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

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Introduction

Tidal marshes are among the most susceptible ecosystems to climate change, especially accelerated sea level rise (SLR). The Intergovernmental 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 is 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 Irregularly Flooded 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 specified interval for large 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 flooding.

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 test the SLAMM conceptual model at each site. The causes of any discrepancies are then tracked down and reported on within the model application report.
- 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.

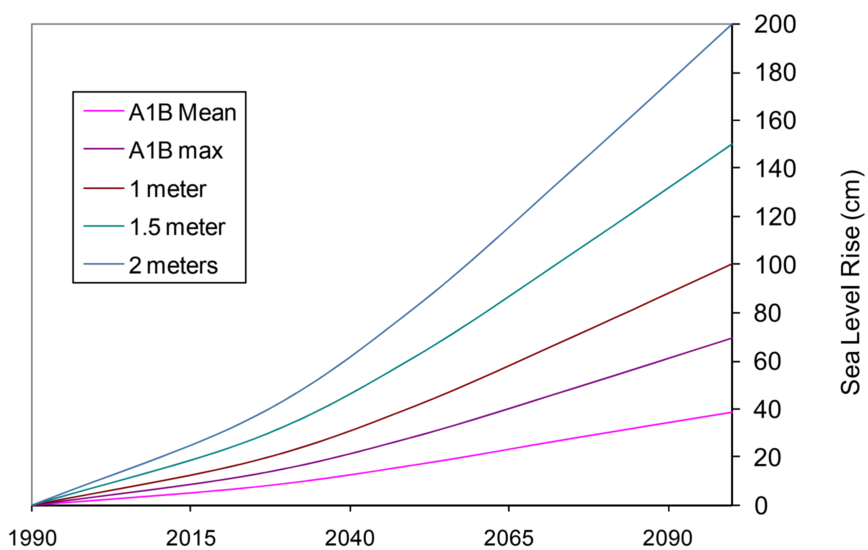
Sea Level Rise Scenarios

SLAMM 6 was run using scenario A1B from the Special Report on Emissions Scenarios (SRES) – mean and maximum estimates. The A1 family of scenarios assumes that the future world includes 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 (IPCC, 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 0.39 meters of global sea level rise by 2100. A1B-maximum predicts 0.69 meters of global SLR 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 of 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…" Grinsted also states that there is a "low probability" that SLR will match the lower IPCC estimates.

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 used in this simulation was derived from LiDAR data as supplied by Florida Division of Emergency Management (FDEM) via NOAA with a timestamp of 2007 (Figure 1).

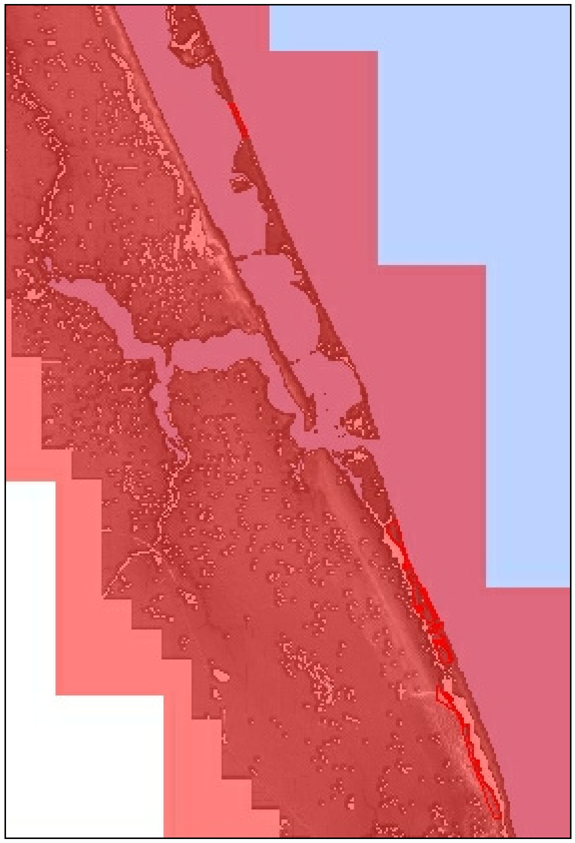


Figure 1: Shade-relief elevation map of study area (red).

The wetlands layer for the study area was produced by the National Wetlands Inventory and was based on both 1984 and 2007 photo dates (Figure 2). Converting the NWI survey into 10 meter cells indicates that the approximately 1286 acre refuge (approved acquisition boundary including water) is composed of the following categories (excluding categories below 1%):

	Undeveloped Dry Land	57.7%
	Mangrove	23.0%
	Estuarine Open Water	5.6%
	Developed Dry Land	4.8%
Open Ocean	Open Ocean	4.5%
	Ocean Beach	4.3%

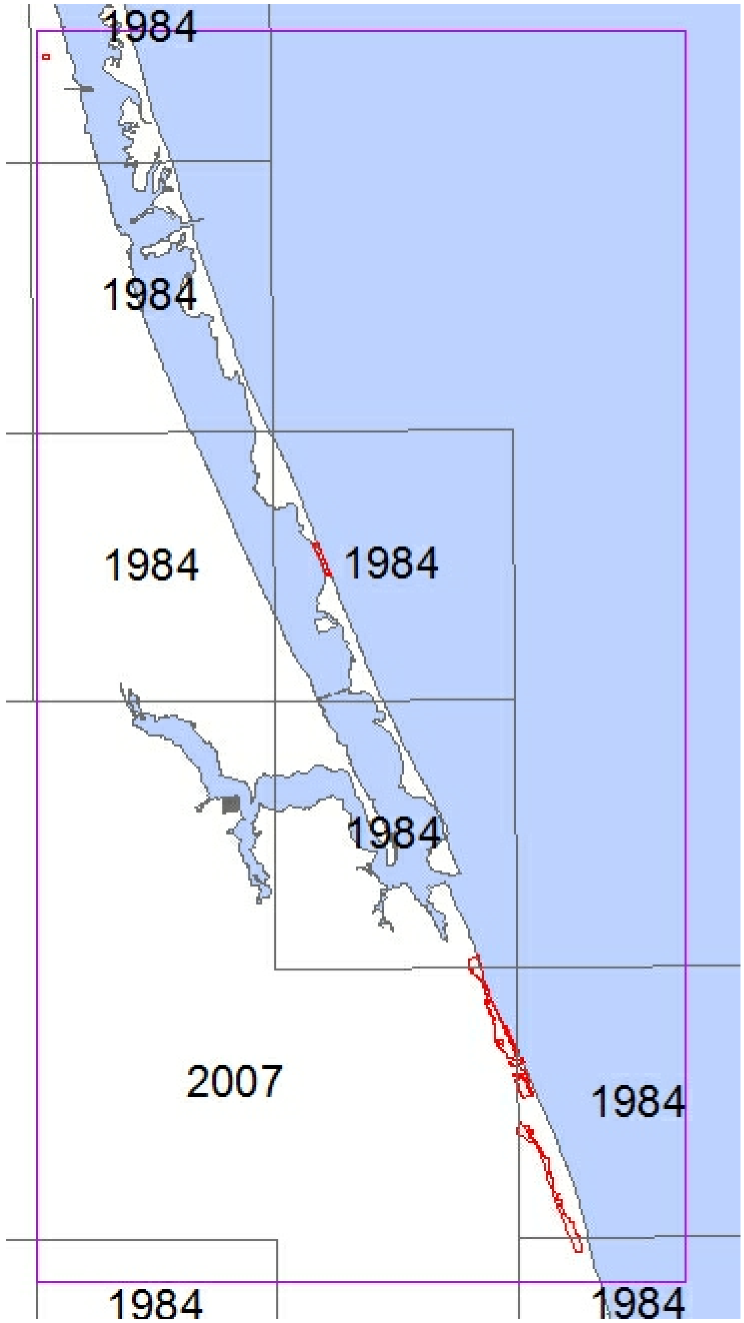


**Figure 2: Dates of NWI Coverage for Study Area.
Refuge Boundary shown in Red**

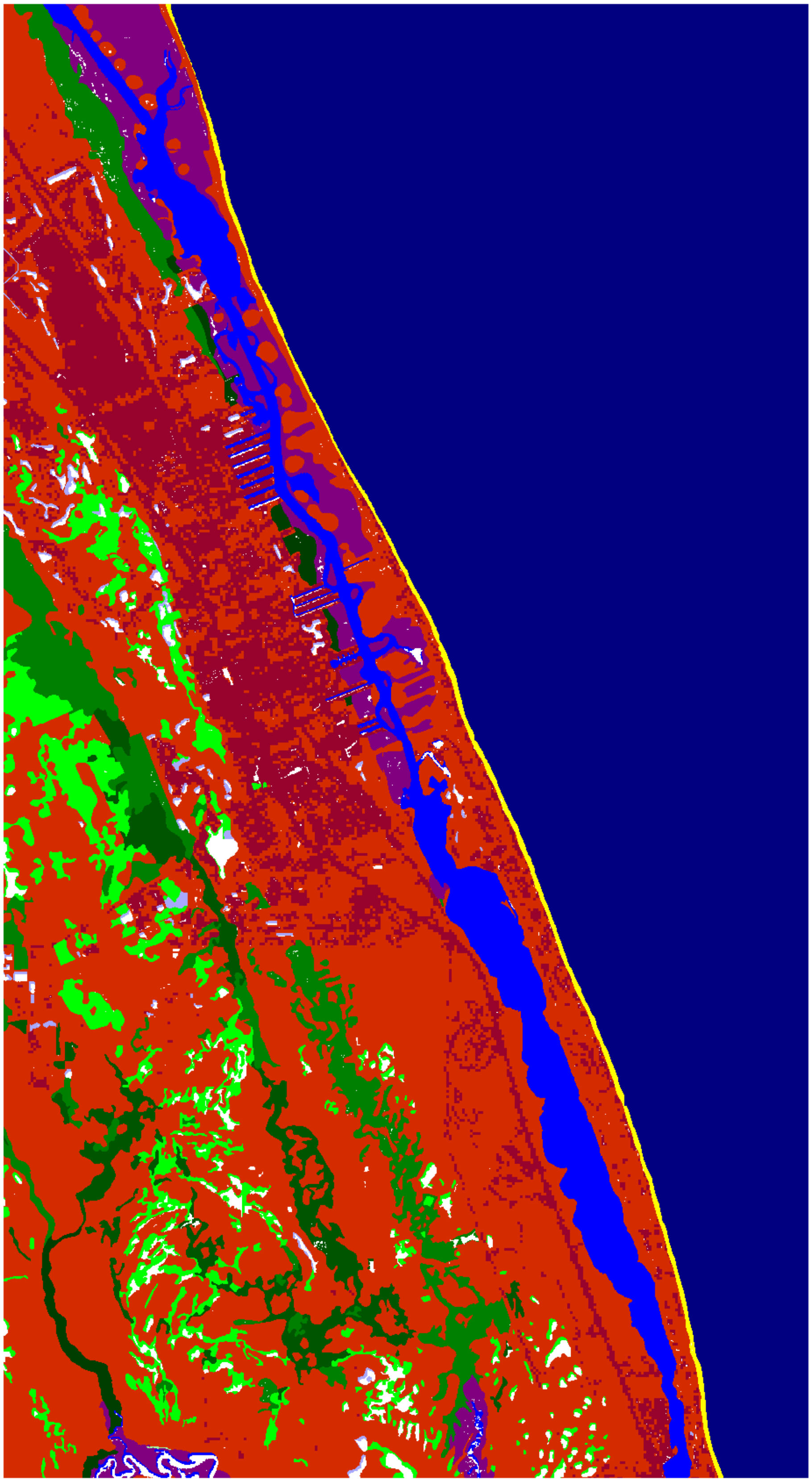


Figure 3: Detail of study area including Jupiter Island and Mainland Tracts of Hobe Sound NWR.

According to the National Wetland Inventory coverage, there are no impounded or diked areas within Hobe Sound NWR. Communication with refuge manager Margo Stahl revealed that some mosquito impoundments do exist in the Jupiter Island Tract. Lacking a GIS layer, these areas were not specifically designated as "diked lands" within the SLAMM parameterization. However, the SLAMM connectivity algorithm was utilized in this simulation; this algorithm takes into account natural and human-made barriers to water flows when calculating inundation (based on their accurate representation in the digital elevation map).

The historic trend for sea level rise was estimated at 2.35 mm/year using the mean value of the two nearest NOAA gages with SLR data (8723170, Miami Beach, FL; 8721120, Daytona Beach Shores, FL). The rate of sea level rise for this region is therefore marginally higher that the global average for the last 100 years (approximately 1.7 mm/year, IPCC 2007a).

Six tide stations were used to parameterize the tide ranges over the geographic extent of this site (Figure 4 and Figure 5). The Jupiter Island and Mainland tracts were divided by tide level, with the Jupiter Island input site set to 0.49 meters (GT or diurnal range) and the mainland input site parameterized with 0.6 meters (8722404, Peck Lake, St. Lucie Inlet, FL; 872414, Gomez, FL; 8722429, Hobe Sound Bridge, Hobe Sound, FL; 8722445, Hobe Sound, State Park, FL). The St. Lucie County tracts were parameterized using the gages at Sewall Point, St. Lucie River, FL (8722371) and North Beach Causeway, FL (8722208).

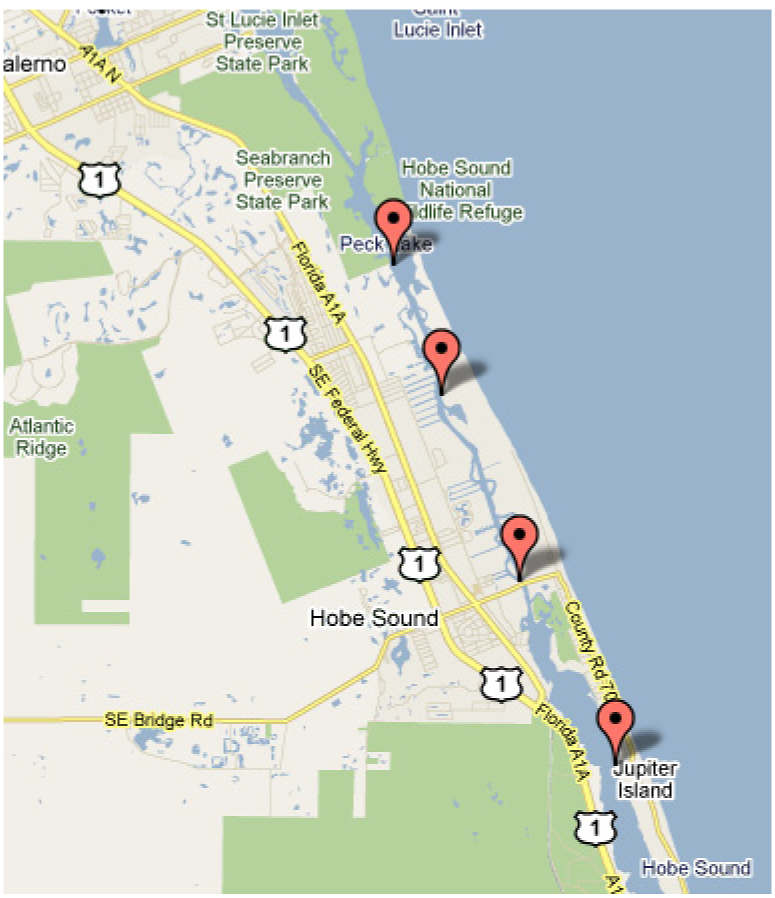


Figure 4: Location of NOAA tides gages used for Jupiter Island and Mainland Tracts.

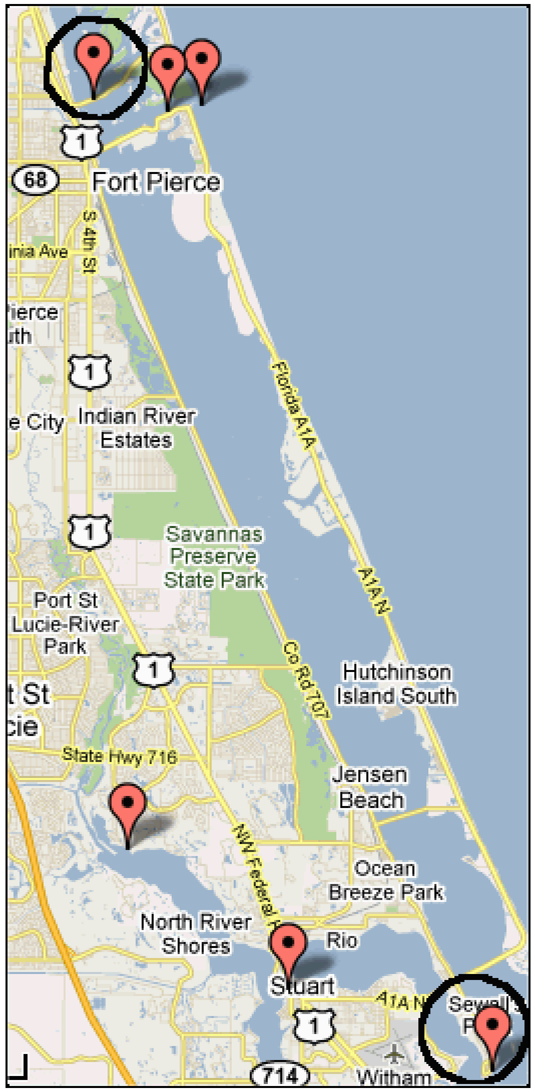


Figure 5: Encircled tide gages used for both St. Lucie County Tracts.

The elevation at which estuarine water is predicted to regularly inundate the land (the salt elevation) was estimated based on a frequency of inundation analysis using data from from the Port of West Palm Beach, FL gage (8722588). This procedure was done to include the effects of wind tides within estimates of land inundation. The regularly flooded inundation level was assumed to occur where water penetrates at least once every 30 days, or approximately 163% of MHHW.

No accretion studies from eastern Florida were located as part of this analysis. Accretion rates in salt marshes were set to 3.9 mm/year, based on measured rates of accretion in Georgia Marshes (Craft et. al, 2009). This value is also very close to several studies measuring accretion rates on the Gulf Coast of Florida (St. Marks FL, 4.0 mm/year from Cahoon et. al. 1995, and Hendrickson, J.C. 1997; Ochlockonee River FL, 4.05 mm/year from Hendrickson, J.C. 1997).

The MTL to NAVD88 correction was derived using the NOAA gages. Across tide gages the correction ranged from -0.348 meters to -0.296 meters.

Modeled U.S. Fish and Wildlife Service refuge boundaries for Florida 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 10 meter by 10 meter cells. Note that the SLAMM model will track partial conversion of cells based on elevation and slope.

SUMMARY OF SLAMM INPUT PARAMETERS FOR HOBE SOUND NWR

Parameter	Global	SubSite 1	SubSite 2	SubSite 3	SubSite 4
Description	Global	Mainland	Jupiter	Middle Lucie	North Lucie
NWI Photo Date (YYYY)	1984	1984	2007	1984	1984
DEM Date (YYYY)	2007	2007	2007	2007	2007
Direction Offshore [n,s,e,w]	East	West	West	West	East
Historic Trend (mm/yr)	2.35	2.35	2.35	2.35	2.35
MTL-NAVD88 (m)	-0.348	-0.296	-0.326	-0.333	-0.329
GT Great Diurnal Tide Range (m)	1.2	0.6	0.49	0.43	0.56
Salt Elev. (m above MTL)	0.8	0.49	0.39	0.35	0.45
Marsh Erosion (horz. m /yr)	1.8	1.8	1.8	1.8	1.8
Swamp Erosion (horz. m /yr)	1	1	1	1	1
T.Flat Erosion (horz. m /yr)	0.5	0.5	0.5	0.5	0.5
Reg. Flood Marsh Accr (mm/yr)	3.9	3.9	3.9	3.9	3.9
Irreg. Flood Marsh Accr (mm/yr)	4.7	4.7	4.7	4.7	4.7
Tidal Fresh Marsh Accr (mm/yr)	5.9	5.9	5.9	5.9	5.9
Beach Sed. Rate (mm/yr)	0.5	0.5	0.5	0.5	0.5
Freq. Overwash (years)	15	15	15	15	15
Use Elev Pre-processor [True,False]	FALSE	FALSE	FALSE	FALSE	FALSE

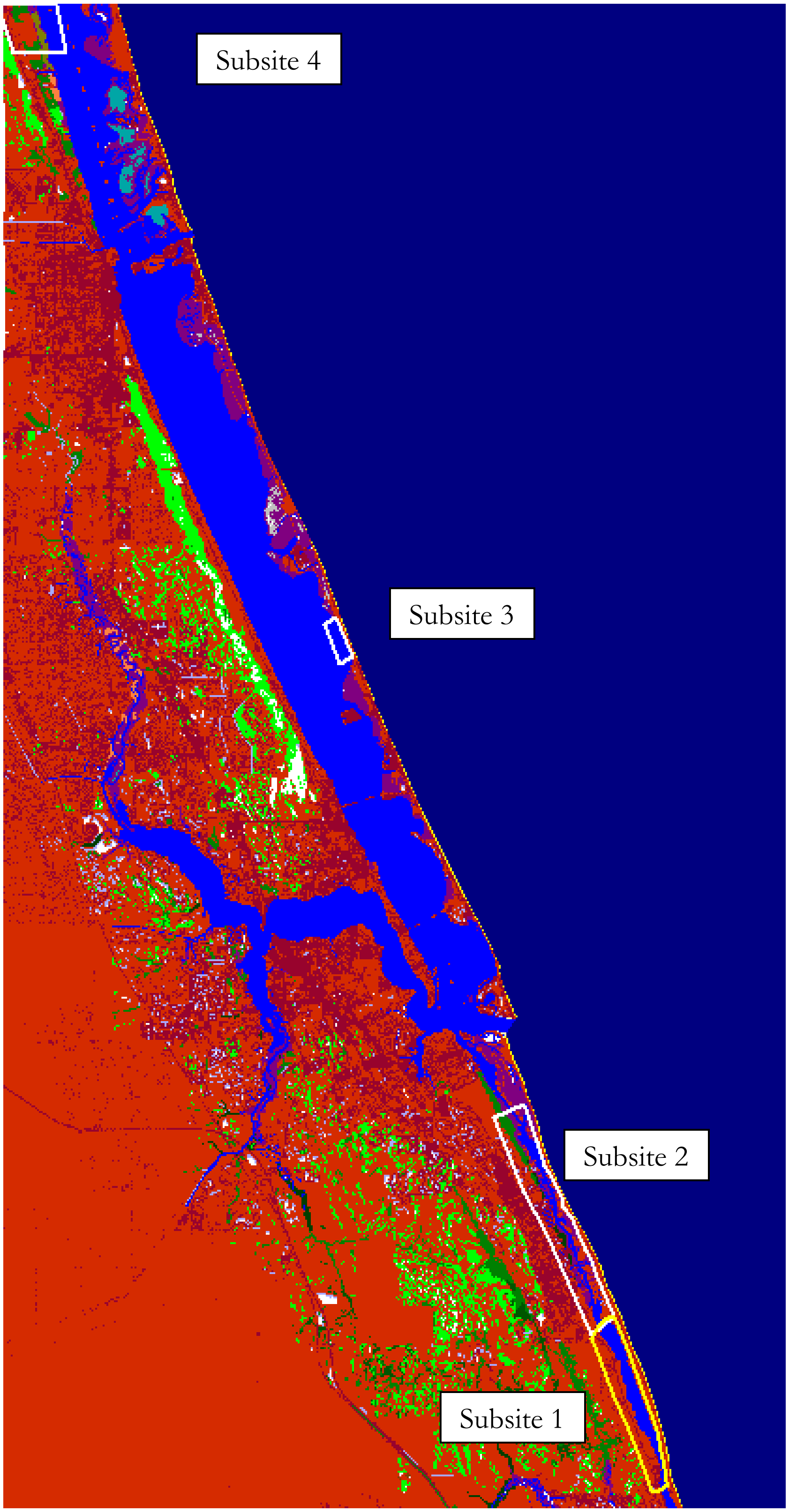


Figure 6: Input subsites for model application.

Results

SLAMM predicts that Hobe Sound NWR will be moderately impacted depending on the SLR scenario and wetland class. Between one quarter and more than one half of refuge undeveloped dry land – which comprises more than half of the refuge – is predicted to be lost across all scenarios. Mangrove swamps are predicted to colonize more land under lower rates of SLR (negative loss rates shown below) but be significantly impacted under SLR above 1 meter (eustatic by 2100).

SLR by 2100 (m)	0.39	0.69	1	1.5	2
Undeveloped Dry Land	25%	33%	39%	48%	56%
Mangrove	-50%	-62%	5%	73%	85%
Developed Dry Land	1%	3%	6%	14%	17%
Ocean Beach	97%	95%	95%	99%	100%

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:

Undeveloped Dry Land	
Swamp	
Tidal Swamp	
Tidal Fresh Marsh	
Riverine Tidal	
Inland Open Water	
Inland Fresh Marsh	
Cypress Swamp	
Irregularly Flooded Marsh	
Estuarine Open Water	
Regularly Flooded Marsh	
Transitional Salt Marsh	
Tidal Flat	

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

Results in Acres

		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	741.9	664.8	633.5	590.0	557.9
	Mangrove	295.5	345.5	373.8	414.0	443.4
	Estuarine Open Water	72.6	96.2	96.3	96.6	97.3
	Developed Dry Land	61.9	61.5	61.3	61.2	61.0
	Open Ocean	57.8	58.2	63.6	87.2	120.7
	Ocean Beach	55.0	57.1	54.5	33.2	1.7
	Swamp	0.6	0.1	0.0	0.0	0.0
	Estuarine Beach	0.0	1.9	2.1	2.8	3.0
	Tidal Flat	0.0	0.1	0.3	0.5	0.5
	Total (incl. water)	**1285.5**	**1285.5**	**1285.5**	**1285.5**	**1285.5**

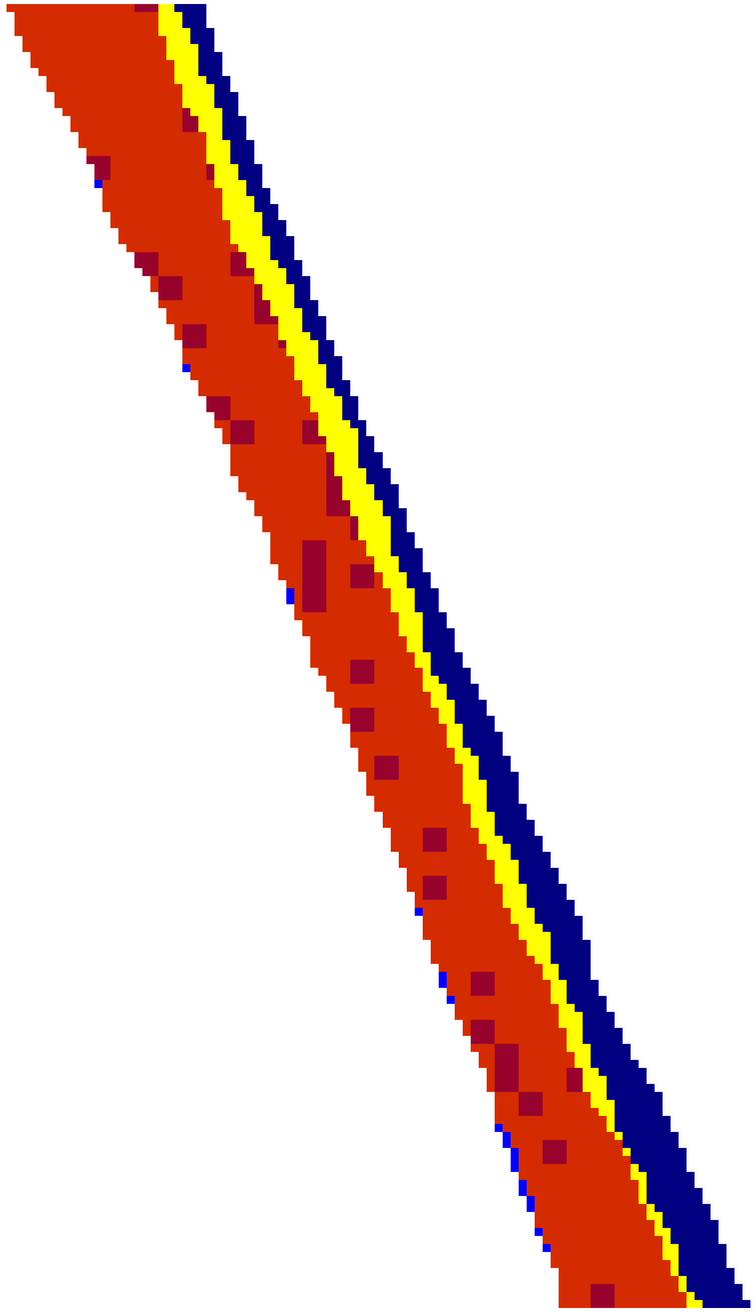
Hobe Sound NWR, Jupiter and Mainland Tracts, Initial Condition

Hobe Sound NWR, Jupiter and Mainland Tracts, 2025, Scenario A1B Mean

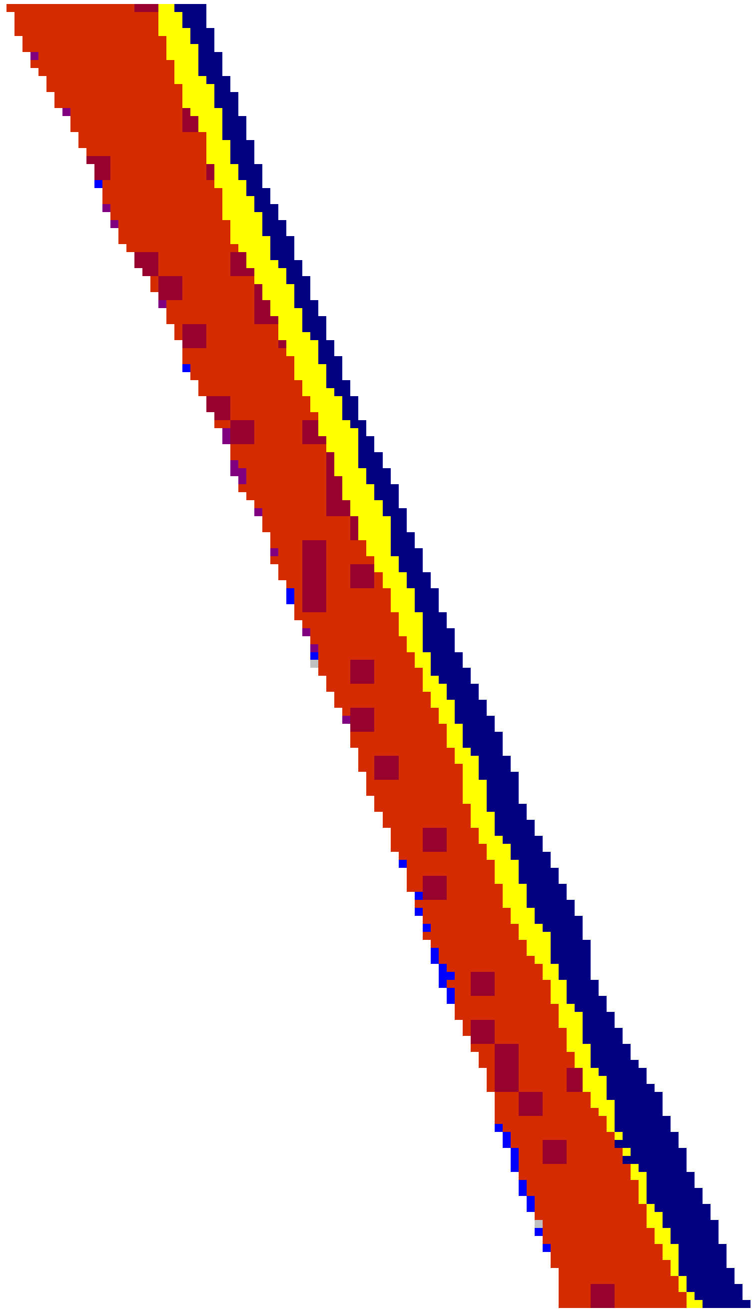
Hobe Sound NWR, Jupiter and Mainland Tracts, 2050, Scenario A1B Mean

