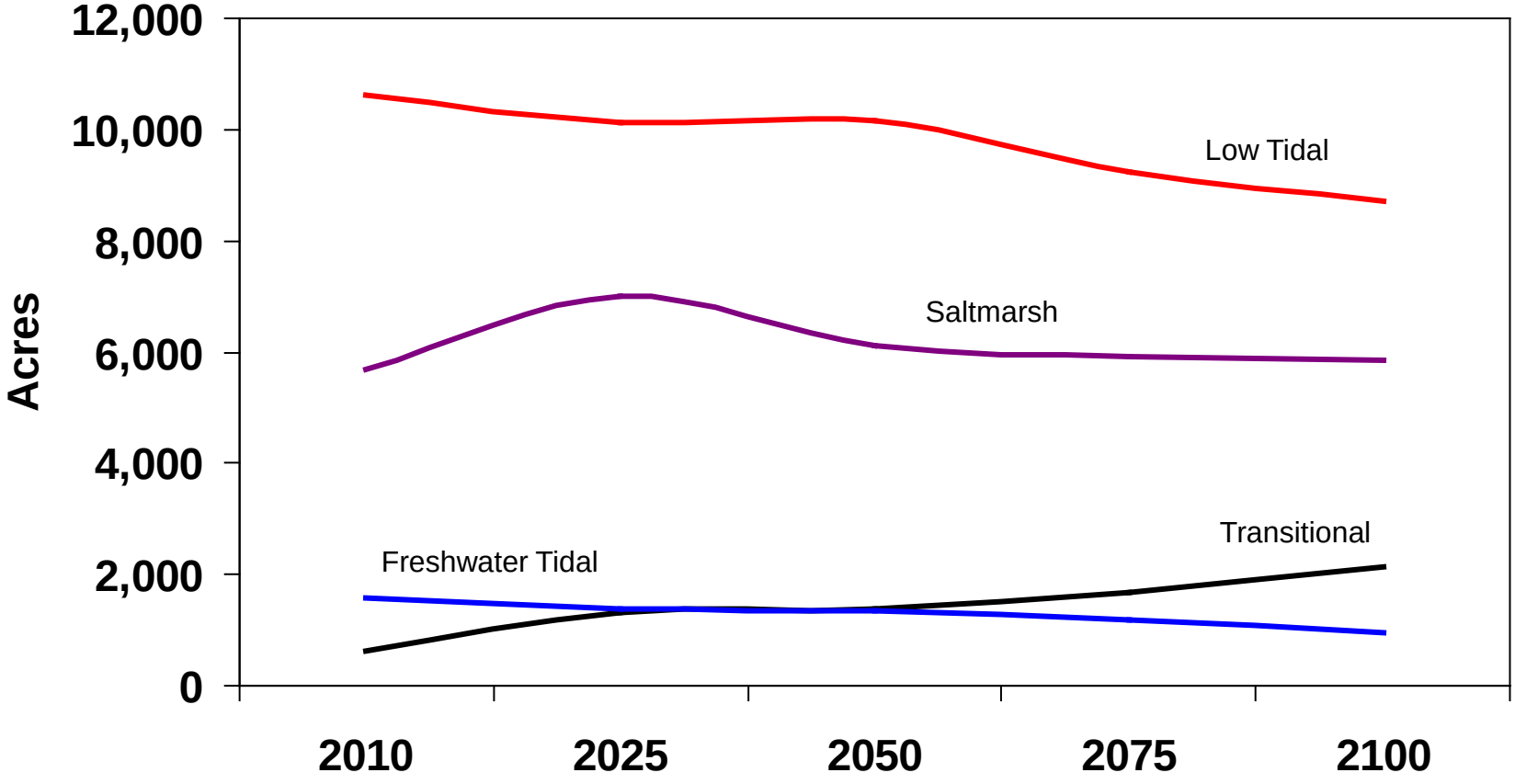
Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	



Samish, Padilla, Skagit, Port Susan Bays, 2100 A1B Max With Dikes

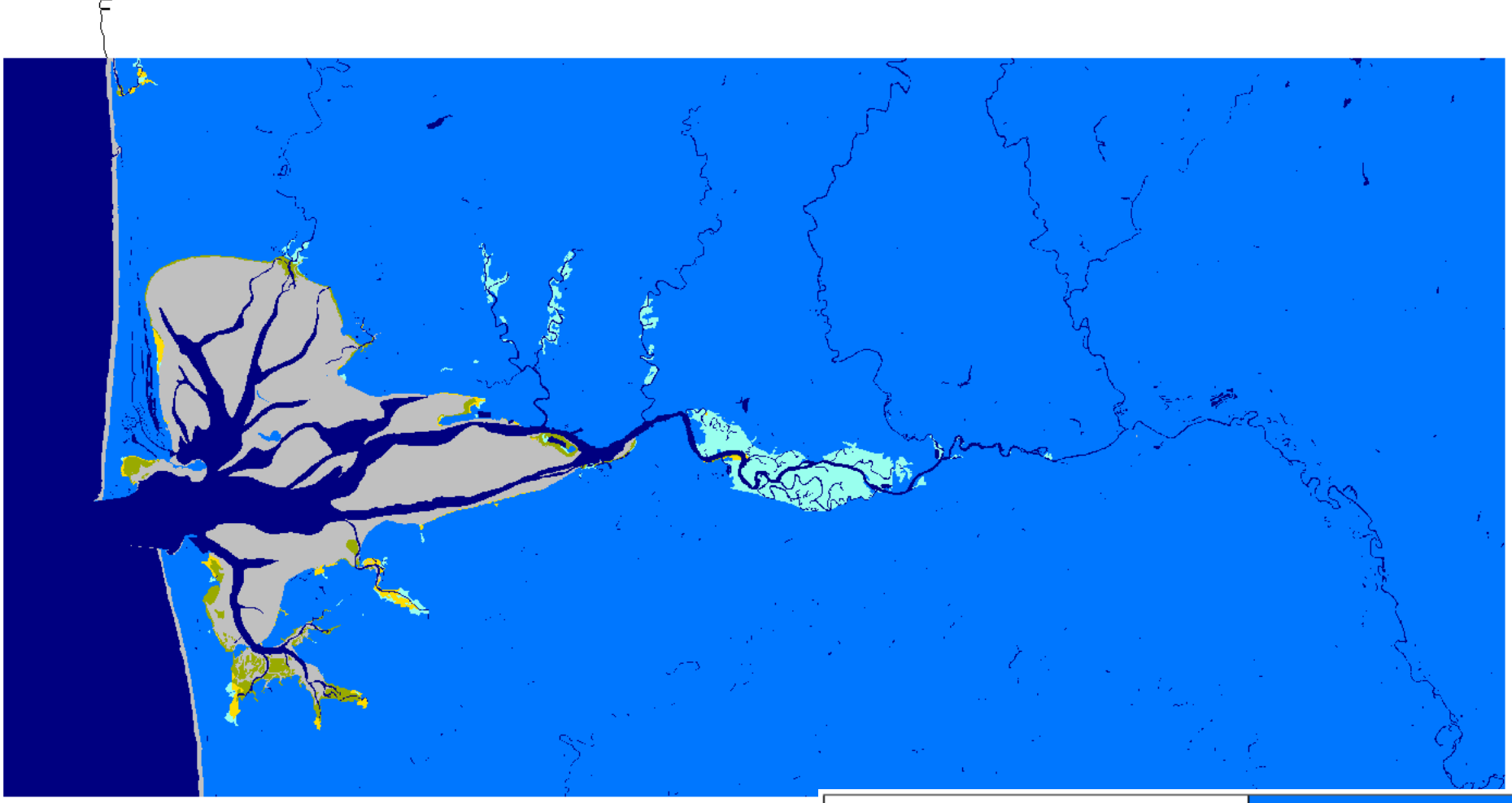
Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	

North Puget Sound



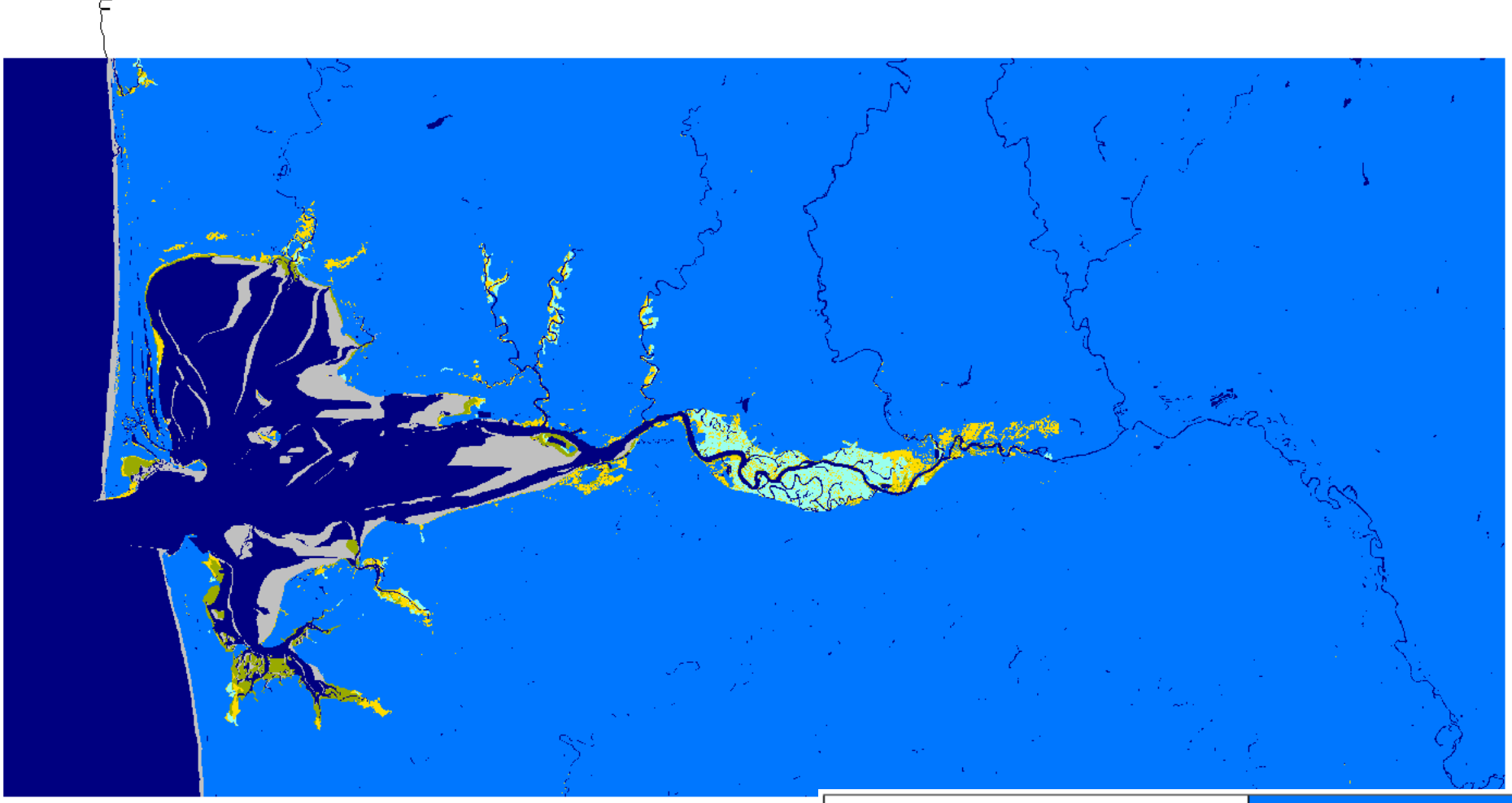
North Puget Sound

Habitat Type	Current Conditions	0.69 SLR	
Low Tidal	10,623	8,723	
Saltmarsh	5,701	5,836	
Transitional	637	2,133	
Freshwater Tidal	1,569	937	



