Application of the Sea-Level Affecting Marshes Model (SLAMM 6) to Mackay Island 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.

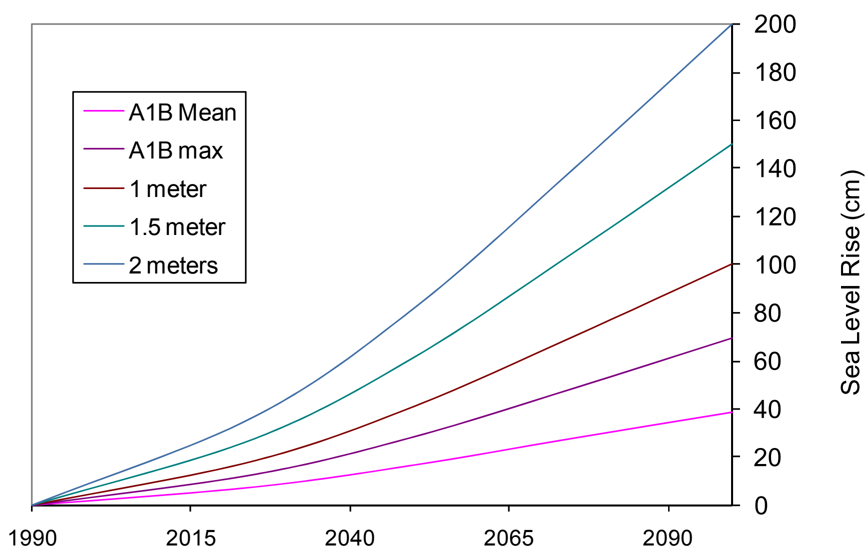
Sea Level Rise Scenarios

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 is a mosaic of three LiDAR-derived DEMs from NOAA (2008), the National Elevation Dataset (NED, 2003) and City of Virginia Beach (2004) (Figure 1).

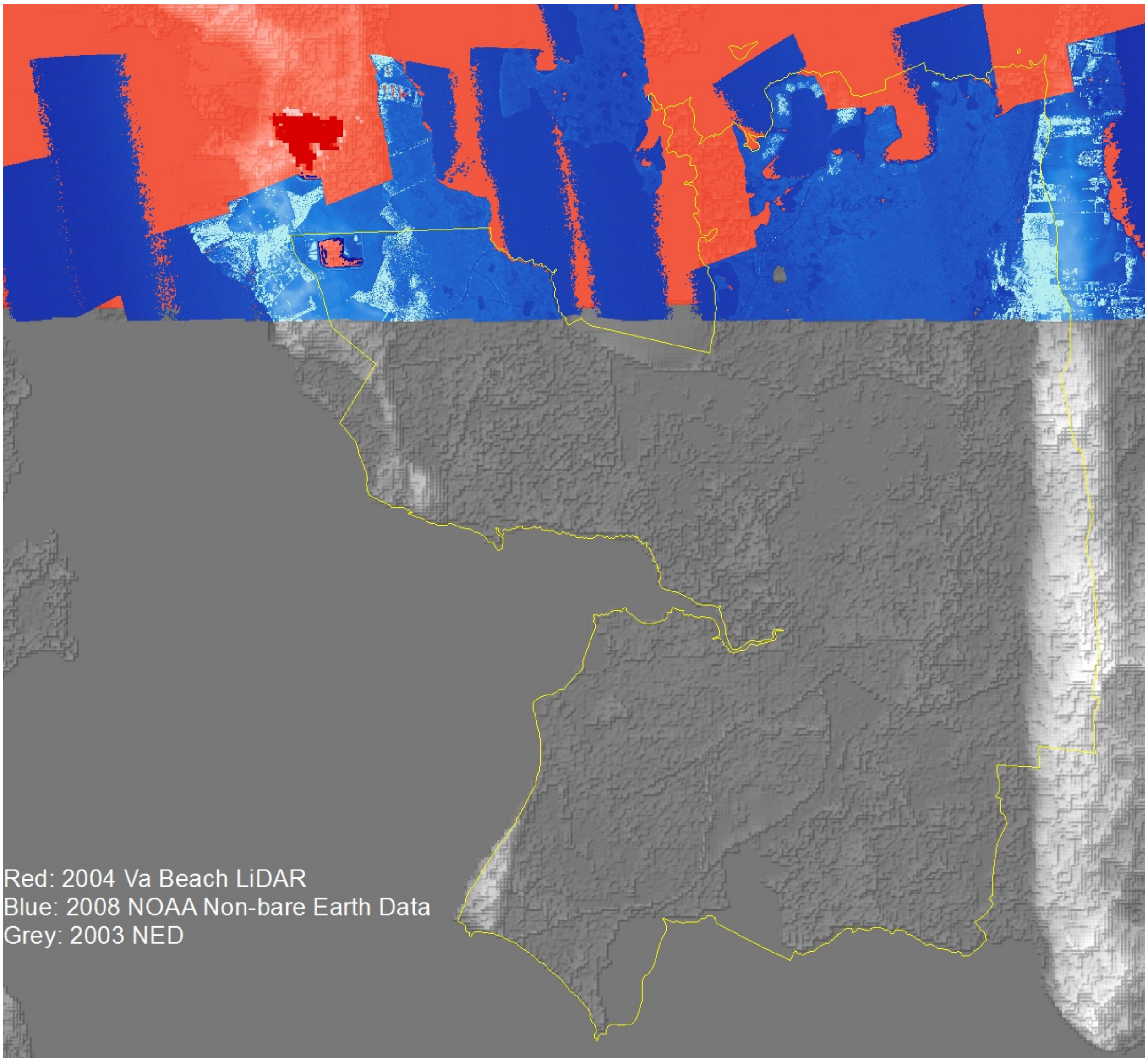


Figure 1: Composition of DEM used in model simulation.
Thin yellow line is the refuge boundary.

The wetlands layer for the study area was produced by the National Wetlands Inventory and is based on a 2008 photo date (Figure 2). Converting the NWI survey into 30 meter cells indicates that the approximately nine thousand acre refuge (approved acquisition boundary including water) is composed of the following categories (excluding categories below 1%):

	Irregularly Flooded Marsh	47.4%
	Regularly Flooded Marsh	13.8%
	Tidal Swamp	13.1%
	Estuarine Open Water	13.1%
	Undeveloped Dry Land	10.4%
	Transitional Salt Marsh	1.3%

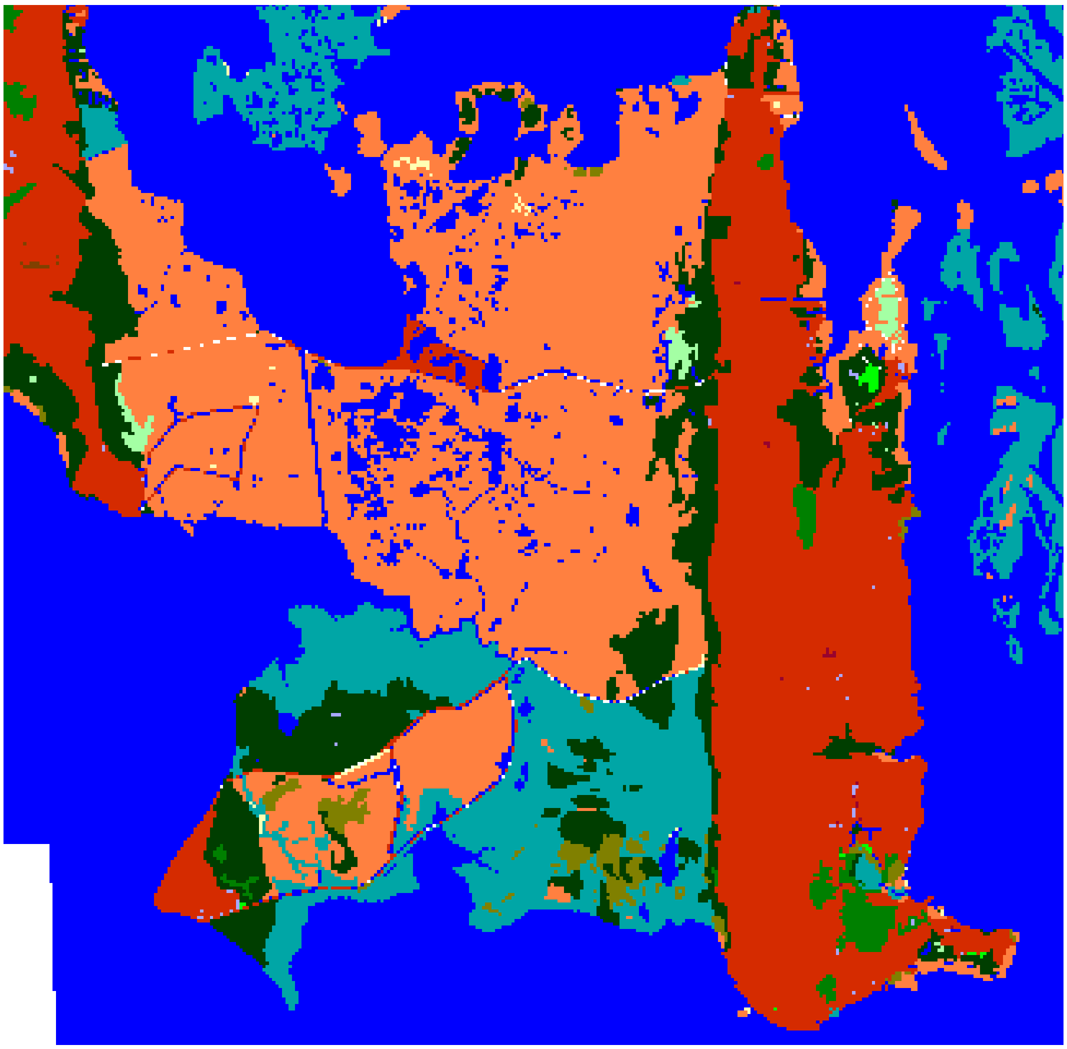


Figure 2: Mackay Island NWR wetlands layer.

According to the Refuge Manager of Mackay Island, Michael Hoff, there are six impounded areas within Mackay Island NWR (Figure 3). The SLAMM model assumes that these areas will be maintained and protected against local sea-level rise of up to two meters.

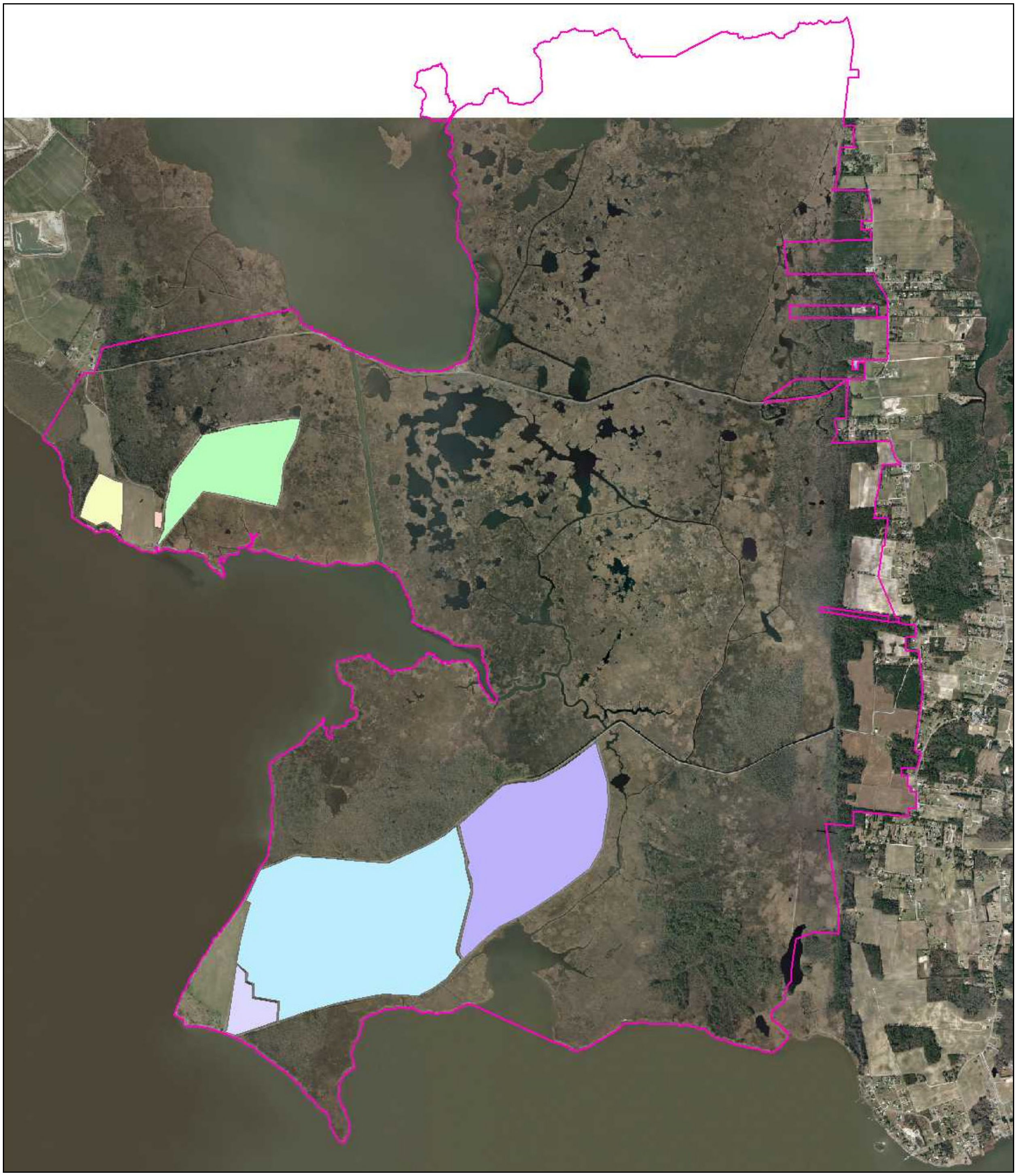


Figure 3: Six impounded areas within the Mackay Island NWR.

The historic trend for sea level rise was estimated at 2.57 mm/year using the nearest NOAA gage with long-term SLR data (8656483, Beaufort, NC). The rate of sea level rise for this refuge has therefore been slightly higher that the global average for the last 100 years (approximately 1.7 mm/year, IPCC 2007a). This differential (between local and global SLR) is carried forward in model projections.

The tide range behind the barrier island was estimated at 0.2 meters using data from the 1999 USGS quadrangle map for Barco, NC.

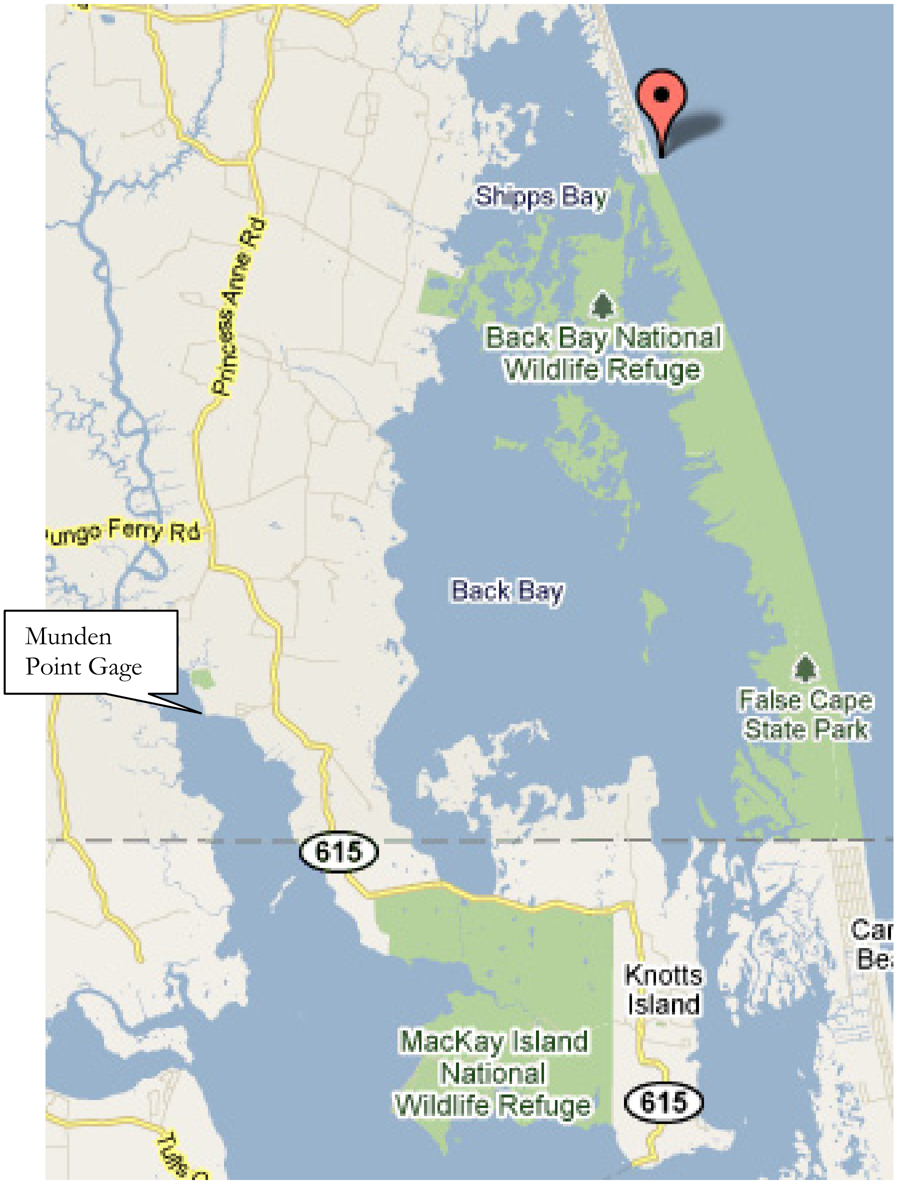


Figure 4: Location of NOAA tides gage used in refuge model application.

As this site is located behind barrier islands, the elevation at which estuarine water is predicted to regularly inundate the land (the salt elevation) has been estimated based on a frequency of inundation analysis using one year of verified hourly water data from from the Munden Point, North Landing River, VA gage (8639908). This procedure was done to incorporate the effects of wind tides within estimates of land inundation. This consideration is especially important at this site given the low magnitude of lunar tides. The boundary between regularly-flooded wetlands and dry lands was assumed to occur where water penetrates at least once every 30 days, or approximately 0.4 meters above the measured mean tide level.

Both regularly flooded and irregularly flooded marshes were parameterized using the nearest-available accretion data (Cedar Island, NC) with accretion rates set to 3.7 mm/year (Cahoon 1995).

Tidal fresh marsh accretion values were set to 5.9 mm/year based upon an average of fresh marsh accretion rates within the region (Reed 2008, n=8)

The MTL to NAVD88 correction was derived using the NOAA VDATUM product. A vertical-datum correction factor of -0.13 meters was used for this study area.

Modeled U.S. Fish and Wildlife Service refuge boundaries for North Carolina 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.

SUMMARY OF SLAMM INPUT PARAMETERS FOR MACKAY ISLAND NWR

Parameter	
Description	Mackay Island
NWI Photo Date (YYYY)	2008
DEM Date (YYYY)	2003
Direction Offshore [n,s,e,w]	South
Historic Trend (mm/yr)	2.82
MTL-NAVD88 (m)	-0.13
GT Great Diurnal Tide Range (m)	0.2
Salt Elev. (m above MTL)	0.4
Marsh Erosion (horz. m /yr)	1.8
Swamp Erosion (horz. m /yr)	1
T.Flat Erosion (horz. m /yr)	0.5
Reg. Flood Marsh Accr (mm/yr)	3.7
Irreg. Flood Marsh Accr (mm/yr)	3.7
Tidal Fresh Marsh Accr (mm/yr)	5.9
Beach Sed. Rate (mm/yr)	0.5
Freq. Overwash (years)	11
Use Elev Pre-processor [True,False]	FALSE

Results

Mackay Island NWR is predicted by SLAMM to be vulnerable to the impacts of SLR, particularly under the higher scenarios. Between 14% and 87% of refuge irregularly flooded marsh, which makes up roughly half of the refuge, is predicted to be lost across all SLR scenarios.