Hobe Sound NWR, Jupiter and Mainland Tracts, 2075, Scenario A1B Mean

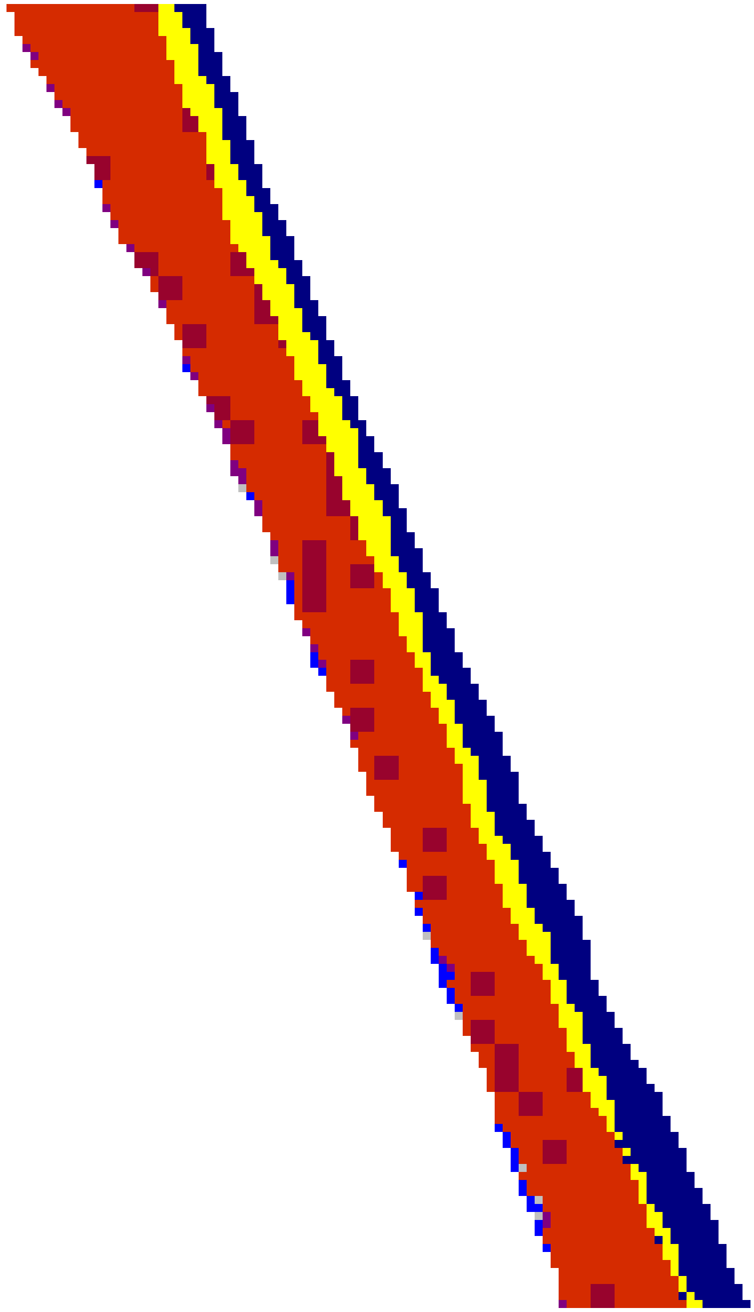
Hobe Sound NWR, Jupiter and Mainland Tracts, 2100, Scenario A1B Mean



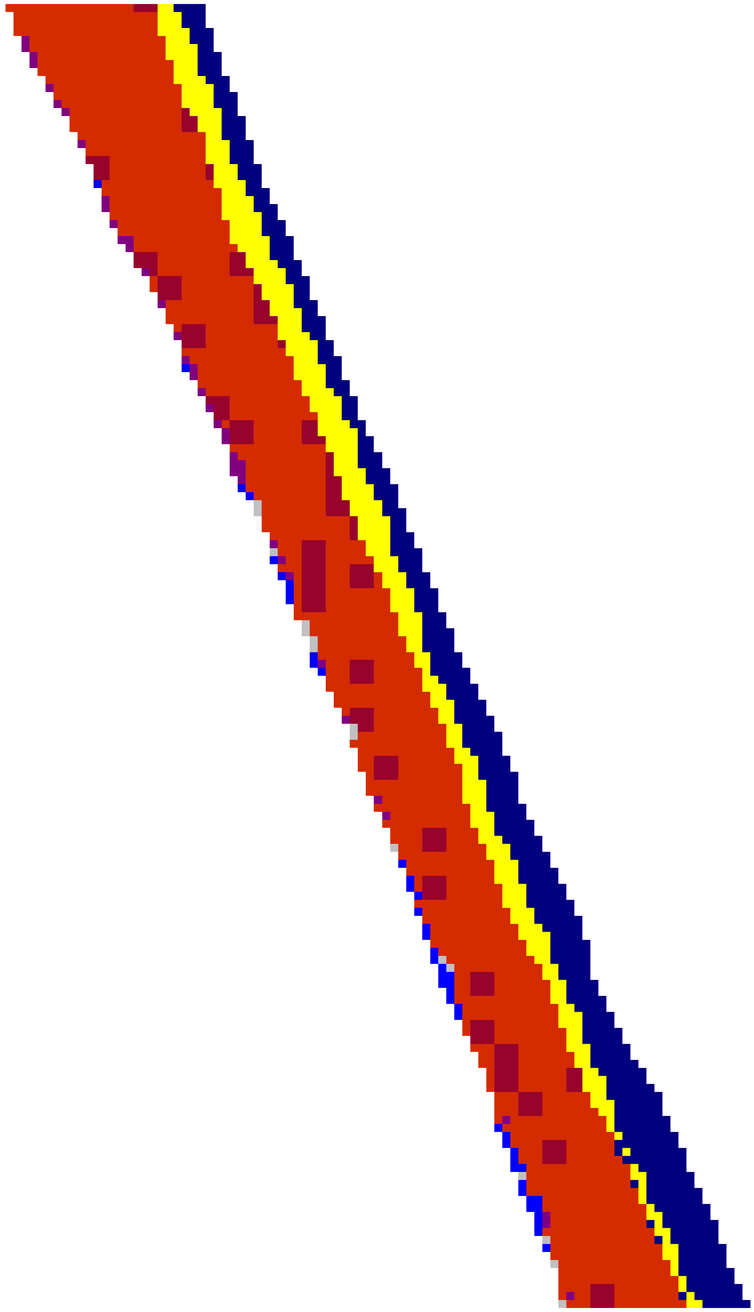
Hobe Sound NWR, South St. Lucie County Tract, Initial Condition



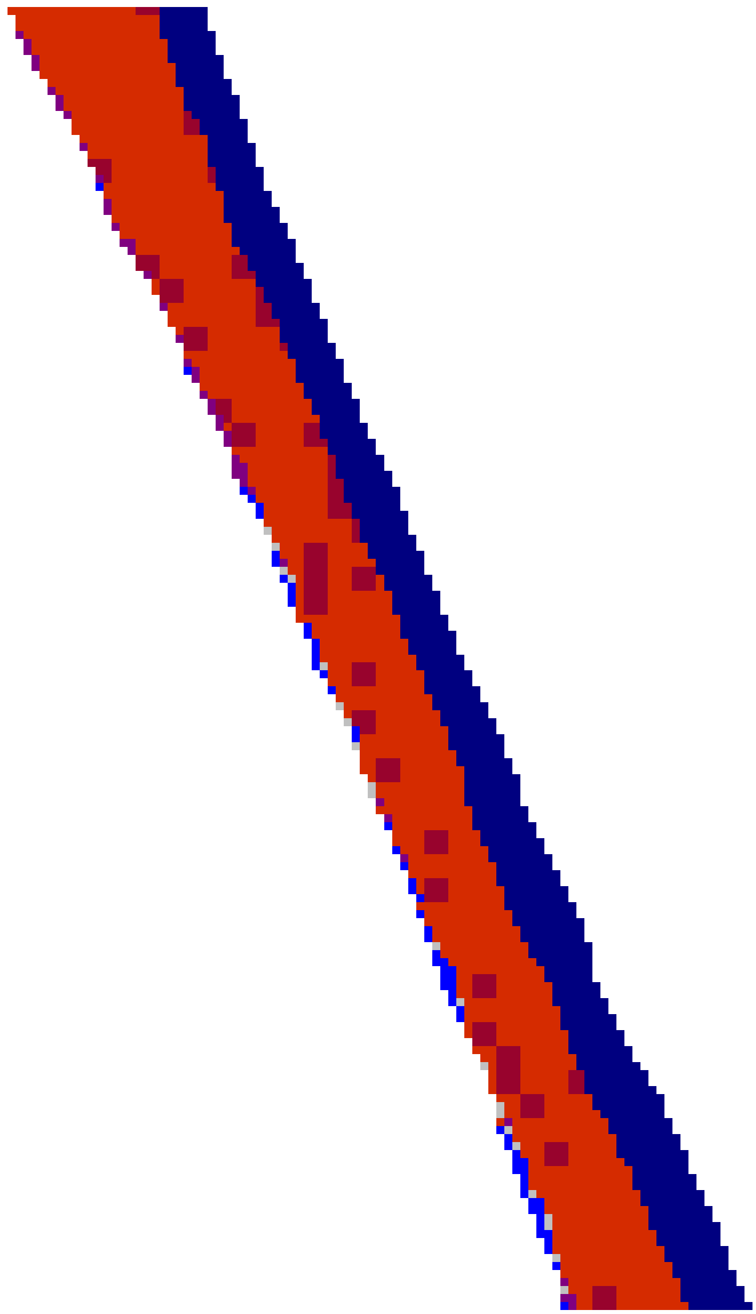
Hobe Sound NWR, South St. Lucie County Tract, 2025, Scenario A1B Mean



Hobe Sound NWR, South St. Lucie County Tract, 2050, Scenario A1B Mean



Hobe Sound NWR, South St. Lucie County Tract, 2075, Scenario A1B Mean



Hobe Sound NWR, South St. Lucie County Tract, 2100, Scenario A1B Mean

Hobe Sound NWR, North St. Lucie County Tract, Initial Condition

Hobe Sound NWR, North St. Lucie County Tract, 2025, Scenario A1B Mean

Hobe Sound NWR, North St. Lucie County Tract, 2050, Scenario A1B Mean

Hobe Sound NWR, North St. Lucie County Tract, 2075, Scenario A1B Mean

Hobe Sound NWR, North St. Lucie County Tract, 2100, Scenario A1B Mean

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

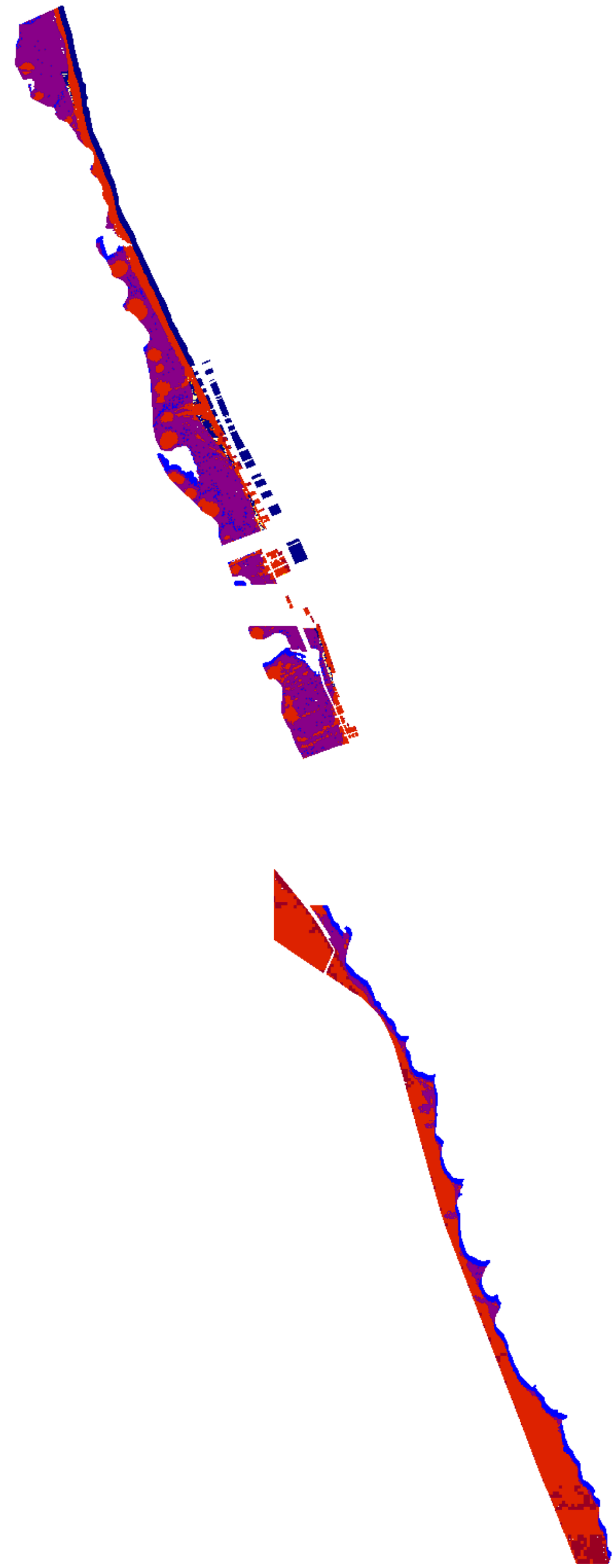
Results in Acres

		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	741.9	655.2	598.7	543.6	499.8
	Mangrove	295.5	353.5	404.4	453.3	479.8
	Estuarine Open Water	72.6	97.5	97.7	100.0	112.5
	Developed Dry Land	61.9	61.4	61.2	60.9	60.1
	Open Ocean	57.8	58.5	102.2	122.5	125.5
	Ocean Beach	55.0	57.1	17.8	0.9	2.6
	Swamp	0.6	0.1	0.0	0.0	0.0
	Estuarine Beach	0.0	2.0	2.9	3.5	4.5
	Tidal Flat	0.0	0.2	0.4	0.8	0.6
	Total (incl. water)	**1285.5**	**1285.5**	**1285.5**	**1285.5**	**1285.5**

Hobe Sound NWR, Jupiter and Mainland Tracts, Initial Condition

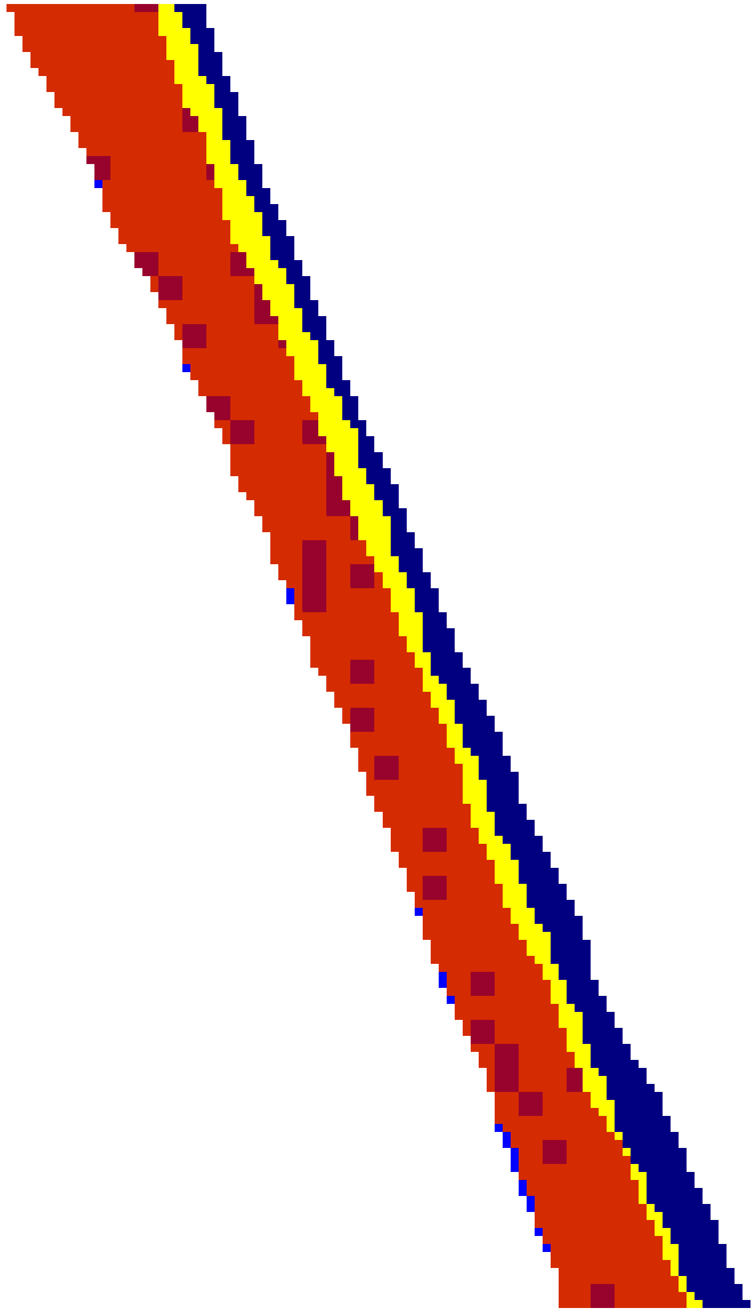
Hobe Sound NWR, Jupiter and Mainland Tracts, 2025, Scenario A1B Maximum

Hobe Sound NWR, Jupiter and Mainland Tracts, 2050, Scenario A1B Maximum

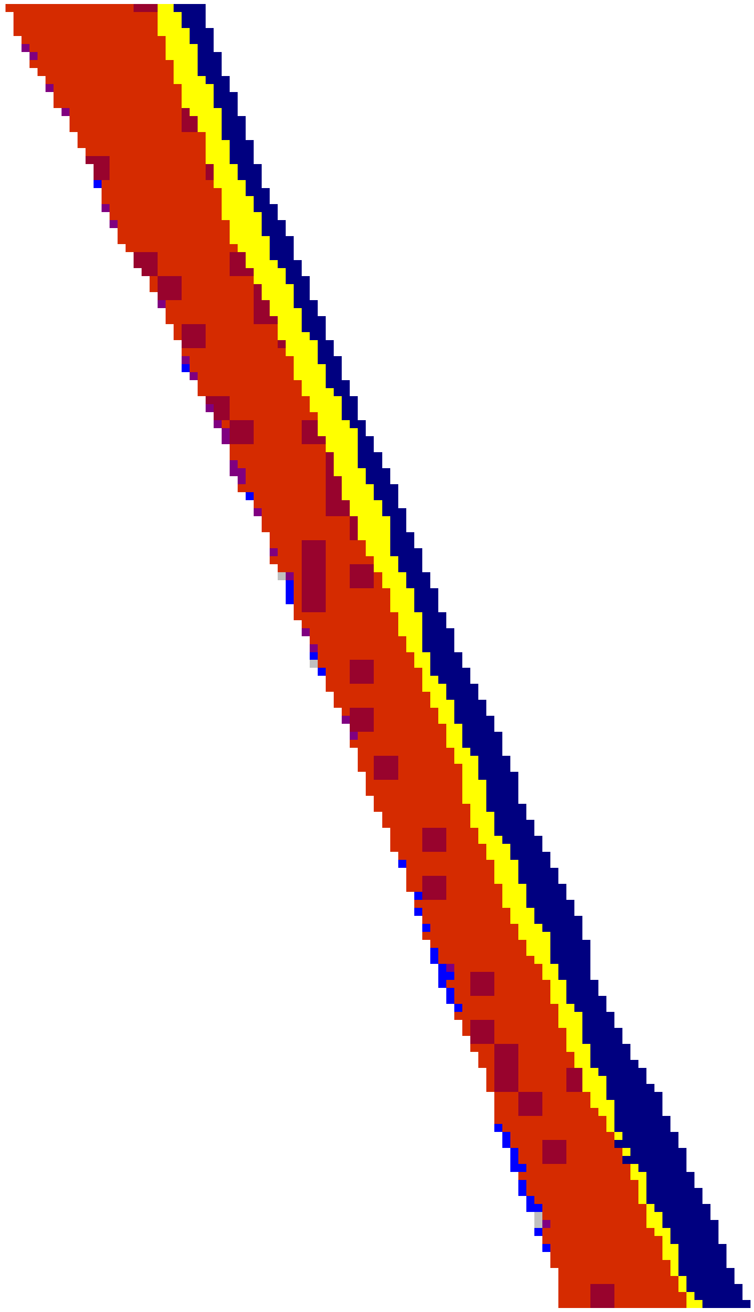


Hobe Sound NWR, Jupiter and Mainland Tracts, 2075, Scenario A1B Maximum

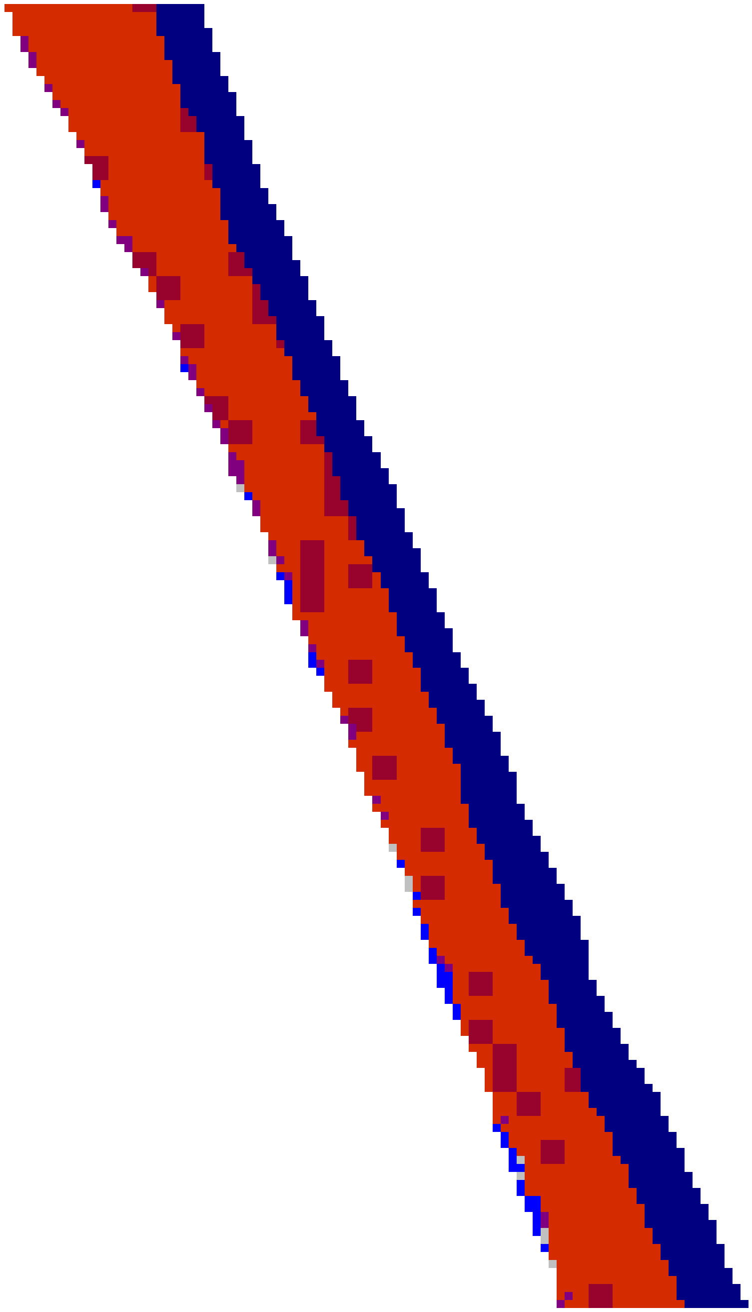
Hobe Sound NWR, Jupiter and Mainland Tracts, 2100, Scenario A1B Maximum



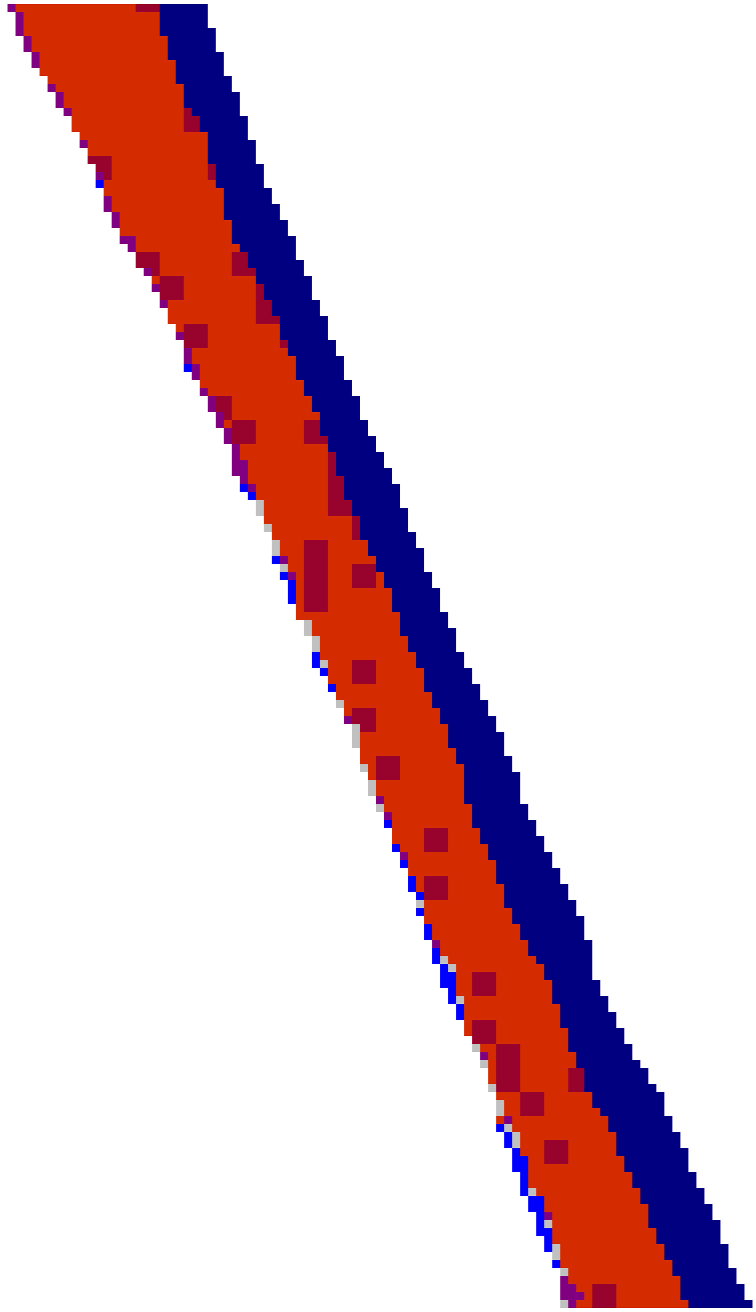
Hobe Sound NWR, South St. Lucie County Tract, Initial Condition



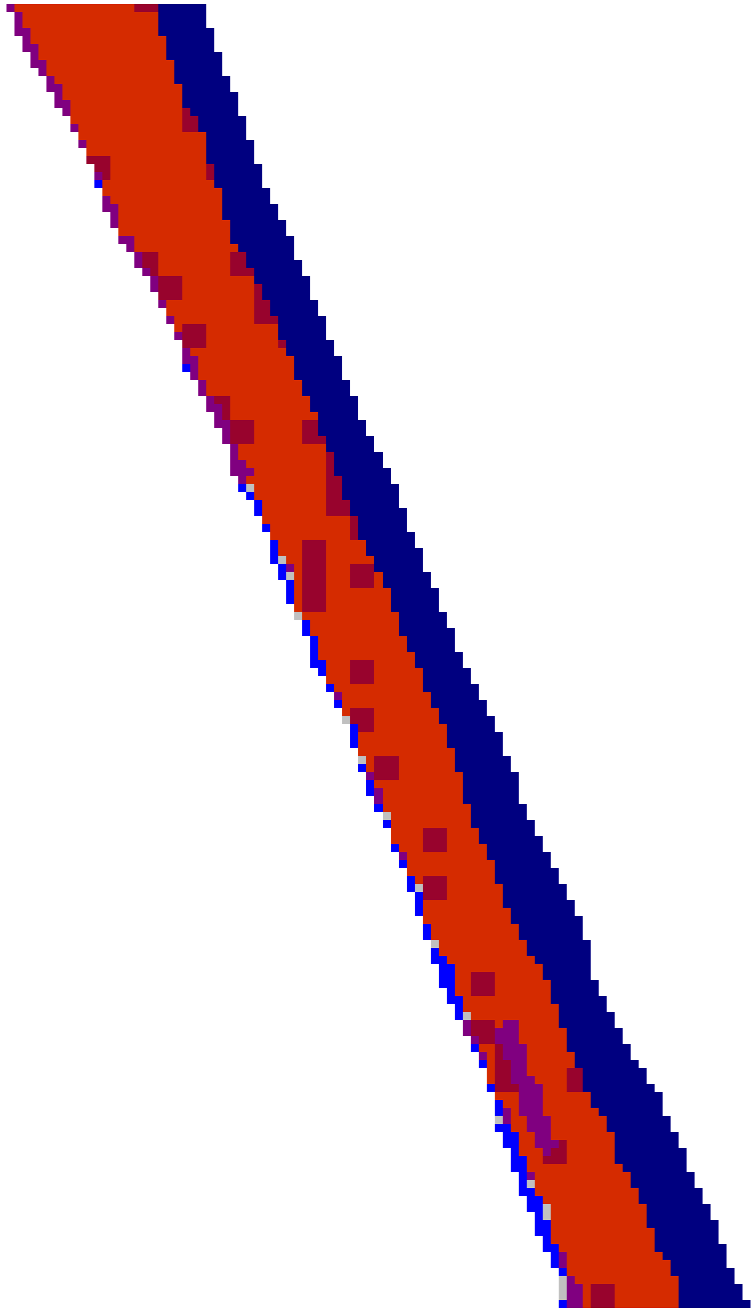
Hobe Sound NWR, South St. Lucie County Tract, 2025, Scenario A1B Maximum



