Appendix B

SLAMM Analysis of Kenai Peninsula and Anchorage, AK

Final Report

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Project Background

In 2008 National Wildlife Federation (NWF) and the United States Fish and Wildlife Service (USFWS) Region 7 Coastal Program entered into a cooperative funding agreement to explore the possibility of SLAMM modeling within Cook Inlet, Alaska. The project was delayed for several months as high vertical-resolution elevation data was obtained.

This project has been considered a pilot project intended to answer questions such as:

- Will SLAMM work in Alaska?
- Is Alaska different in some manner that renders the SLAMM conceptual model ineffectual?
- What are the data needs for SLAMM modeling in Alaska and what is the current inventory of data?

Based on data availability, the SLAMM 6 model was applied to the Kenai Peninsula and Anchorage, AK, areas comprising over 545,000 hectares (Figure 2) and over 24,000 hectares (Figure 3), respectively.

Applying the SLAMM 6 model to other portions of Cook Inlet was not deemed possible, primarily due to limitations in available elevation data. For the western shore of Cook Inlet and areas towards the mouth of the inlet, the best available elevation data were based on large contour intervals (up to 100 feet), and much of these data predated the Alaska earthquake of 1964. More discussion of data availability with Cook Inlet and Alaska in General can be found in a short white-paper titled *Data Requirements and Data Inventory for Alaska SLAMM Analyses*, also completed in December of 2009.

Figure 1: Anchorage Mud Flats

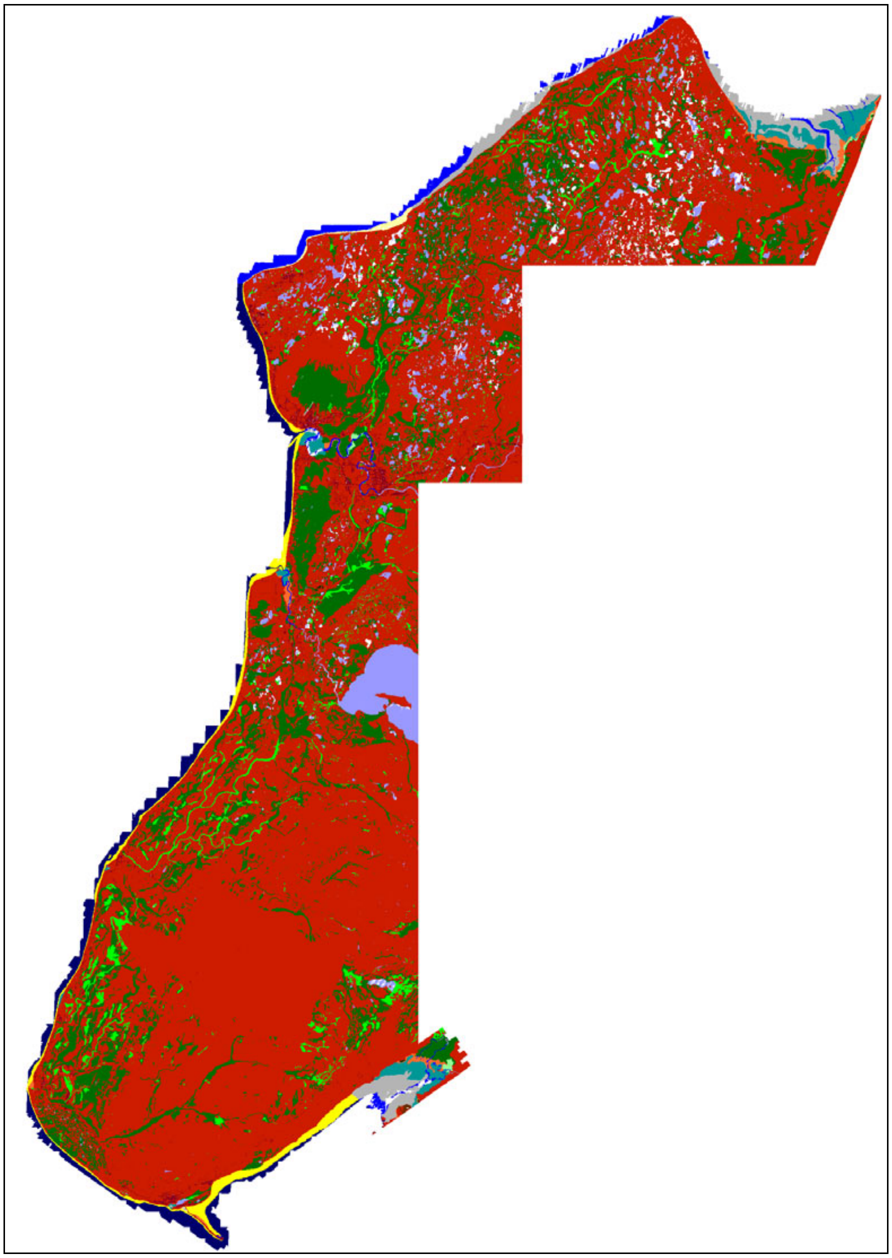


Figure 2: SLAMM Application Study area for the Kenai Peninsula in AK.

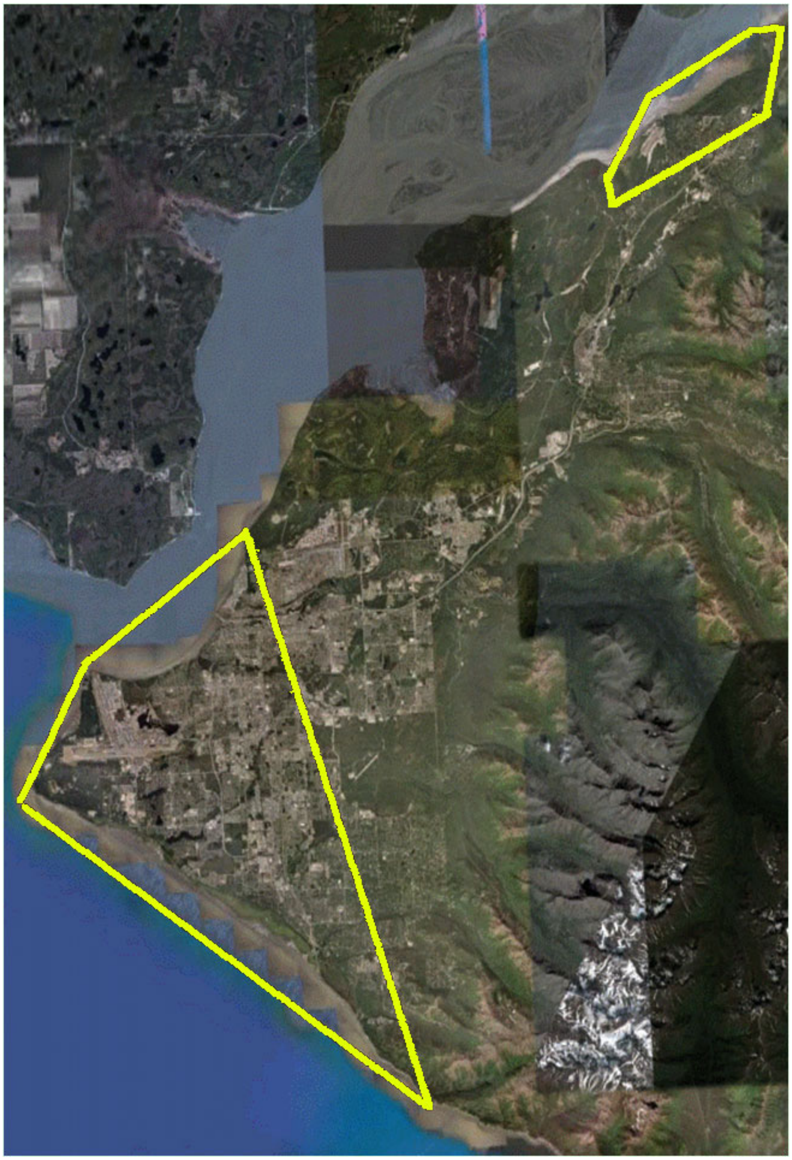


Figure 3: SLAMM Application Study area (yellow) for Anchorage, AK

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. Spatially variable effects of land subsidence or isostatic rebound are included in these elevation calculations. 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.

SLAMM Version 6.0 is the latest version of the SLAMM Model, developed in 2009 and closely based on SLAMM 5. SLAMM 6 is the first open-source version of SLAMM and also provides the following refinements:

- Accretion Feedback Component: Feedbacks based on wetland elevation, distance to channel, and salinity may be specified. Enough data to characterize these feedbacks were not available in Alaska so this model was not used for the results presented in this report.
- 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 was not utilized in the Cook Inlet analyses.
- Integrated Elevation Analysis: SLAMM will summarize site-specific elevation ranges for wetlands as derived from LiDAR data or other high-resolution data sets. This analysis was used to examine the SLAMM conceptual model in Alaska
- Flexible Elevation Ranges for land categories: If site-specific data indicate that wetlands range beyond the SLAMM defaults a different range may be specified within the interface. Minor changes to the SLAMM conceptual model based on the integrated elevation analysis were used for this project as detailed in the Methods section.
- Improved Memory Management: SLAMM no longer requires contiguous memory which improves memory management considerably. This proved to be important given the size of the AK study area
- SLAMM 6 allows a user to import a spatial map of uplift and subsidence which has been critical for the Alaska simulations as discussed below.

- Additional and significant graphical user interface upgrades were also completed.

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).

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 (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 0.40 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 4).

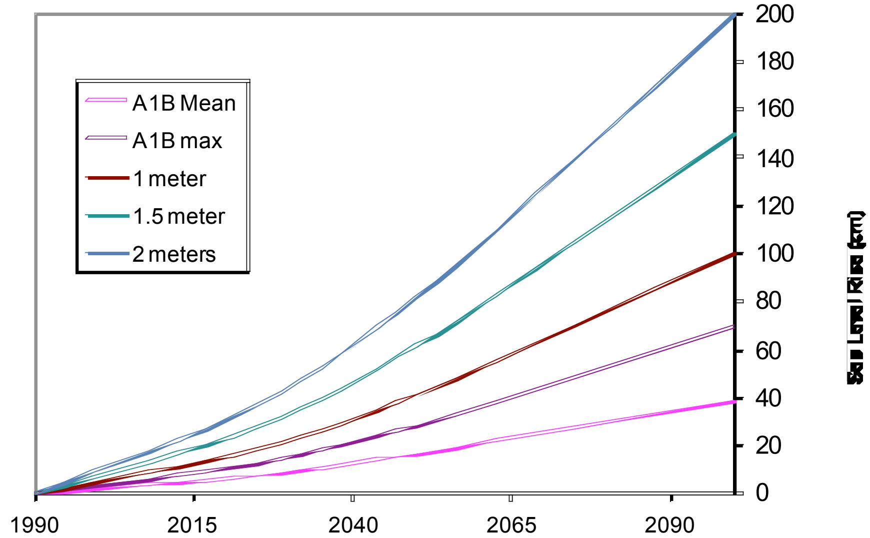


Figure 4: Summary of SLR Scenarios Utilized

Additional information on the development of the SLAMM model is available in the technical documentation, which may be downloaded from the SLAMM website (Clough and Park, 2008).

Figure 5: Anchorage Marshlands near Kinkaid Park

Methods and Data Sources

For the Kenai Peninsula study area, LIDAR elevation data flown in 2007 were utilized to produce a digital elevation map (DEM) for this project. These data were still undergoing final quality assurance at the time of these model runs but the remaining issues were not at the coastal elevations so the data were deemed suitable for our purposes.

The digital elevation map (DEM) used to model the Anchorage study area was derived from LiDAR elevation data with a 2006 flight date. Original LiDAR data were not available, nor was a digital elevation map based on these data. Elevations utilized in this modeling were derived from four-foot contours (Figure 6). In most locations, the contour coverage made available did not extend to the tidal flat/open water interface, significantly increasing uncertainty in tidal flat inundation predictions.

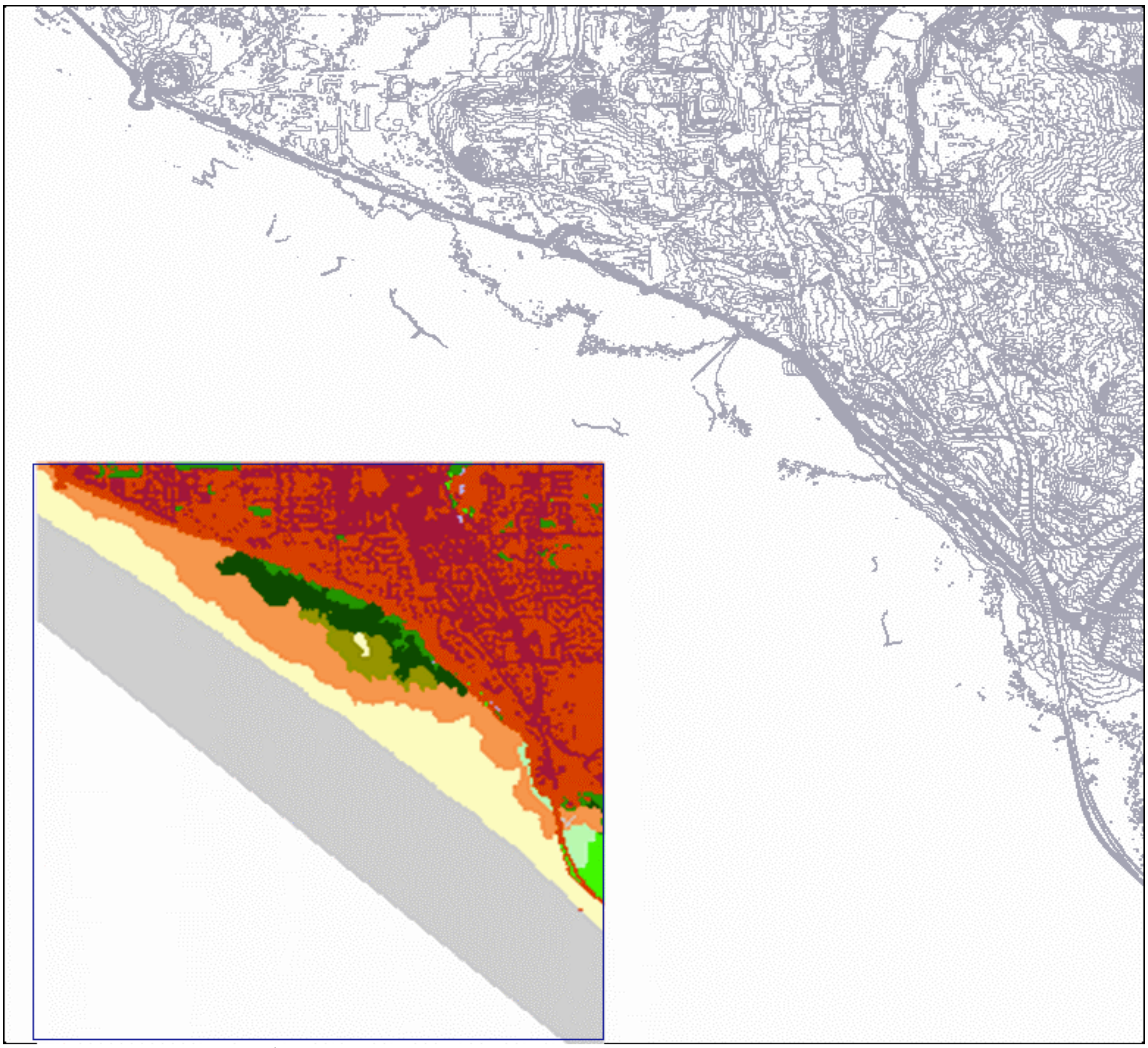


Figure 6: Contour-based LiDAR does not extend out to the tidal flats.

Land-cover categories within the modeling for the Kenai Peninsula and Anchorage were derived from the National Wetlands Inventory (NWI). The NWI coverage for the Kenai Peninsula was based on 1977 photography and Anchorage on 2002 photography.

Converting the NWI surveys to 30 meter cells and then converting to SLAMM cover categories suggests that the study sites were composed of the categories as shown below:

Kenai Peninsula Study Area

Category	% of Study Area	HA
Undeveloped Dry Land	68.7%	374,339.97
Swamp	15.9%	86,664.33
Inland Open Water	3.7%	20,020.23
Inland Fresh Marsh	2.9%	15,648.39
Open Ocean	2.2%	11,858.49
Tidal Flat	1.7%	9,198.54
Ocean Beach	1.2%	6,688.53
Developed Dry Land	1.1%	5,835.24
Regularly Flooded Marsh	1.0%	5,504.40
Estuarine Open Water	1.0%	5,488.20
Irregularly Flooded Marsh	0.4%	2,099.16
Estuarine Beach	0.1%	790.65
Tidal Fresh Marsh	0.1%	403.47
Total (incl. water)	**100%**	**545,066**

Anchorage Study Area

Category	% of Study Area	HA
Undeveloped Dry Land	38.6%	9,324.54
Developed Dry Land	30.1%	7,270.65
Tidal Flat	11.0%	2,667.87
Estuarine Open Water	6.2%	1,492.47
Swamp	4.2%	1,011.33
Estuarine Beach	3.4%	810.54
Irregularly Flooded Marsh	2.8%	667.89
Inland Fresh Marsh	1.7%	411.48
Inland Open Water	1.4%	327.15
Tidal Swamp	0.4%	100.80
Transitional Salt Marsh	0.2%	51.66
Tidal Fresh Marsh	0.1%	18.99
Tidal Creek	0.0%	6.03
Total (incl. water)	**100%**	**24,168**

Because the spatial characterization of land uplift is of critical importance within Alaska, uplift data were gathered from Dr. Jeffery Freymueller (Freymueller et al. 2008). Dr. Freymueller was generously willing to share his point data representing uplift and subsidence rates throughout Alaska. These data were derived from repeated GPS surveys covering the time period from 1992-2007. In our conversation with Dr. Freymueller he indicated that the projection of these measured rates of change over the next 100 years would likely provide the best available estimate of uplift rates during that time period.

Each of Dr. Freymueller's point estimates of land change was associated with an estimate of error in units of centimeters per year. These errors were based both on the numbers of measurement years and also variability within measured rates at a particular site. For this analysis, the data set was censored to remove locations with errors greater than a threshold of 0.4 cm/year.

Within the Anchorage area, uplift rates ranged from 0.5-0.8 cm/yr. For the Kenai Peninsula the range was 0.7-1.1 cm/yr. These rates of land uplift were then smoothed into a spatially continuous two-dimensional map using the ESRI kriging procedure. Rates of uplift were applied within the model on a cell-by-cell basis. Regarding the kriging analysis, various cell-sizes and kriging options were evaluated. The results presented here are based on a one thousand meter cell size, an analysis of the eight closest points to each cell, and an exponential mathematical model of semivariance. Interpolation results within the study area were carefully examined and found to conform to input data closely. Within the study area, data points were fairly plentiful (Figure 7) reducing uncertainty due to this two dimensional interpolation.

The uplift rates estimated for these study areas provide considerable resilience to sea level rise. The scenarios utilized estimate eustatic SLR as ranging from 0.4 to 2 meters by the year 2100. The rates of uplift within the study area are estimated to range from 0.5 to 1.1 meters by 2100. For this reason, few effects of SLR are predicted, especially under the lower scenarios examined. The SLAMM model does not currently model wetland drying and land creation due to sea levels falling.

The tide range for both sites was applied in a spatially variable manner using several NOAA tide gages (Figure 8) and NOAA tide tables (Figure 9). To support this input, the Kenai Peninsula study area was split into multiple input regions (Figure 12).

- The tide gage at Homer Alaska (9455557) was used to determine the tide range of 5.583 meters for Input Site 1.
- The tide range of 5.85 meters at Input Site 2 was estimated using NOAA tide table trends.
- Because of its close proximity to Anchorage, input Site 3 used the Anchorage (9455920) tide gage range of 8.889 meters. This range of tide was also used for the Anchorage simulations.
- No tide data were available for Input Site 4, so an average of two gages were used (Nikiski, Alaska, 9455760; Anchorage, Alaska, 9455920).
- Input Site 5 is located up the Kenai River, where the tide range of 5.95 was used based on NOAA tide tables.
- Coastal Kenai Peninsula tide ranges were estimated at 6.267 meters using the tidal gage in Nikiski, Alaska (9455760).

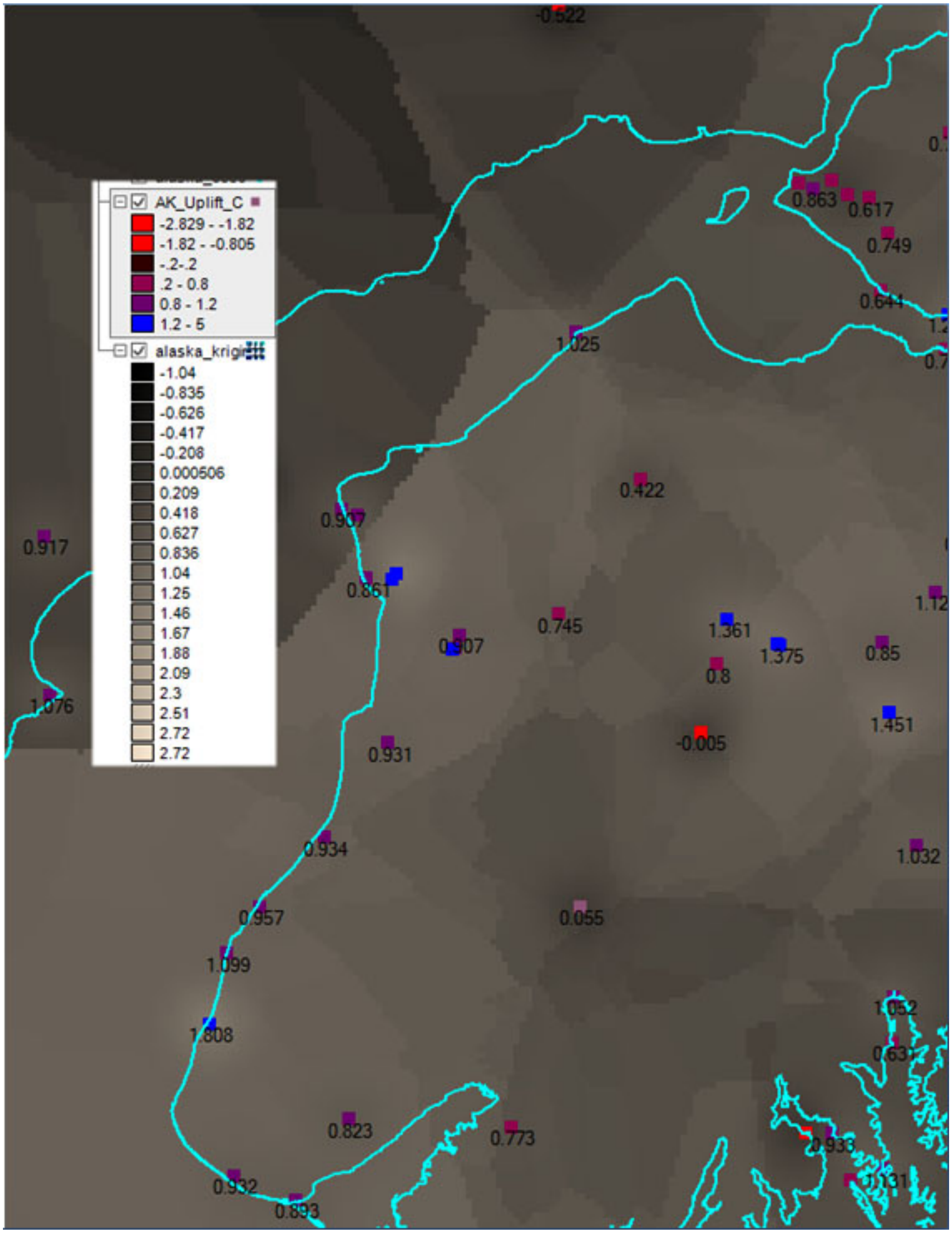


Figure 7: Uplift data for both study regions (cm/year).

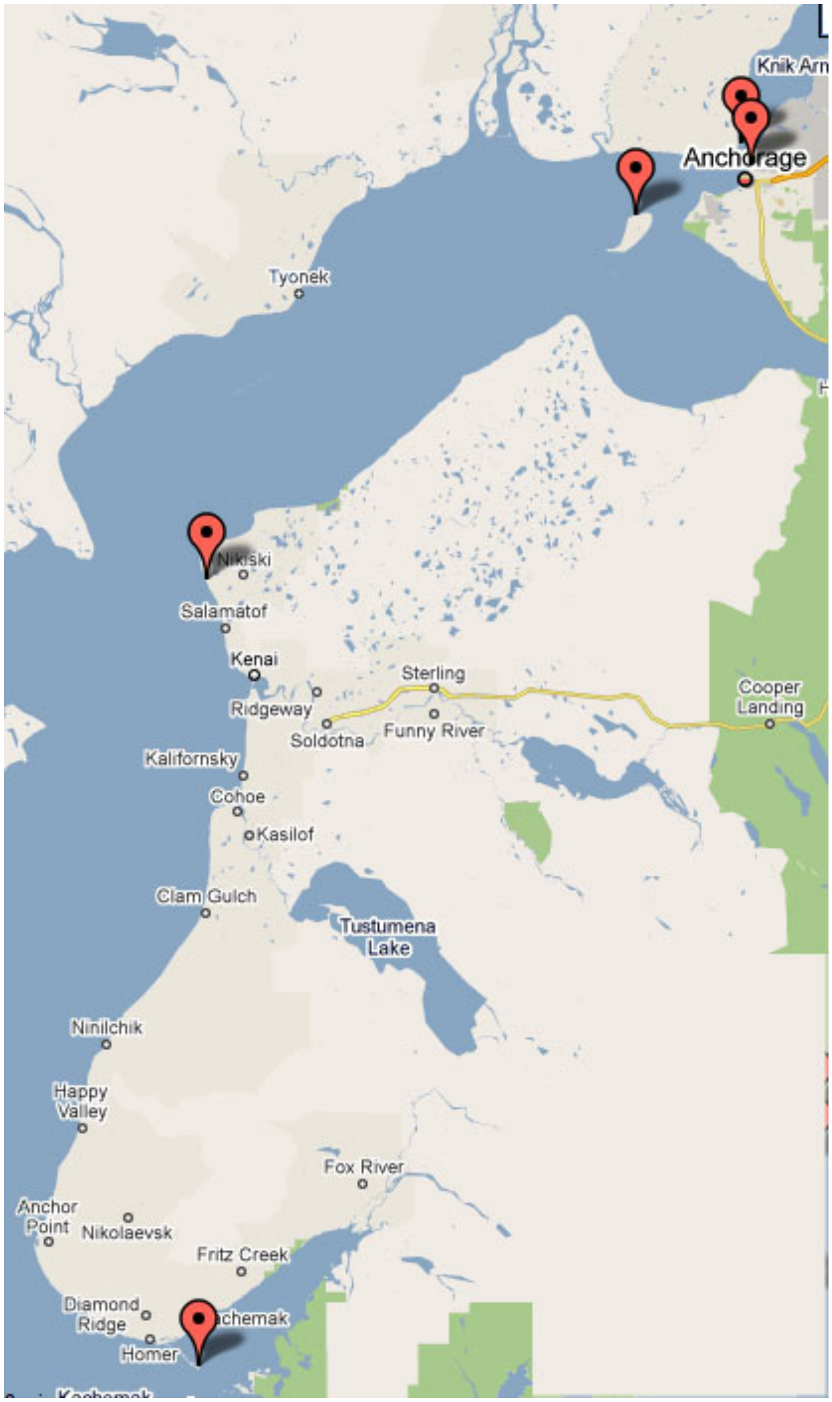


Figure 8: NOAA Gages Relevant to the Study Area.

