Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Willapa NWR

Prepared For: Dr. Brian Czech, Conservation Biologist

U. S. Fish and Wildlife Service
National Wildlife Refuge System
Division of Natural Resources and Conservation Planning
Conservation Biology Program
4401 N. Fairfax Drive - MS 670
Arlington, VA 22203

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Jonathan S. Clough & Evan C. Larson, Warren Pinnacle Consulting, Inc.
PO Box 253, Warren VT, 05674
(802)-496-3476

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Introduction

Tidal marshes are among the most susceptible ecosystems to climate change, especially accelerated sea level rise (SLR). The International Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) suggested that global sea level will increase by approximately 30 cm to 100 cm by 2100 (IPCC 2001). Rahmstorf (2007) suggests that this range may be too conservative and that the feasible range by 2100 could be 50 to 140 cm. Rising sea levels may result in tidal marsh submergence (Moorhead and Brinson 1995) and habitat migration as salt marshes transgress landward and replace tidal freshwater and brackish marsh (Park et al. 1991).

In an effort to address the potential effects of sea level rise on United States national wildlife refuges, the U. S. Fish and Wildlife Service contracted the application of the SLAMM model for most Region 1 refuges. This analysis is designed to assist in the production of comprehensive conservation plans (CCPs) for each refuge along with other long-term management plans.

Model Summary

Changes in tidal marsh area and habitat type in response to sea-level rise were modeled using the Sea Level Affecting Marshes Model (SLAMM 6) that accounts for the dominant processes involved in wetland conversion and shoreline modifications during long-term sea level rise (Park et al. 1989; www.warrenpinnacle.com/prof/SLAMM).

Successive versions of the model have been used to estimate the impacts of sea level rise on the coasts of the U.S. (Titus et al., 1991; Lee, J.K., R.A. Park, and P.W. Mausel. 1992; Park, R.A., J.K. Lee, and D. Canning 1993; Galbraith, H., R. Jones, R.A. Park, J.S. Clough, S. Herrod-Julius, B. Harrington, and G. Page. 2002; National Wildlife Federation et al., 2006; Glick, Clough, et al. 2007; Craft et al., 2009).

Within SLAMM, there are five primary processes that affect wetland fate under different scenarios of sea-level rise:

- **Inundation:** The rise of water levels and the salt boundary are tracked by reducing elevations of each cell as sea levels rise, thus keeping mean tide level (MTL) constant at zero. The effects on each cell are calculated based on the minimum elevation and slope of that cell.
- **Erosion:** Erosion is triggered based on a threshold of maximum fetch and the proximity of the marsh to estuarine water or open ocean. When these conditions are met, horizontal erosion occurs at a rate based on site-specific data.
- **Overwash:** Barrier islands of under 500 meters width are assumed to undergo overwash during each 25-year time-step due to storms. Beach migration and transport of sediments are calculated.
- **Saturation:** Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to rising sea level close to the coast.

- **Accretion:** Sea level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category. Accretion rates may be spatially variable within a given model domain or can be specified to respond to feedbacks such as frequency of inundation.

SLAMM Version 6.0 was developed in 2008/2009 and is based on SLAMM 5. SLAMM 6.0 provides backwards compatibility to SLAMM 5, that is, SLAMM 5 results can be replicated in SLAMM 6. However, SLAMM 6 also provides several optional capabilities.

- Accretion Feedback Component: Feedbacks based on wetland elevation, distance to channel, and salinity may be specified. This feedback will be used in USFWS simulations, but only where adequate data exist for parameterization.
- Salinity Model: Multiple time-variable freshwater flows may be specified. Salinity is estimated and mapped at MLLW, MHHW, and MTL. Habitat switching may be specified as a function of salinity. This optional sub-model is not utilized in USFWS simulations.
- Integrated Elevation Analysis: SLAMM will summarize site-specific categorized elevation ranges for wetlands as derived from LiDAR data or other high-resolution data sets. This functionality is used in USFWS simulations to confirm the SLAMM conceptual model at each site.
- Flexible Elevation Ranges for land categories: If site-specific data indicate that wetland elevation ranges are outside of SLAMM defaults, a different range may be specified within the interface. In USFWS simulations, the use of values outside of SLAMM defaults is rarely utilized. If such a change is made, the change and the reason for it are fully documented within the model application reports.
- Many other graphic user interface and memory management improvements are also part of the new version including an updated *Technical Documentation*, and context sensitive help files.

For a thorough accounting of SLAMM model processes and the underlying assumptions and equations, please see the SLAMM 6.0 *Technical Documentation* (Clough, Park, Fuller, 2010). This document is available at http://warrenpinnacle.com/prof/SLAMM

All model results are subject to uncertainty due to limitations in input data, incomplete knowledge about factors that control the behavior of the system being modeled, and simplifications of the system (CREM 2008). Site-specific factors that increase or decrease model uncertainty may be covered in the *Discussion* section of this report.

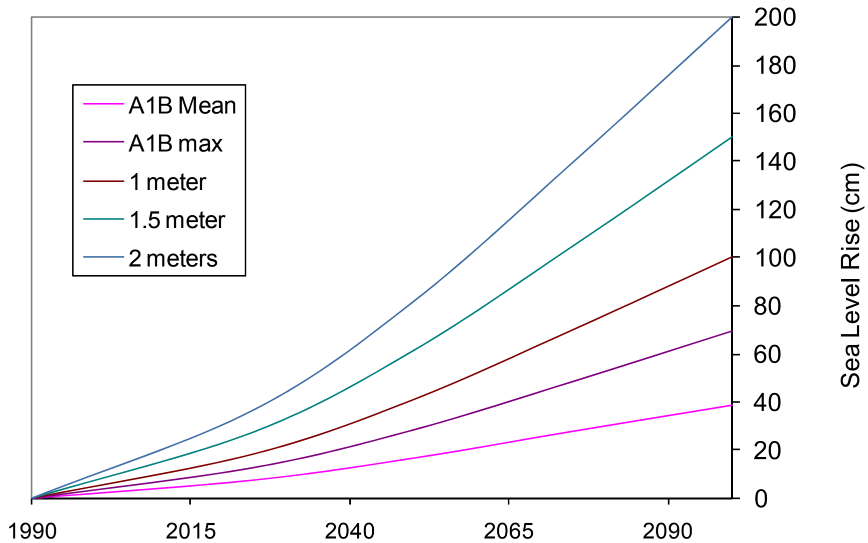
Sea Level Rise Scenarios

SLAMM 6 was run using scenario A1B from the Special Report on Emissions Scenarios (SRES) – mean and maximum estimates. The A1 scenario assumes that the future world includes very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. In particular, the A1B scenario assumes that energy sources will be balanced across all sources. Under the A1B scenario, the IPCC WGI Fourth Assessment Report (IPC, 2007) suggests a likely range of 0.21 to 0.48 meters of sea level rise by 2090-2099 "excluding future rapid dynamical changes in ice flow." The A1B-mean scenario that was run as a part of this project falls near the middle of this estimated range, predicting 0.40 meters of global sea level rise by 2100.

The latest literature (Chen et al., 2006, Monaghan et al., 2006) indicates that the eustatic rise in sea levels is progressing more rapidly than was previously assumed, perhaps due to the dynamic changes in ice flow omitted within the IPCC report's calculations. A recent paper in the journal *Science* (Rahmstorf, 2007) suggests that, taking into account possible model error, a feasible range by 2100 might be 50 to 140 cm. This work was recently updated and the ranges were increased to 75 to 190 cm (Vermeer and Rahmstorf, 2009). Pfeffer et al. (2008) suggests that 2 meters by 2100 is at the upper end of plausible scenarios due to physical limitations on glaciological conditions. A recent US intergovernmental report states "Although no ice-sheet model is currently capable of capturing the glacier speedups in Antarctica or Greenland that have been observed over the last decade, including these processes in models will very likely show that IPCC AR4 projected sea level rises for the end of the 21st century are too low." (US Climate Change Science Program, 2008) A recent paper by Grinsted et. al. (2009) states that "sea level 2090-2099 is projected to be 0.9 to 1.3 m for the A1B scenario, with low probability of the rise being within Intergovernmental Panel on Climate Change (IPCC) confidence limits."

To allow for flexibility when interpreting the results, SLAMM was also run assuming 1 meter, 1½ meters, and 2 meters of eustatic sea-level rise by the year 2100. The A1B- maximum scenario was scaled up to produce these bounding scenarios (Figure 1).

Figure 1: Summary of SLR Scenarios Utilized



Methods and Data Sources

The digital elevation map (DEM) used in this model simulation was derived from a combination of LiDAR and the USGS National Elevation Dataset (NED Figure 1). The two LiDAR layers include a dataset produced by NOAA with flight dates within 2002 and a dataset produced by USFWS with flight dates within 2009. Surrounding areas are composed of USGS NED based on surveys from around 1950.

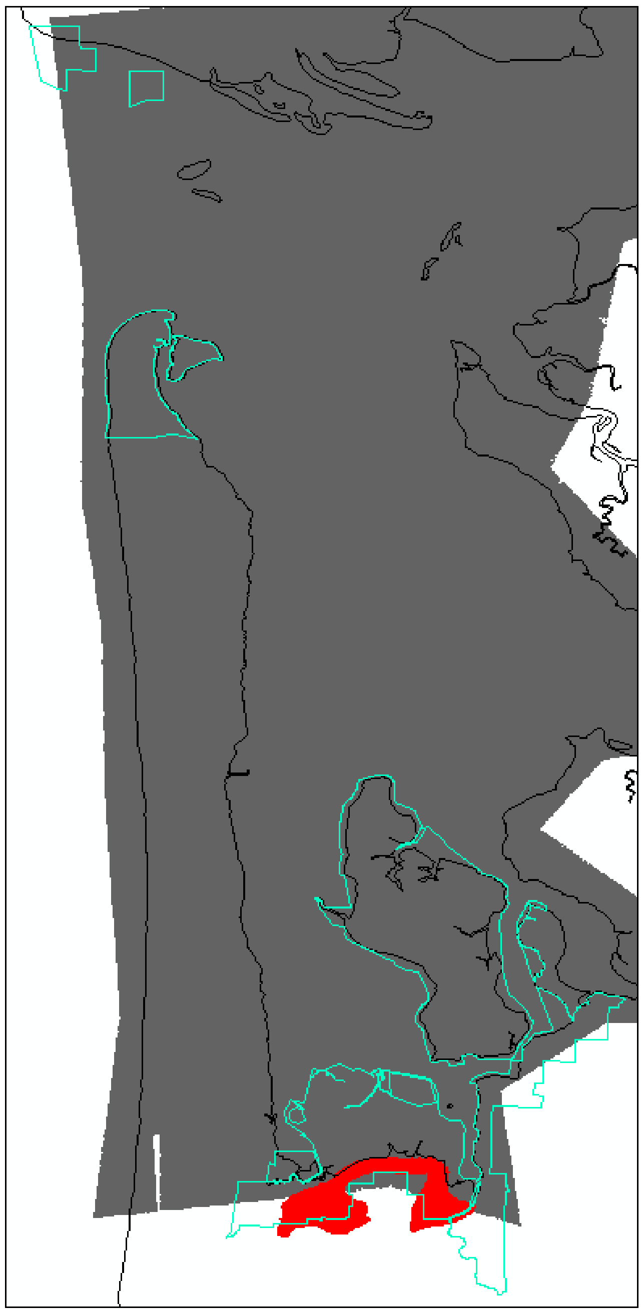


Figure 1: Elevation Coverage map for Willapa NWR (blue).
2002 NOAA LiDAR coverage (grey); 2009 FWS LiDAR coverage (red); White areas covered by NED.

Land-cover data were derived from a National Wetlands Inventory (NWI) data layer with a photo date of 1981. After converting this NWI survey into 30-meter cells, and translating coverage to SLAMM land-cover categories the approximately sixteen thousand acre refuge (approved acquisition boundary including water) is composed of the following categories:

Undeveloped Dry Land	48.1%
Tidal Flat	20.9%
Saltmarsh	12.0%
Inland Fresh Marsh	6.2%
Estuarine Open Water	4.2%
Swamp	2.1%
Brackish Marsh	1.7%
Tidal Swamp	1.4%
Ocean Beach	1.1%

The refuge has one impounded area in the south according to the National Wetland Inventory (Figure 2). This NWI-based dike data was also refined using USGS topo maps and with the help of GIS personnel from Ducks Unlimited.

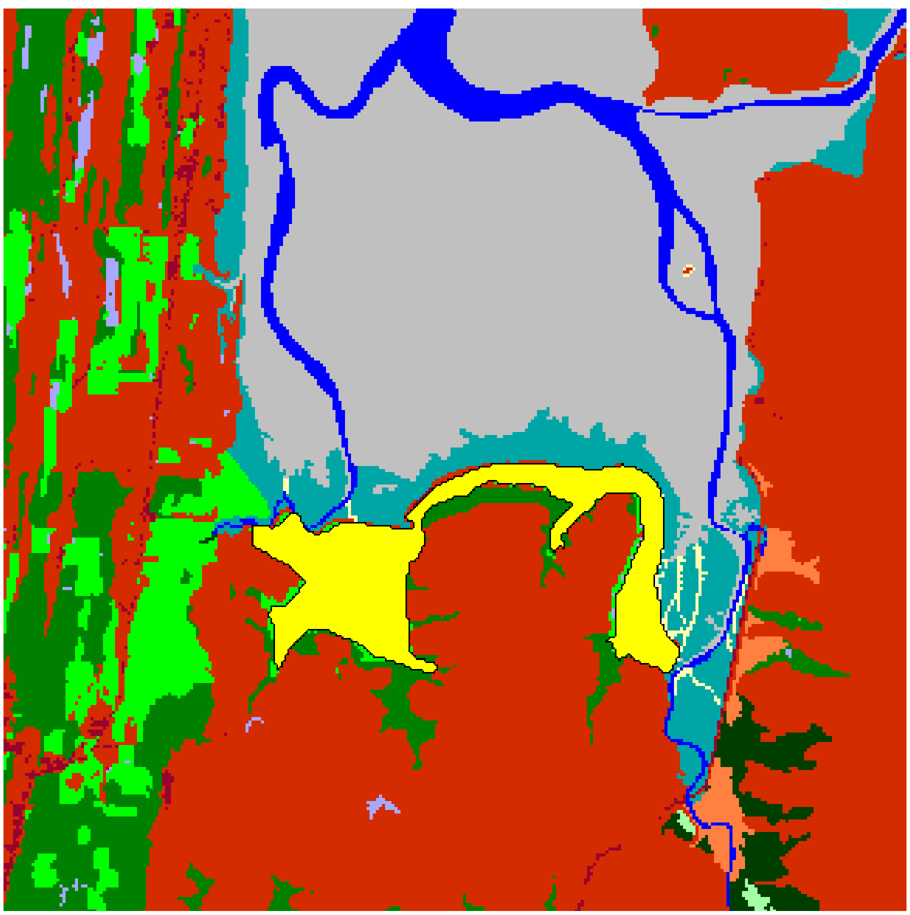


Figure 2: Diked areas in yellow.

The historic trend for sea level rise was estimated at 1.6 mm/year using the nearest NOAA gage with SLR trend data (9440910, Toke Point, Washington). The rate of sea level rise for this refuge is roughly equal to the global average for the last 100 years (approximately 1.7 mm/year).

For the model simulation, the site is divided into 6 subsites based on tide range and LiDAR coverage (Figure 4). Tide range varies from 2.7 meters to 3.3 meters across the refuge. Tide range values were determined using nearby NOAA tide gages (9440910, Toke Point, WA; 9440747, Nahcotta, Willapa Bay, WA; 9440846, Bay Center, Palix River, Willapa Bay, WA; 9440875, South Bend, WA; 9440691, Naselle River Swing Bridge, WA) (Figure 3).