Hobe Sound NWR, South St. Lucie County Tract, 2050, Scenario A1B Maximum



Hobe Sound NWR, South St. Lucie County Tract, 2075, Scenario A1B Maximum



Hobe Sound NWR, South St. Lucie County Tract, 2100, Scenario A1B Maximum

Hobe Sound NWR, North St. Lucie County Tract, Initial Condition

Hobe Sound NWR, North St. Lucie County Tract, 2025, Scenario A1B Maximum

Hobe Sound NWR, North St. Lucie County Tract, 2050, Scenario A1B Maximum

Hobe Sound NWR, North St. Lucie County Tract, 2075, Scenario A1B Maximum

Hobe Sound NWR, North St. Lucie County Tract, 2100, Scenario A1B Maximum

Hobe Sound NWR
1 Meter Eustatic SLR by 2100

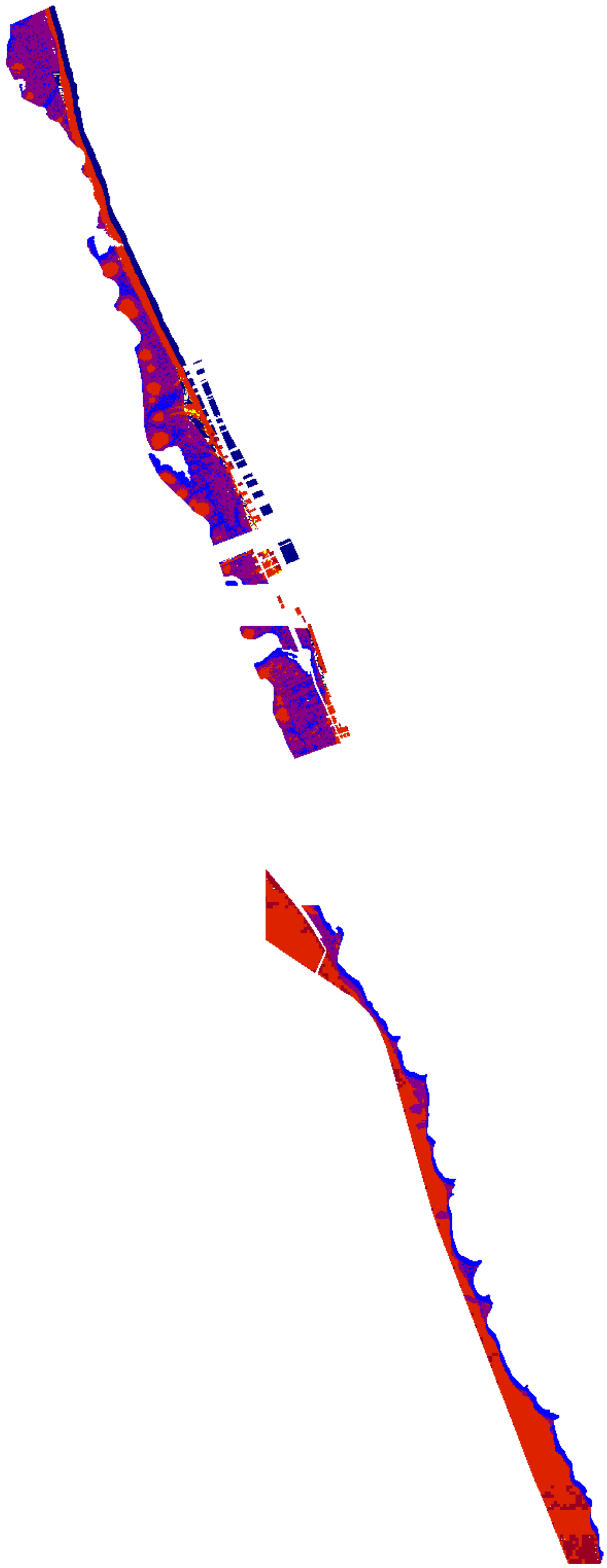
Results in Acres

		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	741.9	643.6	568.9	505.1	452.1
	Mangrove	295.5	361.1	417.2	408.4	279.7
	Estuarine Open Water	72.6	99.1	112.6	178.7	350.9
	Developed Dry Land	61.9	61.3	61.0	60.1	58.2
	Open Ocean	57.8	79.4	119.5	123.5	129.8
	Ocean Beach	55.0	38.5	1.4	2.0	2.8
	Swamp	0.6	0.0	0.0	0.0	0.0
	Estuarine Beach	0.0	2.2	4.2	6.9	11.1
	Tidal Flat	0.0	0.3	0.5	0.8	0.9
	Total (incl. water)	**1285.5**	**1285.5**	**1285.5**	**1285.5**	**1285.5**

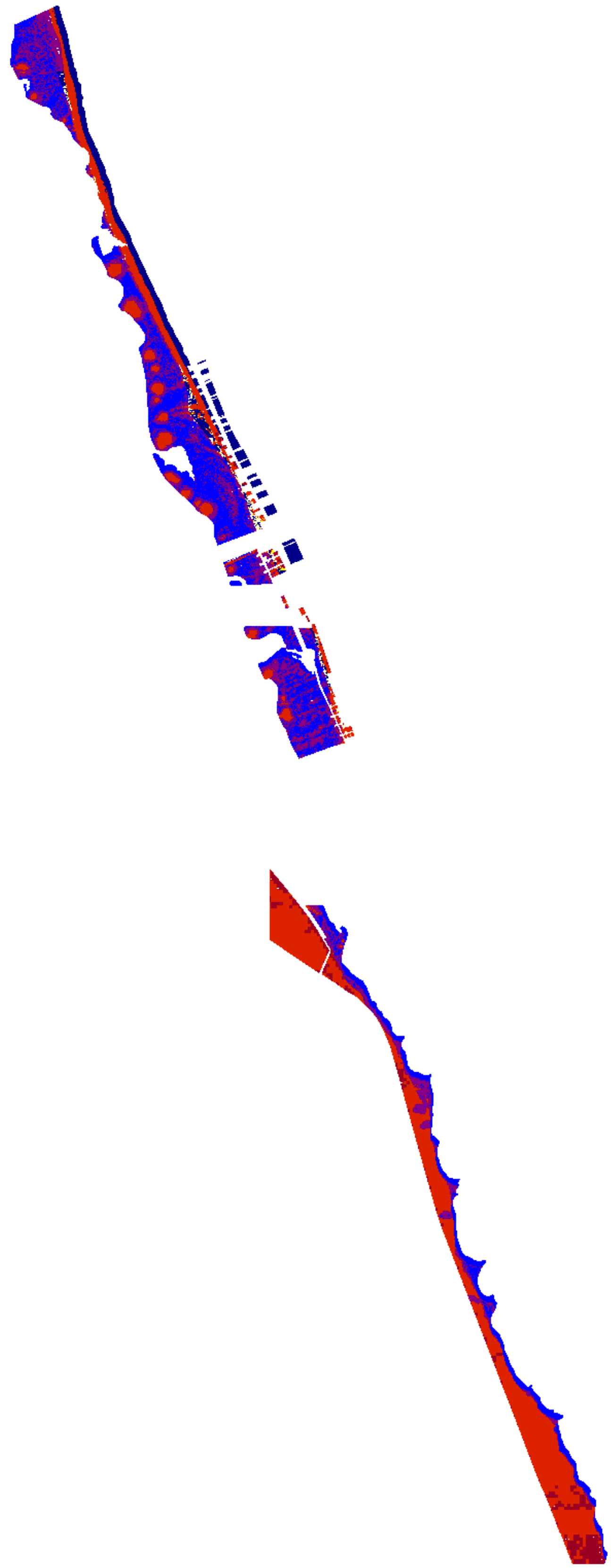
Hobe Sound NWR, Jupiter and Mainland Tracts, Initial Condition

Hobe Sound NWR, Jupiter and Mainland Tracts, 2025, 1 Meter

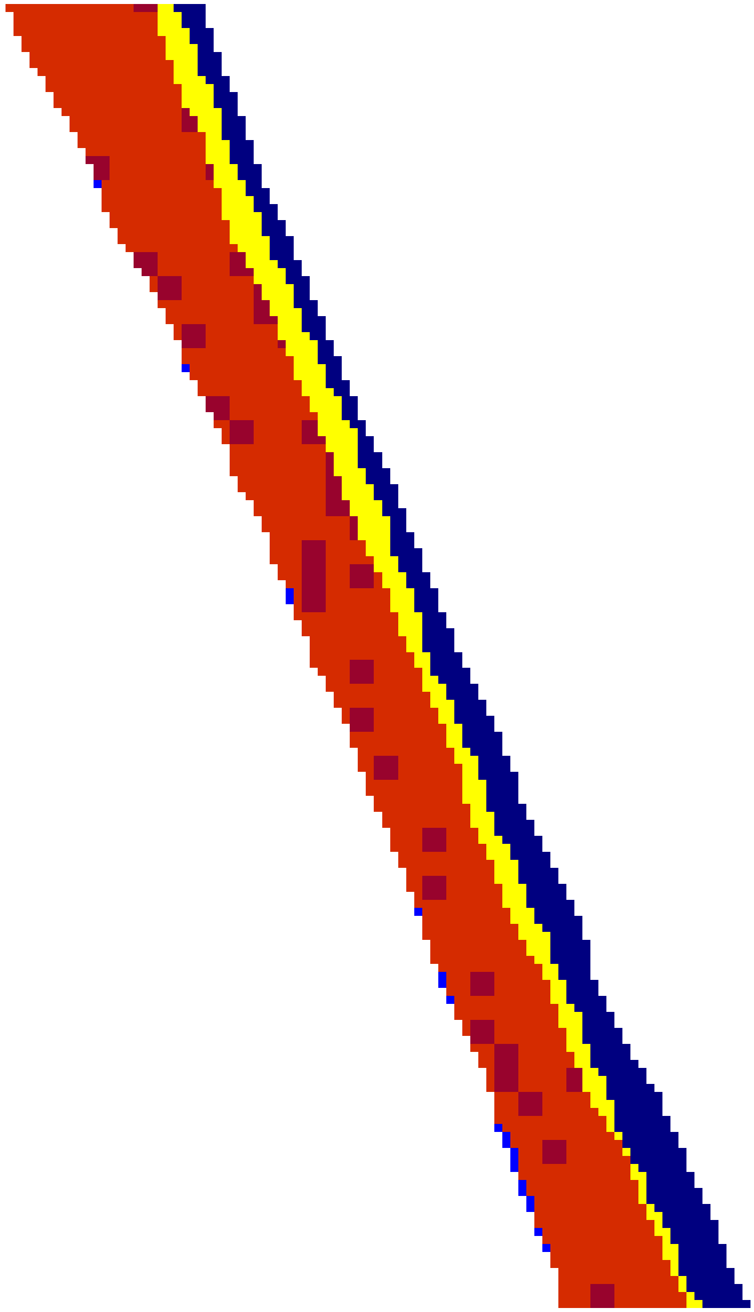
Hobe Sound NWR, Jupiter and Mainland Tracts, 2050, 1 Meter



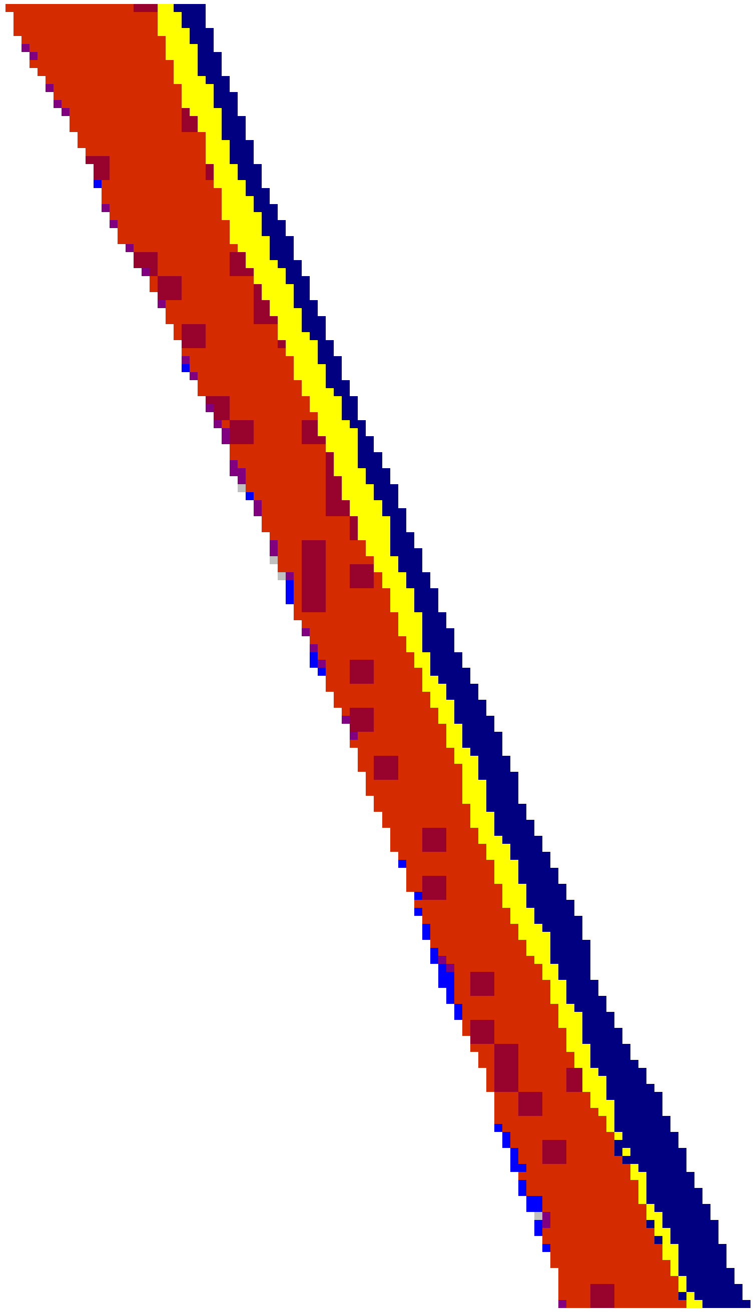
Hobe Sound NWR, Jupiter and Mainland Tracts, 2075, 1 Meter



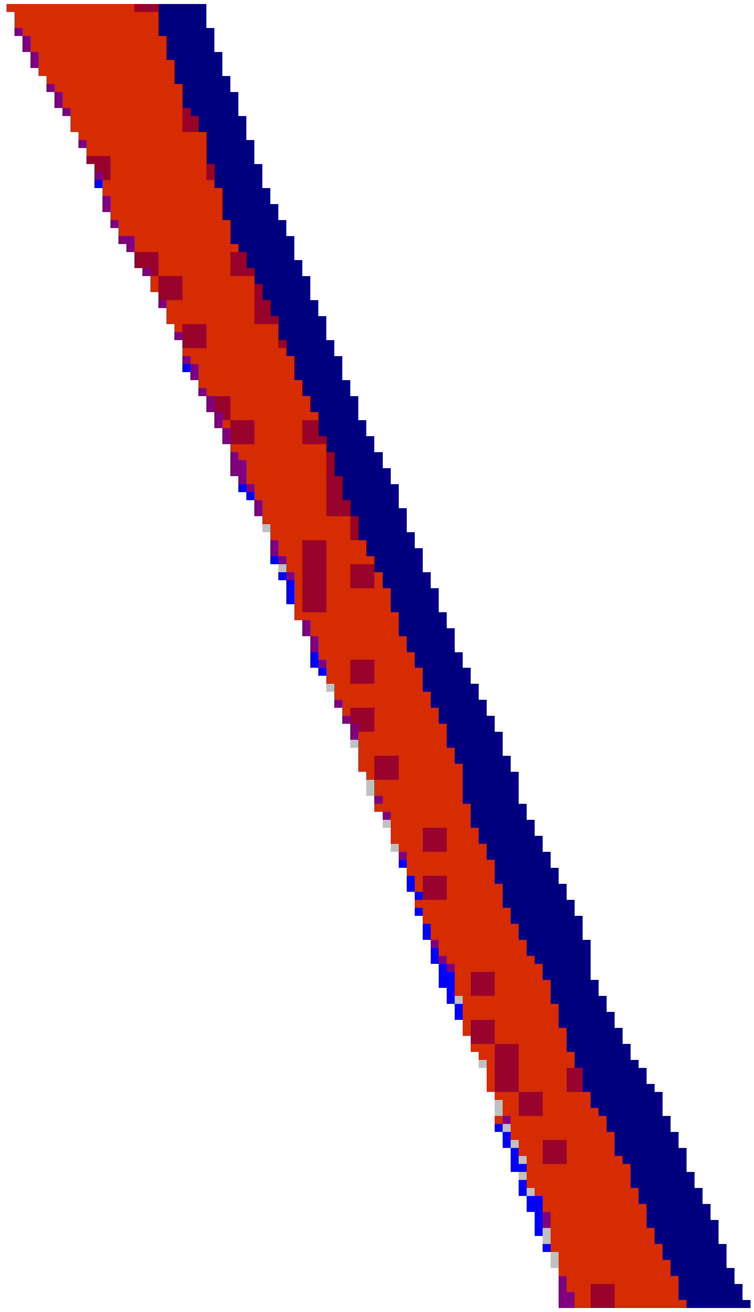
Hobe Sound NWR, Jupiter and Mainland Tracts, 2100, 1 Meter



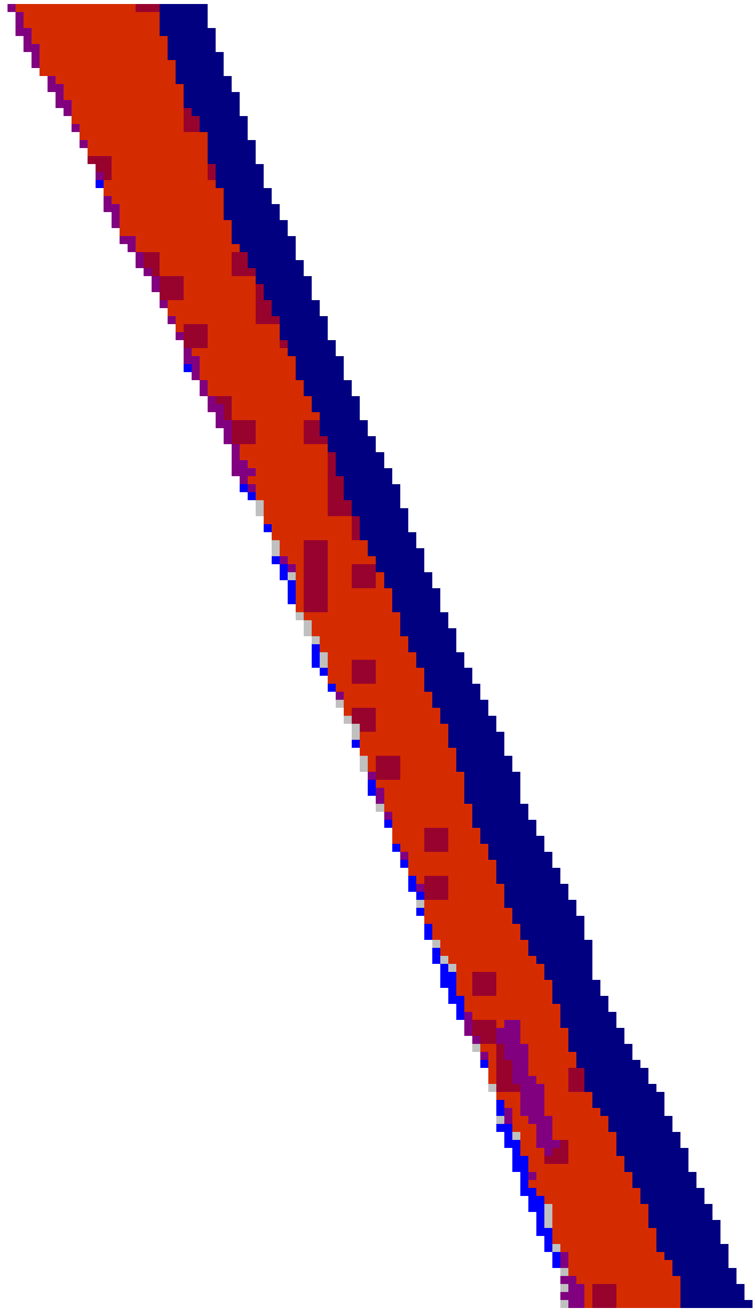
Hobe Sound NWR, South St. Lucie County Tract, Initial Condition



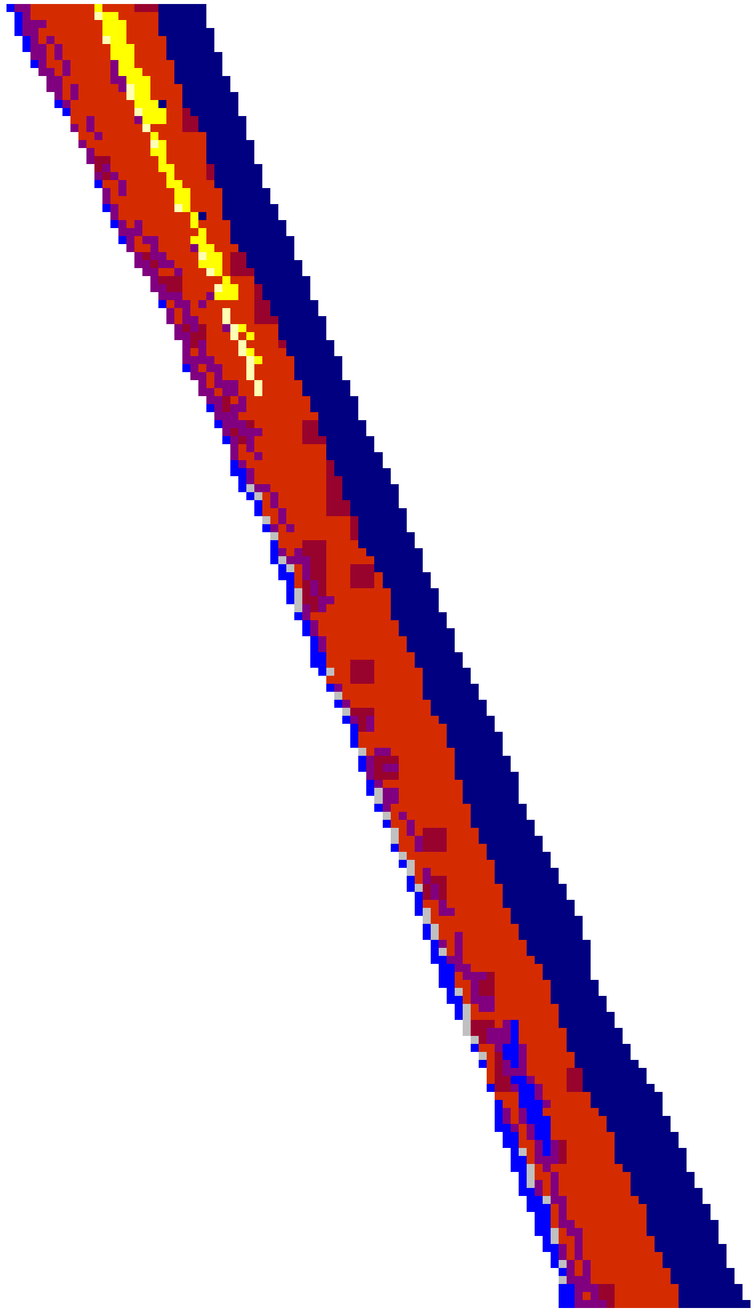
Hobe Sound NWR, South St. Lucie County Tract, 2025, 1 Meter



Hobe Sound NWR, South St. Lucie County Tract, 2050, 1 Meter



Hobe Sound NWR, South St. Lucie County Tract, 2075, 1 Meter



Hobe Sound NWR, South St. Lucie County Tract, 2100, 1 Meter

Hobe Sound NWR, North St. Lucie County Tract, Initial Condition

Hobe Sound NWR, North St. Lucie County Tract, 2025, 1 Meter

Hobe Sound NWR, North St. Lucie County Tract, 2050, 1 Meter

Hobe Sound NWR, North St. Lucie County Tract, 2075, 1 Meter

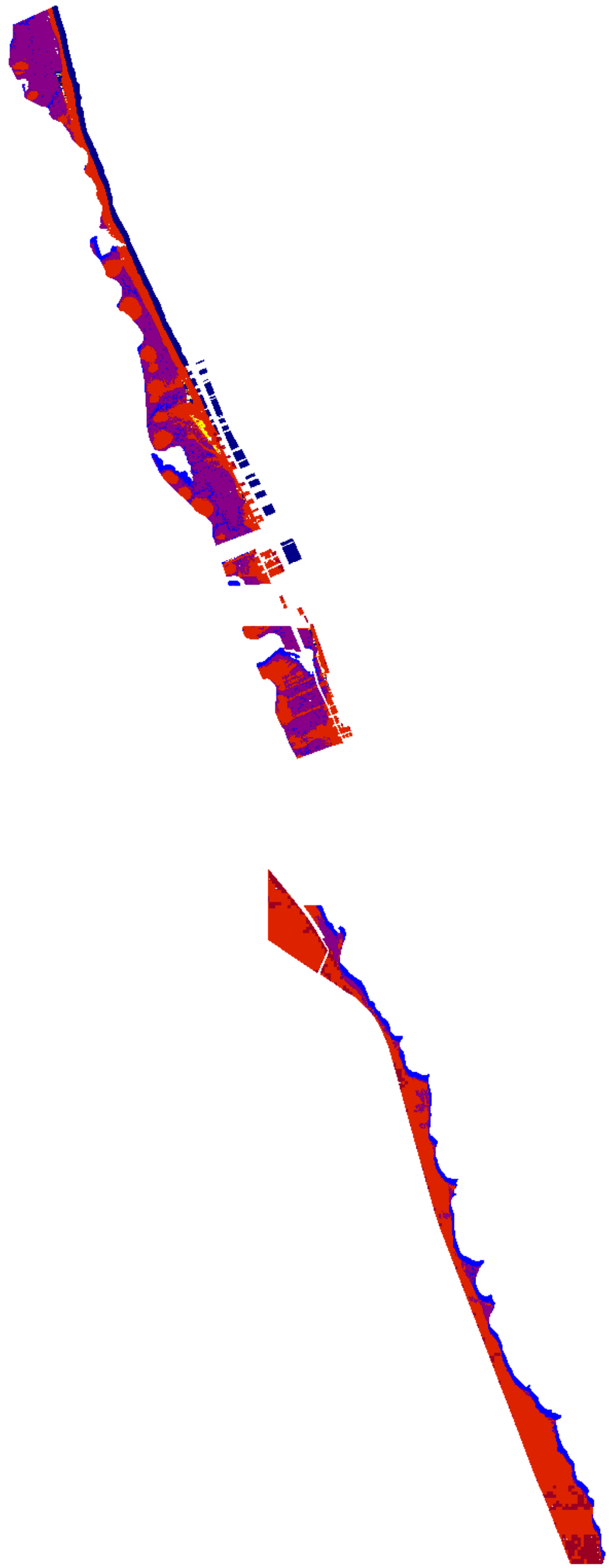
Hobe Sound NWR, North St. Lucie County Tract, 2100, 1 Meter

Hobe Sound NWR
1.5 Meters Eustatic SLR by 2100

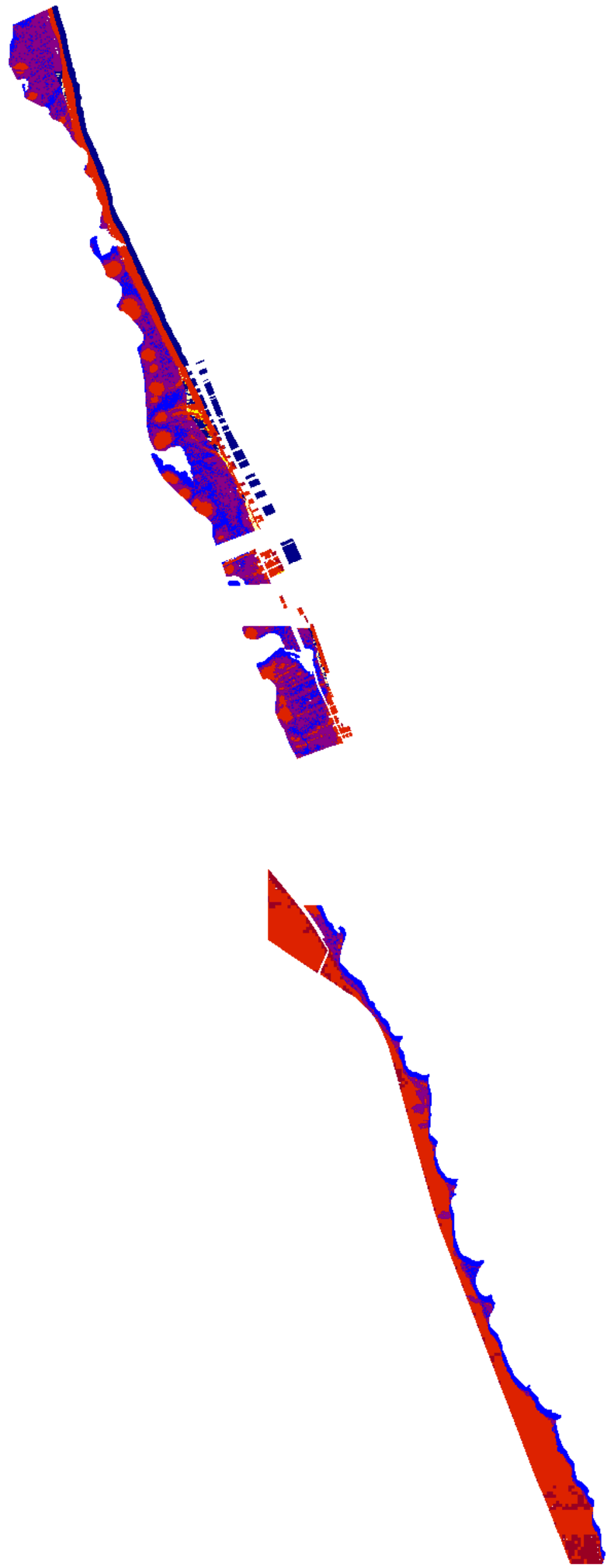
Results in Acres

		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	741.9	626.6	531.1	450.6	383.0
	Mangrove	295.5	368.0	364.2	142.6	80.4
	Estuarine Open Water	72.6	107.8	199.2	488.8	602.0
	Developed Dry Land	61.9	61.2	60.8	57.8	53.6
	Open Ocean	57.8	114.8	121.1	128.3	142.9
	Ocean Beach	55.0	3.9	1.8	2.7	0.5
	Swamp	0.6	0.0	0.0	0.0	0.0
	Estuarine Beach	0.0	2.6	6.6	14.0	22.4
	Tidal Flat	0.0	0.4	0.6	0.7	0.5
	Total (incl. water)	**1285.5**	**1285.5**	**1285.5**	**1285.5**	**1285.5**