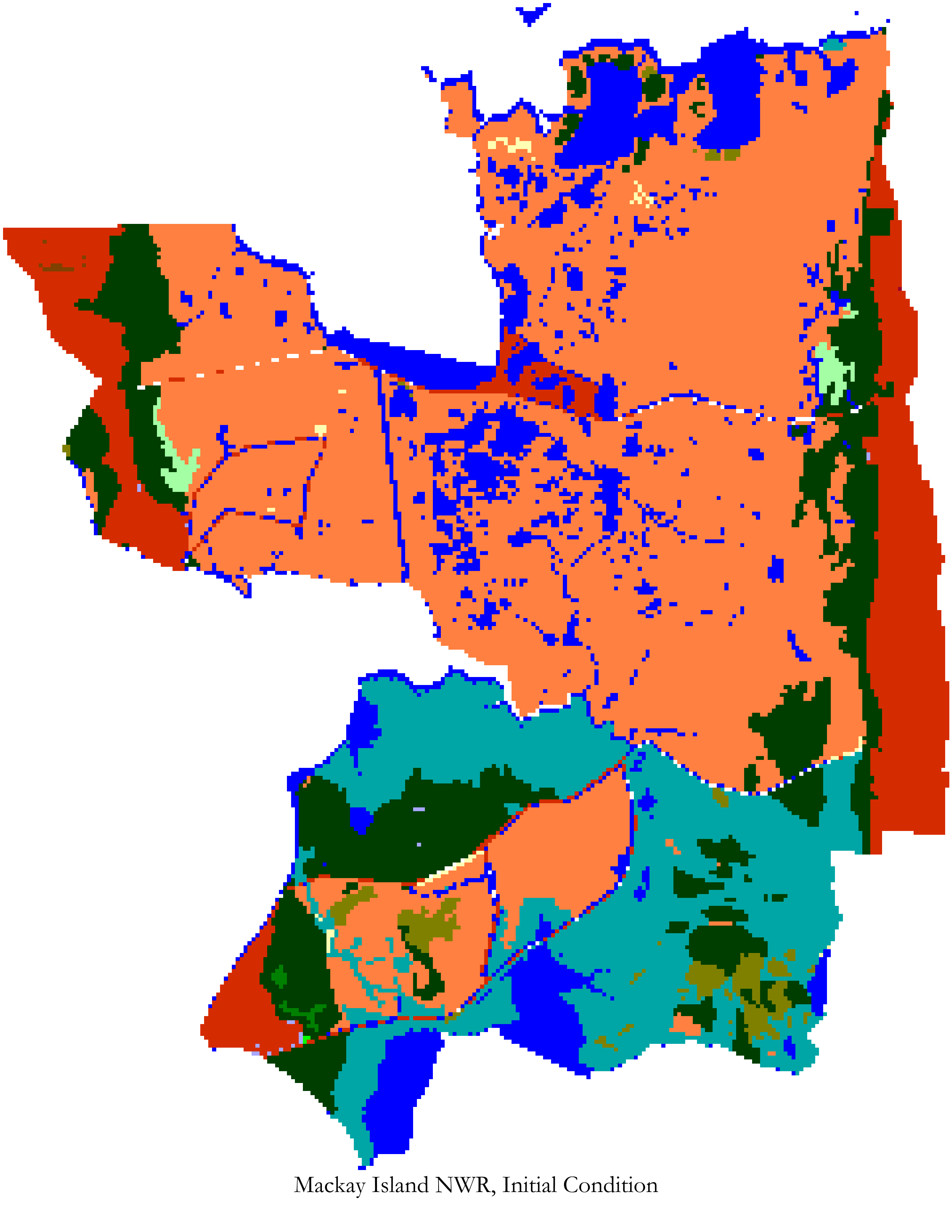
SLR by 2100 (m)	0.39	0.69	1	1.5	2
Irregularly Flooded Marsh	14%	53%	76%	86%	87%
Regularly Flooded Marsh	-71%	-21%	11%	57%	76%
Tidal Swamp	66%	74%	77%	80%	81%
Undeveloped Dry Land	14%	18%	24%	31%	39%

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

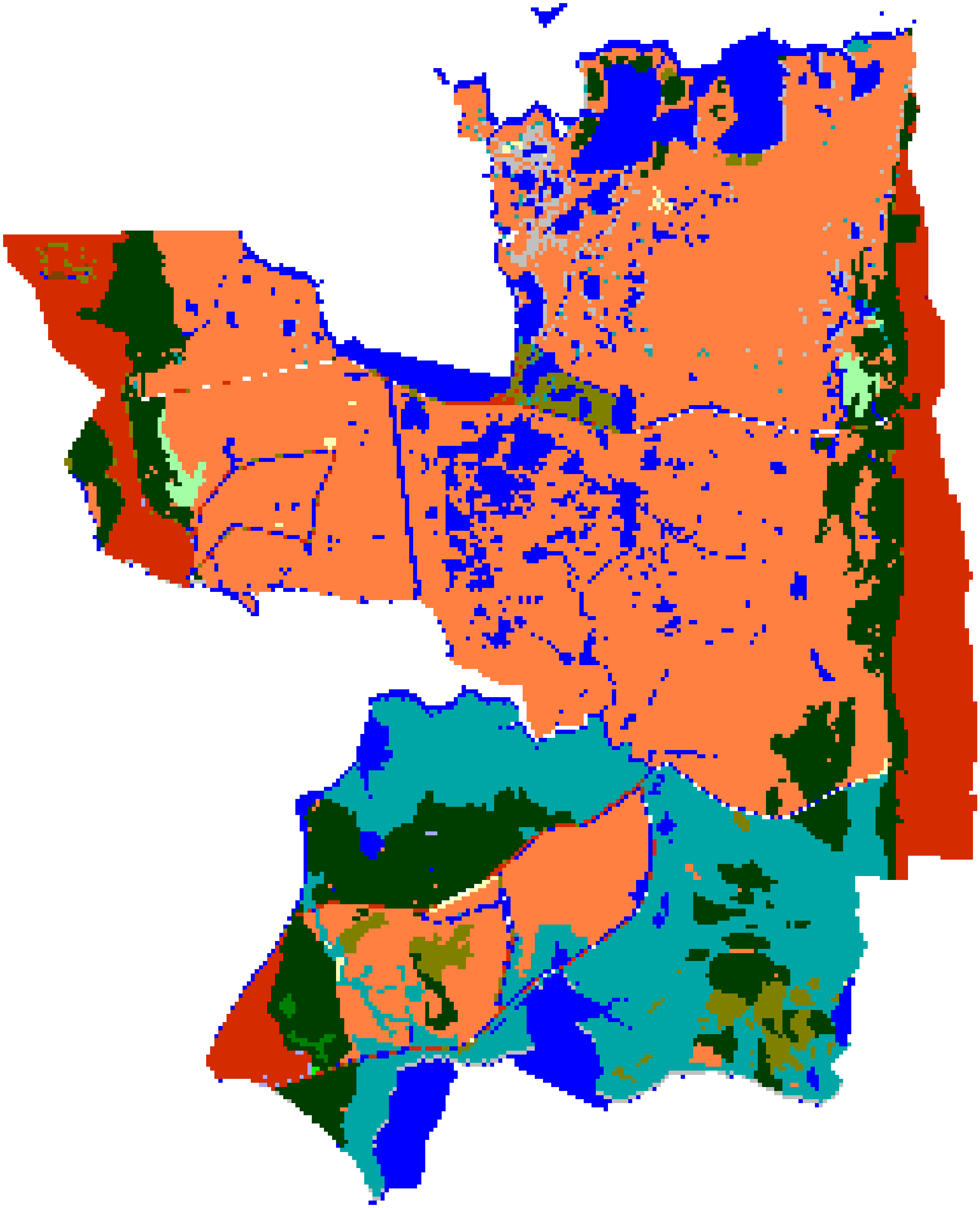
Mackay Island NWR
IPCC Scenario A1B-Mean, 0.39 M SLR Eustatic by 2100

Results in Acres

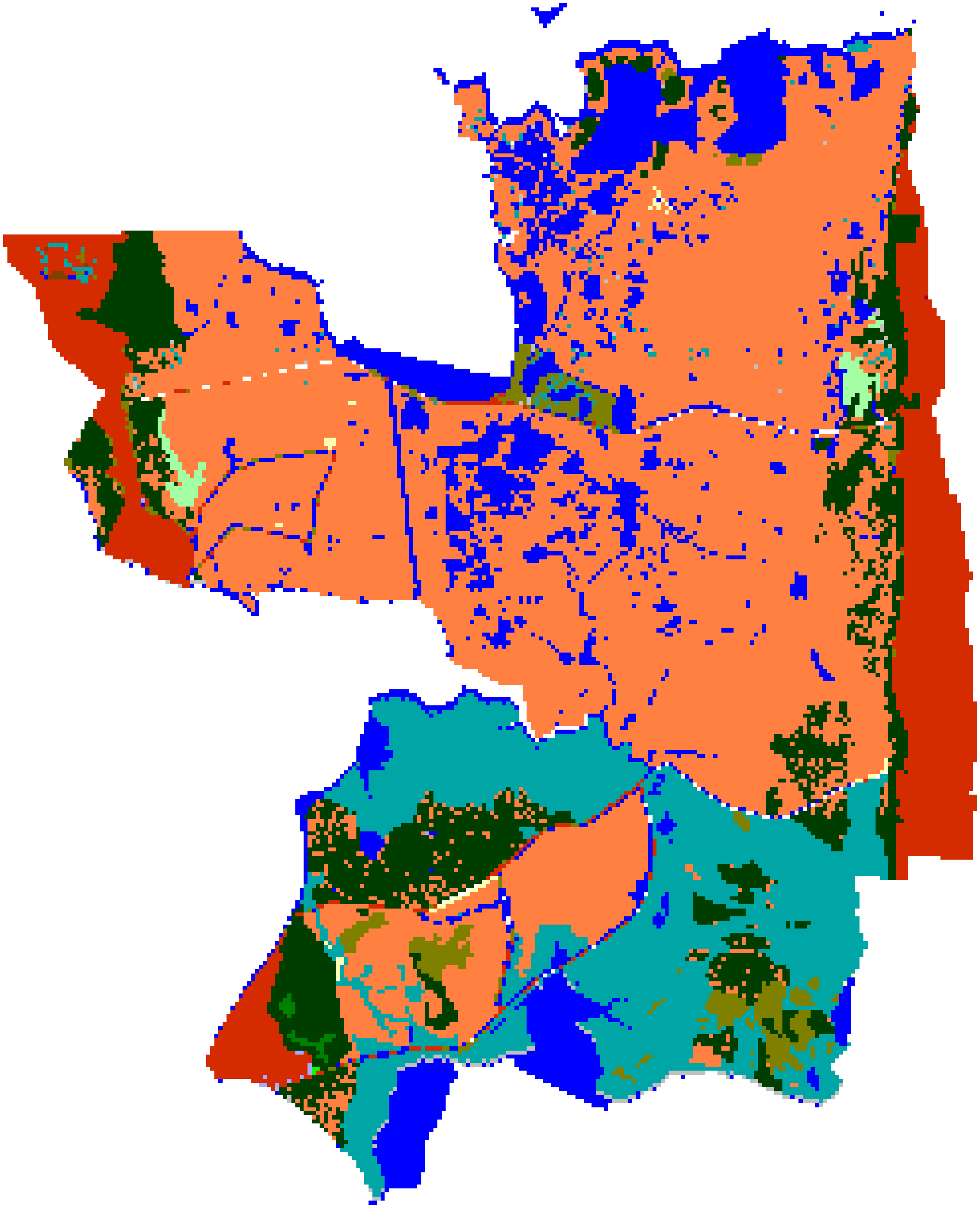
		Initial	2025	2050	2075	2100
	Irregularly Flooded Marsh	4278.9	4230.4	4420.1	4396.3	3687.9
	Regularly Flooded Marsh	1242.3	1266.6	1285.3	1617.2	2143.3
	Tidal Swamp	1185.4	1107.5	889.5	552.6	390.4
	Estuarine Open Water	1180.5	1191.0	1286.1	1335.5	1409.3
	Undeveloped Dry Land	941.6	918.3	895.1	872.2	853.9
	Transitional Salt Marsh	115.4	132.2	138.6	137.0	127.6
	Tidal Fresh Marsh	38.9	34.6	34.6	34.6	34.6
	Estuarine Beach	18.7	15.4	13.9	8.2	4.6
	Swamp	9.1	9.1	9.1	9.1	9.1
	Inland Open Water	4.4	4.4	4.2	2.9	2.9
	Inland Shore	3.3	2.2	2.2	2.2	2.1
	Inland Fresh Marsh	0.7	0.7	0.7	0.7	0.7
	Developed Dry Land	0.2	0.2	0.2	0.2	0.2
	Tidal Flat	0.0	106.6	39.8	50.7	352.9
	Total (incl. water)	**9019.4**	**9019.4**	**9019.4**	**9019.4**	**9019.4**



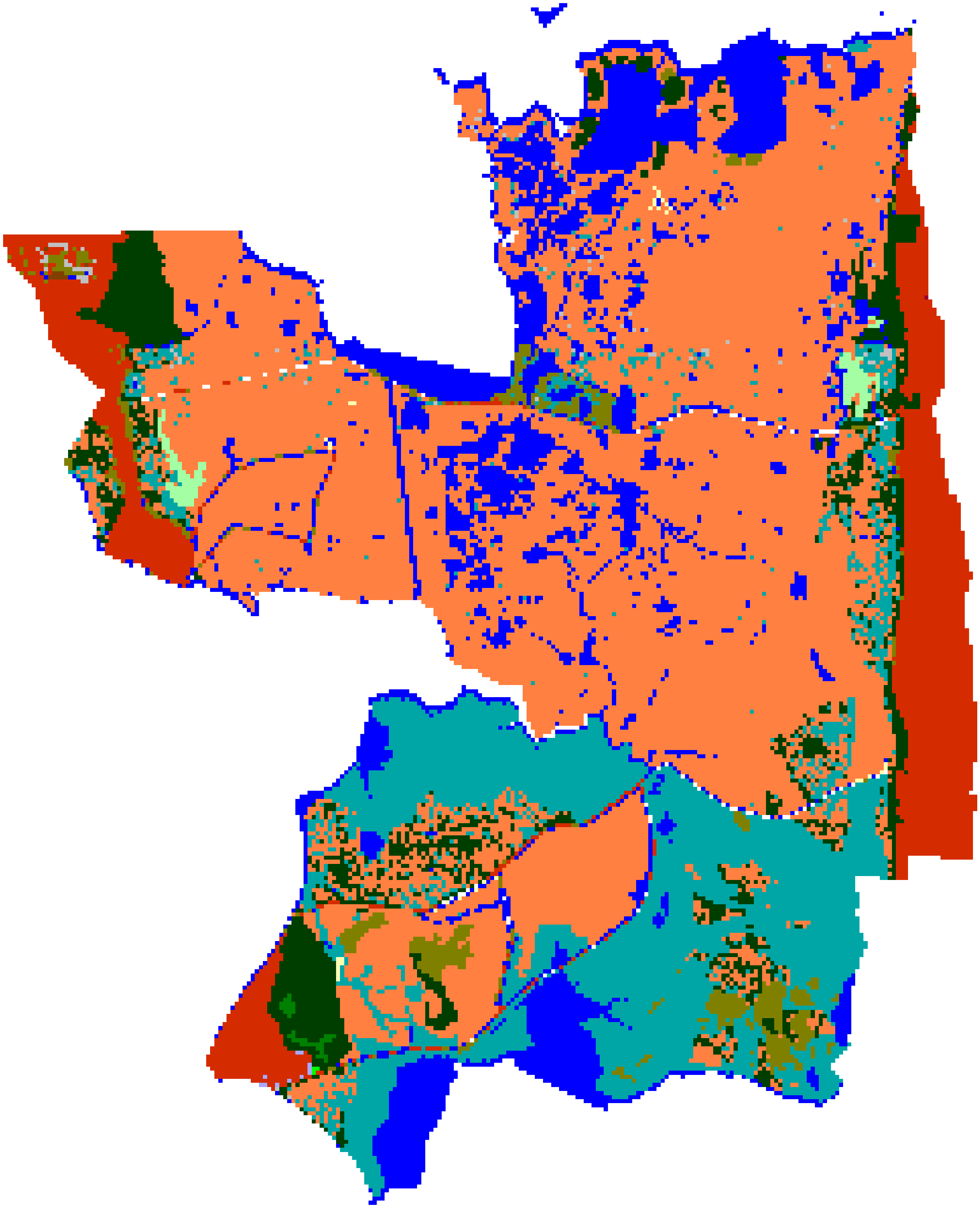
Mackay Island NWR, Initial Condition



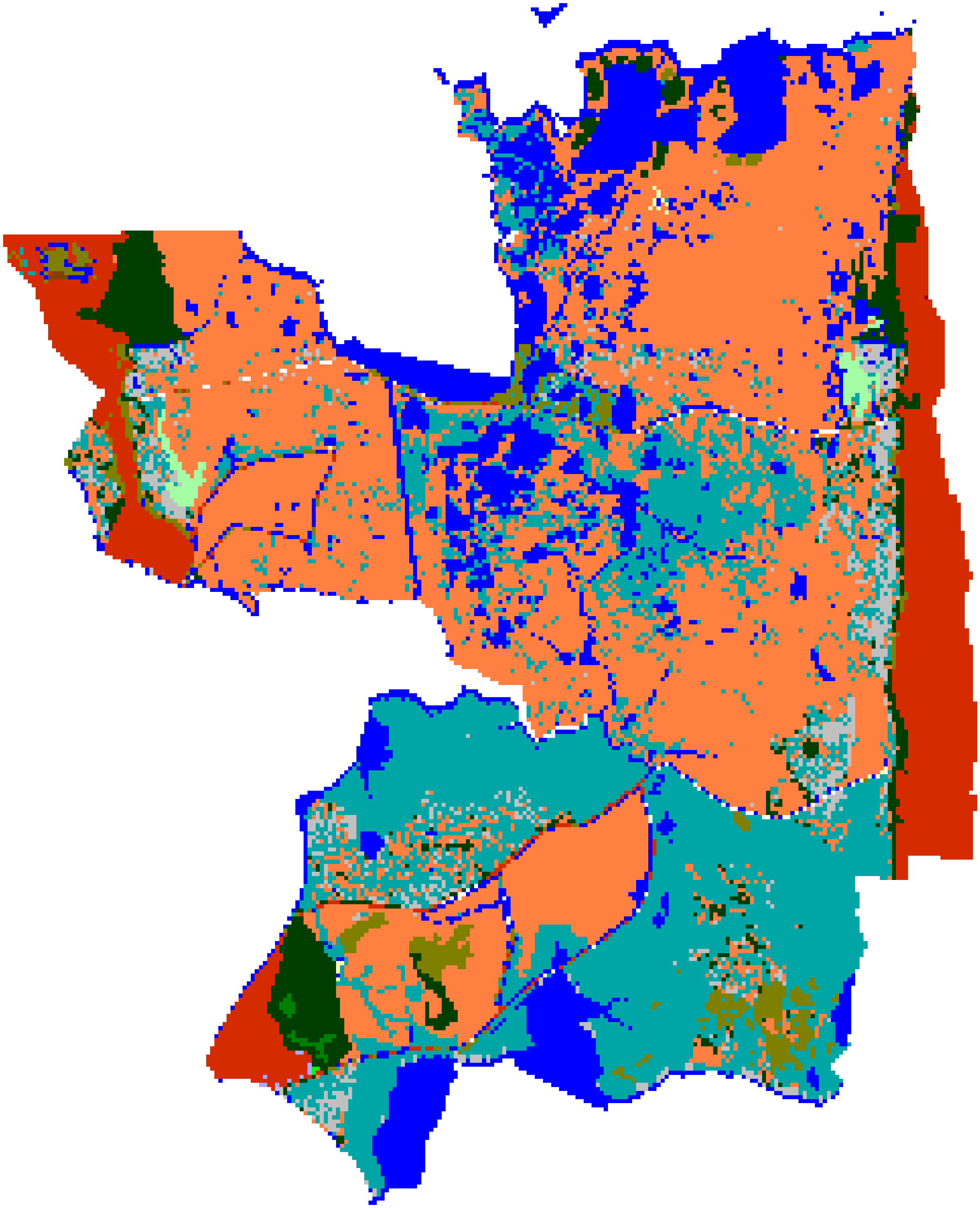
Mackay Island NWR, 2025, Scenario A1B Mean