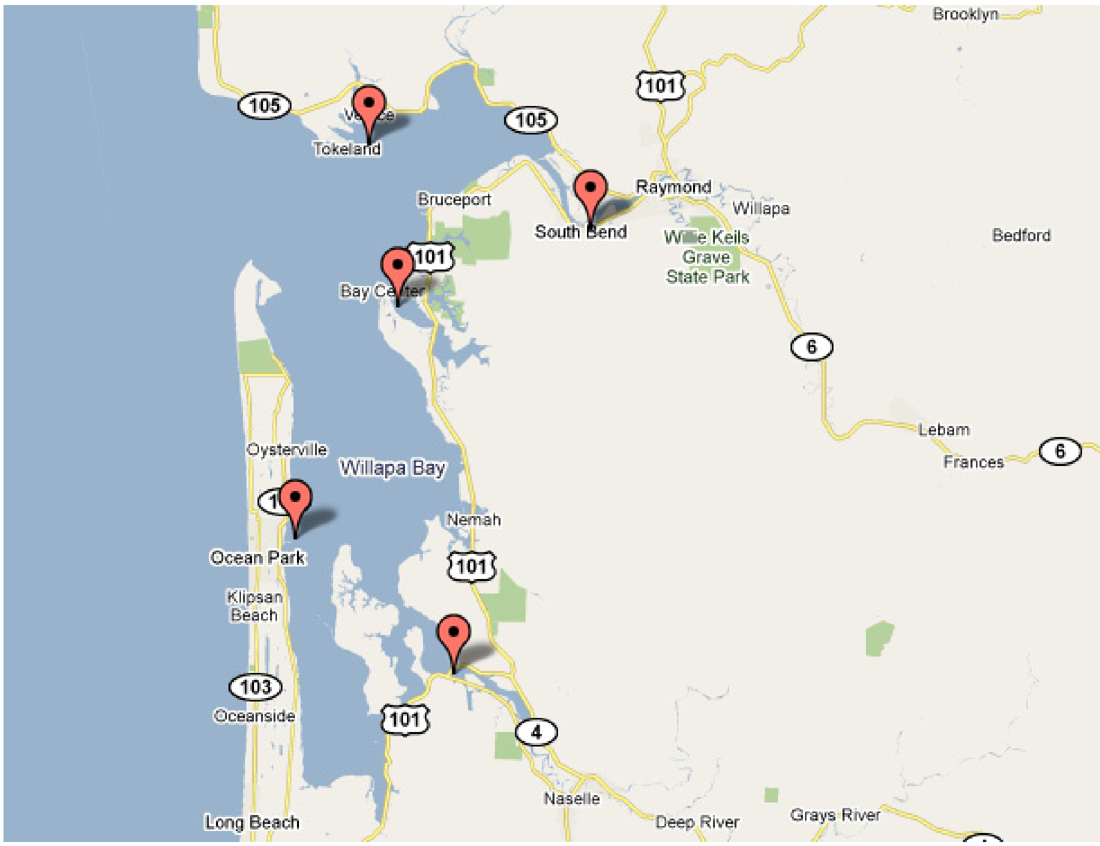


Figure 3: NOAA Gage Relevant to the Study Area.

Model marsh accretion values were determined using data from an unpublished study by Young, Atwater and McKee (Reusser, 2010). Cores were taken in the summer of 1995, with low marsh (regularly flooded) accretion estimated at 2.1 mm/year and high marsh (irregularly flooded) accretion estimated at 2.8 mm/year.

Erosion rates for refuge tidal flats were set to 0.2 meters/year, roughly based on a regional map of shoreline erosion (Keuler, 1988). Erosion rates for marshes and swamps were set to 2.0 meters/year and 1.0 meter/year, respectively. Horizontal erosion of marshes and swamps occurs only at the wetland-to-open-water interface and only when adequate open water (fetch) exists for wave setup.

The MTL to NAVD88 correction was derived using the NOAA VDATUM product. A spatially variable raster map of elevation corrections was created for this site using the VDATUM software.

Modeled U.S. Fish and Wildlife Service refuge boundaries for Washington are based on Approved Acquisition Boundaries as published on the FWS National Wildlife Refuge Data and Metadata website. The cell-size used for this analysis was 30 meter by 30 meter cells.

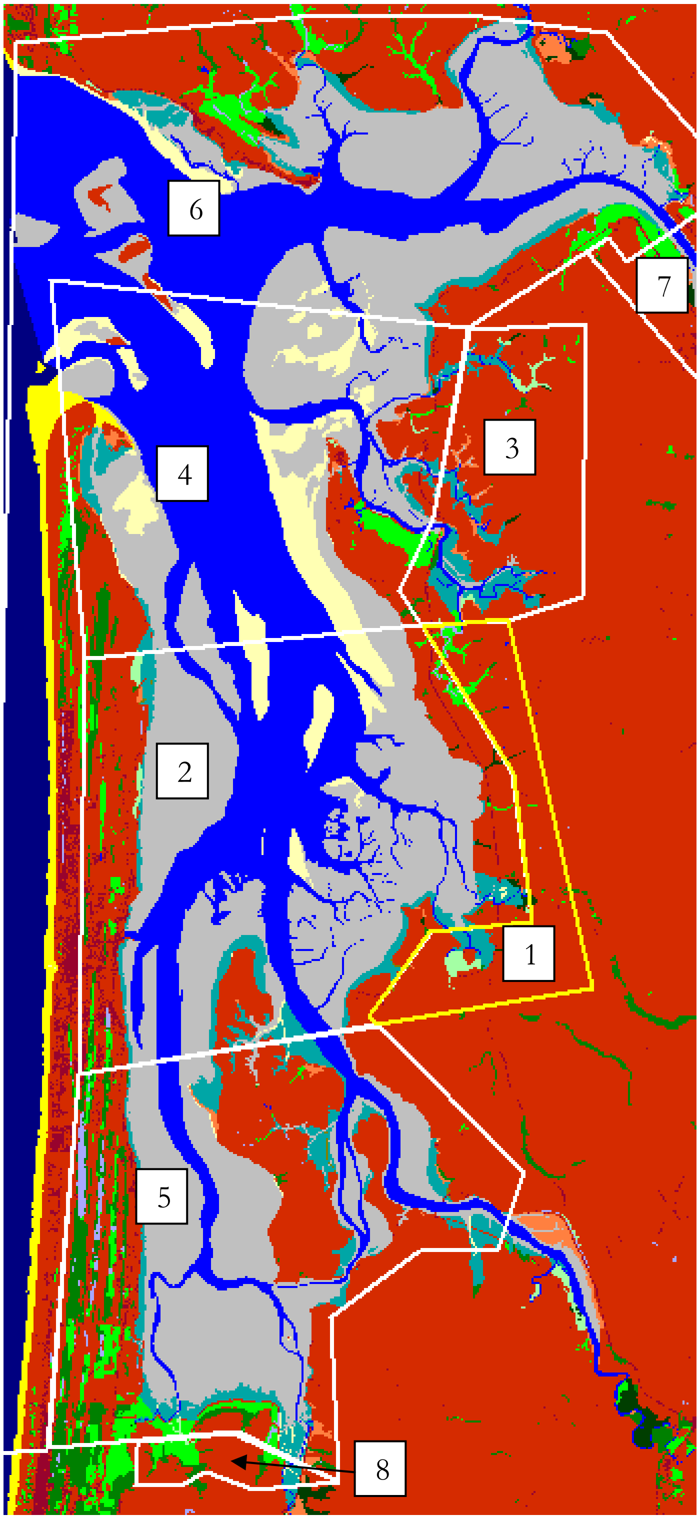


Figure 4: Input subsites for Willapa NWR.

SUMMARY OF SLAMM INPUT PARAMETERS FOR WILLAPA NWR

Parameter	Global	SubSite 1	SubSite 2	SubSite 3	SubSite 4
Description	Willapa Bay	SubSite 1	SubSite 2	SubSite 3	SubSite 4
NWI Photo Date (YYYY)	1981	1981	1981	1981	1981
DEM Date (YYYY)	2000	2000	2002	2000	2002
Direction Offshore [n,s,e,w]	West	West	North	West	North
Historic Trend (mm/yr)	1.6	1.6	1.6	1.6	1.6
MTL-NAVD88 (m)	0	0	0	0	0
GT Great Diurnal Tide Range (m)	2.7	3.19	3.19	2.8	2.8
Salt Elev. (m above MTL)	1.8	2.12	2.12	1.86	1.86
Marsh Erosion (horz. m /yr)	2	2	2	2	2
Swamp Erosion (horz. m /yr)	1	1	1	1	1
T.Flat Erosion (horz. m /yr)	0.2	0.2	0.2	0.2	0.2
Reg. Flood Marsh Accr (mm/yr)	2.1	2.1	2.1	2.1	2.1
Irreg. Flood Marsh Accr (mm/yr)	2.8	2.8	2.8	2.8	2.8
Tidal Fresh Marsh Accr (mm/yr)	2.8	2.8	2.8	2.8	2.8
Beach Sed. Rate (mm/yr)	0.5	0.5	0.5	0.5	0.5
Freq. Overwash (years)	0	0	0	0	0
Use Elev Pre-processor [True,False]	TRUE	TRUE	FALSE	TRUE	FALSE

Parameter	SubSite 5	SubSite 6	SubSite 7	SubSite 8
Description	SubSite 5	SubSite 6	SubSite 7	FWS LiDAR
NWI Photo Date (YYYY)	1981	1981	1981	1981
DEM Date (YYYY)	2002	2002	2000	2009
Direction Offshore [n,s,e,w]	North	West	West	West
Historic Trend (mm/yr)	1.6	1.6	1.6	1.6
MTL-NAVD88 (m)	0	0	0	0
GT Great Diurnal Tide Range (m)	3.3	2.7	3.1	2.7
Salt Elev. (m above MTL)	2.19	1.8	2.1	1.8
Marsh Erosion (horz. m /yr)	2	2	2	2
Swamp Erosion (horz. m /yr)	1	1	1	1
T.Flat Erosion (horz. m /yr)	0.2	0.2	0.2	0.2
Reg. Flood Marsh Accr (mm/yr)	2.1	2.1	2.1	2.1
Irreg. Flood Marsh Accr (mm/yr)	2.8	2.8	2.8	2.8
Tidal Fresh Marsh Accr (mm/yr)	2.8	2.8	2.8	2.8
Beach Sed. Rate (mm/yr)	0.5	0.5	0.5	0.5
Freq. Overwash (years)	0	0	0	0
Use Elev Pre-processor [True,False]	FALSE	FALSE	TRUE	FALSE

Results

The SLAMM simulation for Willapa NWR indicates that the refuge will show some effects from sea level rise (SLR). However, the extent of the effects predicted is very-much affected by the extent of SLR predicted. Under the lowest SLR scenario, tidal flats are not predicted to be lost, but roughly 20% of swamp and tidal swamp are lost. Above the 0.39 meter scenario, loss of refuge tidal flat ranges between 30% and 37%. However, swamps and tidal swamps are quite vulnerable in simulations above one meter, losing as much as 95% of their extent. Finally, as much as 16% of the refuge's dry land may be subject to inundation and conversion to wetlands.

SLR by 2100 (m)	0.39	0.69	1	1.5	2
Undev. Dry Land	5%	7%	10%	13%	16%
Tidal Flat	-7%	30%	31%	25%	37%
Saltmarsh	-2%	-1%	4%	16%	28%
Inland Fresh Marsh	14%	16%	18%	24%	30%
Swamp	18%	31%	40%	56%	74%
Brackish Marsh	-3%	-16%	-22%	7%	56%
Tidal Swamp	20%	49%	75%	93%	95%
Ocean Beach	0%	1%	4%	62%	76%

Predicted Loss Rates of Land Categories by 2100 Given Simulated Scenarios of Eustatic Sea Level Rise

Maps of SLAMM input and output to follow will use the following legend:

Willapa NWR
IPCC Scenario A1B-Mean, 0.39 M SLR Eustatic by 2100

Results in Acres

	Initial	2025	2050	2075	2100
Undev. Dry Land	7911.0	7590.0	7564.9	7529.1	7489.4
Tidal Flat	3429.3	3614.8	3699.8	3666.1	3667.1
Saltmarsh	1968.9	2097.5	2014.1	2006.8	1999.6
Inland Fresh Marsh	1013.9	873.4	870.7	869.3	867.7
Estuarine Open Water	684.8	568.3	466.7	492.2	448.9
Swamp	343.6	295.9	292.5	287.8	281.9
Brackish Marsh	287.3	262.6	270.2	284.0	296.5
Tidal Swamp	229.5	221.2	213.5	198.4	183.3
Ocean Beach	181.0	181.1	181.2	181.1	181.0
Estuarine Beach	154.3	114.7	113.7	112.5	111.4
Open Ocean	123.0	321.4	435.8	465.2	529.8
Tidal Fresh Marsh	44.7	44.6	44.6	44.4	44.2
Inland Open Water	34.0	30.0	30.0	30.0	30.0
Dev. Dry Land	26.9	18.8	17.6	17.3	17.3
Trans. Salt Marsh	8.9	206.9	226.0	256.8	293.1
Total (incl. water)	**16441.1**	**16441.1**	**16441.1**	**16441.1**	**16441.1**

Willapa NWR, Initial Condition

Willapa NWR, 2025, Scenario A1B Mean

Willapa NWR, 2050, Scenario A1B Mean

Willapa NWR, 2075, Scenario A1B Mean

Willapa NWR, 2100, Scenario A1B Mean

Willapa NWR
IPCC Scenario A1B-Max, 0.69 M SLR Eustatic by 2100

Results in Acres

	Initial	2025	2050	2075	2100
Undev. Dry Land	7911.0	7578.7	7529.5	7448.2	7336.2
Tidal Flat	3429.3	3624.4	3733.3	3694.7	2399.7
Saltmarsh	1968.9	2098.7	2010.9	2014.8	1982.9
Inland Fresh Marsh	1013.9	869.6	864.5	859.4	852.5
Estuarine Open Water	684.8	572.0	479.3	556.1	1878.2
Swamp	343.6	293.5	286.9	270.5	236.8
Brackish Marsh	287.3	267.8	284.2	307.8	333.8
Tidal Swamp	229.5	215.0	191.6	155.7	117.7
Ocean Beach	181.0	181.2	181.1	180.5	179.5
Estuarine Beach	154.3	114.1	112.3	110.1	106.9
Open Ocean	123.0	321.4	436.0	466.1	532.8
Tidal Fresh Marsh	44.7	44.5	43.9	42.3	40.4
Inland Open Water	34.0	30.0	30.0	29.8	29.6
Dev. Dry Land	26.9	18.5	17.3	17.2	17.1
Trans. Salt Marsh	8.9	211.9	240.3	287.9	397.2
Total (incl. water)	**16441.1**	**16441.1**	**16441.1**	**16441.1**	**16441.1**

Willapa NWR, Initial Condition

Willapa NWR, 2025, Scenario A1B Maximum

Willapa NWR, 2050, Scenario A1B Maximum

Willapa NWR, 2075, Scenario A1B Maximum

Willapa NWR, 2100, Scenario A1B Maximum

Willapa NWR
1 Meter Eustatic SLR by 2100

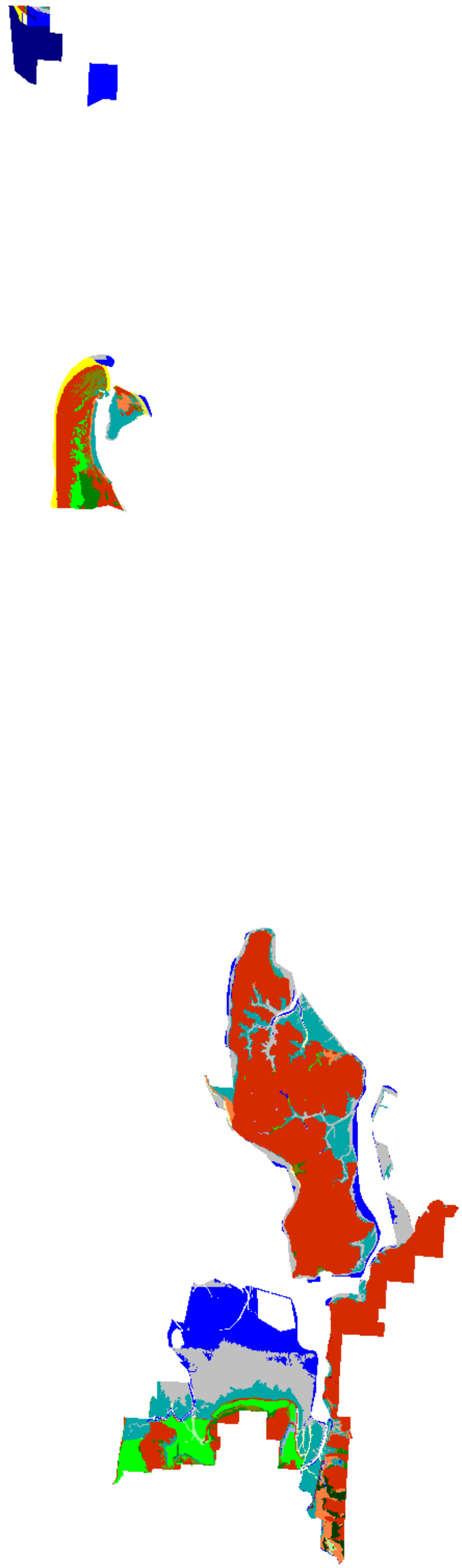
Results in Acres

	Initial	2025	2050	2075	2100
Undev. Dry Land	7911.0	7563.8	7482.6	7333.8	7133.8
Tidal Flat	3429.3	3637.2	3763.0	2425.2	2371.1
Saltmarsh	1968.9	2101.8	2022.0	1980.2	1893.7
Inland Fresh Marsh	1013.9	866.0	858.3	845.6	829.5
Estuarine Open Water	684.8	577.2	507.8	1964.6	2209.4
Swamp	343.6	291.0	278.4	234.8	204.6
Brackish Marsh	287.3	273.3	298.1	331.9	350.2
Tidal Swamp	229.5	205.1	165.6	110.2	57.7
Ocean Beach	181.0	181.2	180.8	179.0	174.7
Estuarine Beach	154.3	113.5	110.9	106.5	101.2
Open Ocean	123.0	321.4	436.6	468.1	539.8
Tidal Fresh Marsh	44.7	44.1	42.4	39.3	36.0
Inland Open Water	34.0	30.0	30.0	29.8	29.4
Dev. Dry Land	26.9	17.6	17.2	17.1	16.7
Trans. Salt Marsh	8.9	217.8	247.4	374.9	493.3
Total (incl. water)	**16441.1**	**16441.1**	**16441.1**	**16441.1**	**16441.1**