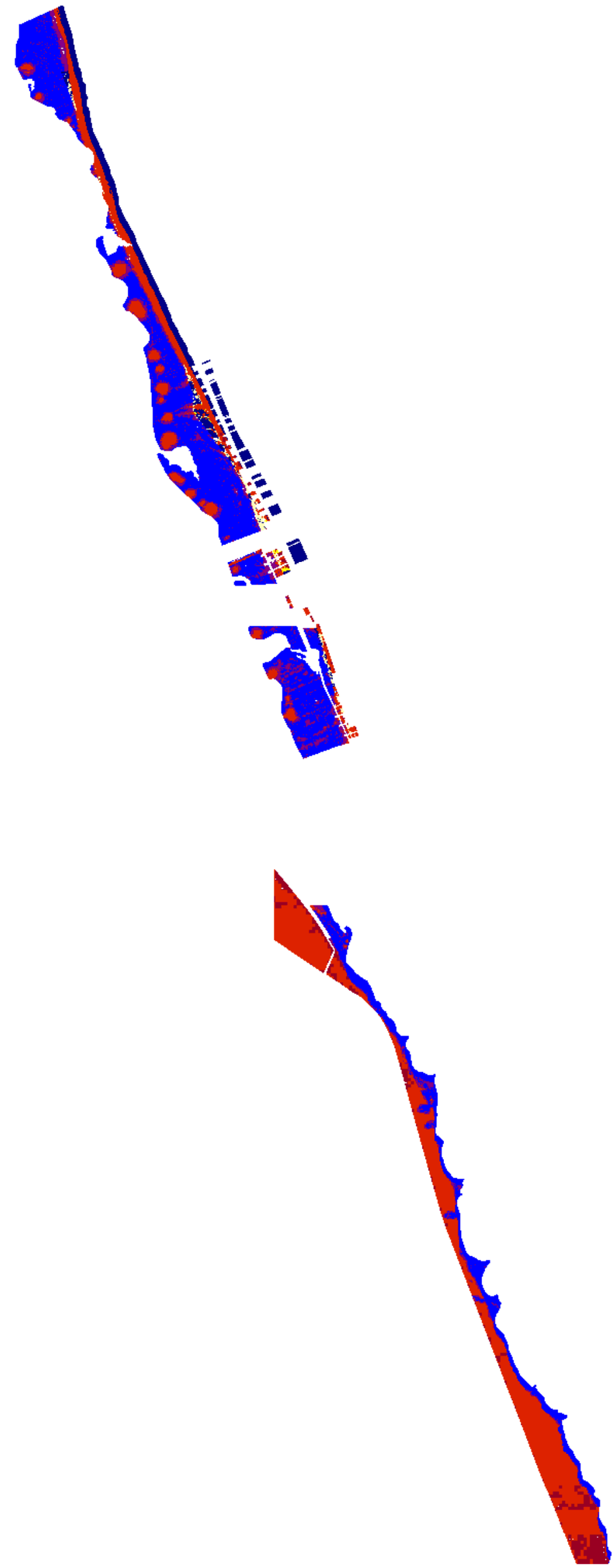
Hobe Sound NWR, Jupiter and Mainland Tracts, Initial Condition



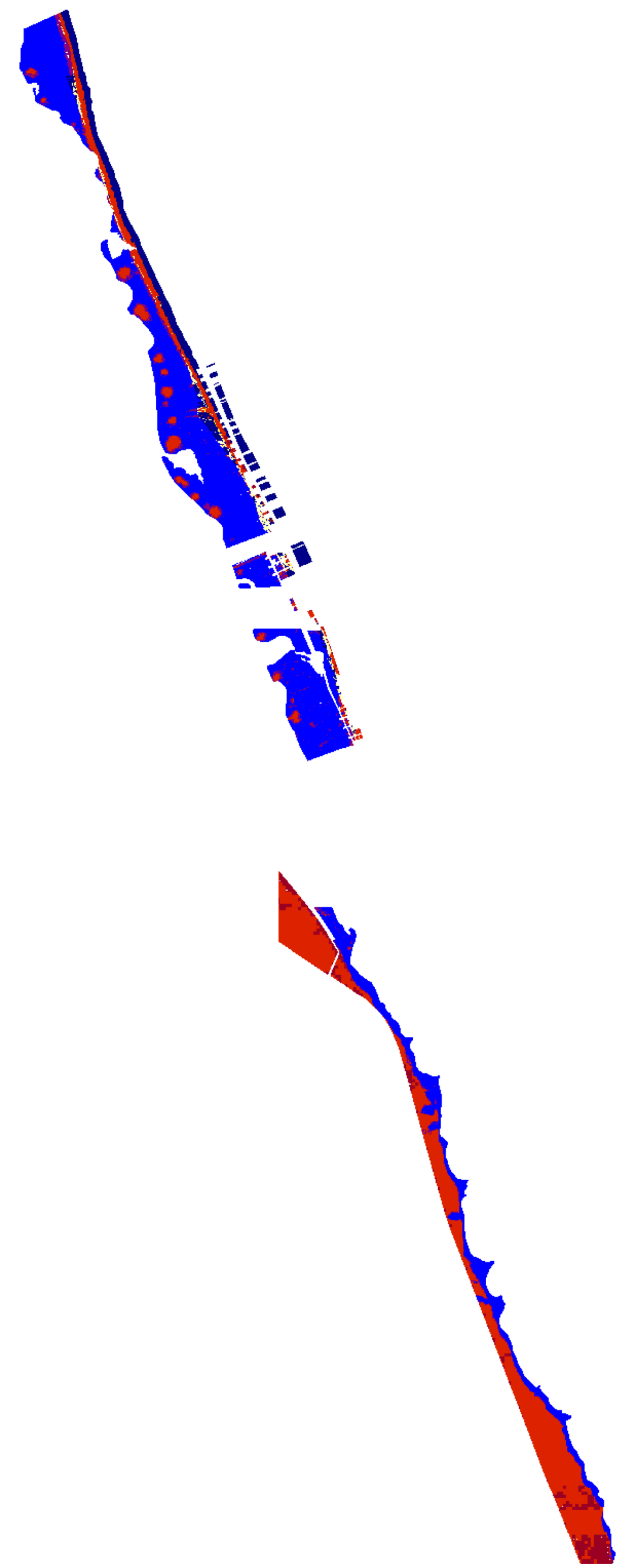
Hobe Sound NWR, Jupiter and Mainland Tracts, 2025, 1.5 Meters



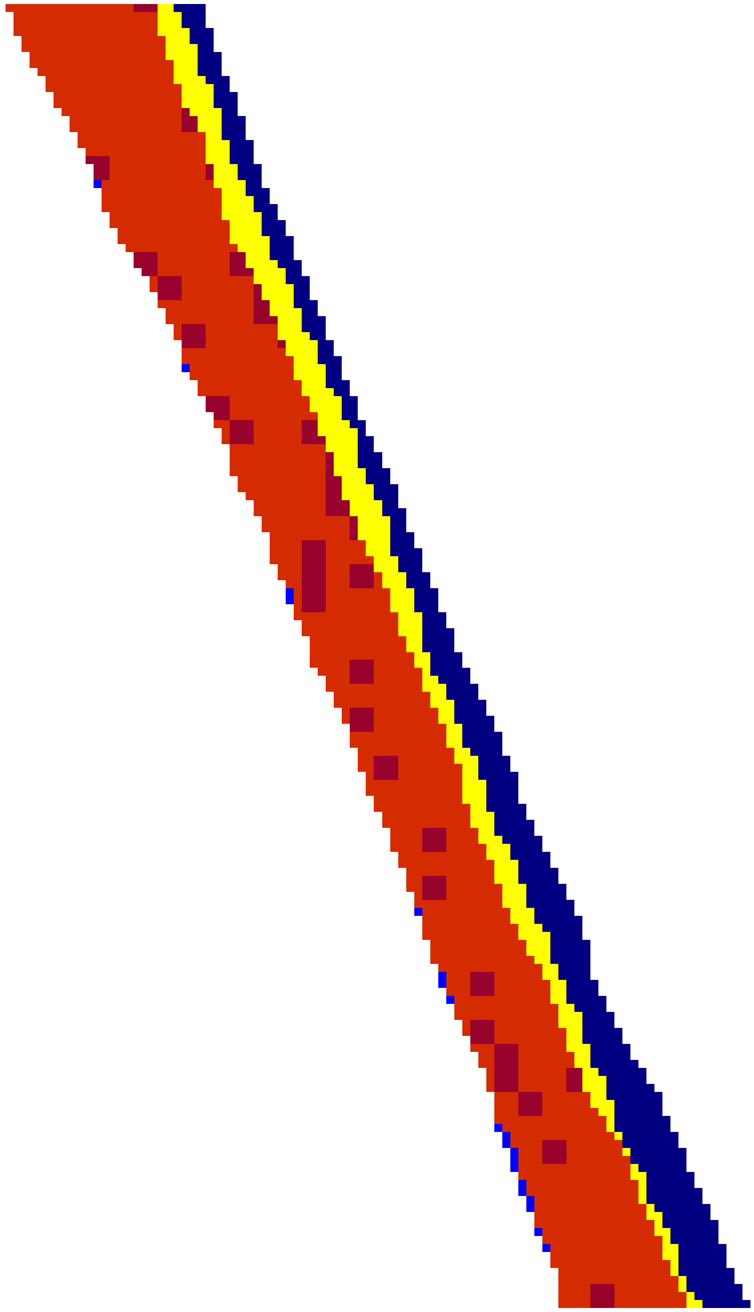
Hobe Sound NWR, Jupiter and Mainland Tracts, 2050, 1.5 Meters



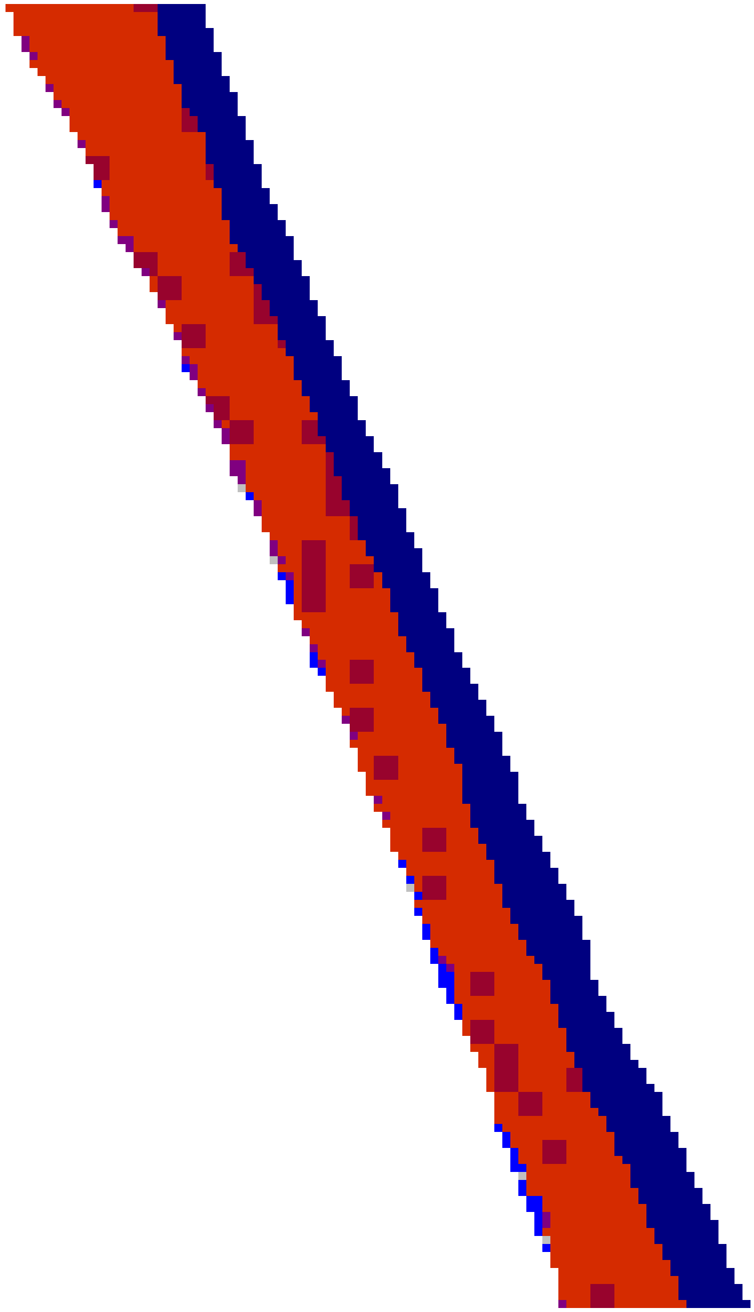
Hobe Sound NWR, Jupiter and Mainland Tracts, 2075, 1.5 Meters



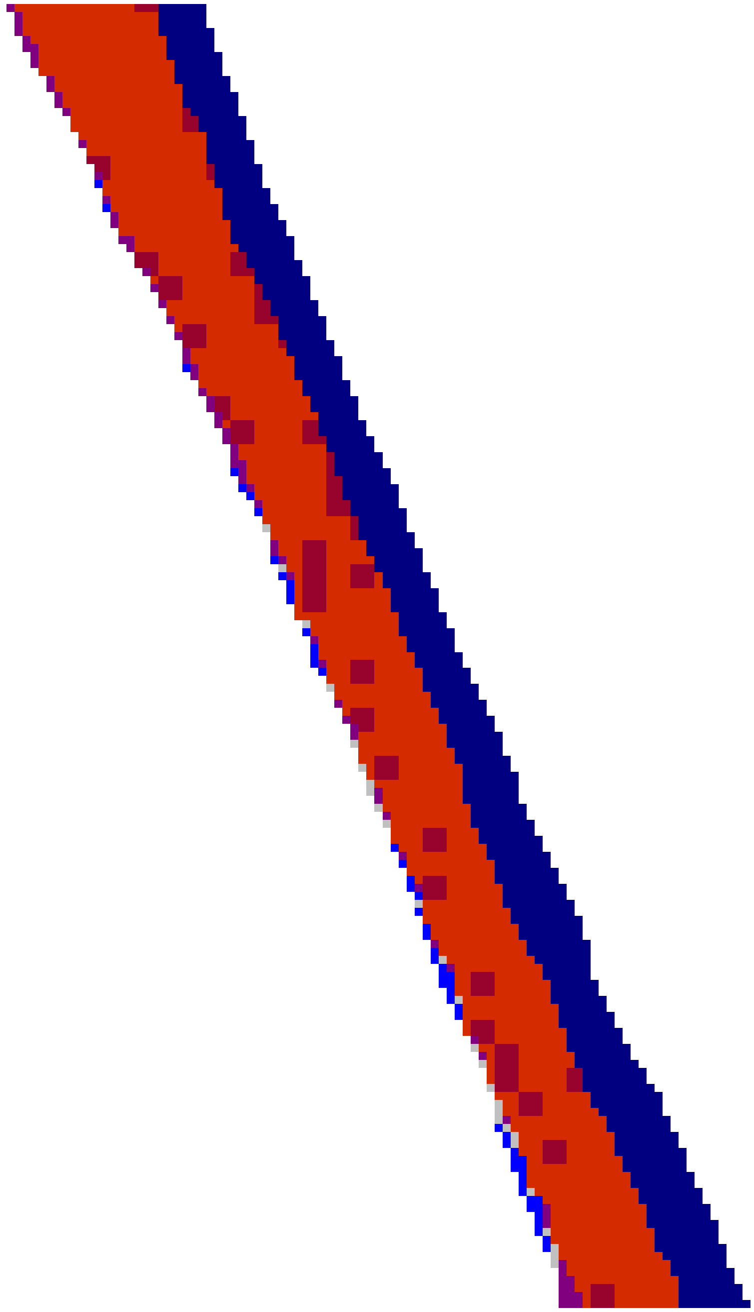
Hobe Sound NWR, Jupiter and Mainland Tracts, 2100, 1.5 Meters



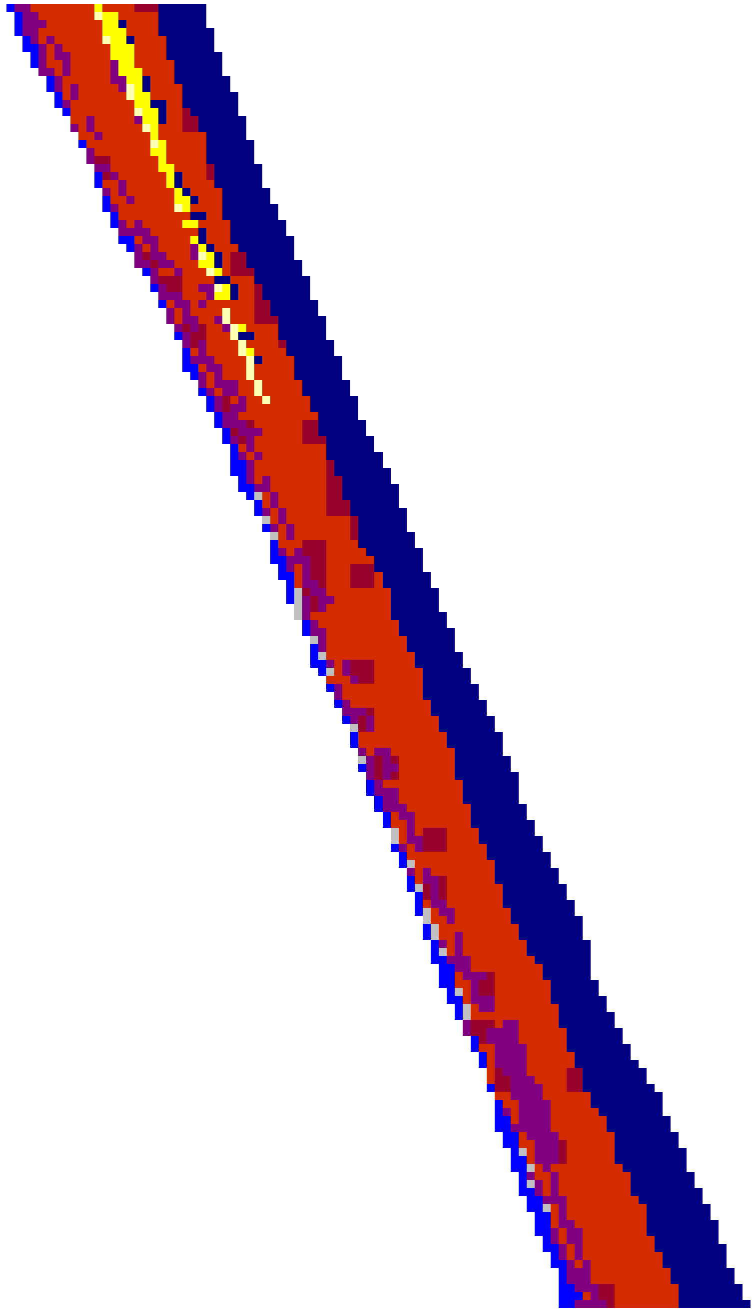
Hobe Sound NWR, South St. Lucie County Tract, Initial Condition



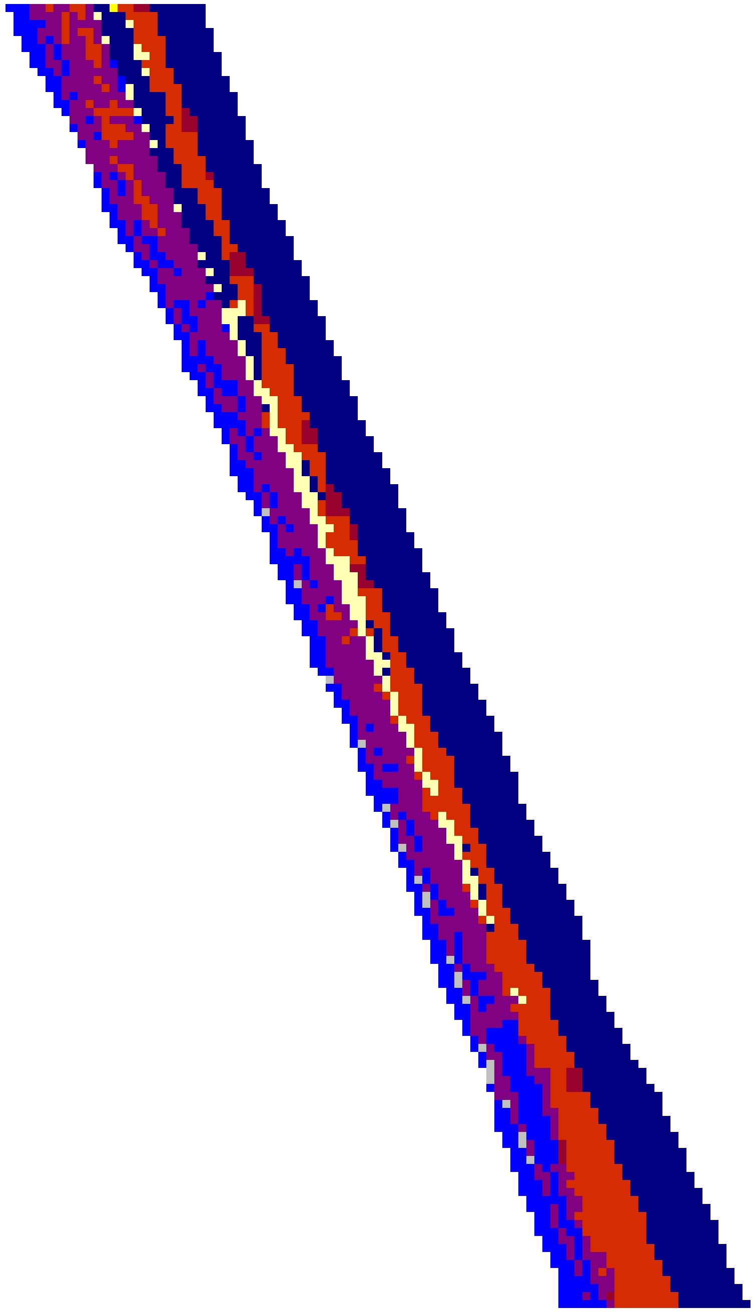
Hobe Sound NWR, South St. Lucie County Tract, 2025, 1.5 Meters



Hobe Sound NWR, South St. Lucie County Tract, 2050, 1.5 Meters



Hobe Sound NWR, South St. Lucie County Tract, 2075, 1.5 Meters



Hobe Sound NWR, South St. Lucie County Tract, 2100, 1.5 Meters

Hobe Sound NWR, North St. Lucie County Tract, Initial Condition

Hobe Sound NWR, North St. Lucie County Tract, 2025, 1.5 Meters

Hobe Sound NWR, North St. Lucie County Tract, 2050, 1.5 Meters

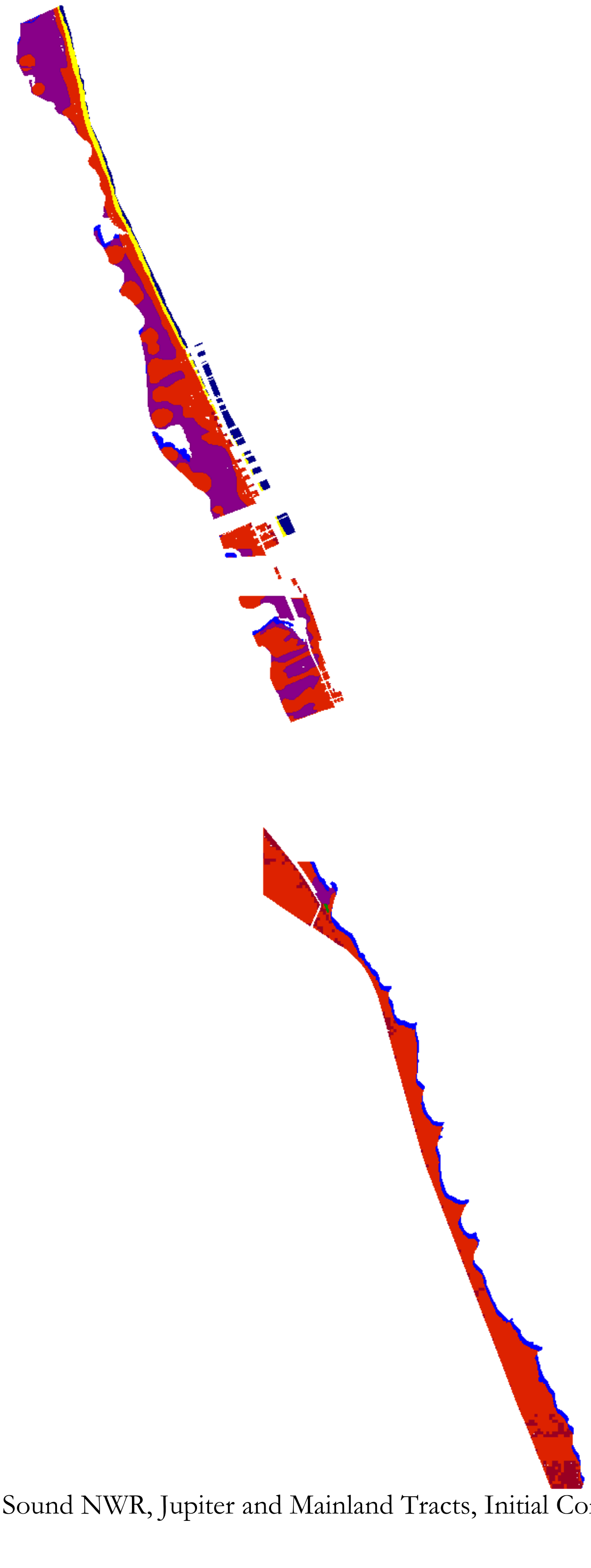
Hobe Sound NWR, North St. Lucie County Tract, 2075, 1.5 Meters

Hobe Sound NWR, North St. Lucie County Tract, 2100, 1.5 Meters

Hobe Sound NWR
2 Meters Eustatic SLR by 2100

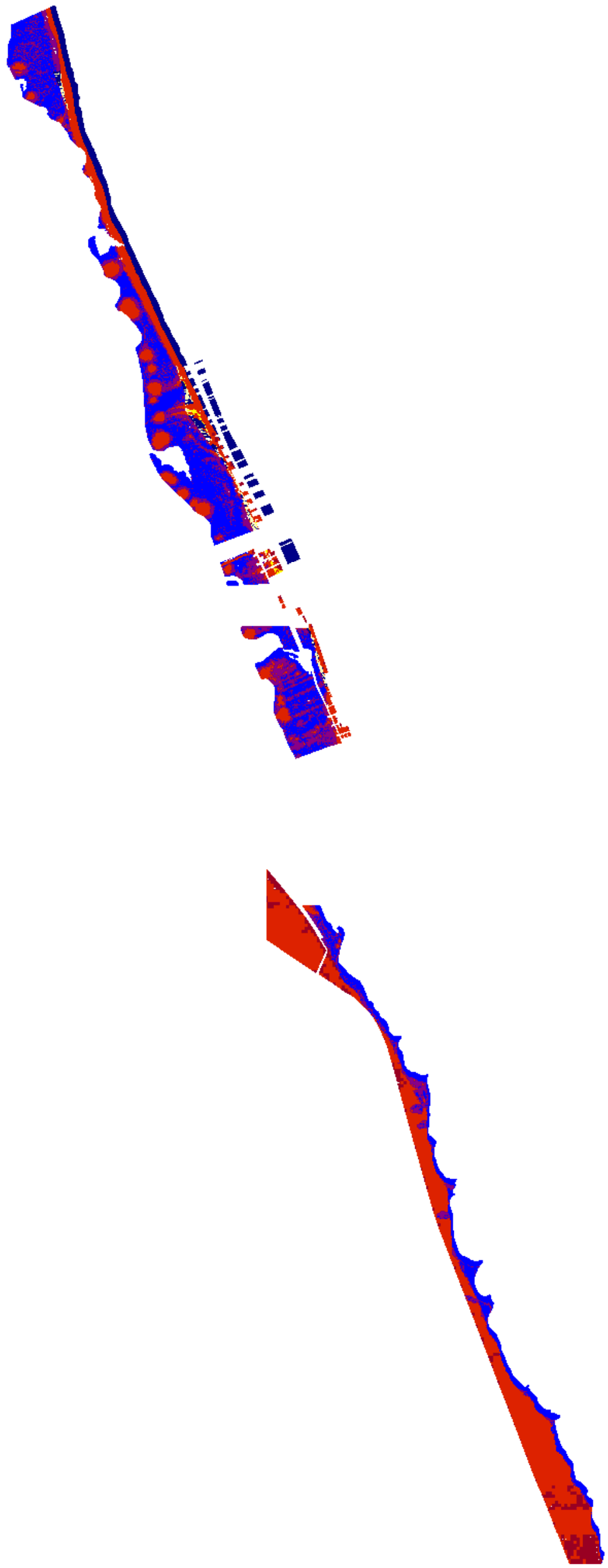
Results in Acres

		Initial	2025	2050	2075	2100
	Undeveloped Dry Land	741.9	605.8	497.1	400.4	327.1
	Mangrove	295.5	369.4	228.7	91.8	44.9
	Estuarine Open Water	72.6	124.6	363.7	578.0	668.7
	Developed Dry Land	61.9	61.1	59.8	54.4	51.2
	Open Ocean	57.8	116.2	122.7	138.0	160.0
	Ocean Beach	55.0	3.4	2.9	0.8	0.0
	Swamp	0.6	0.0	0.0	0.0	0.0
	Estuarine Beach	0.0	4.5	10.1	21.6	33.5
	Tidal Flat	0.0	0.5	0.6	0.6	0.0
	Total (incl. water)	**1285.5**	**1285.5**	**1285.5**	**1285.5**	**1285.5**