Mackay Island NWR, 2050, Scenario A1B Mean



Mackay Island NWR, 2075, Scenario A1B Mean

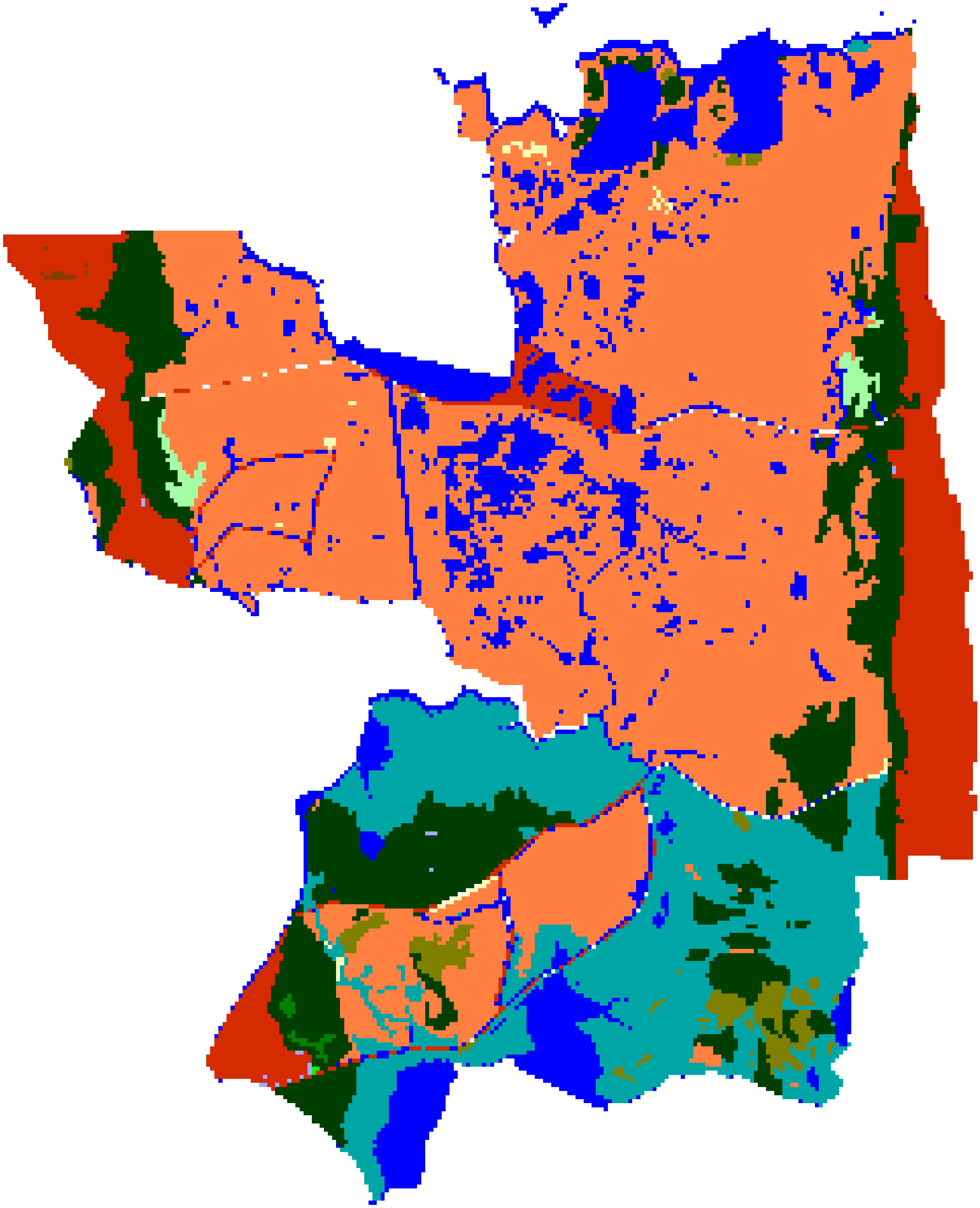


Mackay Island NWR, 2100, Scenario A1B Mean

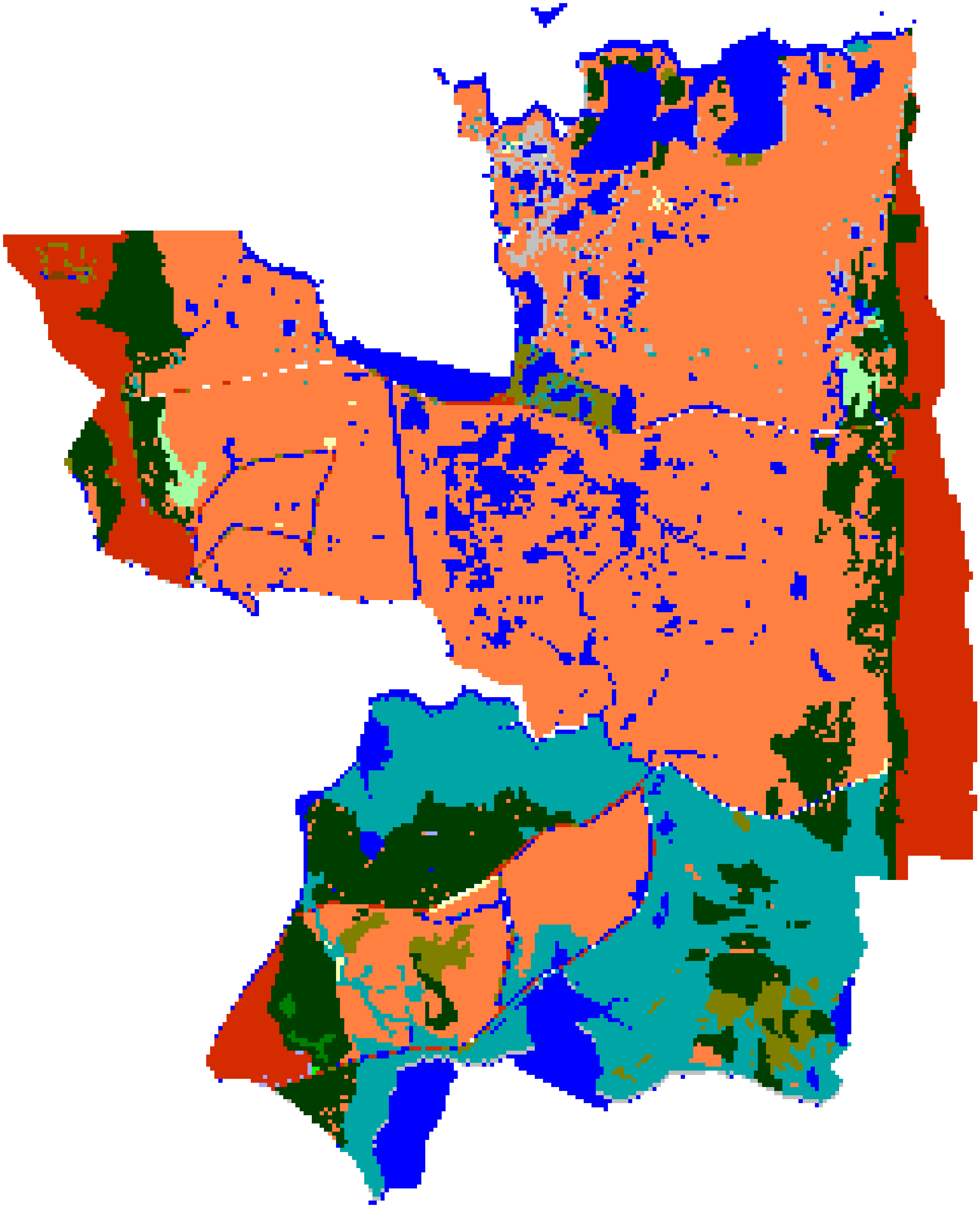
Mackay Island NWR
IPCC Scenario A1B-Max, 0.69 M SLR Eustatic by 2100

Results in Acres

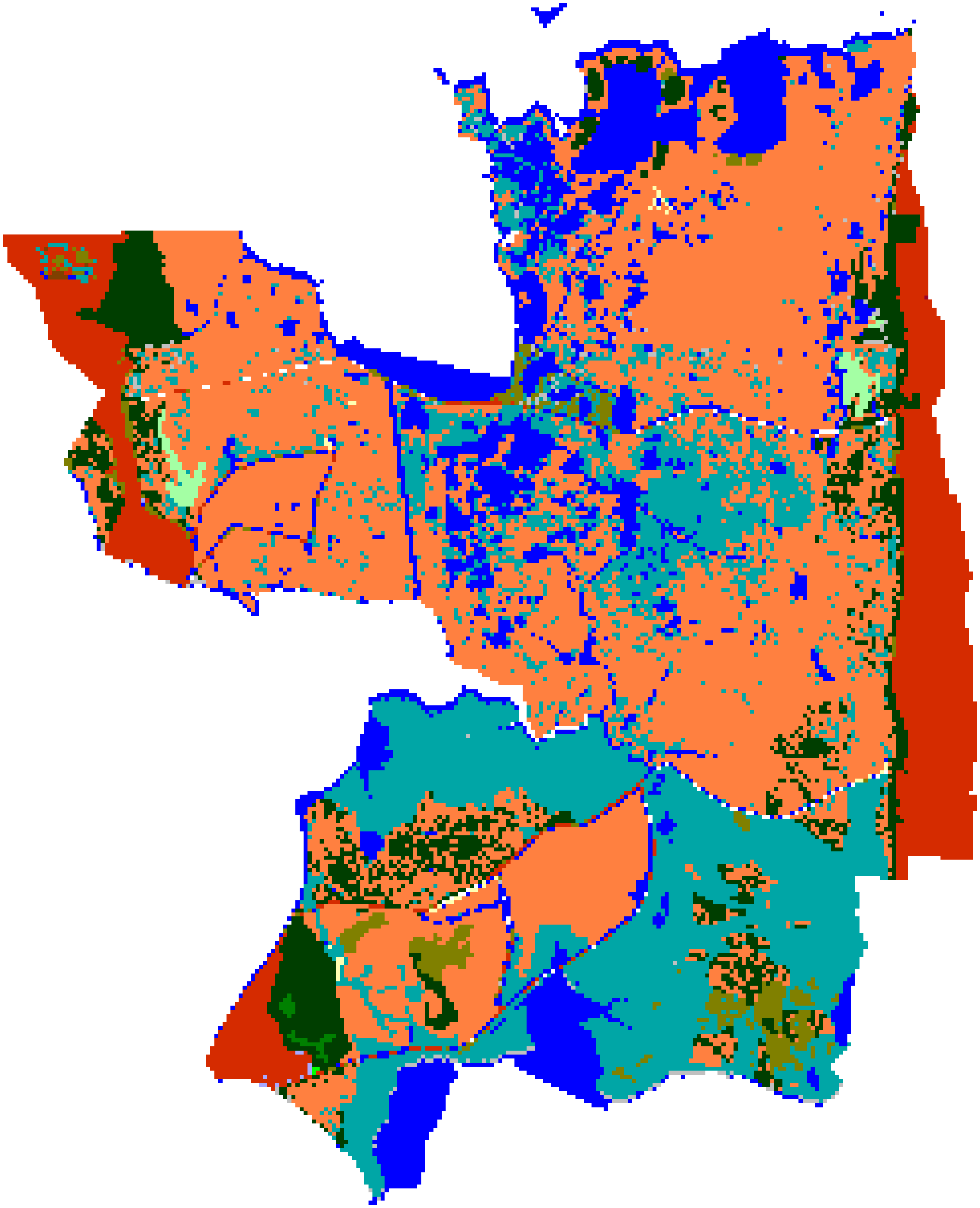
		Initial	2025	2050	2075	2100
	Irregularly Flooded Marsh	4278.9	4255.3	3948.5	2928.1	1997.6
	Regularly Flooded Marsh	1242.3	1279.5	1987.8	2189.0	1448.9
	Tidal Swamp	1185.4	1061.2	608.6	353.2	306.1
	Estuarine Open Water	1180.5	1192.2	1309.2	1453.4	2606.3
	Undeveloped Dry Land	941.6	913.1	879.5	848.6	816.5
	Transitional Salt Marsh	115.4	135.2	143.4	105.4	85.8
	Tidal Fresh Marsh	38.9	34.6	32.8	23.5	12.7
	Estuarine Beach	18.7	15.2	9.7	3.9	1.8
	Swamp	9.1	9.1	9.1	9.1	9.1
	Inland Open Water	4.4	4.2	2.9	2.7	2.7
	Inland Shore	3.3	2.2	2.2	2.1	1.8
	Inland Fresh Marsh	0.7	0.7	0.7	0.7	0.7
	Developed Dry Land	0.2	0.2	0.2	0.2	0.2
	Tidal Flat	0.0	116.5	84.8	1099.6	1729.2
	Total (incl. water)	**9019.4**	**9019.4**	**9019.4**	**9019.4**	**9019.4**



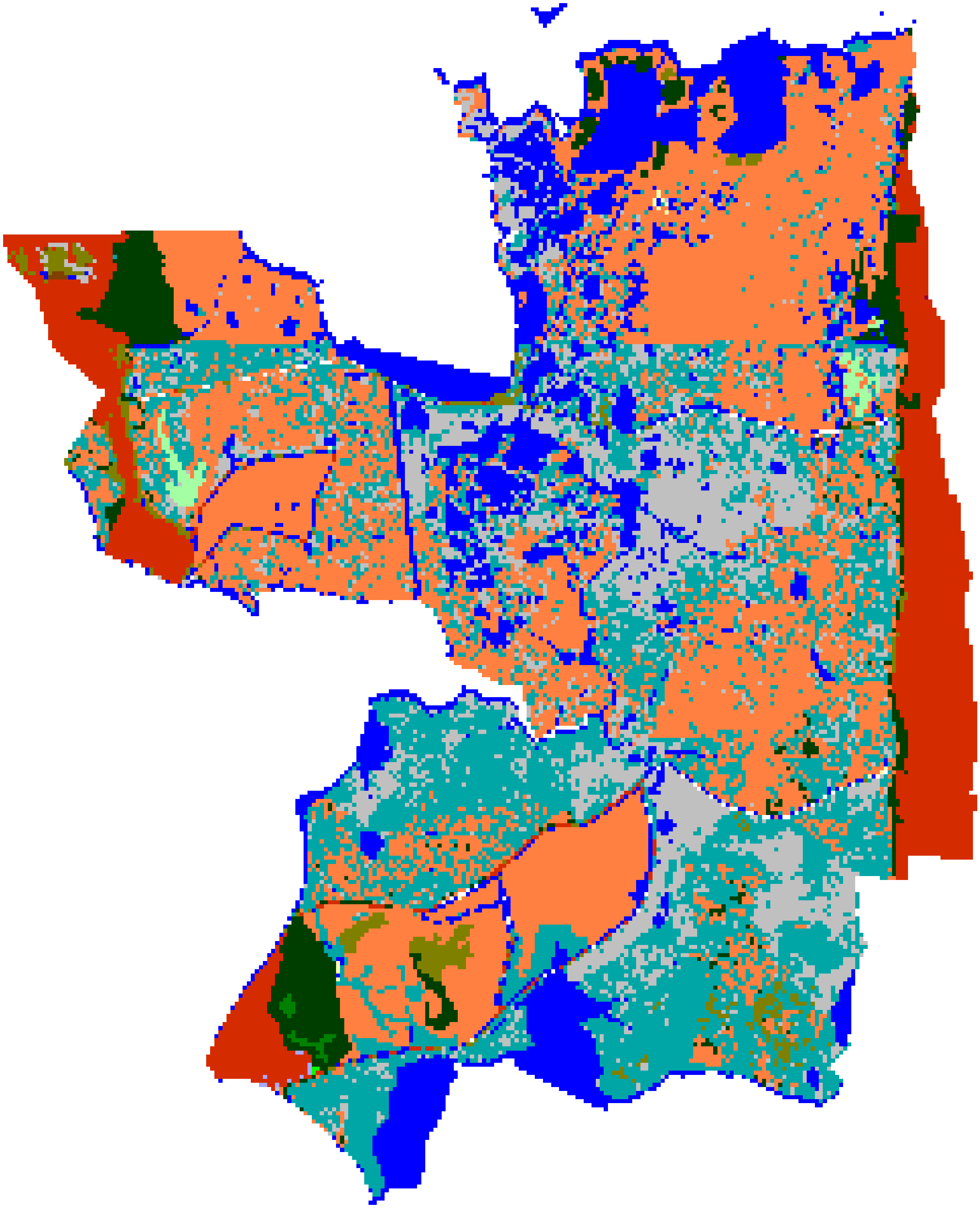
Mackay Island NWR, Initial Condition



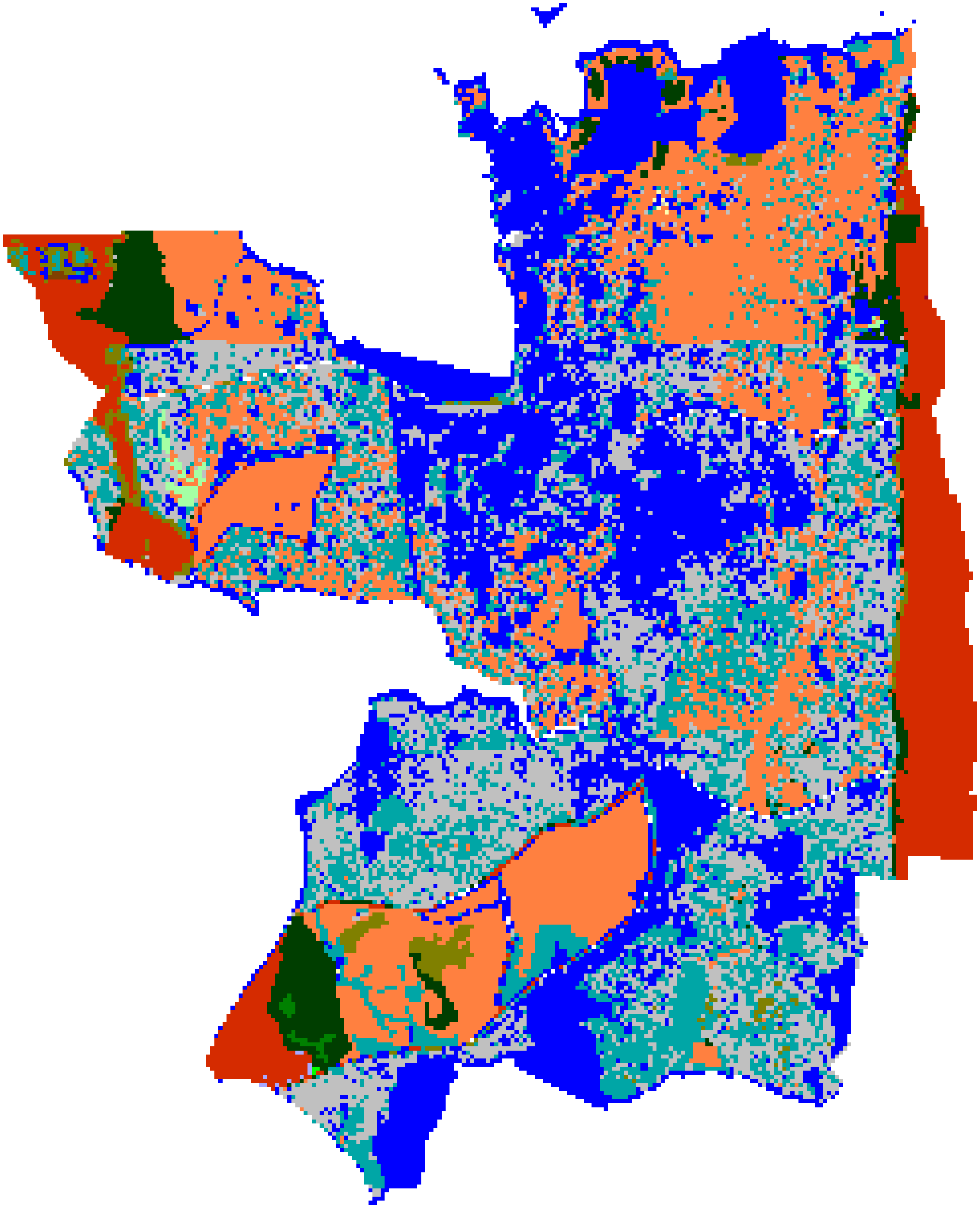
Mackay Island NWR, 2025, Scenario A1B Maximum