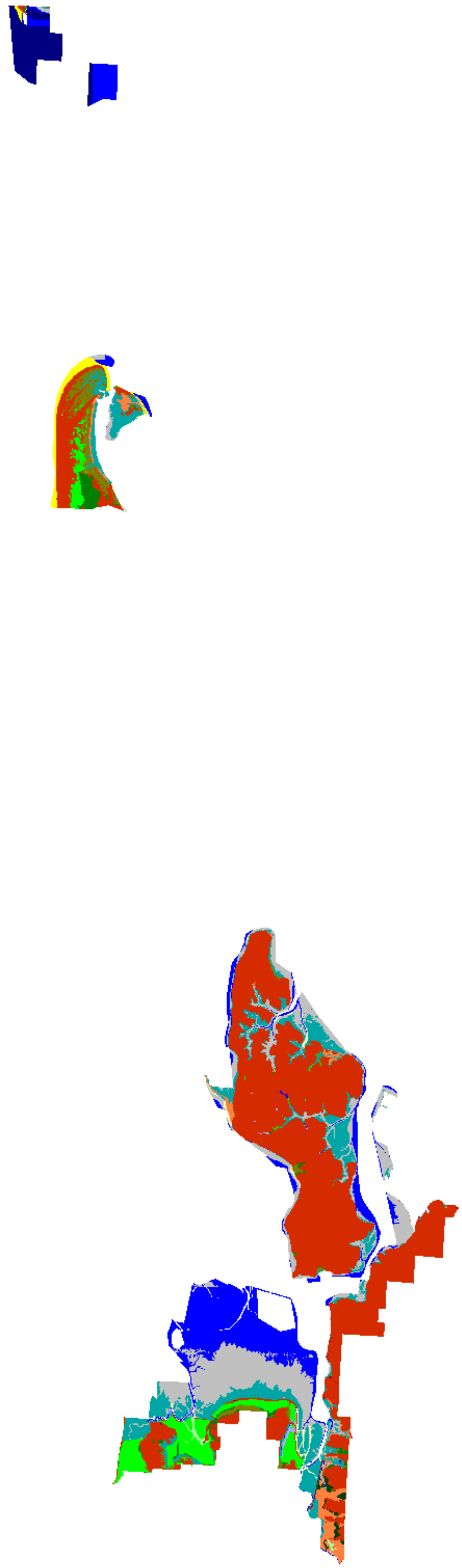
Willapa NWR, Initial Condition

Willapa NWR, 2025, 1 meter

Willapa NWR, 2050, 1 meter



Willapa NWR, 2075, 1 meter



Willapa NWR, 2100, 1 meter

Willapa NWR
1.5 Meters Eustatic SLR by 2100

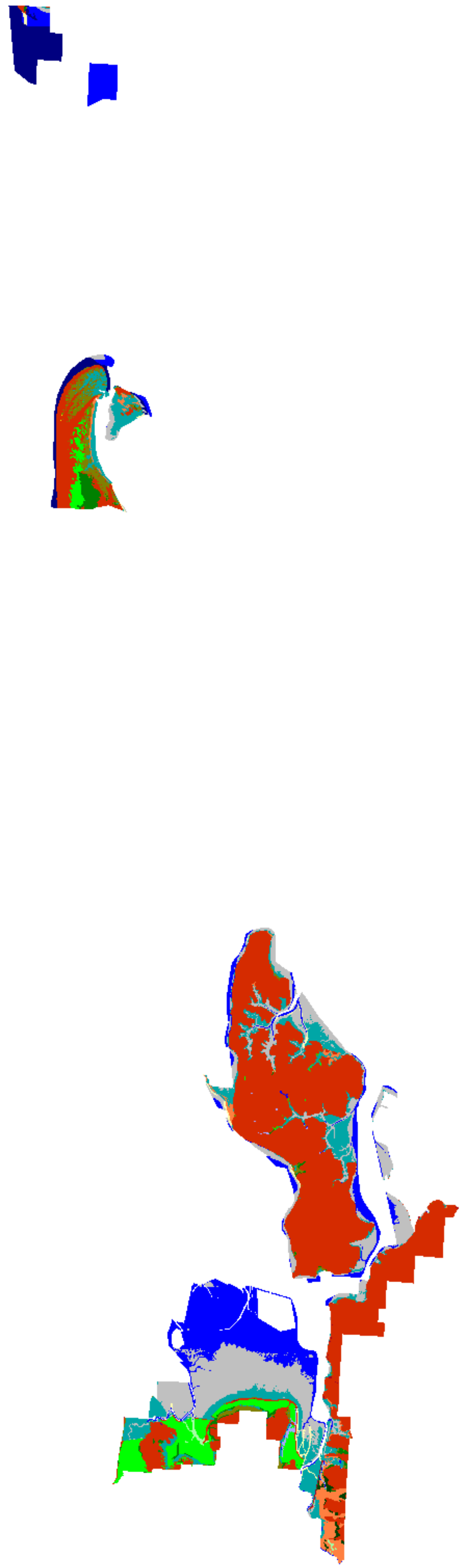
Results in Acres

	Initial	2025	2050	2075	2100
Undev. Dry Land	7911.0	7537.1	7383.8	7106.6	6850.5
Tidal Flat	3429.3	3660.5	2539.7	2609.3	2588.2
Saltmarsh	1968.9	2110.6	1995.1	1699.1	1647.0
Inland Fresh Marsh	1013.9	859.4	845.6	817.9	767.2
Estuarine Open Water	684.8	587.6	1857.9	2334.3	2816.7
Swamp	343.6	285.8	245.4	200.1	150.8
Brackish Marsh	287.3	282.0	322.0	327.0	266.1
Tidal Swamp	229.5	187.2	121.7	47.3	15.5
Ocean Beach	181.0	181.1	158.6	57.4	69.2
Estuarine Beach	154.3	112.3	107.7	99.9	87.9
Open Ocean	123.0	321.7	459.3	591.2	764.5
Tidal Fresh Marsh	44.7	43.2	39.5	33.9	26.4
Inland Open Water	34.0	30.0	29.8	29.4	28.9
Dev. Dry Land	26.9	17.3	17.1	16.7	15.8
Trans. Salt Marsh	8.9	225.2	318.0	471.1	346.5
Total (incl. water)	**16441.1**	**16441.1**	**16441.1**	**16441.1**	**16441.1**

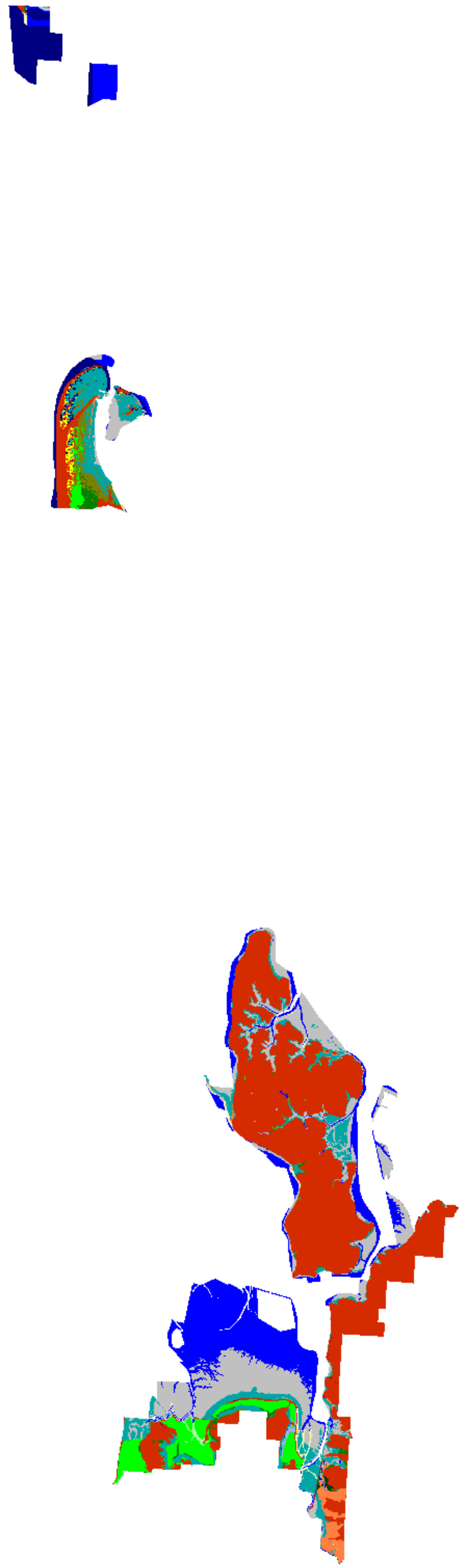
Willapa NWR, Initial Condition

Willapa NWR, 2025, 1.5 meter

Willapa NWR, 2050, 1.5 meter



Willapa NWR, 2075, 1.5 meter



Willapa NWR, 2100, 1.5 meter

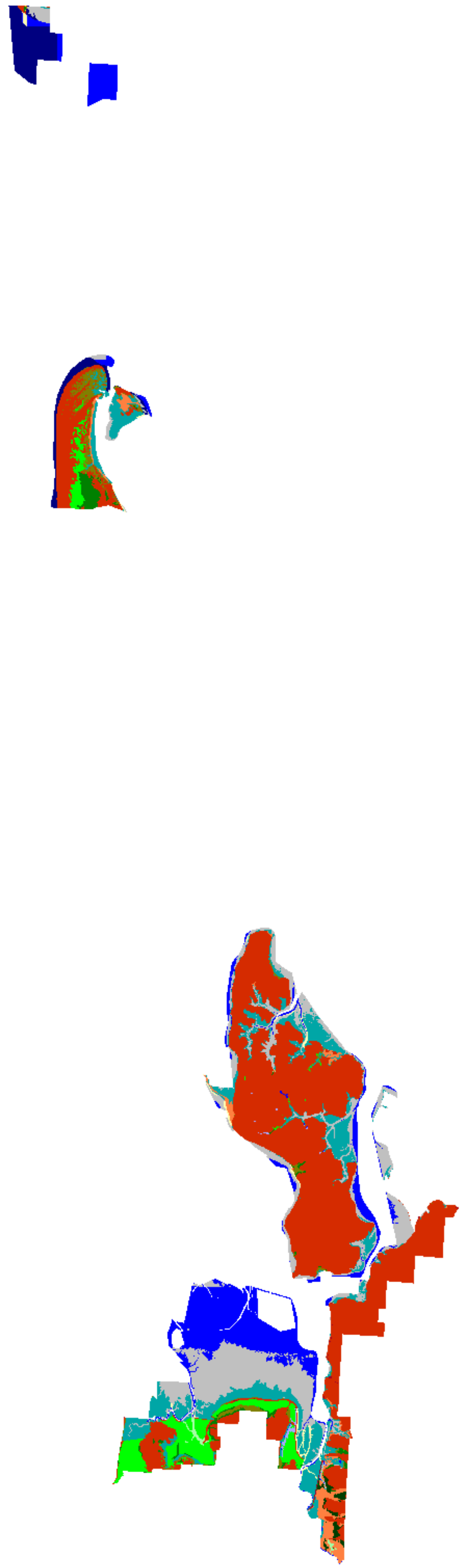
Willapa NWR
2 Meters Eustatic SLR by 2100

Results in Acres

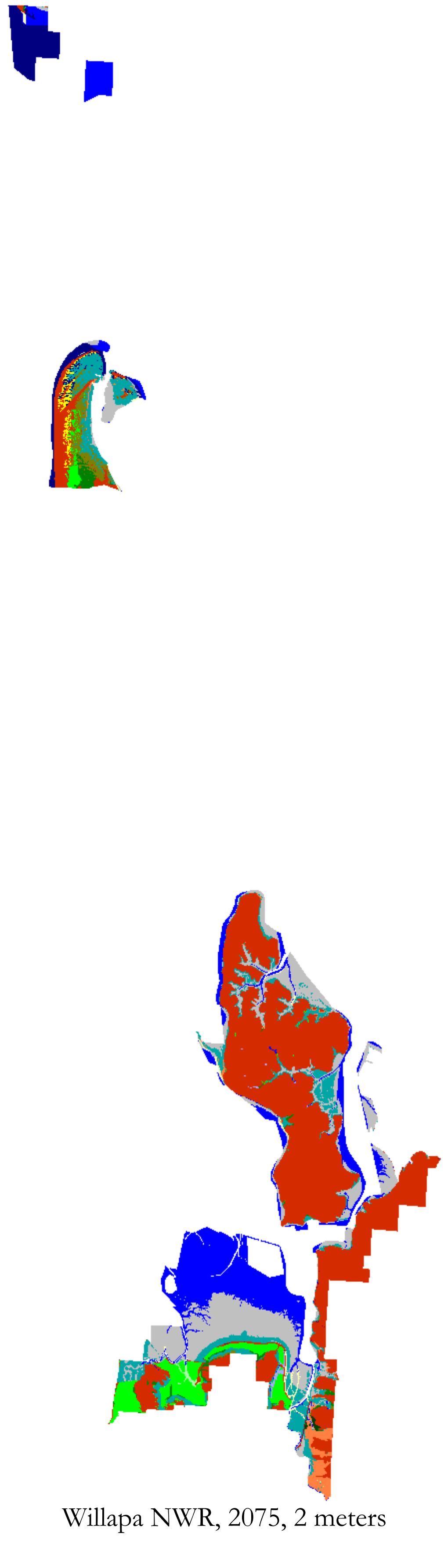
	Initial	2025	2050	2075	2100
Undev. Dry Land	7911.0	7504.0	7259.0	6902.3	6675.3
Tidal Flat	3429.3	3679.9	2495.1	2708.4	2155.0
Saltmarsh	1968.9	2124.1	1926.0	1578.8	1427.3
Inland Fresh Marsh	1013.9	854.5	829.9	771.3	713.2
Estuarine Open Water	684.8	606.6	2097.6	2723.1	3862.2
Swamp	343.6	280.0	216.7	165.6	88.5
Brackish Marsh	287.3	292.9	336.7	273.3	127.0
Tidal Swamp	229.5	167.8	77.9	16.1	11.6
Ocean Beach	181.0	133.1	0.3	86.4	44.1
Estuarine Beach	154.3	111.3	104.2	91.0	68.7
Open Ocean	123.0	369.9	618.0	696.3	929.1
Tidal Fresh Marsh	44.7	41.9	36.4	27.0	23.9
Inland Open Water	34.0	30.0	29.8	29.1	28.7
Dev. Dry Land	26.9	17.3	17.0	16.1	15.0
Trans. Salt Marsh	8.9	227.9	396.4	356.3	271.6
Total (incl. water)	**16441.1**	**16441.1**	**16441.1**	**16441.1**	**16441.1**

Willapa NWR, Initial Condition

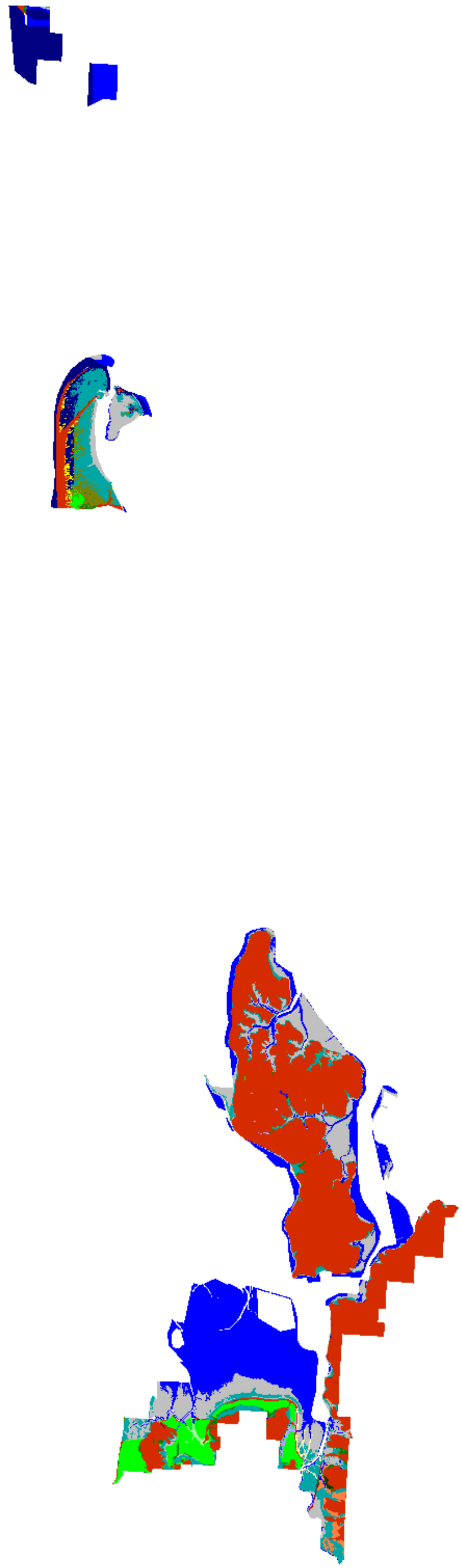
Willapa NWR, 2025, 2 meters



Willapa NWR, 2050, 2 meters



Willapa NWR, 2075, 2 meters



Willapa NWR, 2100, 2 meters

Discussion

The majority of this site is covered with high-vertical-resolution LiDAR elevation data which reduces model uncertainty and refines model predictions to some extent. For example, tidal flat loss within the refuge itself is limited to 37% (even under the highest SLR simulations) due to relatively high initial-condition elevations.