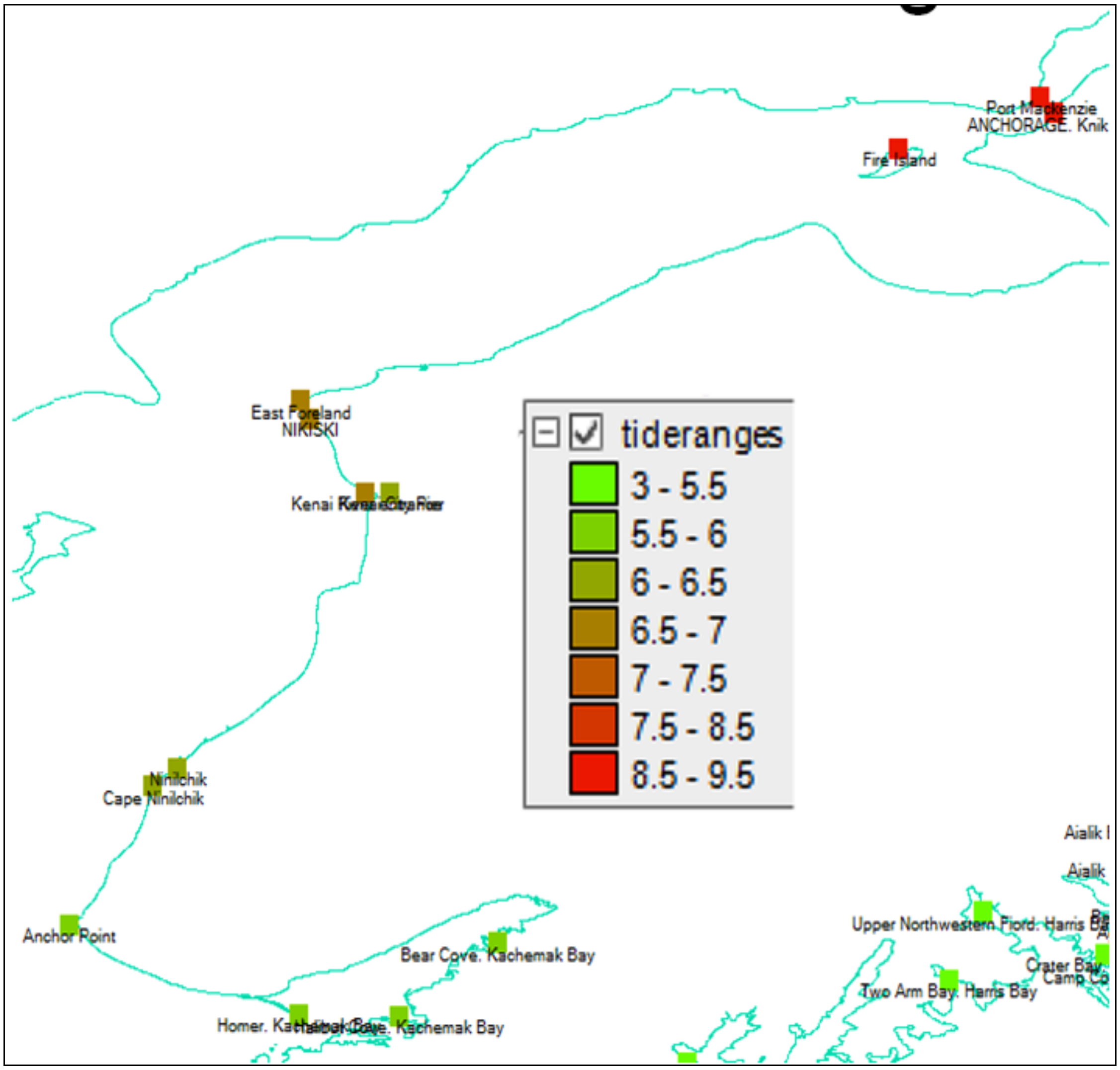


Figure 9: Tide range trends from NOAA Tide Tables

Within the Anchorage study area, the Potter Marsh input-site was estimated as having a reduced tide range (7 meters) due to the effects of culverts on water access (Figure 10). After model results initially suggested saline intrusion, a site visit confirmed that a lower tide range is present at this site due to the railroad embankment between Rabbit and Potter creeks that restricts tides and storm surges.

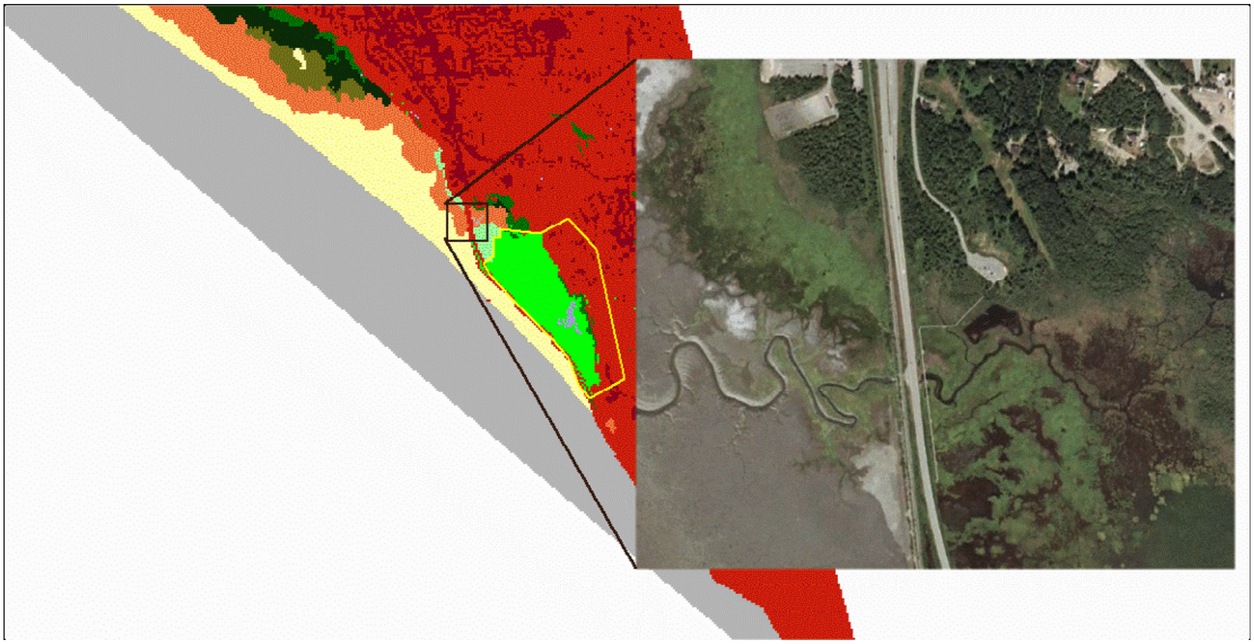


Figure 10: Potter Marsh region.

Figure 11: Salt water access to Potter Marsh

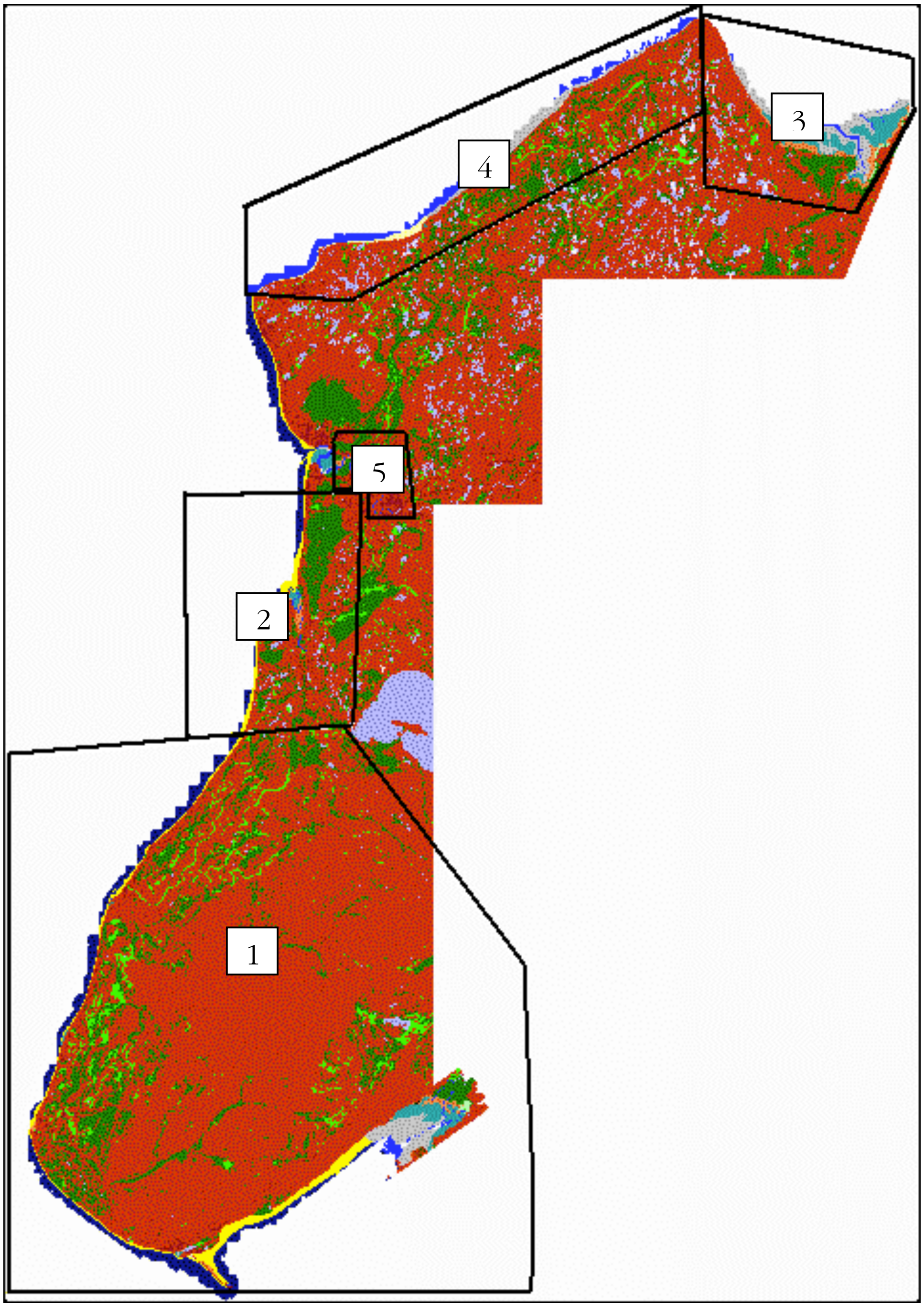


Figure 12: Kenai Peninsula Input subsites.

Studies of vertical accretion rates within the wetlands of Cook Inlet (and Alaska in general) are not plentiful. Within the study area two studies were located. One is an analysis of Eagle River Flats in Fort Richardson Alaska (Lawson et. al, 1995). The other is a set of unpublished marker/horizon data provided by Jerry Hupp USGS from Cook Inlet (Hupp 2009). For the USGS study, one field site was located near the Little Susitna River, the other was located near Ivan River on the west side of Cook Inlet.

From the Eagle River study (Lawson, et al, 1995) vertical accretion rates in marshes were measured at 2-10 mm during summer of 1992. Marsh sedimentation rates in the Eagle River study were stated to be uncertain due to problems in sampling within thick sedges.

For this reason data from western Cook Inlet as received from Jerry Hupp were used preferentially. These marker/horizon data included regularly flooded and irregularly flooded marsh accretion measured from 1998-2001. These rates were normalized to annual rates. Averaging regularly flooded marsh accretion rates (based on the lat-long of each sample and the NWI land-cover maps) resulted in a value of 3.6 mm/year. Averaging irregularly flooded marsh rates resulted in a value of 3.5 mm/year. No local data for accretion of fresh and tidal fresh marshes were located; these values were set to 4 mm/year based on professional judgment.

Tidal flat erosion rates were derived using the average of "headwall recession rates in 1992 and 1993" from the Eagle River study (Lawson et. al 1995). The resulting average (taking mid-points of minimum and maximum readings and normalizing them to yearly rates) was 1.75 horizontal meters / year. This value was applied uniformly to tidal flats and mud flats across the study area.

The cell size used for this analysis was 30 meter by 30 meter cells. SLAMM will also track partial conversion of cells based on elevation and slope.

Elevation data were converted to a mean tide level (MTL) basis using data available from NOAA tide gages. Kenai Peninsula data were delivered with a vertical datum basis of NAVD88 (GEOID06 derived) and were converted to MTL with corrections ranging from 1.21 to 1.47 meters. Anchorage data were originally in NGVD29 (NGS1972) and were converted using a correction of -0.28 meters as derived from the National Geodetic Survey (PID TT0711).

Also worth noting is that there is additional uncertainty in Alaska elevation data due to uncertainty in the vertical control network. Renee Shields of the NOAA National Geodetic Survey writes:

> "Heights derived this way are, in areas of the country with significant geodetic control, at best good to about 4 cm. Alaska does not have a good vertical control network, and I'm not sure when the heights there were last leveled, so while GEOID06 is significantly better than previous geoid models, it could be much less accurate than 4 cm."

Two output sites (sites over which model outputs are mapped and tabulated) were designated for the Anchorage study area. Output Site 1 is encompasses an area north of Chugiak, AK (near Birchwood Airport) and Output Site 2 encompasses the shoreline around Anchorage proper (Figure 13). These were the two locations for which LiDAR data were available in the Anchorage region.

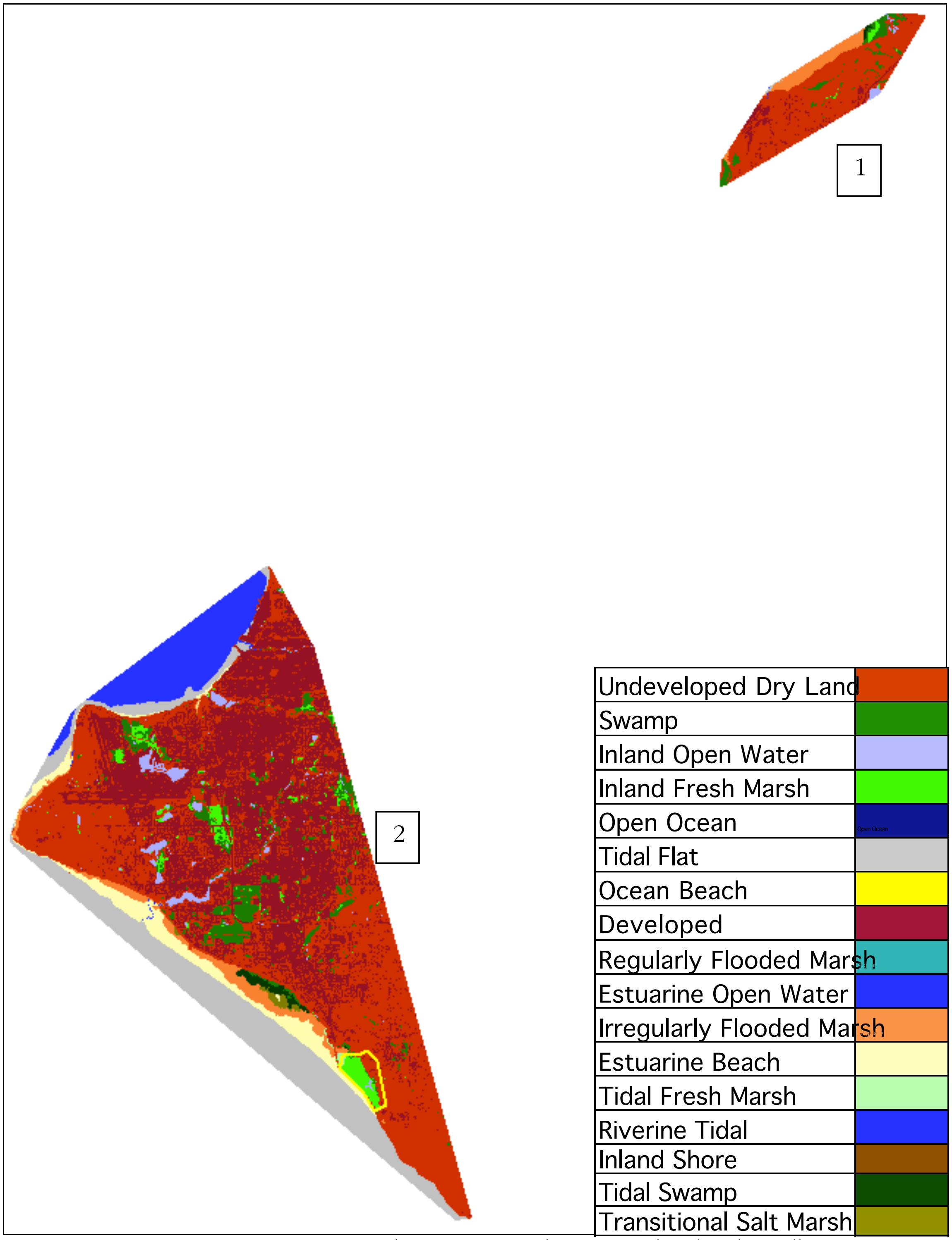


Figure 13: Output Sites 1 and 2. Potter Marsh input site bordered in yellow.

To simplify data presentation, and improve the resolution of maps within this report, the Kenai Peninsula site was broken into four different output sites (**Figure 14**). Output site 1 focuses on Fox River Flats (Eastern Kachemak Bay), site 2 focuses on Chickaloon Bay, site 3 focuses on the City of Kenai and site 4 focuses on the northern Cohoe/Kasilof region.

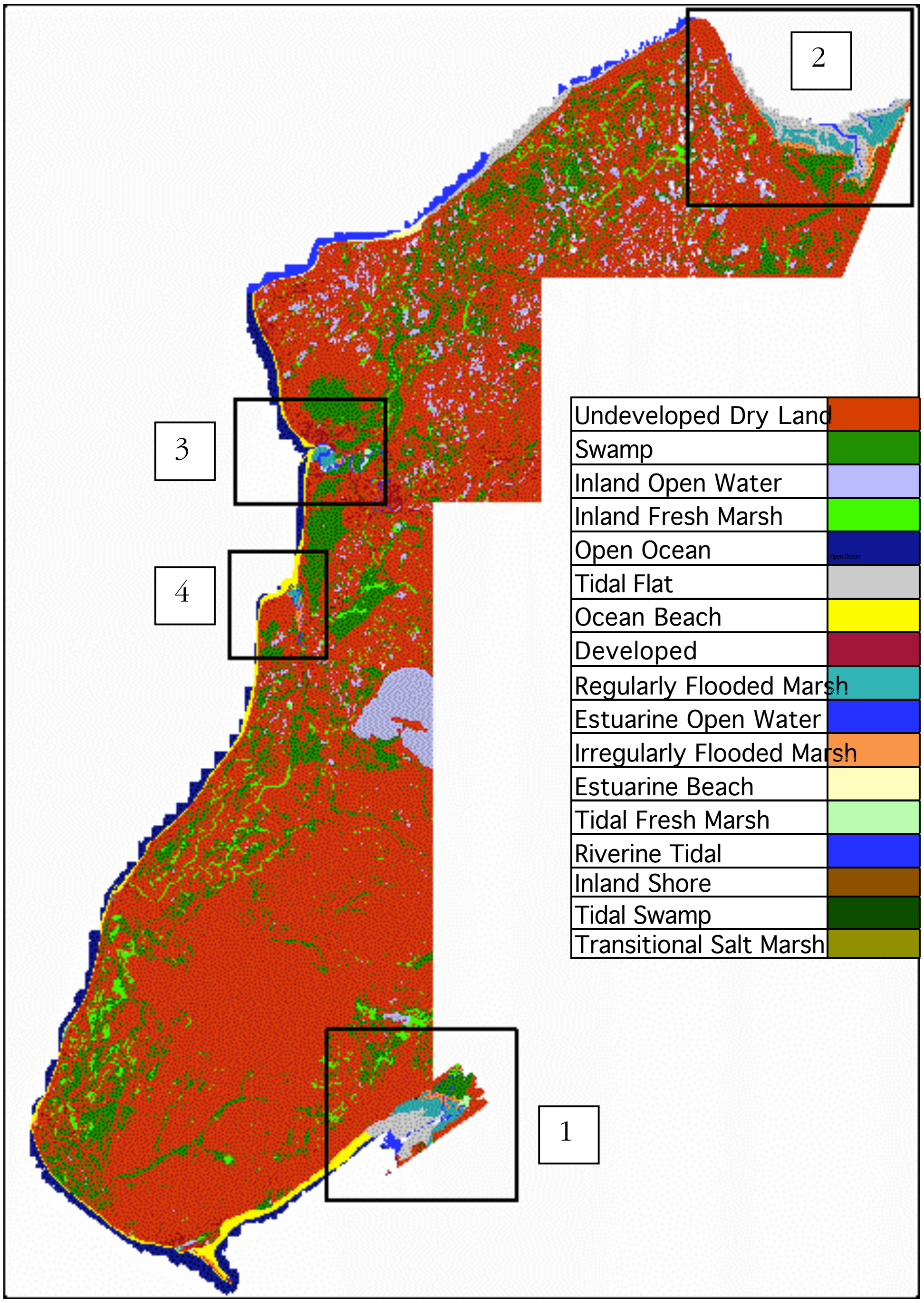


Figure 14: Kenai Peninsula output sites.

SUMMARY OF SLAMM INPUT PARAMETERS FOR KENAI PENINSULA SITE

(See Figure 12 for a map of "Input Site" locations)

Parameter	Global	Input Site 1	Input Site 2	Input Site 3	Input Site 4	Input Site 5
Description	Kenai Peninsula Alaska	Subsite Homer	SubSite 2	Near Anchorage	SubSite 4	Kenai River
NWI Photo Date (YYYY)	1977	1977	1977	1977	1977	1977
DEM Date (YYYY)	2007	2007	2007	2007	2007	2007
Direction Offshore [n,s,e,w]	West	West	West	North	North	West
Historic Trend (mm/yr)	*Kriging*	*Kriging*	*Kriging*	*Kriging*	*Kriging*	*Kriging*
MTL-NAVD88 (m)	1.21	1.4	1.31	1.47	1.4	1.21
GT Great Diurnal Tide Range (m)	6.267	5.583	5.85	8.889	7.5	5.953
Salt Elev. (m above MTL)	4.51	4	4.21	6.4	5.4	4.28
Marsh Erosion (horz. m /yr)	2	2	2	2	2	2
Swamp Erosion (horz. m /yr)	1	1	1	1	1	1
T.Flat Erosion (horz. m /yr)	1.75	1.75	1.75	1.75	1.75	1.75
Reg. Flood Marsh Accr (mm/yr)	3.6	3.6	3.6	3.6	3.6	3.6
Irreg. Flood Marsh Accr (mm/yr)	3.5	3.5	3.5	3.5	3.5	3.5
Tidal Fresh Marsh Accr (mm/yr)	4	4	4	4	4	4
Beach Sed. Rate (mm/yr)	5	5	5	5	5	5
Freq. Overwash (years)	0	0	0	0	0	0
Use Elev Pre-processor [True,False]	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE

SUMMARY OF SLAMM INPUT PARAMETERS FOR ANCHORAGE SITE

Description	Anchorage Alaska	Potter Marsh (Figure 10)
NWI Photo Date (YYYY)	2002	2002
DEM Date (YYYY)	2006	2006
Direction Offshore [n,s,e,w]	West	West
Historic Trend (mm/yr)	*Kriging*	*Kriging*
MTL-NGVD29 (m)	-0.28	-0.28
GT Great Diurnal Tide Range (m)	8.9	7
Salt Elev. (m above MTL)	5.92	4.55
Marsh Erosion (horz. m /yr)	2	2
Swamp Erosion (horz. m /yr)	1	1
T.Flat Erosion (horz. m /yr)	1.75	1.75
Reg. Flood Marsh Accr (mm/yr)	3.6	3.6
Irreg. Flood Marsh Accr (mm/yr)	3.5	3.5
Tidal Fresh Marsh Accr (mm/yr)	4	4
Beach Sed. Rate (mm/yr)	10	10
Freq. Overwash (years)	0	0

Use Elev Pre-processor [True,False]	FALSE	FALSE

Additional Model Parameterization

The "Salt Boundary" parameter within SLAMM designates the salt boundary -- the boundary between wet lands and dry lands or saline wetlands and fresh water wetlands. As such, this value may be best derived by examining historical tide gage data. For this application, the salt boundary was defined as the elevation above which inundation is predicted less than once per thirty days. Based on this analysis (Figure 15) the global SLAMM mean high water spring (MHWS) was set to 4.01 meters or 144% of the MHHW. Lands above this elevation are assumed to be free of saline influence for the most part (e.g. dry lands, inland fresh marsh, and swamps.)

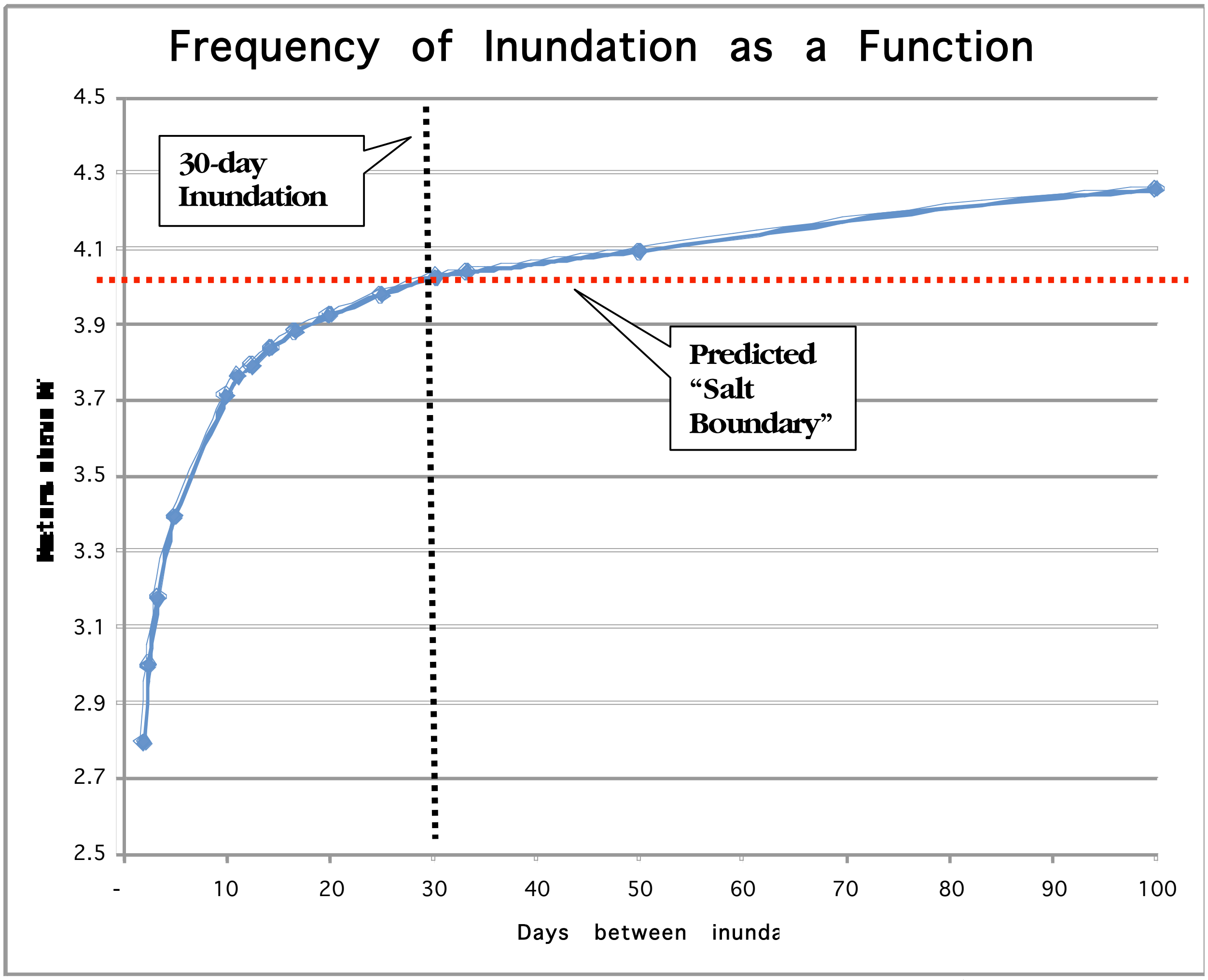


Figure 15: Frequency of inundation a function of tidal range based on 2006-2009 data from Nikiski, AK NOAA gage 9455760 (blue).

Given the thorough coverage of high-quality elevation data at these sites, it was also possible to closely examine SLAMM elevation range assumptions. A calculation of elevation statistics tabulated by SLAMM categories was performed for each study site. Due to the differences in sources of elevation data, the analysis is presented separately for Anchorage and Kenai Peninsula data.

An important caveat about this examination— as noted above, the Kenai Peninsula LiDAR data and NWI data are roughly 30 years apart. For this reason, there may be mismatches between what the model assumes is marsh and what the LiDAR shows as open water, for example.

To assess this potential difference we examined NWI polygons projected over current satellite imagery. For the most part, the NWI data seem to match current conditions fairly well. Beaches seemed to be subject to more changes, though it was often difficult to discern the edges of beaches in satellite imagery due to uncertainty as to what the tide level was when the photos were taken.

In some cases, though, this difference in time-stamps helps to explain why SLAMM predicts some immediate changes in land cover. For example, in Kachemak bay, SLAMM predicts the immediate disappearance of some beaches which seems to be borne out by this NWI-to-satelite examination Figure 16.

Figure 16: Possible Discrepancy between Satellite Imagery and NWI Beach Cover Class in Kachemak Bay.

The elevation analysis for Kenai Peninsula reveals that tidal flat, ocean beach and estuarine beach match reasonably well with the lower boundary SLAMM expectations. The lower boundary is most important because when land cover classes are predicted to move below this level they convert to another SLAMM category. Regularly and irregularly flooded marshes do not match as well, possibly due to historical land uplift combined with the difference between NWI and DEM dates (Figure 17). Marshes that are located in a higher elevation with respect to mean tide level tend to be more resilient to the effects of sea level rise. Note that SLAMM does not predict marshes to dry up when they exceed their upper boundary, however.

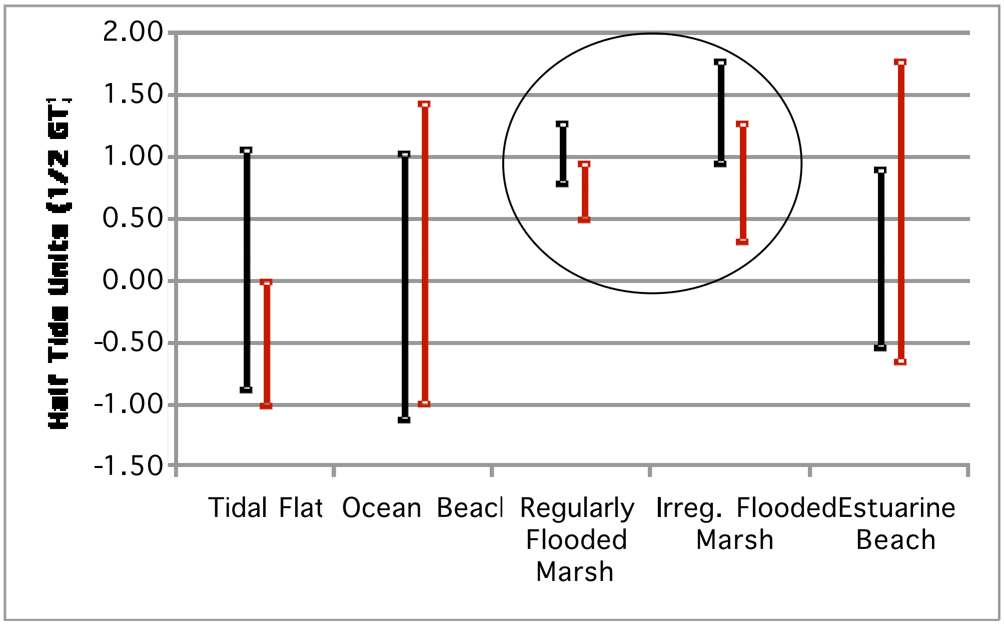


Figure 17: 5th to 95th Percentile Comparison, LiDAR data vs. SLAMM Expectations, Kenai Peninsula Site

(LiDAR data are in Black, SLAMM expectations in Red.)