Mackay Island NWR, 2050, Scenario A1B Maximum



Mackay Island NWR, 2075, Scenario A1B Maximum

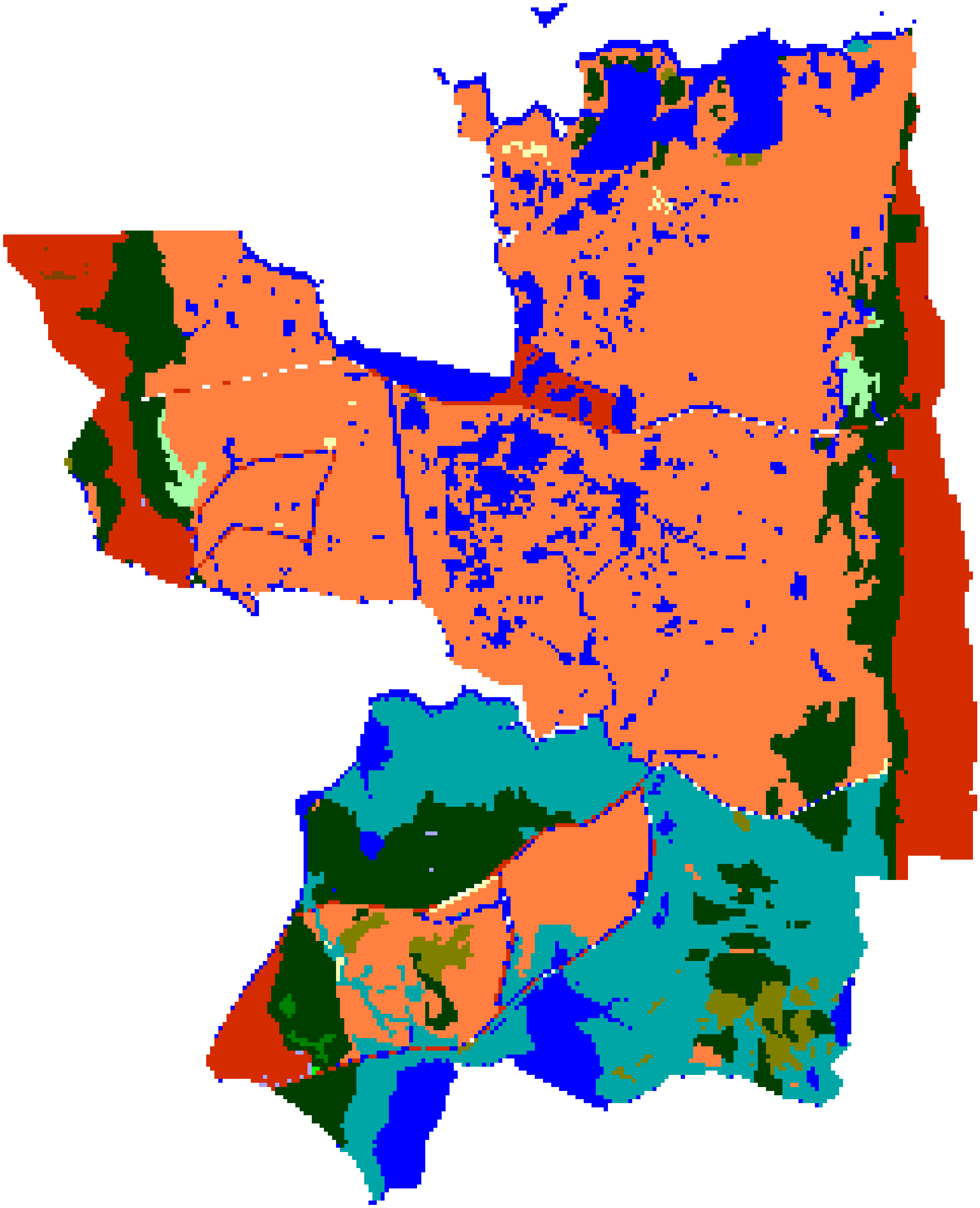


Mackay Island NWR, 2100, Scenario A1B Maximum

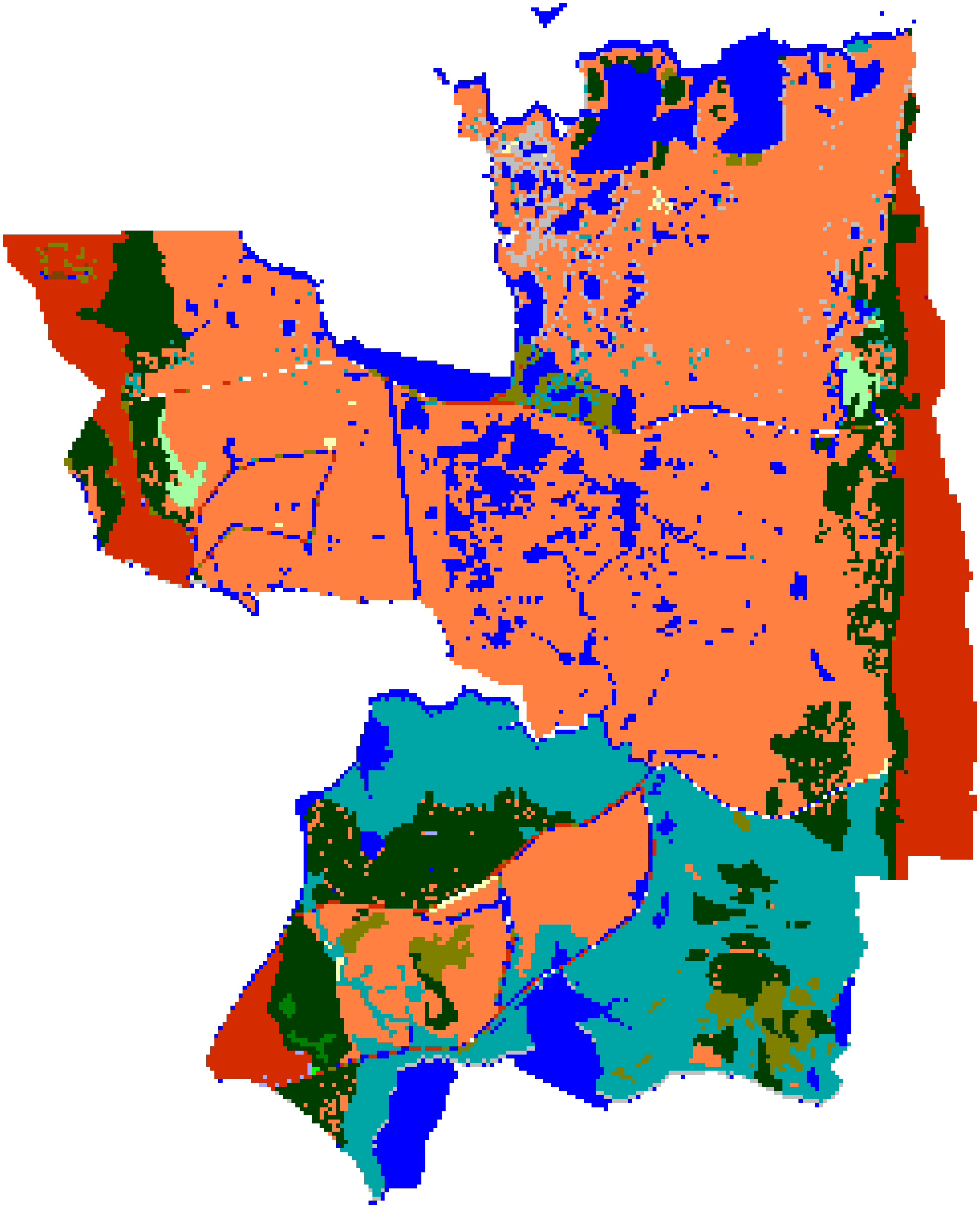
Mackay Island NWR
1 Meter Eustatic SLR by 2100

Results in Acres

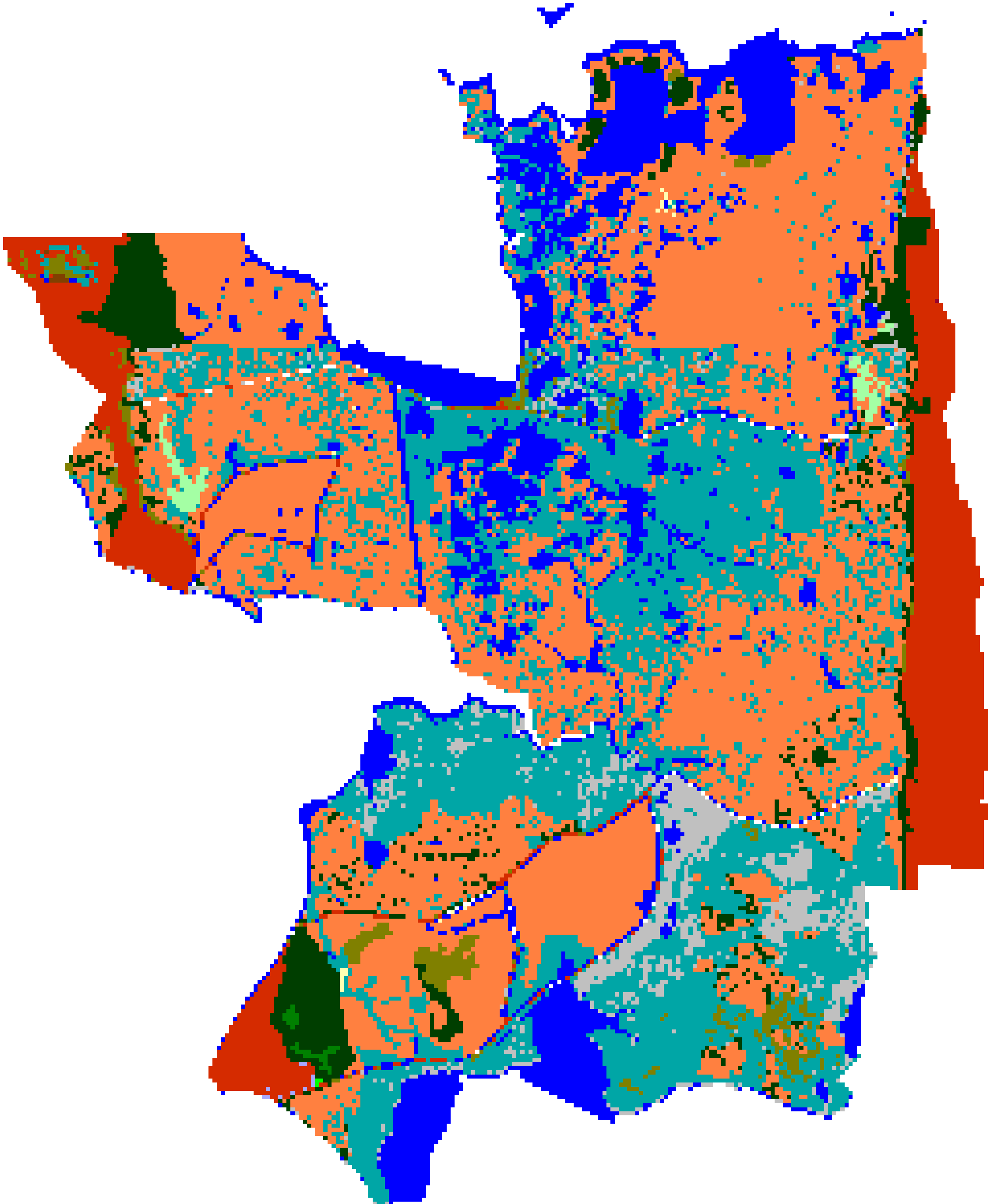
		Initial	2025	2050	2075	2100
	Irregularly Flooded Marsh	4278.9	4260.5	3481.1	1895.5	1029.4
	Regularly Flooded Marsh	1242.3	1319.9	2371.1	2131.8	1076.4
	Tidal Swamp	1185.4	1000.3	422.8	312.2	270.5
	Estuarine Open Water	1180.5	1194.3	1341.3	1785.3	3794.3
	Undeveloped Dry Land	941.6	907.8	864.5	823.8	779.7
	Transitional Salt Marsh	115.4	140.3	128.2	91.1	84.2
	Tidal Fresh Marsh	38.9	33.9	21.4	6.0	2.2
	Estuarine Beach	18.7	14.7	6.4	1.9	0.6
	Swamp	9.1	9.1	9.1	9.1	9.1
	Inland Open Water	4.4	4.2	2.9	2.4	2.4
	Inland Shore	3.3	2.2	2.2	1.9	0.7
	Inland Fresh Marsh	0.7	0.7	0.7	0.7	0.7
	Developed Dry Land	0.2	0.2	0.2	0.2	0.2
	Tidal Flat	0.0	131.3	367.6	1957.4	1969.0
	Total (incl. water)	**9019.4**	**9019.4**	**9019.4**	**9019.4**	**9019.4**