As Figure 1 illustrates, there are some regions of the refuge that are covered with data from the National Elevation Dataset (NED). These areas are subject to a high amount of uncertainty. The USGS NED maps in the region are roughly 50 years old and drawn with 40 and 50 foot contour intervals. In these regions, the SLAMM elevation processor is used to predict wetland elevations due to the poor quality of the source data.

The border between LiDAR data and the NED cuts through the northwest section of the refuge and this helps to explain the unusual land loss patterns there (Figure 1). Interestingly, the section covered with LiDAR data (to the east) predicts more severe losses than that section covered with the NED (to the west).

Another source of model uncertainty is the extent of feedbacks between sea level rise and marsh accretion rates. The current model runs assumed that marsh accretion rates will remain constant over the extent of the simulation time period. A future analysis could benefit from assessing model uncertainty-- directly examining different strengths of accretion-to-cell-elevation feedbacks.

Within these model results, the diked regions at the south of the refuge are predicted to be maintained against up to two-meters of sea level rise.

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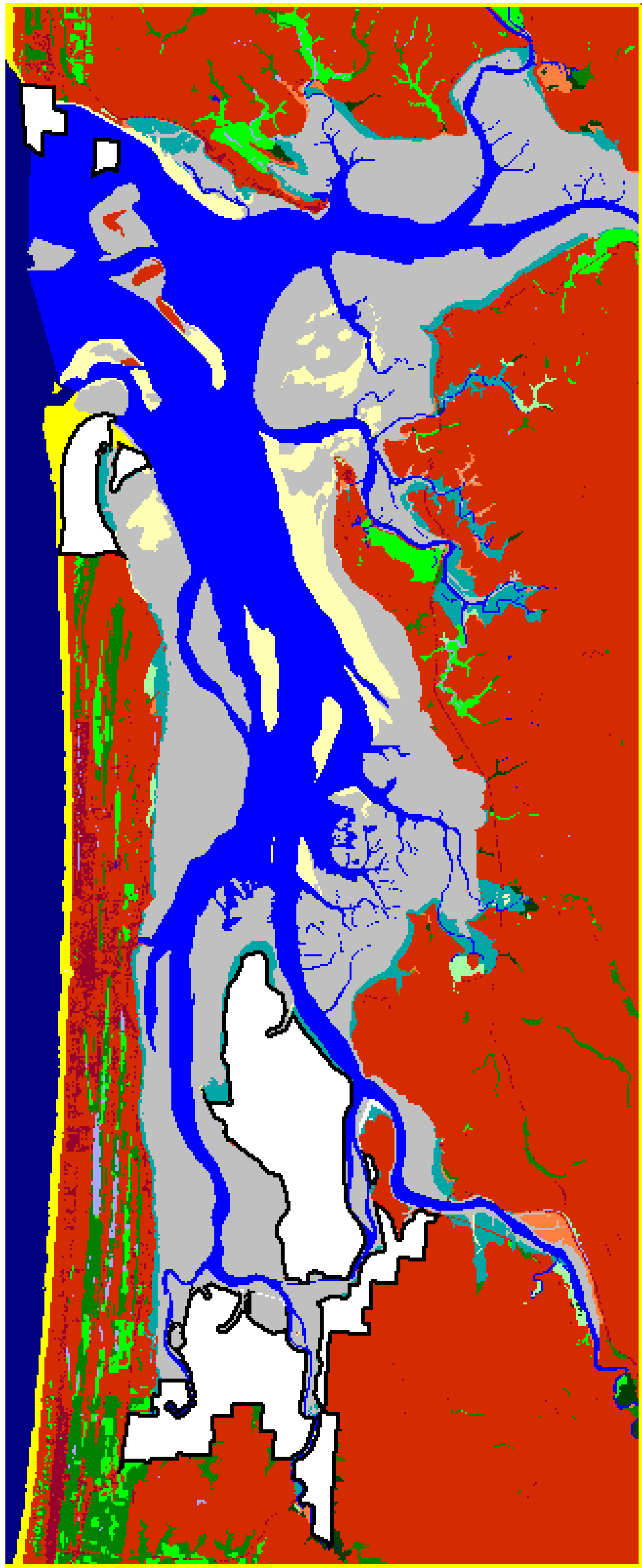
Appendix A: Contextual Results

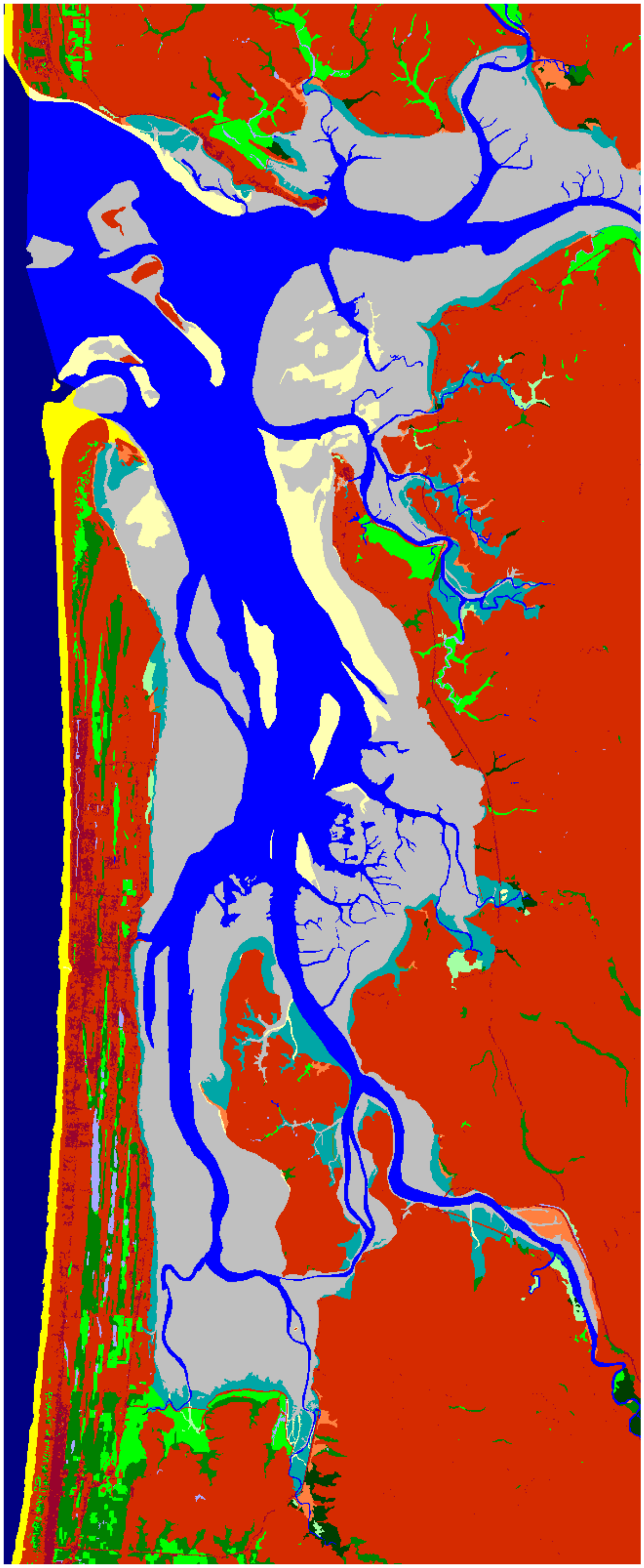
The SLAMM model does take into account the context of the surrounding lands or open water when calculating effects. For example, erosion rates are calculated based on the maximum fetch (wave action) which is estimated by assessing contiguous open water to a given marsh cell. Another example is that inundated dry lands will convert to marshes or ocean beach depending on their proximity to open ocean.

For this reason, an area larger than the boundaries of the USFWS refuge was modeled. These results maps are presented here with the following caveats:

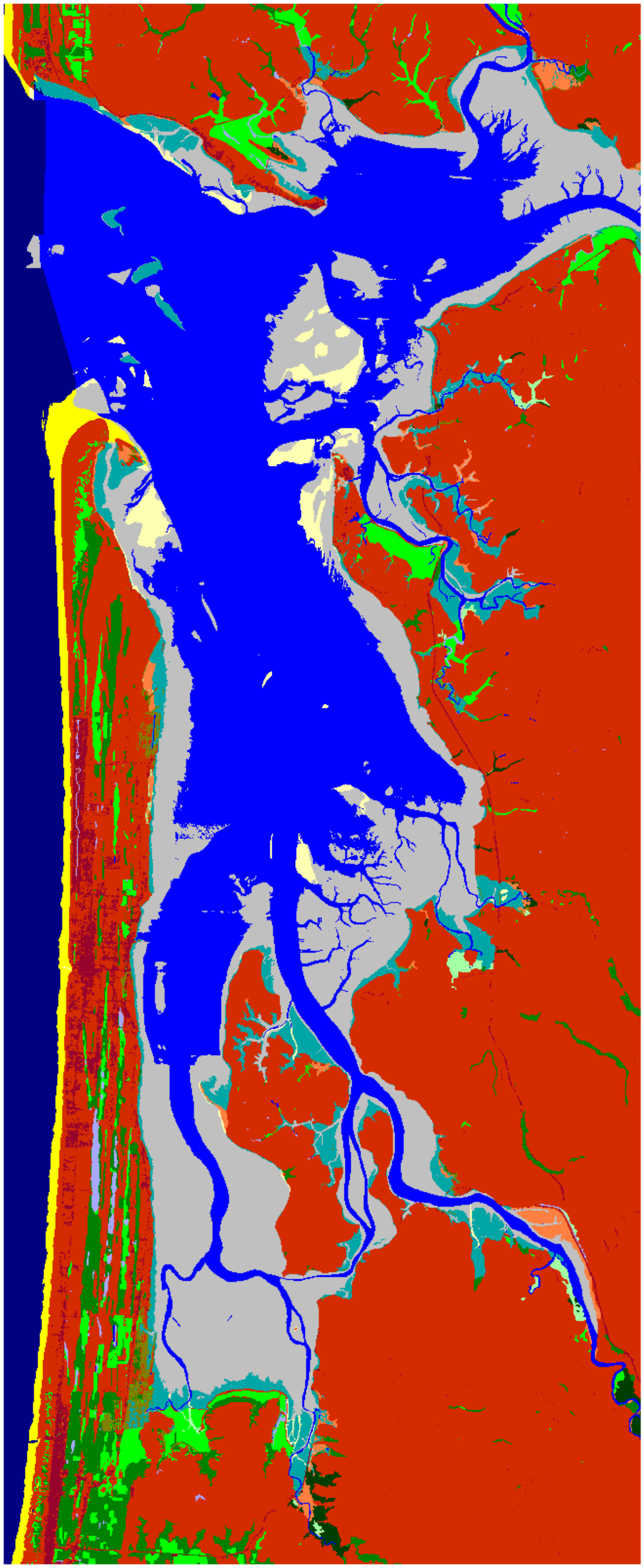
- Results were closely examined (quality assurance) within USFWS refuges but not closely examined for the larger region.
- Site-specific parameters for the model were derived for USFWS refuges whenever possible and may not be regionally applicable.
- Especially in areas where dikes are present, an effort was made to assess the probable location and effects of dikes for USFWS refuges, but this effort was not made for surrounding areas.



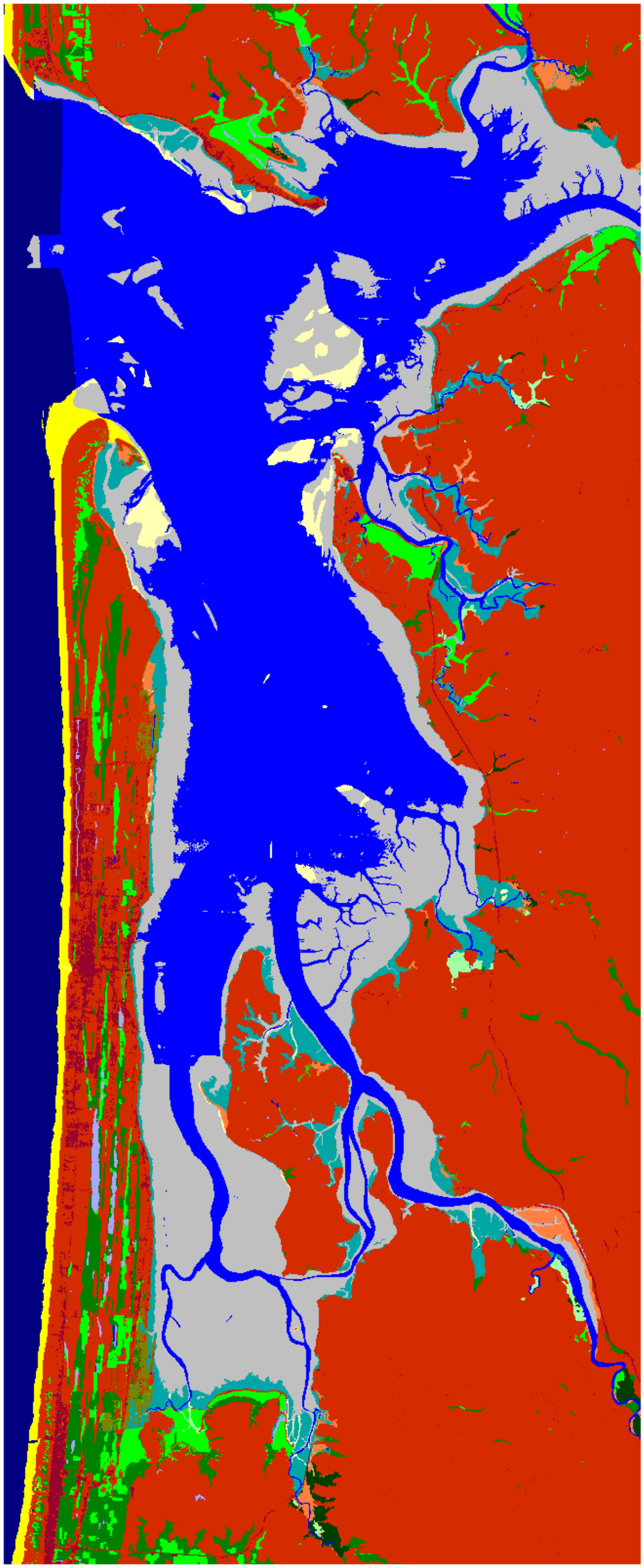
Location of Willapa National Wildlife Refuge within simulation context