The elevation analysis for Anchorage reveals that swamp and inland fresh marsh match SLAMM expectations pretty well, both matching the salt boundary lower elevation limit. Dry lands fall well above the assumed salt boundary indicating that extensive dry land inundation is not imminent at this site. On the other hand, tidal flats and estuarine beach elevation ranges do not match SLAMM expectations, falling well above the expected lower bound. This is likely caused by the limitations in the input data set, in which contours did not extend to tidal flats and beaches (Figure 6). For this reason, SLAMM predictions of tidal flat and beach vulnerability are highly uncertain for this study area.

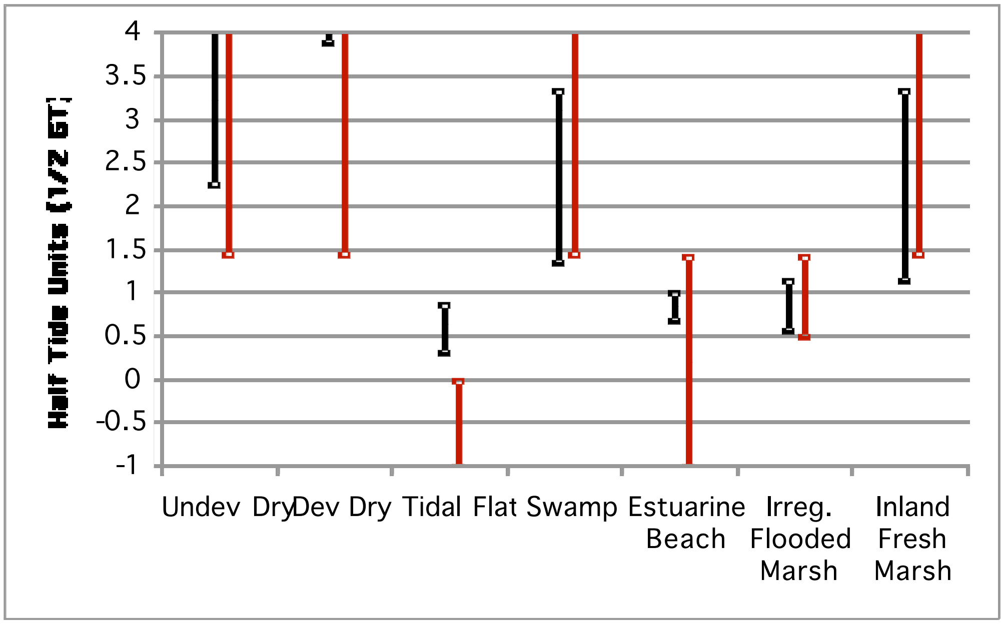


Figure 18: 5th to 95th Percentile Comparison, LiDAR data vs. SLAMM Expectations, Anchorage
(LiDAR data are in Black, SLAMM expectations in Red.)

A full accounting of site-specific elevation ranges are shown in the tables below. In order to test the assumption that wetlands are located in elevations as a function of tidal range, results are given in "half tide units" or half the great diurnal tide.

Kenai Peninsula-Specific Elevation Ranges

Numbers are "half-tide" units relative to mean tide level

SLAMM Category	n cells	mean (HTU)	5th Pctile (HTU)	95th Pctile (HTU)
Undeveloped Dry Land	4159333	64.55	8.06	197.90
Swamp	962869	29.54	3.13	137.02
Inland Open Water	221566	16.37	8.08	26.36
Inland Fresh Marsh	173871	37.83	6.44	147.88
Tidal Flat	102206	0.20	-0.88	1.07
Ocean Beach	74317	-0.01	-1.12	1.04
Developed Dry Land	64836	16.34	3.48	34.13
Regularly Flooded Marsh	61160	1.06	0.79	1.27
Irreg. Flooded Marsh	23324	1.20	0.95	1.78
Estuarine Beach	8785	0.19	-0.53	0.90
Tidal Fresh Marsh	4483	1.31	1.02	1.51
Riverine Tidal	4314	1.82	-0.12	4.12
Inland Shore	1031	2.63	1.31	4.46
Tidal Swamp	463	14.90	2.74	23.27
Transitional Salt Marsh	39	1.39	1.21	1.54

Anchorage-Specific Elevation Ranges

Numbers are "half-tide" units relative to mean tide level

SLAMM Category	Number of Cells	Mean	5th Pctile	95th Pctile
Undeveloped Dry Land	103606	3.23	2.25	3.35
Developed Dry Land	80785	3.28	3.34	3.35
Tidal Flat	29643	0.66	0.33	0.88
Swamp	11225	3.11	1.36	3.35
Estuarine Beach	9006	0.86	0.70	1.02
Irreg. Flooded Marsh	7421	1.02	0.58	1.15
Inland Fresh Marsh	3121	3.18	1.41	3.35
Inland Open Water	2773	3.16	1.43	3.35
Tidal Swamp	1120	1.21	1.11	1.36
Transitional Salt Marsh	574	1.06	0.88	1.20
Tidal Creek	67	0.74	0.24	0.99
Tidal Fresh Marsh	56	1.17	1.15	1.26
Inland Shore	40	1.80	0.61	3.35

Riverine Tidal	17	1.16	0.33	1.70

Model Results

Kenai Peninsula

The Kenai Peninsula study site consists mostly of dry land, with swamp and inland fresh marsh being the second and third most common land categories.

Looking at the entire peninsula, less than 1% of dry land is predicted to be lost to the effects of sea level rise. Between 0% and 2% of the total study area swamp lands are predicted to be lost across all scenarios. The site is predicted to lose 14% to 15% of its tidal flat. Some of this loss is likely to have already occurred, since the 1977 NWI initial condition. Additional loss is predicted primarily due to erosion.

Substantial losses of ocean beach seem to be triggered at eustatic rates of sea level rise above 1.5 meters. Ocean beach predictions are uncertain, however, due to highly spatially variable erosion and sedimentation rates that are may not be accurately predicted by the SLAMM model.

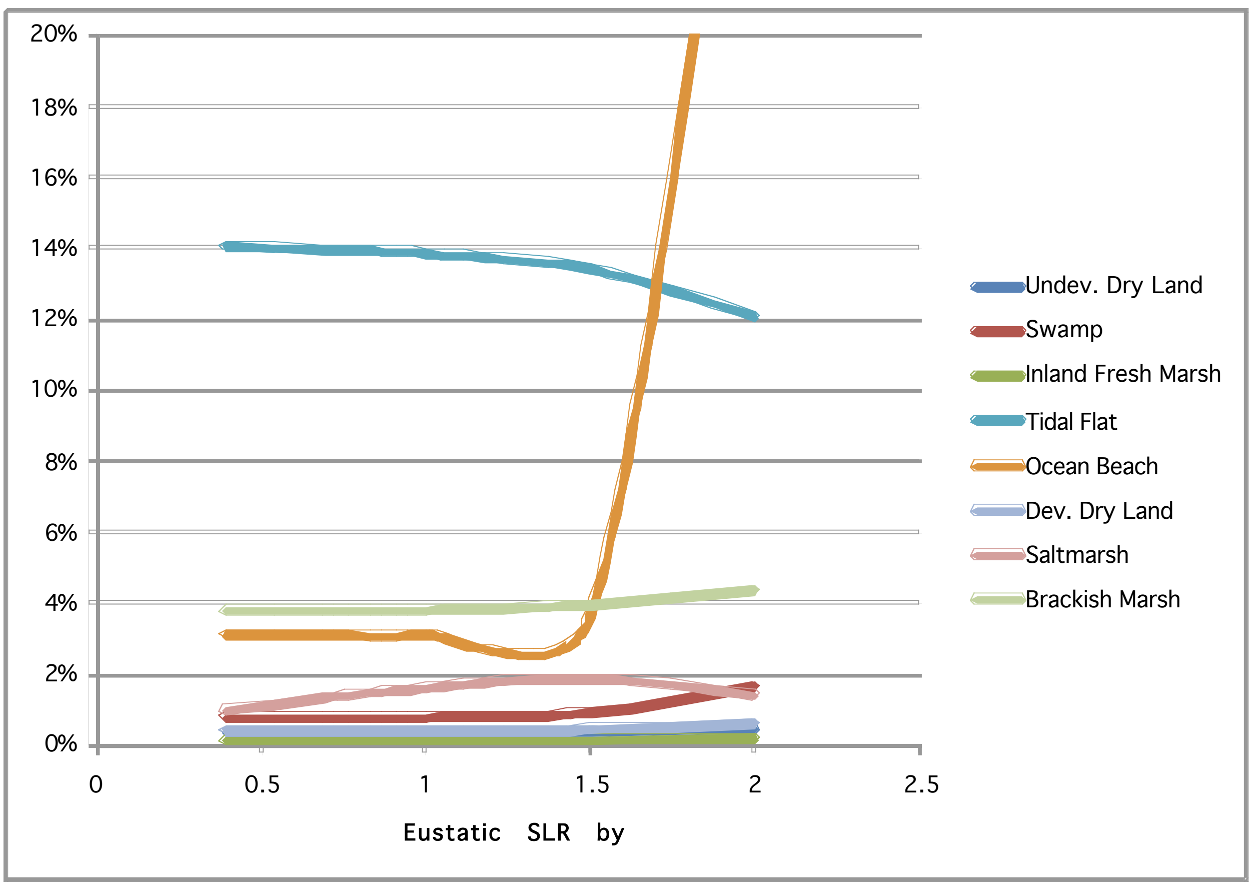


Figure 19: Rates of Land Loss for **Kenai Peninsula**

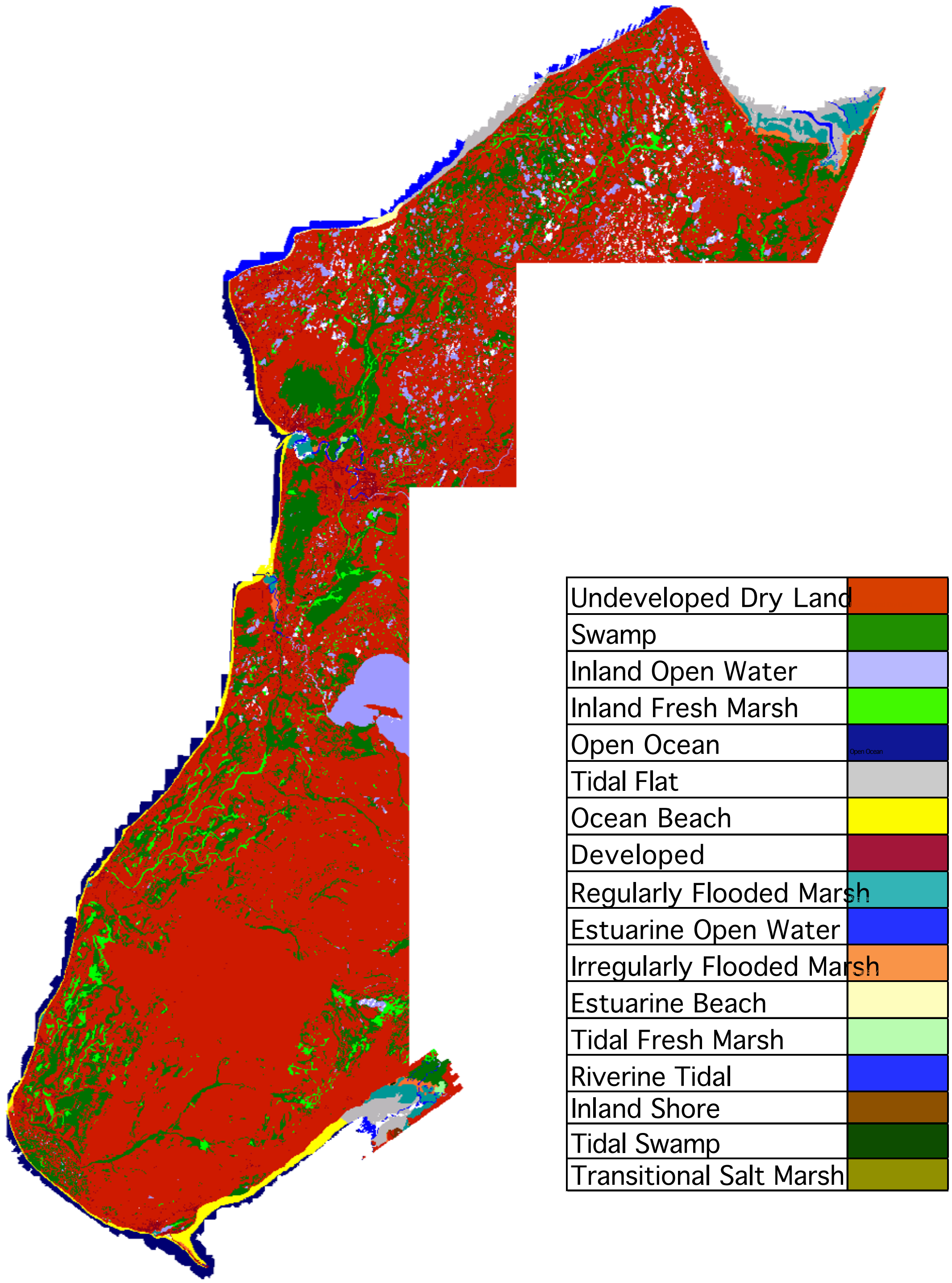
Kenai Peninsula Study Area

SLR by 2100 (m)	0.39	0.69	1	1.5	2
Undeveloped Dry Land	0.4%	0.4%	0.4%	0.4%	0.5%
Swamp	0.8%	0.8%	0.8%	0.9%	1.7%
Inland Fresh Marsh	0.2%	0.2%	0.2%	0.2%	0.2%
Tidal Flat	14.1%	14.0%	13.9%	13.4%	12.1%
Ocean Beach	3.1%	3.1%	3.1%	3.7%	31.7%
Developed Dry Land	0.4%	0.4%	0.4%	0.4%	0.6%
Regularly Flooded Marsh	1.0%	1.3%	1.6%	1.9%	1.4%
Irregularly Flooded Marsh	3.8%	3.8%	3.8%	4.0%	4.4%
Tidal Fresh Marsh	4.4%	4.4%	4.3%	4.4%	27.9%
Riverine Tidal	33.0%	33.3%	33.8%	36.0%	39.3%

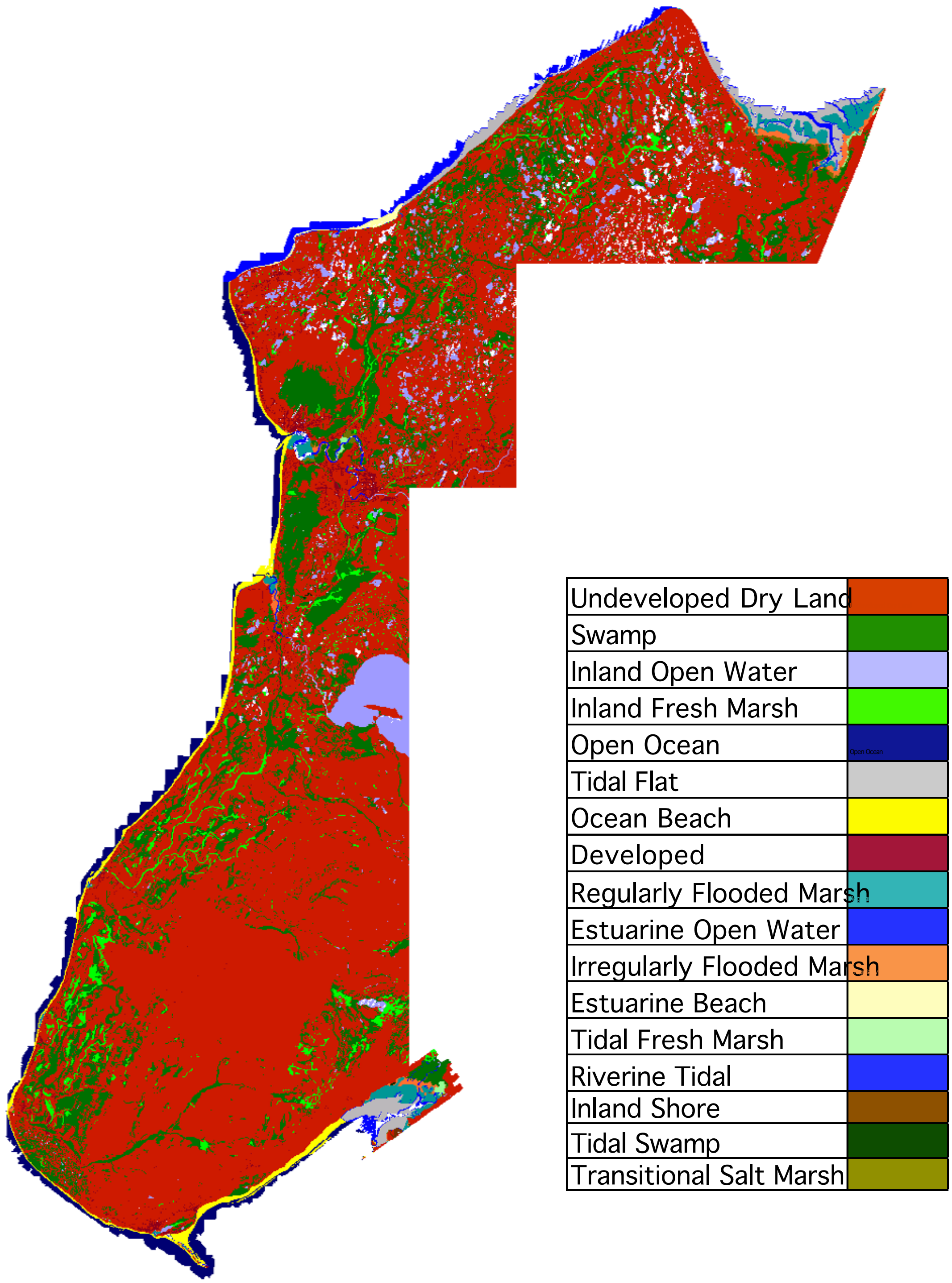
Predicted Loss Rates by Land Category and Eustatic SLR Scenario

Because predicted changes within the Alaska study area are relatively gradual, primarily due to the uplift of land, maps of results are shown as initial conditions followed by year 2100 predictions under many different scenarios of SLR. Predictions are shown ranging from 0.4 to 2.0 meters of eustatic SLR by 2100. Results maps for all scenarios for years 2025, 2050, 2075, and 2100 are availble upon request either in Microsoft Word or GIS Raster formats.

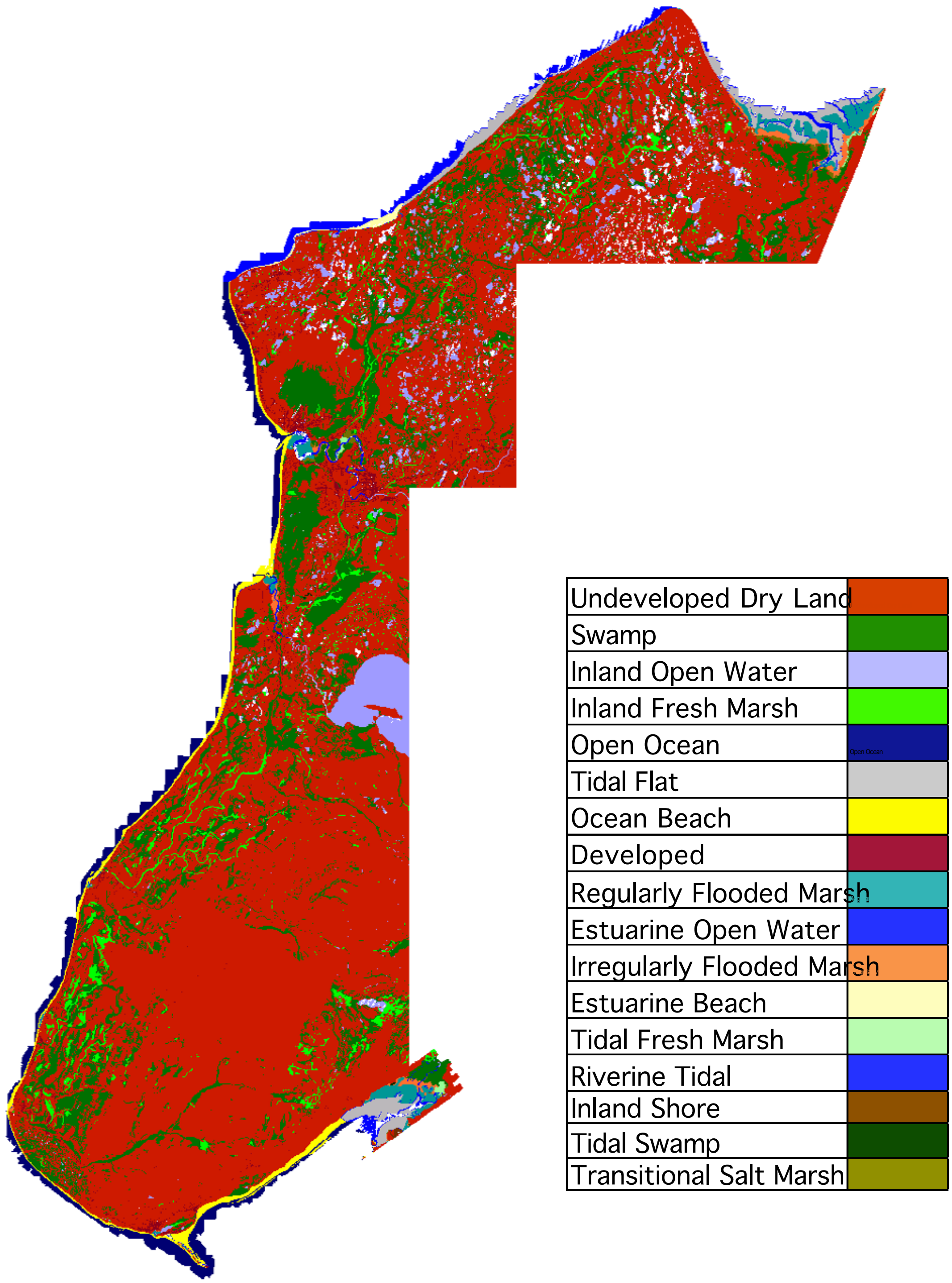
Maps of Entire Kenai Peninsula



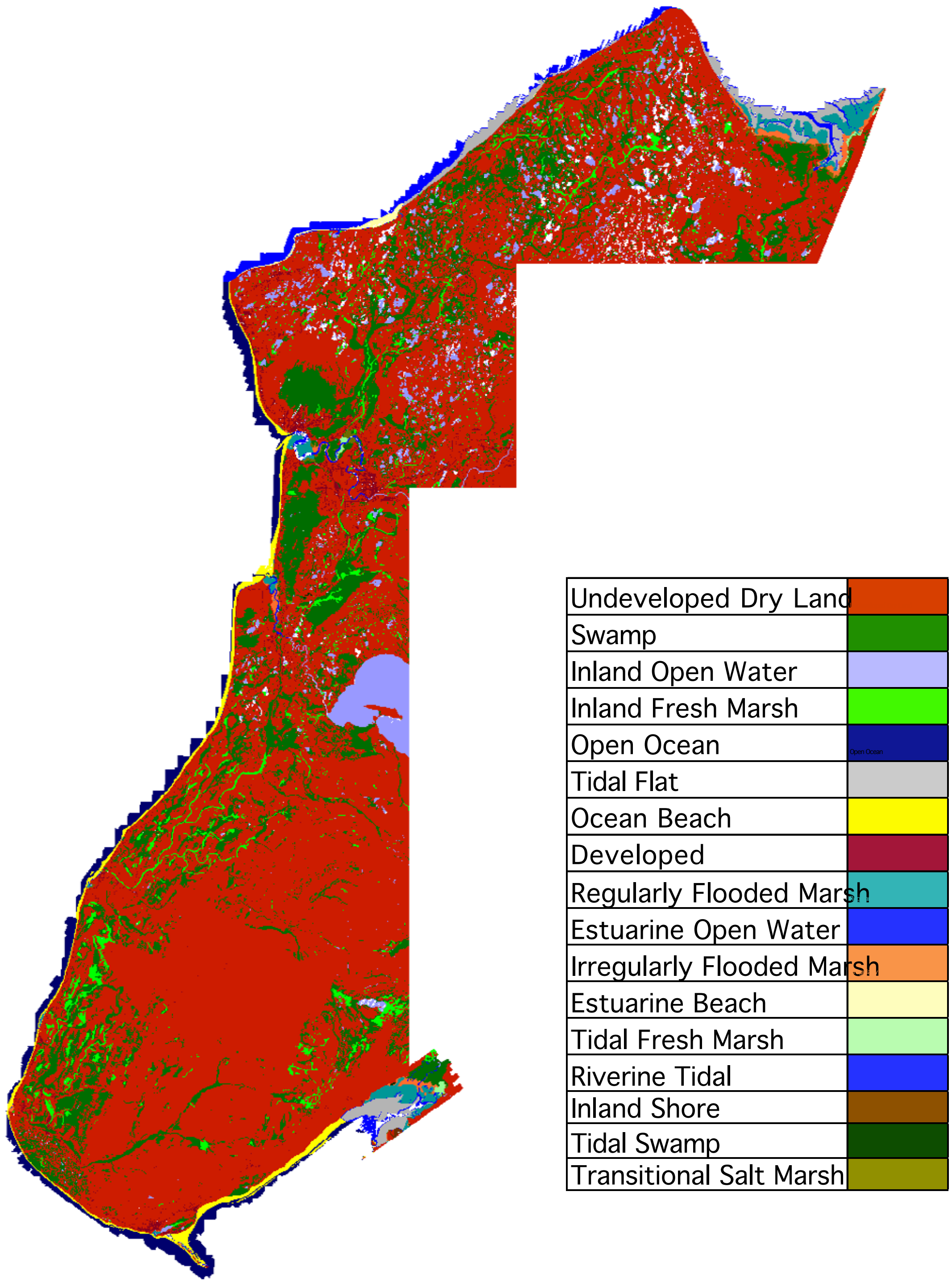
Kenai Peninsula, Initial Condition



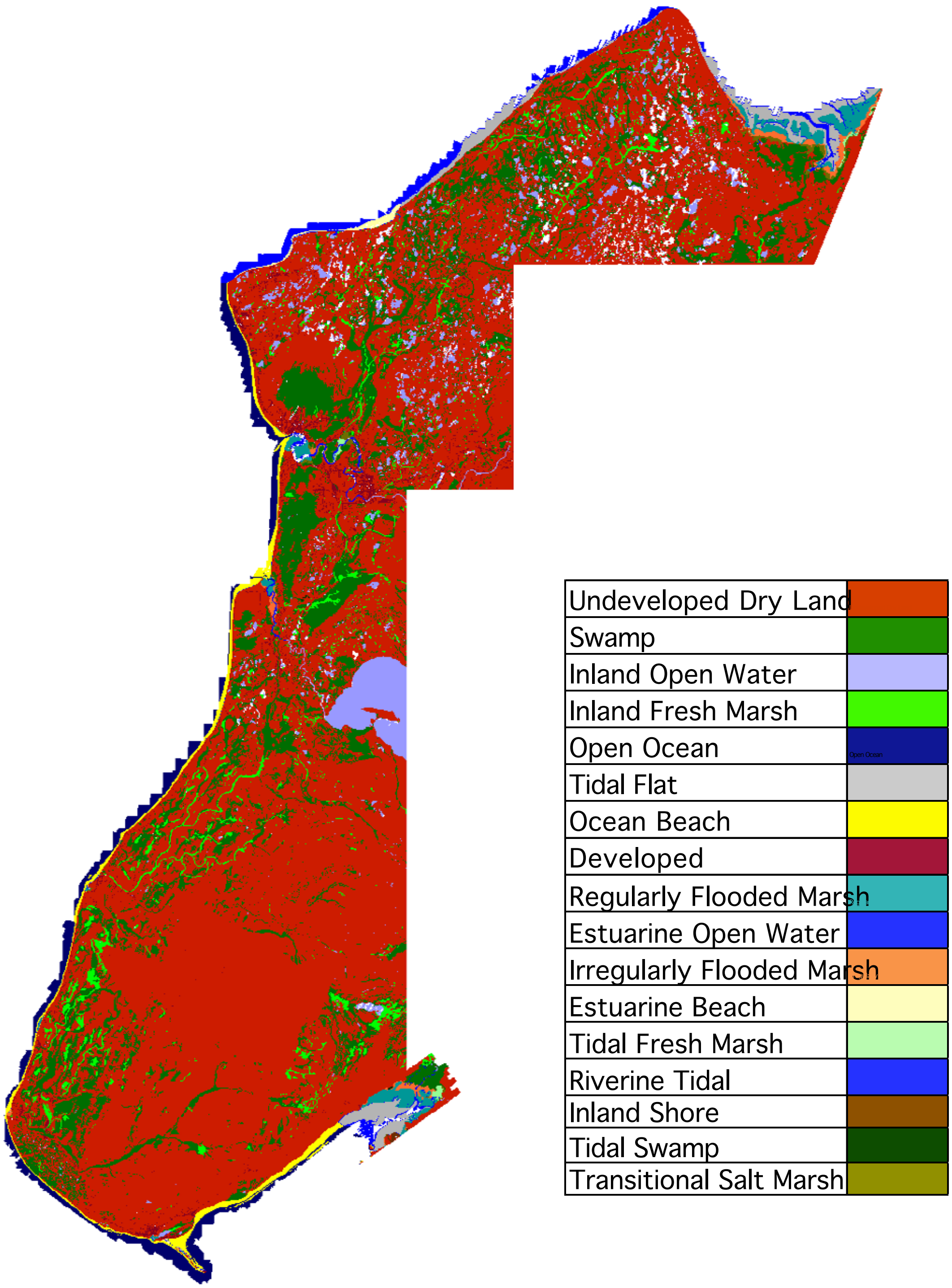
Kenai Peninsula, A1B-Mean (0.39M Eustatic SLR)