Gray's Harbor, Initial Condition

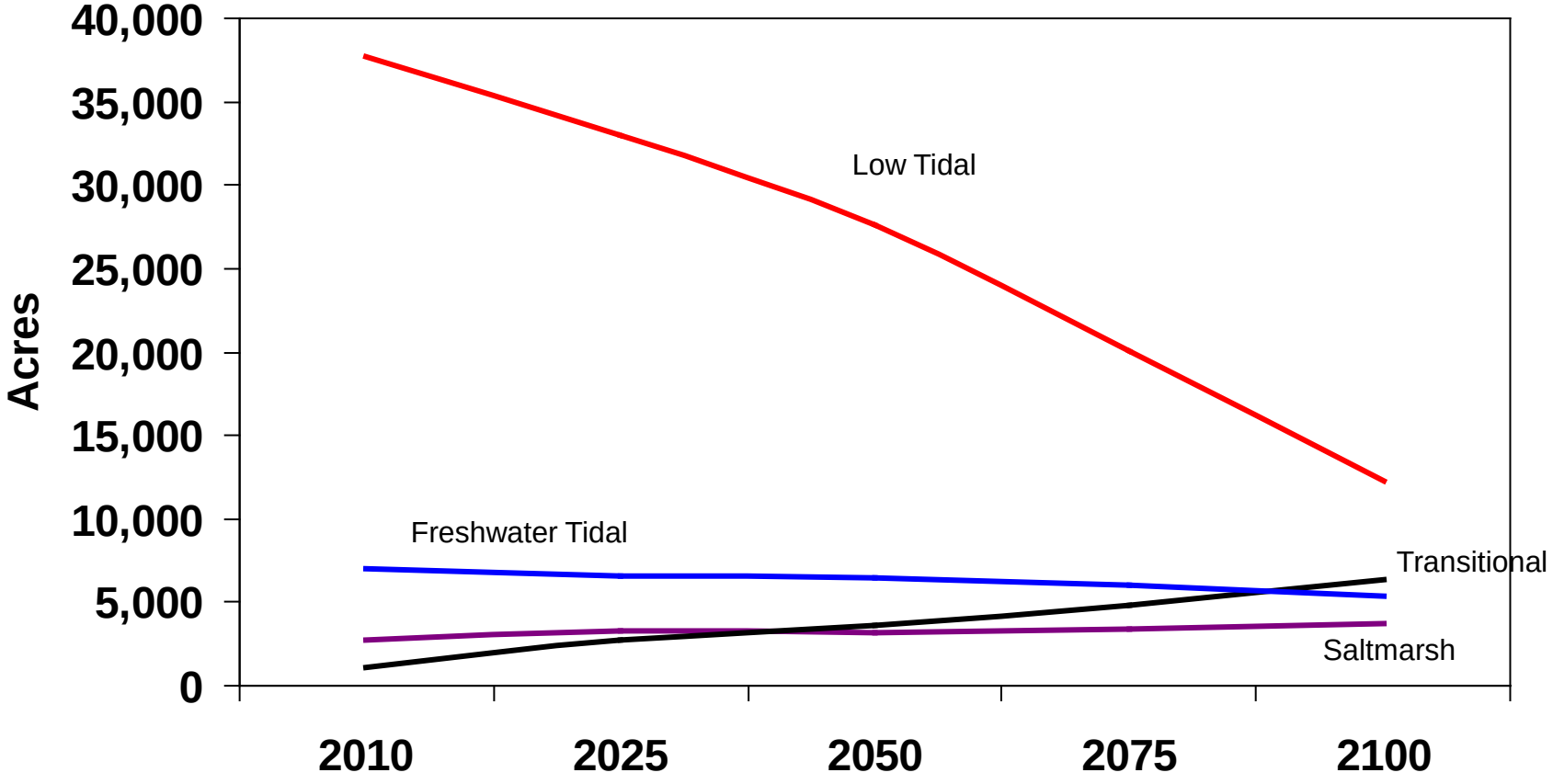
Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	



Gray's Harbor, 2100 A1B Max with Dikes

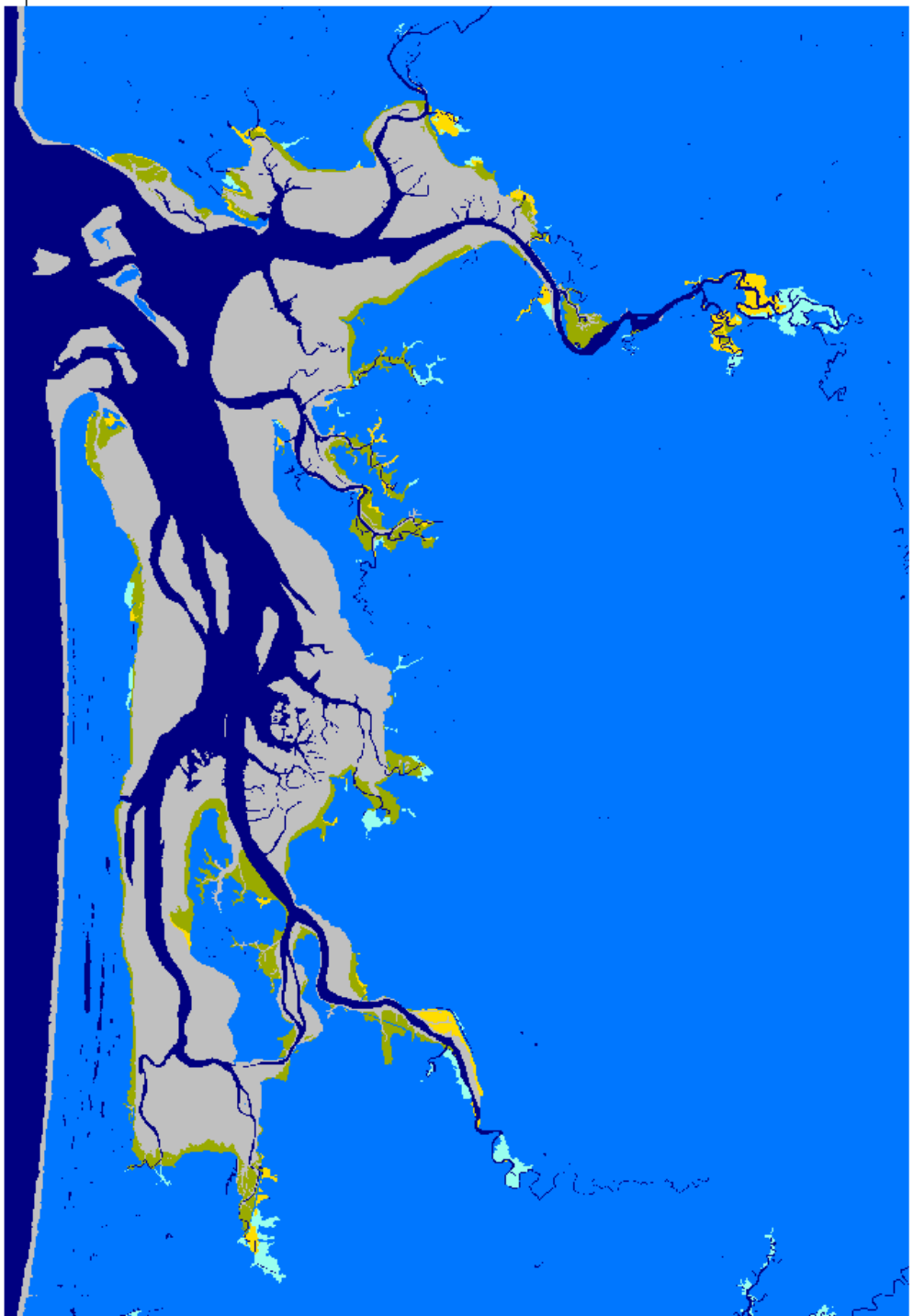
Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	