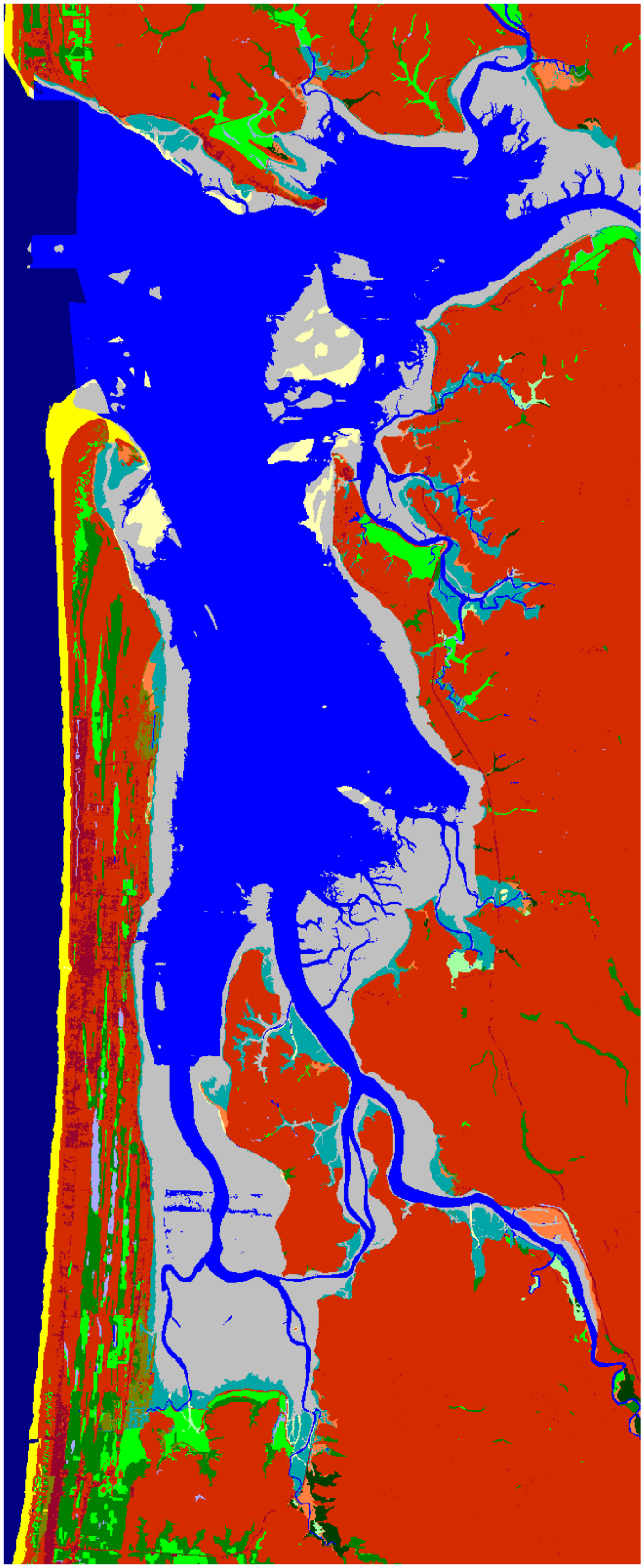


Willapa NWR, Initial Condition



Willapa NWR, 2025, Scenario A1B Mean


Willapa NWR, 2050, Scenario A1B Mean



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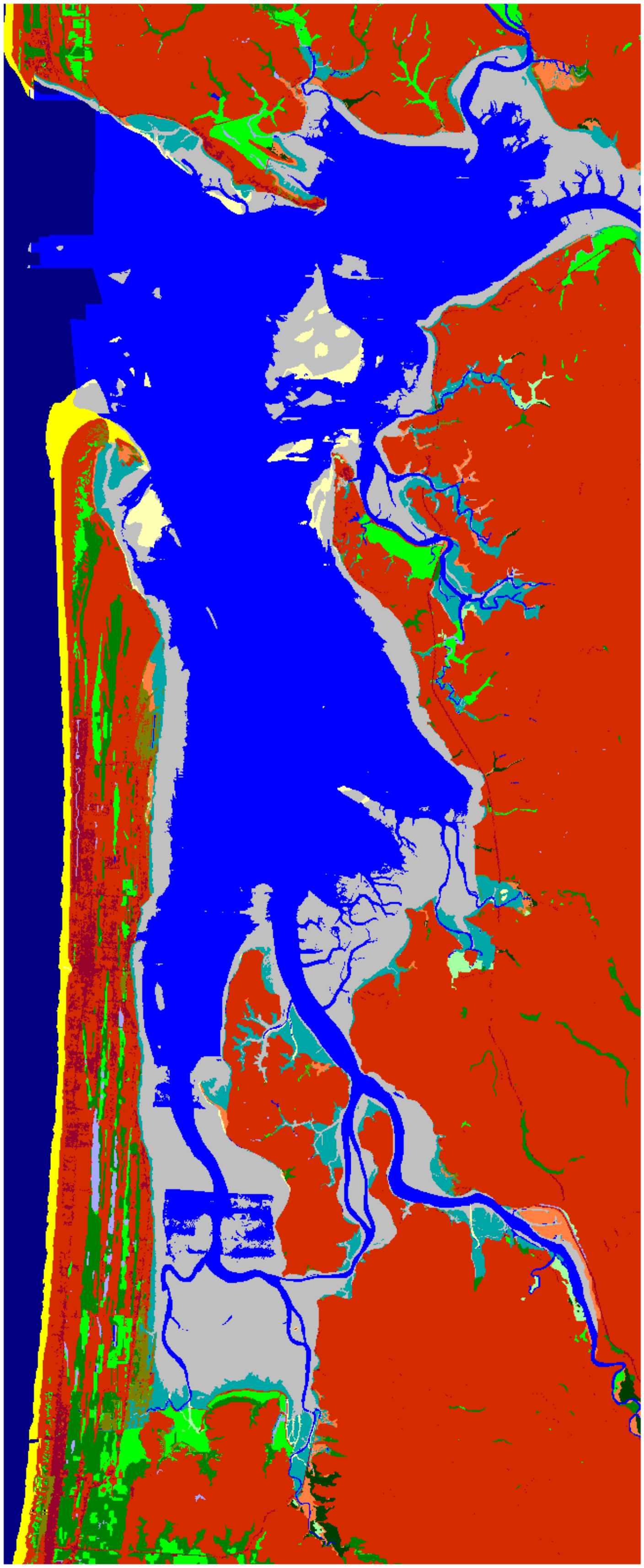
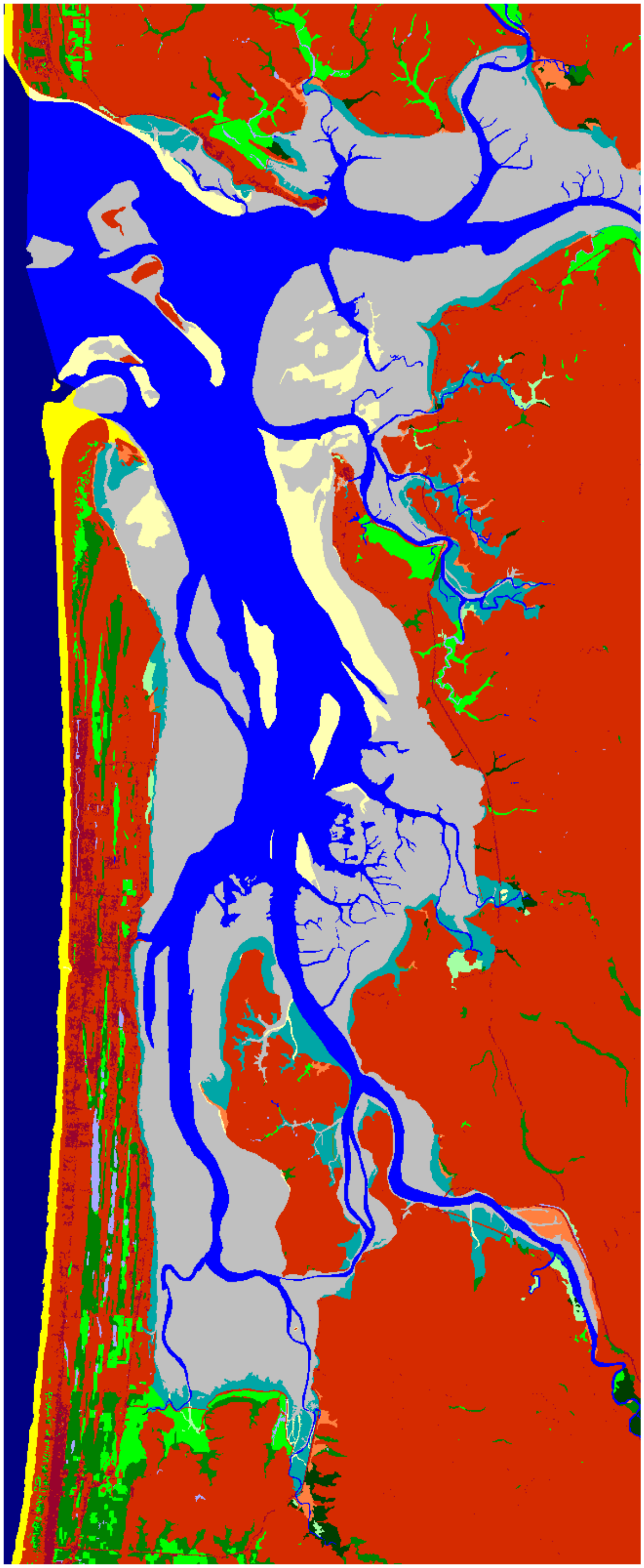
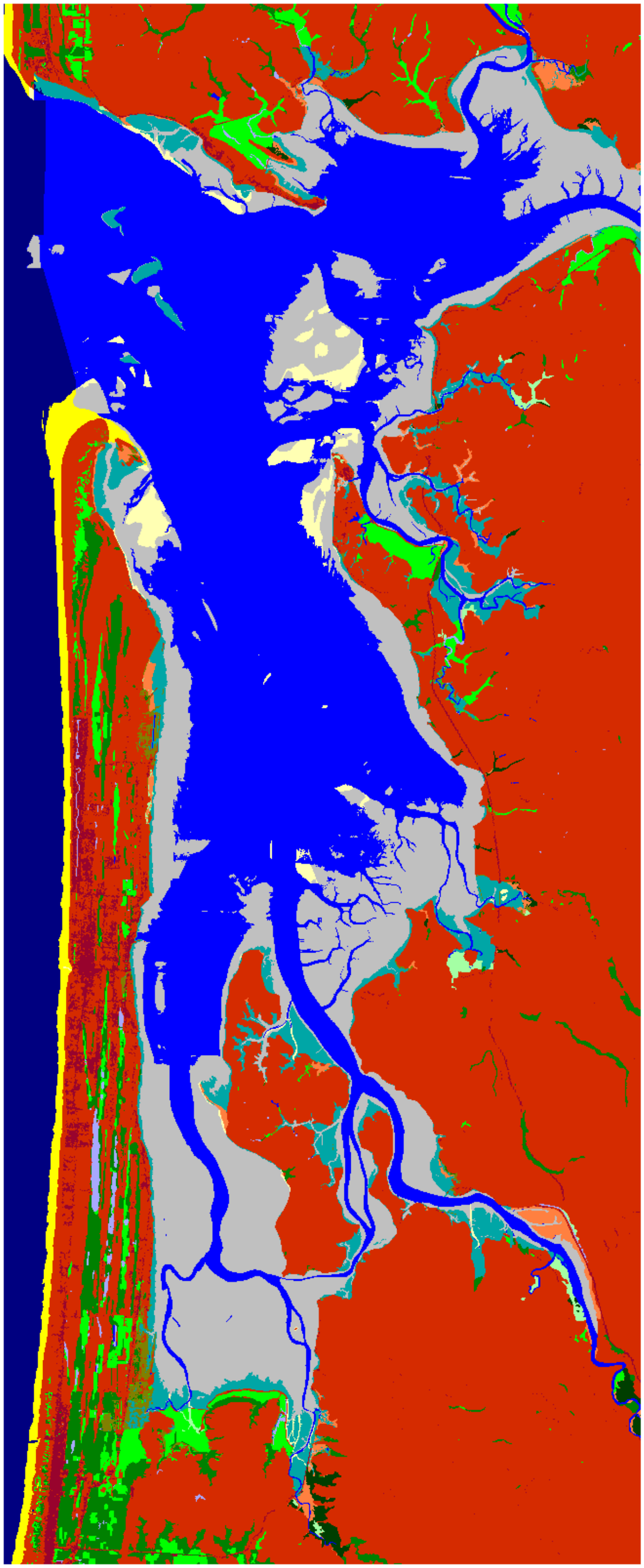


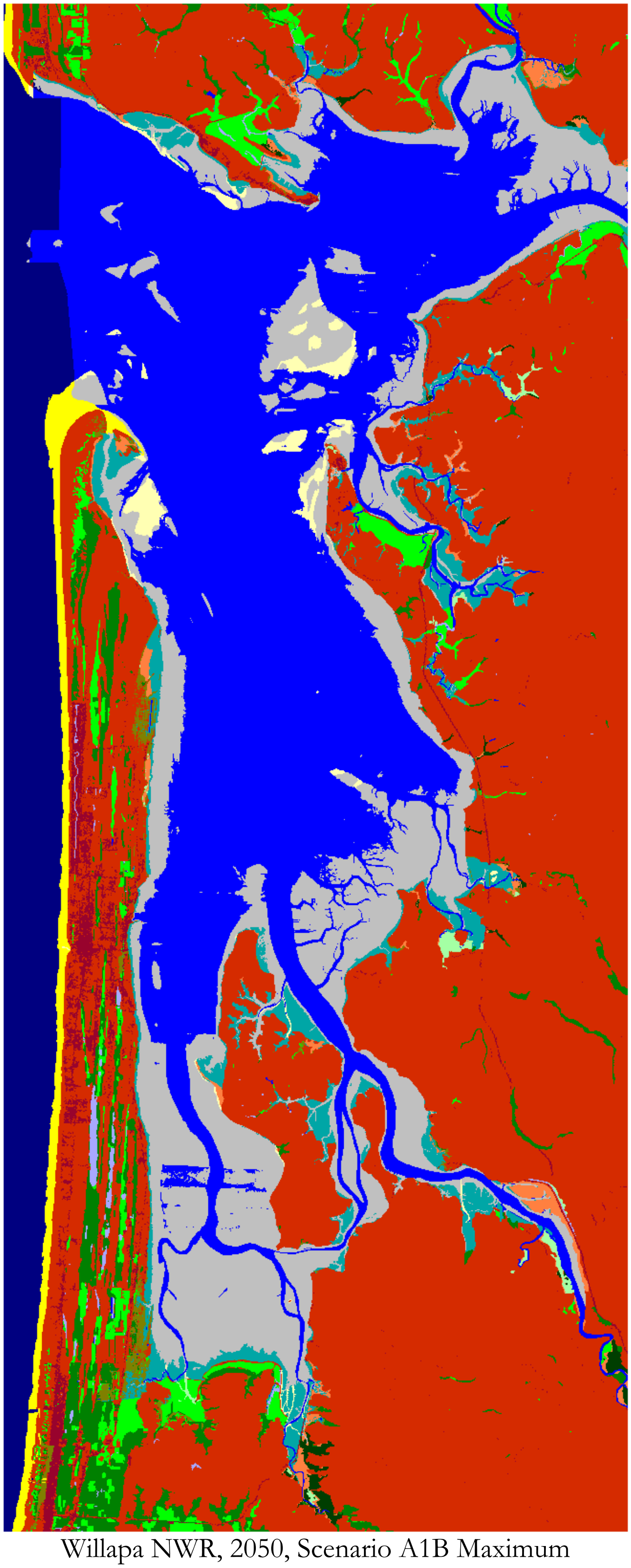
Willapa NWR, 2100, Scenario A1B Mean



Willapa NWR, Initial Condition



Willapa NWR, 2025, Scenario A1B Maximum



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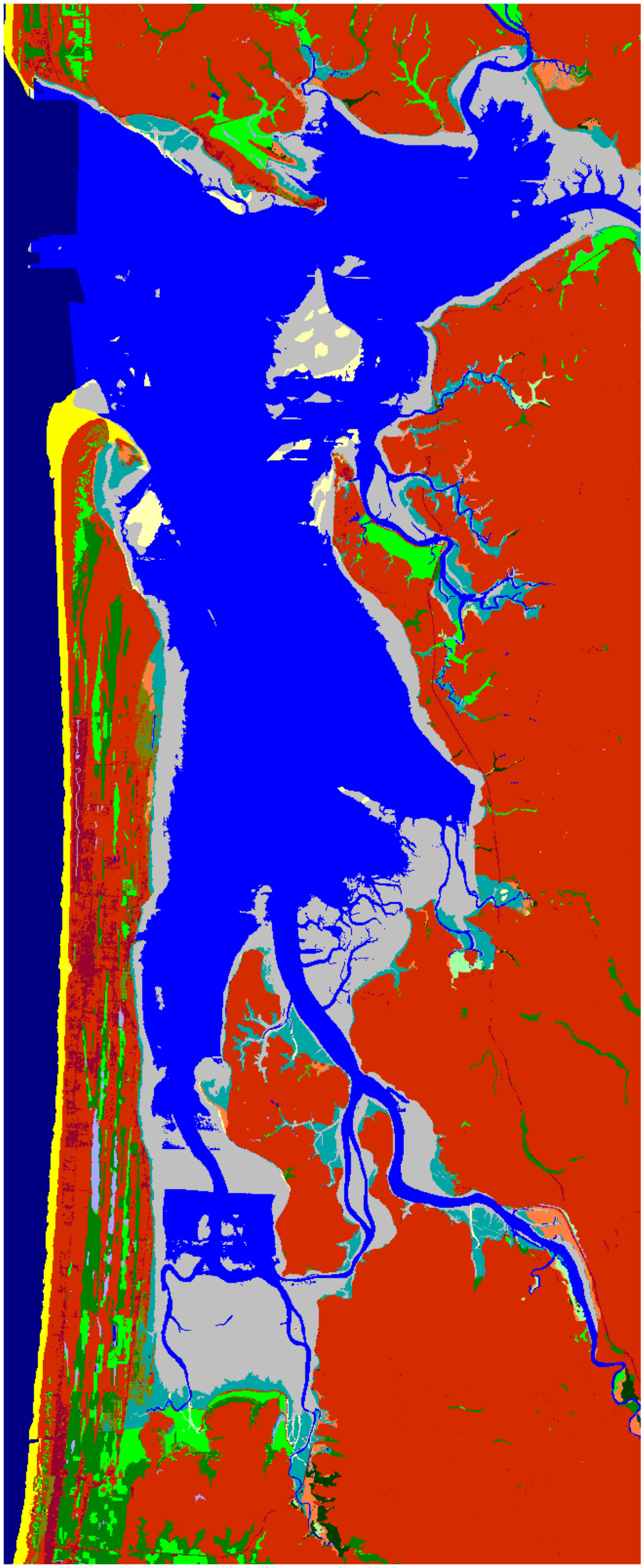