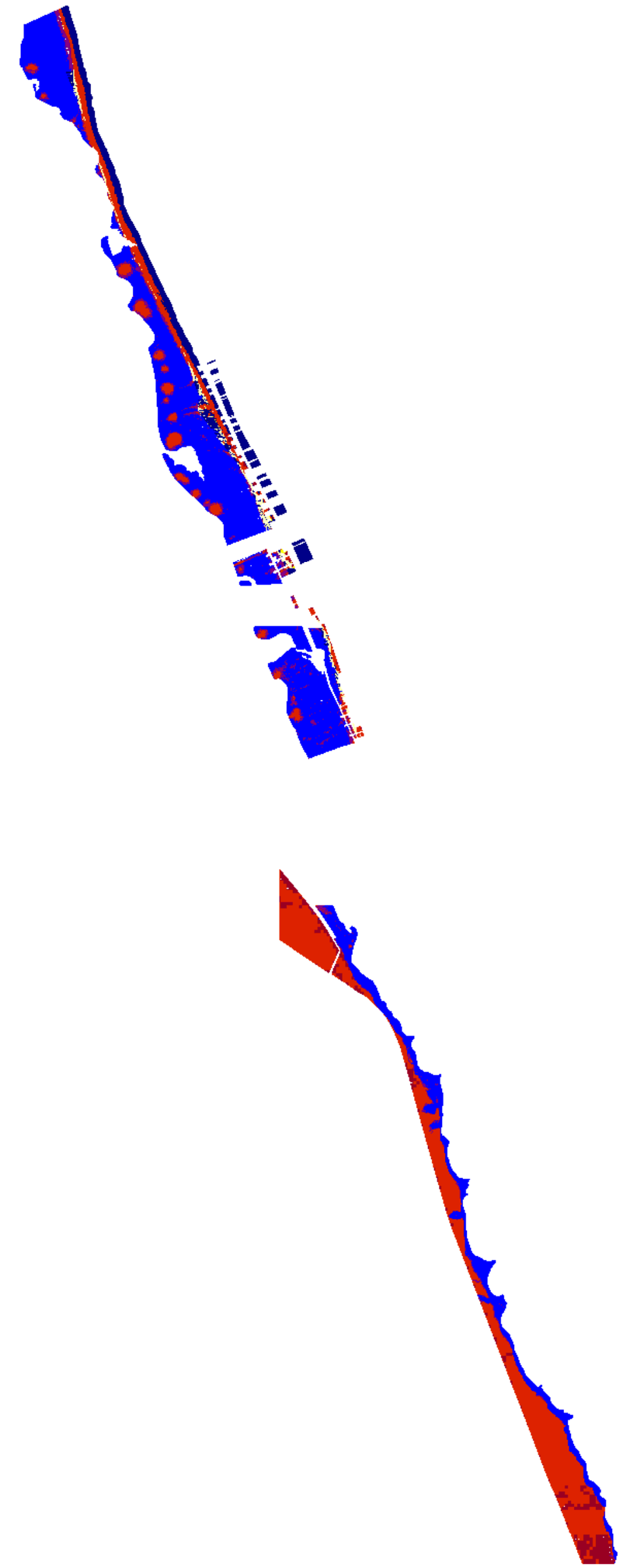


Hobe Sound NWR, Jupiter and Mainland Tracts, Initial Condition

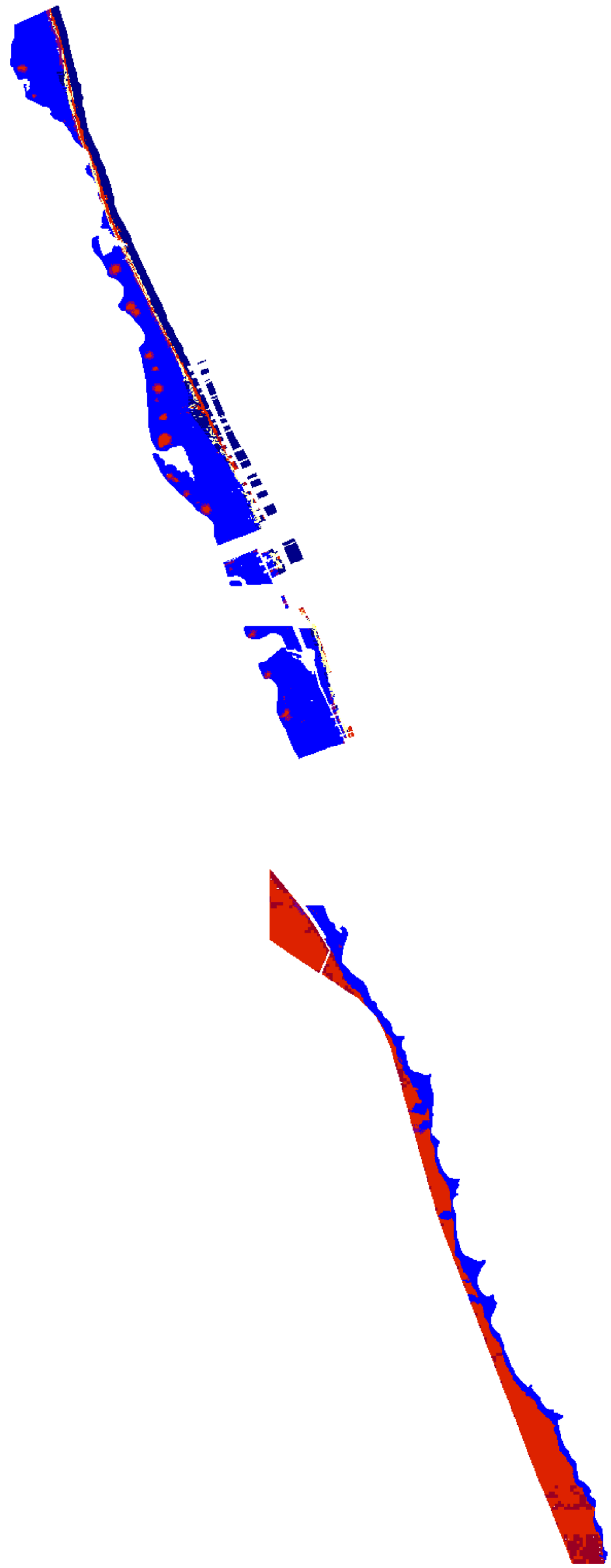
Hobe Sound NWR, Jupiter and Mainland Tracts, 2025, 2 Meters



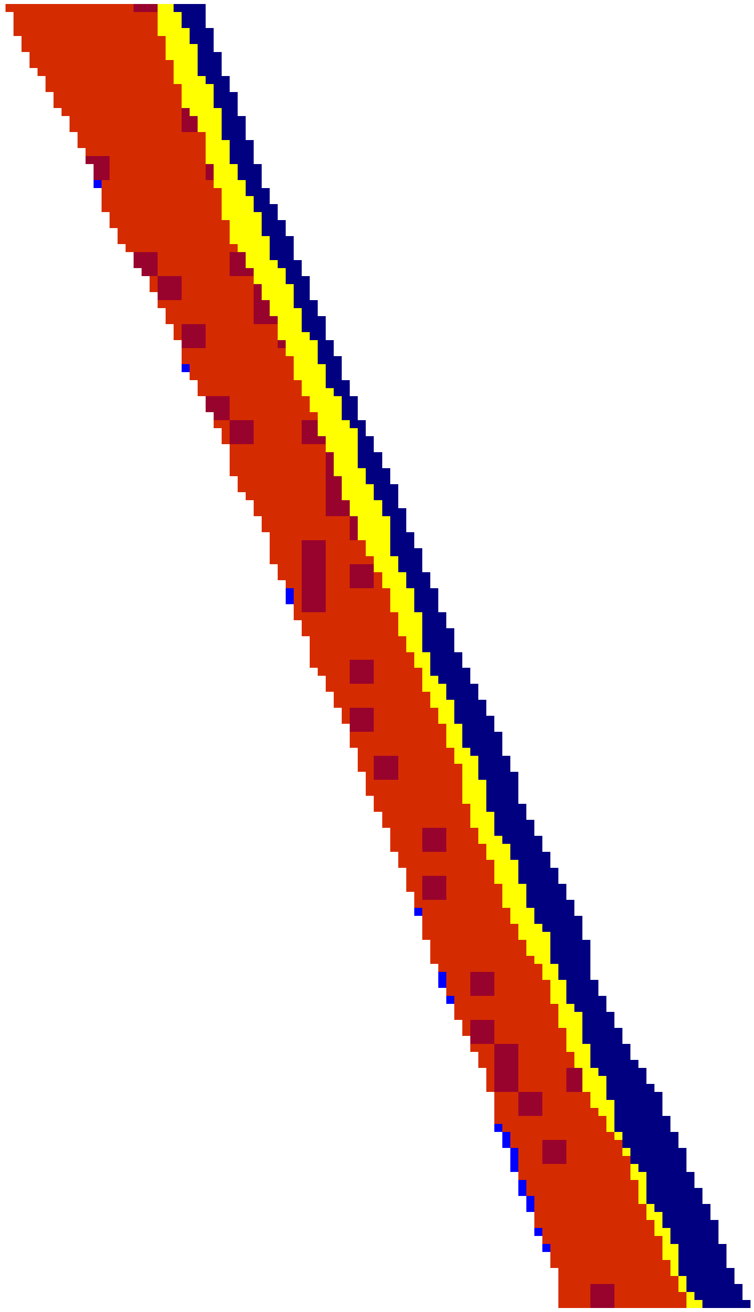
Hobe Sound NWR, Jupiter and Mainland Tracts, 2050, 2 Meters



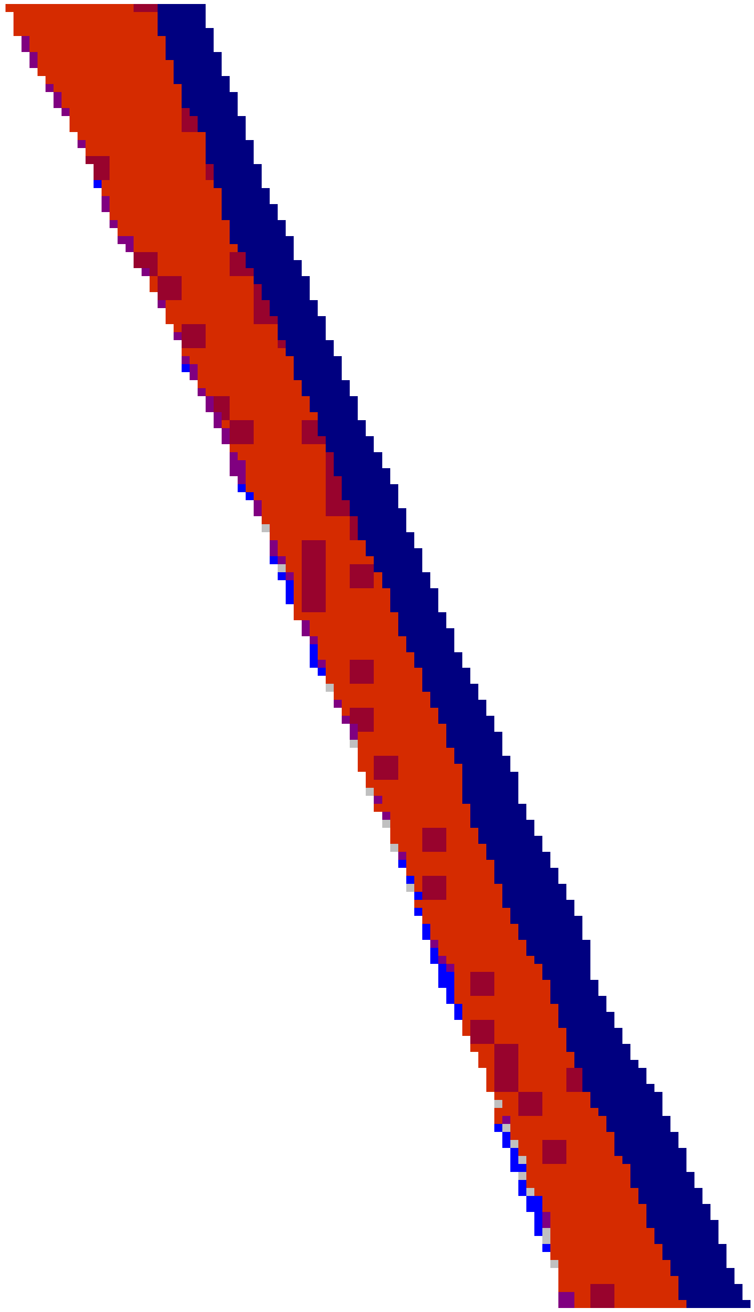
Hobe Sound NWR, Jupiter and Mainland Tracts, 2075, 2 Meters



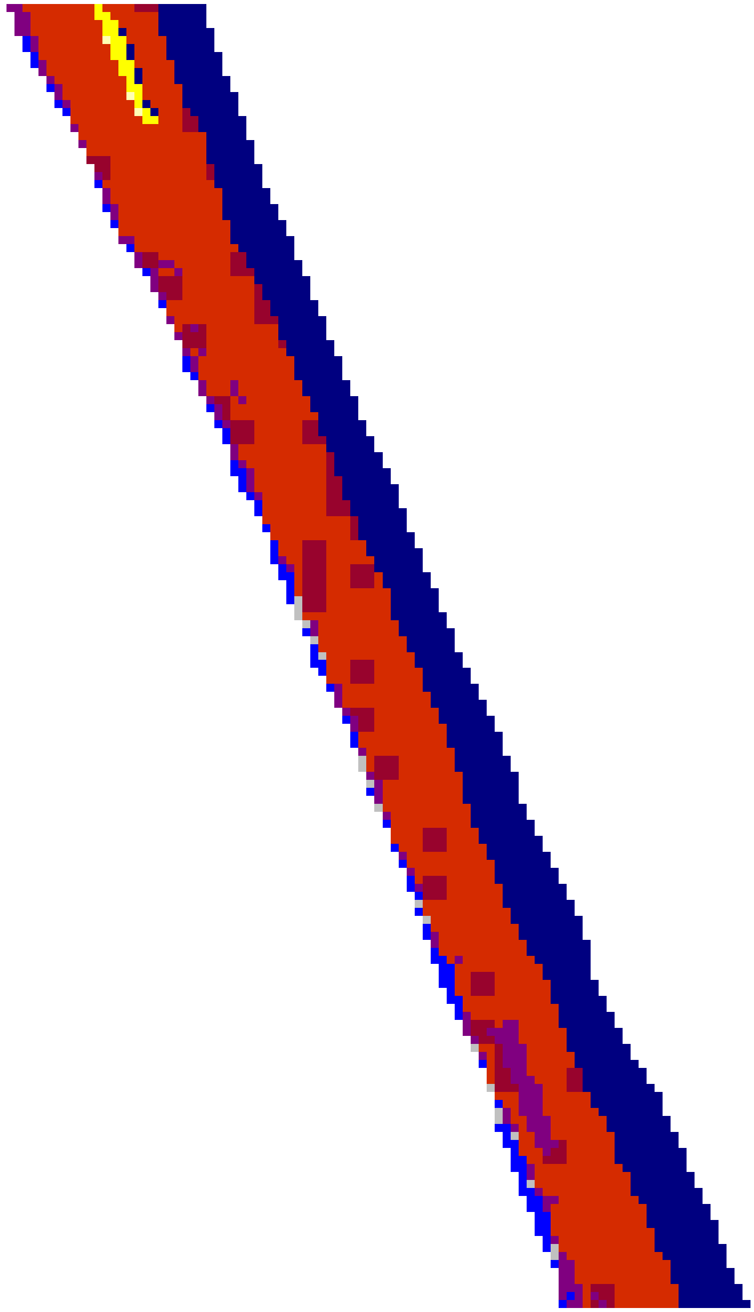
Hobe Sound NWR, Jupiter and Mainland Tracts, 2100, 2 Meters



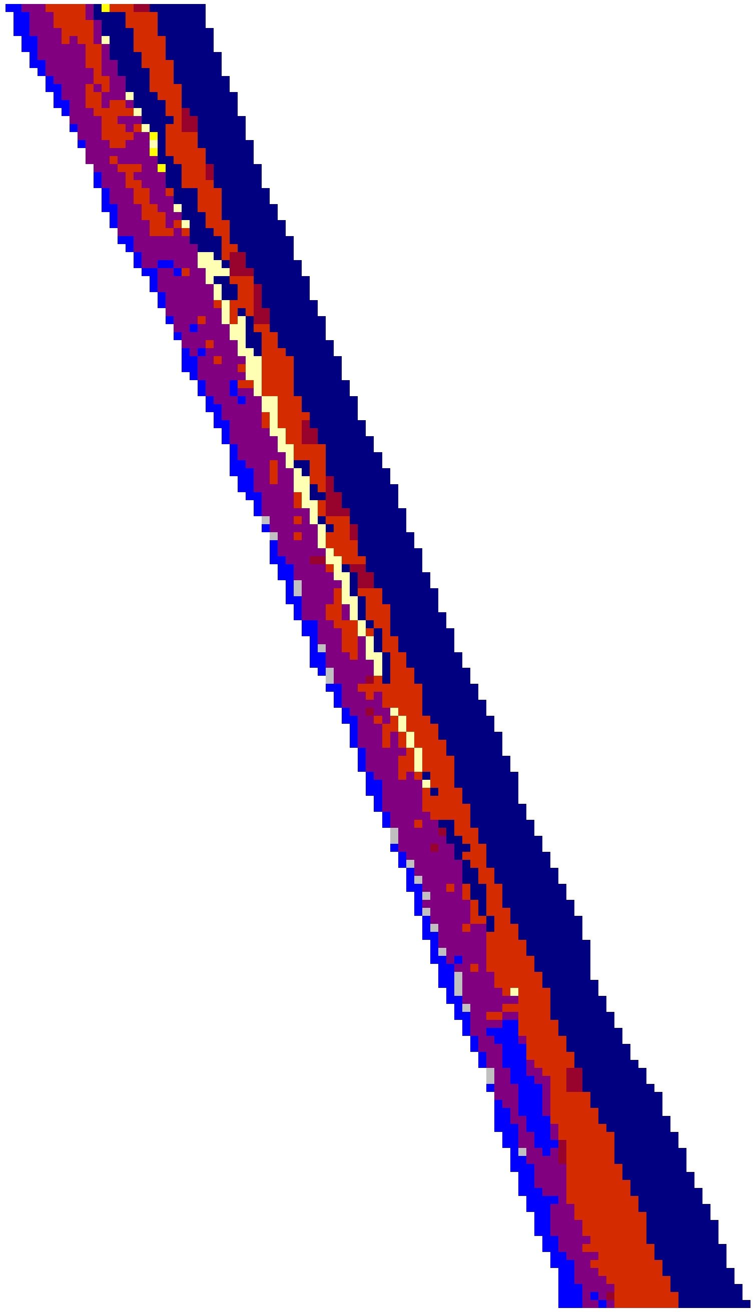
Hobe Sound NWR, South St. Lucie County Tract, Initial Condition



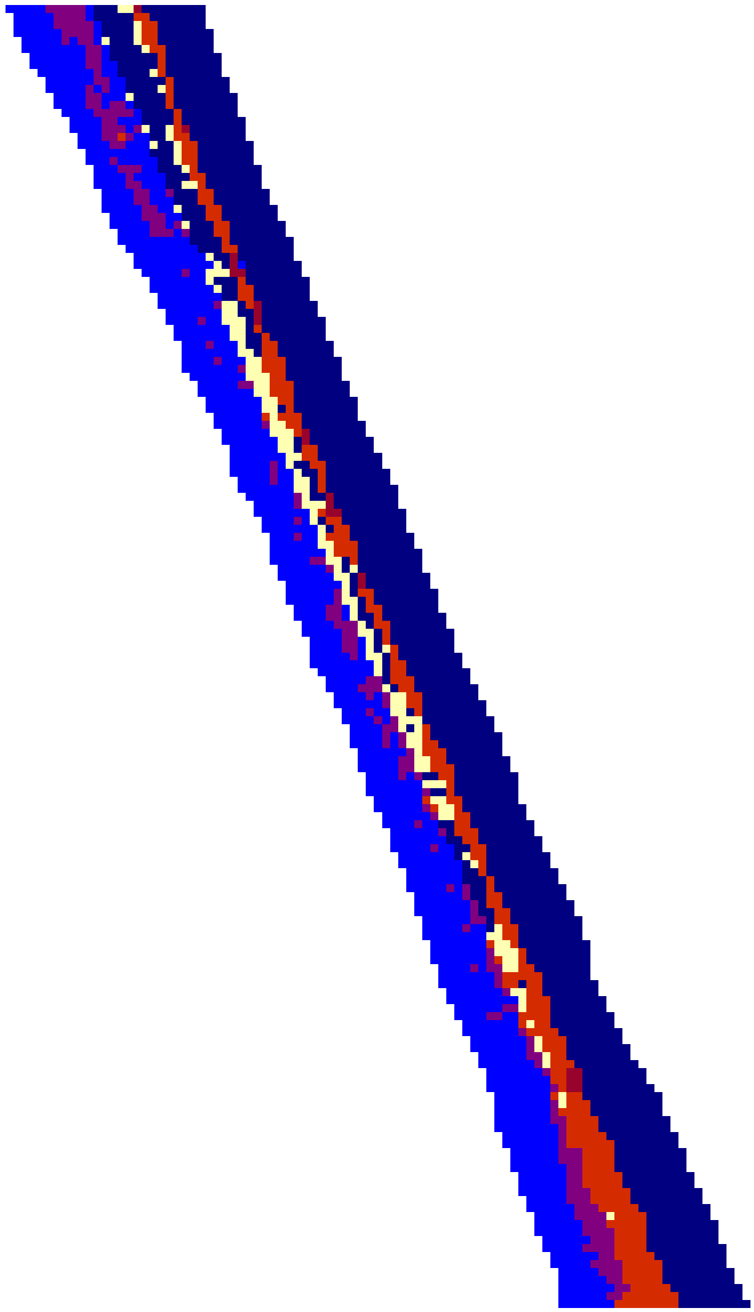
Hobe Sound NWR, South St. Lucie County Tract, 2025, 2 Meters



Hobe Sound NWR, South St. Lucie County Tract, 2050, 2 Meters



Hobe Sound NWR, South St. Lucie County Tract, 2075, 2 Meters



Hobe Sound NWR, South St. Lucie County Tract, 2100, 2 Meters

Hobe Sound NWR, North St. Lucie County Tract, Initial Condition

Hobe Sound NWR, North St. Lucie County Tract, 2025, 2 Meters

Hobe Sound NWR, North St. Lucie County Tract, 2050, 2 Meters

Hobe Sound NWR, North St. Lucie County Tract, 2075, 2 Meters

Hobe Sound NWR, North St. Lucie County Tract, 2100, 2 Meters

Discussion

Much of Hobe Sound National Wildlife Refuge is composed of low-elevation land in a region with low tidal ranges. This makes most of the refuge highly vulnerable to sea-level rise (SLR) within SLAMM predictions. The exception to this rule is the northern-most portion in the St. Lucie County tract which is buffered by the mainland. Additionally, the southern mainland tract has higher elevations and is predicted to suffer fewer losses.

Ocean beach losses are predicted to be quite high, but these results are subject to uncertainty; an accurate spatial representation of ocean-beach erosion is difficult to characterize within a relatively simple model. This application of SLAMM utilized an implementation of the Bruun Rule to determine average ocean-beach erosion rates.

Mangrove habitat is actually predicted to increase in acreage during early SLR scenarios as it has been shown to have a relatively high vertical accretion rate (Cahoon et al. 1999) and also can thrive over a relatively wide elevation range. However, once SLR exceeds 1 meter by 2100, mangrove habitats rapidly begin to decline. This model does not include an accounting of potential killing frosts.

A large portion of the refuge wetland data is over 25 years old, a factor which increases model uncertainty (Figure 2). Future model applications of Hobe Sound NWR would benefit from updated wetland data.

As mentioned above, wind-tides can have an effect on the elevation range at which salt water penetrates. Our accounting of the effects of wind-tides is uncertain due to the relatively long distance between the study site and the gage where the inundation data was derived from (Port of West Palm Beach).

Model uncertainty for this application is further increased by the reliance on off-site accretion data. Site specific accretion data would considerably reduce model uncertainty, and especially a spatial coverage.

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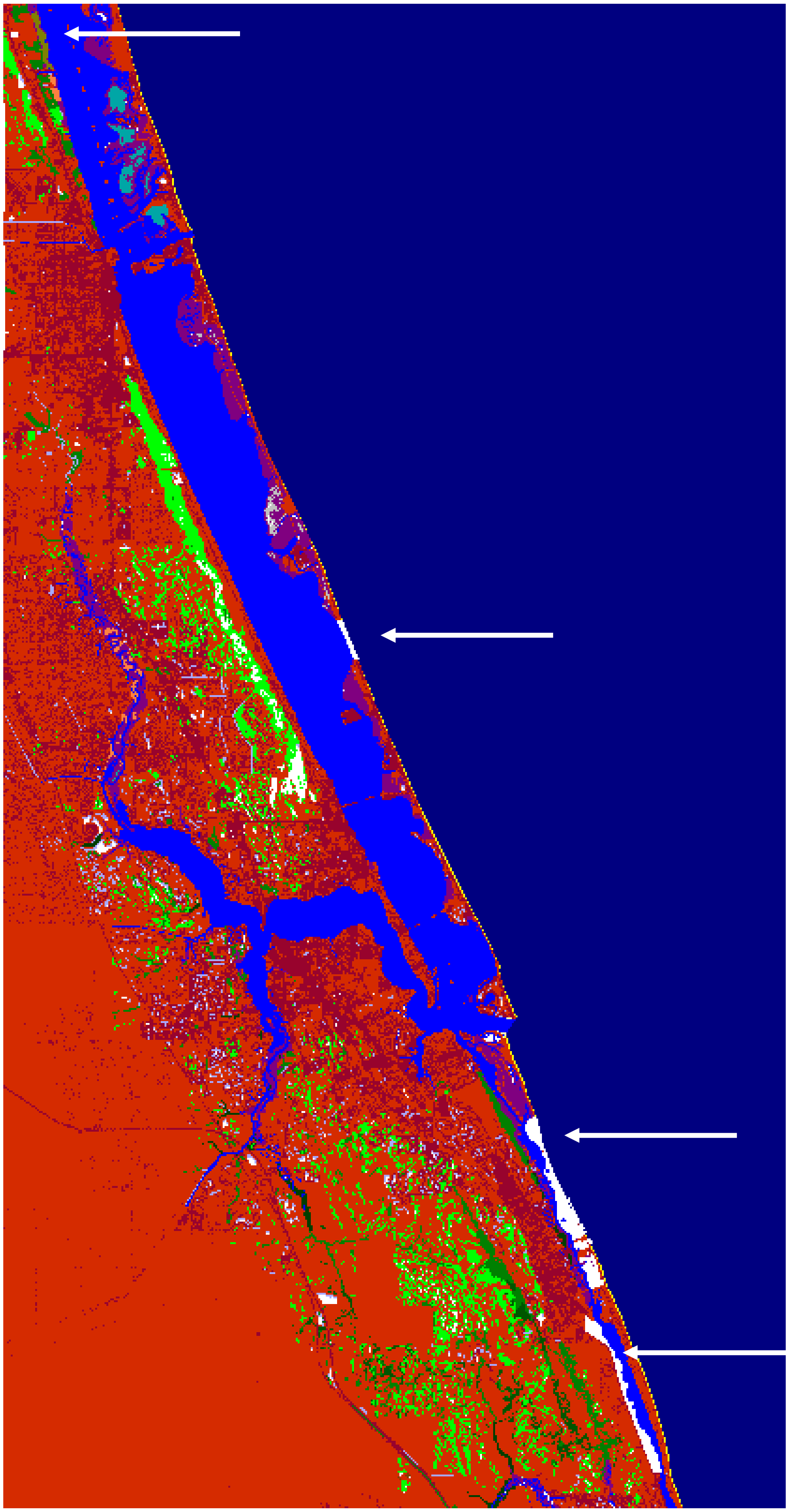
Appendix A: Contextual Results

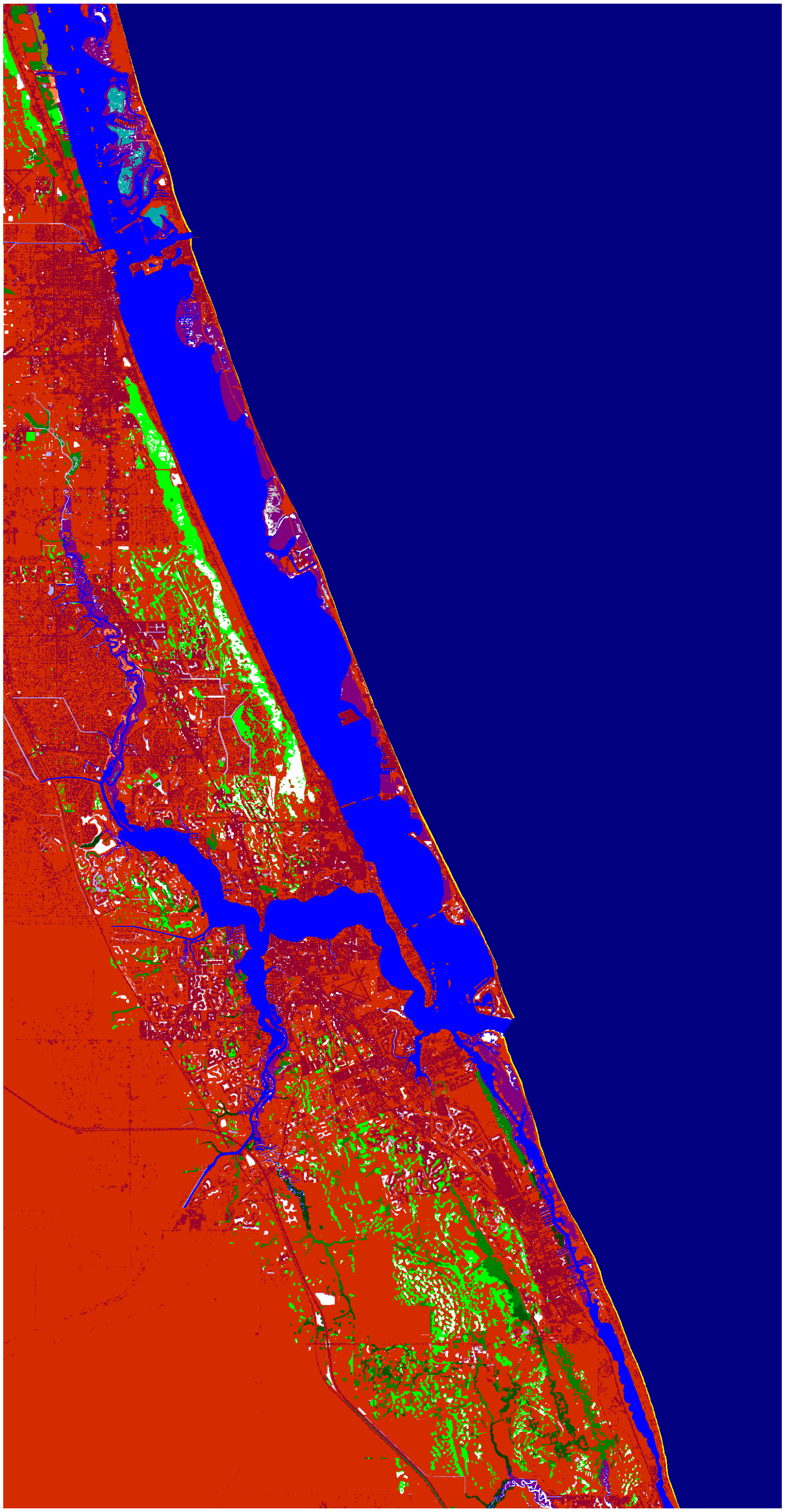
The SLAMM model does take into account the context of the surrounding lands or open water when calculating effects. For example, erosion rates are calculated based on the maximum fetch (wave action) which is estimated by assessing contiguous open water to a given marsh cell. Another example is that inundated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

