SLAMM Analysis of the Oregon Coast

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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).

Project Background

The SLAMM 6 model was applied to eleven sites, numbered consecutively from North to South, along the coast of Oregon. The entire study area was just over two million acres in size. The sites are shown in Figure 1. Sites 3 (Nestucca) and 4 (Siletz) were analyzed as entire sites as well broken down by watershed.

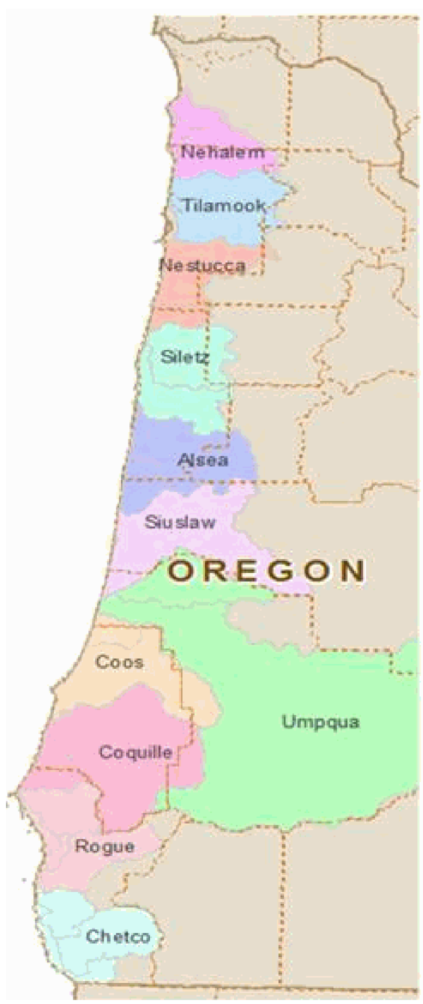

Figure 1. Study sites in coastal Oregon

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 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 et al. 1992; Park et al. 1993; Galbraith et al. 2002; National Wildlife Federation & Florida Wildlife Federation 2006; Glick et al. 2007; Craft et al. 2009). The first phase of this work was completed using SLAMM 5, while the second phase simulations were run with SLAMM 6.

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. This optional sub-model is not used in simulations of coastal Oregon.
- **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 and 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 was not used in these simulations due to the lack of adequate data 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 simulations of coastal Oregon.
- 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 the current simulations to test the SLAMM conceptual model. 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. If such a change is made, the change and the reason for it are fully documented.
- 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 et al. 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 (Council for Regulatory Environmental Modeling 2008). Site-specific factors that increase or decrease model uncertainty may be covered in the Results and Discussion section of this report.

Sea Level Rise Scenarios

Forecast simulations used 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. Given this A1B scenario, the IPCC WGI Fourth Assessment Report (IPCC 2007) suggests a likely range of 0.21 m to 0.48 m of SLR by 2090-2099 "excluding future rapid dynamical changes in ice flow." The IPCC-produced A1B-mean scenario that was run as a part of this project falls near the middle of this estimated range, predicting 0.39 m of global SLR by 2100. A1B-maximum predicts 0.69 m of global SLR by 2100. However, other scientists using the same set of economic growth scenarios have produced much higher estimates of SLR as discussed below.

Recent 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 m 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." (Clark 2009) 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 in this report, SLAMM was also run assuming 1 m, 1.5 m, and 2 m of eustatic sea level rise by the year 2100. The A1B- maximum scenario was scaled up to produce these bounding scenarios (Figure 2).

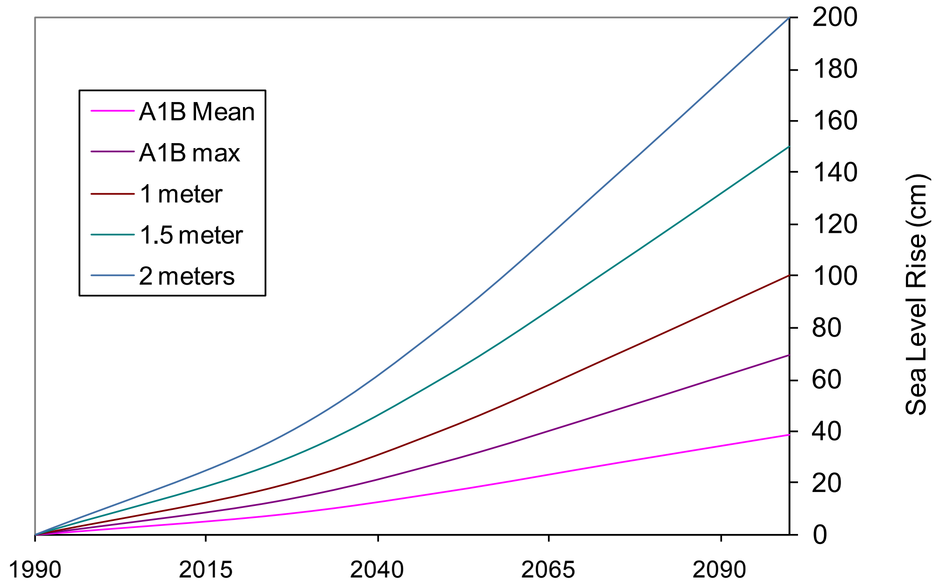

Figure 2. Summary of SLR Scenarios

Methods and Data Sources

Digital Elevation Models

Except where otherwise noted, elevation maps used in this model application were derived from Oregon Department of Geology and Mineral Industries (DOGAMI) LiDAR collected in 2010 (http://www.oregongeology.org/sub/lidardataviewer/index.htm). The boundaries of the eleven sites analyzed were defined by the extent of LiDAR coverage. A map of each of these sites is shown in Figure 3. Detailed elevation data for each site are shown in the individual site subsections of this report.