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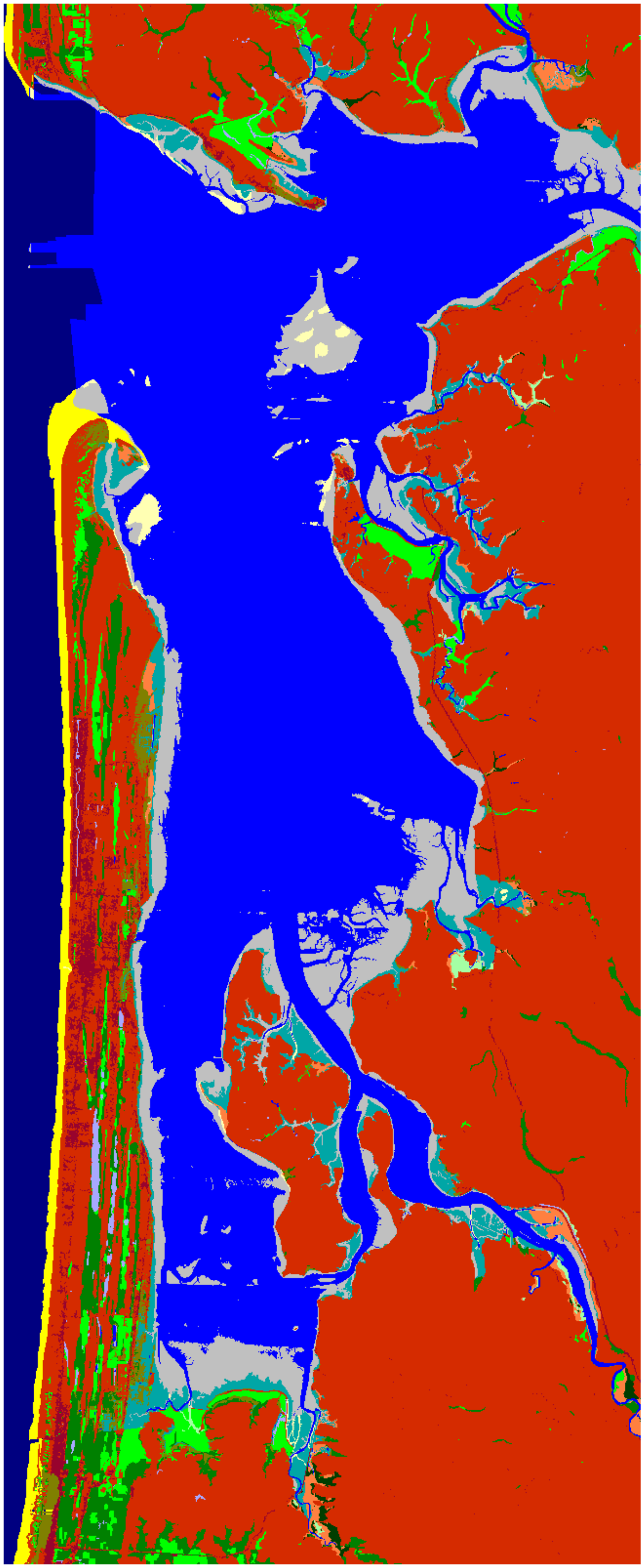
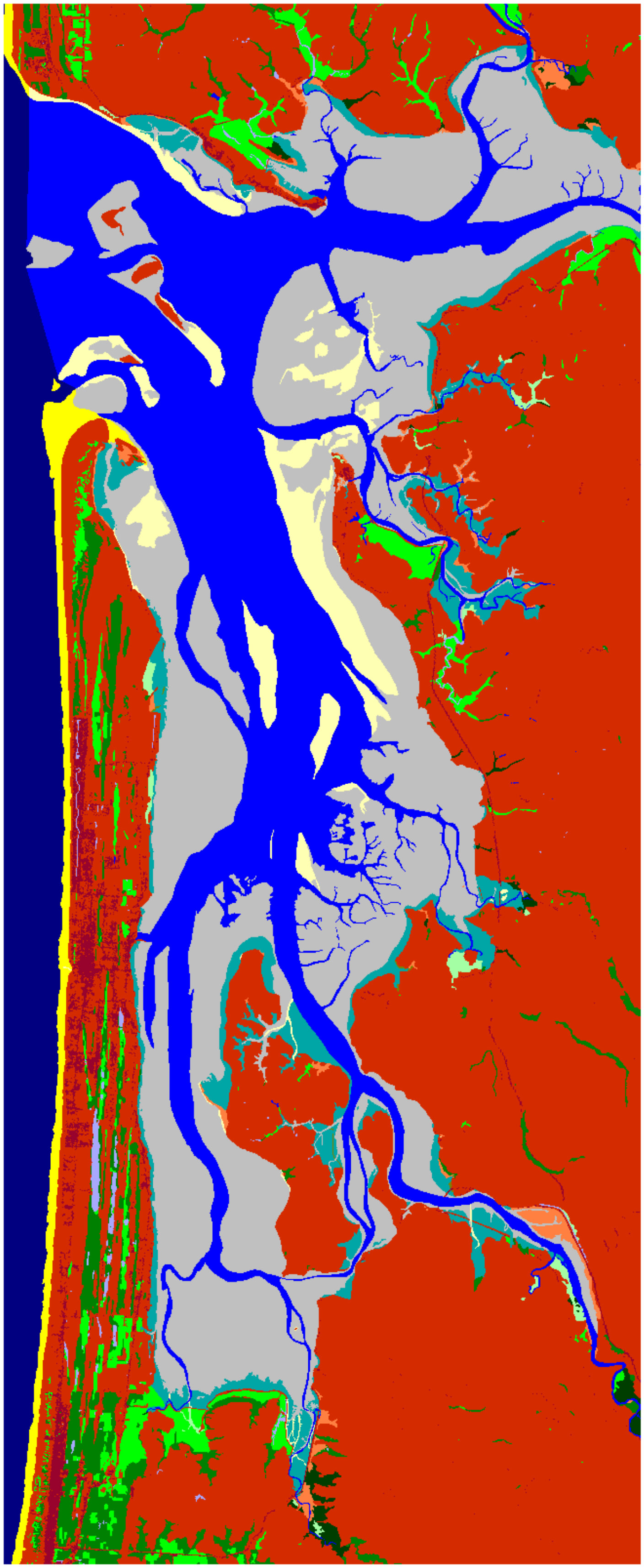


Willapa NWR, 2100, Scenario A1B Maximum



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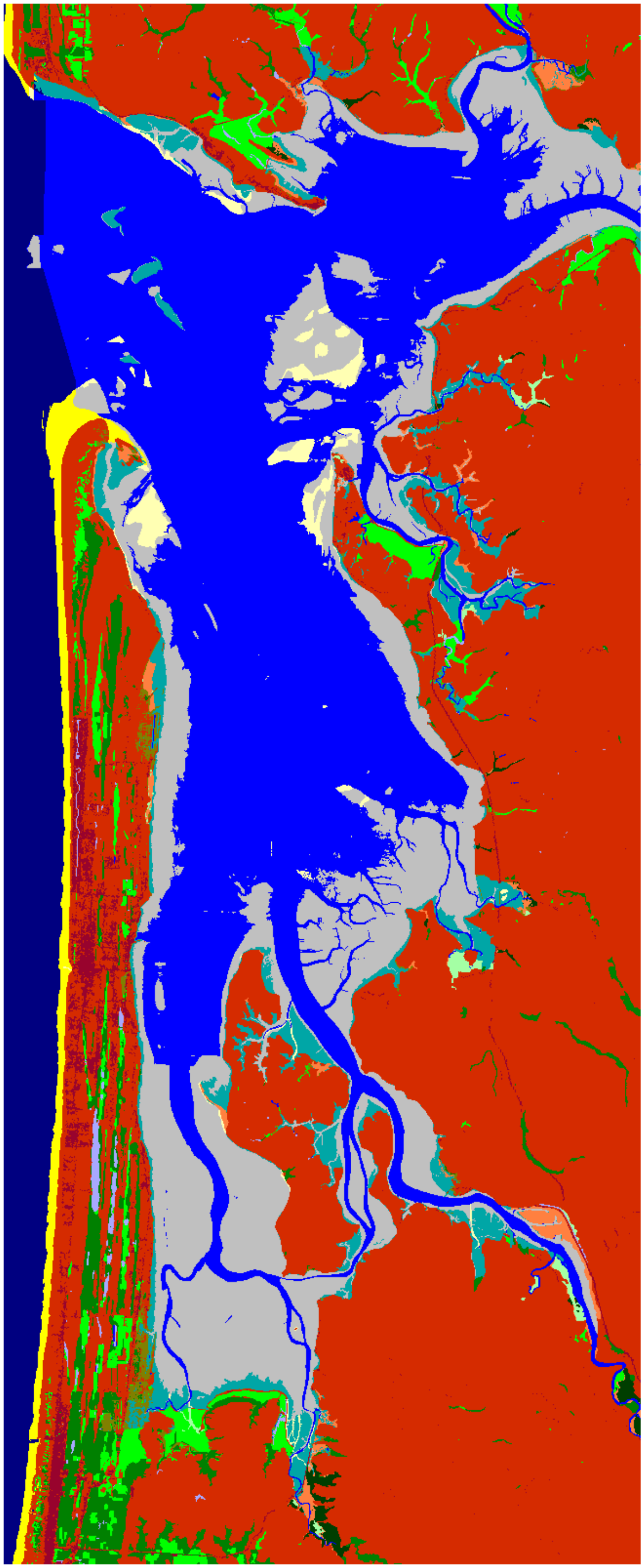
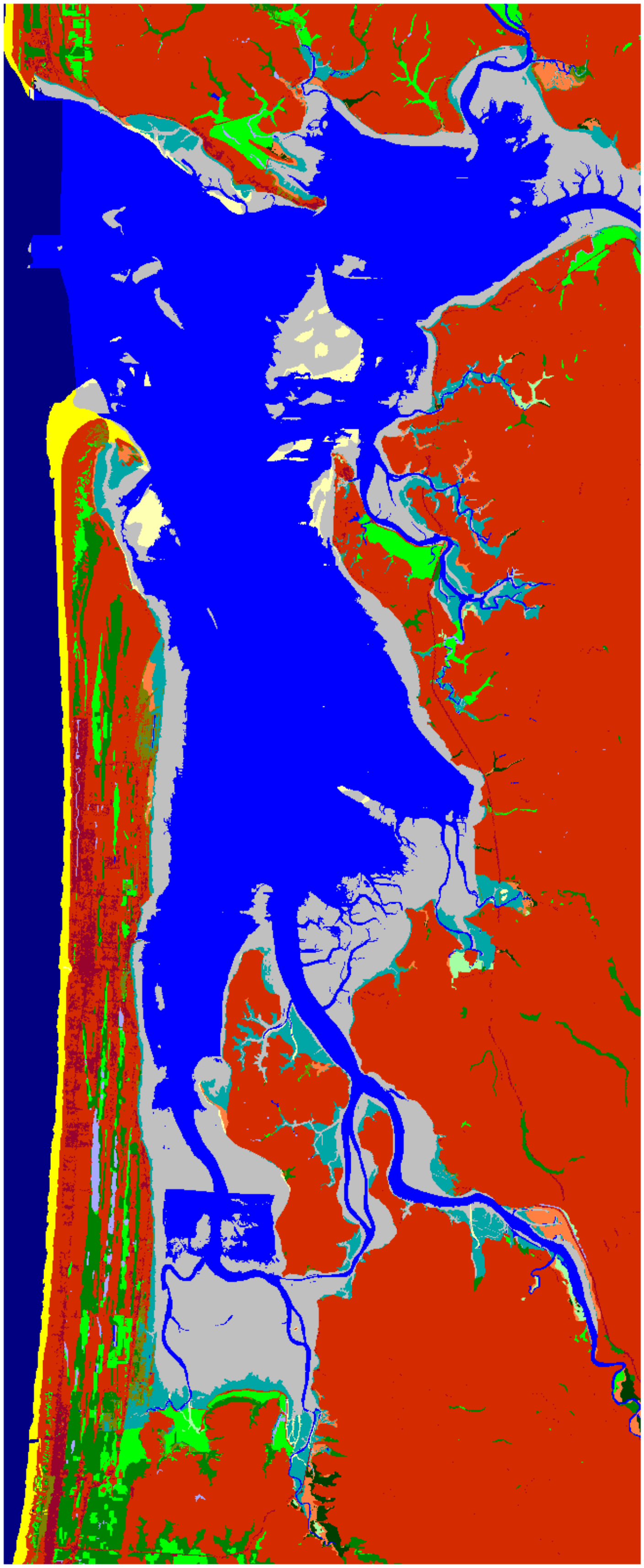

Willapa NWR, 2025, 1 meter



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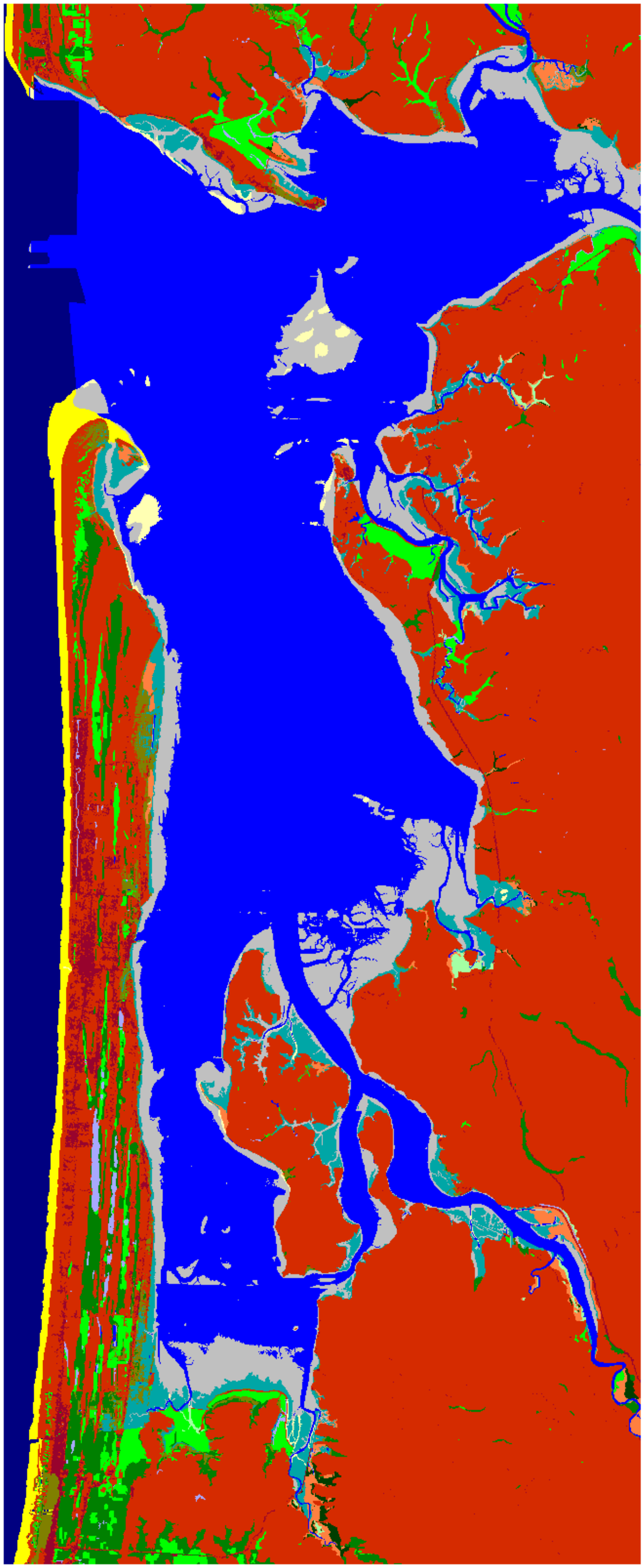