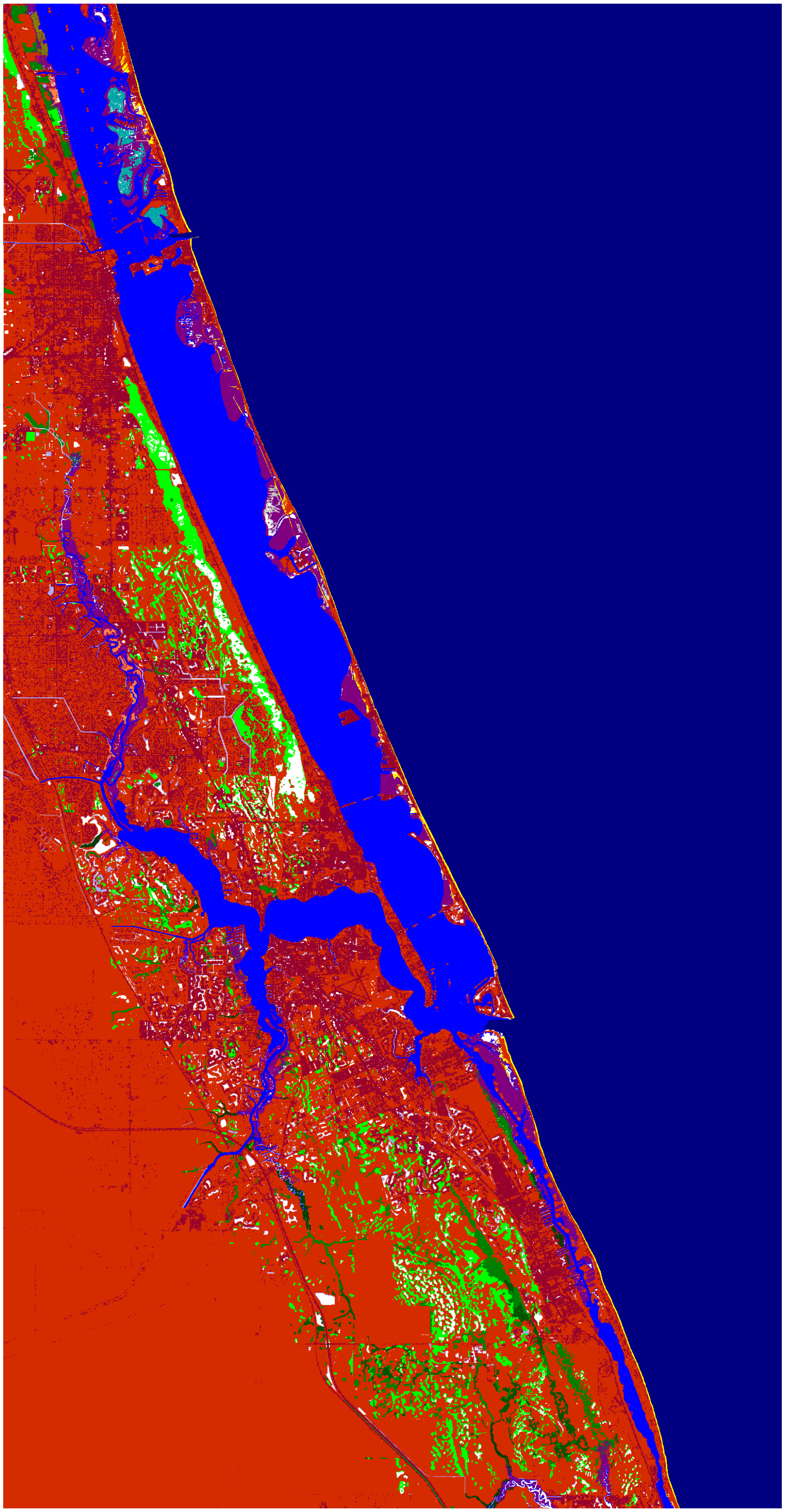
- Results were closely examined (quality assurance) within USFWS refuges but not closely examined for the larger region.
- Site-specific parameters for the model were derived for USFWS refuges whenever possible and may not be regionally applicable.
- Especially in areas where dikes are present, an effort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



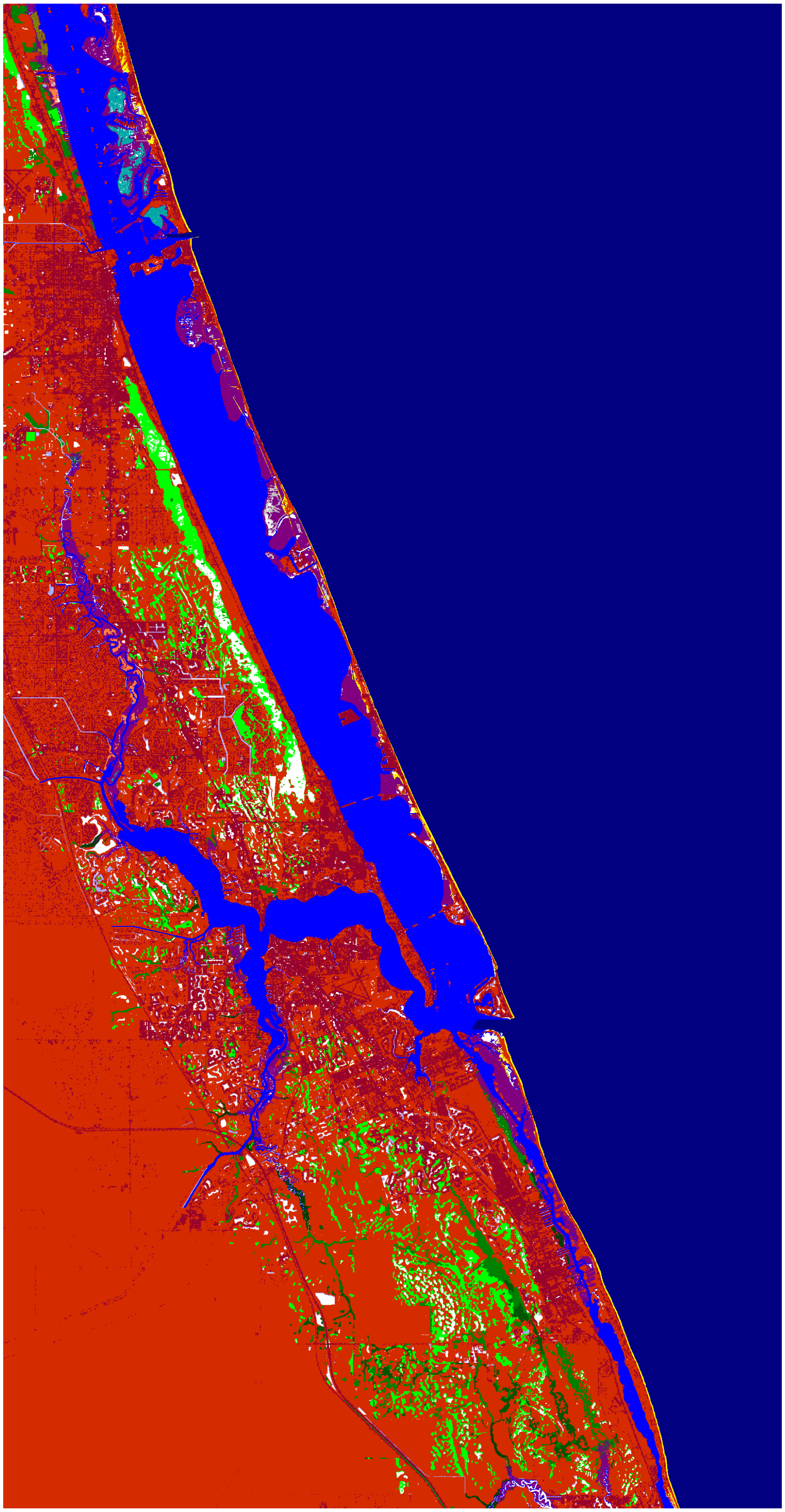
Hobe Sound National Wildlife Refuge within simulation context (white).



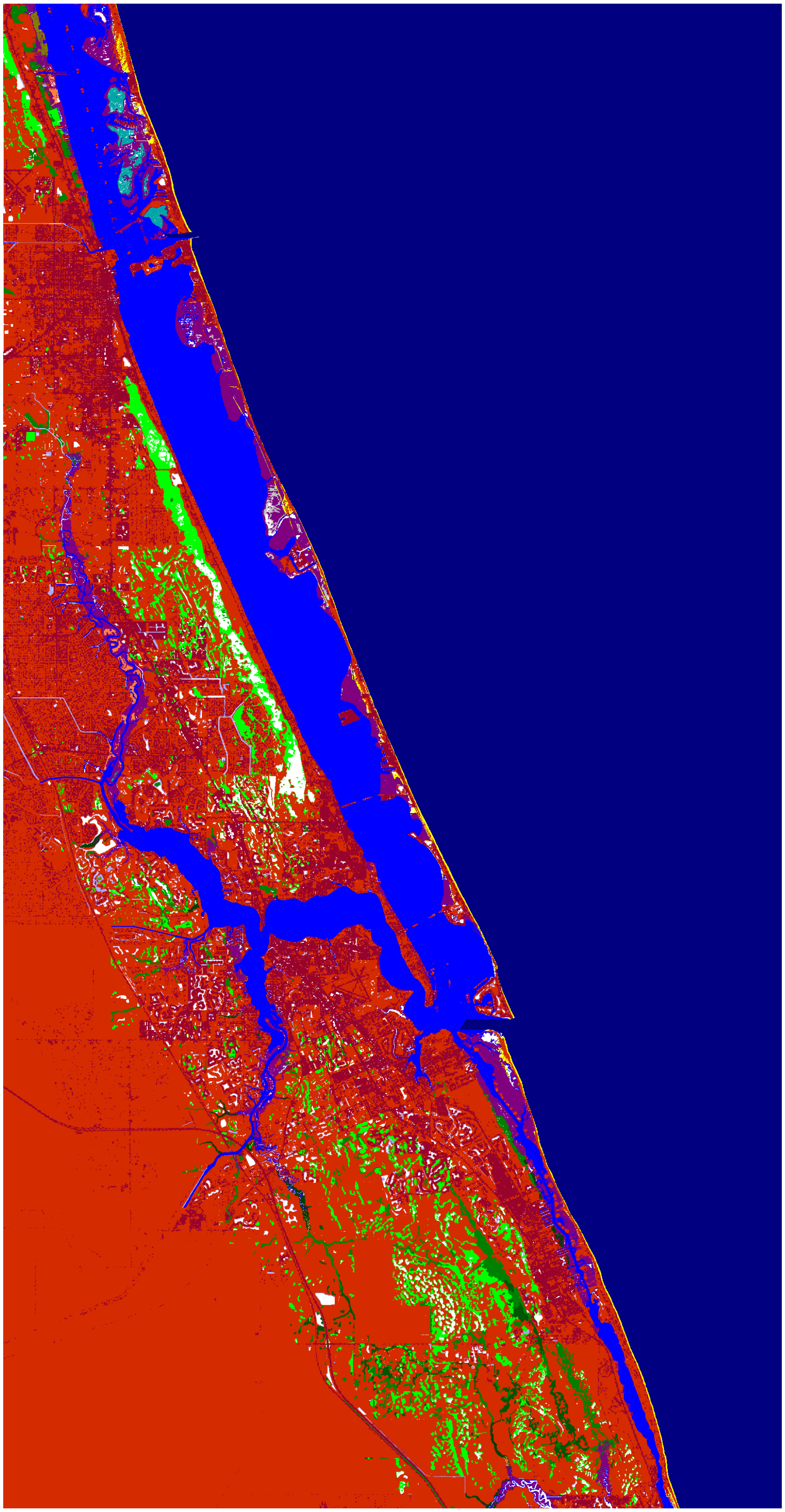
Hobe Sound Context, Initial Condition



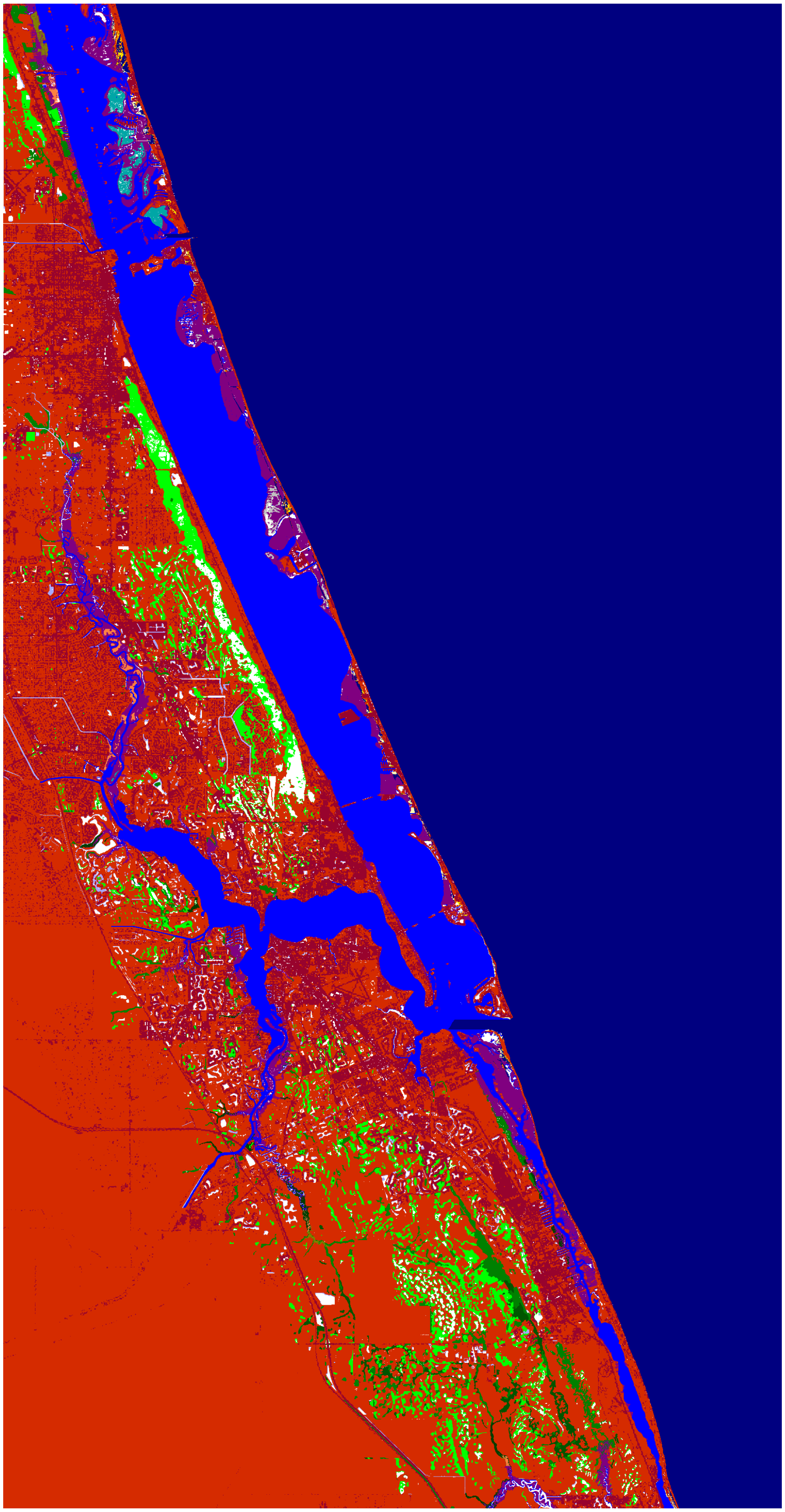
Hobe Sound Context, 2025, Scenario A1B Mean



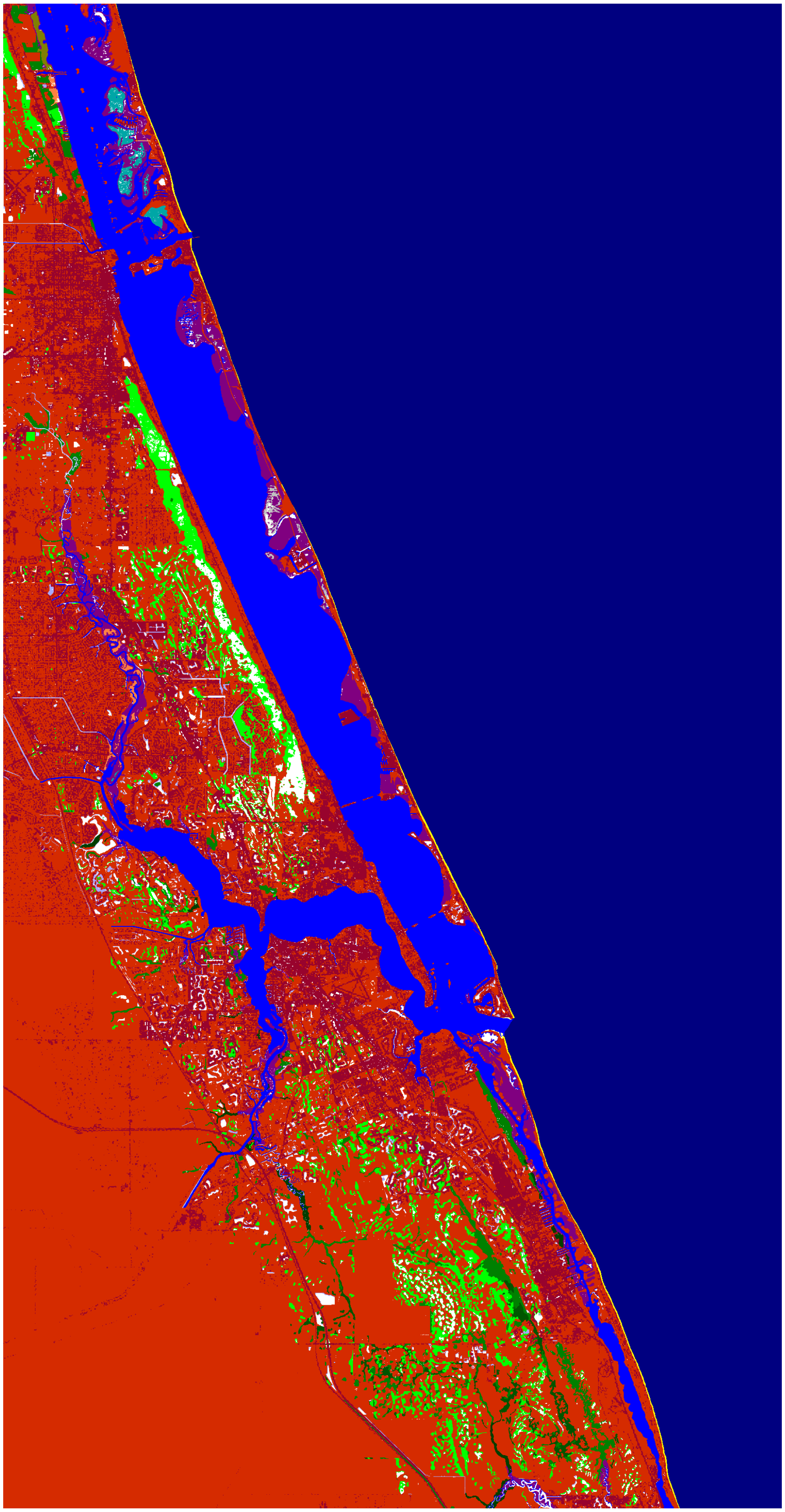
Hobe Sound Context, 2050, Scenario A1B Mean



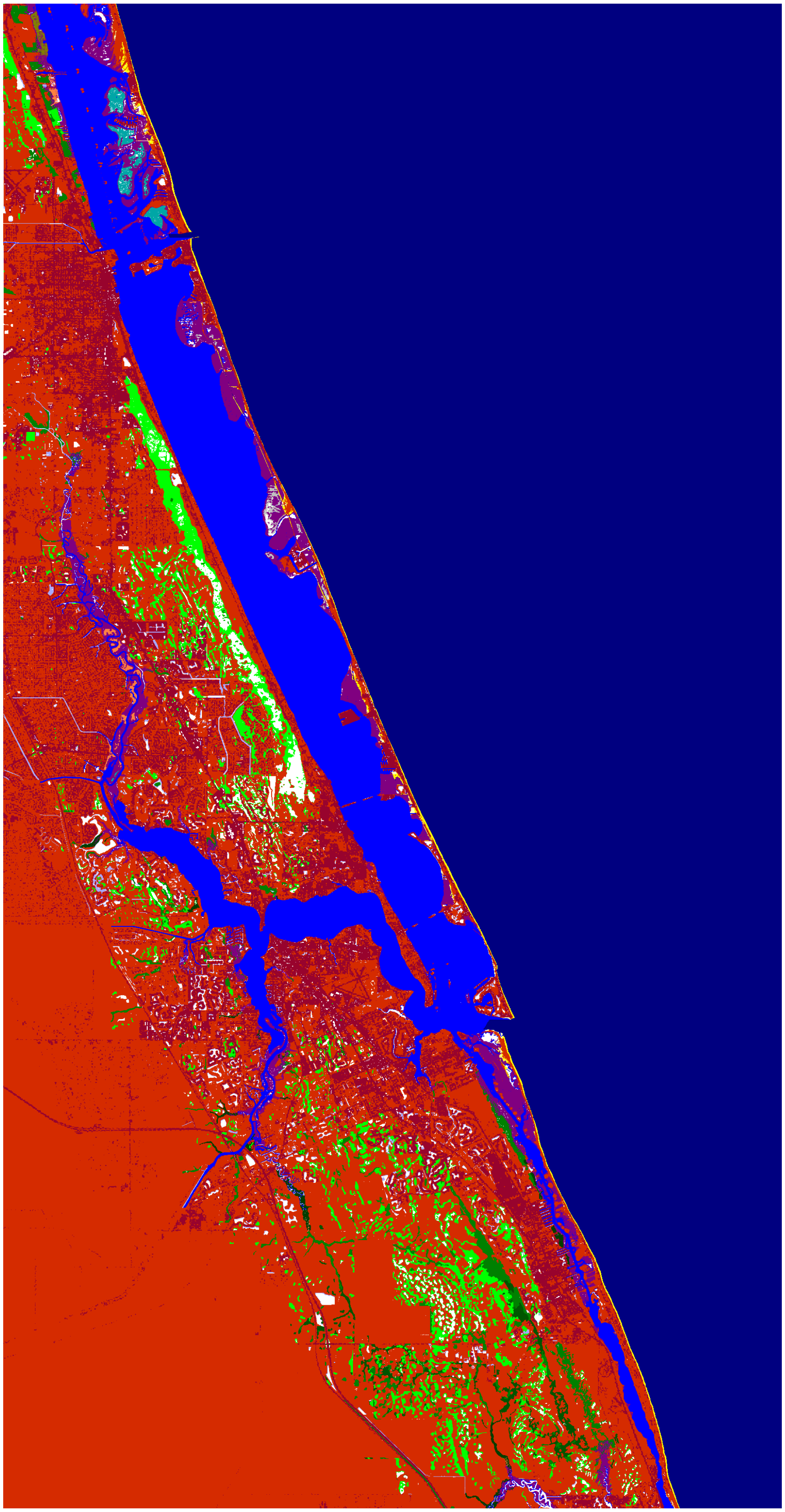
Hobe Sound Context, 2075, Scenario A1B Mean



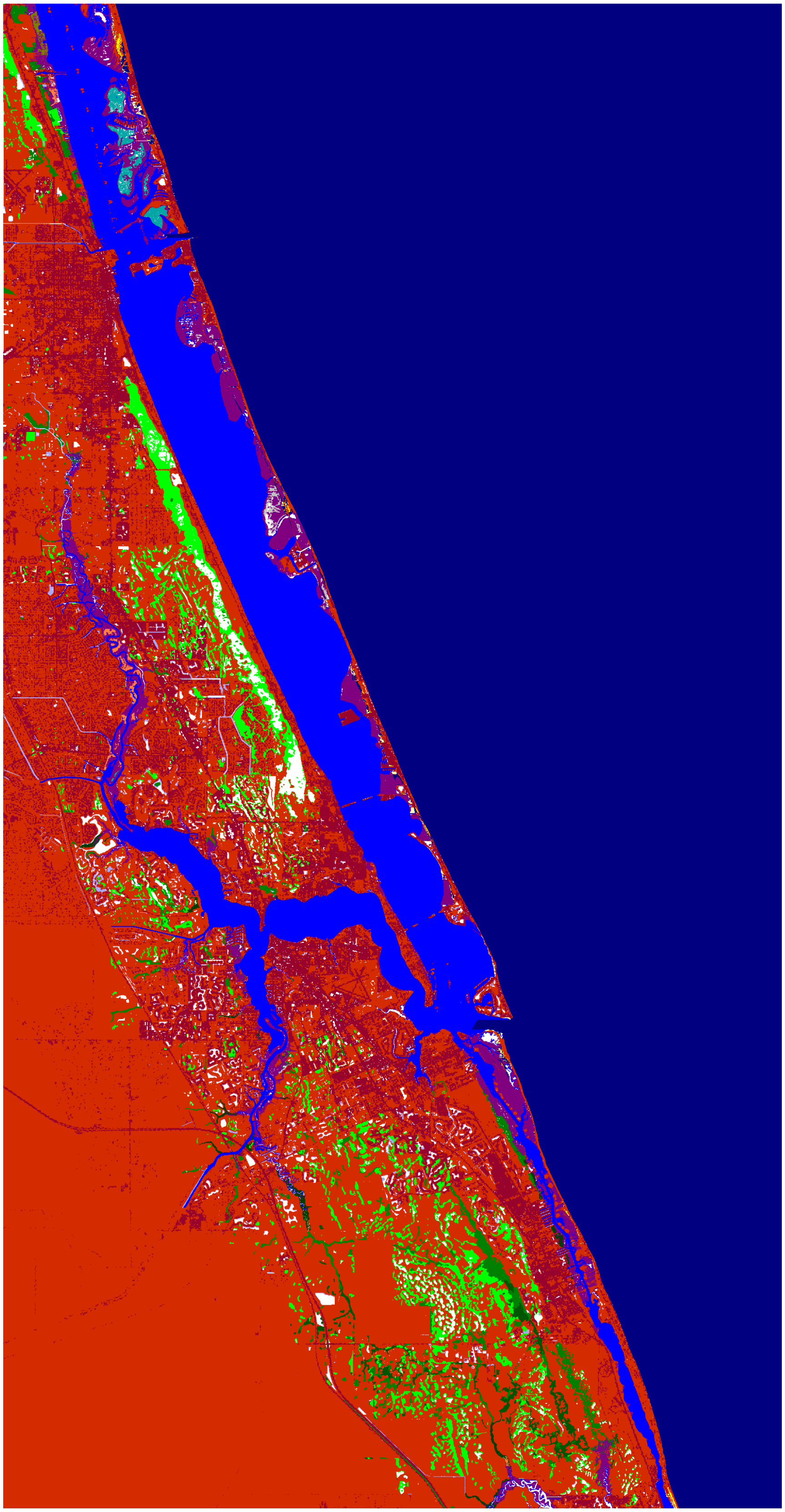
Hobe Sound Context, 2100, Scenario A1B Mean