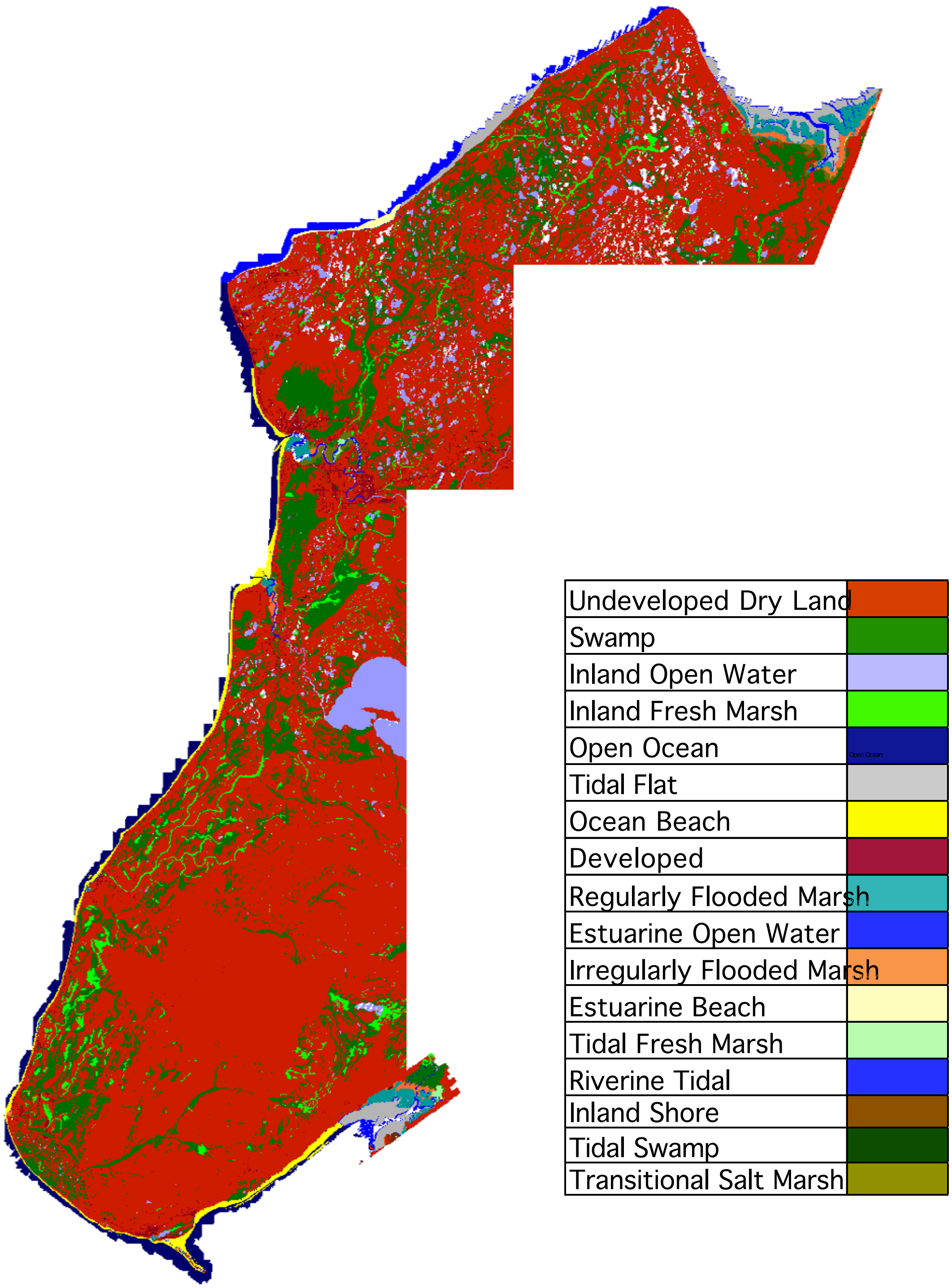
Kenai Peninsula, A1B-Max (0.69M Eustatic SLR)



Kenai Peninsula, 1M Eustatic SLR by 2100

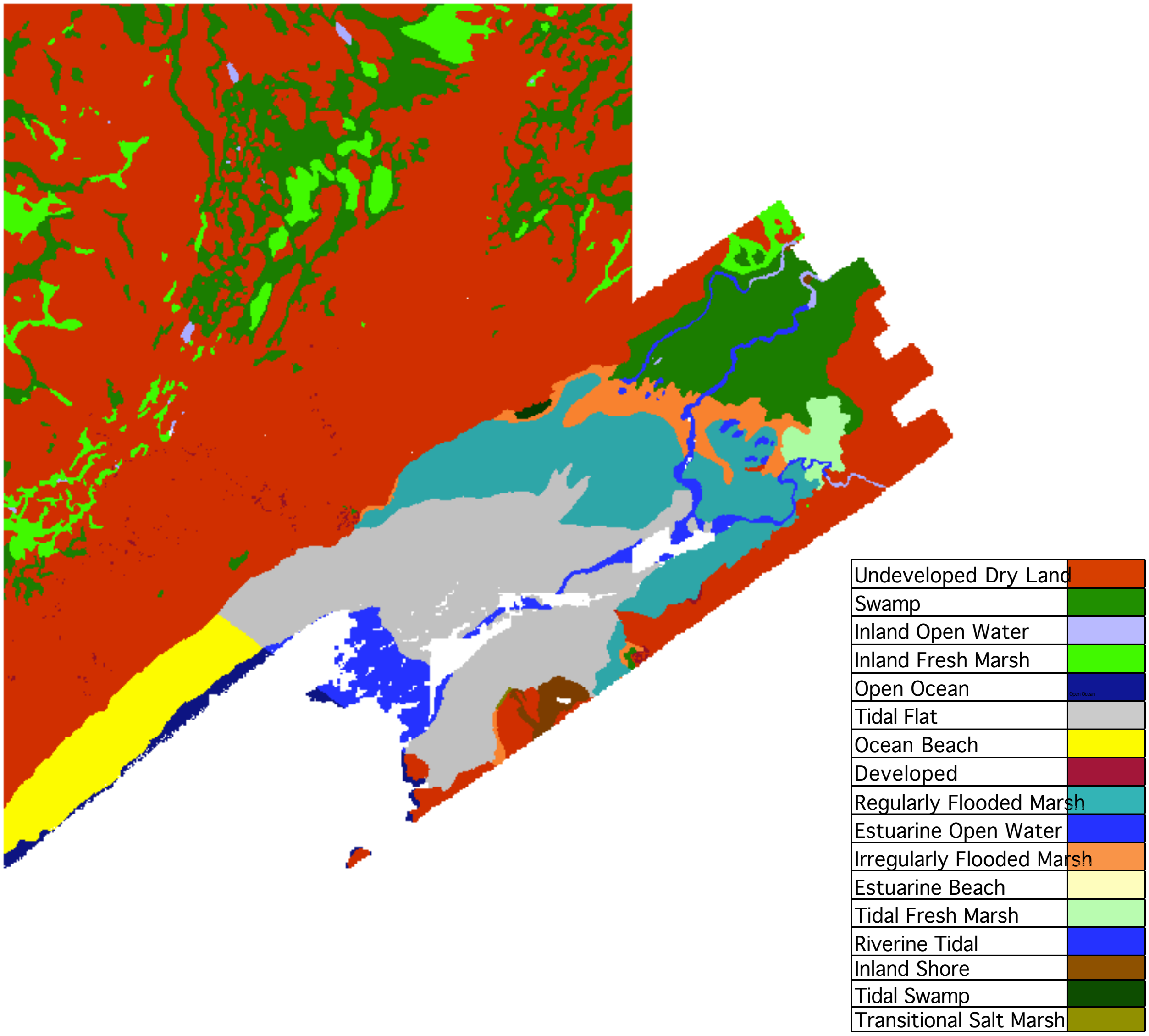


Kenai Peninsula, 1.5M Eustatic SLR by 2100



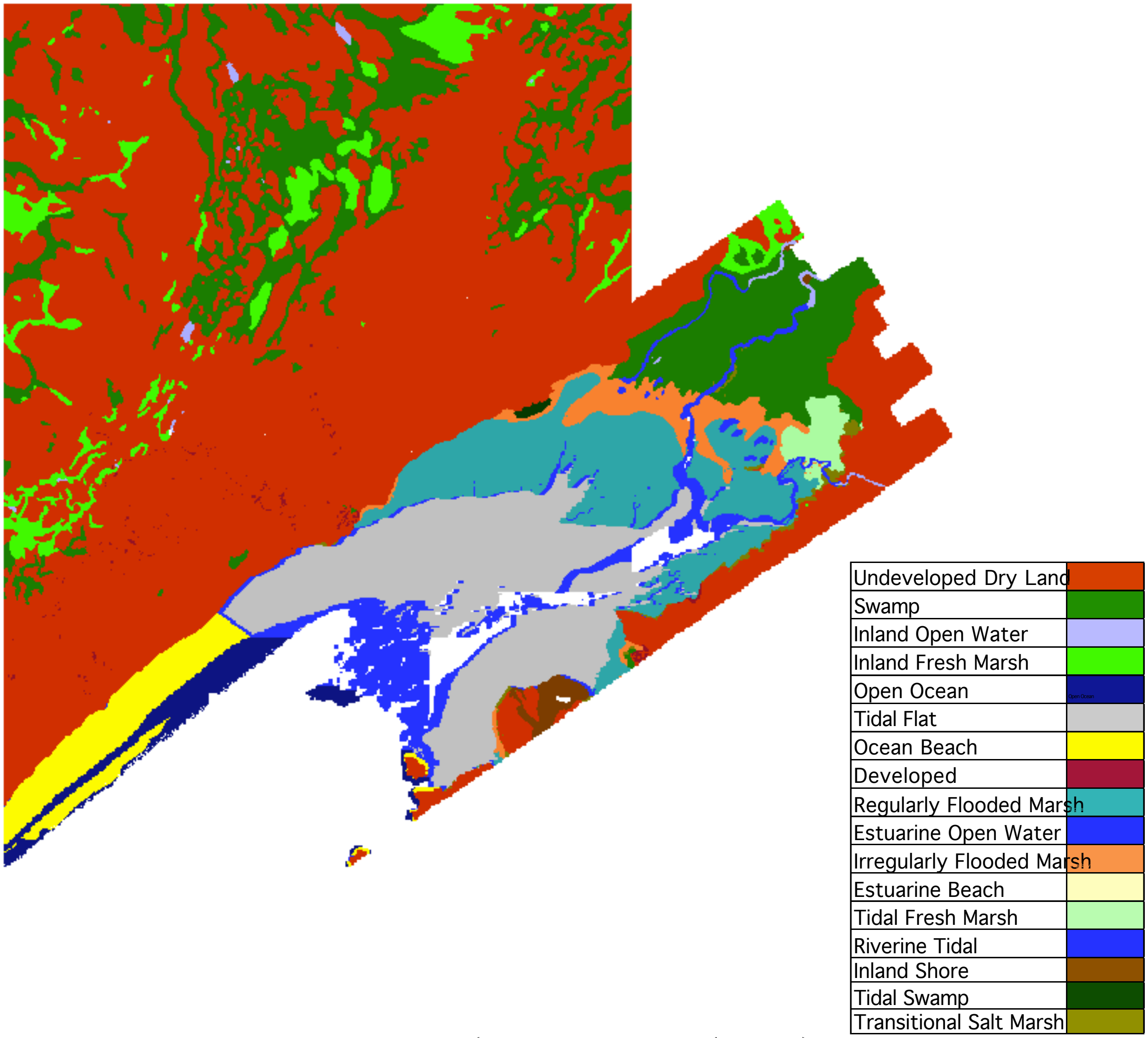
Kenai Peninsula, 2M Eustatic SLR by 2100

Fox River Flats (Eastern Kachemak Bay)

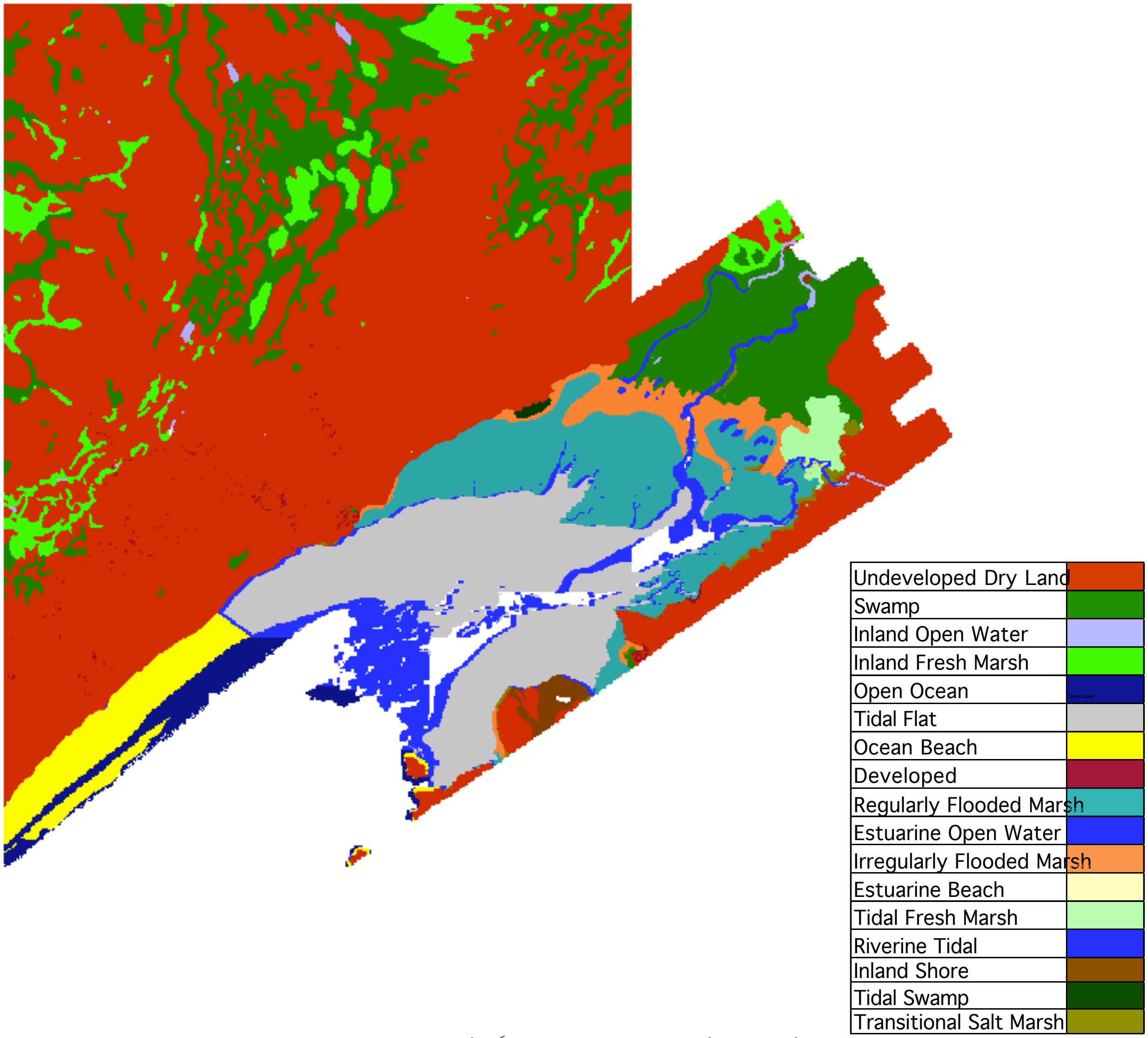


Initial Condition

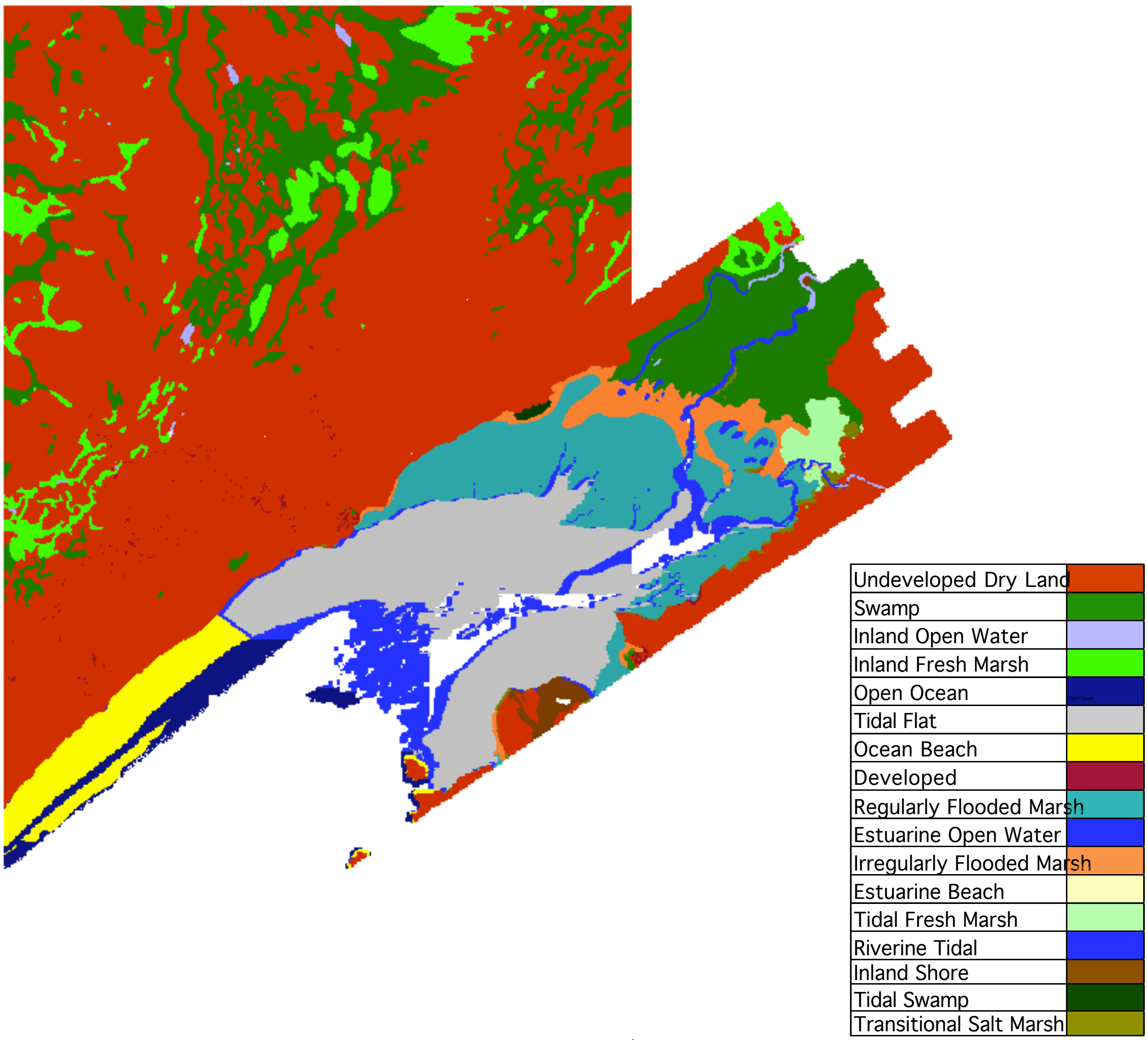
The ocean beach to the west of this "output site" is predicted to be reformulated, primarily as a result of the initial condition LiDAR elevations we received for this site. Tidal flat erosion is predicted to occur at this site, though the model does not predict the precise spatial location of such erosion.



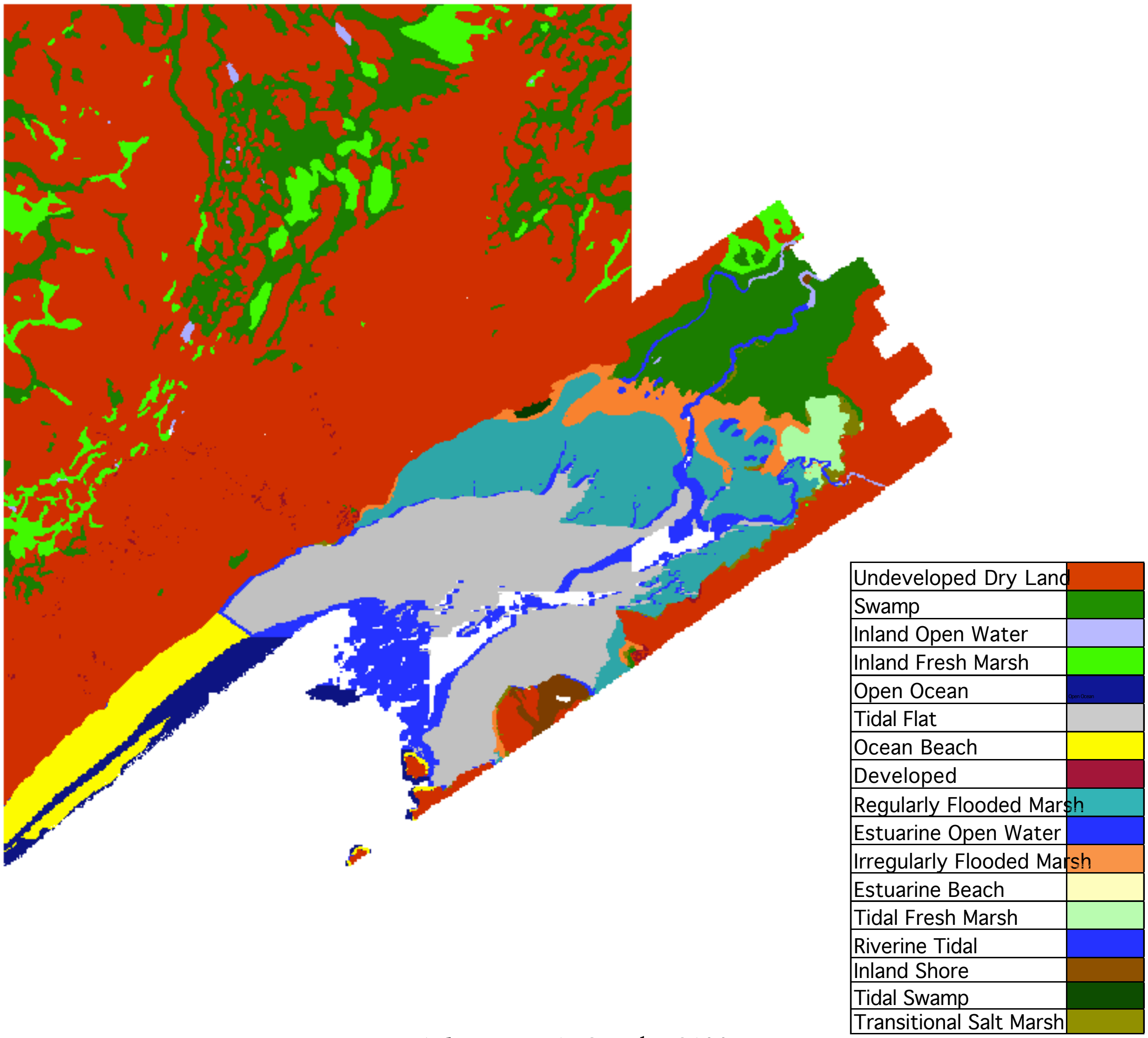
A1B-Mean (0.39M Eustatic SLR by 2100)



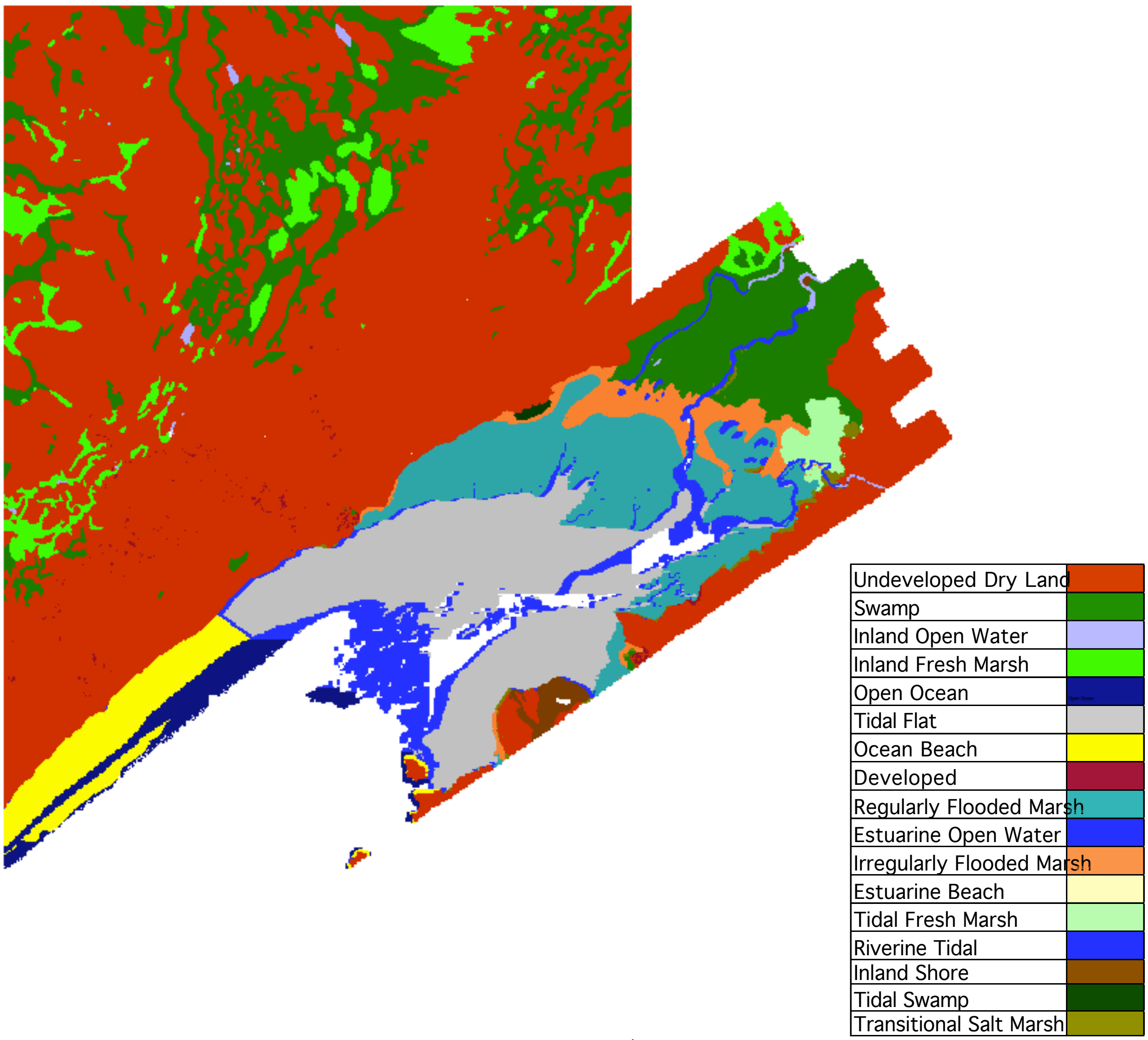
A1B-Max (0.69M Eustatic SLR by 2100)