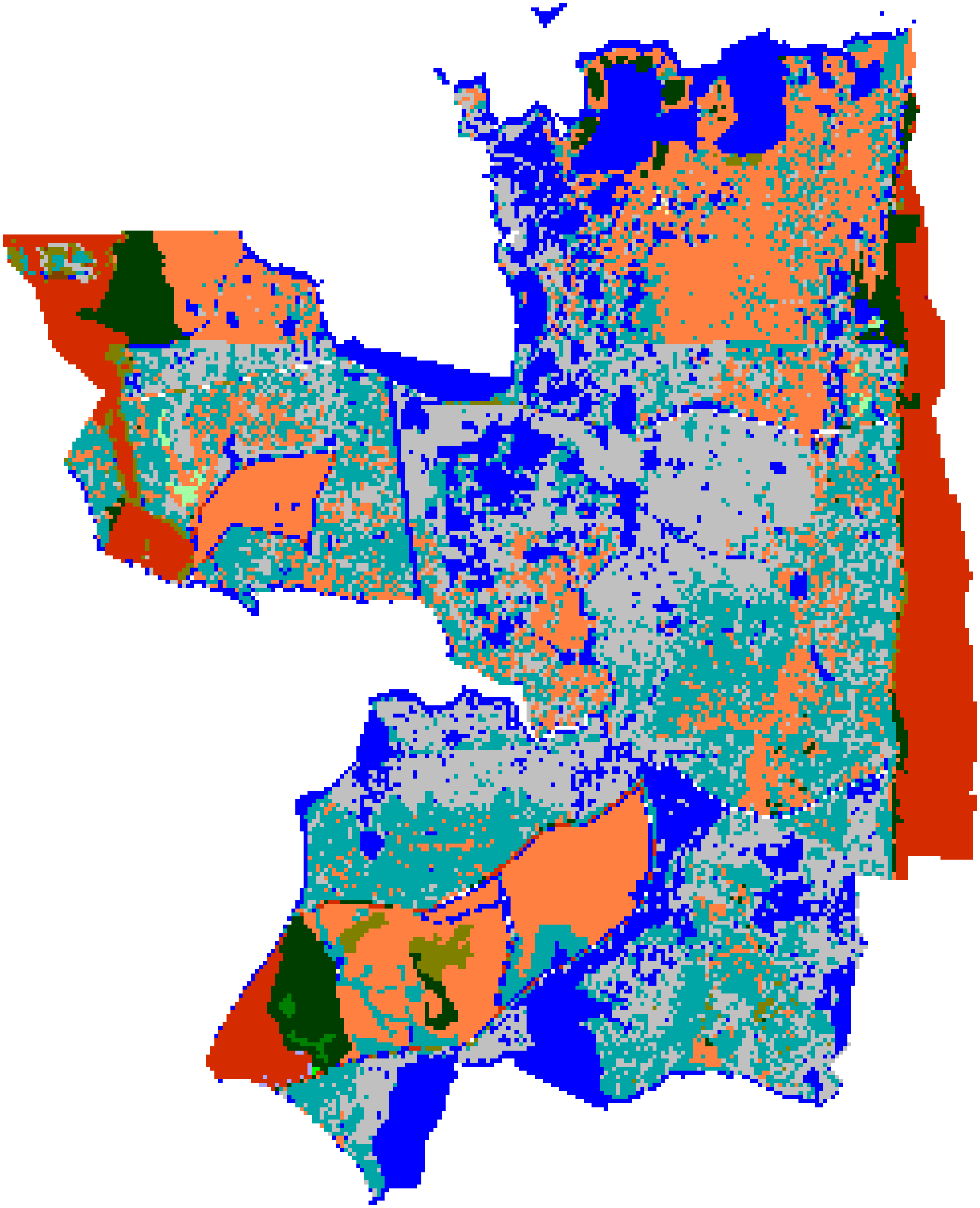
Mackay Island NWR, Initial Condition



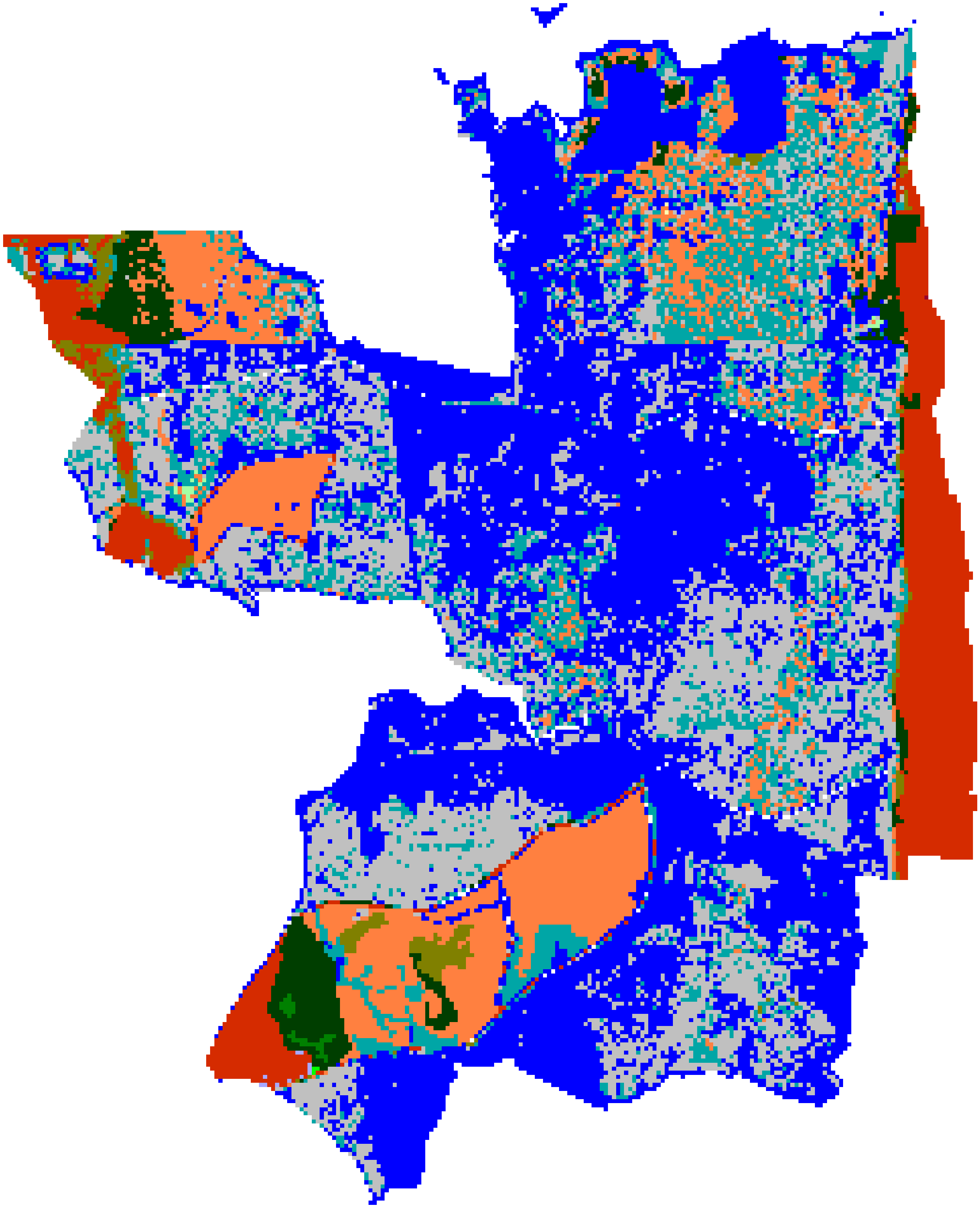
Mackay Island NWR, 2025, 1 meter



Mackay Island NWR, 2050, 1 meter



Mackay Island NWR, 2075, 1 meter

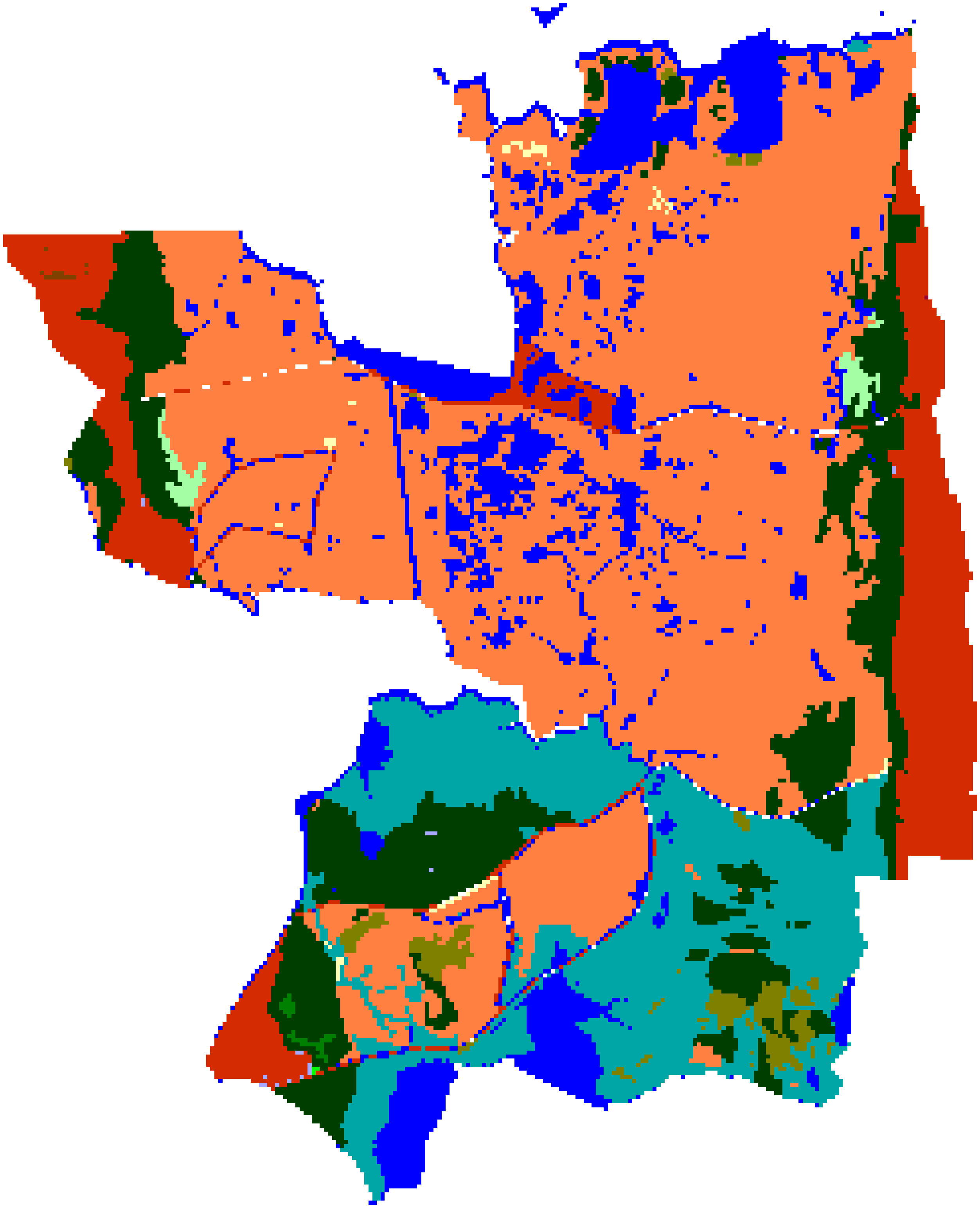


Mackay Island NWR, 2100, 1 meter

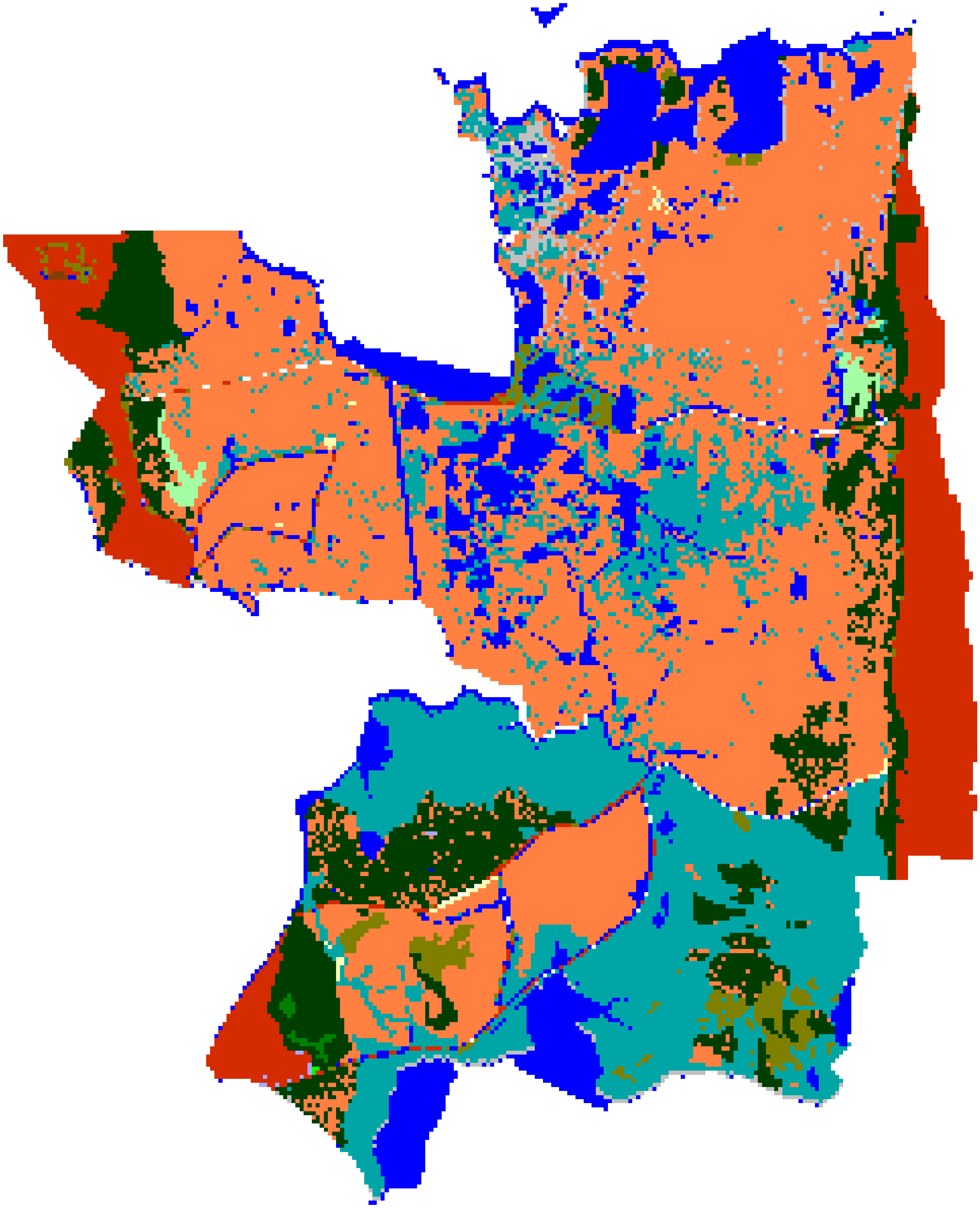
Mackay Island NWR
1.5 Meters Eustatic SLR by 2100

Results in Acres

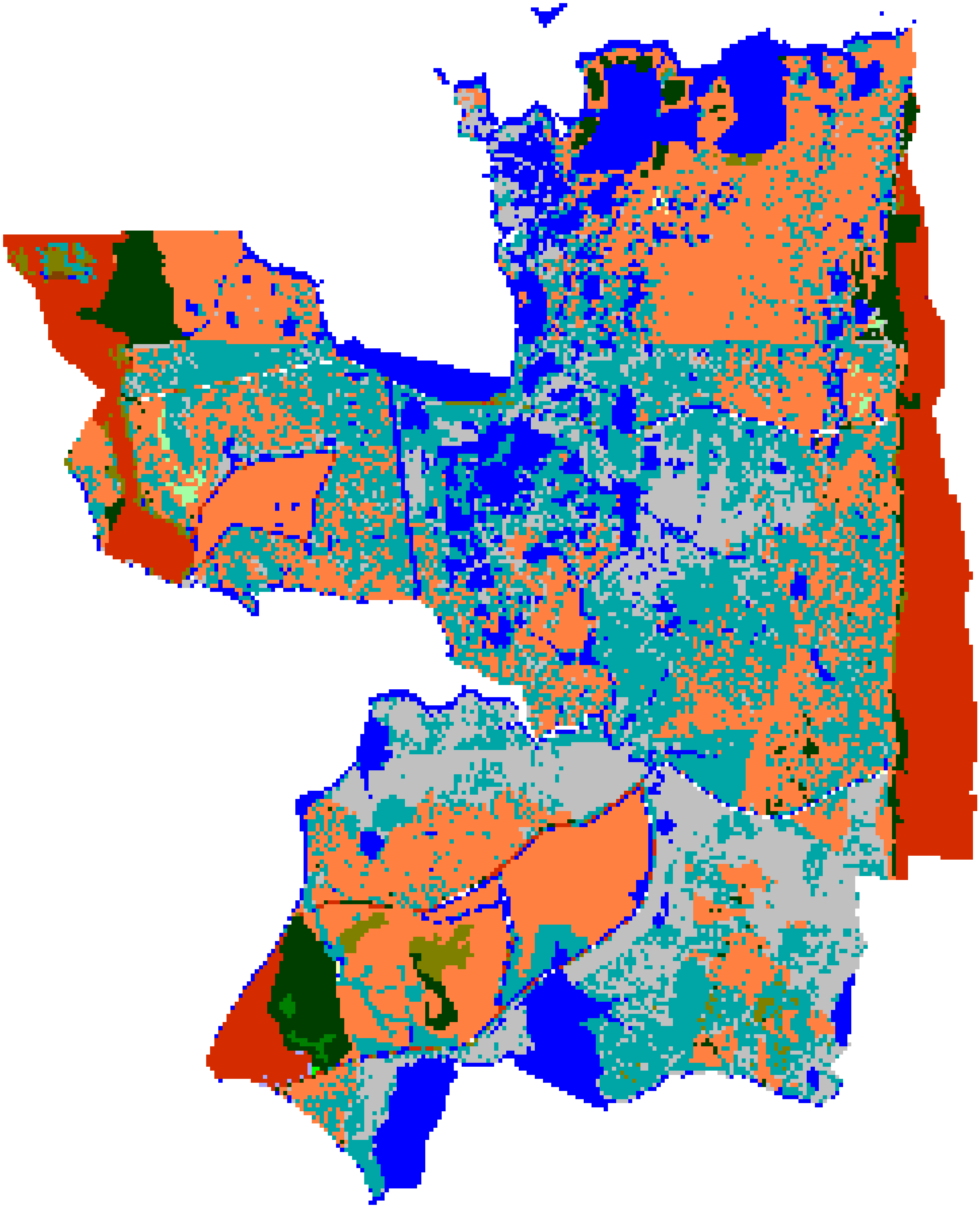
		Initial	2025	2050	2075	2100
	Irregularly Flooded Marsh	4278.9	3949.8	2623.6	915.9	589.1
	Regularly Flooded Marsh	1242.3	1756.1	2452.2	1947.2	504.8
	Tidal Swamp	1185.4	871.4	336.6	273.2	240.7
	Estuarine Open Water	1180.5	1196.9	1387.0	2704.9	5033.5
	Undeveloped Dry Land	941.6	898.8	845.6	784.3	693.5
	Transitional Salt Marsh	115.4	146.3	110.2	101.5	127.2
	Tidal Fresh Marsh	38.9	28.9	6.5	1.2	0.7
	Estuarine Beach	18.7	14.0	3.4	0.6	0.0
	Swamp	9.1	9.1	9.1	9.1	9.1
	Inland Open Water	4.4	4.2	2.7	2.4	2.4
	Inland Shore	3.3	2.2	2.1	0.7	0.0
	Inland Fresh Marsh	0.7	0.7	0.7	0.7	0.7
	Developed Dry Land	0.2	0.2	0.2	0.2	0.2
	Tidal Flat	0.0	140.8	1239.7	2277.5	1817.4
	Total (incl. water)	**9019.4**	**9019.4**	**9019.4**	**9019.4**	**9019.4**