Grays Harbor



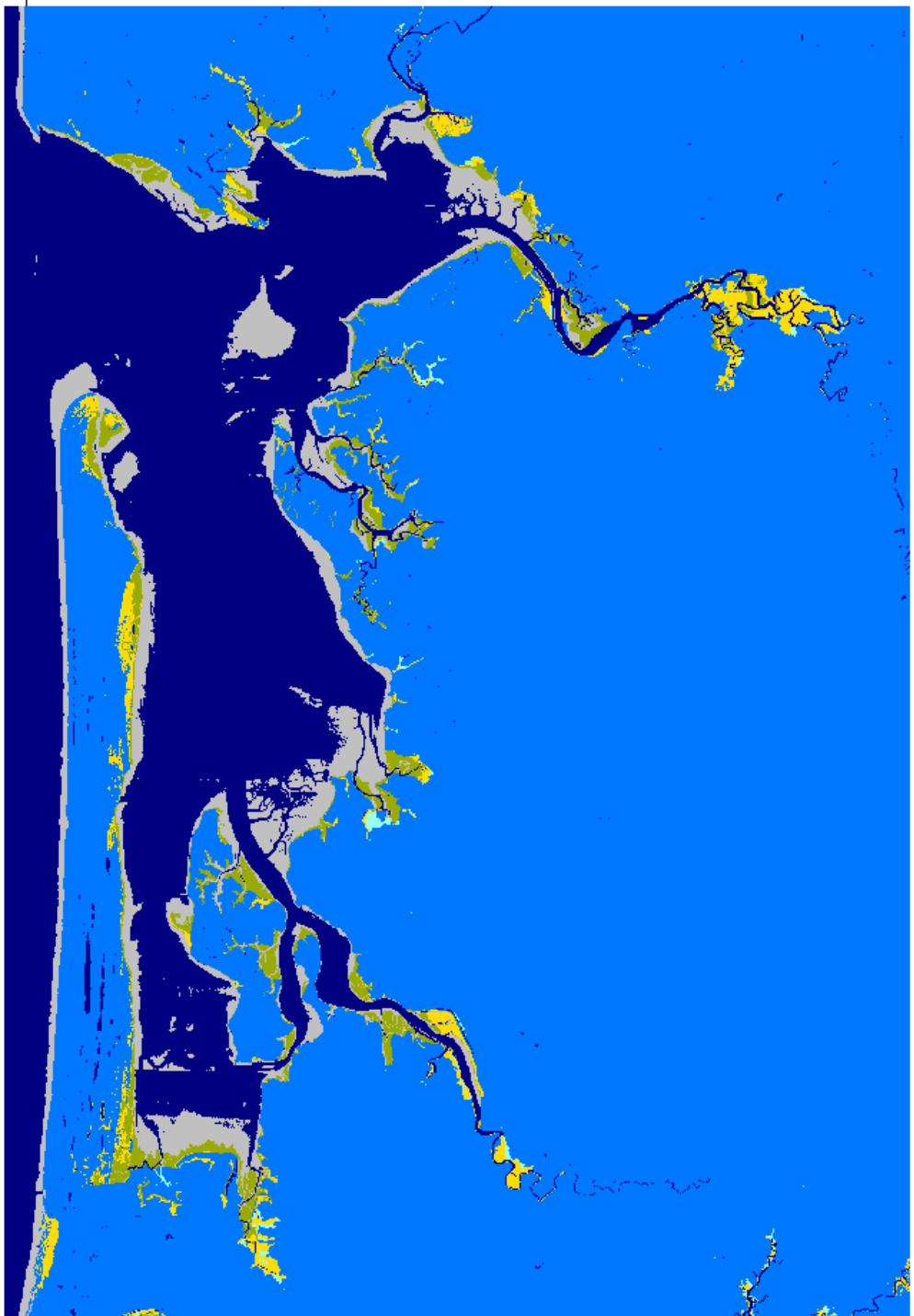
Gray’s Harbor

Habitat Type	Current Conditions	0.69 SLR Dikes in Place	
Low Tidal	37,646	12,271	
Saltmarsh	2,758	3,716	
Transitional	1,135	6,373	
Freshwater Tidal	6,993	5,317	



Willapa Bay, Initial Condition

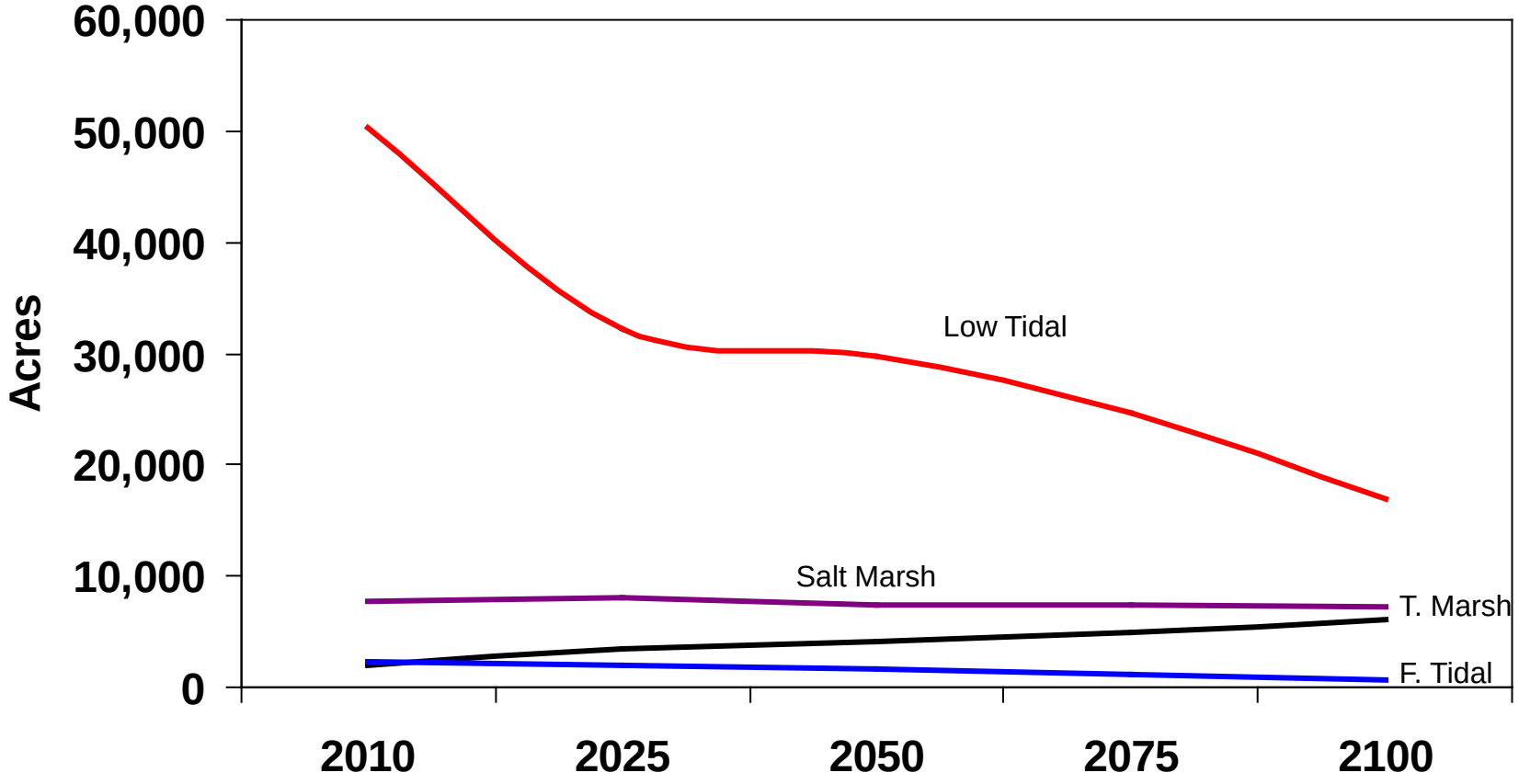
Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	



Willapa Bay, 2100 A1B Max with Dikes

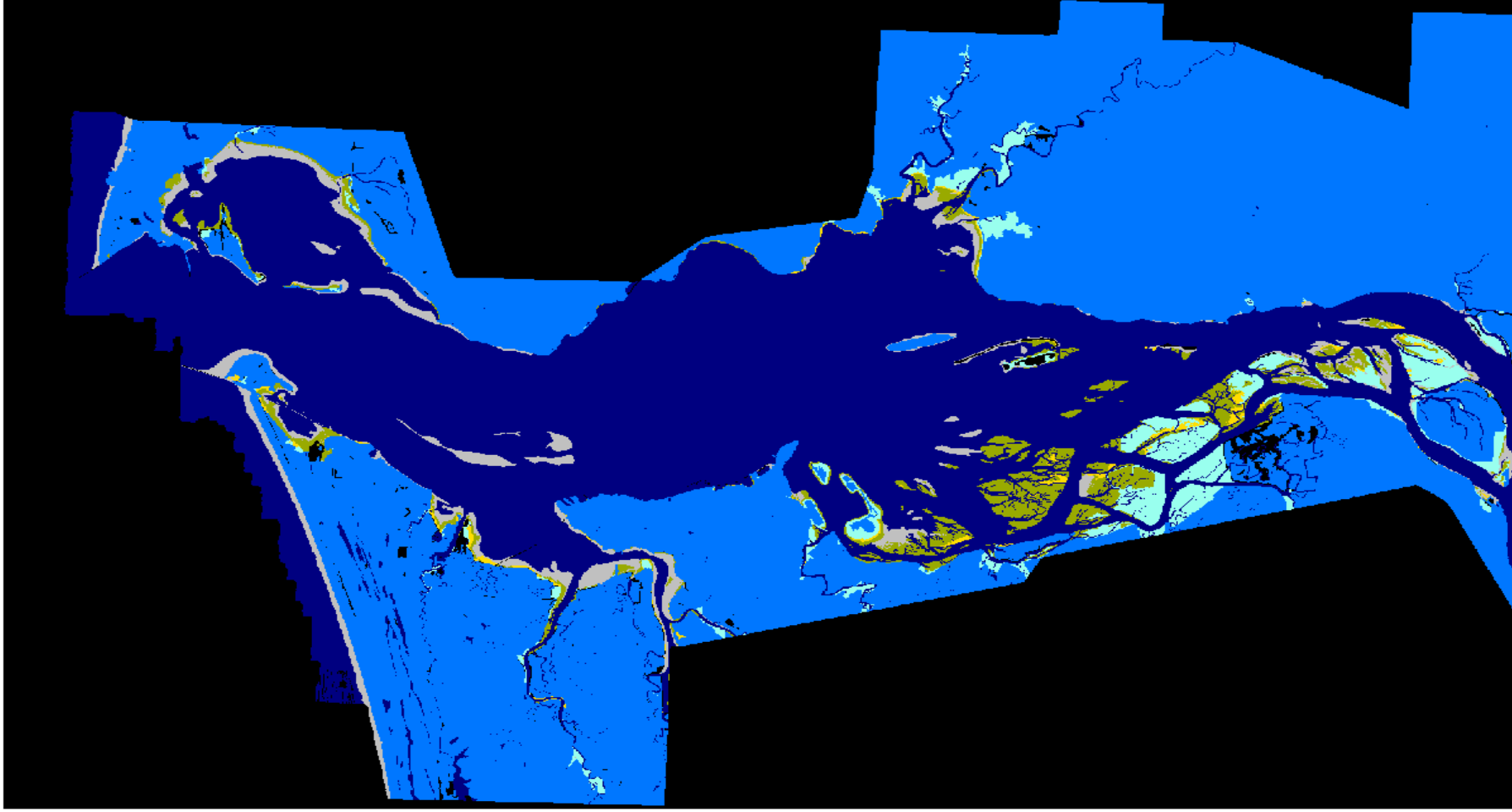
Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	

Willapa Bay


60,000
50,000
40,000
30,000
20,000
10,000
0
Acres
Low Tidal
Salt Marsh
T. Marsh
F. Tidal
2010
2025
2050
2075
2100