1M Eustatic SLR by 2100

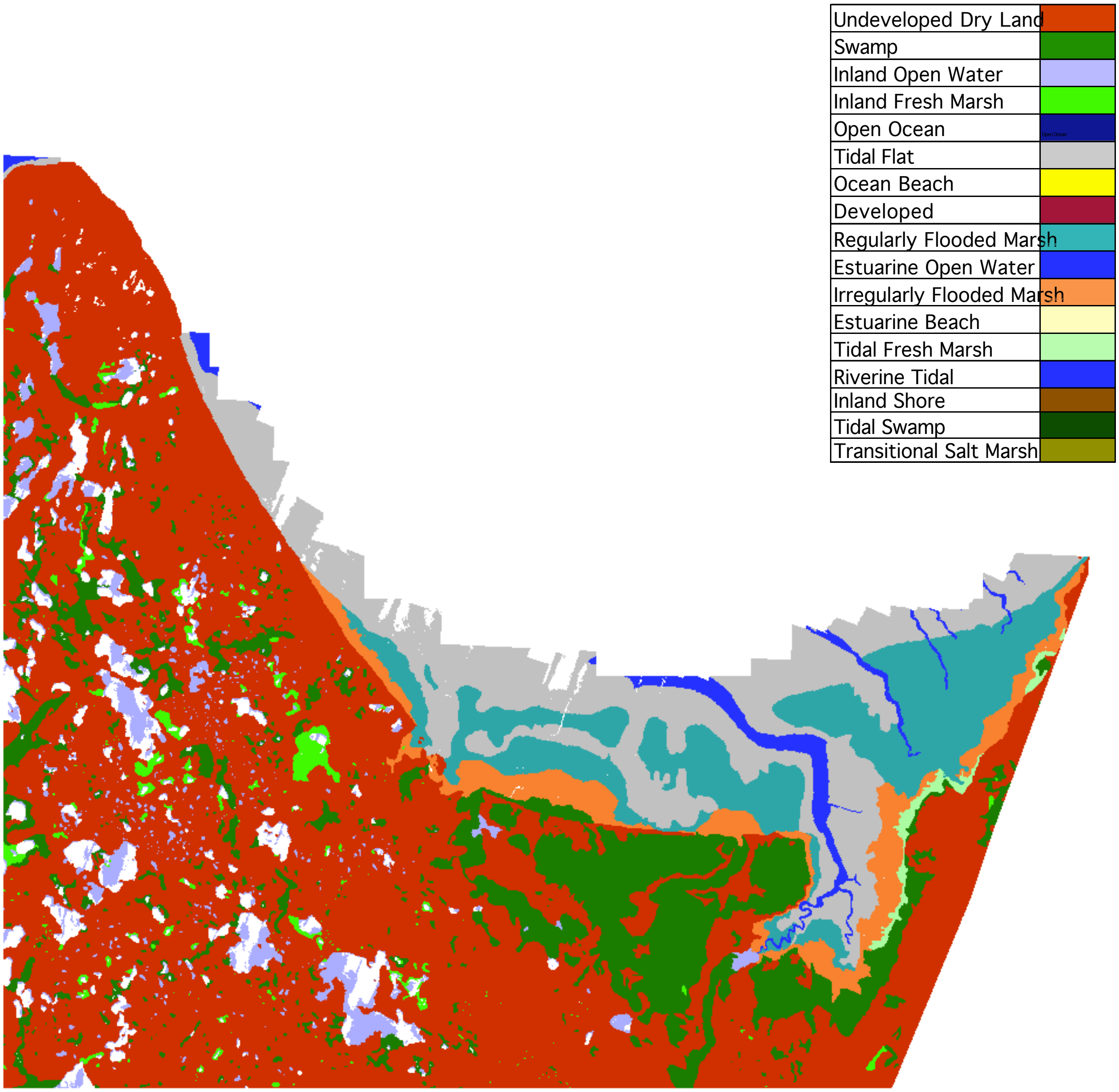


1.5M Eustatic SLR by 2100



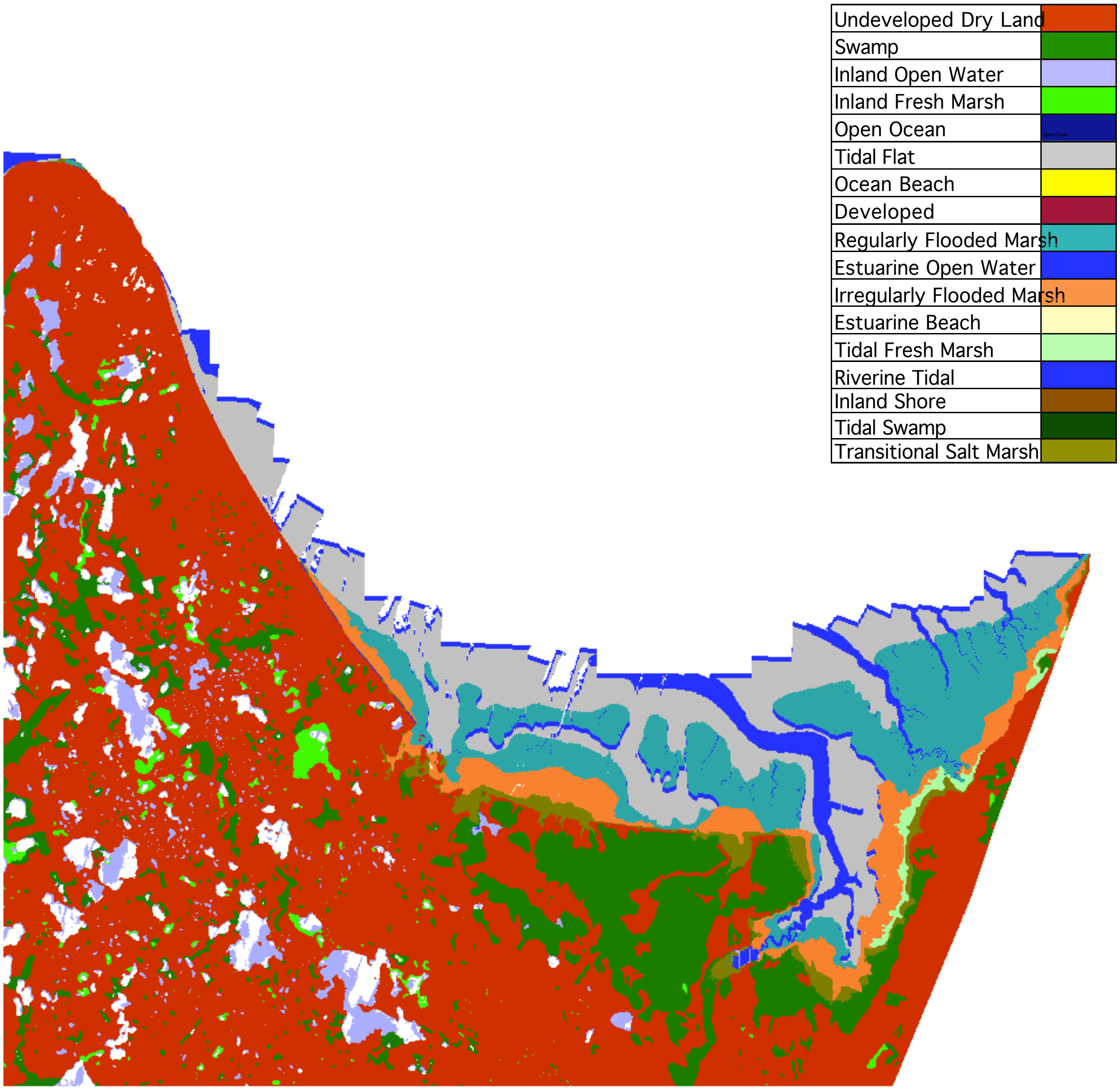
2M Eustatic SLR by 2100

Chickaloon Bay

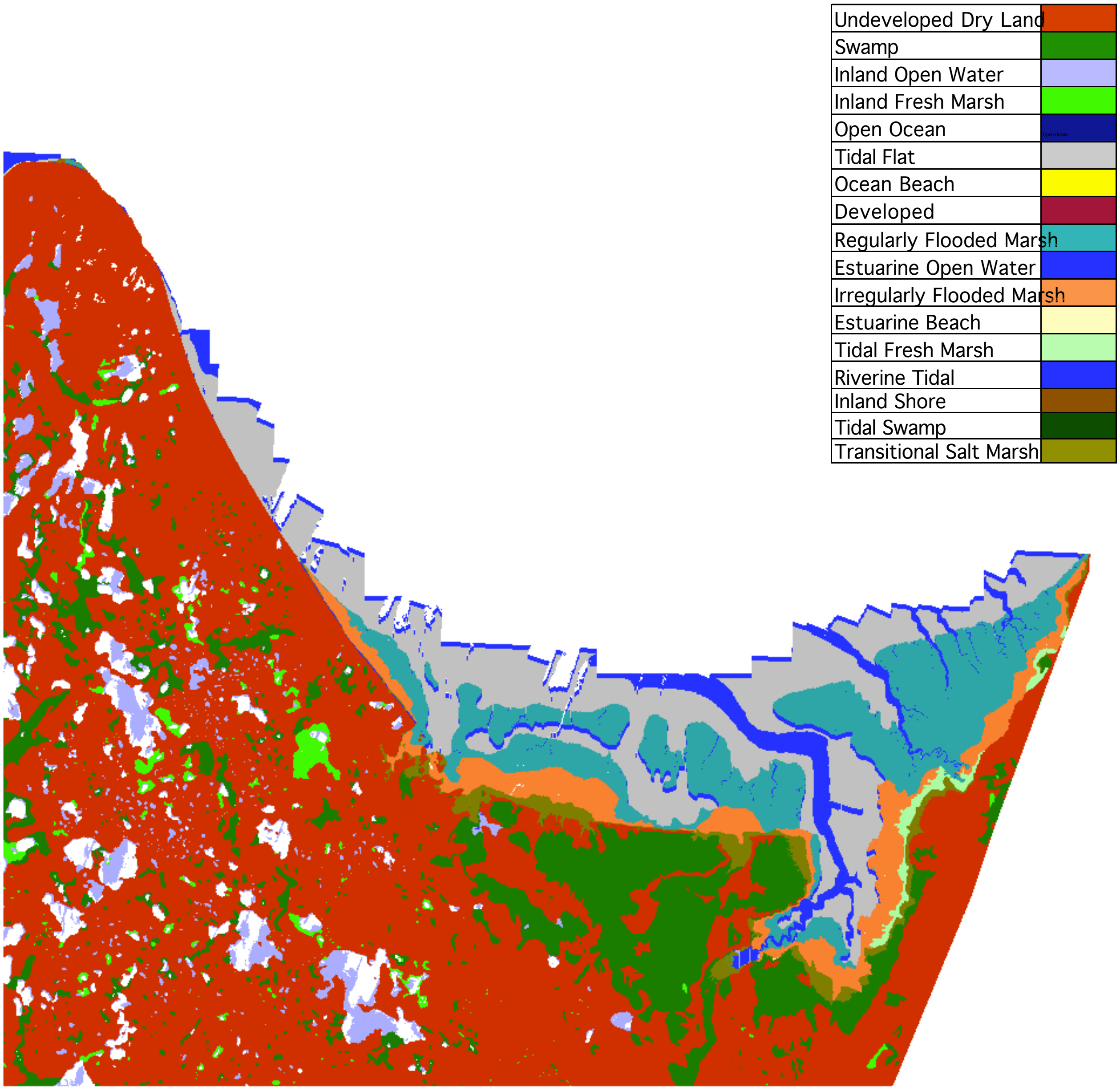


Initial Condition

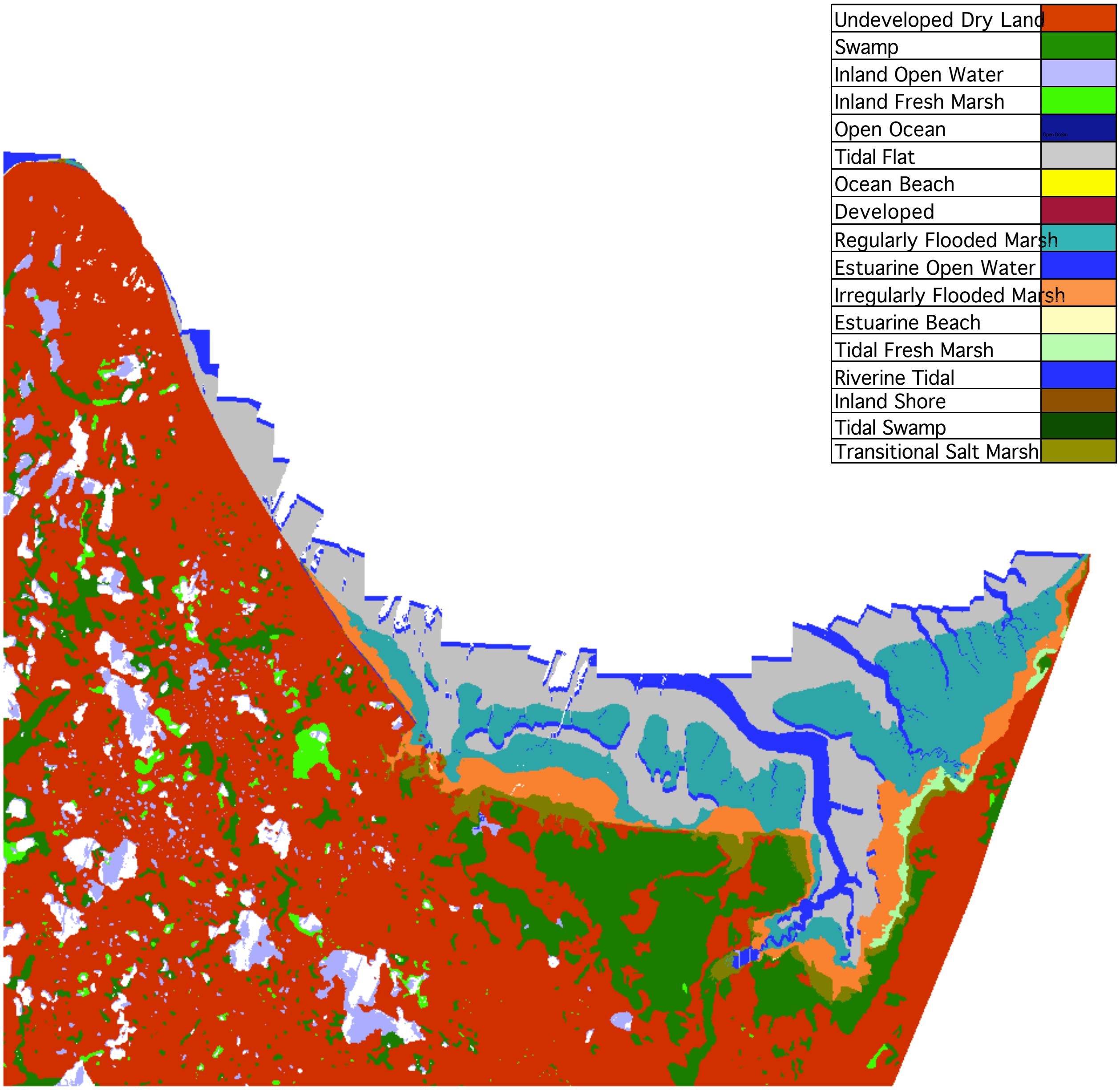
Fresh-water swamps at the south of this site are predicted to start to convert to transitional salt marsh as they fall below the salt boundary. The spatial extent of this conversion depends on the sea level rise scenario utilized.



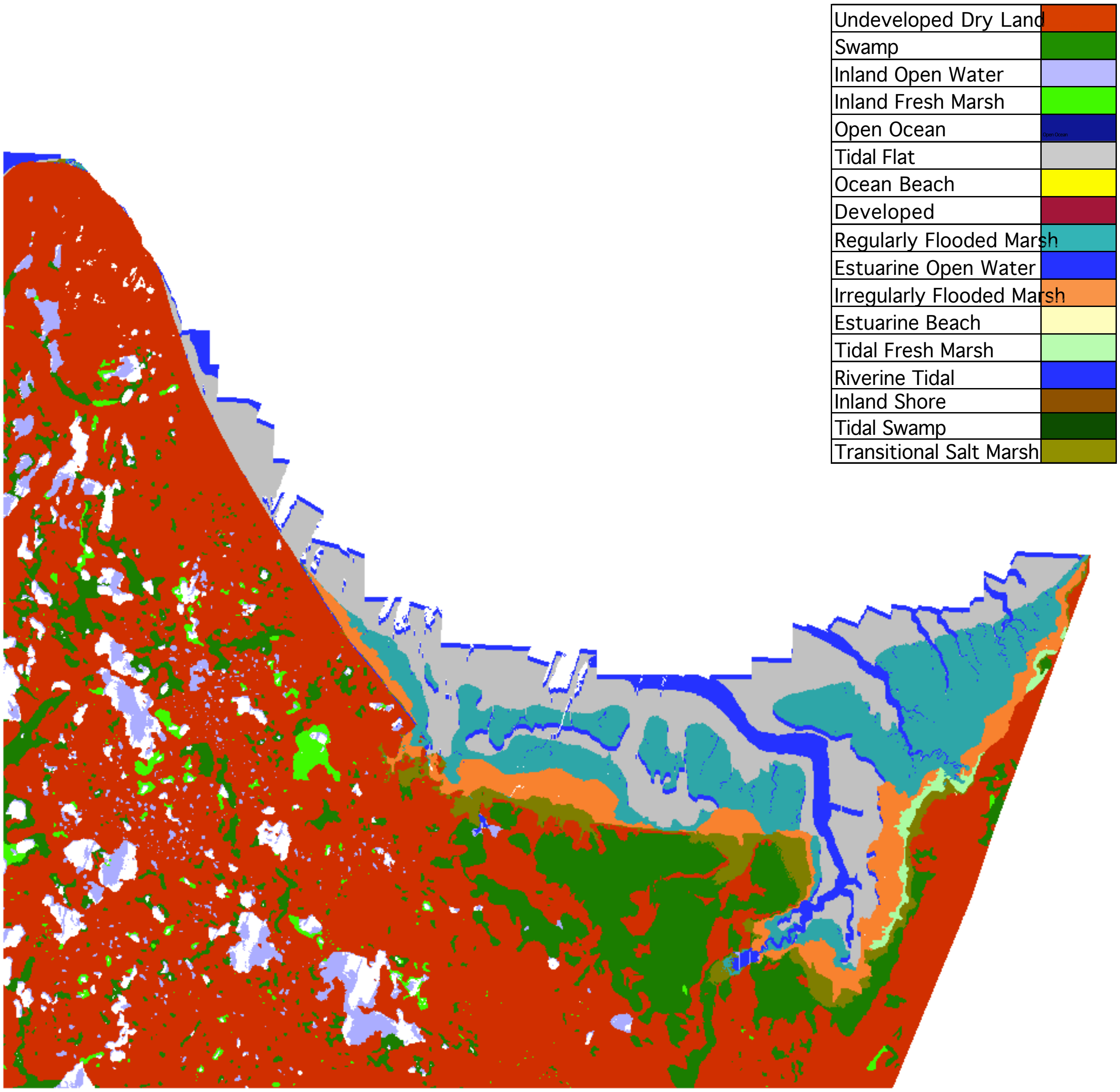
A1B-Mean (0.39M Eustatic SLR by 2100)



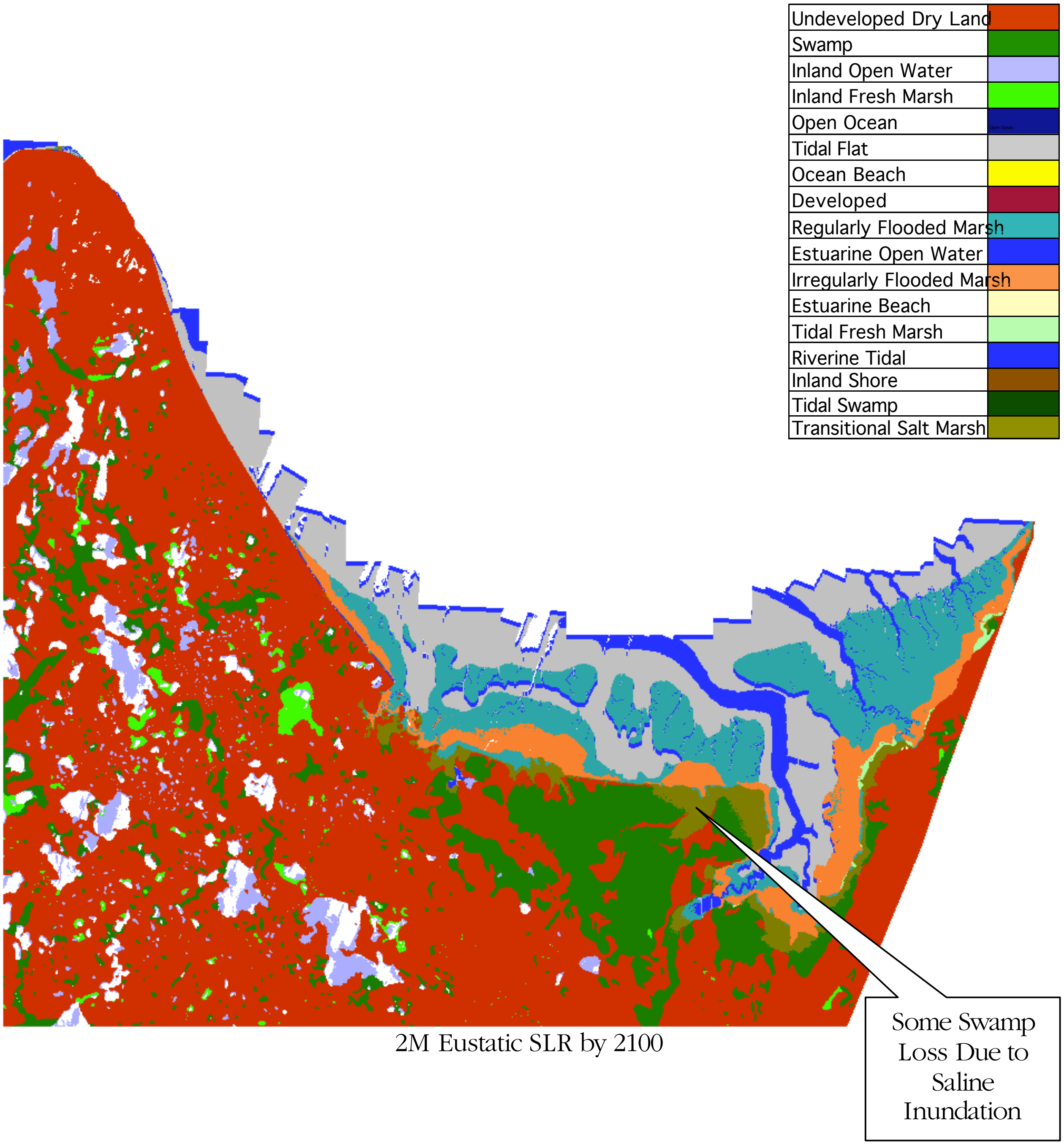
A1B-Max (0.69M Eustatic SLR by 2100)



1M Eustatic SLR by 2100

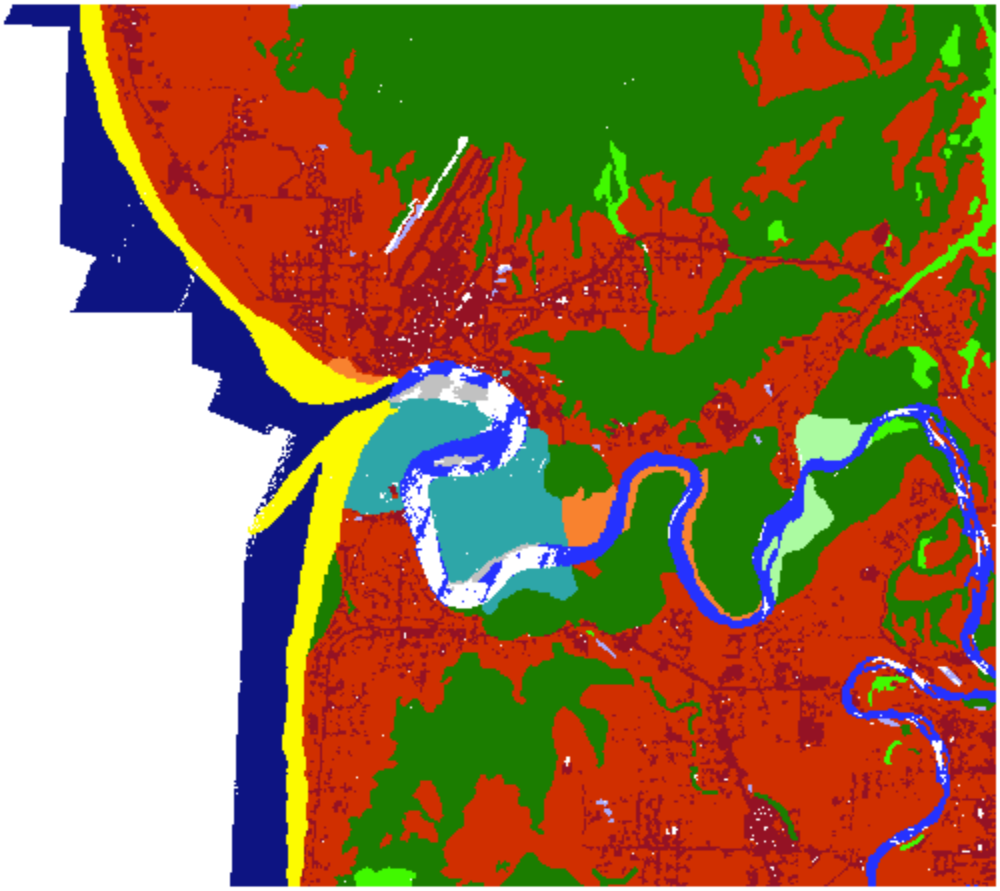


1.5M Eustatic SLR by 2100



2M Eustatic SLR by 2100

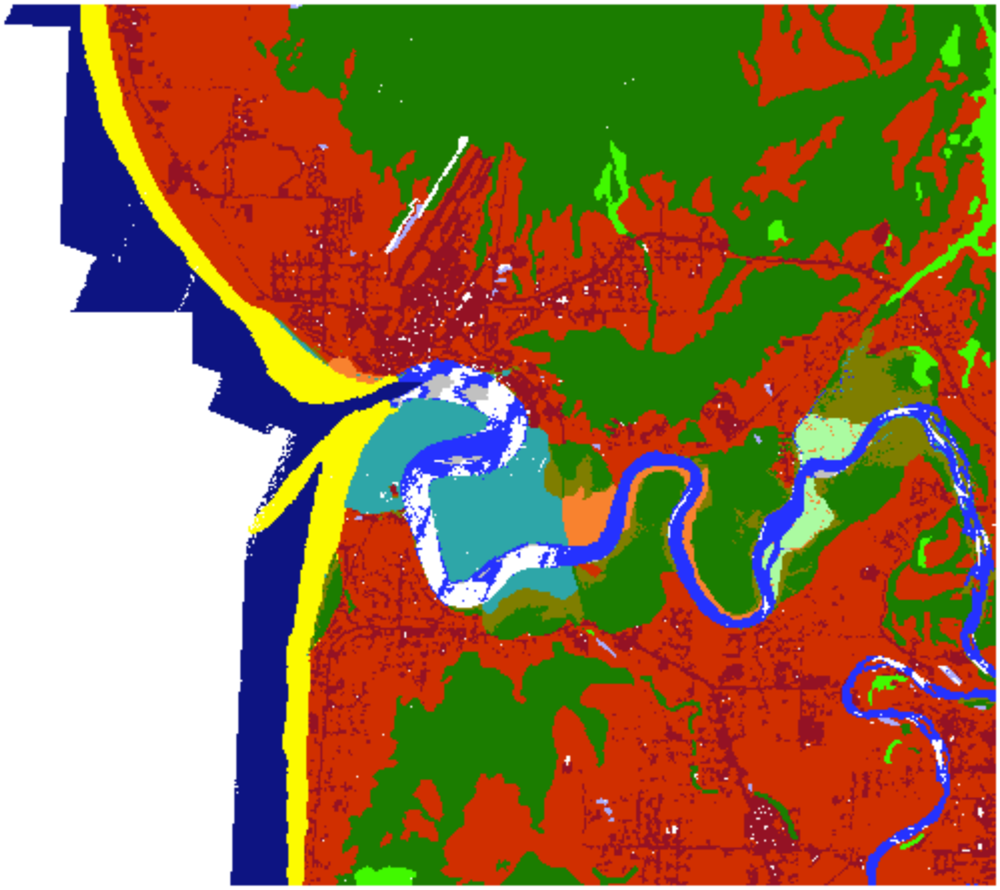
City of Kenai



Initial Condition

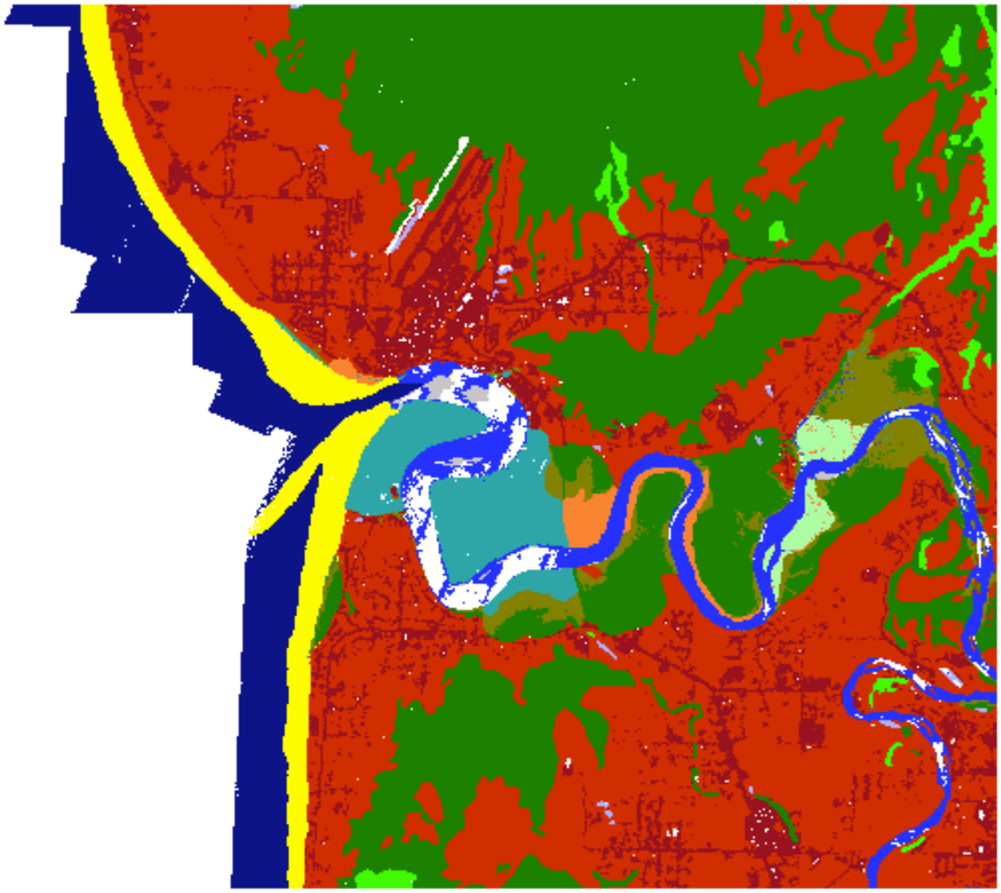
The fresh-water swamps along the Kenai River are predicted to start to show salinity effects, especially under the highest rate of SLR simulated (2 meters by 2100).