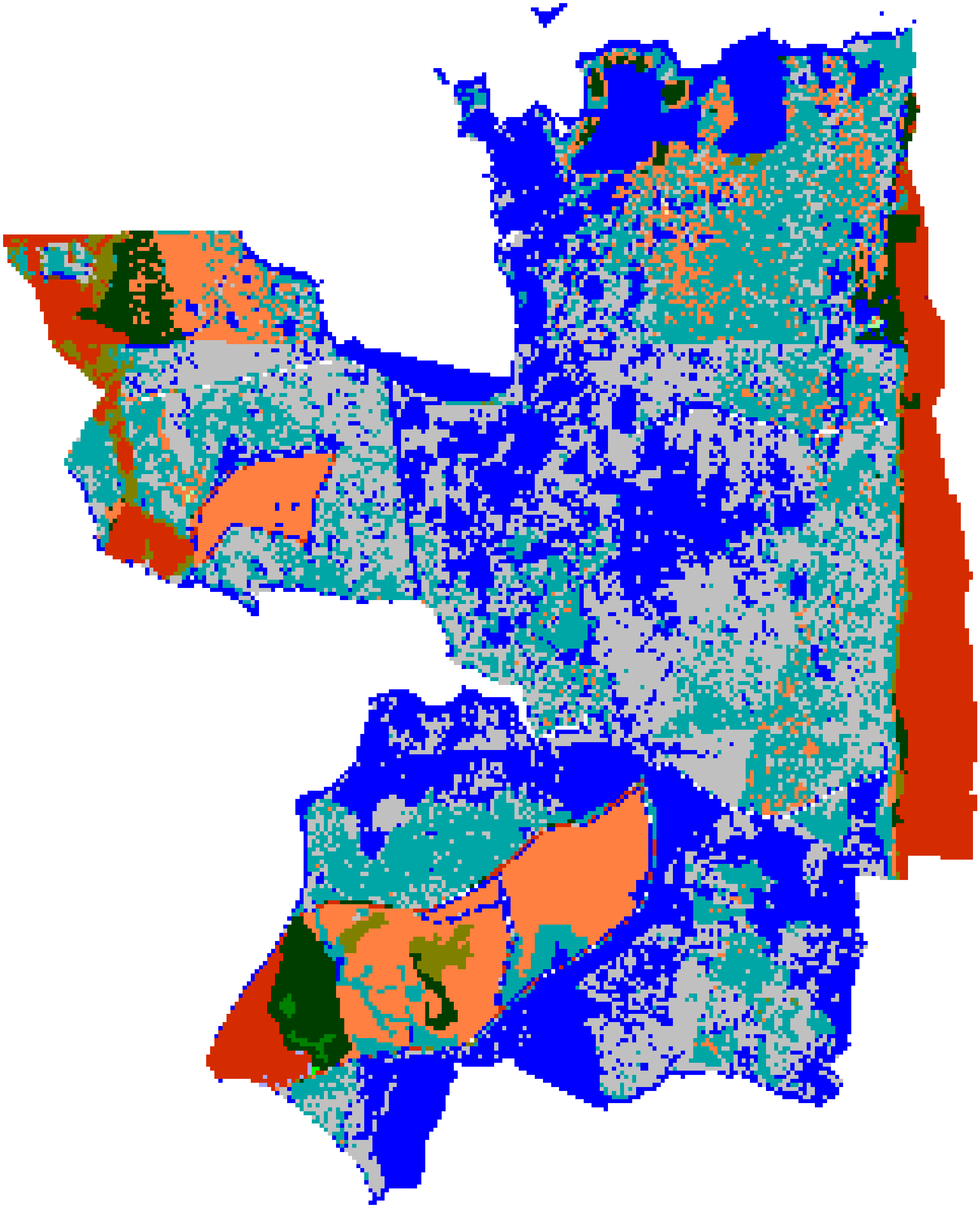
Mackay Island NWR, Initial Condition



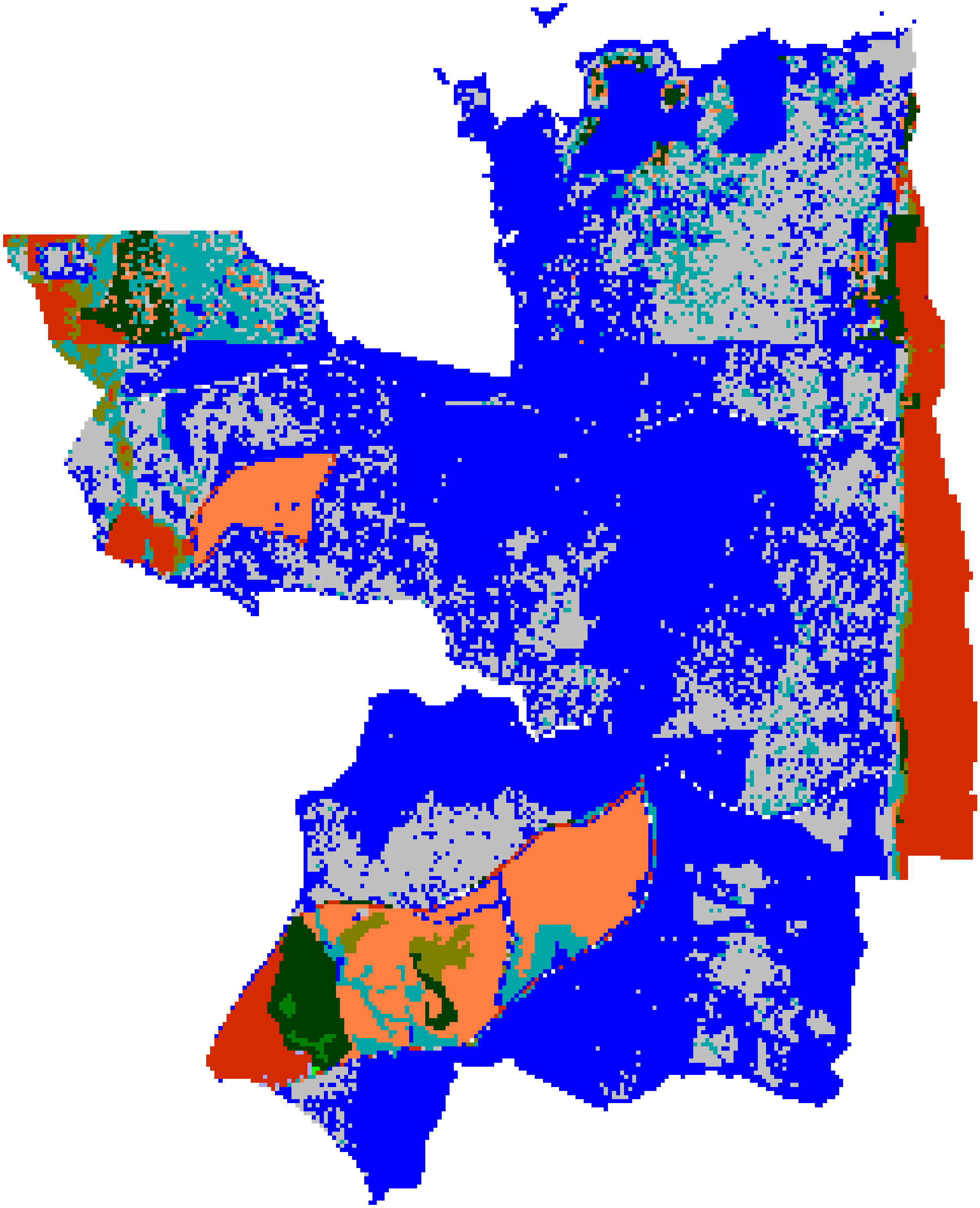
Mackay Island NWR, 2025, 1.5 meter



Mackay Island NWR, 2050, 1.5 meter



Mackay Island NWR, 2075, 1.5 meter

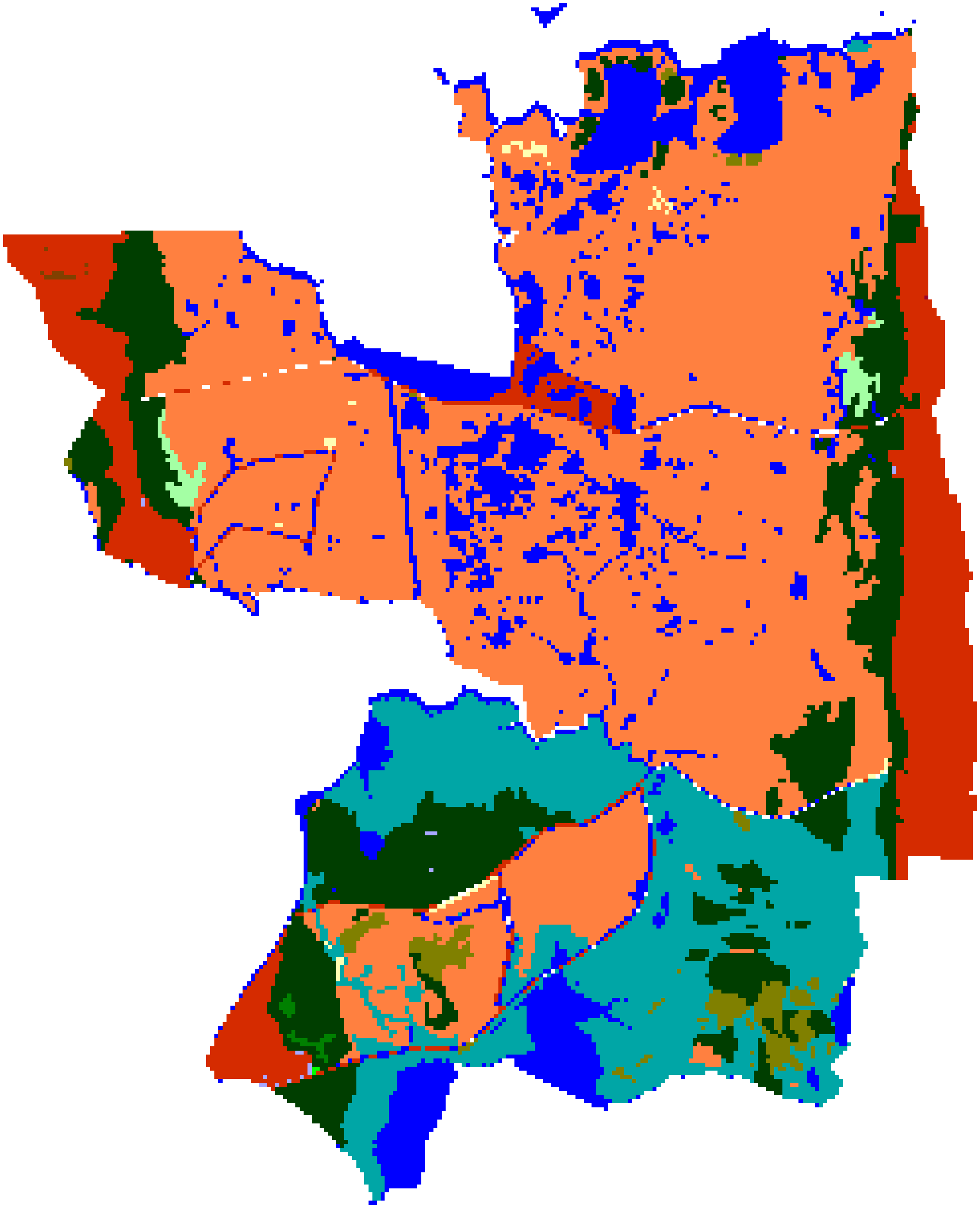


Mackay Island NWR, 2100, 1.5 meter

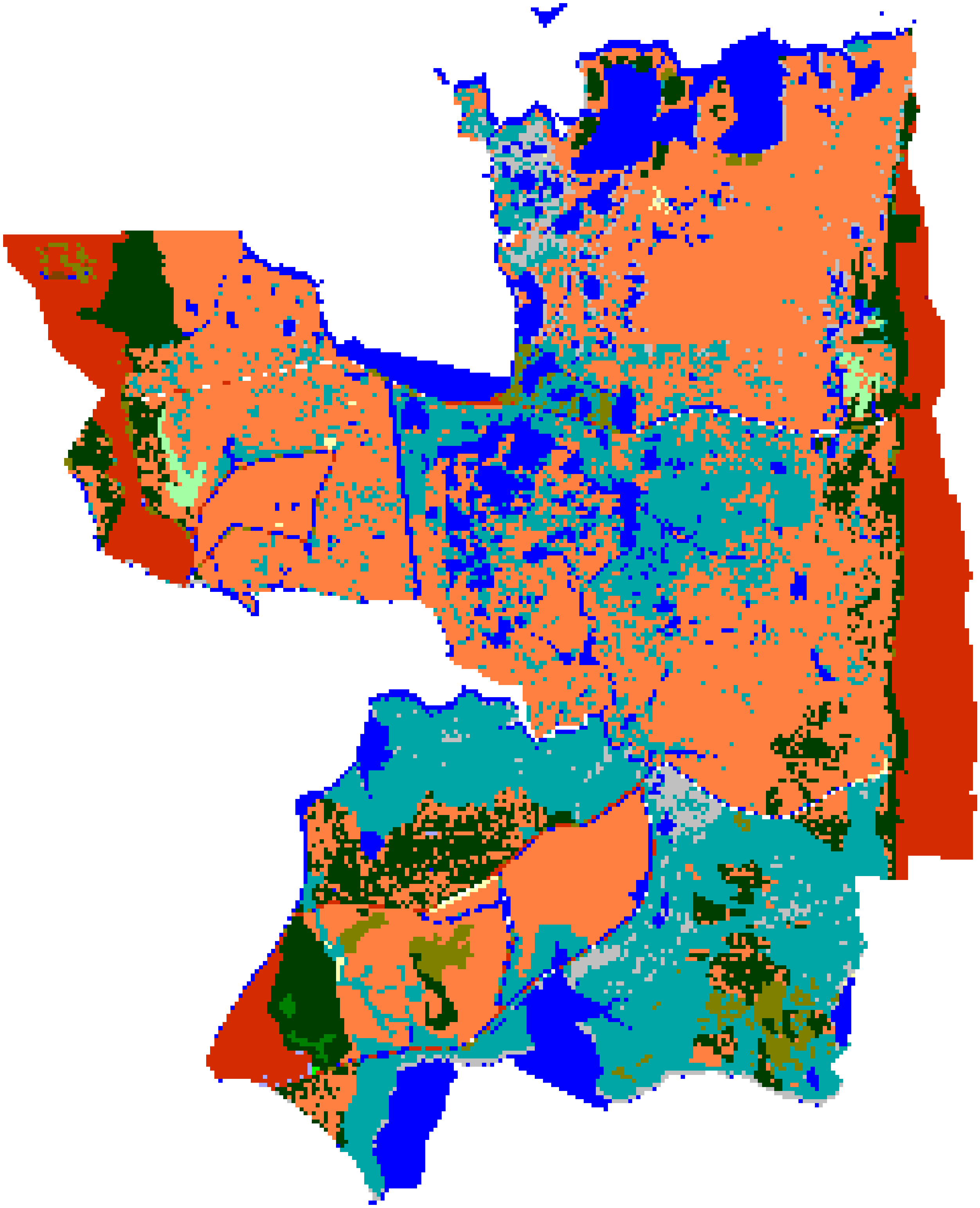
Mackay Island NWR
2 Meters Eustatic SLR by 2100

Results in Acres

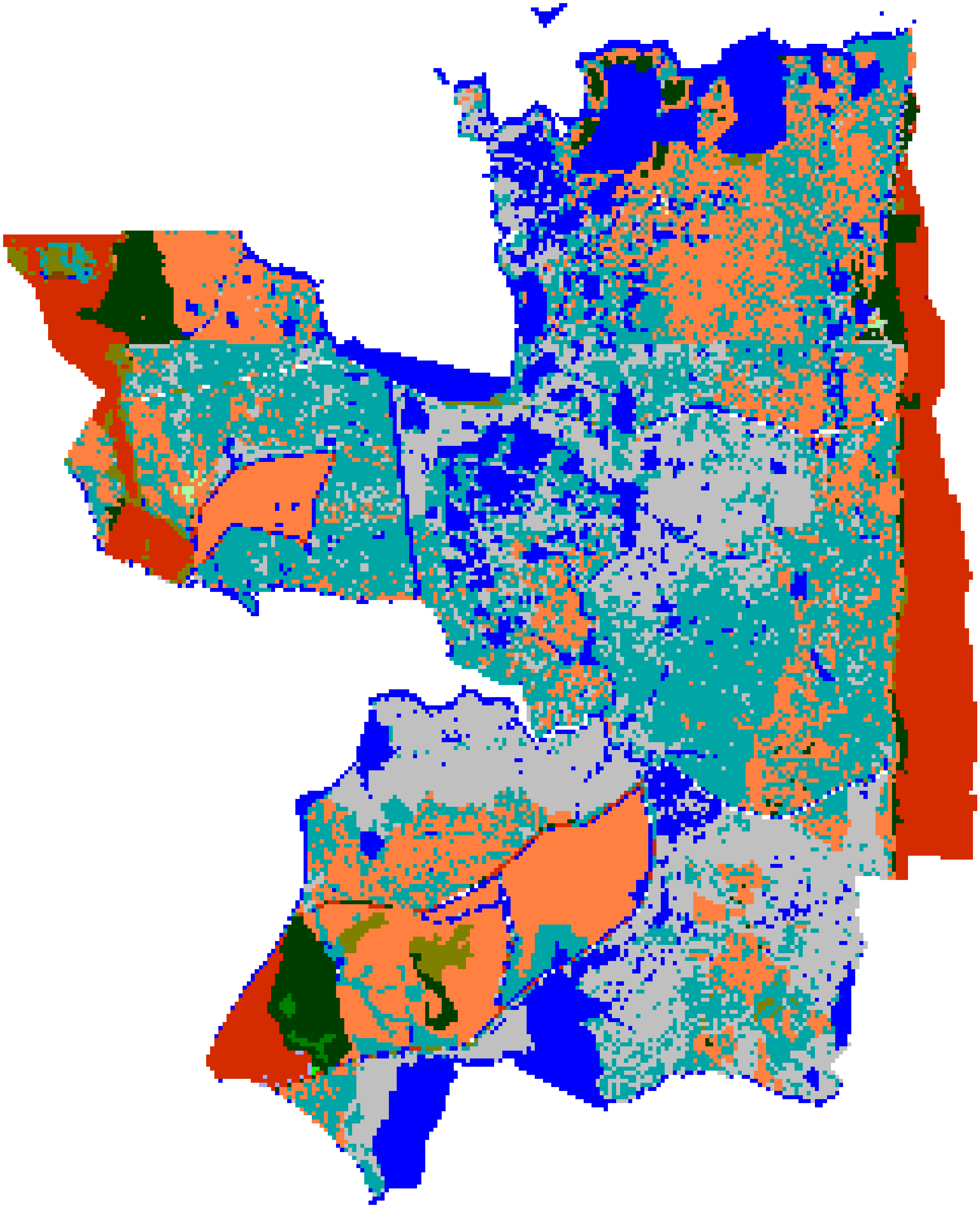
		Initial	2025	2050	2075	2100
	Irregularly Flooded Marsh	4278.9	3753.0	1870.7	637.1	565.6
	Regularly Flooded Marsh	1242.3	2025.0	2650.0	1448.1	280.7
	Tidal Swamp	1185.4	728.8	308.7	252.6	222.6
	Estuarine Open Water	1180.5	1199.6	1485.1	3303.3	5850.0
	Undeveloped Dry Land	941.6	889.6	824.0	725.8	628.4
	Transitional Salt Marsh	115.4	148.2	111.6	135.0	134.9
	Tidal Fresh Marsh	38.9	23.6	3.1	0.8	0.7
	Estuarine Beach	18.7	13.4	1.9	0.0	0.0
	Swamp	9.1	9.1	9.1	9.1	9.1
	Inland Open Water	4.4	4.0	2.4	2.4	2.4
	Inland Shore	3.3	2.2	1.9	0.2	0.0
	Inland Fresh Marsh	0.7	0.7	0.7	0.7	0.7
	Developed Dry Land	0.2	0.2	0.2	0.2	0.2
	Tidal Flat	0.0	222.1	1749.9	2504.0	1324.2
	Total (incl. water)	**9019.4**	**9019.4**	**9019.4**	**9019.4**	**9019.4**