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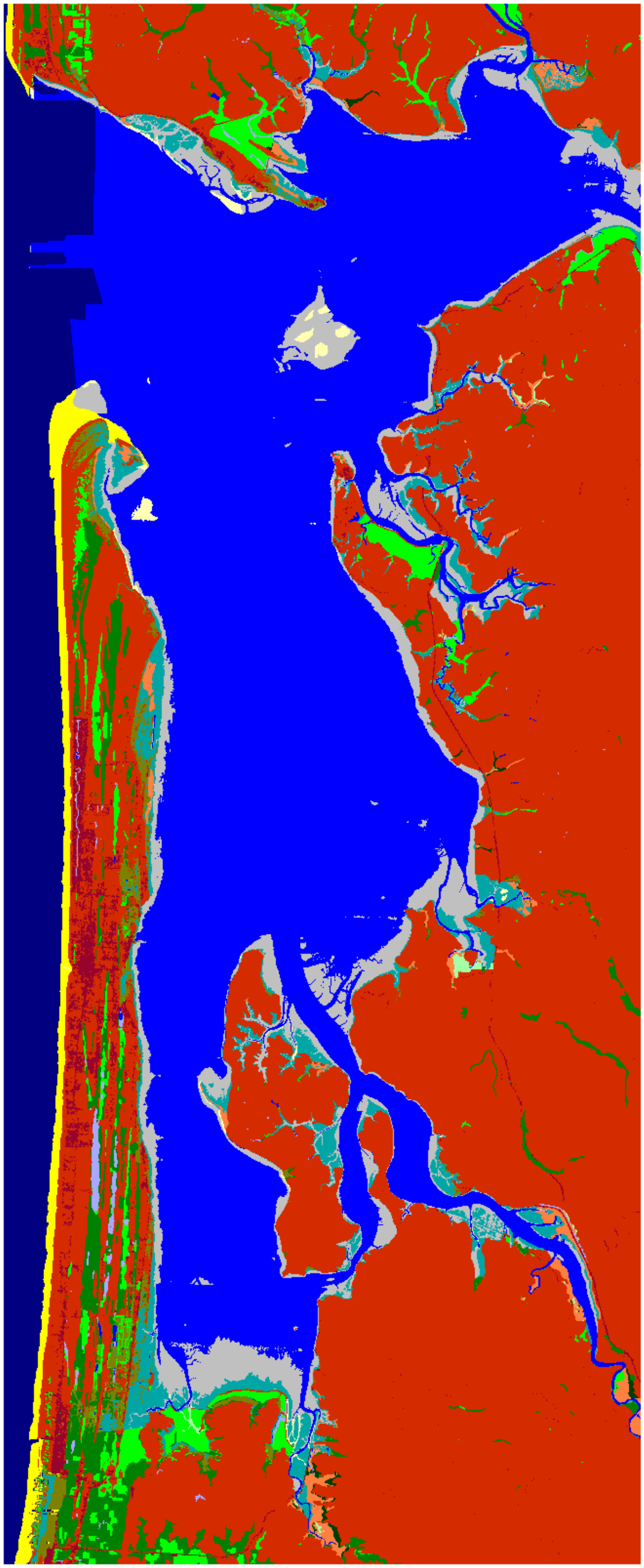

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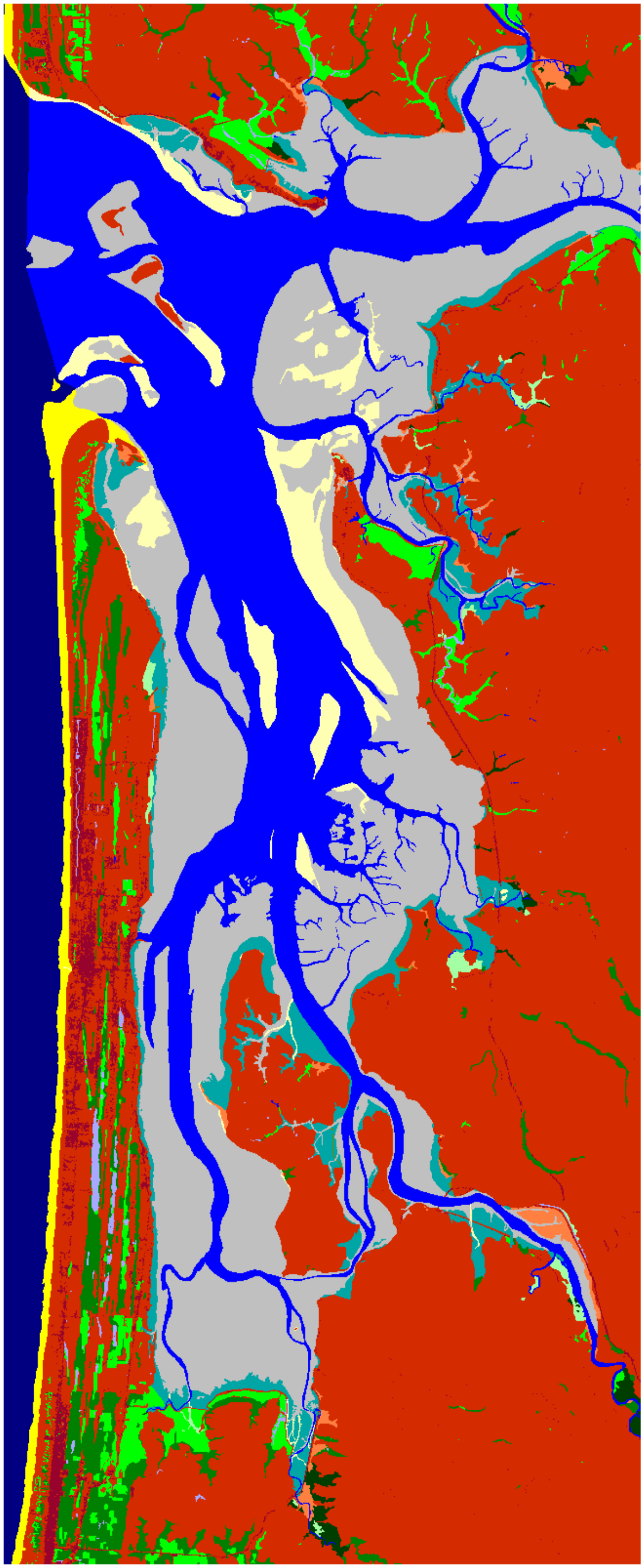

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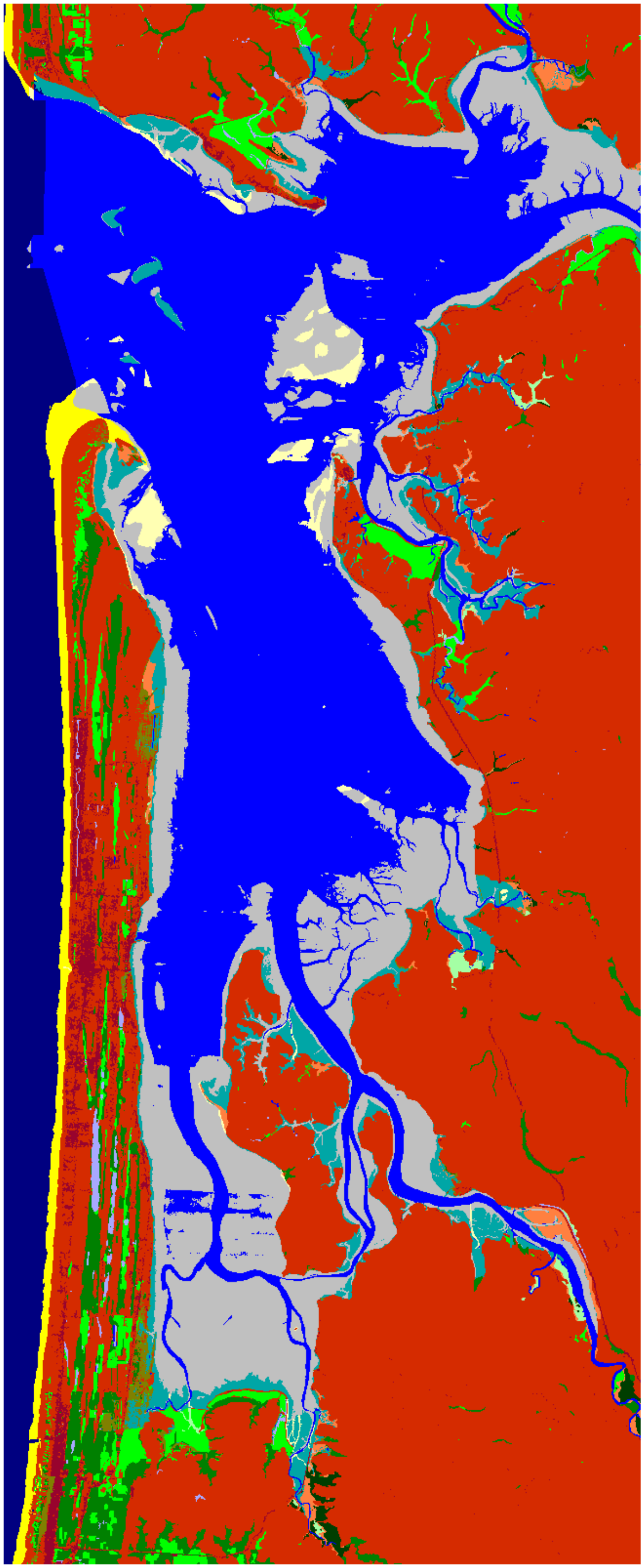
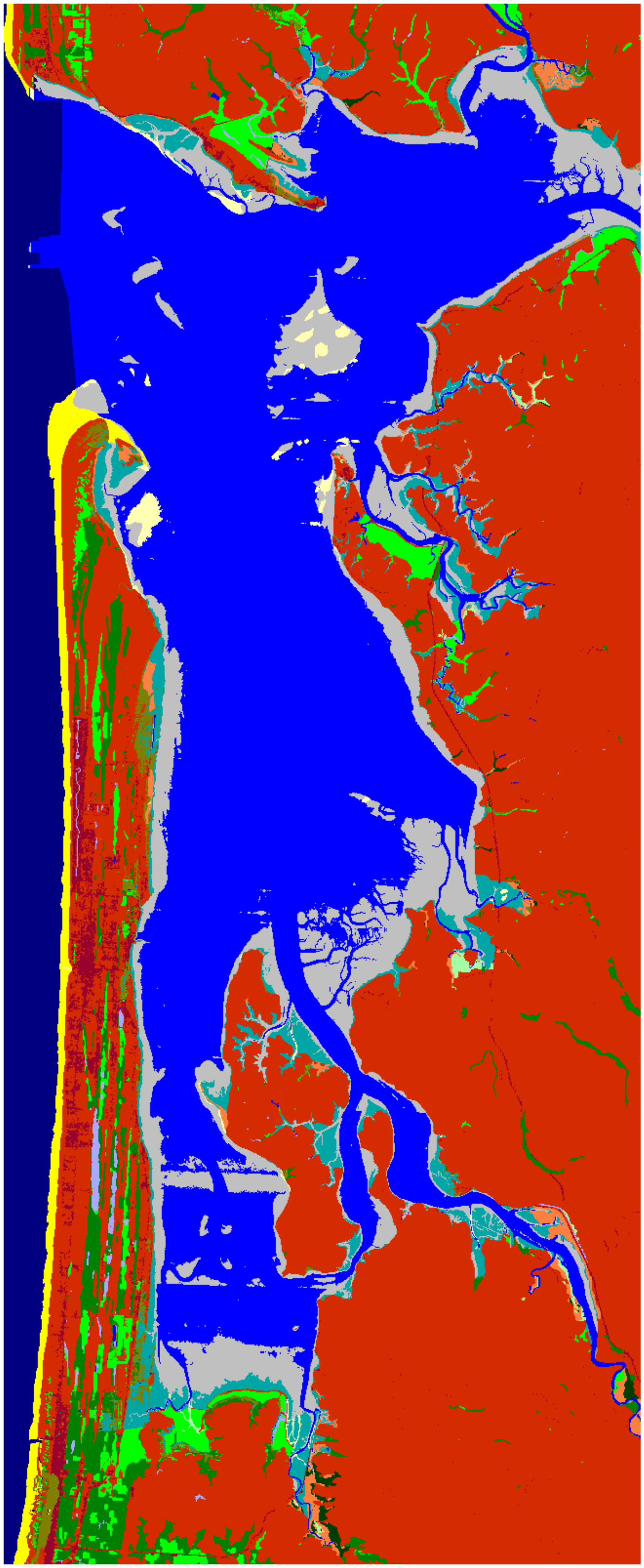


Willapa NWR, 2025, 1.5 meter



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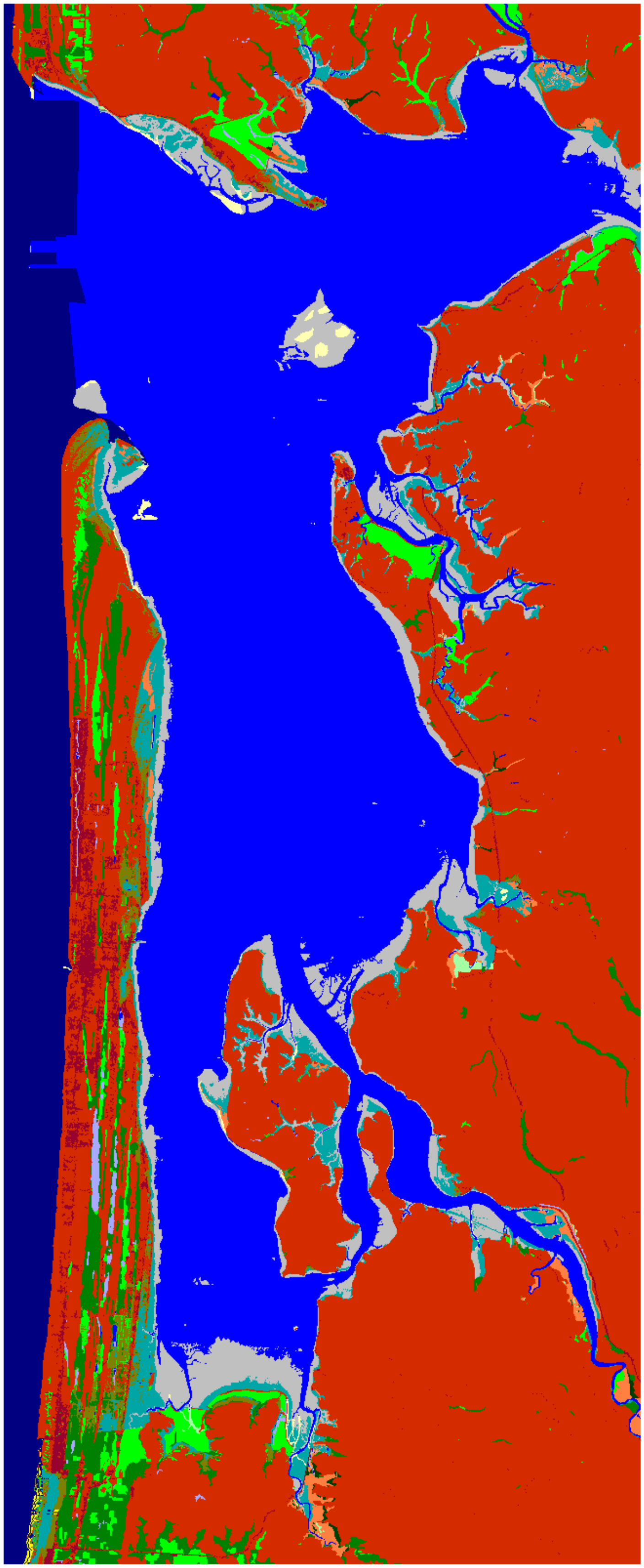

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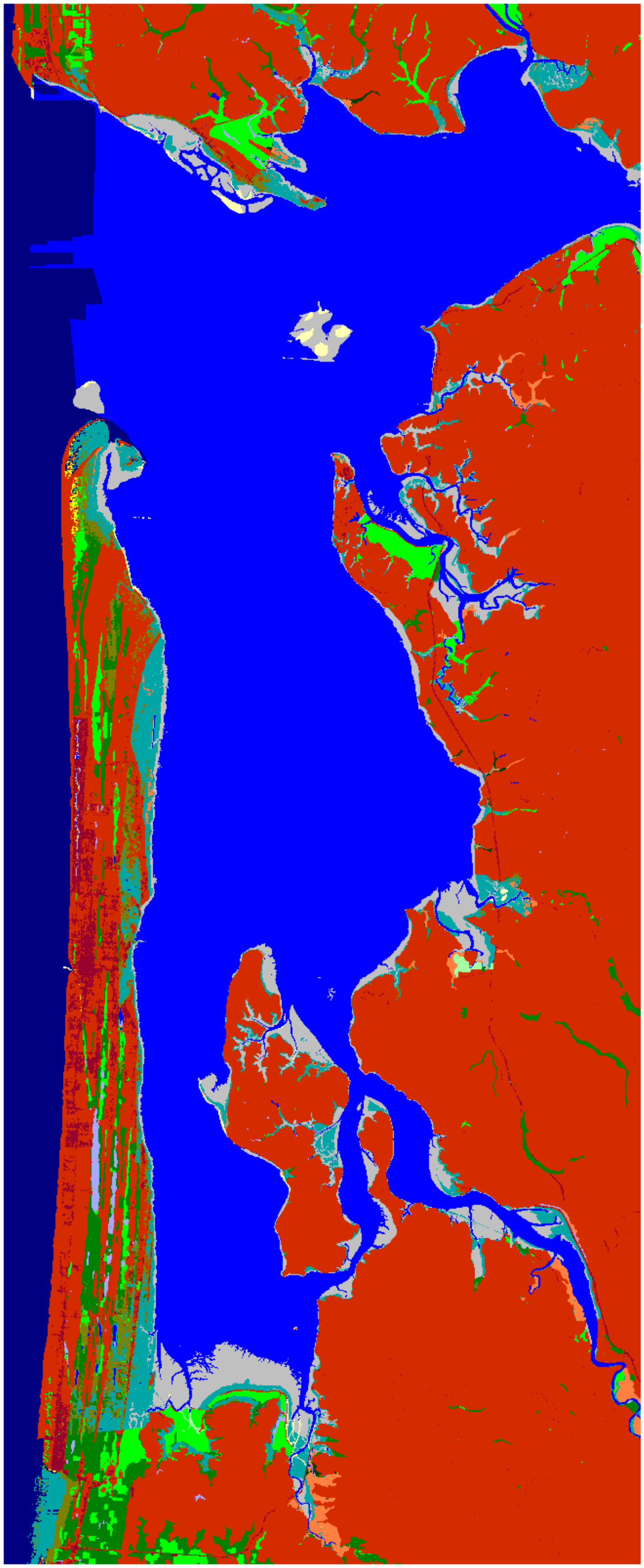