Undeveloped Dry Land	
Swamp	
Inland Open Water	
Inland Fresh Marsh	
Open Ocean	
Tidal Flat	
Ocean Beach	
Developed	
Regularly Flooded Marsh	
Estuarine Open Water	
Irregularly Flooded Marsh	
Estuarine Beach	
Tidal Fresh Marsh	
Riverine Tidal	
Inland Shore	
Tidal Swamp	
Transitional Salt Marsh	

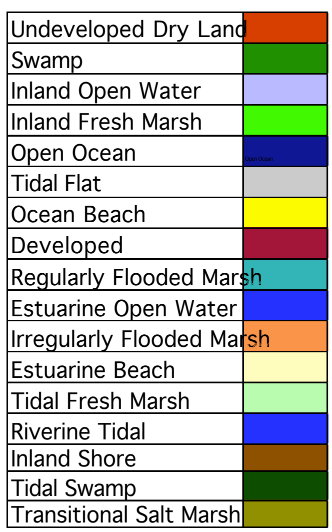


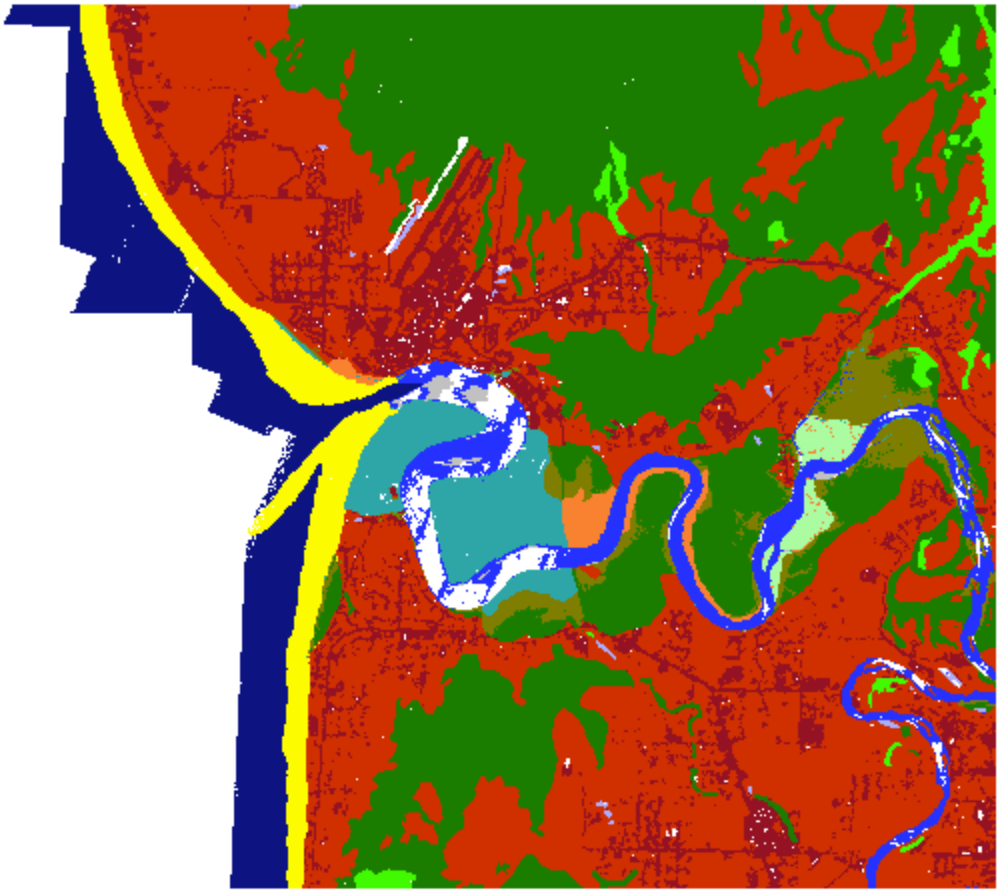
A1B-Mean (0.39M Eustatic SLR by 2100)

Undeveloped Dry Land
Swamp
Inland Open Water
Inland Fresh Marsh
Open Ocean
Tidal Flat
Ocean Beach
Developed
Regularly Flooded Marsh
Estuarine Open Water
Irregularly Flooded Marsh
Estuarine Beach
Tidal Fresh Marsh
Riverine Tidal
Inland Shore
Tidal Swamp
Transitional Salt Marsh



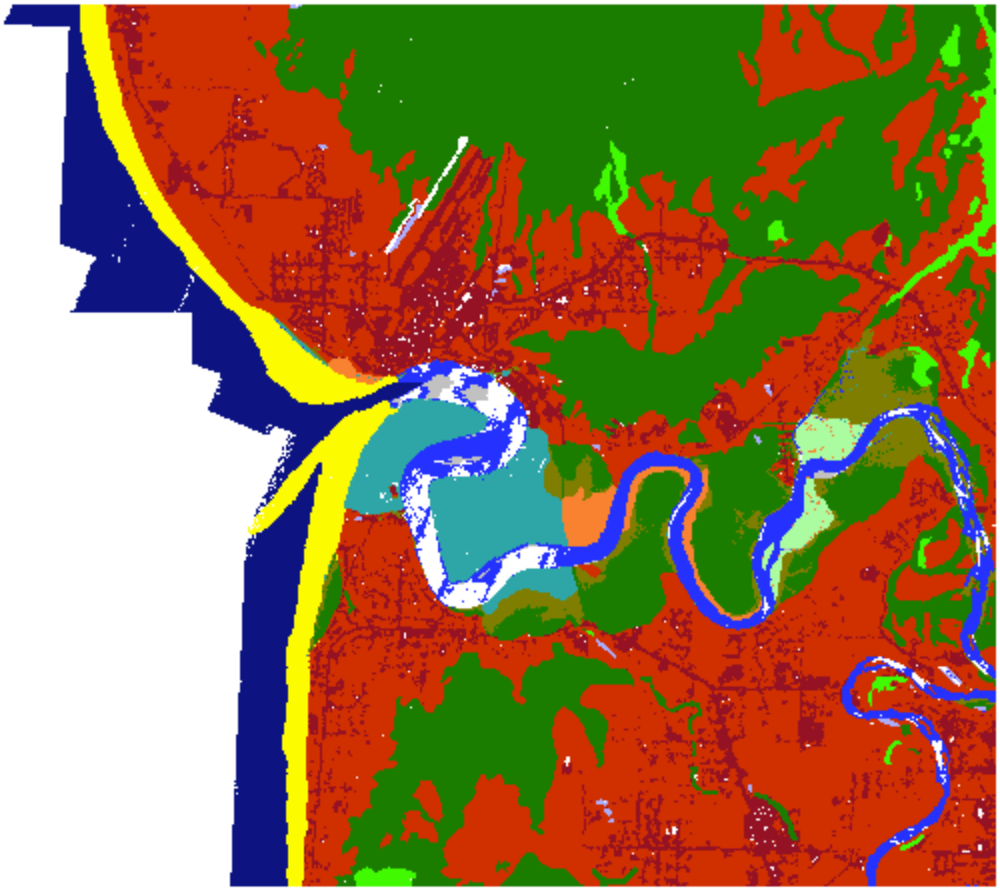
A1B-Max (0.69M Eustatic SLR by 2100)





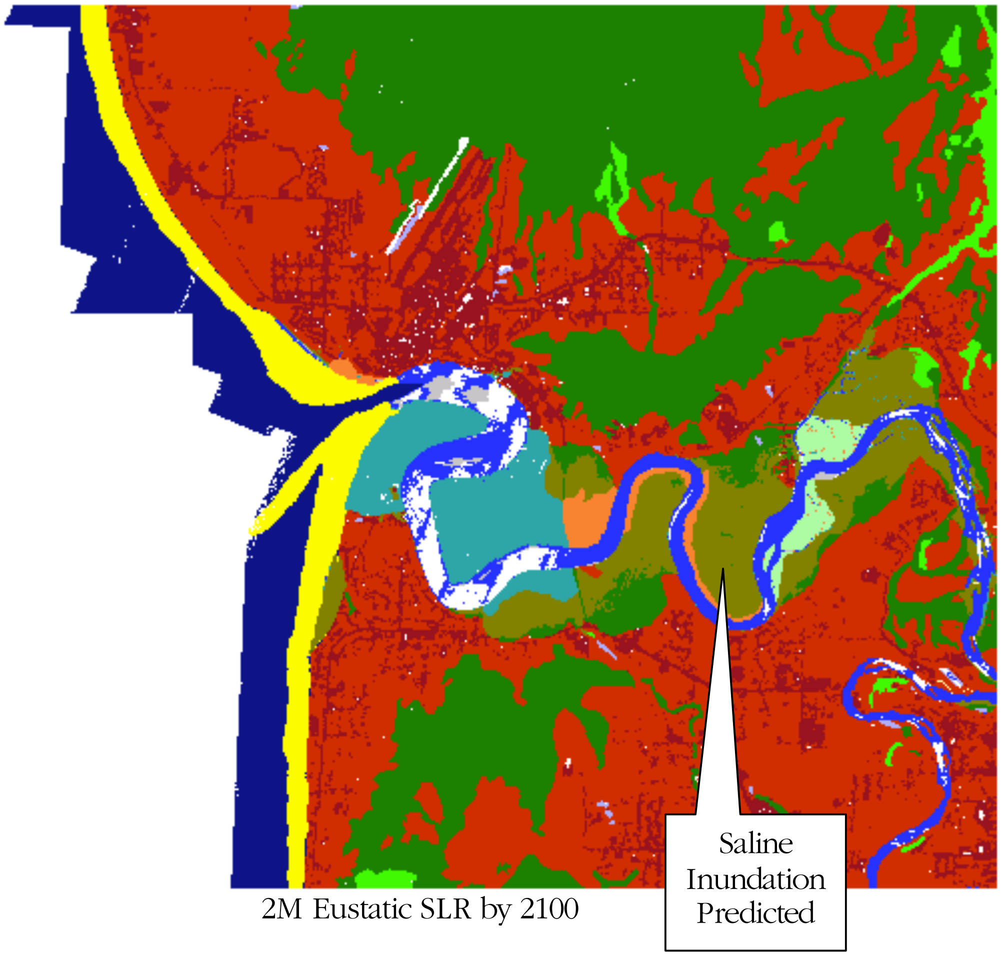
1M Eustatic SLR by 2100

Undeveloped Dry Land
Swamp
Inland Open Water
Inland Fresh Marsh
Open Ocean
Tidal Flat
Ocean Beach
Developed
Regularly Flooded Marsh
Estuarine Open Water
Irregularly Flooded Marsh
Estuarine Beach
Tidal Fresh Marsh
Riverine Tidal
Inland Shore
Tidal Swamp
Transitional Salt Marsh



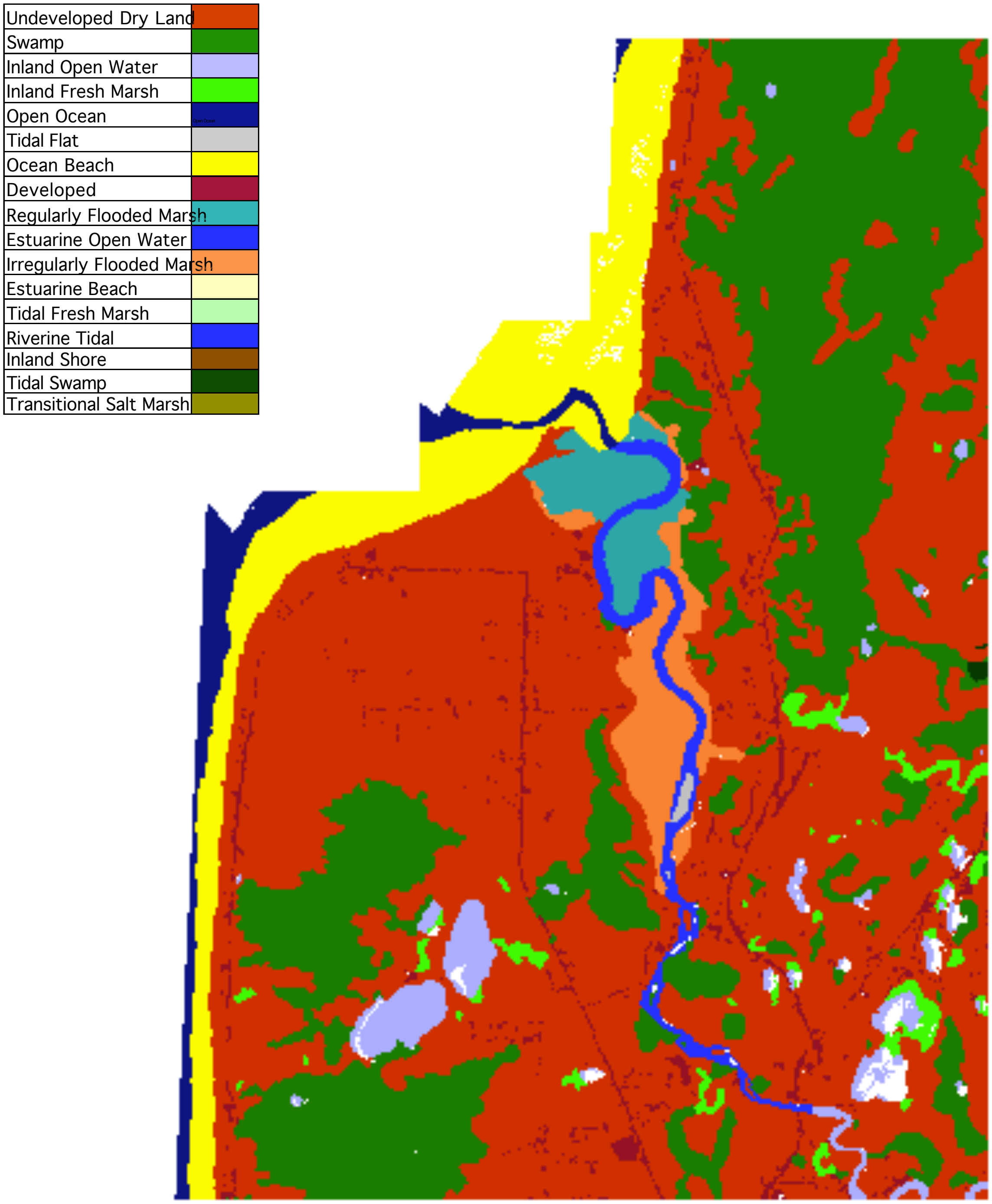
1.5M Eustatic SLR by 2100

Undeveloped Dry Land	
Swamp	
Inland Open Water	
Inland Fresh Marsh	
Open Ocean	
Tidal Flat	
Ocean Beach	
Developed	
Regularly Flooded Marsh	
Estuarine Open Water	
Irregularly Flooded Marsh	
Estuarine Beach	
Tidal Fresh Marsh	
Riverine Tidal	
Inland Shore	
Tidal Swamp	
Transitional Salt Marsh	



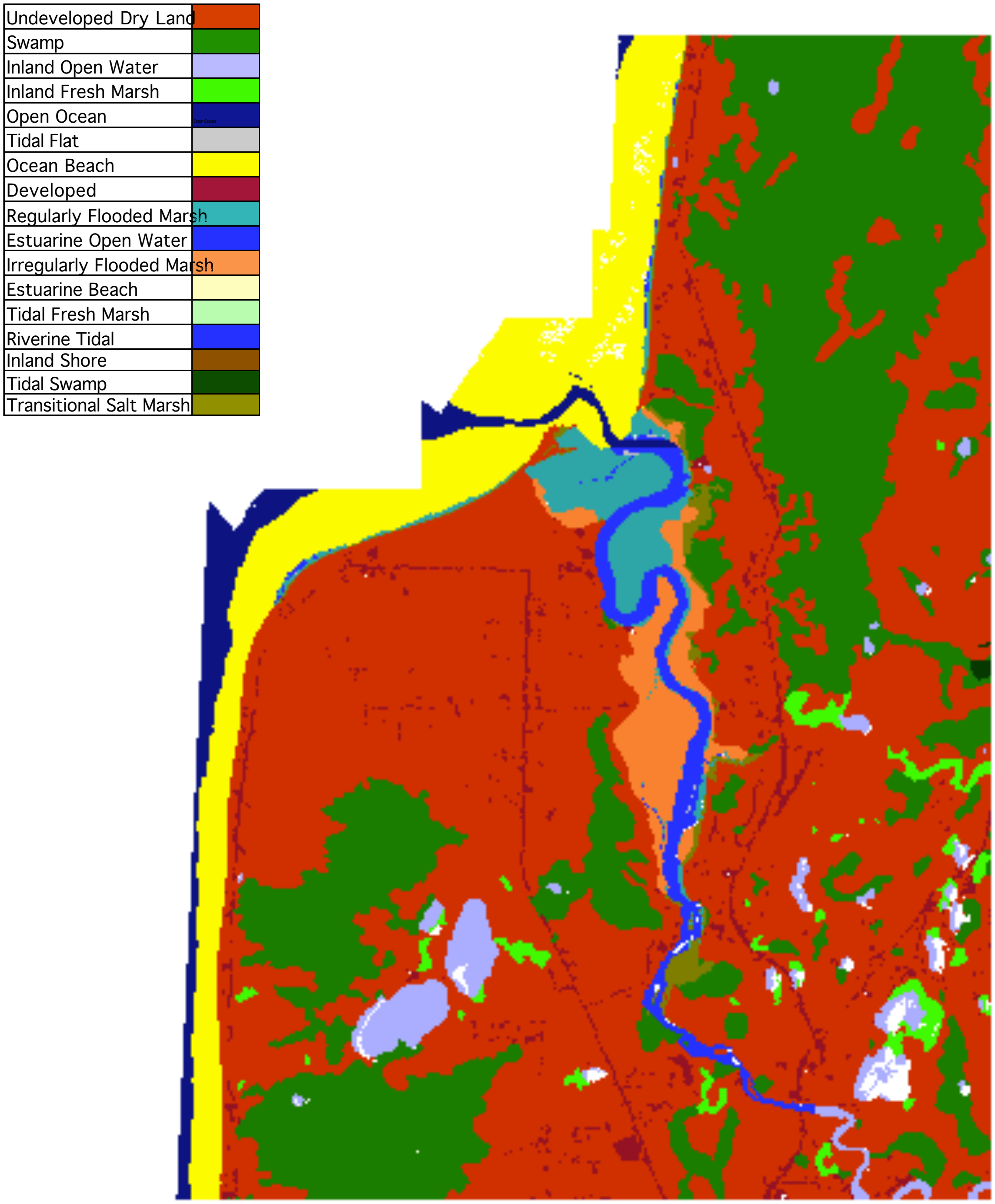
2M Eustatic SLR by 2100

Northern Cohoe/Kasilof

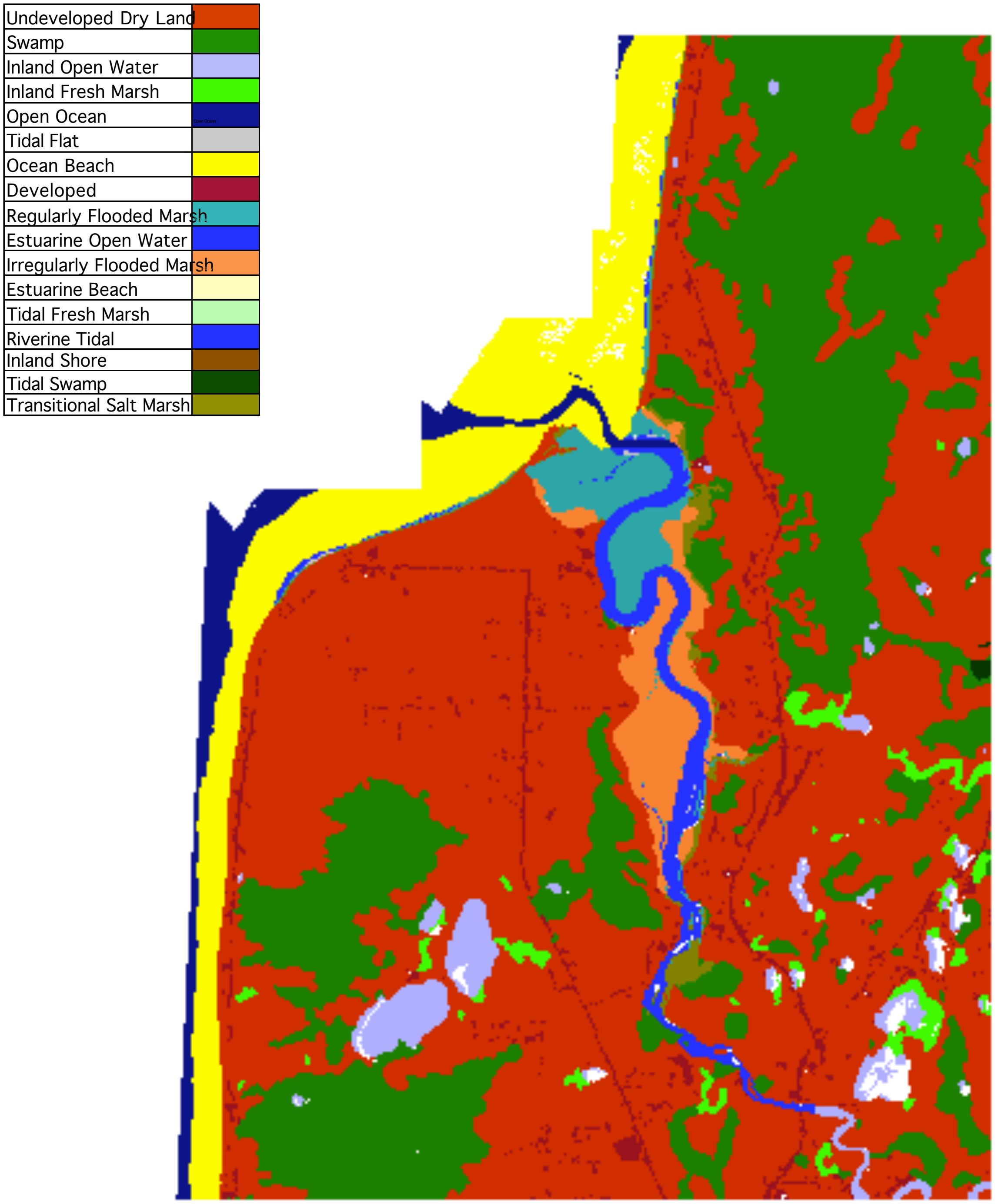


Initial Condition

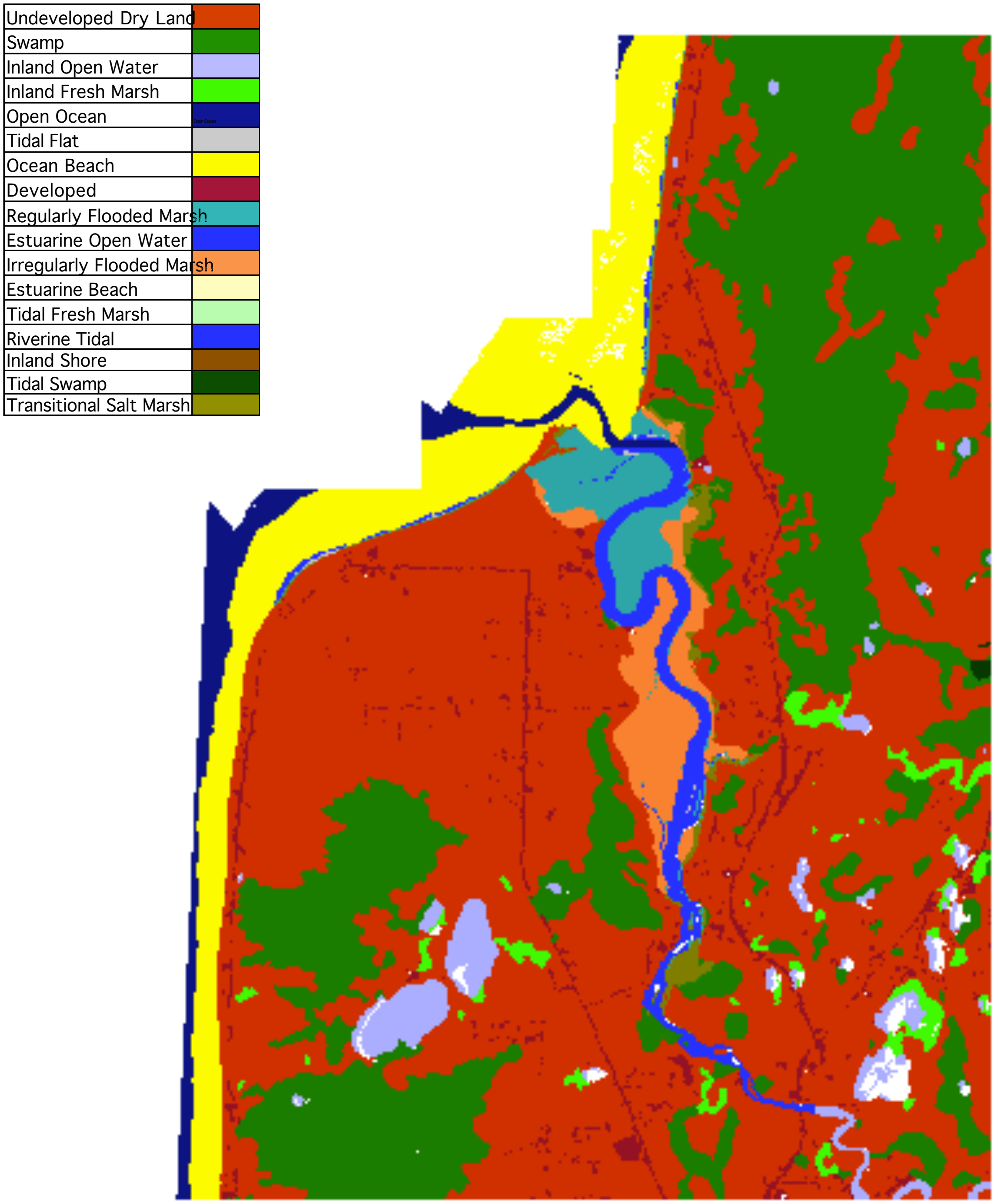
Some saline inundation of the dry lands and swamps to the east of the river are predicted, especially under higher eustatic scenarios of sea level rise.