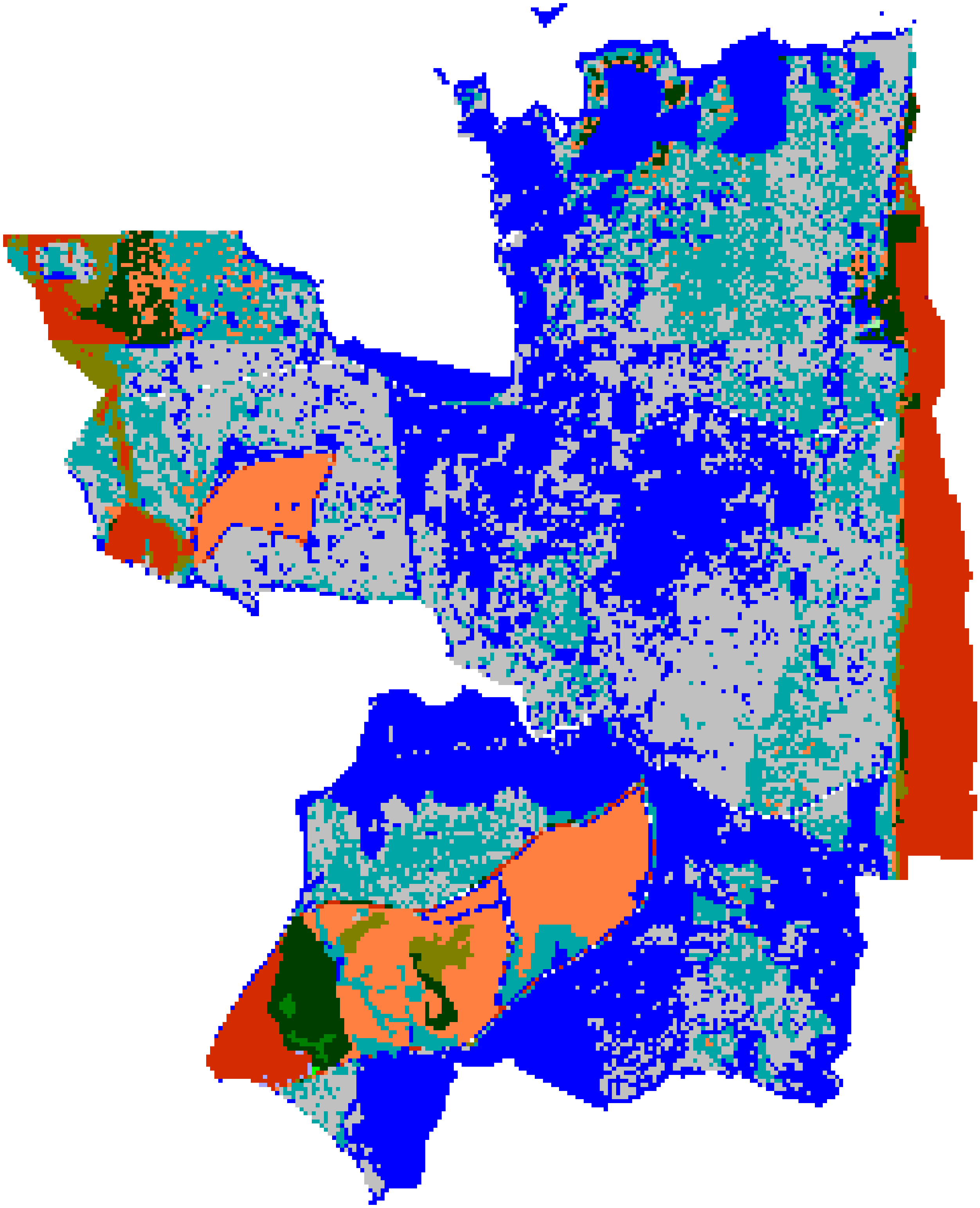
Mackay Island NWR, Initial Condition



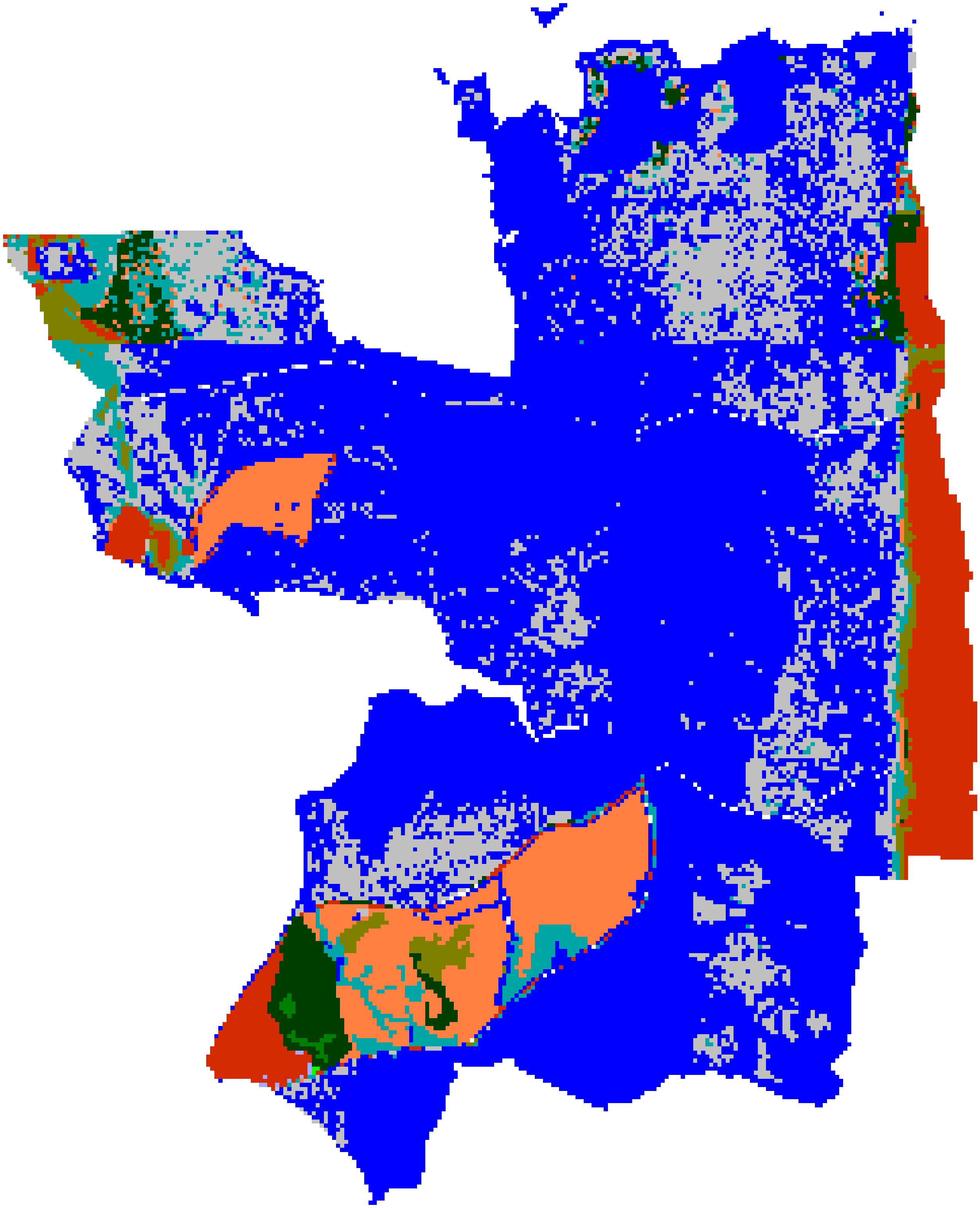
Mackay Island NWR, 2025, 2 meters



Mackay Island NWR, 2050, 2 meters



Mackay Island NWR, 2075, 2 meters



Mackay Island NWR, 2100, 2 meters

Discussion

Under the lowest sea-level rise (SLR) scenario analyzed, the largest predicted effect is the conversion of irregularly-flooded marsh into regularly-flooded marsh habitats, along with a likely increase in salinity. As SLR meets and exceeds 0.69 meters by 2100, however, significant marsh loss is predicted as regularly-flooded marsh falls below the mean tide level and is converted first to tidal flats and then to open water. As this site is located within a microtidal regime, impacts of SLR are more exaggerated as the percentage change as a function of tide-range is much greater.

This site is well covered with high vertical resolution LiDAR elevation data which considerably reduces model uncertainty (Figure 1.)

On the other hand, tidal swamp and tidal-fresh marsh results remain somewhat uncertain. The lower-elevation boundaries for these wetland categories can vary with geography and the effects of fresh-water flows from various tributaries. The SLAMM model predicts that tidal swamp will convert to irregularly flooded marsh when it falls below its lower elevation boundary of 87% of MHHW (mean higher high water). This elevation boundary was derived from site-specific LiDAR data for this category. However, potential effects of changes in fresh-water flows are not captured within this model simulation.

Marsh accretion rates also remain an important source of model uncertainty. Marsh accretion parameters were based on regional data from Cedar Island, NC. Furthermore this model application did not account for potential changes in marsh accretion as a function of sea-level rise. This model assumed constant accretion rates over the course of the simulation based on historical measurements. Insufficient data were available to define a relationship between marsh elevation, sea-level rise, and accretion rates at this time.

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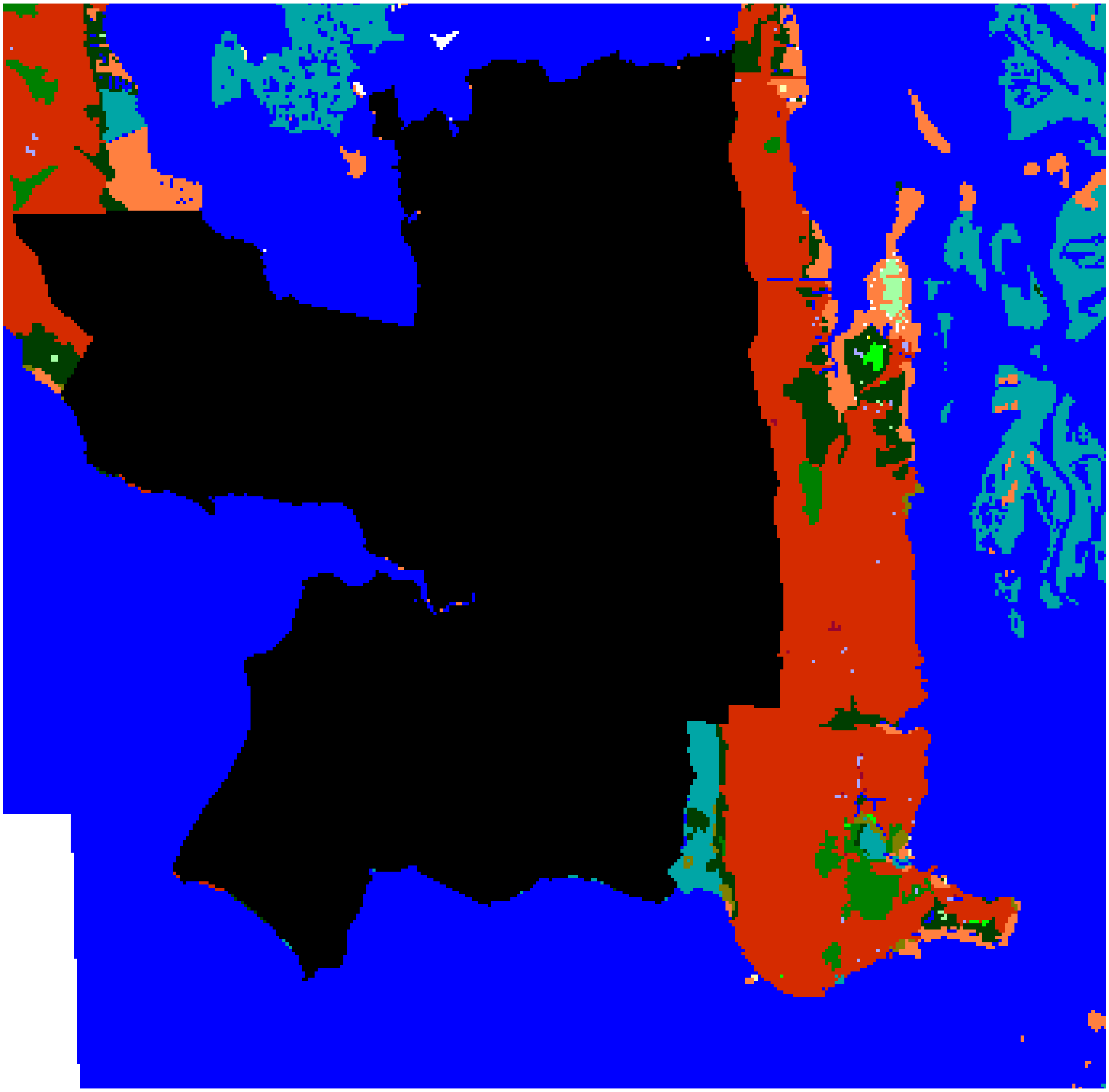
Appendix A: Contextual Results

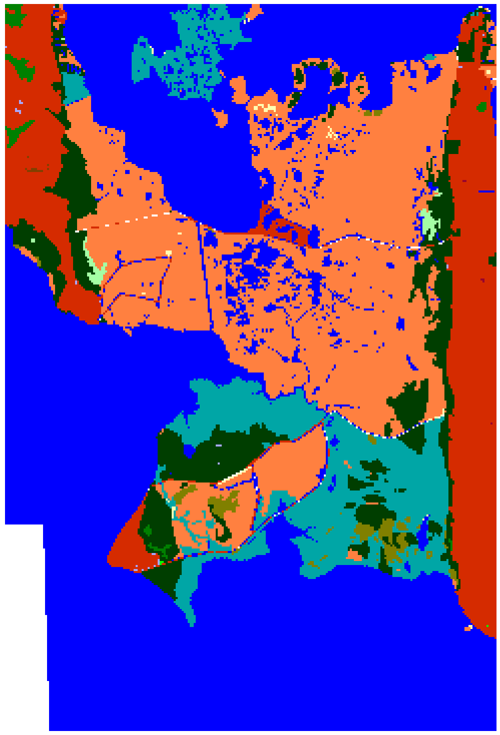
The SLAMM model does take into account the context of the surrounding lands or open water when calculating effects. For example, erosion rates are calculated based on the maximum fetch (wave action) which is estimated by assessing contiguous open water to a given marsh cell. Another example is that inundated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

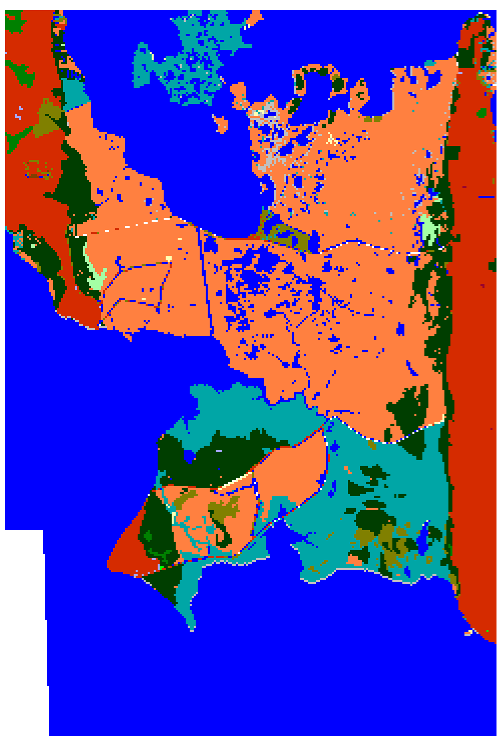
- Results were closely examined (quality assurance) within USFWS refuges but not closely examined for the larger region.
- Site-specific parameters for the model were derived for USFWS refuges whenever possible and may not be regionally applicable.
- Especially in areas where dikes are present, an effort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



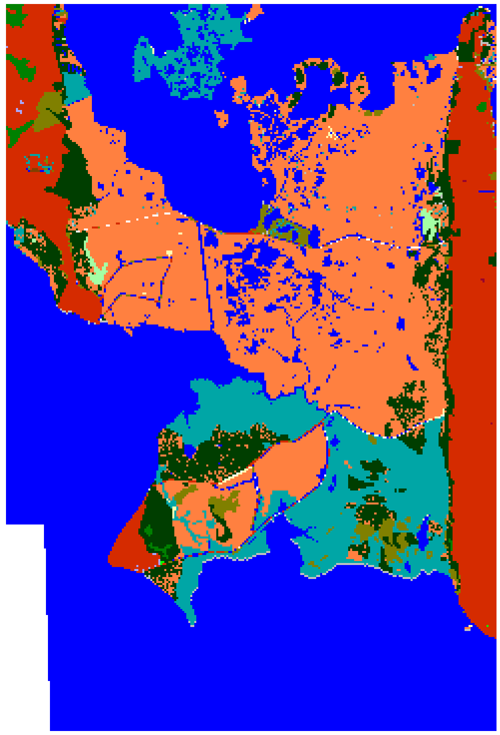
Mackay Island National Wildlife Refuge within simulation context (black).

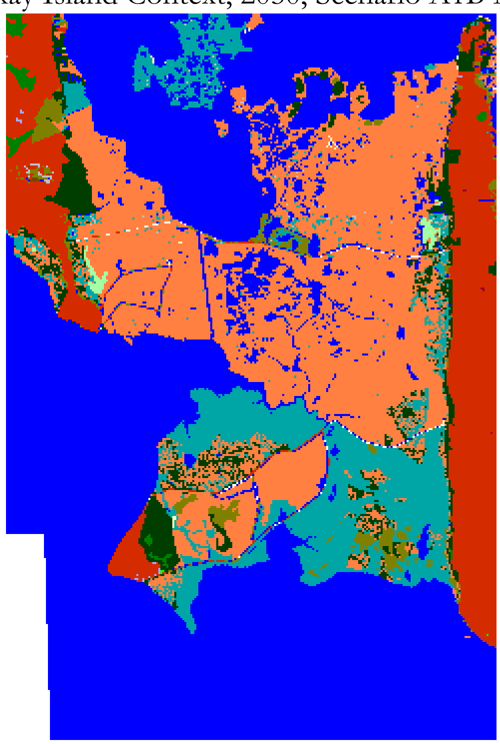


Mackay Island Context, Initial Condition



Mackay Island Context, 2025, Scenario A1B Mean


Mackay Island Context, 2050, Scenario A1B Mean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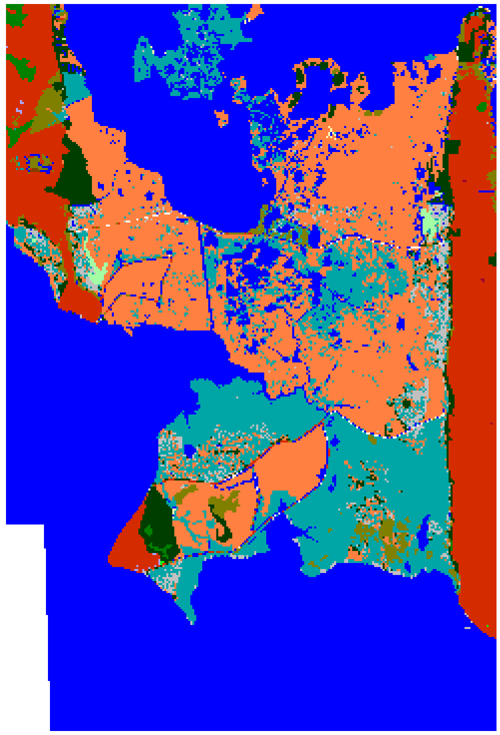
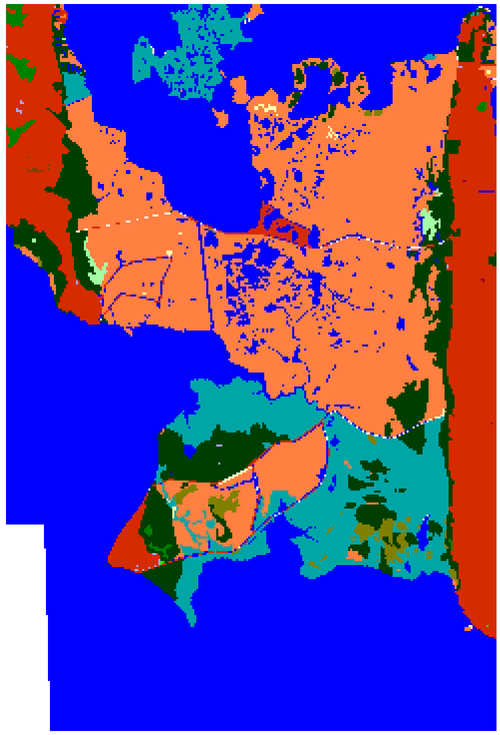
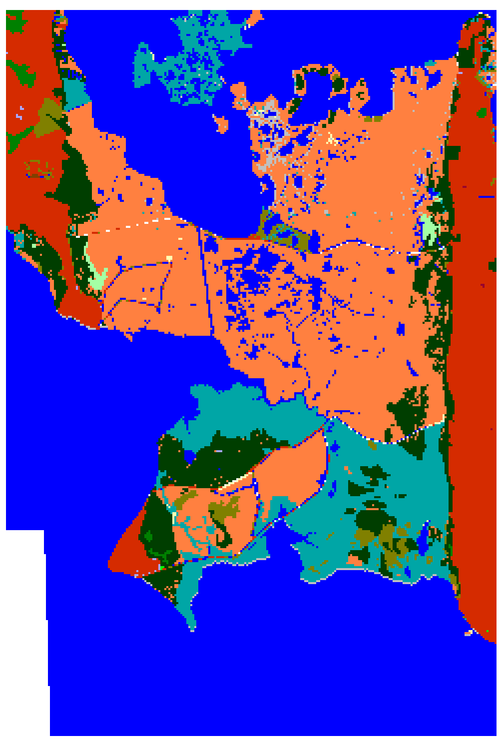


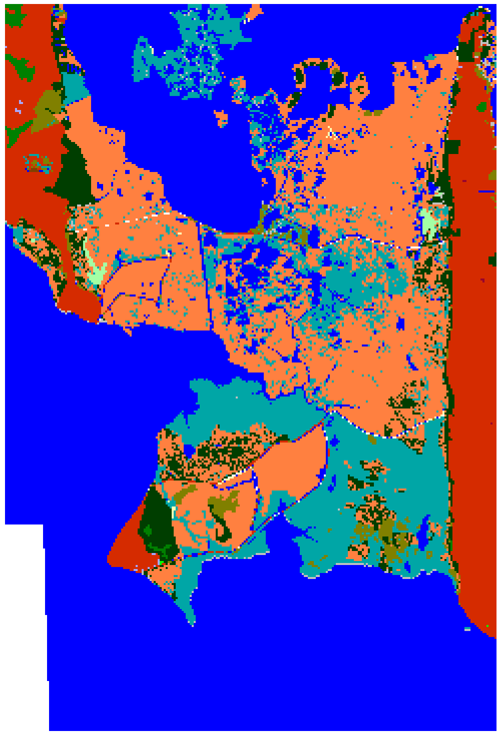
Mackay Island Context, 2100, Scenario A1B Mean



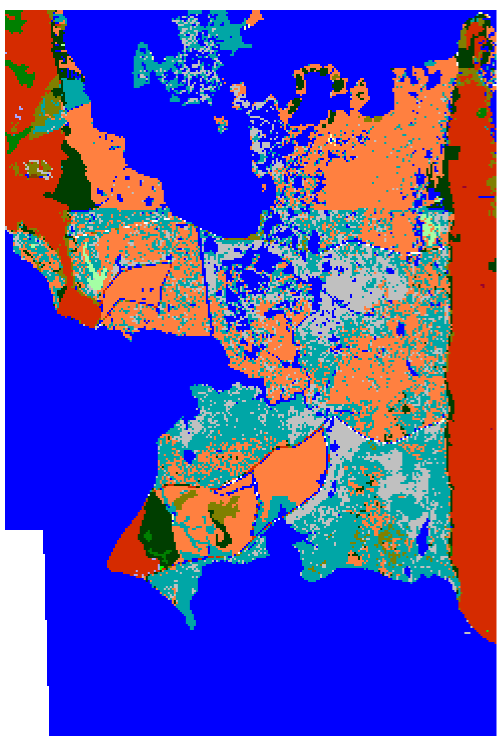
Mackay Island Context, Initial Condition