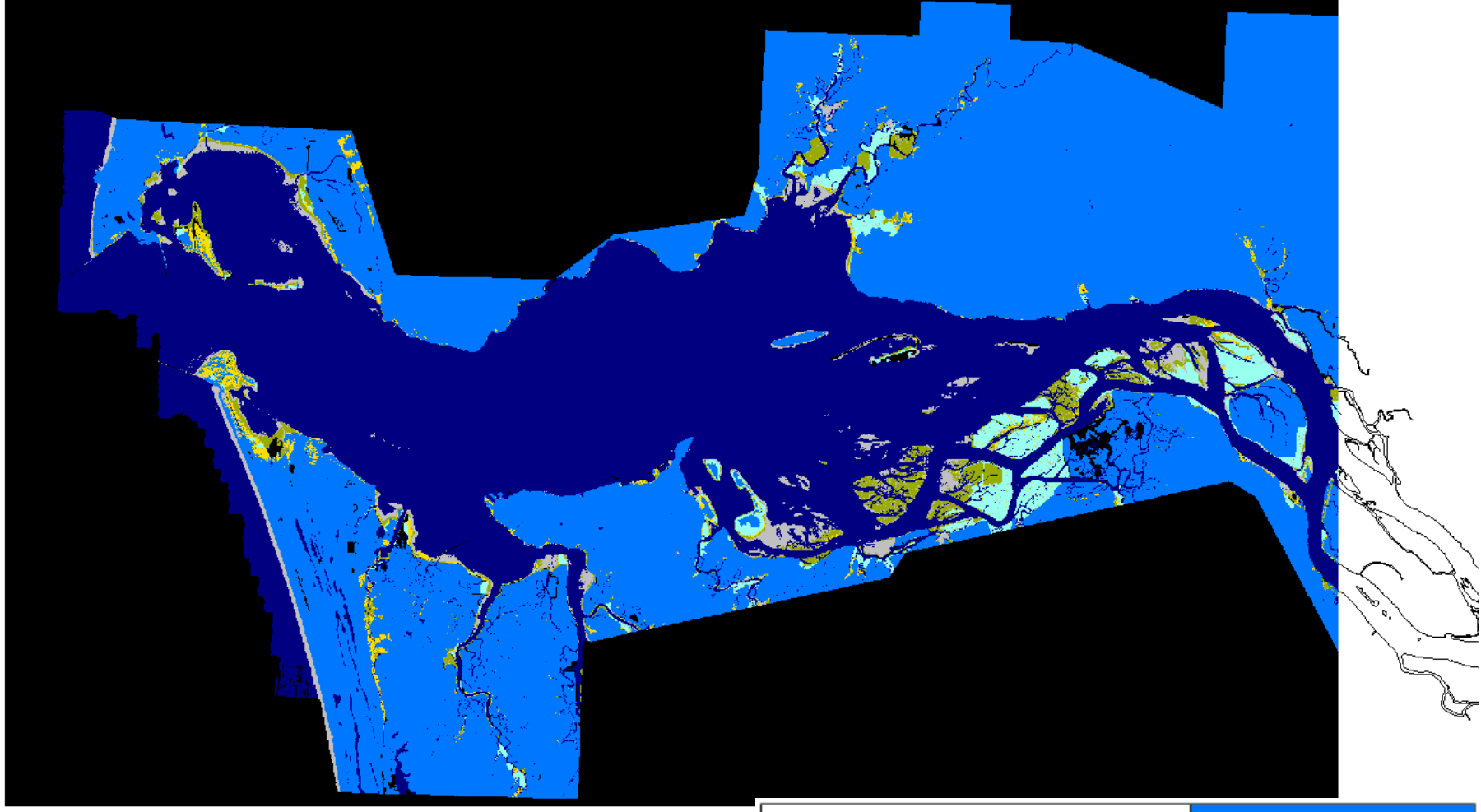
Willapa Bay

Habitat Type	Current Conditions	0.69 SLR Dikes in Place	
Low Tidal	50,268	16,889	
Saltmarsh	7,806	7,307	
Transitional	1,972	6,046	
Freshwater Tidal	1,653	724	



Lower Columbia, Initial Condition

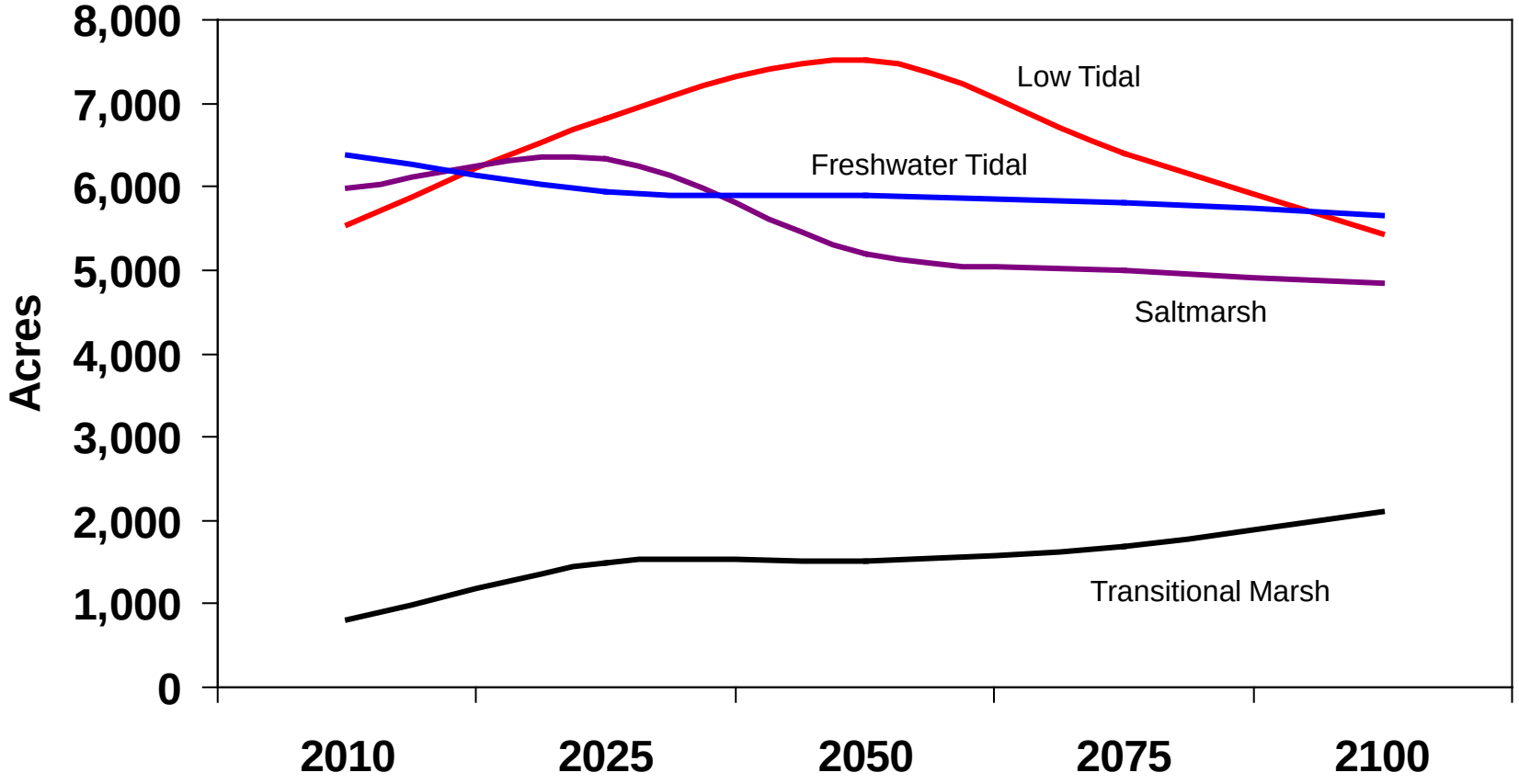
Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	



Lower Columbia, 2100 A1B Max with Dikes

Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	

Lower Columbia



Lower Columbia

Habitat Type	Current Conditions	0.69 SLR Dikes in Place	
Low Tidal	5,545	5,433	
Saltmarsh	5,975	4,848	
Transitional	810	2,103	
Freshwater Tidal	6,370	5,654	