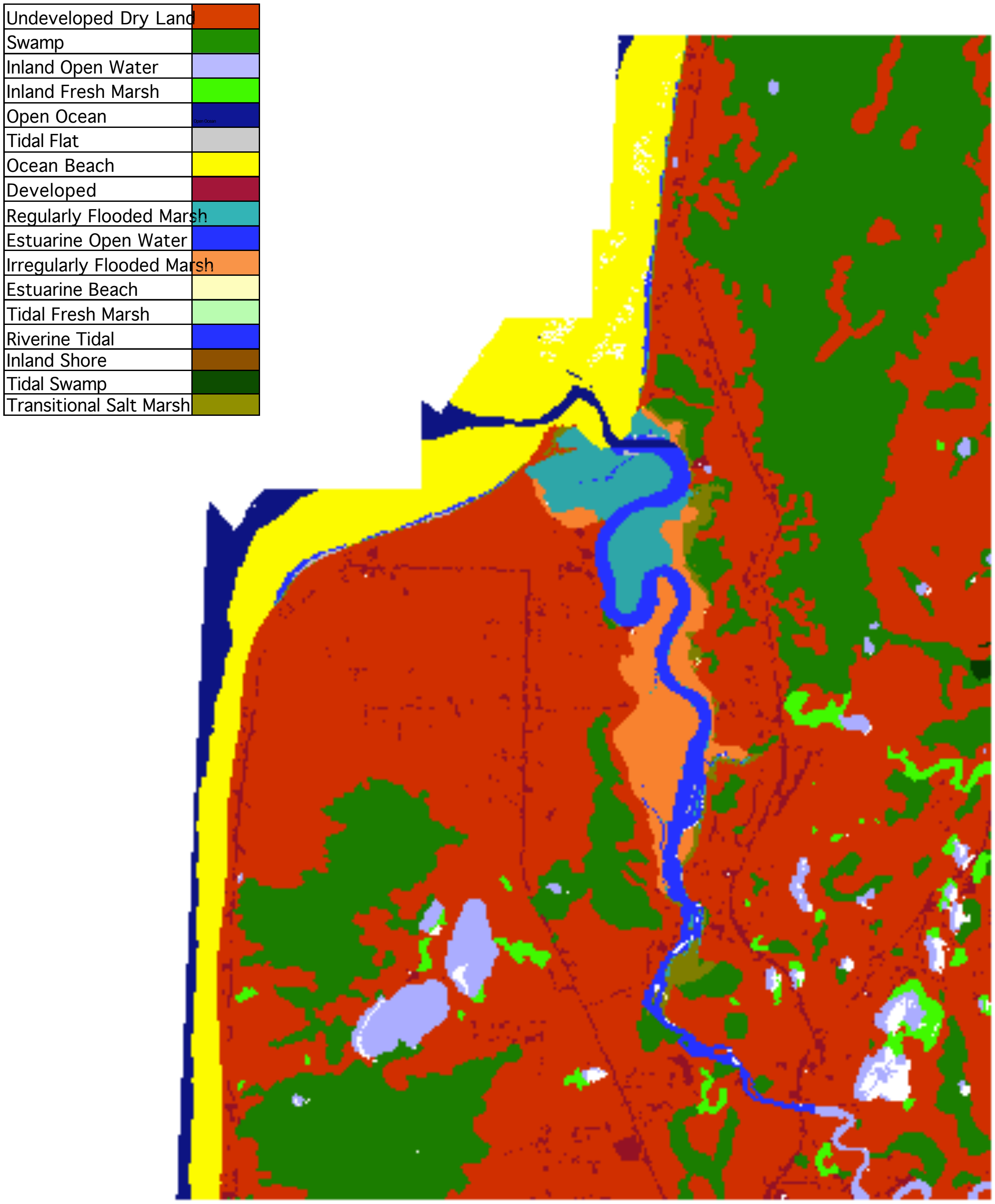
A1B-Mean (0.39M Eustatic SLR by 2100)



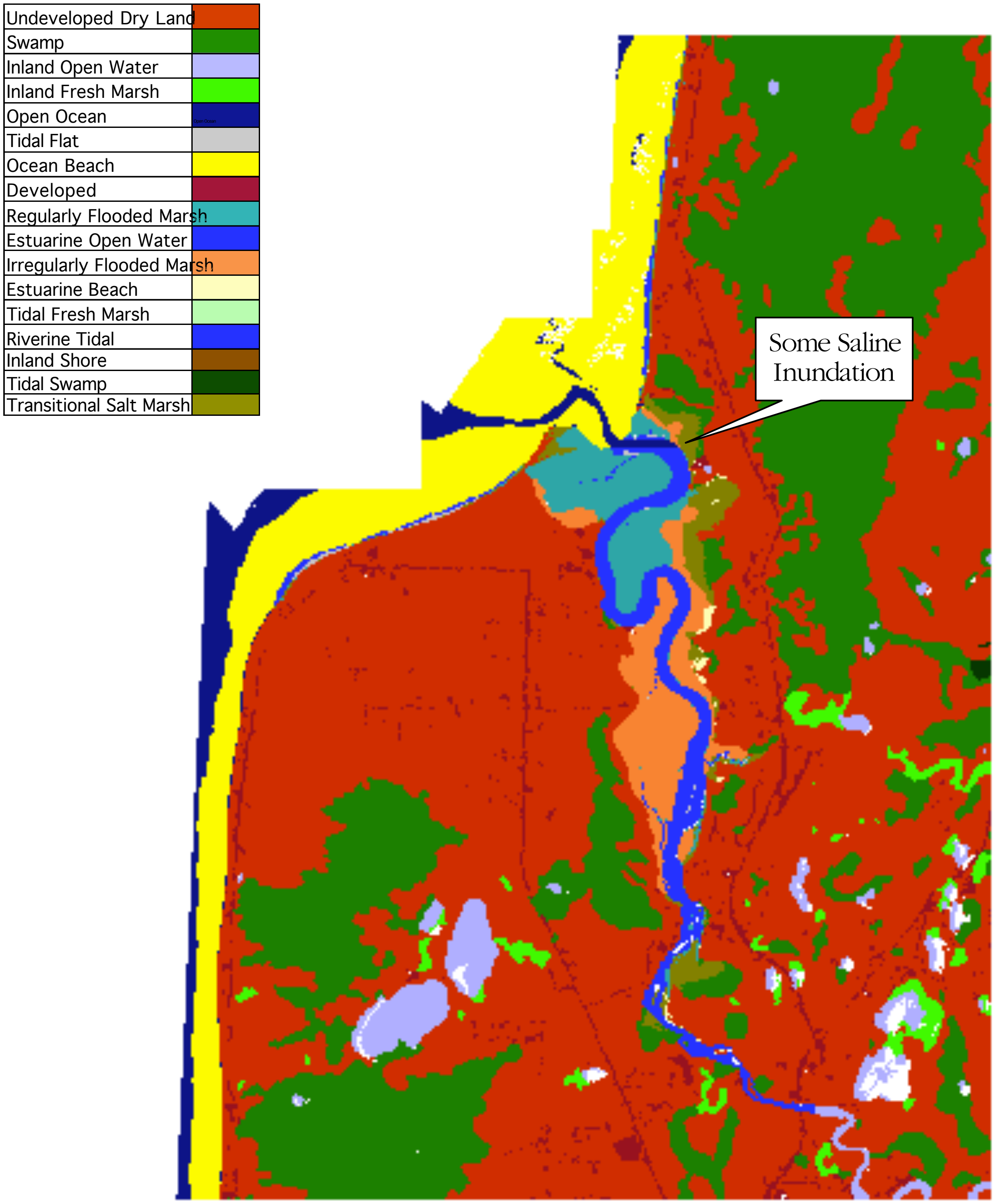
A1B-Max (0.69M Eustatic SLR by 2100)



1M Eustatic SLR by 2100



1.5M Eustatic SLR by 2100



2M Eustatic SLR by 2100

Kenai Peninsula, Tables of Results

Kenai Peninsula
Alaska
IPCC Scenario A1B-Mean, 0.39 M SLR Eustatic by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undeveloped Dry Land	374340.0	372872.3	372864.1	372862.3	372860.9
Swamp	86664.3	85974.4	85980.8	85982.3	85983.1
Inland Open Water	20020.2	19976.2	19976.2	19976.2	19976.2
Inland Fresh Marsh	15648.4	15625.0	15624.8	15624.7	15624.6
Open Ocean	11858.5	12649.4	12655.9	12658.0	12659.8
Tidal Flat	9198.5	8799.6	8649.5	8251.5	7905.0
Ocean Beach	6688.5	6480.1	6480.1	6480.1	6480.1
Dev. Dry Land	5835.2	5810.8	5810.8	5810.8	5810.8
Regularly Flooded Marsh	5504.4	5792.5	5450.4	5450.3	5450.3
Estuarine Open Water	5488.2	6299.0	6789.4	7187.6	7534.0
Irregularly Flooded Marsh	2099.2	2019.2	2019.2	2019.2	2019.2
Estuarine Beach	790.7	791.3	787.8	784.5	782.6
Tidal Fresh Marsh	403.5	384.3	384.6	385.0	385.5
Riverine Tidal	388.3	260.0	260.0	260.0	260.0
Inland Shore	92.8	92.8	92.8	92.8	92.8
Tidal Swamp	41.7	41.7	41.7	41.7	41.7
Transitional Salt Marsh	3.5	1197.3	1197.8	1198.9	1199.0
Total (incl. water)	**545065.8**	**545065.8**	**545065.8**	**545065.8**	**545065.8**

Kenai Peninsula Alaska
IPCC Scenario A1B-Max, 0.69 M SLR Eustatic by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undev. Dry Land	374340.0	372870.5	372861.7	372859.2	372856.2
Swamp	86664.3	85976.1	85983.0	85985.1	85987.3
Inland Open Water	20020.2	19976.1	19976.1	19976.0	19976.0
Inland Fresh Marsh	15648.4	15625.0	15624.7	15624.6	15624.5
Open Ocean	11858.5	12649.5	12655.9	12658.1	12659.9
Tidal Flat	9198.5	8802.1	8664.4	8261.7	7912.9
Ocean Beach	6688.5	6480.0	6480.0	6480.0	6480.0
Dev. Dry Land	5835.2	5810.8	5810.8	5810.8	5810.8
Regularly Flooded Marsh	5504.4	5794.1	5430.5	5430.4	5430.4
Estuarine Open Water	5488.2	6302.5	6802.1	7205.3	7554.1
Irregularly Flooded Marsh	2099.2	2019.0	2019.0	2019.0	2019.0
Estuarine Beach	790.7	791.3	787.8	784.4	782.6
Tidal Fresh Marsh	403.5	384.3	384.7	385.2	385.7
Riverine Tidal	388.3	258.9	258.9	258.9	258.9
Inland Shore	92.8	92.8	92.8	92.8	92.8
Tidal Swamp	41.7	41.7	41.7	41.7	41.7
Transitional Salt Marsh	3.5	1191.2	1191.7	1192.7	1193.0
Total (incl. water)	**545065.8**	**545065.8**	**545065.8**	**545065.8**	**545065.8**

Kenai Peninsula Alaska
1 Meter Eustatic SLR by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undev. Dry Land	374340.0	372867.5	372857.0	372849.0	372833.2
Swamp	86664.3	85979.1	85987.6	85993.5	85981.4
Inland Open Water	20020.2	19976.0	19976.0	19975.7	19973.8
Inland Fresh Marsh	15648.4	15624.9	15624.6	15624.4	15624.2
Open Ocean	11858.5	12649.6	12656.1	12658.8	12661.4
Tidal Flat	9198.5	8804.4	8680.1	8273.8	7923.6
Ocean Beach	6688.5	6480.0	6479.9	6479.3	6478.5
Dev. Dry Land	5835.2	5810.8	5810.8	5810.8	5810.8
Regularly Flooded Marsh	5504.4	5797.4	5414.0	5414.3	5415.0
Estuarine Open Water	5488.2	6305.2	6811.1	7219.5	7573.5
Irregularly Flooded Marsh	2099.2	2018.7	2018.8	2018.8	2018.8
Estuarine Beach	790.7	791.2	787.7	784.8	783.8
Tidal Fresh Marsh	403.5	384.3	384.9	385.5	386.0
Riverine Tidal	388.3	257.7	257.8	257.7	257.2
Inland Shore	92.8	92.8	92.8	92.8	92.8
Tidal Swamp	41.7	41.7	41.7	41.7	41.7
Transitional Salt Marsh	3.5	1184.5	1184.8	1185.5	1210.1
Total (incl. water)	**545065.8**	**545065.8**	**545065.8**	**545065.8**	**545065.8**

Kenai Peninsula Alaska
1.5 Meters Eustatic SLR by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undev. Dry Land	374340.0	372863.3	372842.2	372800.7	372732.9
Swamp	86664.3	85983.3	85986.8	85944.9	85874.9
Inland Open Water	20020.2	19976.0	19975.8	19972.5	19968.1
Inland Fresh Marsh	15648.4	15624.9	15624.5	15623.9	15623.5
Open Ocean	11858.5	12649.7	12660.5	12683.4	12705.0
Tidal Flat	9198.5	8807.3	8700.6	8298.7	7962.0
Ocean Beach	6688.5	6479.8	6475.7	6455.8	6442.6
Dev. Dry Land	5835.2	5810.8	5810.8	5810.8	5809.5
Regularly Flooded Marsh	5504.4	5804.9	5401.3	5405.1	5399.8
Estuarine Open Water	5488.2	6308.1	6823.3	7244.6	7622.3
Irregular. Flooded Marsh	2099.2	2018.4	2018.4	2018.1	2015.7
Estuarine Beach	790.7	791.2	788.3	786.8	793.3
Tidal Fresh Marsh	403.5	384.3	385.1	385.7	385.8
Riverine Tidal	388.3	256.2	254.1	251.9	248.5
Inland Shore	92.8	92.8	92.8	92.8	92.8
Tidal Swamp	41.7	41.7	41.7	41.7	41.7
Transitional Salt Marsh	3.5	1173.2	1184.1	1248.3	1347.4
Total (incl. water)	**545065.8**	**545065.8**	**545065.8**	**545065.8**	**545065.8**

Kenai Peninsula Alaska
2 Meters Eustatic SLR by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undev. Dry Land	374340.0	372858.0	372810.3	372688.0	372546.5
Swamp	86664.3	85988.2	85953.6	85712.4	85200.6
Inland Open Water	20020.2	19975.7	19973.3	19966.8	19963.2
Inland Fresh Marsh	15648.4	15624.8	15624.1	15623.4	15618.4
Open Ocean	11858.5	12649.9	12687.2	13183.5	14613.9
Tidal Flat	9198.5	8809.7	8723.2	8350.8	8084.2
Ocean Beach	6688.5	6479.6	6449.8	5971.2	4569.1
Dev. Dry Land	5835.2	5810.8	5810.8	5806.7	5800.1
Regularly Flooded Marsh	5504.4	5813.9	5400.8	5389.5	5425.8
Estuarine Open Water	5488.2	6312.0	6837.2	7301.5	7781.4
Irregularly Flooded Marsh	2099.2	2017.9	2017.3	2025.1	2007.4
Estuarine Beach	790.7	791.2	789.5	803.0	827.1
Tidal Fresh Marsh	403.5	384.3	384.8	371.0	291.0
Riverine Tidal	388.3	253.7	251.1	246.4	235.7
Inland Shore	92.8	92.8	92.8	92.8	92.8
Tidal Swamp	41.7	41.7	41.7	41.7	41.7
Transitional Salt Marsh	3.5	1161.6	1218.3	1492.5	1966.8
Total (incl. water)	**545065.8**	**545065.8**	**545065.8**	**545065.8**	**545065.8**

Anchorage

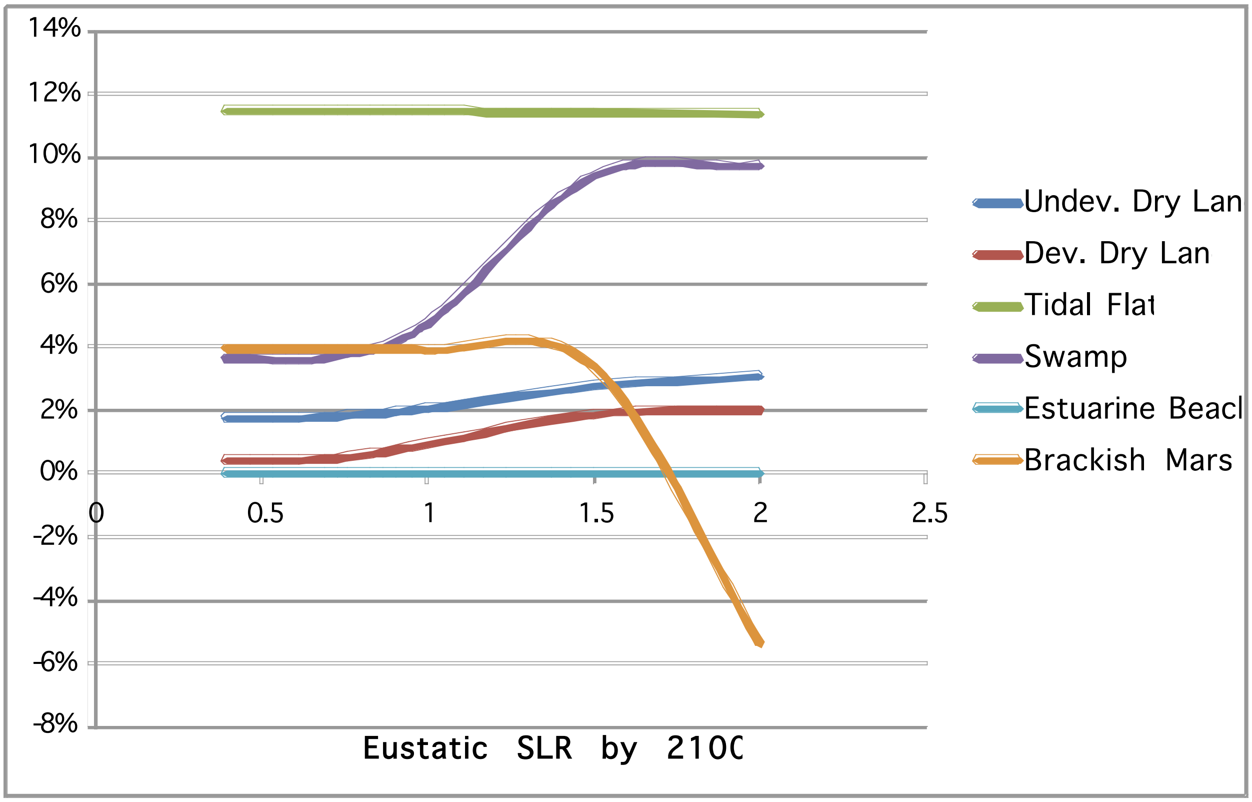


Figure 20: Rates of Land Loss for Anchorage

Results for the Anchorage study region show minor susceptibility to the effects of sea level rise. Dry land, which comprises slightly more than one third of the study area, is calculated to lose between 2% and 3% of its initial land coverage across all sea level rise scenarios. Swamp lands – which comprise roughly 4% of the study area – are predicted to lose between 4% and 10% of their initial land coverage across all sea level rise scenarios.

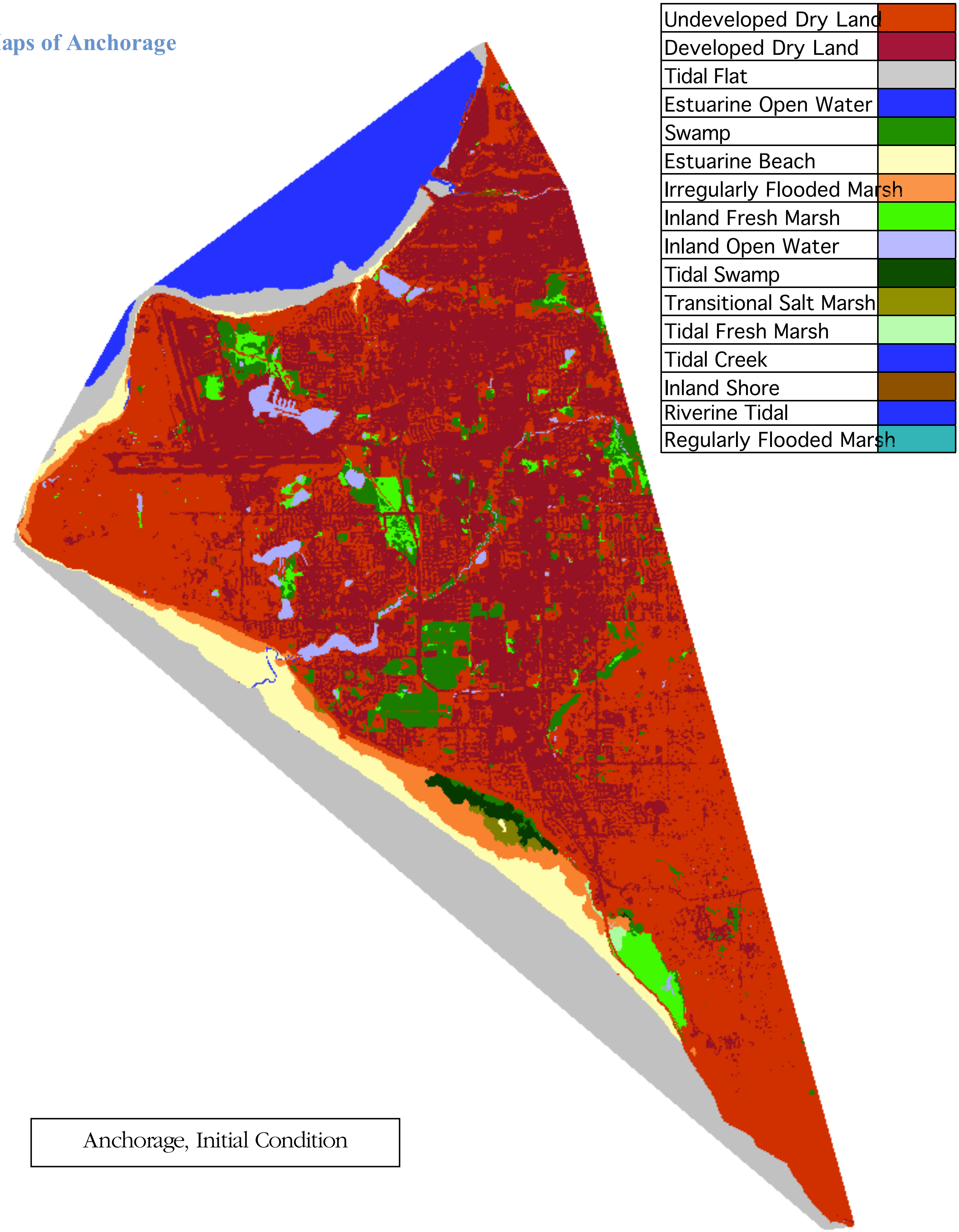
Irregularly flooded marsh – often “Irregularly Flooded Marsh”—makes up roughly 3% of this site. This category is predicted to lose up to 4% of its initial land coverage to sea level rise on a site-wide scale. However, in the most extreme scenarios of SLR some tidal swamp is predicted to convert to irregularly flooded marsh resulting in overall gain for that category.

SLR by 2100 (m)	0.39	0.69	1	1.5	2
Undeveloped Dry Land	1.8%	1.8%	2.1%	2.8%	3.1%
Developed Dry Land	0.4%	0.5%	0.9%	1.9%	2.0%
Tidal Flat	11.5%	11.5%	11.5%	11.4%	11.4%
Swamp	3.7%	3.7%	4.7%	9.4%	9.7%
Irregularly Flooded Marsh	0.0%	0.0%	0.0%	0.0%	0.0%
Inland Fresh Marsh	4.0%	4.0%	3.9%	3.4%	-5.3%
Tidal Swamp	1.9%	1.9%	1.9%	2.6%	5.0%
Tidal Fresh Marsh	0.7%	0.7%	1.0%	7.8%	71.3%
Inland Shore	0.0%	0.0%	0.0%	0.0%	22.1%
Riverine Tidal	25.9%	25.9%	25.9%	25.9%	25.9%

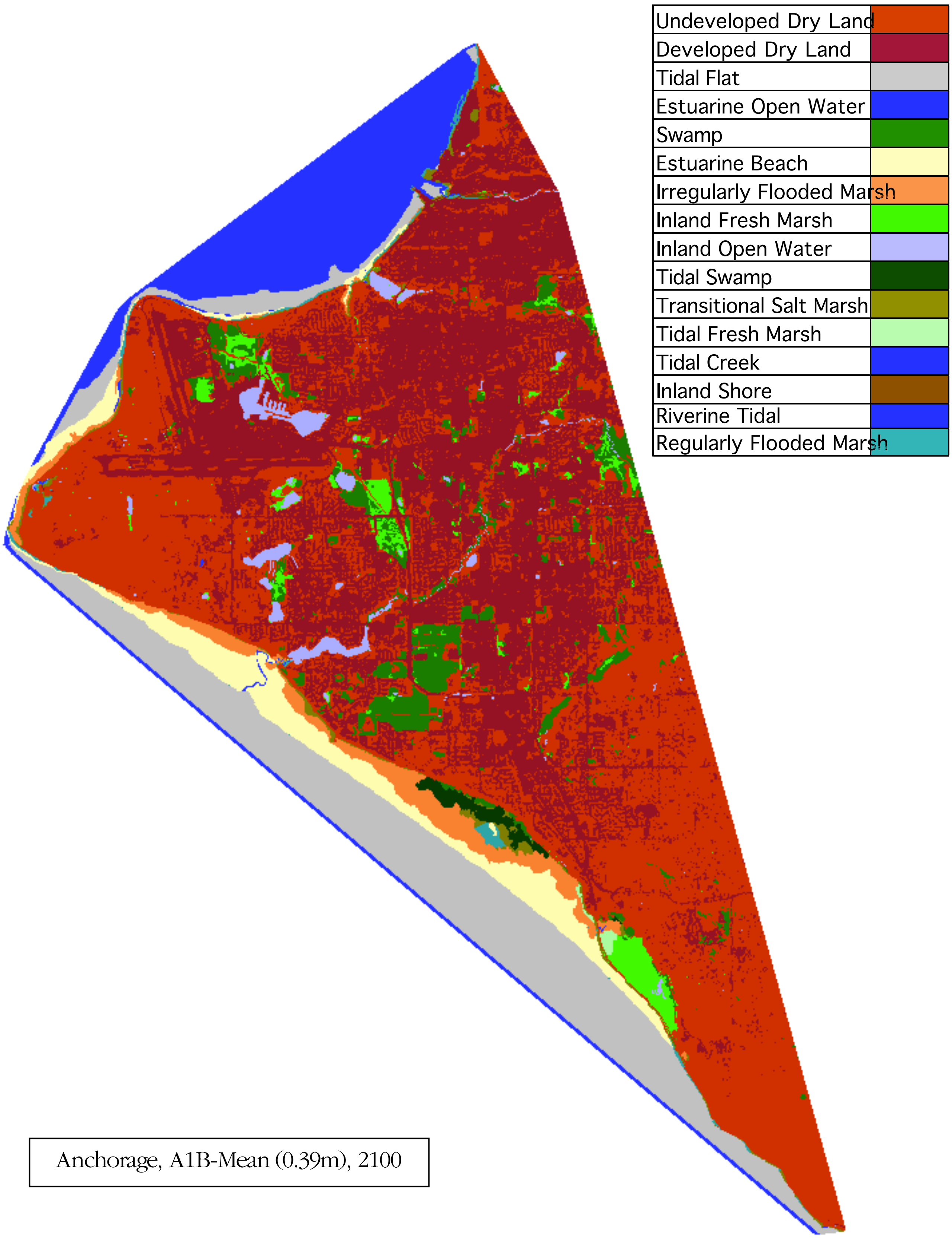
Loss Rates by 2100 by Land Category and Eustatic SLR Scenario

Looking at maps of results for Anchorage (over the next few pages) the most substantial spatial predictions seem to be the potential inundation of developed land at the northern portion of the study site (Ship Creek area) and the potential vulnerability of the tidal swamp northwest of Potter Marsh.