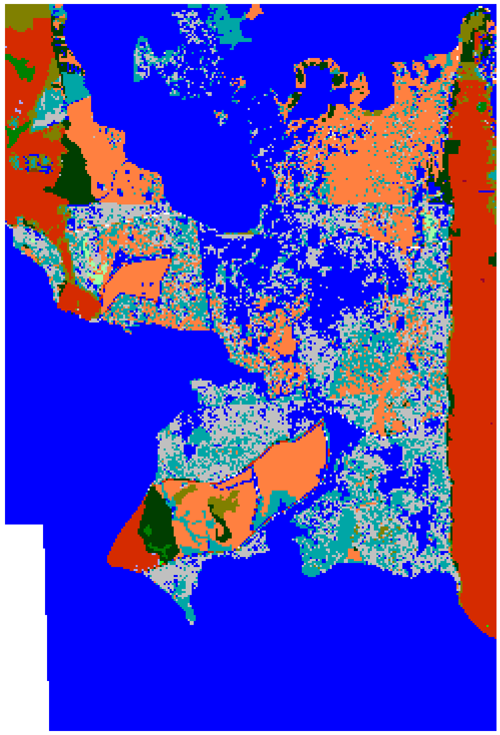
Mackay Island Context, 2025, Scenario A1B Maximum



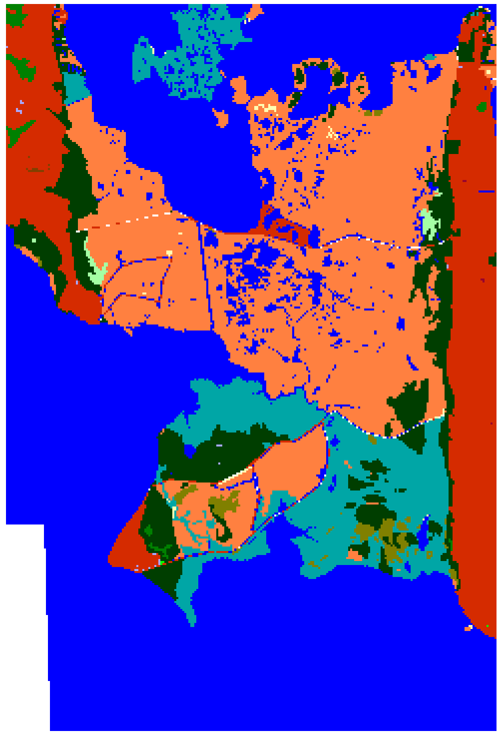
Mackay Island Context, 2050, Scenario A1B Maximum



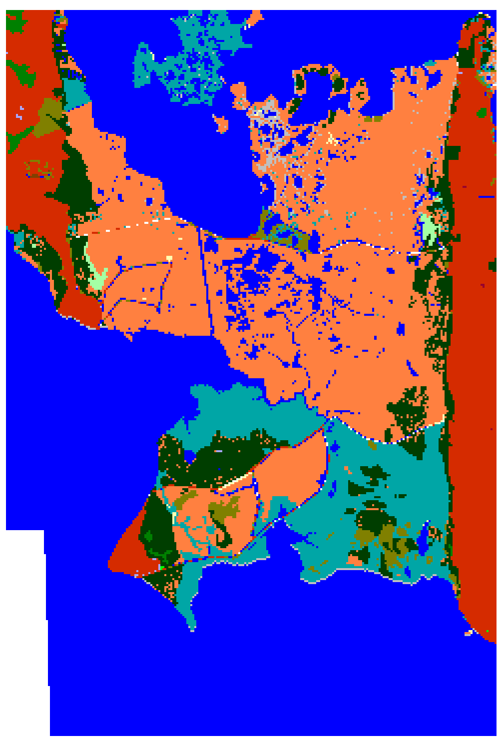
Mackay Island Context, 2075, Scenario A1B Maximum



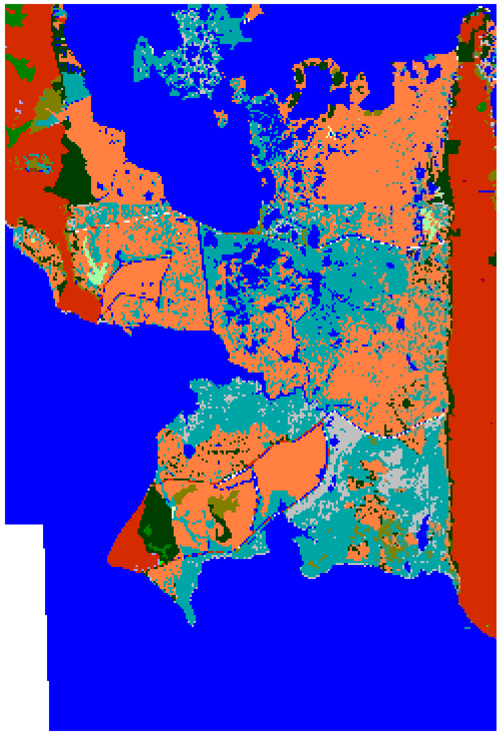
Mackay Island Context, 2100, Scenario A1B Maximum



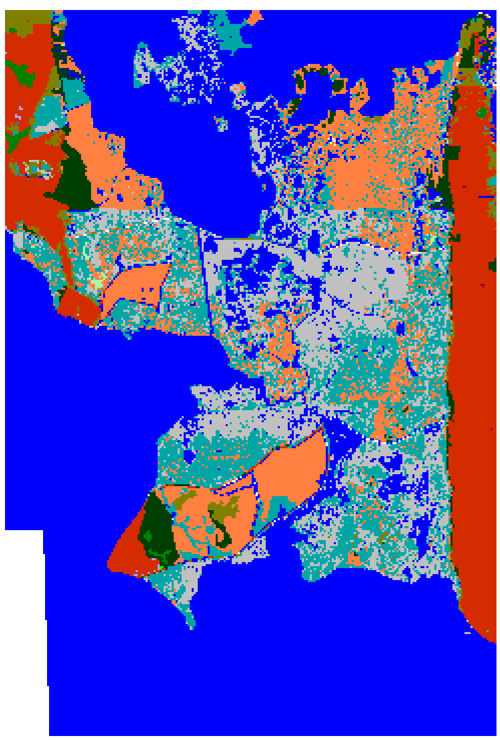
Mackay Island Context, Initial Condition



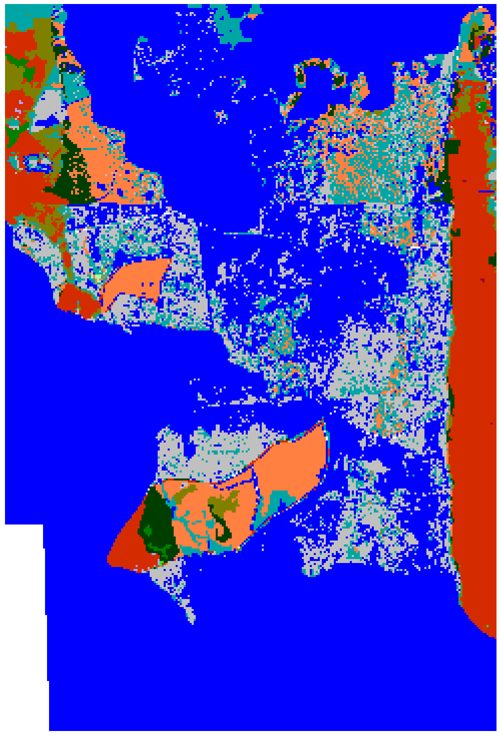
Mackay Island Context, 2025, 1 meter



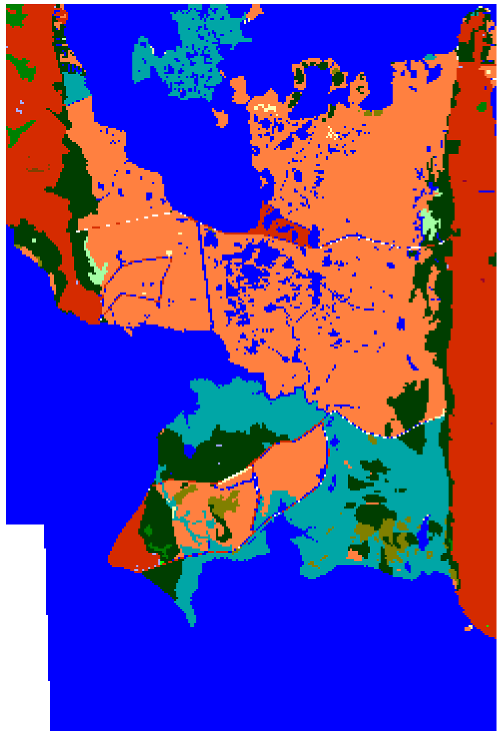
Mackay Island Context, 2050, 1 meter



Mackay Island Context, 2075, 1 meter



Mackay Island Context, 2100, 1 meter



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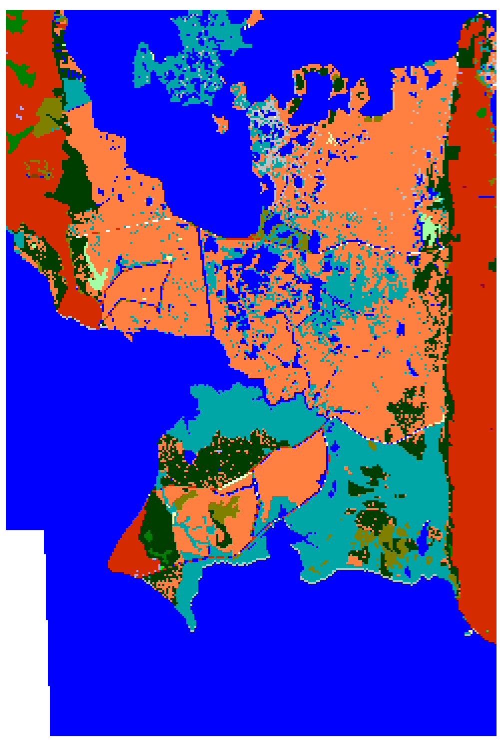
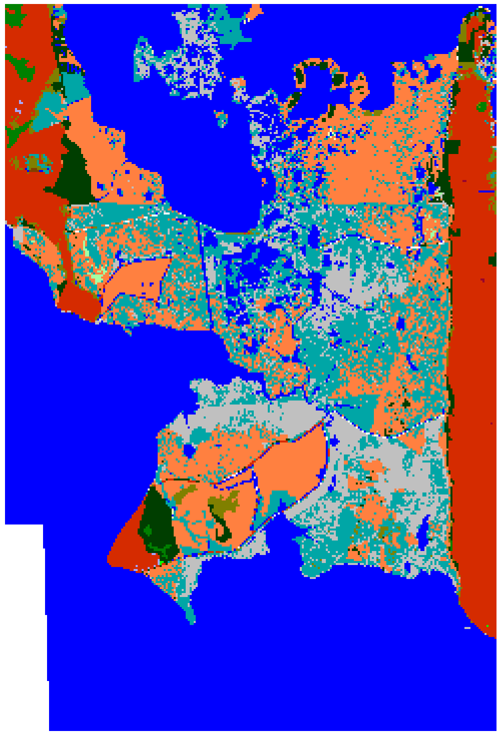
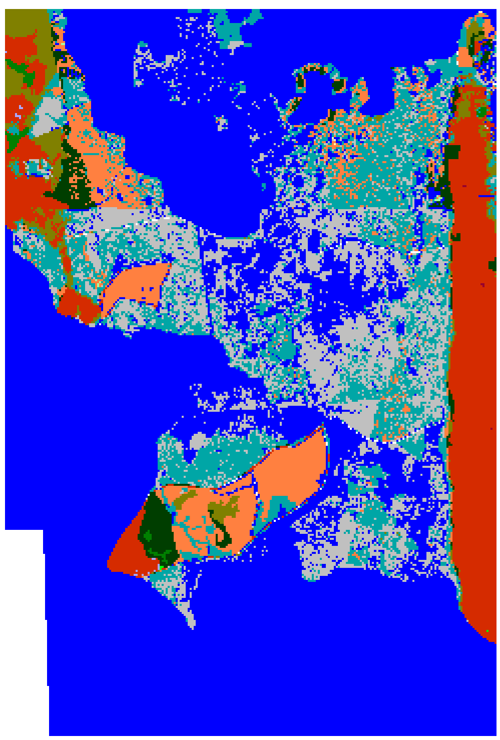


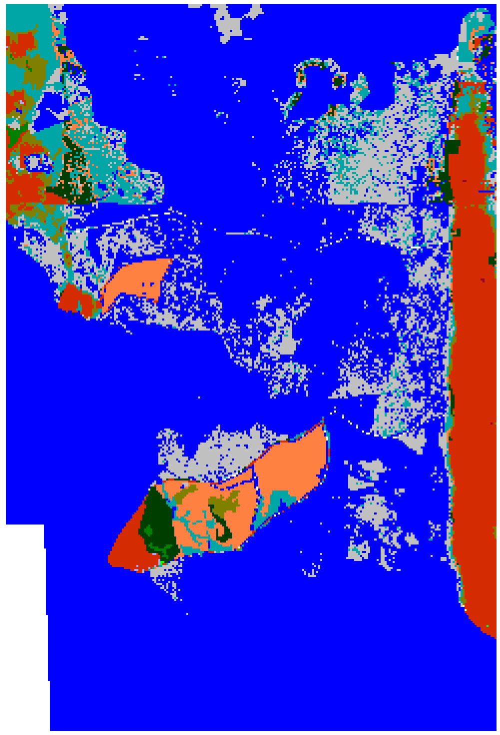
Mackay Island Context, 2025, 1.5 meter

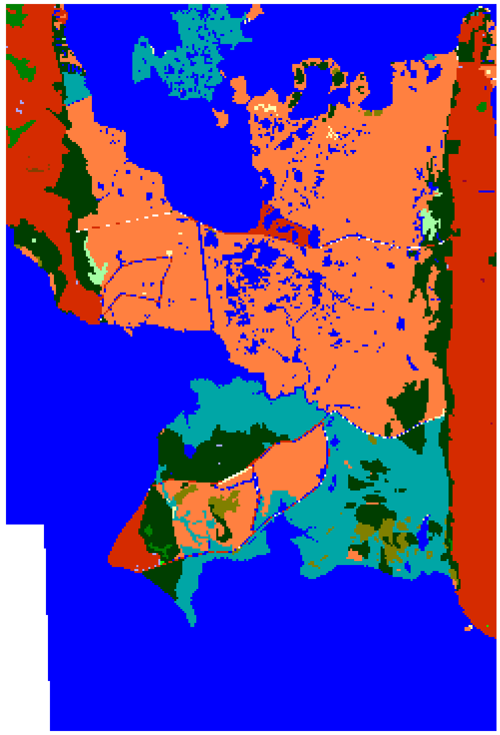


Mackay Island Context, 2050, 1.5 meter

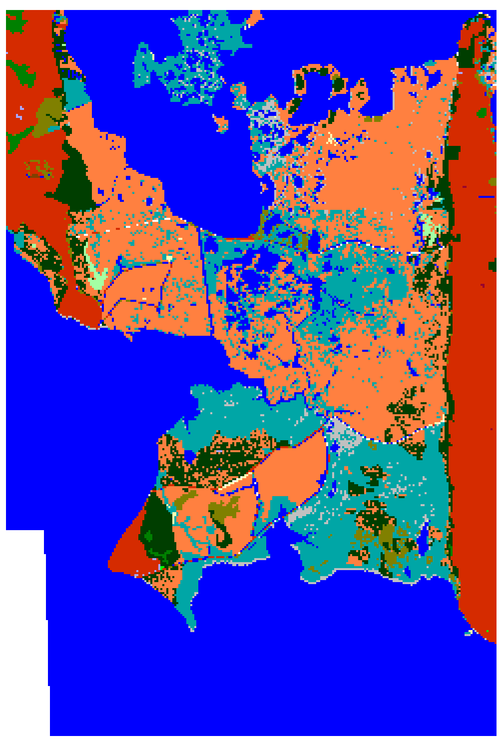


Mackay Island Context, 2075, 1.5 meter

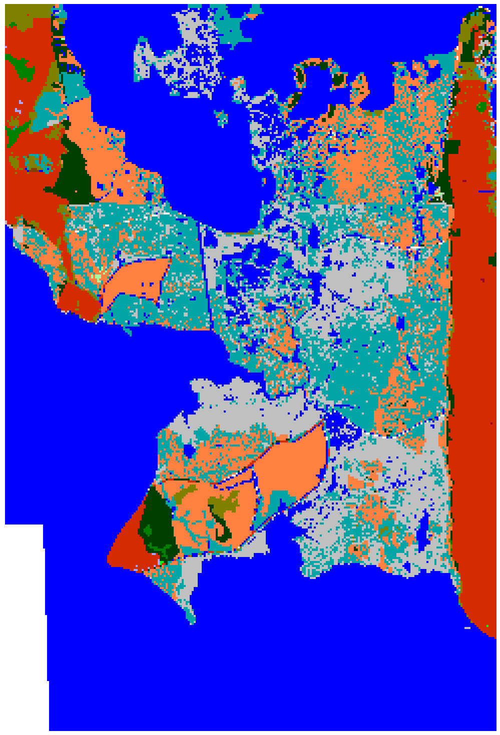

Mackay Island Context, 2100, 1.5 meter



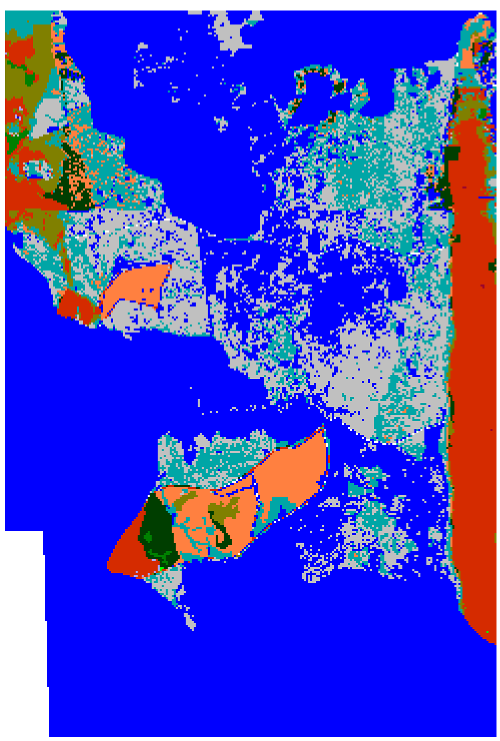
Mackay Island Context, Initial Condition



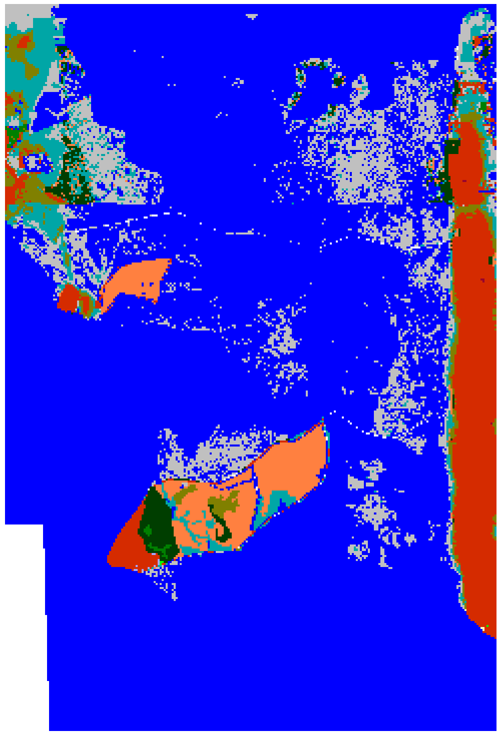
Mackay Island Context, 2025, 2 meter



Mackay Island Context, 2050, 2 meter



Mackay Island Context, 2075, 2 meter



Mackay Island Context, 2100, 2 meter