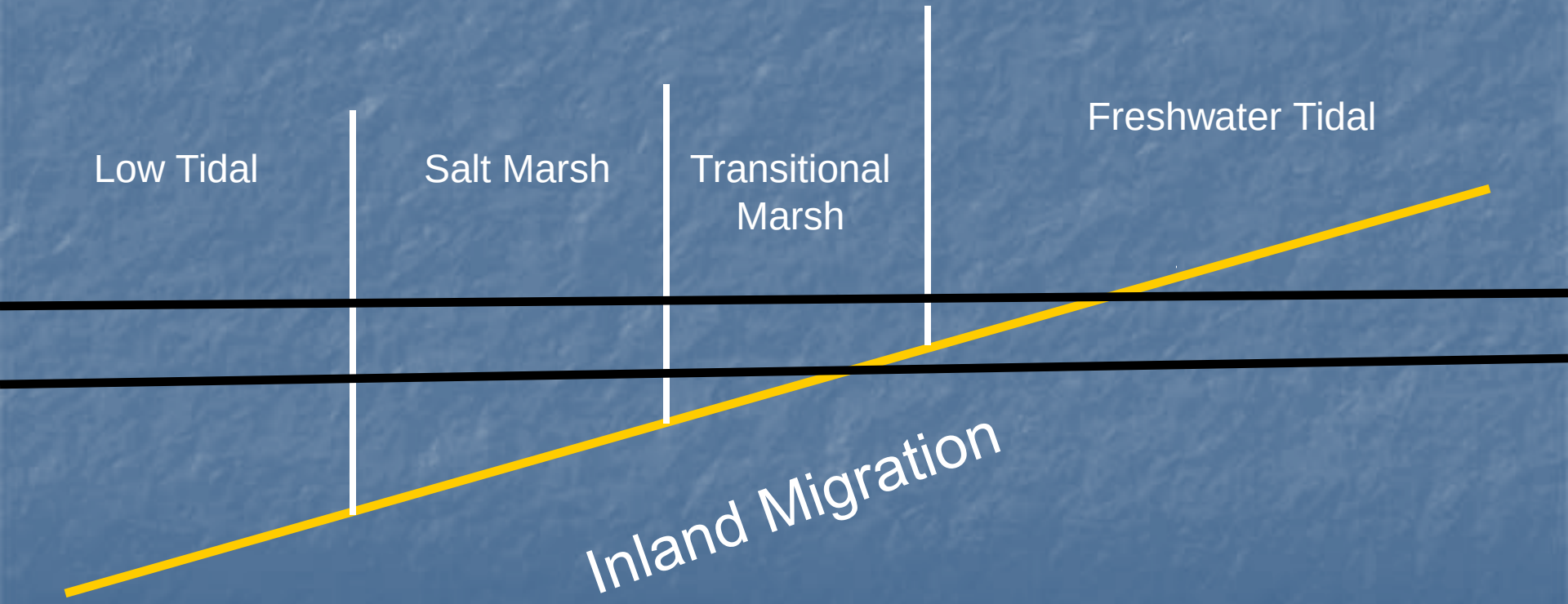
Opportunities to Adapt

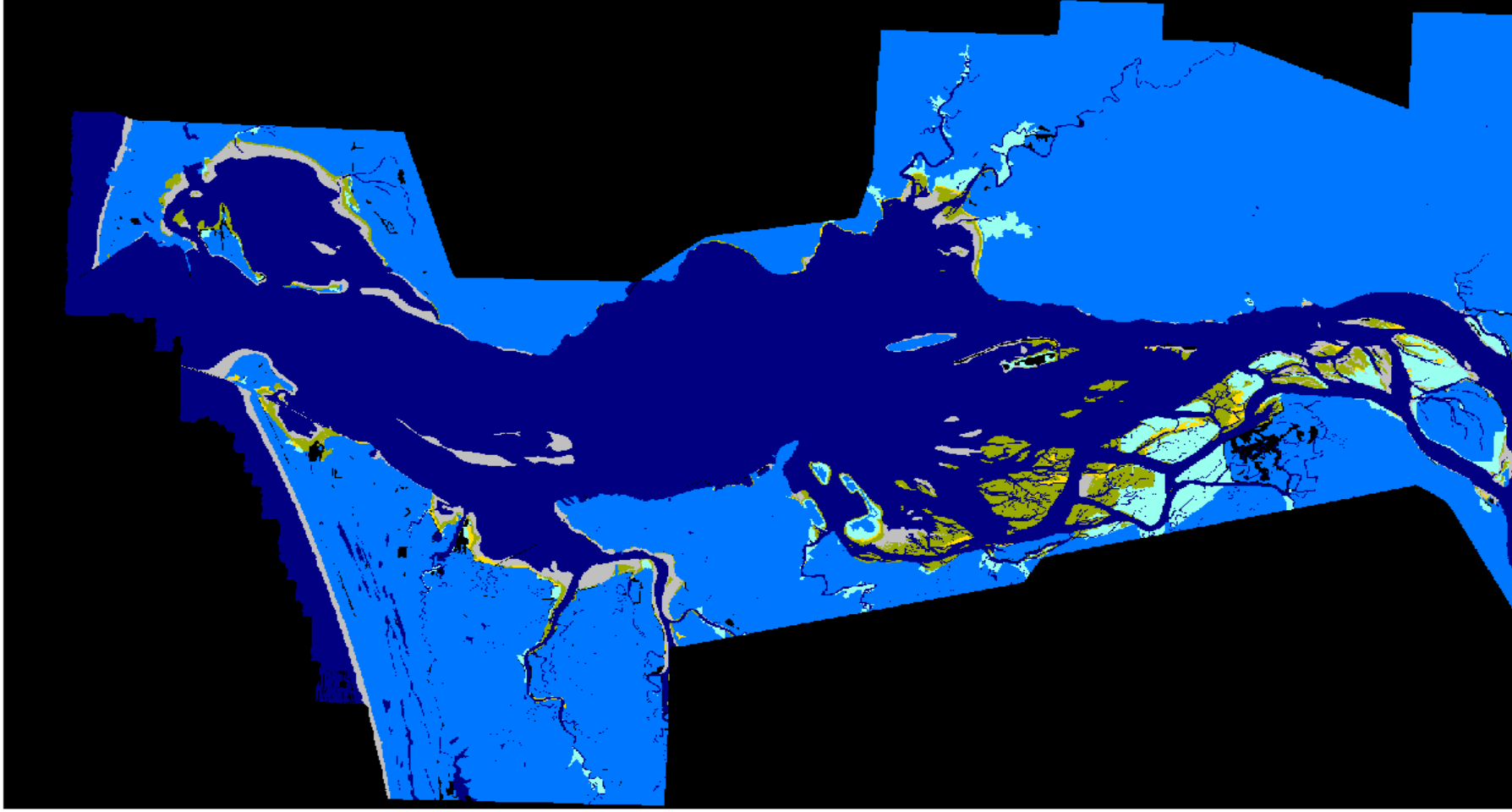
Opportunities to Adapt

"Addressing this issue is urgent only because there are inexpensive opportunities to solve the problem now – opportunities that will be prohibitively costly if we wait until housing developments replace our shorefront farms and forests"