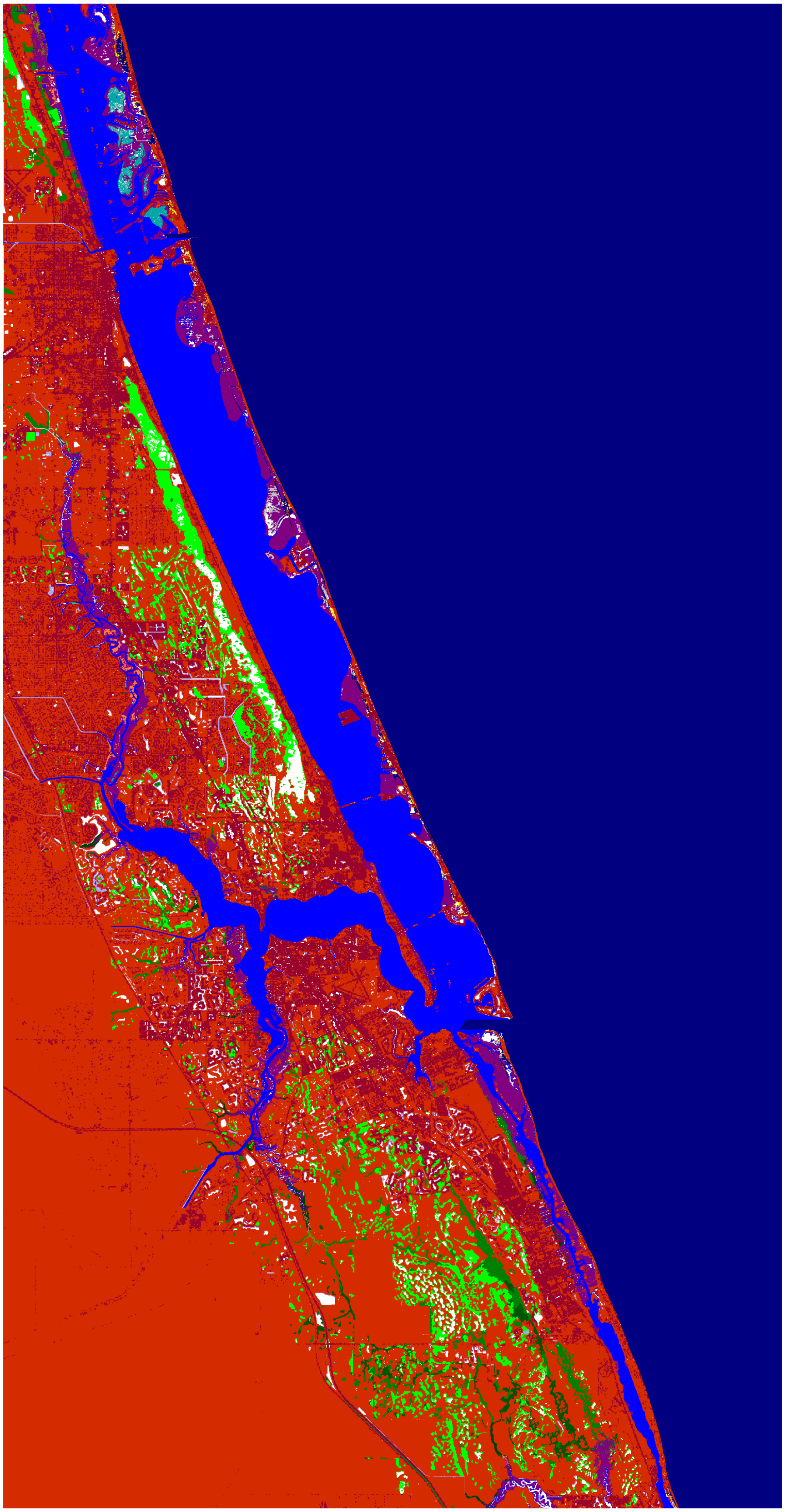


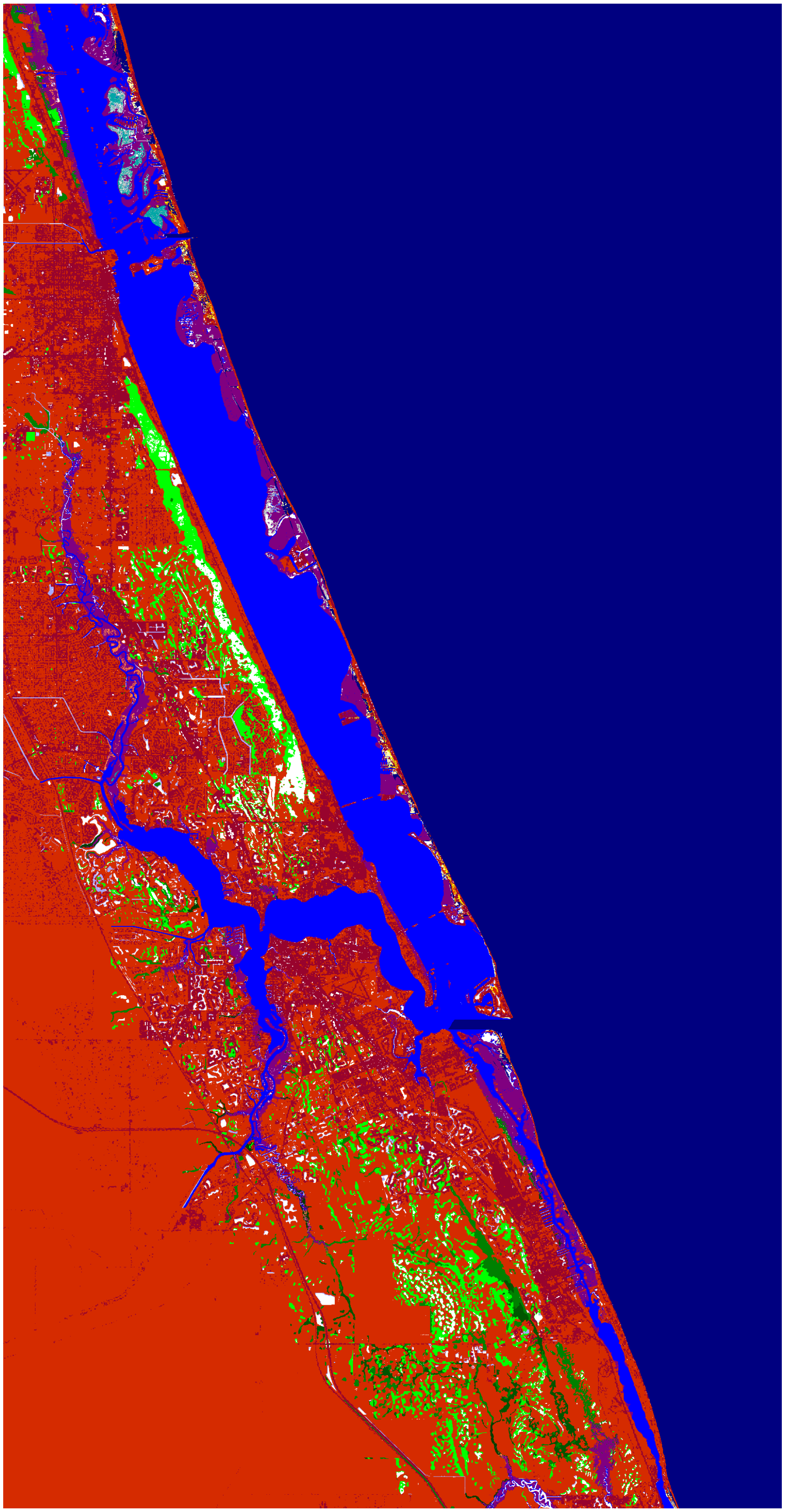
Hobe Sound Context, Initial Condition



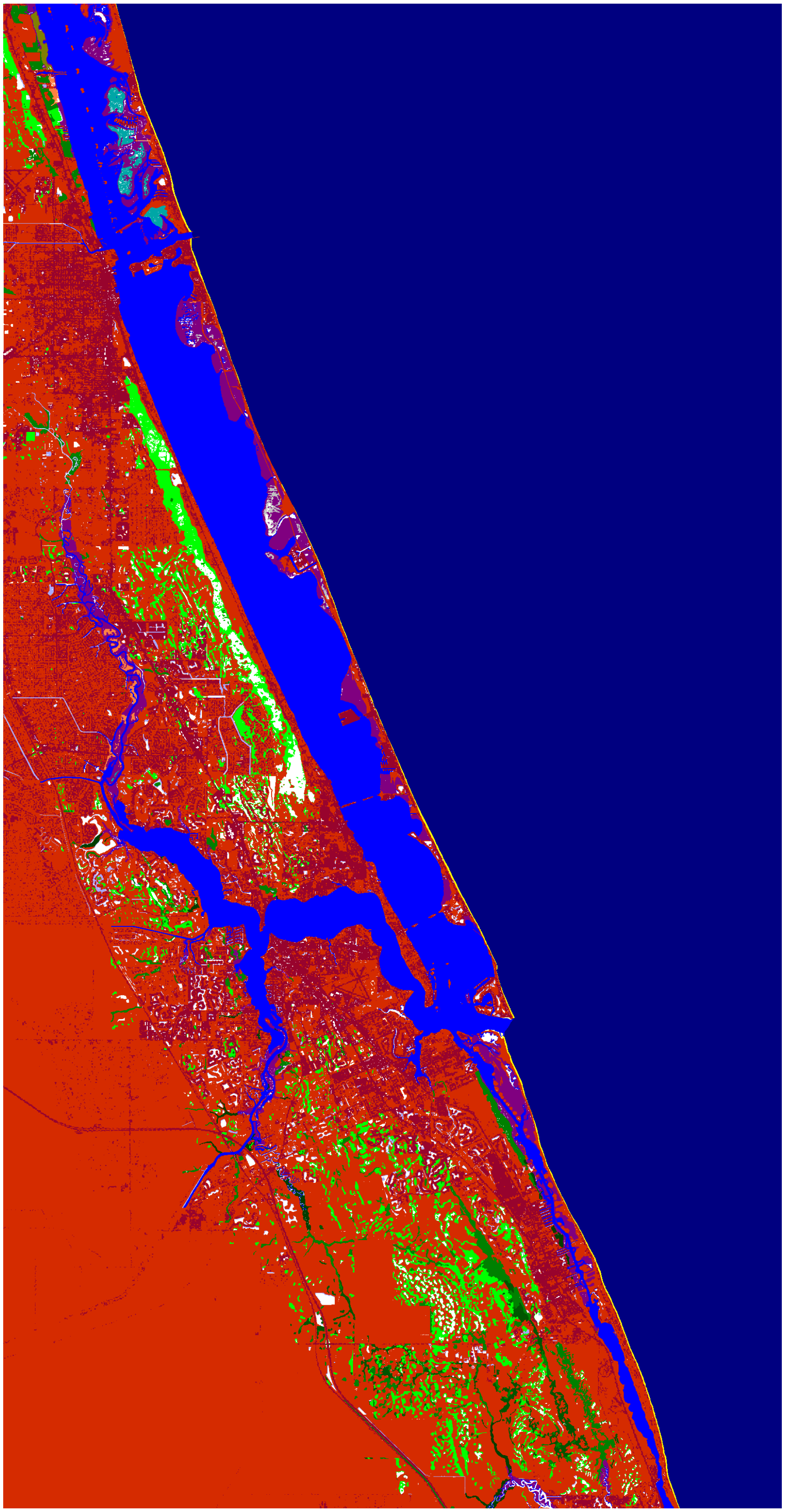
Hobe Sound Context, 2025, Scenario A1B Maximum


Hobe Sound Context, 2050, Scenario A1B Maximum

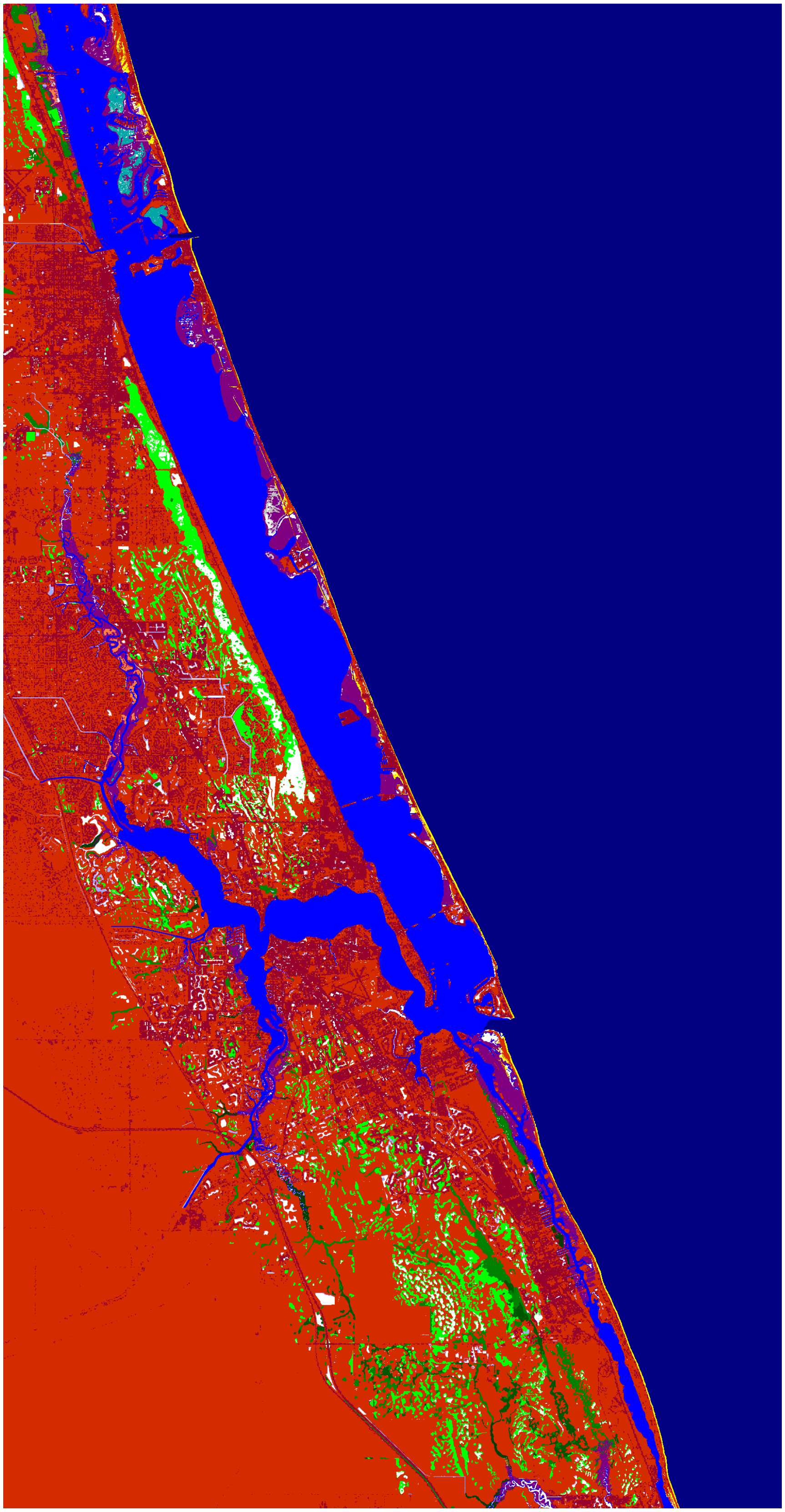

Hobe Sound Context, 2075, Scenario A1B Maximum



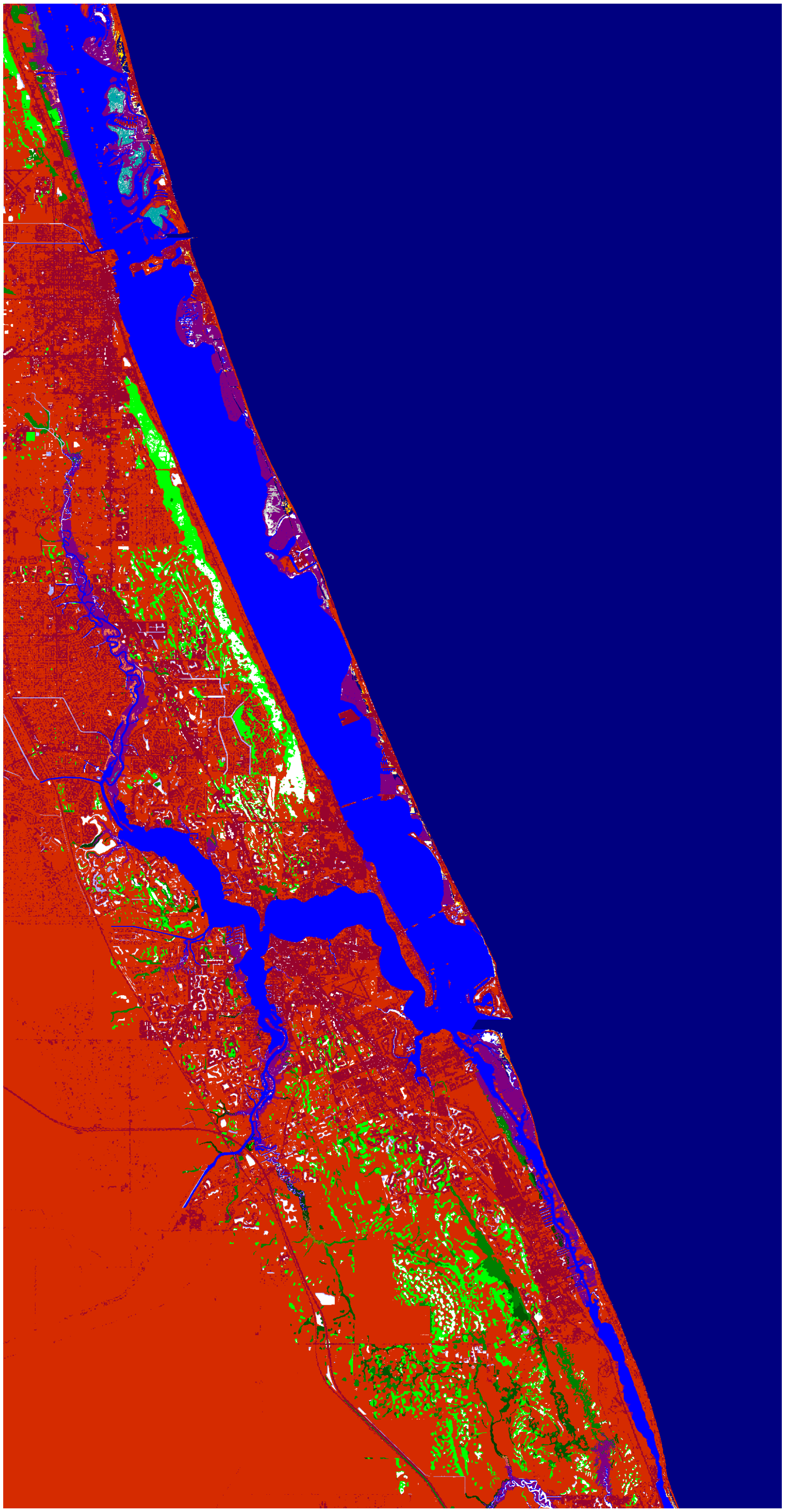
Hobe Sound Context, 2100, Scenario A1B Maximum