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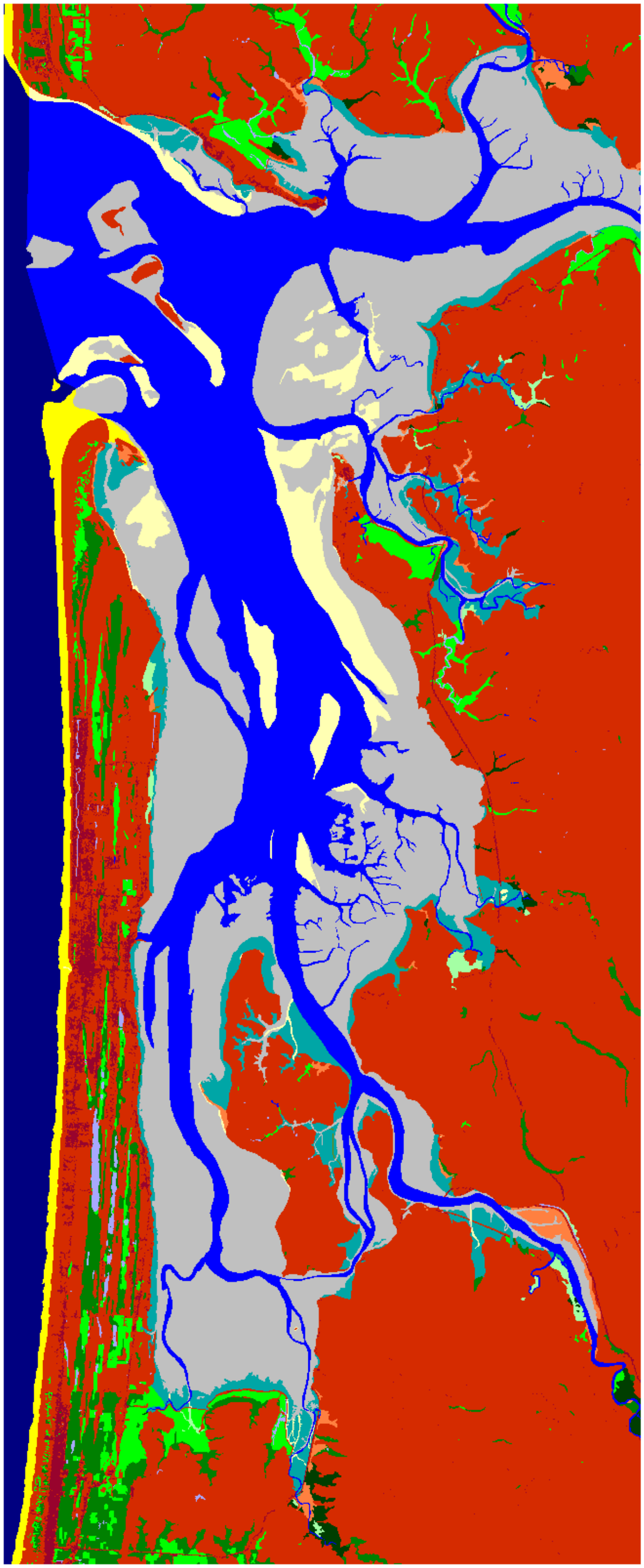
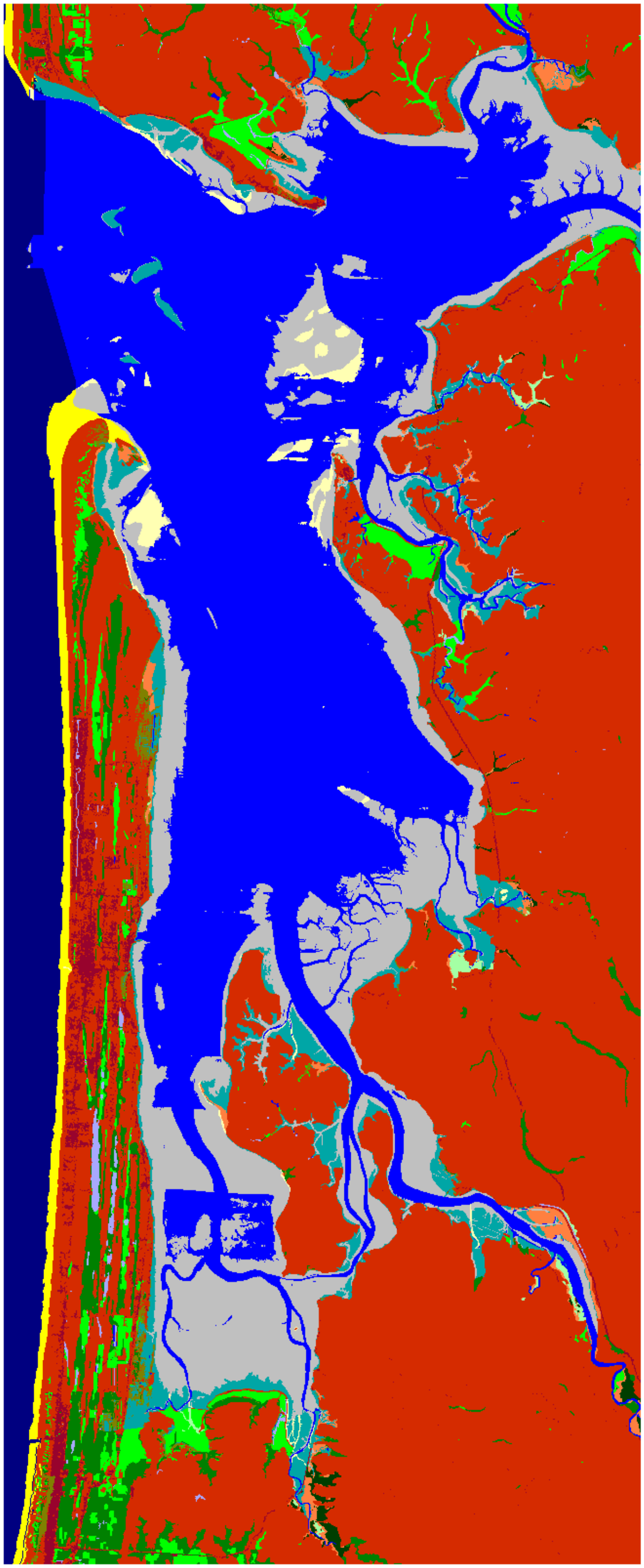
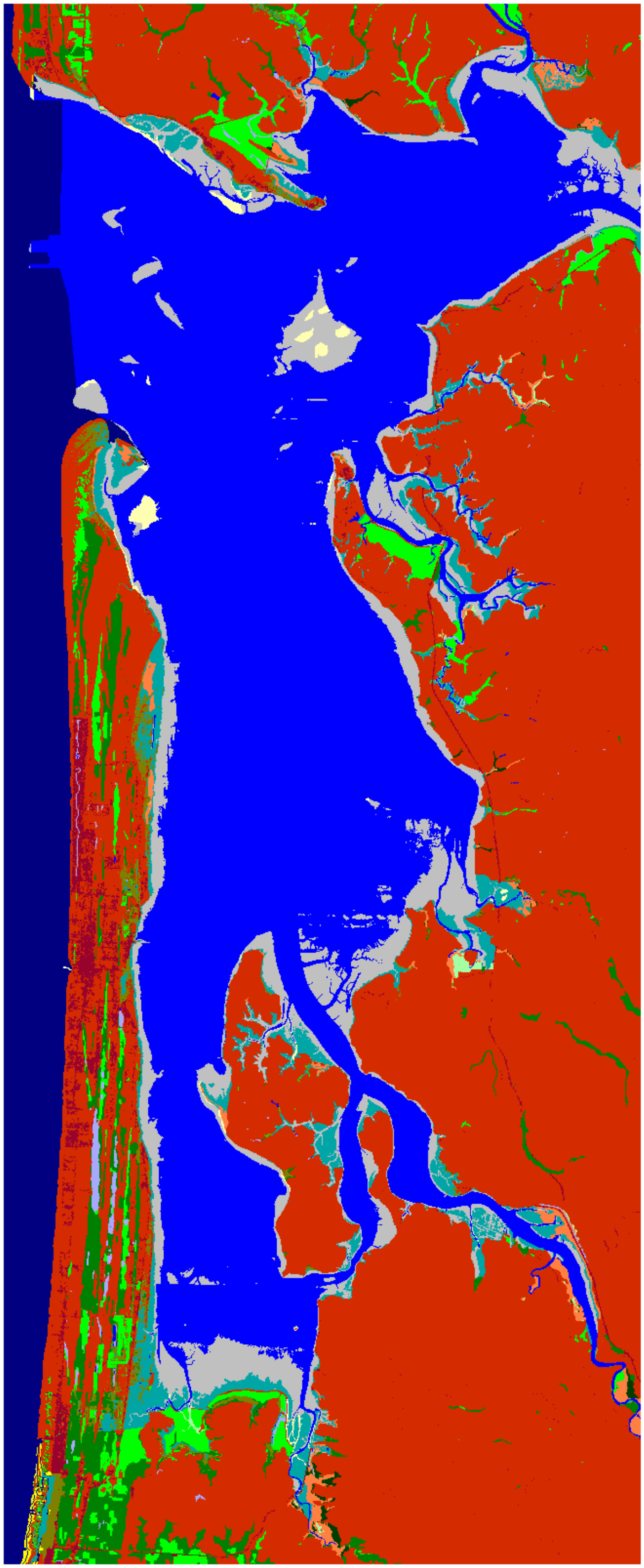


Willapa NWR, Initial Condition



Willapa NWR, 2025, 2 meter



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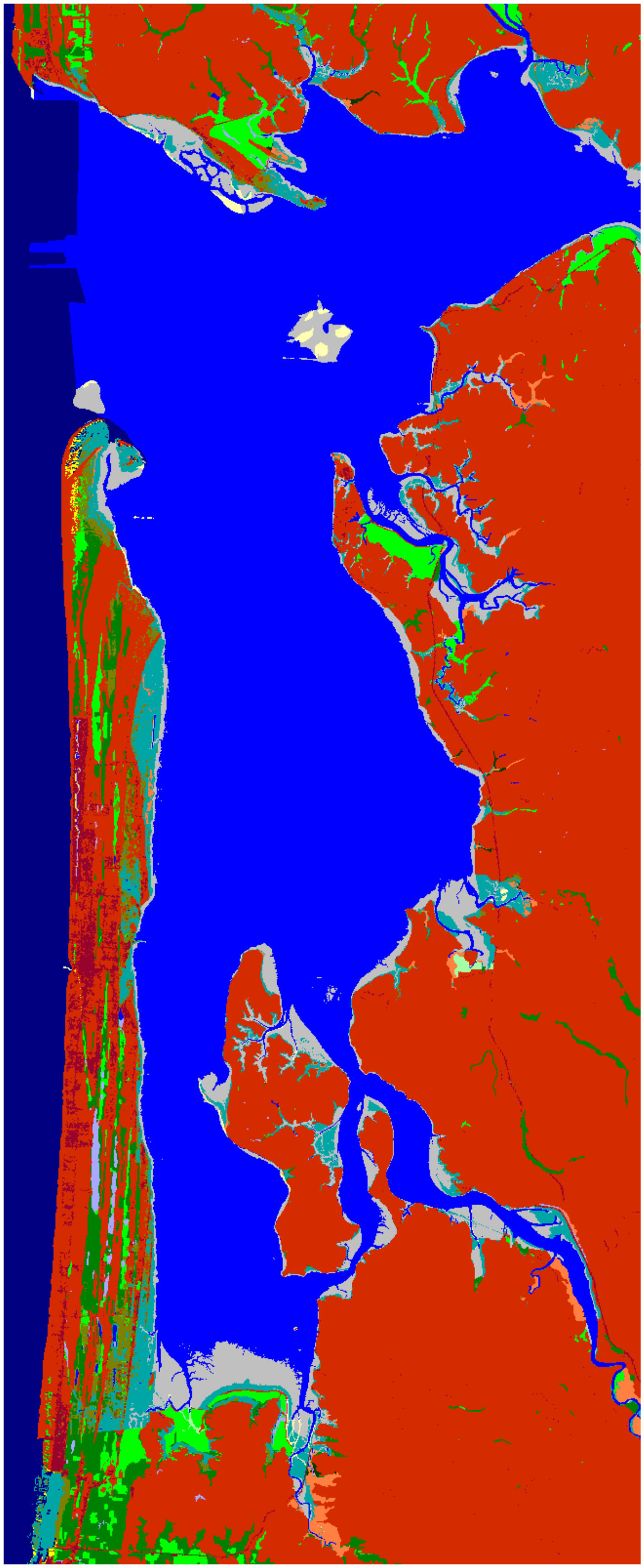
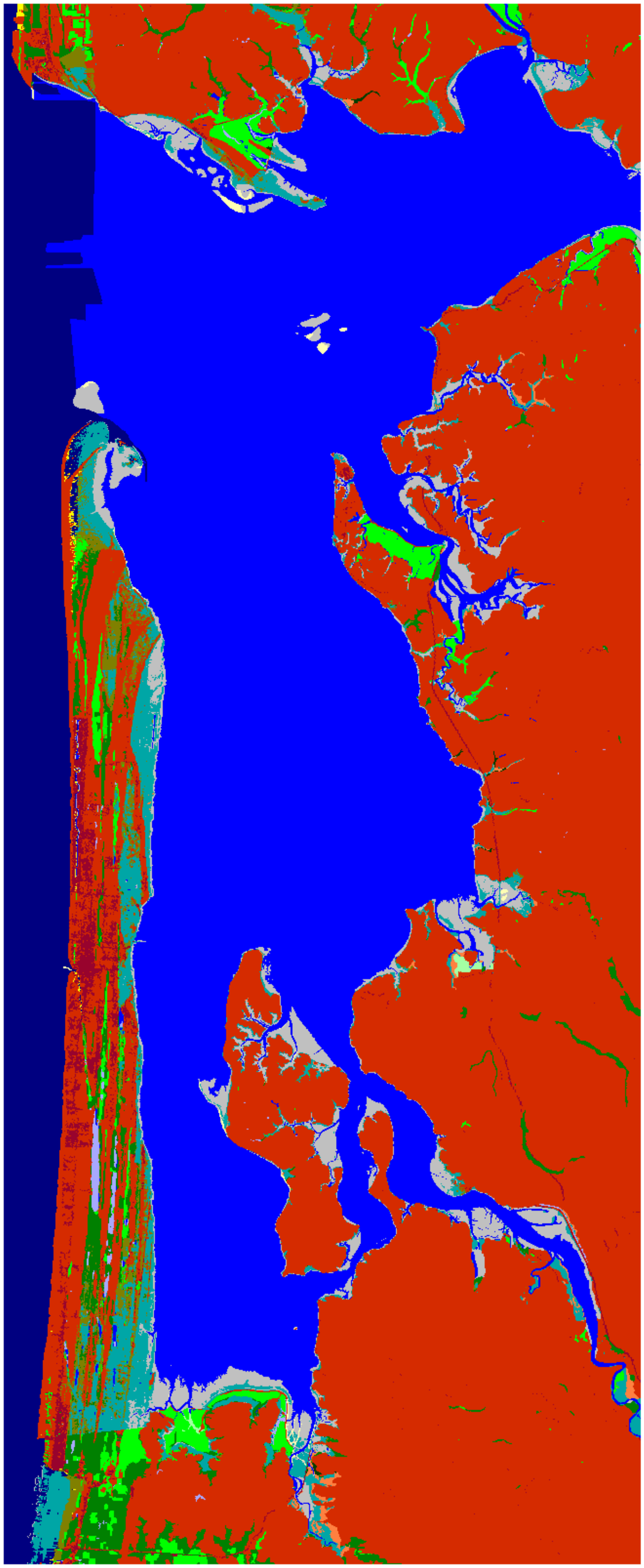


Willapa NWR, 2075, 2 meter



Willapa NWR, 2100, 2 meter