James Titus 1998

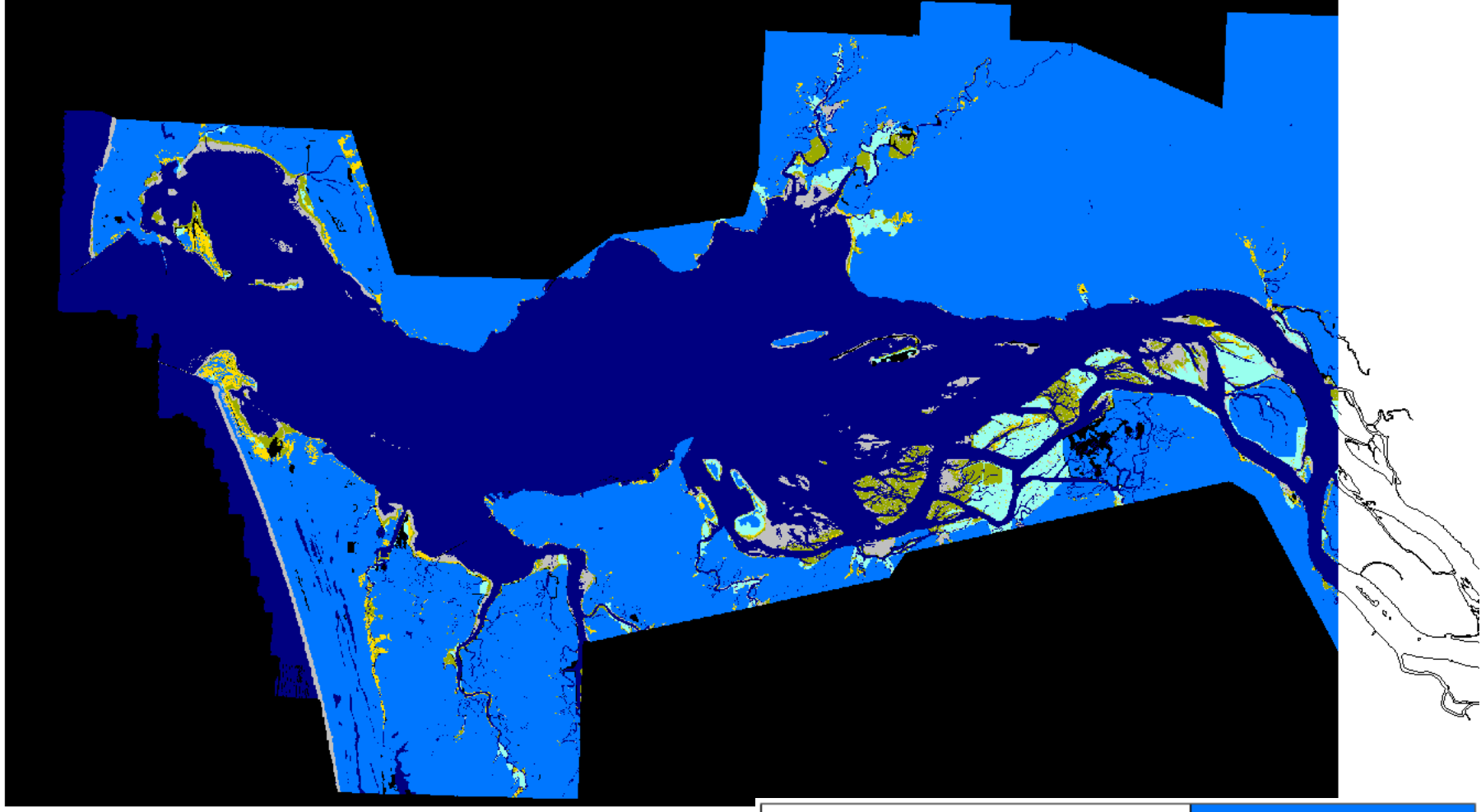
Wetland Classes





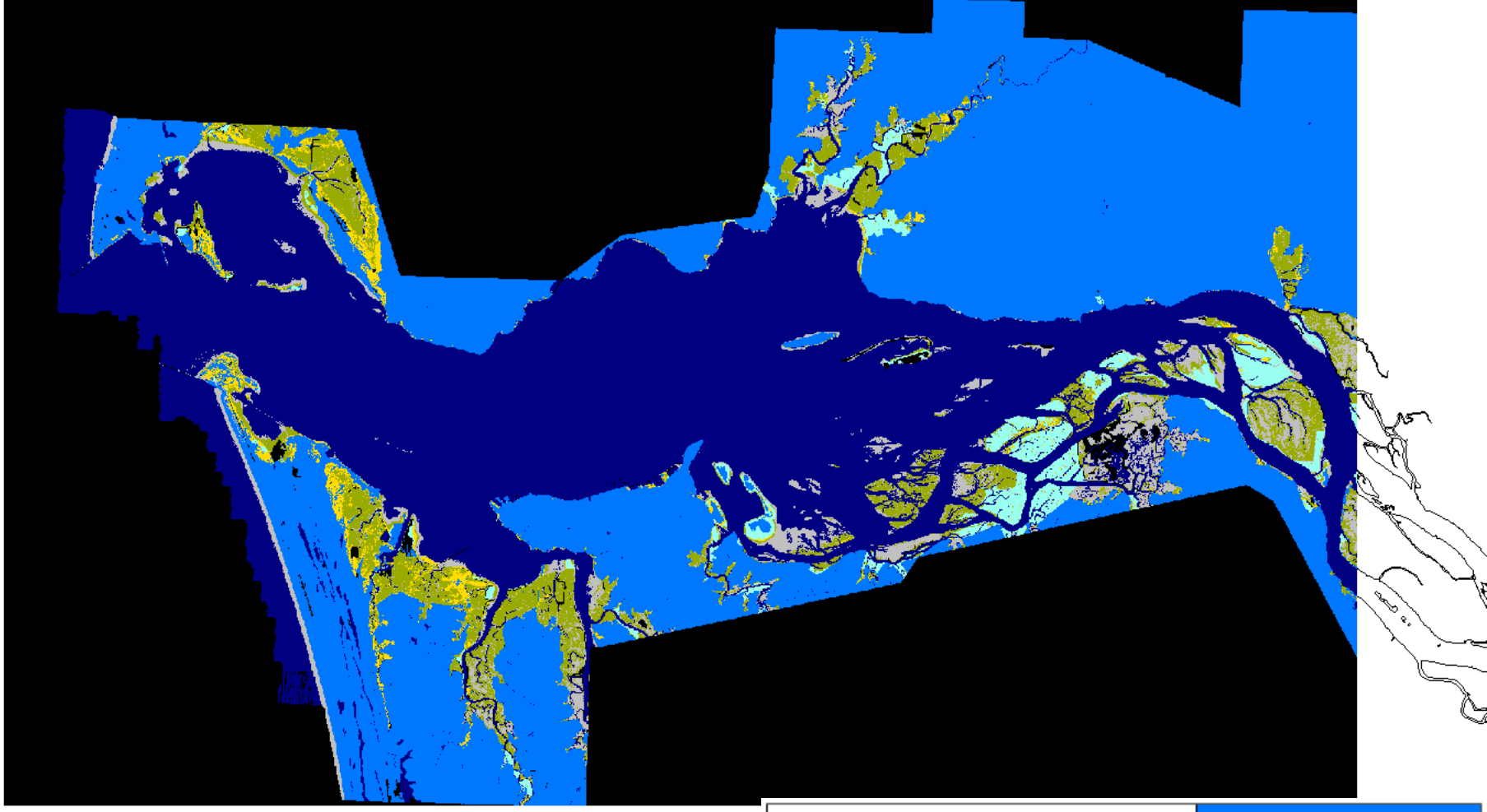
Lower Columbia, Initial Condition

Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	



Lower Columbia, 2100 A1B Max with Dikes

Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	



Lower Columbia, 2100 A1B Max without Dikes

Non Tidal	
Open Water	
Low Tidal	
Saltmarsh	
Transitional	
Freshwater Tidal	

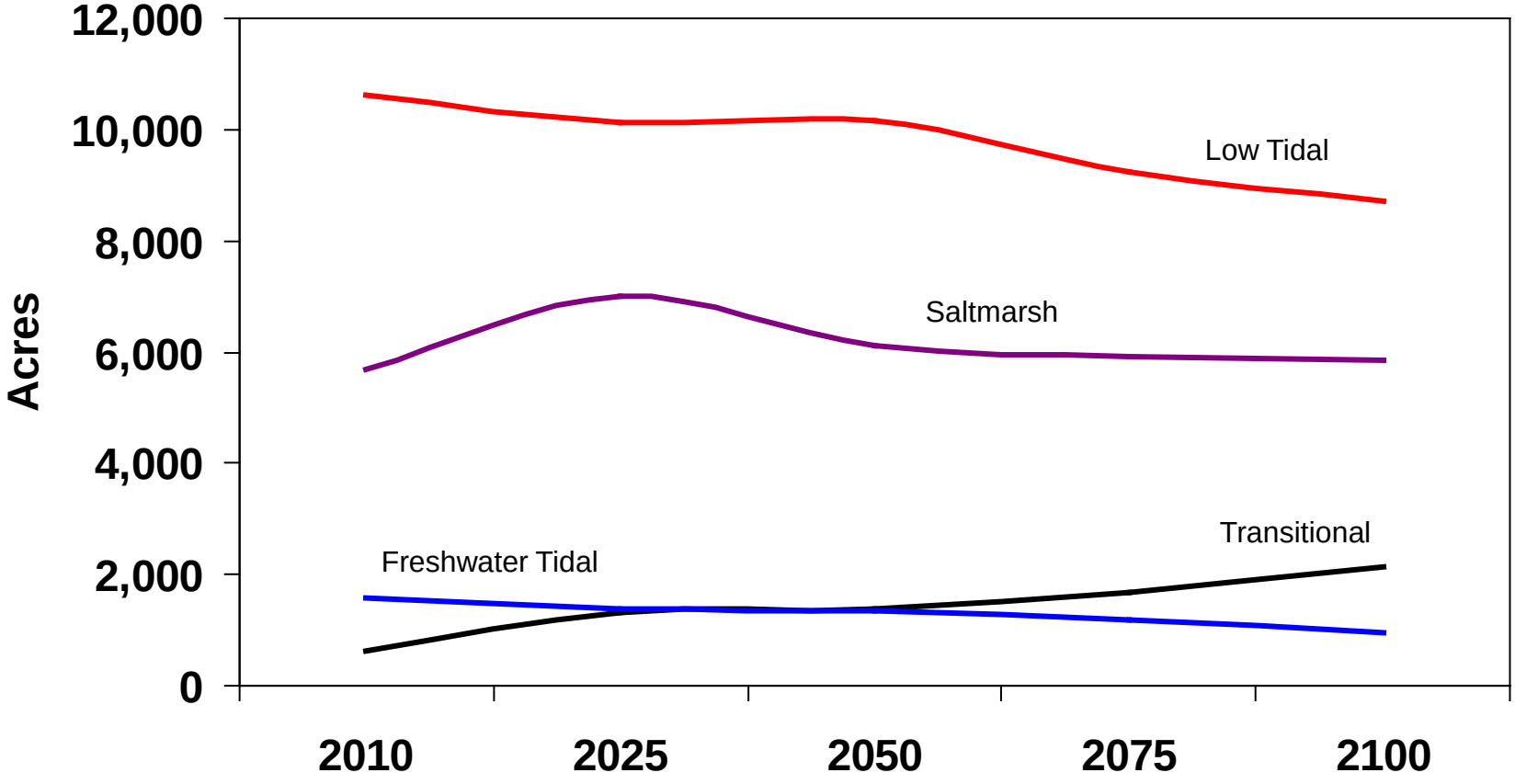
Lower Columbia

Habitat Type	Current Conditions	0.69 SLR Dikes in Place	0.69 SLR Dikes Removed
Low Tidal	5,545	5,433	9,703
Saltmarsh	5,975	4,848	13,990
Transitional	810	2,103	4,218
Freshwater Tidal	6,370	5,654	5,587

ADAPTING TO SLR
Landscape Scale

- Understanding long-term regional changes
- Shorefront easement programs centered on agricultural lands
- Shoreline Management Act
- Floodplain Management
- Hydraulic Code

North Puget Sound



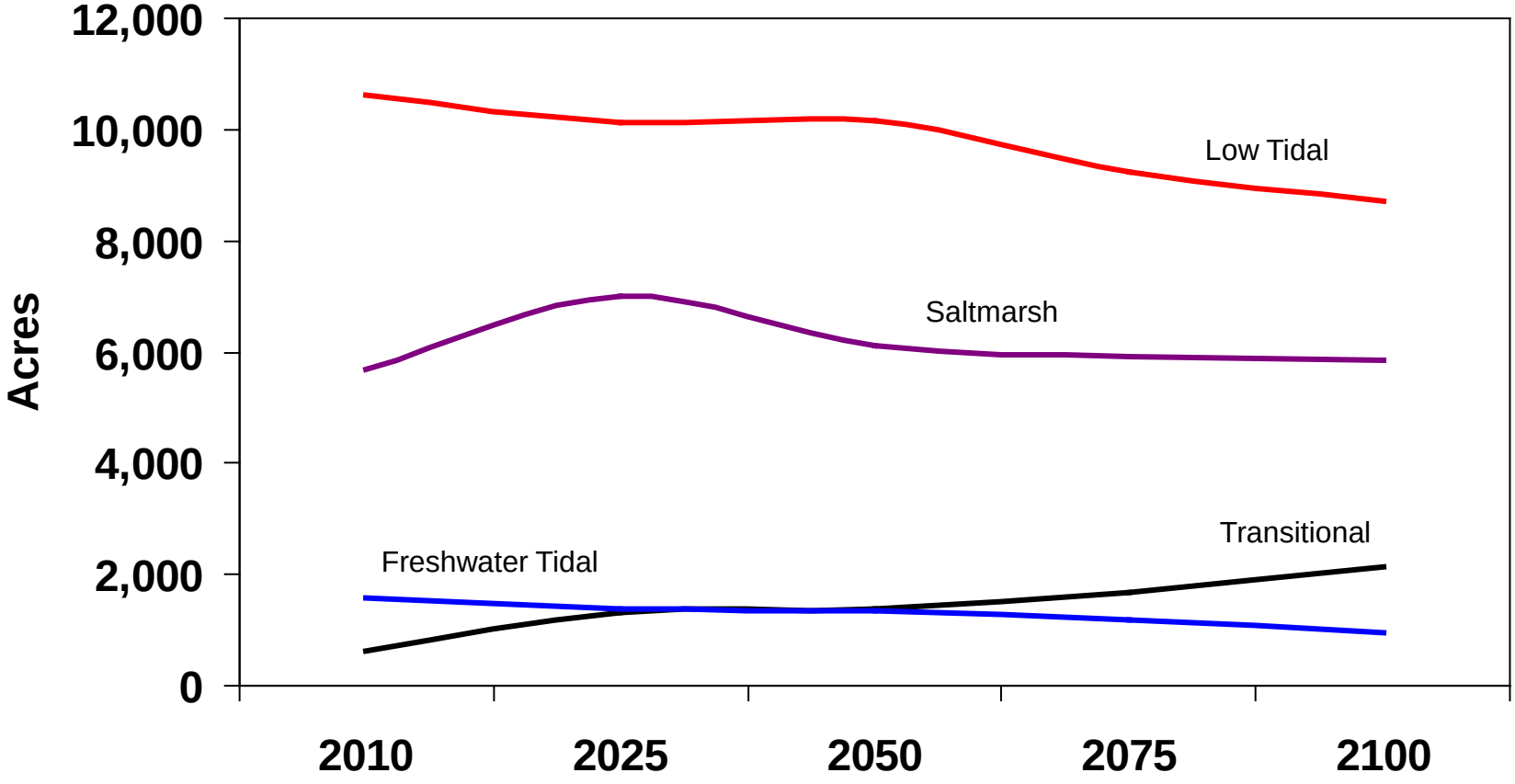
Landowner Interest

Easements (Incentive Based)

ADAPTING TO SLR
Project Scale

- Predicting long-term changes at the project scale (will the project's evolution help offset habitat loss at the larger scale)
- Providing upslope migration opportunities at the project scale