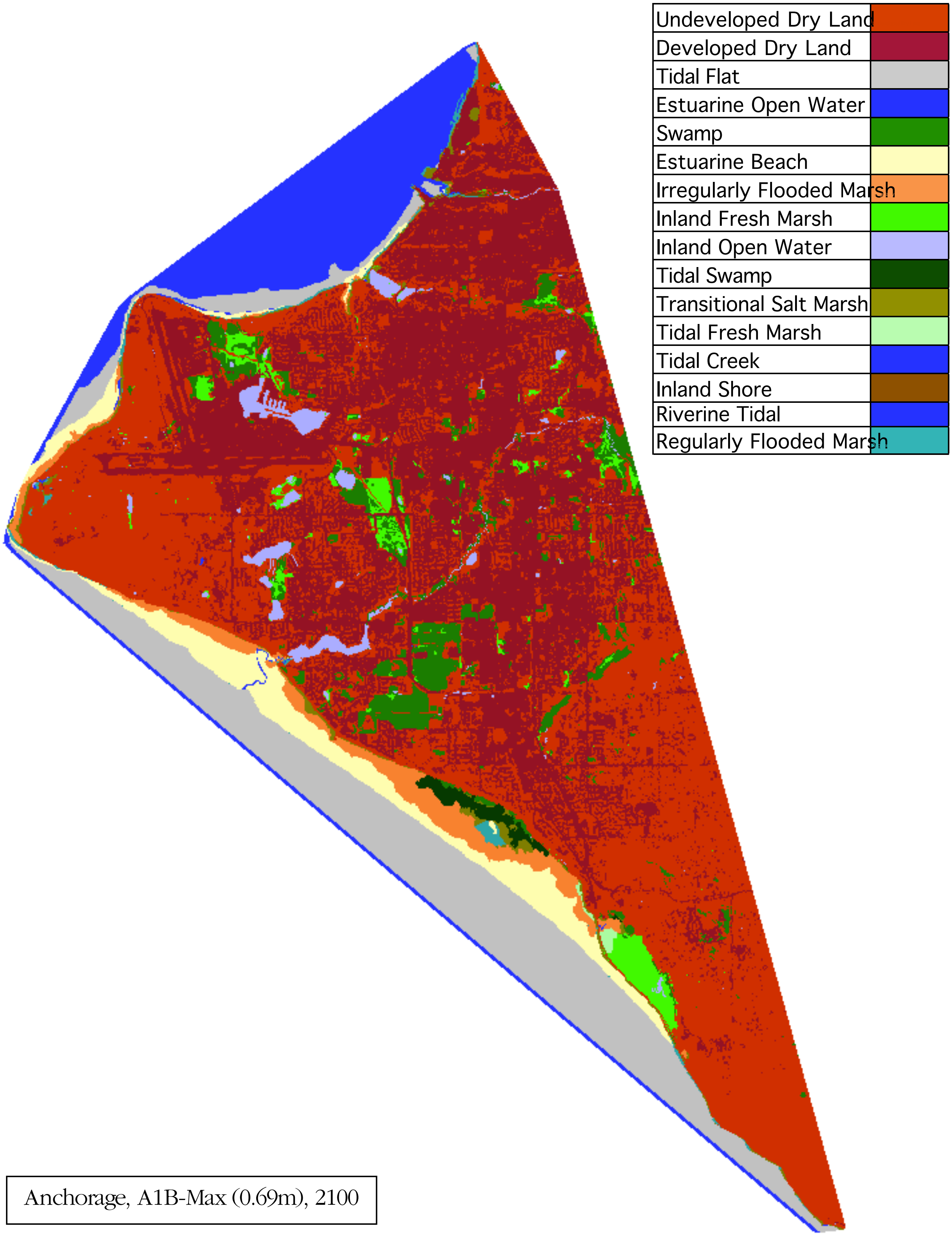
Maps of Anchorage



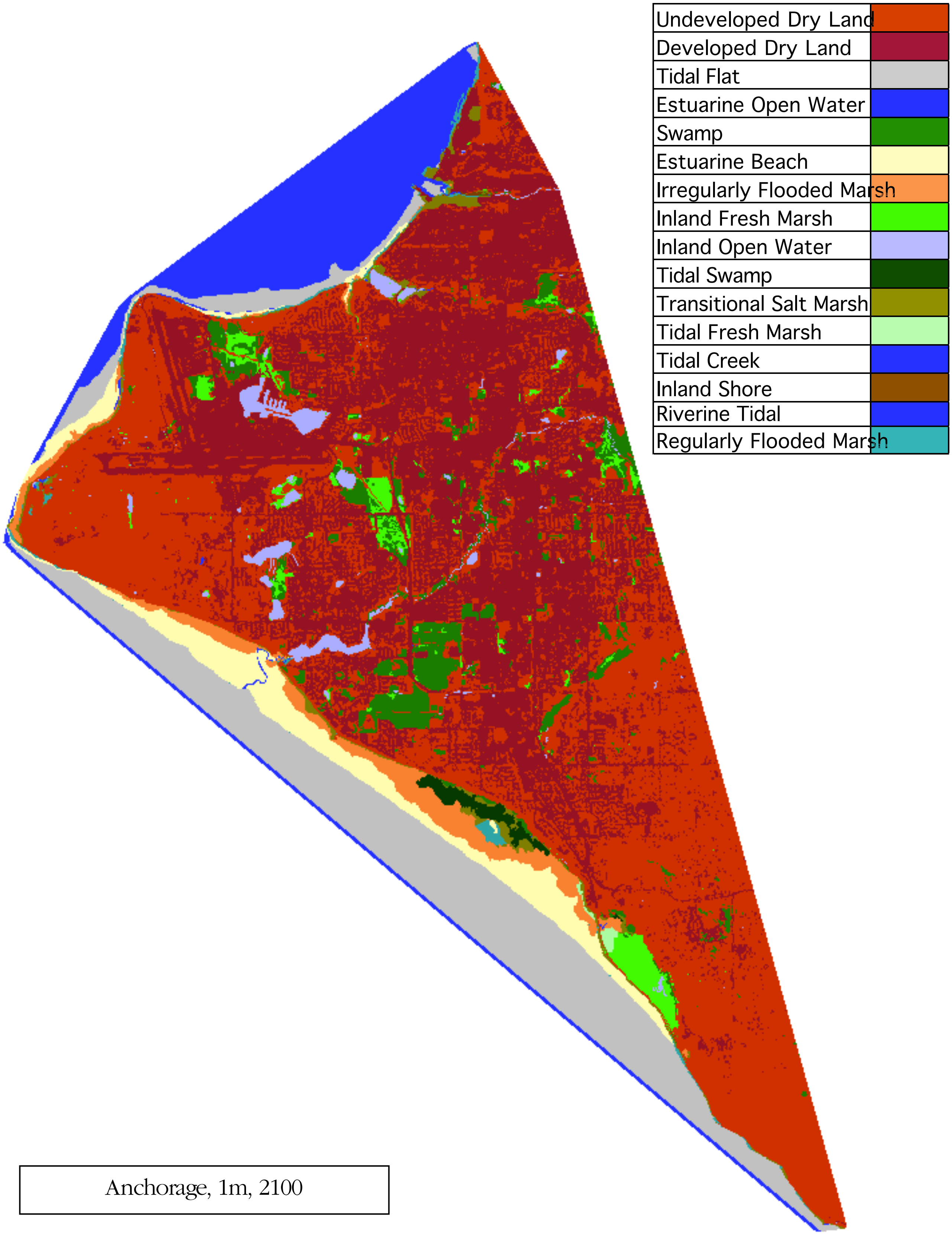
Anchorage, Initial Condition



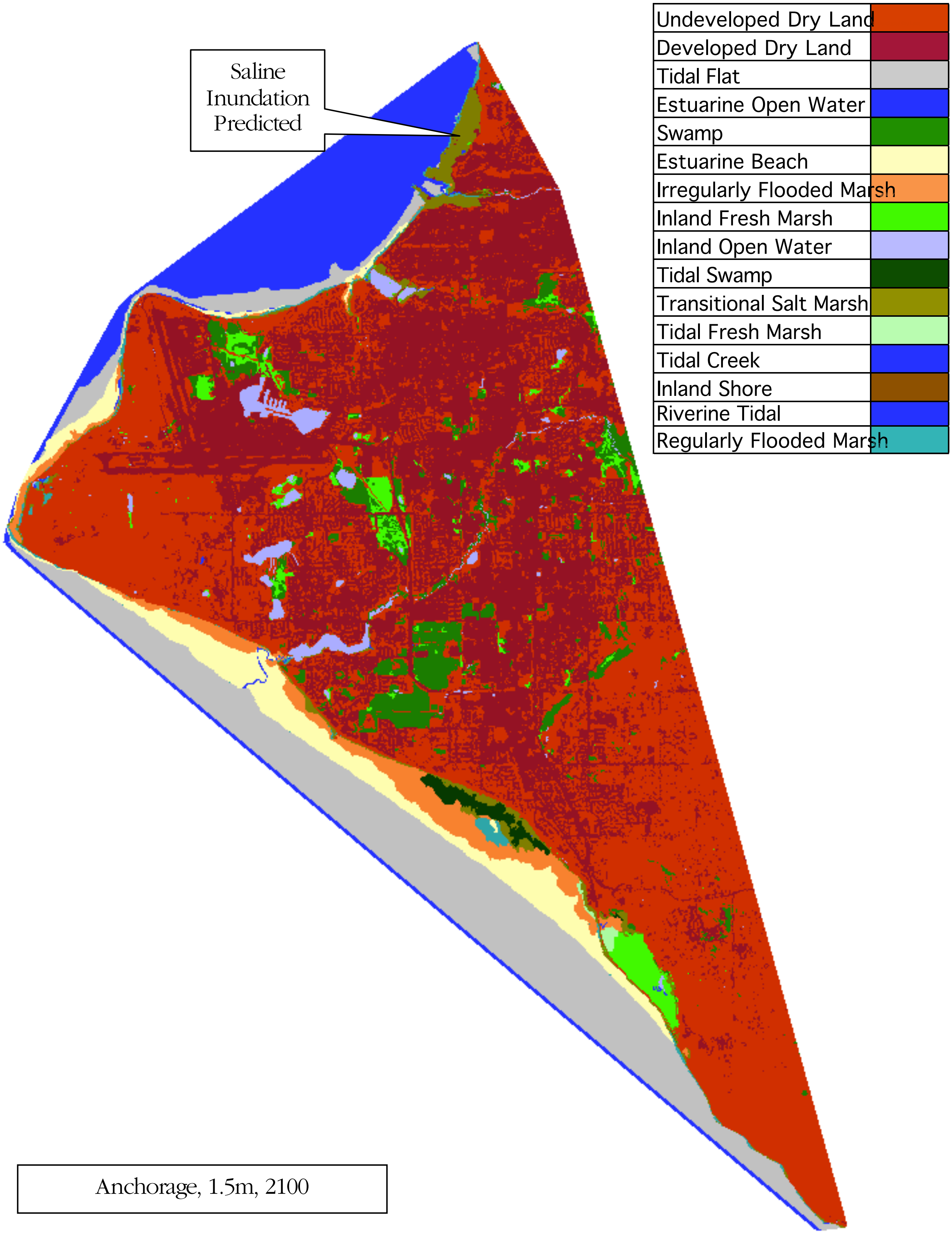
Anchorage, A1B-Mean (0.39m), 2100

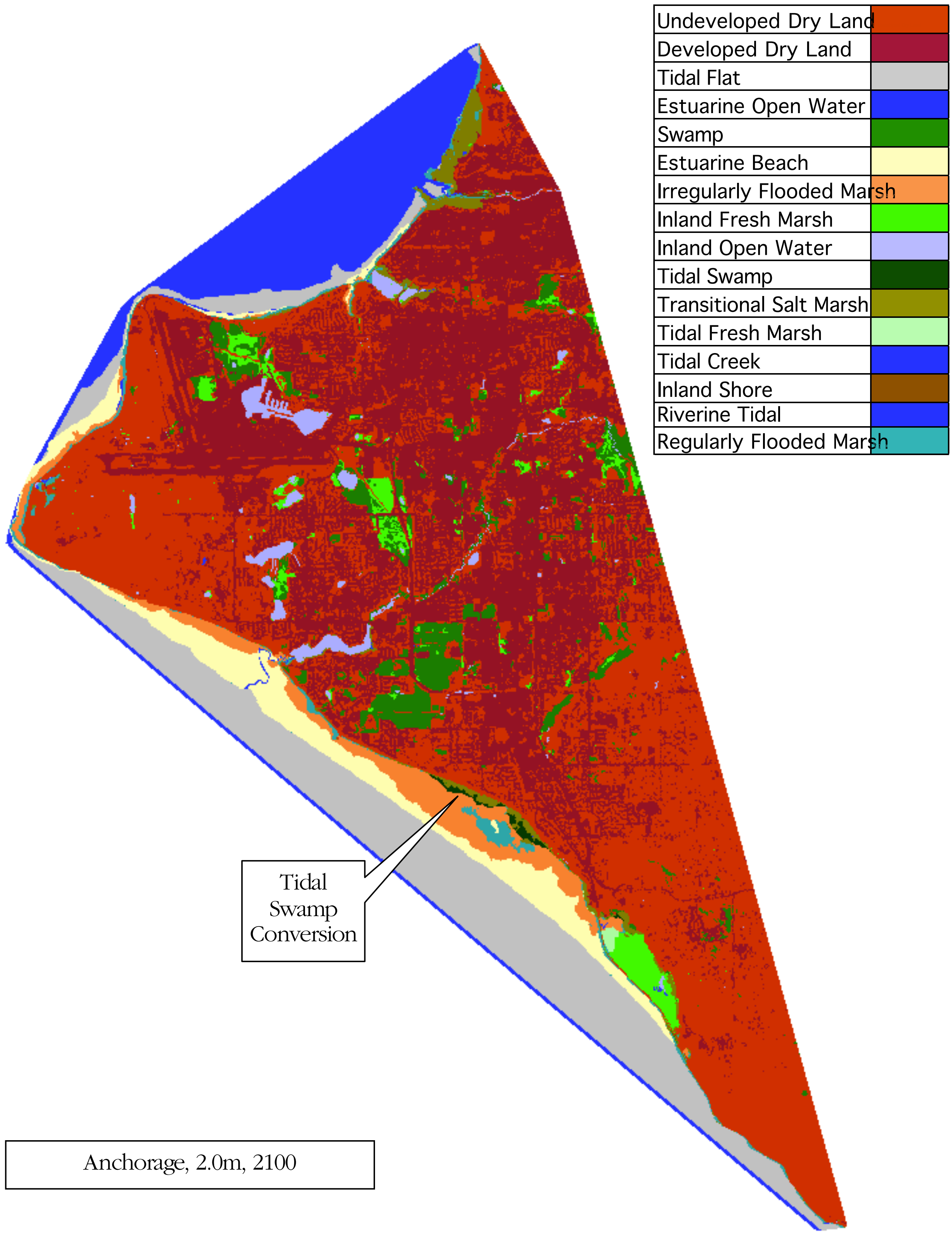


Anchorage, A1B-Max (0.69m), 2100

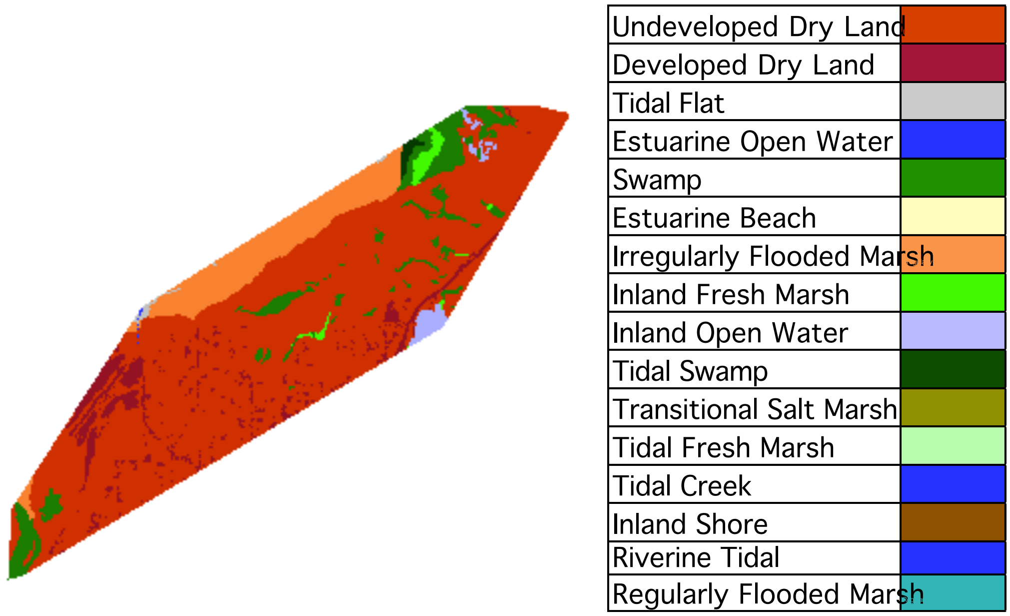


Anchorage, 1m, 2100

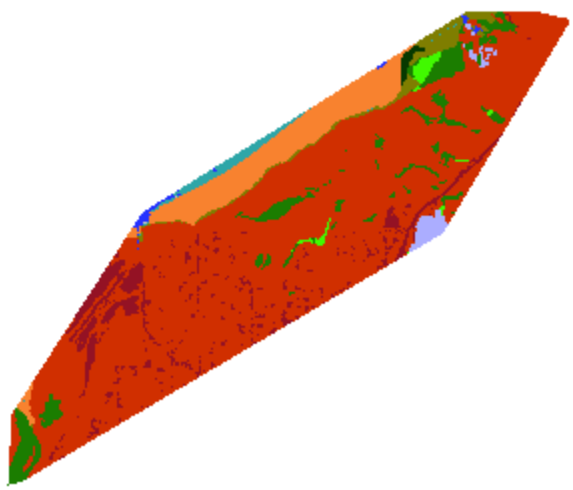

Saline Inundation Predicted
Undeveloped Dry Land
Developed Dry Land
Tidal Flat
Estuarine Open Water
Swamp
Estuarine Beach
Irregularly Flooded Marsh
Inland Fresh Marsh
Inland Open Water
Tidal Swamp
Transitional Salt Marsh
Tidal Fresh Marsh
Tidal Creek
Inland Shore
Riverine Tidal
Regularly Flooded Marsh
Anchorage, 1.5m, 2100


Undeveloped Dry Land
Developed Dry Land
Tidal Flat
Estuarine Open Water
Swamp
Estuarine Beach
Irregularly Flooded Marsh
Inland Fresh Marsh
Inland Open Water
Tidal Swamp
Transitional Salt Marsh
Tidal Fresh Marsh
Tidal Creek
Inland Shore
Riverine Tidal
Regularly Flooded Marsh
Tidal Swamp Conversion
Anchorage, 2.0m, 2100

North of Chugiak, AK (Near Birchwood Airport)

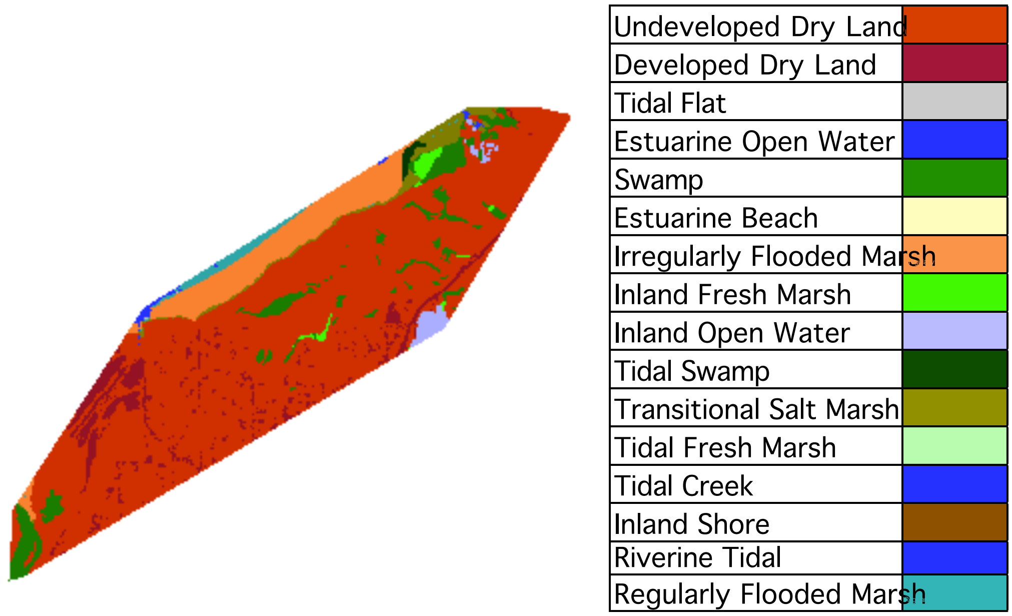


Initial Condition

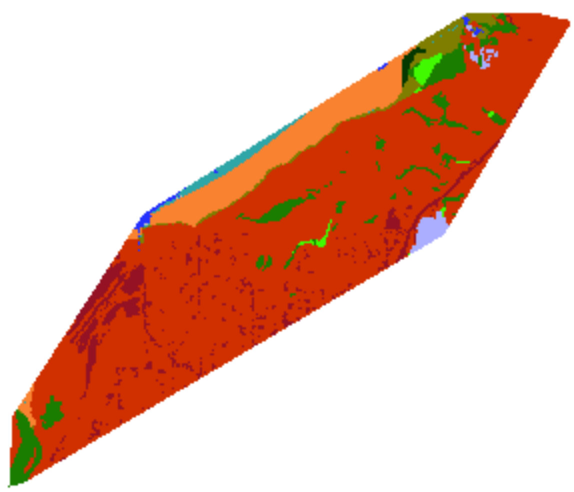


Scenario A1B-Mean (0.39M Eustatic SLR by 2100)

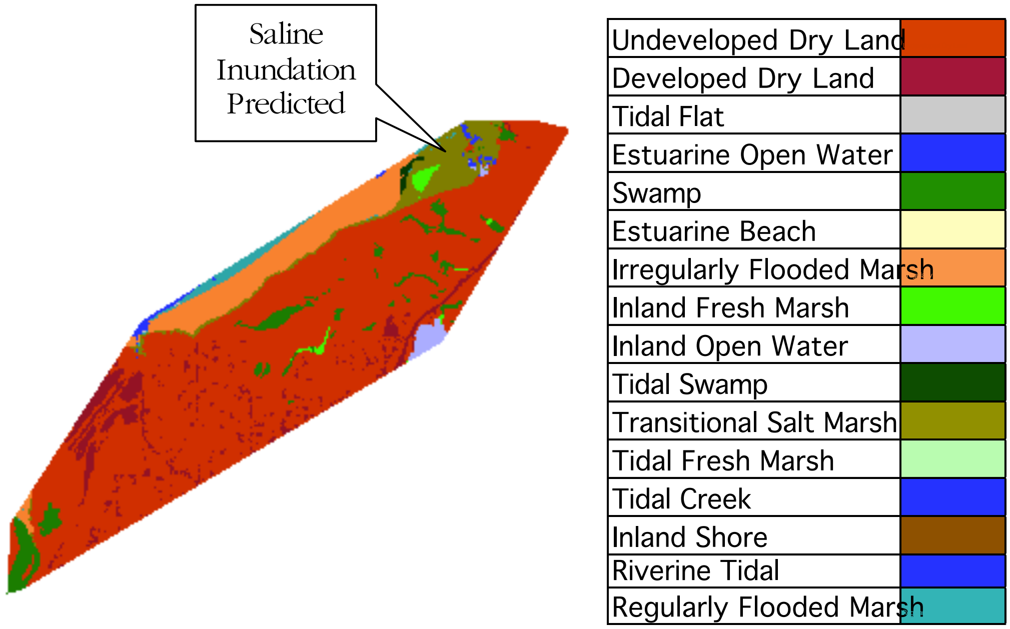
The dry lands and swamps at the north of this portion of the study area are predicted to be subject to saline inundation, especially under the highest scenarios run.



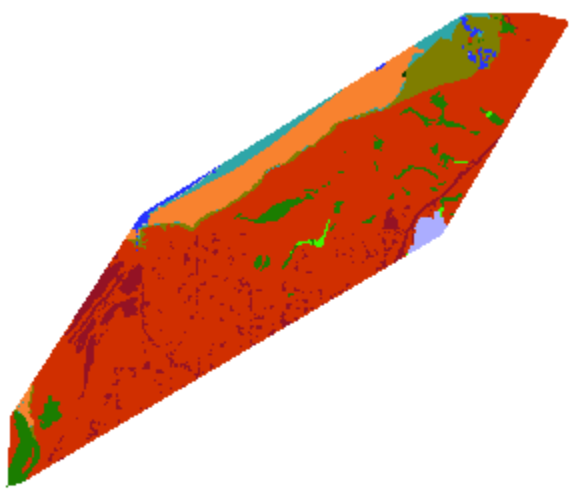
Scenario A1B-Max (0.69M Eustatic SLR by 2100)



1M Eustatic SLR by 2100



1.5M Eustatic SLR by 2100



2M Eustatic SLR by 2100

Anchorage Study Area, Tables of Results

Anchorage Alaska
IPCC Scenario A1B-Mean, 0.39 M SLR Eustatic by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undeveloped Dry Land	9324.5	9161.4	9161.3	9161.2	9161.2
Developed Dry Land	7270.7	7241.0	7241.0	7241.0	7241.0
Tidal Flat	2667.9	2585.9	2507.6	2433.4	2362.1
Estuarine Open Water	1492.5	1581.2	1660.2	1734.4	1805.7
Swamp	1011.3	974.3	974.3	974.3	974.3
Estuarine Beach	810.5	810.5	810.5	810.5	810.5
Irregularly Flooded Marsh	667.9	641.4	641.4	641.4	641.4
Inland Fresh Marsh	411.5	403.8	403.8	403.8	403.8
Inland Open Water	327.2	325.8	325.9	326.0	326.0
Tidal Swamp	100.8	100.0	100.0	100.0	100.0
Transitional Salt Marsh	51.7	201.2	201.2	201.2	201.2
Tidal Fresh Marsh	19.0	19.0	19.0	19.0	19.0
Tidal Creek	6.0	6.0	6.0	6.0	6.0
Inland Shore	5.2	3.9	3.9	3.9	3.9
Riverine Tidal	1.5	0.4	0.4	0.4	0.4
Regularly Flooded Marsh	0.0	112.4	111.7	111.7	111.7
Total (incl. water)	**24168.2**	**24168.2**	**24168.2**	**24168.2**	**24168.2**

Anchorage Alaska
IPCC Scenario A1B-Max, 0.69 M SLR Eustatic by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undeveloped Dry Land	9324.5	9161.3	9161.1	9159.9	9157.7
Developed Dry Land	7270.7	7241.0	7240.9	7239.3	7237.0
Tidal Flat	2667.9	2586.0	2507.7	2433.4	2362.1
Estuarine Open Water	1492.5	1581.2	1660.5	1735.5	1807.3
Swamp	1011.3	974.3	974.3	974.3	974.3
Estuarine Beach	810.5	810.5	810.5	810.5	810.5
Irregularly Flooded Marsh	667.9	641.4	641.4	641.4	641.4
Inland Fresh Marsh	411.5	403.8	403.8	403.8	403.8
Inland Open Water	327.2	325.9	325.9	325.3	325.2
Tidal Swamp	100.8	100.0	100.0	100.0	100.0
Transitional Salt Marsh	51.7	199.9	200.0	202.7	207.1
Tidal Fresh Marsh	19.0	19.0	19.0	19.0	19.0
Tidal Creek	6.0	6.0	6.0	6.0	6.0
Inland Shore	5.2	3.9	3.9	3.9	3.9
Riverine Tidal	1.5	0.4	0.4	0.4	0.2
Regularly Flooded Marsh	0.0	113.6	112.7	112.7	112.7
Total (incl. water)	**24168.2**	**24168.2**	**24168.2**	**24168.2**	**24168.2**

Anchorage Alaska
1 Meter Eustatic SLR by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undeveloped Dry Land	9324.5	9161.3	9158.4	9150.2	9133.0
Developed Dry Land	7270.7	7240.9	7238.4	7232.6	7202.7
Tidal Flat	2667.9	2586.1	2507.9	2433.7	2362.4
Estuarine Open Water	1492.5	1581.2	1661.6	1736.6	1809.3
Swamp	1011.3	974.3	973.8	969.5	963.3
Estuarine Beach	810.5	810.5	810.5	810.5	810.5
Irregularly Flooded Marsh	667.9	641.4	641.4	641.5	641.6
Inland Fresh Marsh	411.5	403.8	403.7	403.7	403.6
Inland Open Water	327.2	325.8	325.1	325.0	324.0
Tidal Swamp	100.8	100.0	100.0	100.0	99.8
Transitional Salt Marsh	51.7	198.6	204.2	220.9	271.7
Tidal Fresh Marsh	19.0	19.0	19.0	19.0	19.0
Tidal Creek	6.0	6.0	6.0	6.0	6.0
Inland Shore	5.2	3.9	3.9	3.9	3.9
Riverine Tidal	1.5	0.4	0.4	0.2	0.2
Regularly Flooded Marsh	0.0	114.9	113.9	115.0	117.1
Total (incl. water)	**24168.2**	**24168.2**	**24168.2**	**24168.2**	**24168.2**

Anchorage Alaska
1.5 Meters Eustatic SLR by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undeveloped Dry Land	9324.5	9160.0	9147.2	9107.7	9067.3
Developed Dry Land	7270.7	7239.3	7232.0	7143.5	7133.9
Tidal Flat	2667.9	2586.2	2508.2	2435.0	2363.5
Estuarine Open Water	1492.5	1581.5	1662.0	1742.0	1821.0
Swamp	1011.3	973.6	966.1	948.7	915.9
Estuarine Beach	810.5	810.5	810.5	810.5	810.5
Irregularly Flooded Marsh	667.9	641.4	641.7	643.0	645.2
Inland Fresh Marsh	411.5	403.6	403.3	402.5	400.6
Inland Open Water	327.2	325.1	324.9	322.6	317.1
Tidal Swamp	100.8	100.0	99.7	97.8	93.0
Transitional Salt Marsh	51.7	200.5	223.7	358.0	424.7
Tidal Fresh Marsh	19.0	19.0	19.0	19.0	19.0
Tidal Creek	6.0	6.0	6.0	6.0	6.0
Inland Shore	5.2	3.9	3.9	3.9	3.9
Riverine Tidal	1.5	0.4	0.2	0.0	0.0
Regularly Flooded Marsh	0.0	117.2	119.7	127.8	146.4
Total (incl. water)	**24168.2**	**24168.2**	**24168.1**	**24168.2**	**24168.2**

Anchorage Alaska
2 Meters Eustatic SLR by 2100

Results in Hectares

	Initial	2025	2050	2075	2100
Undeveloped Dry Land	9324.5	9156.0	9123.2	9064.9	9036.6
Developed Dry Land	7270.7	7237.6	7163.5	7134.1	7124.4
Tidal Flat	2667.9	2586.4	2509.3	2435.8	2364.6
Estuarine Open Water	1492.5	1581.7	1665.6	1749.7	1827.2
Swamp	1011.3	970.7	956.5	915.6	912.8
Estuarine Beach	810.5	810.5	810.5	810.5	810.5
Irregularly Flooded Marsh	667.9	641.5	641.2	678.0	703.5
Inland Fresh Marsh	411.5	403.4	402.2	398.5	390.8
Inland Open Water	327.2	325.1	323.6	317.6	315.0
Tidal Swamp	100.8	99.9	98.6	56.7	28.9
Transitional Salt Marsh	51.7	206.6	316.1	417.3	389.5
Tidal Fresh Marsh	19.0	19.0	19.0	19.0	14.8
Tidal Creek	6.0	6.0	6.0	6.0	6.0
Inland Shore	5.2	3.9	3.9	3.9	3.9
Riverine Tidal	1.5	0.3	0.1	0.0	0.0
Regularly Flooded Marsh	0.0	119.6	128.9	160.5	239.7
Total (incl. water)	**24168.2**	**24168.2**	**24168.1**	**24168.2**	**24168.2**

Discussion of Model Results

Overall the simulated study area is not predicted to be particularly vulnerable to the effects of sea level rise (SLR), primarily due to estimated land uplift over the next century. Coastal uplift is predicted to range from approximately 0.7 meters to 1.1 meters by 2100 based on long-term GPS measurements for these sites (Figure 7: Uplift data for both study regions (cm/year).Figure 7). When this uplift is combined with a predicted eustatic rate of sea level rise from 0.4 meters to 2 meters, the resulting predicted local SLR range declines to negative 0.7 meters to positive 1.3 meters by 2100. In addition to this reduced range, we estimate that marsh lands will capture sediment and therefore vertically accrete at a rate roughly equivalent to an additional 0.4 meters per century. This further reduces predicted increases in water heights relative to marshes across the study area.

The entire study area, and the Anchorage site in particular, have relatively high tidal ranges (Figure 9). Areas with larger tide ranges are significantly less vulnerable to SLR than microtidal regimes are, because marshes extend over a much wider vertical range. Additionally, any increase in relative sea level rise relative to the overall tide range is much lower. This results in considerably less horizontal migration of wetlands in response to the same sea level rise signal.

Tidal and mudflat erosion rates were modeled using a constant rate of 1.75 meters per year based on a single site-specific study (Lawson et. al 1995). This average rate was not spatially differentiated over the study area meaning that prediction maps of tidal flat extents remain uncertain. Furthermore, there is significant uncertainty in the Anchorage modeling of tidal flats due to the limited range of the LiDAR data source (Figure 6).

Within this model, vertical movements of land have been held constant over time. Marsh loss or gain has the potential to be temporally variable due to variations in land subsidence and rebound rates. For example, according to Steve Baird from the Kachemak Bay Research Reserve,

> "the historic salt marsh shift is pretty interesting. It looks like it shifted landward (both lower extent and upper extent of salt marsh) by about 250 meters or so between images from 1951 and 1975. Between 1975 and 2008 it's moved back seaward by about ½ that distance. Since the shift has happened on both upper and lower extent of the salt-marsh vegetation, I would guess that it's mostly due to the initial subsidence and subsequent rebound, rather than accretion."

This type of temporally-variable ebb and flow of marshes is not something that the relatively simple SLAMM model can predict.

It should be noted that even though predictions of saline inundation for marshes and dry lands are not severe, this does not mean that global warming will not have a significant impact on these regions of Alaska. This model does not account for water quality changes, changes in the snow-free season, changes in wildlife ranges due to temperature changes, nor increased erosion due to climate changes.

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Figure 21: Descending to Anchorage Marshlands Fringed with Tidal Flats