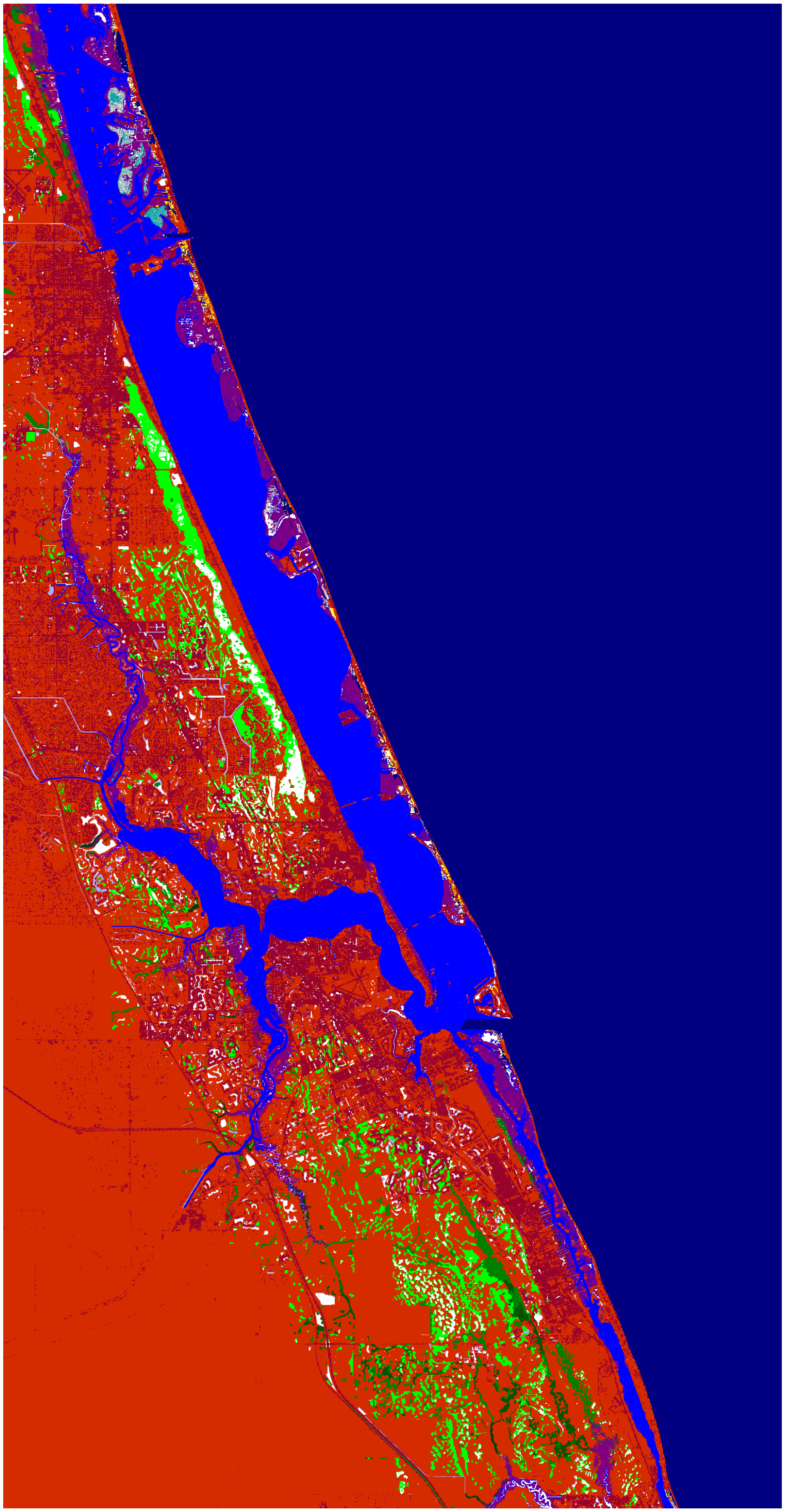
Hobe Sound Context, Initial Condition



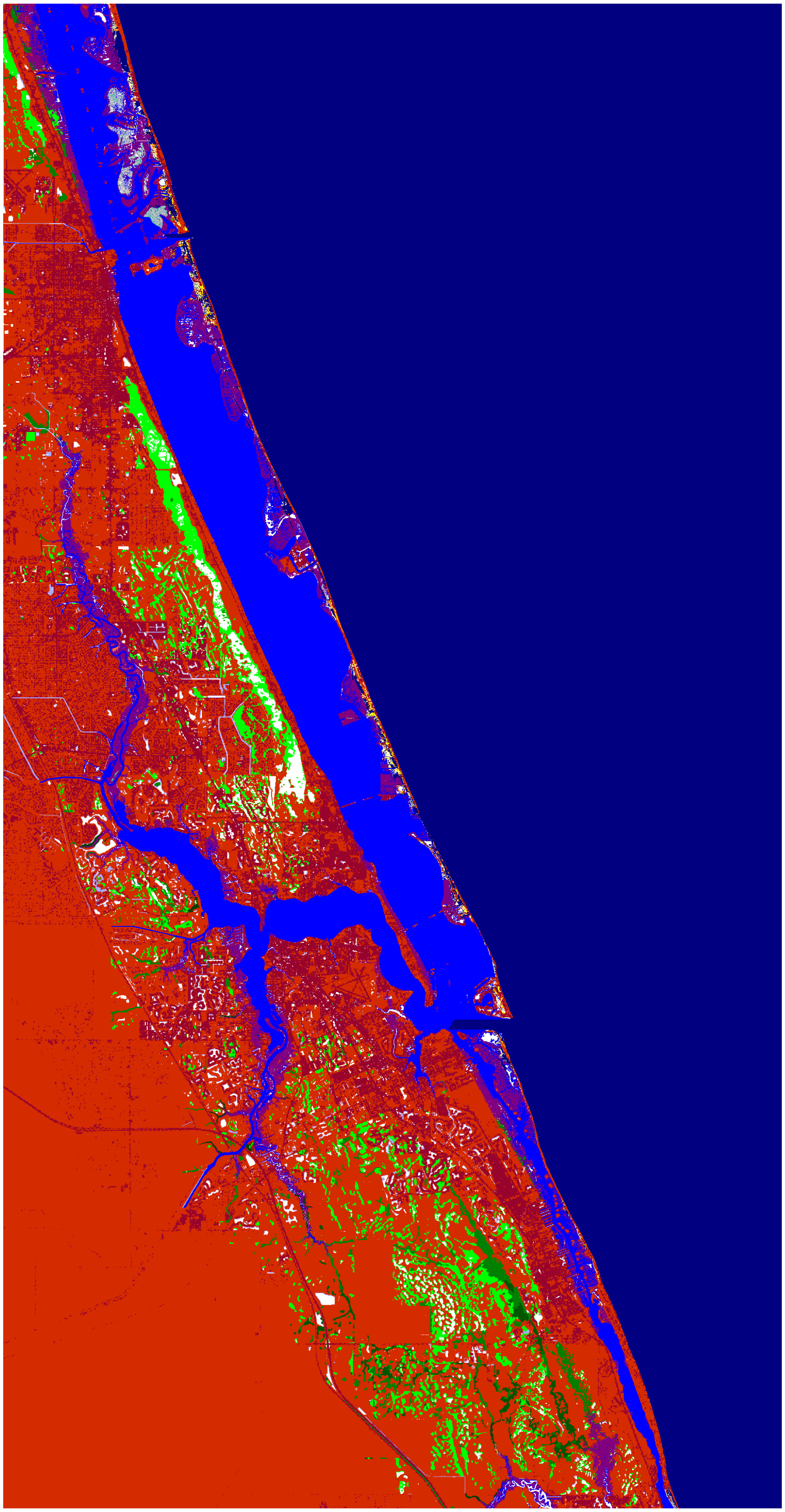
Hobe Sound Context, 2025, 1 meter



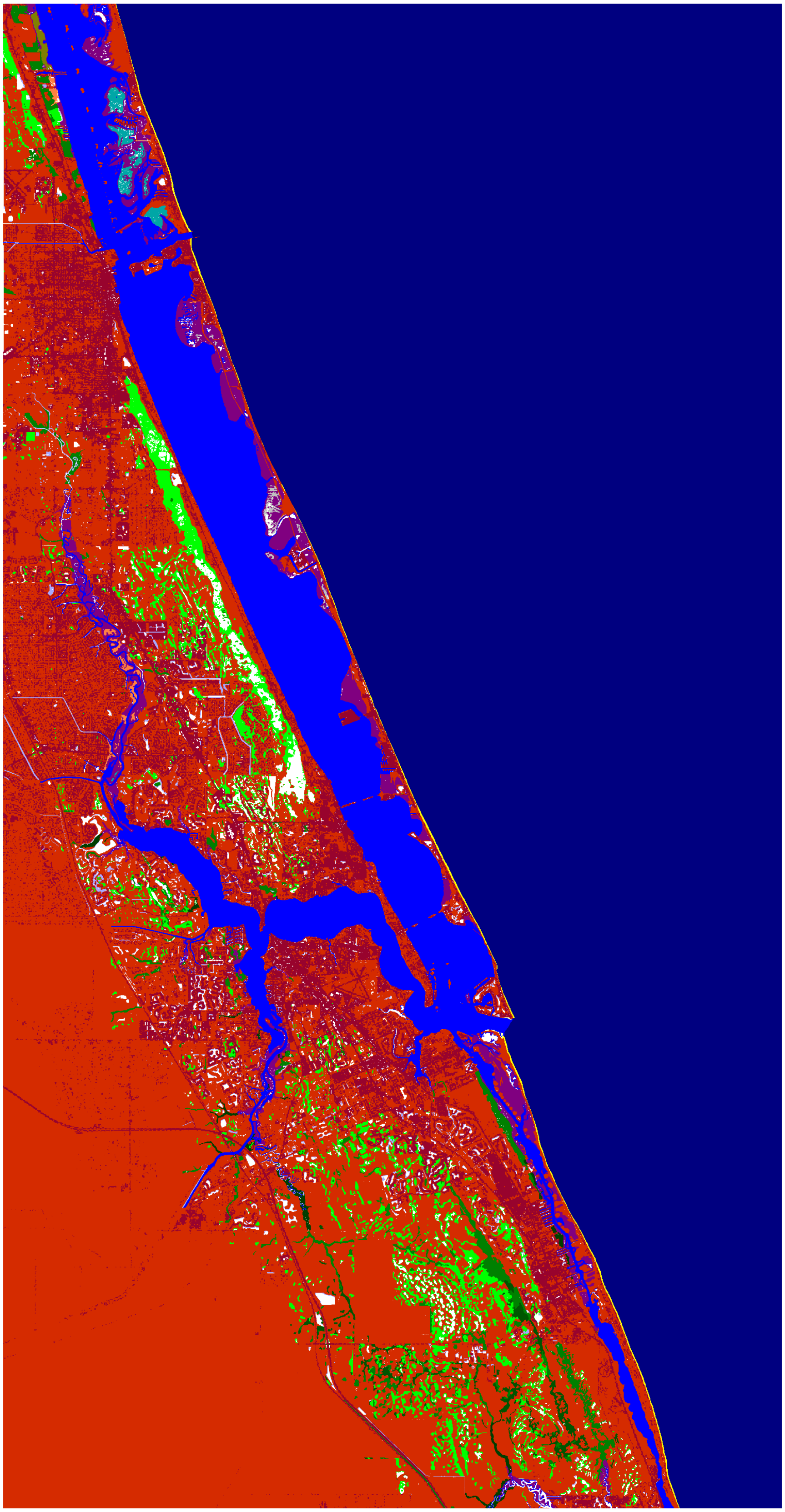
Hobe Sound Context, 2050, 1 meter



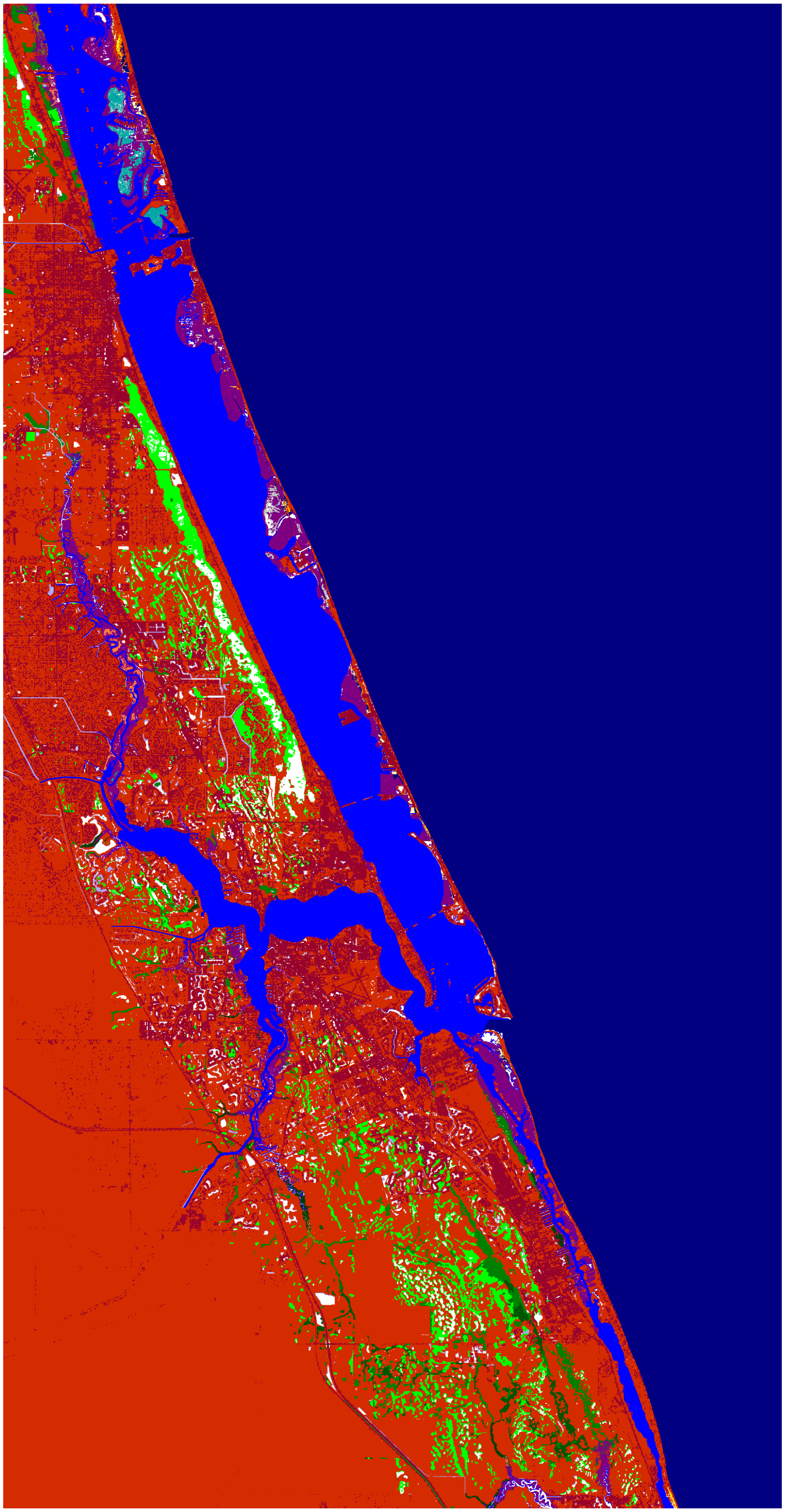
Hobe Sound Context, 2075, 1 meter



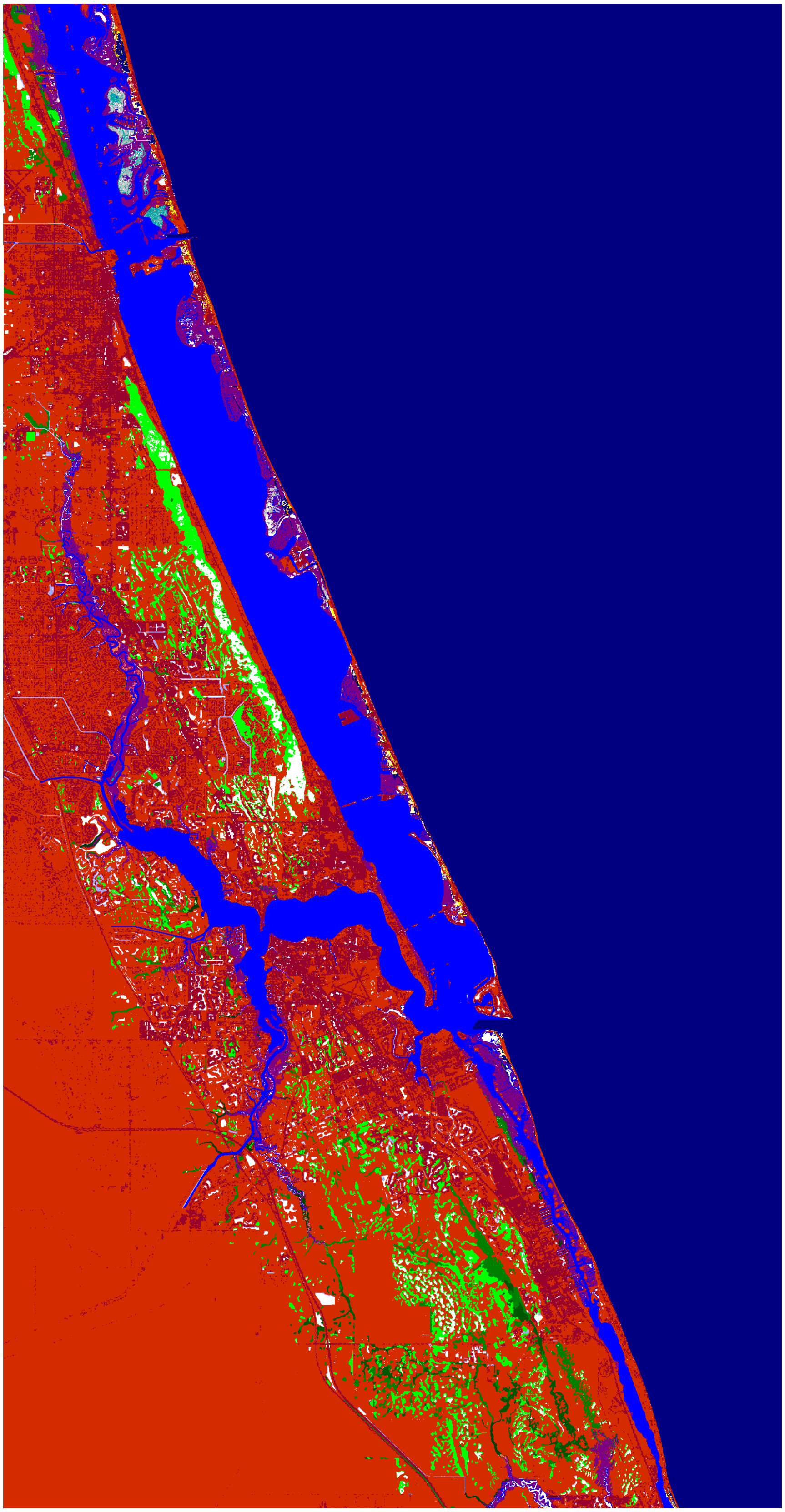
Hobe Sound Context, 2100, 1 meter



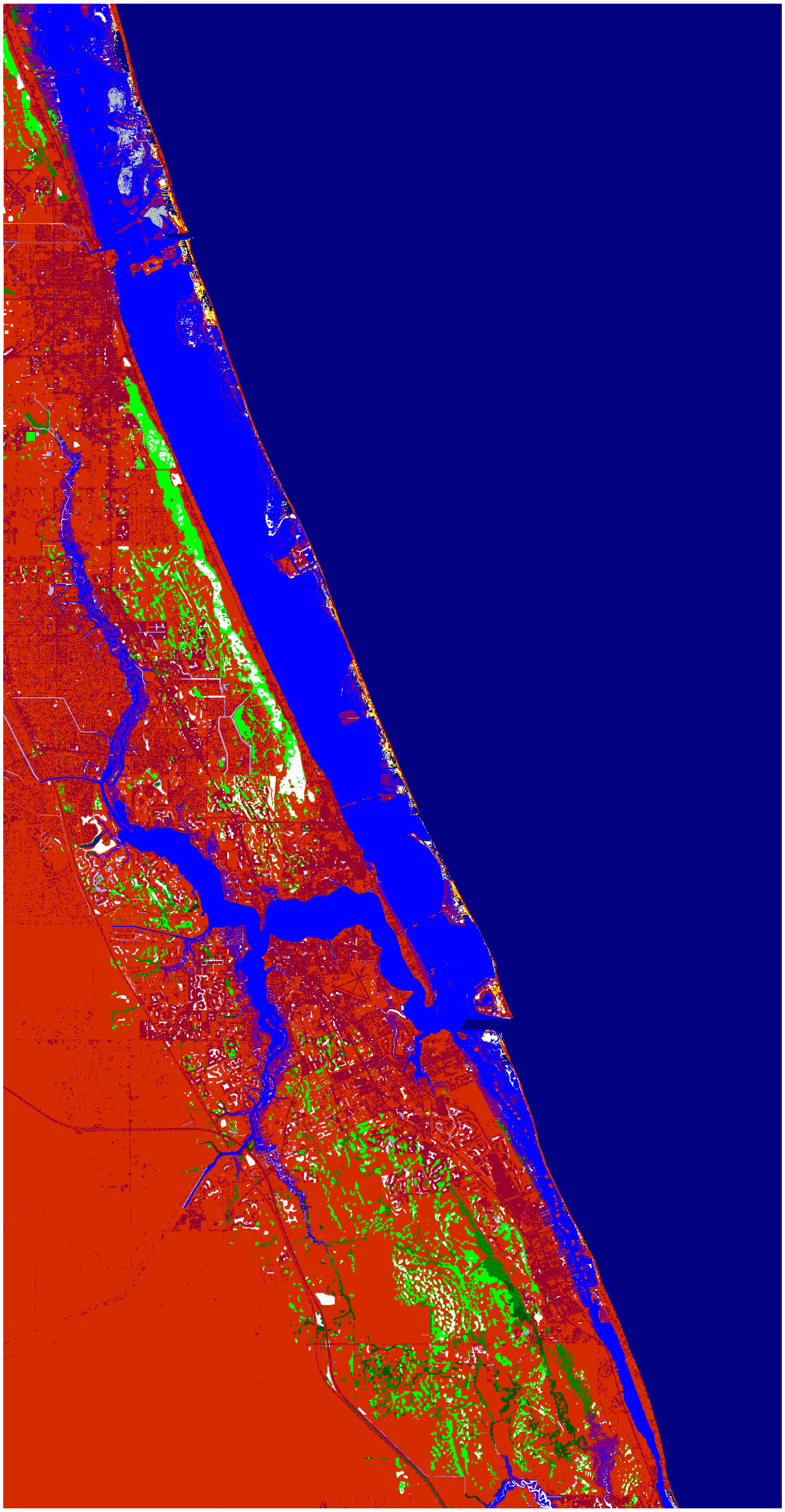
Hobe Sound Context, Initial Condition



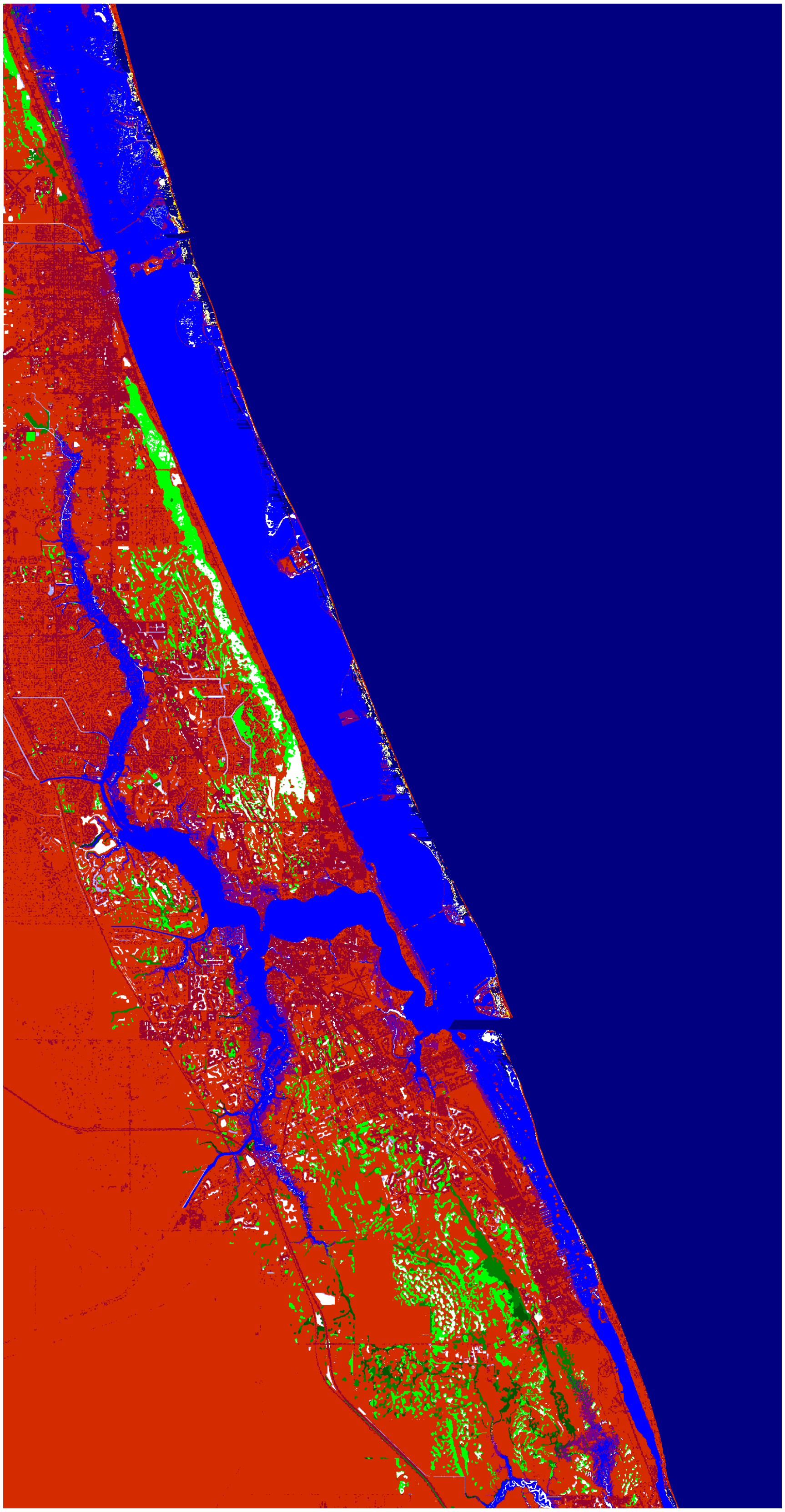
Hobe Sound Context, 2025, 1.5 meter



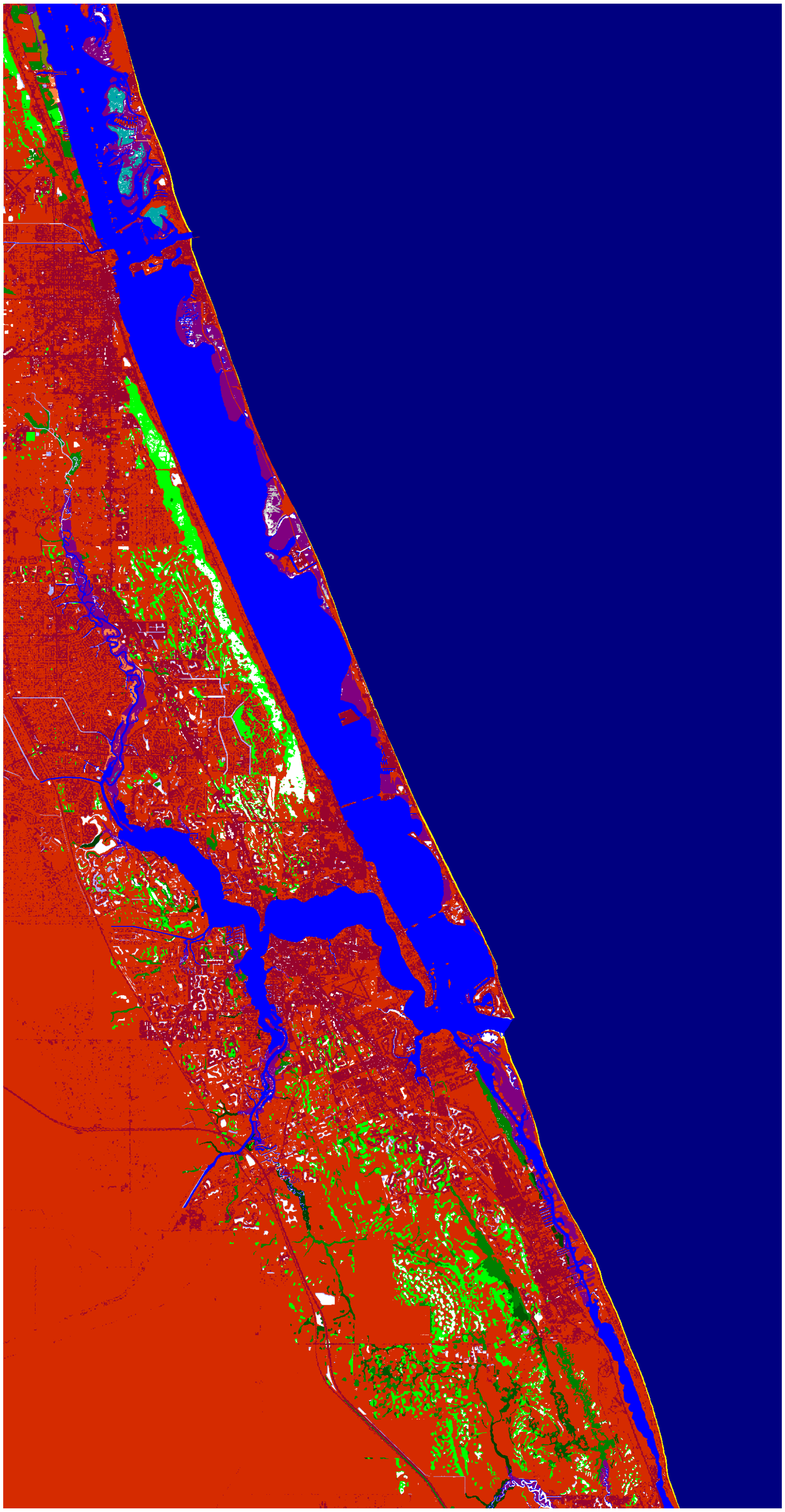
Hobe Sound Context, 2050, 1.5 meter



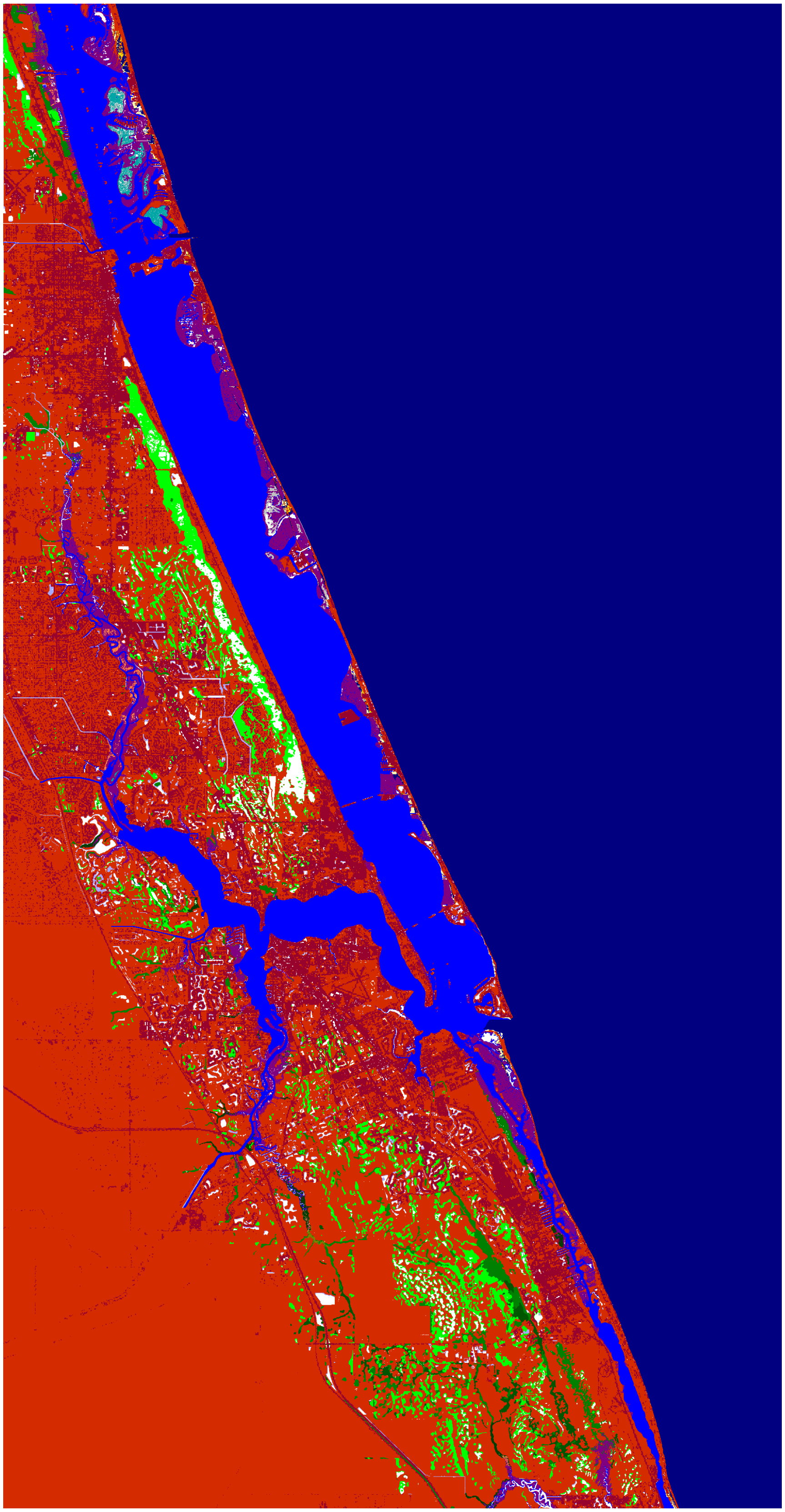
Hobe Sound Context, 2075, 1.5 meter



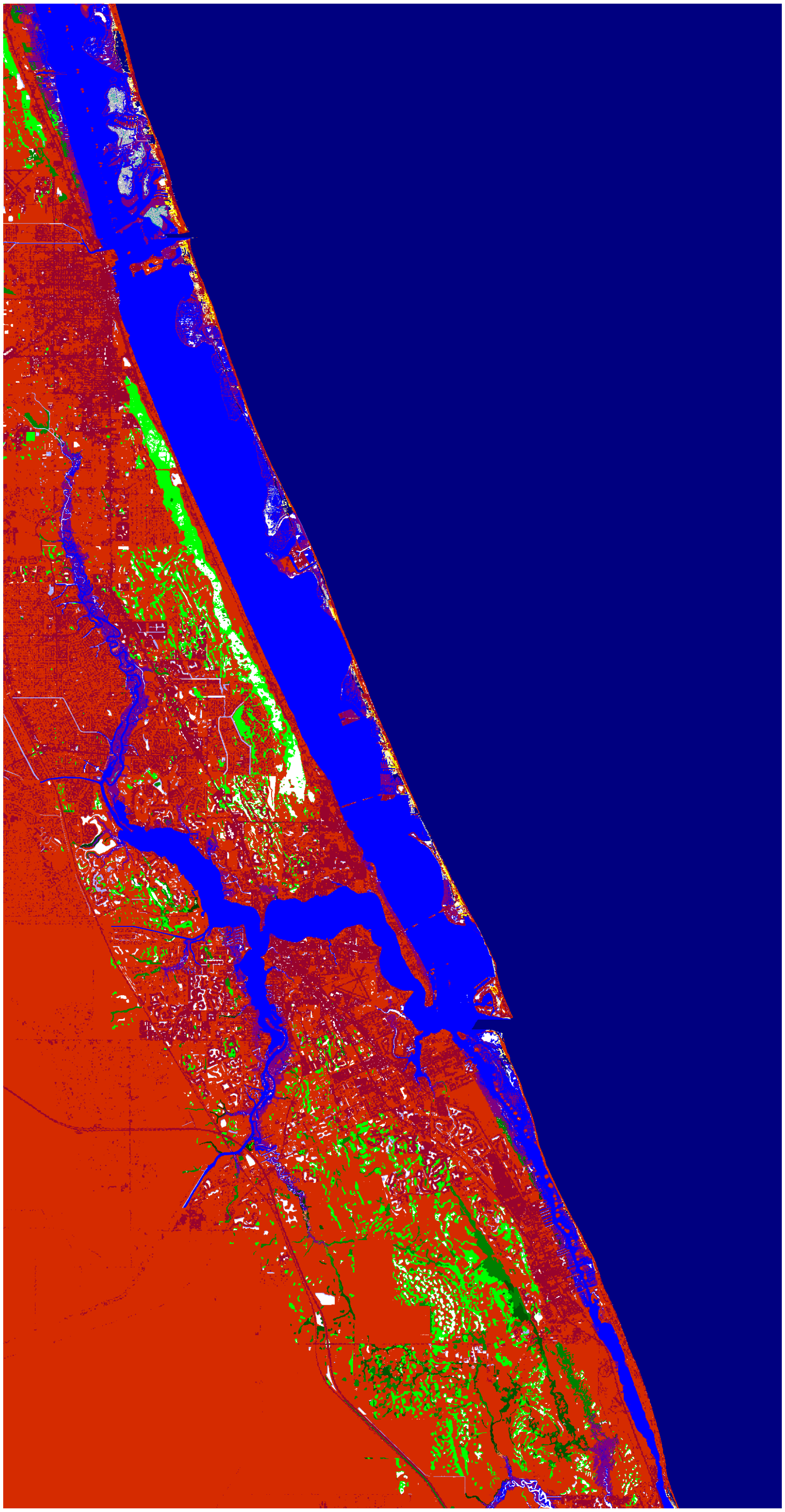
Hobe Sound Context, 2100, 1.5 meter



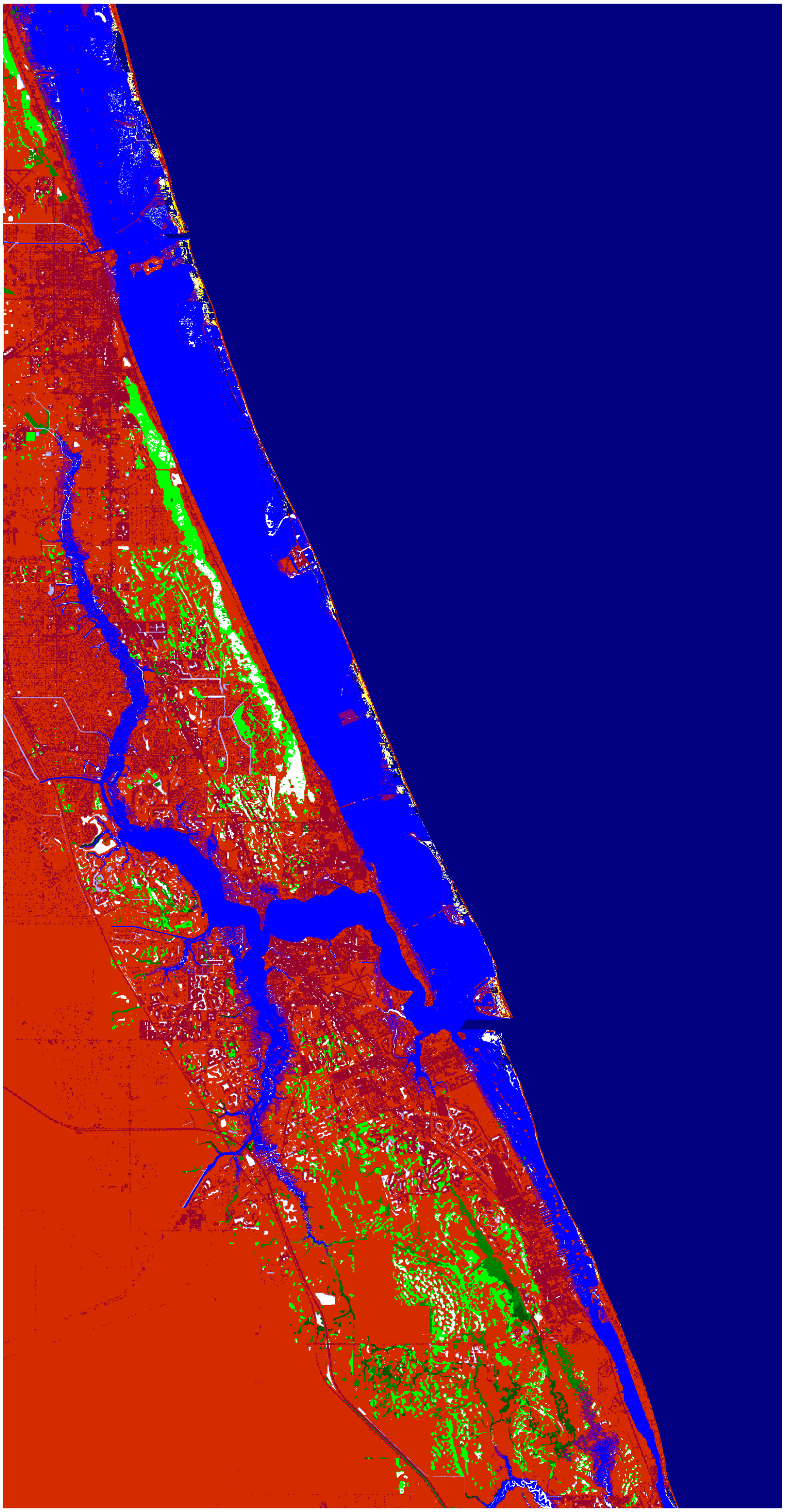
Hobe Sound Context, Initial Condition



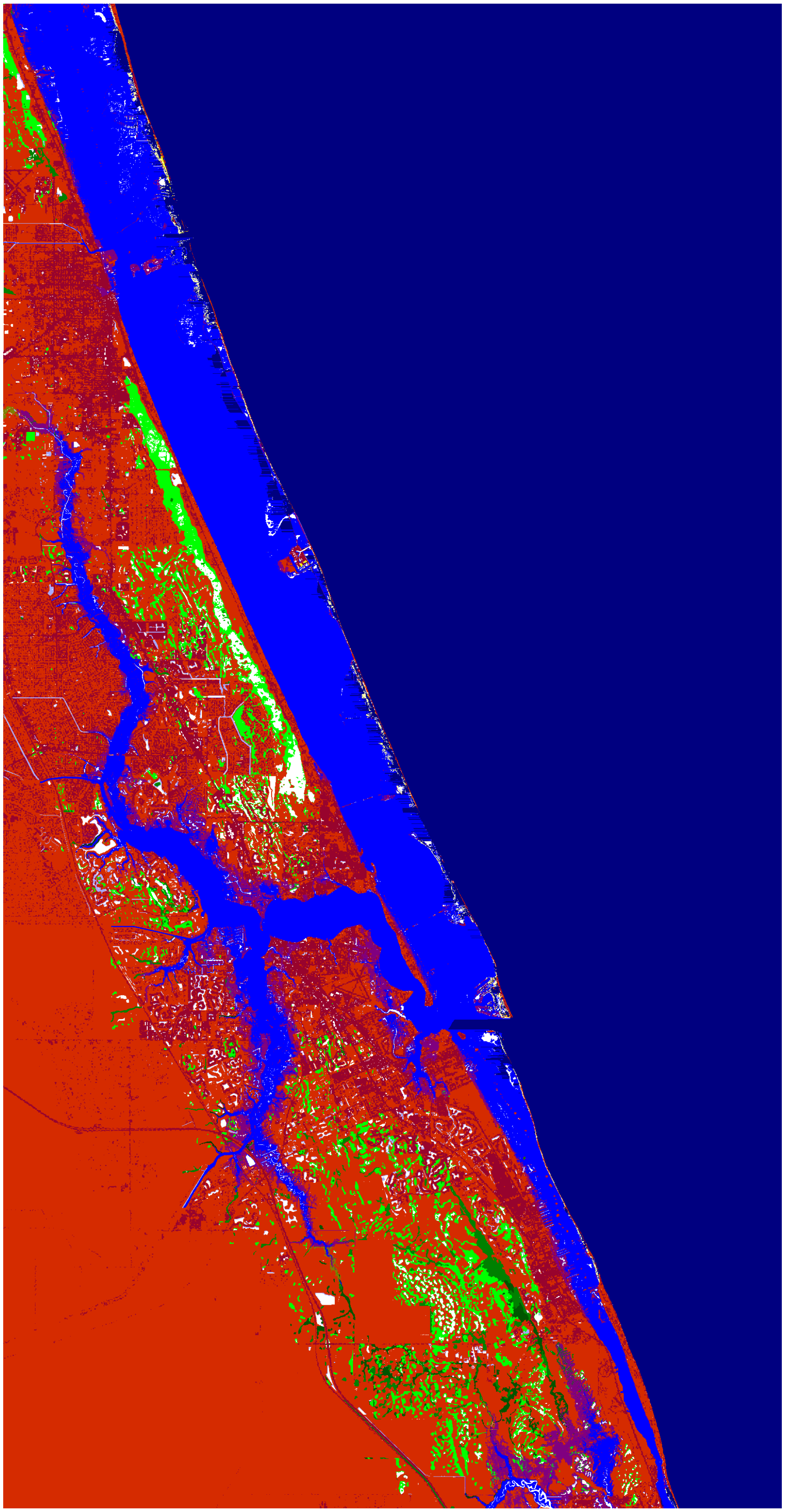
Hobe Sound Context, 2025, 2 meter



Hobe Sound Context, 2050, 2 meter



Hobe Sound Context, 2075, 2 meter



Hobe Sound Context, 2100, 2 meter