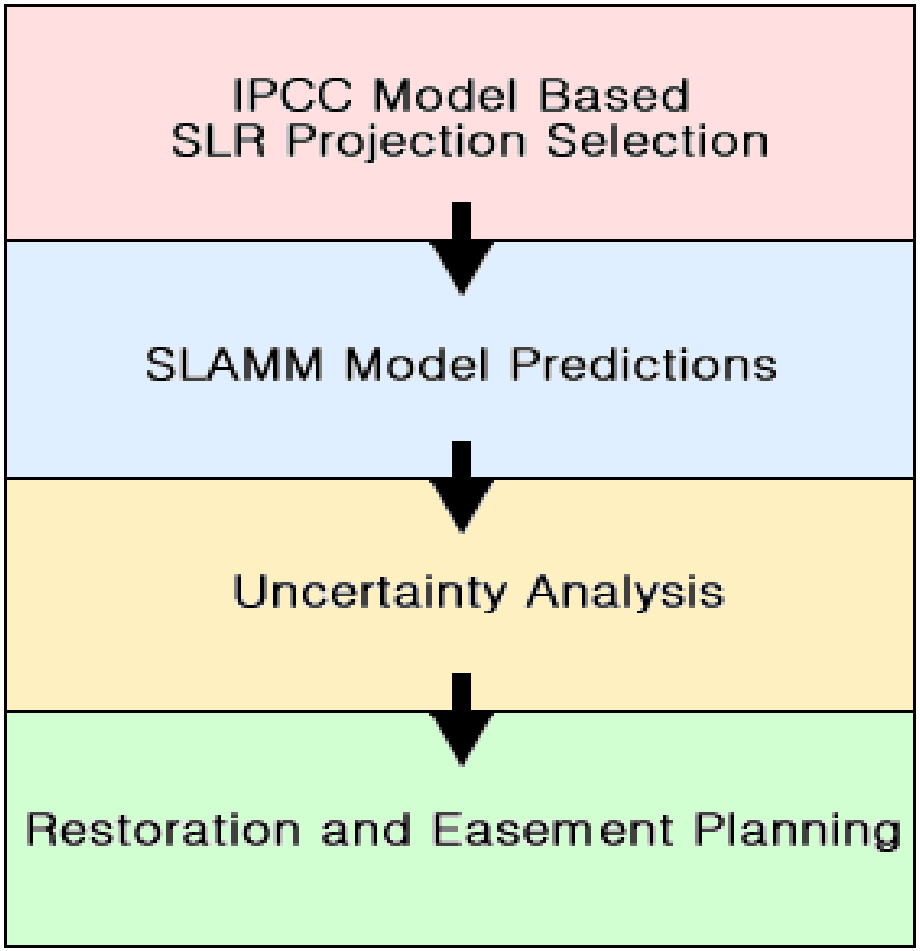
North Puget Sound



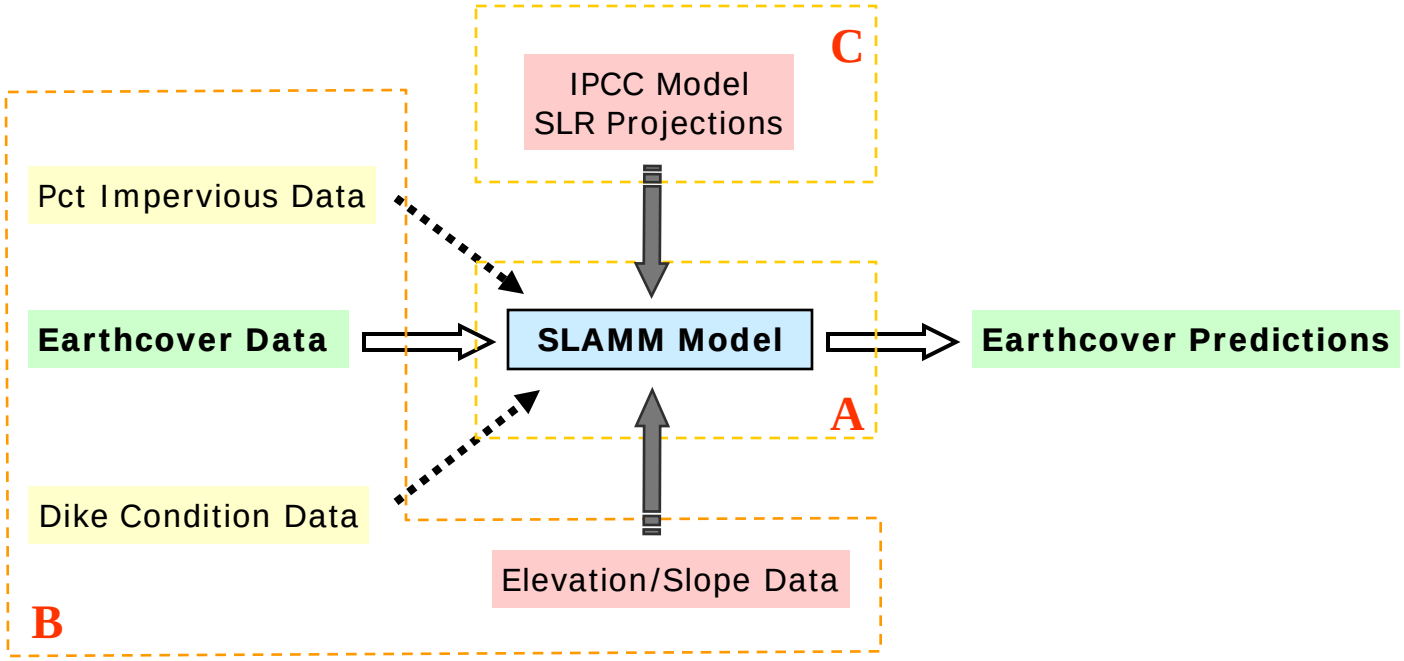
THE ‘IDEAL’ PROJECT

- Adds low tidal or freshwater tidal habitat in the long-term (2100)
- Providing transitional marsh habitat not a priority

Uncertainty Analysis Integration for Coastal Wetlands Conservation Planning



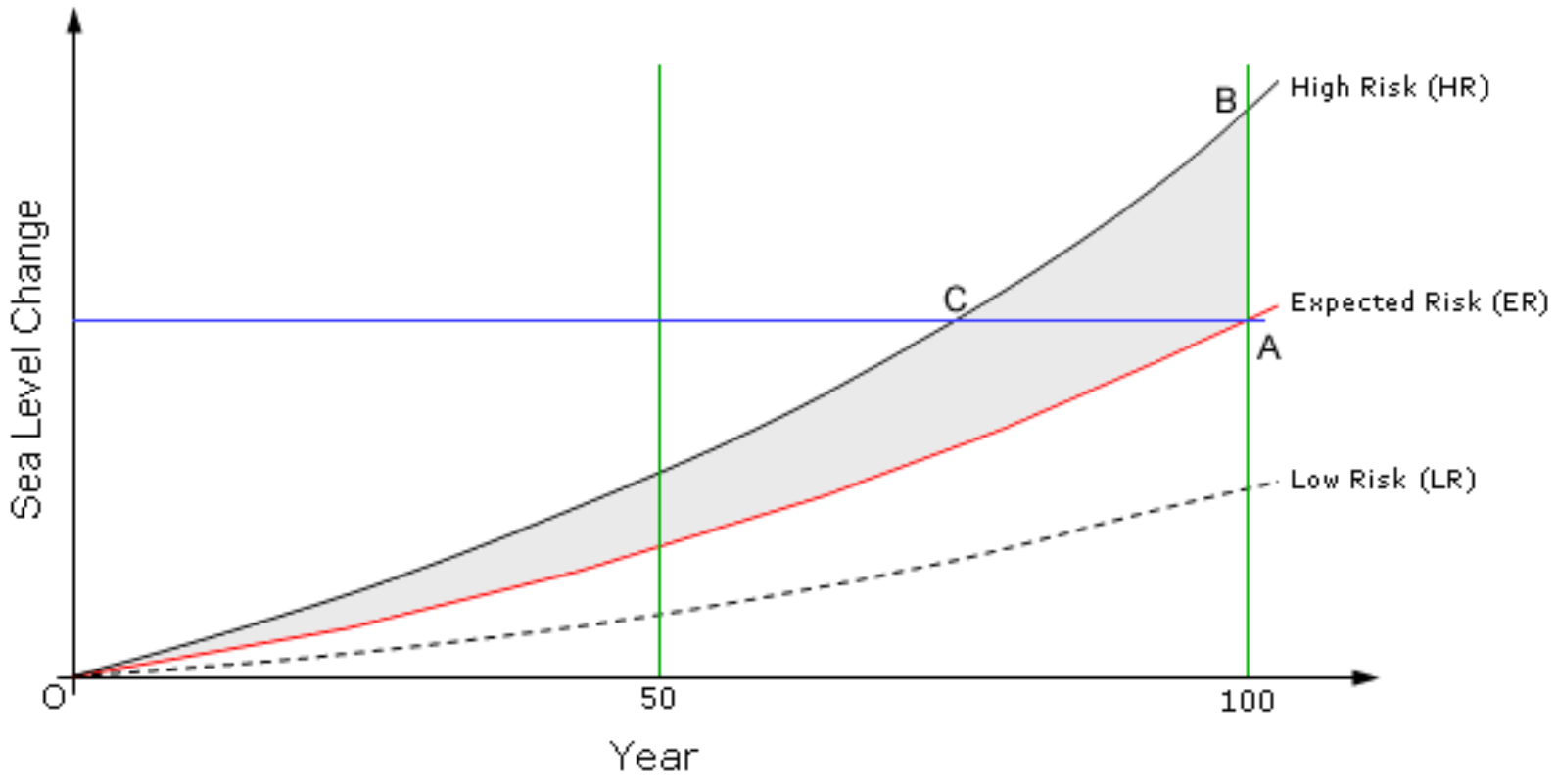
SLAMM Model Working Principle and Uncertainty Sources



New SLAMM Uncertainty Component

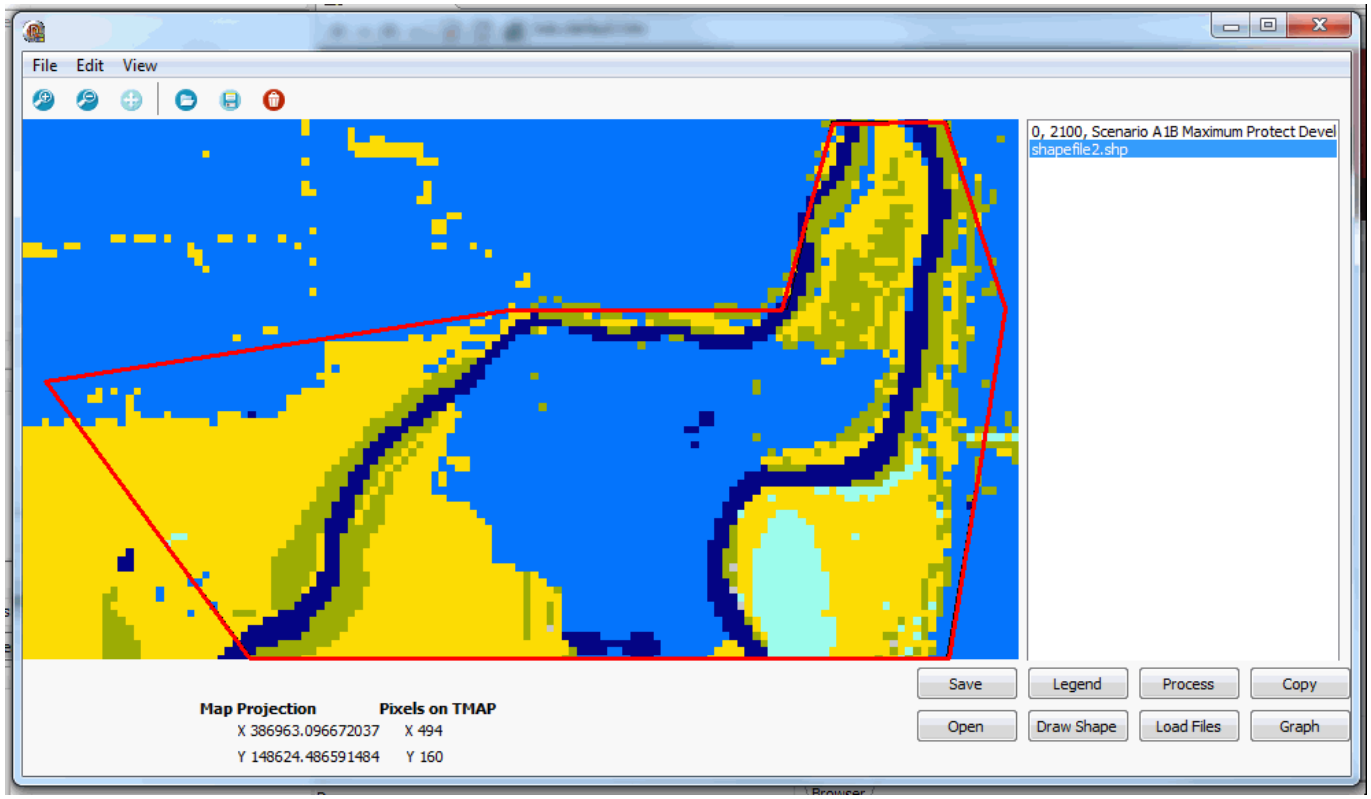
- Ducks Unlimited has funded creation of a new SLAMM uncertainty component that allows for site-specific information about model uncertainty.
- Coding is underway
- Product expected to be available in early 2011

Conservation Risk – Uncertainty above Expected SLR Projection

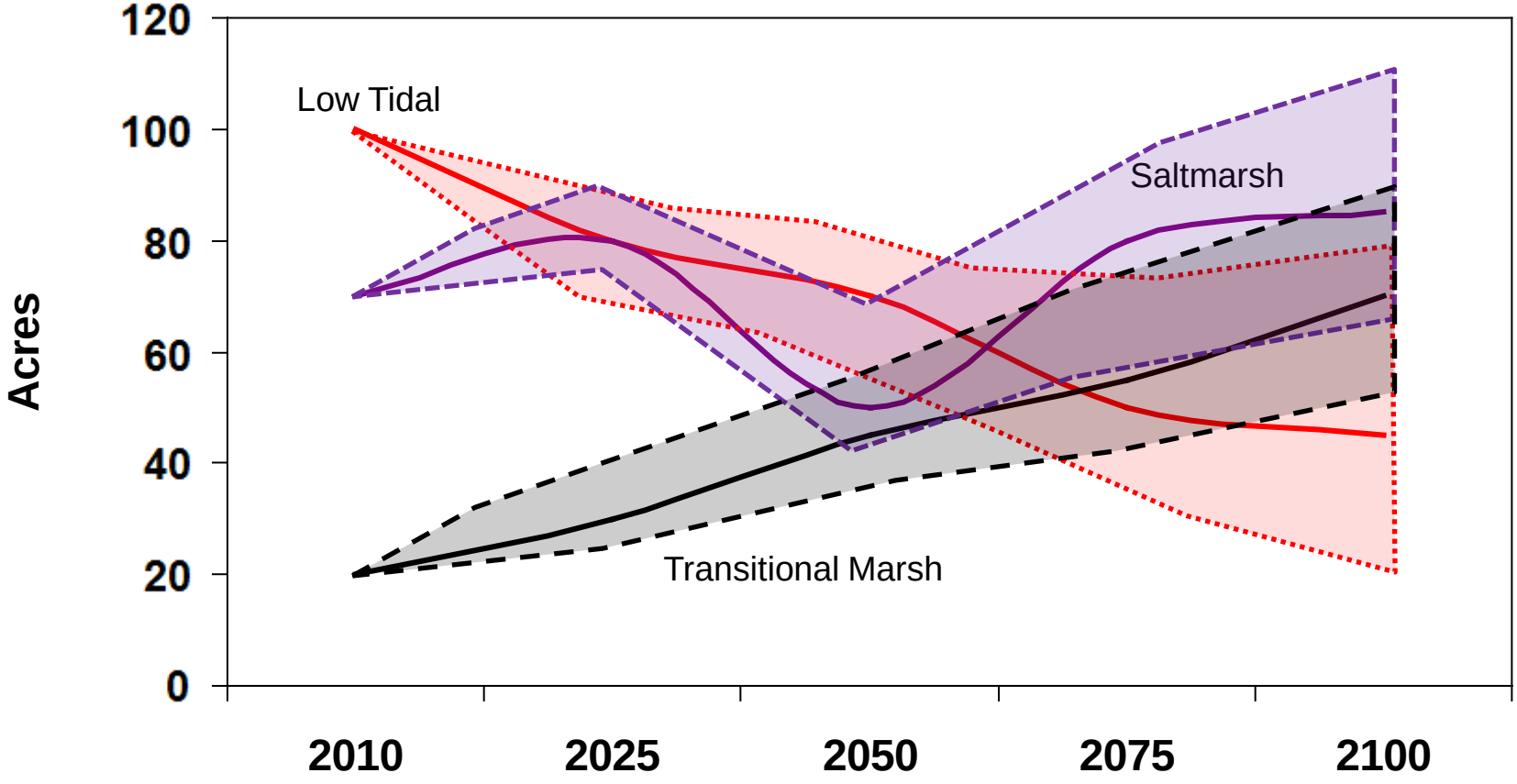


Select Site of Interest

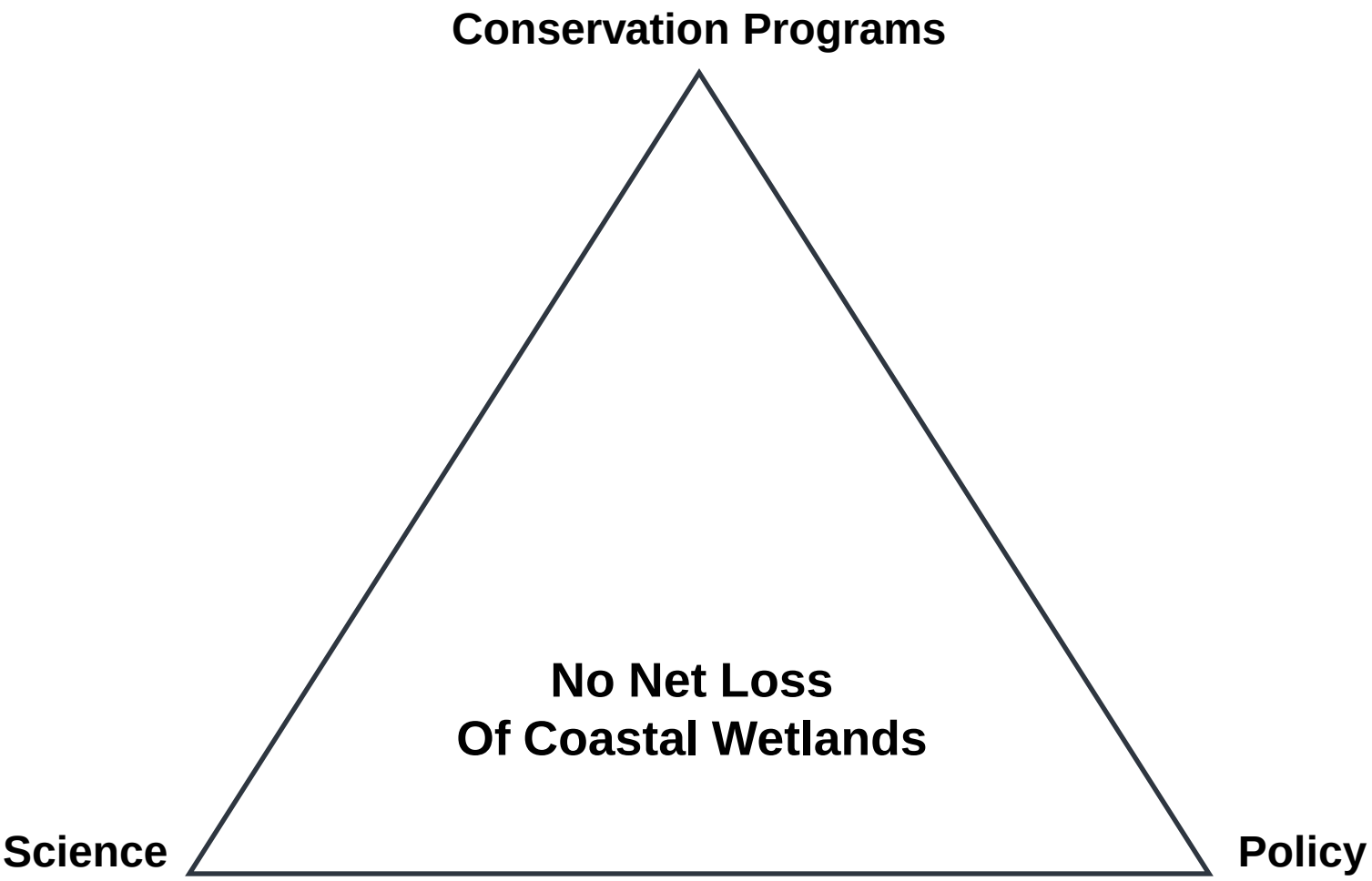
- SLAMM Uncertainty Viewer integrates with available GIS layers or allows user to draw polygon of interest



View uncertainty results on “plot” basis to support decisionmaking



Providing Nature A-Right-of-Way



ACKNOWLEDGEMENTS

- Dr. Jonathan Clough, Warren Pinnacle Consulting
- Dr. Mark Petrie, Ducks Unlimited, Inc.
- Dr. Xiangyue Wei, Ducks Unlimited, Inc.
- Kevin Petrik, Ducks Unlimited, Inc.