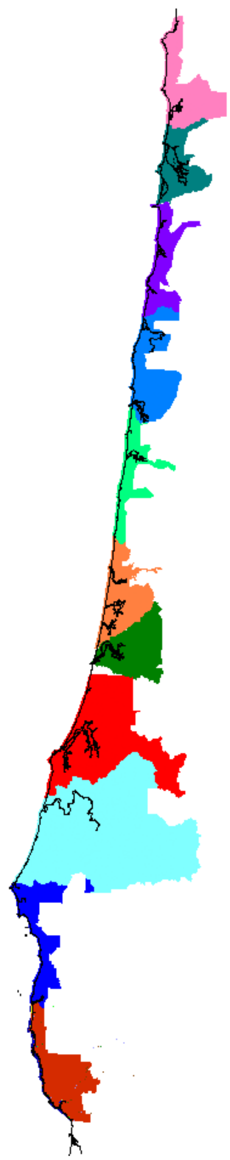

Figure 3. Extent of LiDAR elevation dataset for each site

Wetland coverage layers

Land-cover categories within the modeling for Lower Columbia were derived from the National Wetlands Inventory (NWI) downloaded from the US Fish and Wildlife Service website. Kevin Petrik of Ducks Unlimited confirmed with Elaine F. Block, Regional Wetlands Coordinator for the Pacific Southwest National Wetlands Inventory, that wetlands below 100 feet in elevation were updated in 2002. Therefore, the photo date used for all wetland layers was 2002.

The cell-size used for this analysis was 30 m by 30 m cells. Wetland data layers were converted from the NWI surveys to fit these cells, then to SLAMM categories. Wetland data were subsequently aggregated from the 26 SLAMM categories to one of seven wetland categories according to the crosswalk shown in Table 1[*].

Table 1. Crosswalk of SLAMM categories to aggregated categories

SLAMM Code	SLAMMNAME	Aggregated Category
1	Developed Dry land	Non Tidal
2	Undeveloped Dry land	Non Tidal
3	Swamp	Freshwater Non-Tidal
4	Cypress Swamp	Freshwater Non-Tidal
5	Inland Fresh Marsh	Freshwater Non-Tidal
6	Tidal Fresh Marsh	Freshwater Tidal
7	Transitional Marsh	Transitional
8	Regularly Flooded Marsh	Saltmarsh
9	Mangrove	Transitional
10	Estuarine Beach	Low Tidal
11	Tidal Flat	Low Tidal
12	Ocean Beach	Low Tidal
13	Ocean Flat	Low Tidal
14	Rocky Intertidal	Low Tidal
15	Inland Open Water	Open Water
16	Riverine Tidal	Open Water
17	Estuarine Water	Open Water
18	Tidal Creek	Open Water
19	Open Ocean	Open Water
20	Irregularly Flooded Marsh	Transitional
21	Not Used	
22	Inland Shore	Freshwater Non-Tidal
23	Tidal Swamp	Freshwater Tidal
24	Blank	
25	Vegetated Tidal Flat	Low Tidal
26	Back Shore	Transitional

[*] Results maps depicting each site in the full set of SLAMM categories are available on request.

The conversion of NWI wetland data to aggregated wetland categories suggests the approximately two million acre study area is composed of the categories as shown in Table 2. In reviewing the combined results for the entire study area, it is important to note that some overlap exists between sites 10 & 11, in order to capture whole watersheds and their boundaries. In this area the boundaries of the Rogue River watershed are highly curved and the watershed boundaries have been buffered by a half mile to capture all the major features on the coast in this area. In addition, a small portion of coastline between sites 7 and 8 was not modeled.

Table 2. Land cover categories and their abundance in the coastal Oregon study area according to the 2002 NWI layer.

Land cover type	Area (acres)	Percentage (%)
Upland	1891802	90
Freshwater Non-Tidal	79295	4
Open Water	87375	4
Low Tidal	34068	2
Saltmarsh	4241	< 1
Transitional	5414	< 1
Freshwater Tidal	3501	< 1
Total (incl. water)	**2105696**	**100**

Tidal Data

The tide range was applied in a spatially variable manner in each site depending on data availability. NOAA data for the Oregon coast were gathered from 43 tidal gauge stations (11 tidal datums and 32 tide table sites) to parameterize the model for tidal range. Table 3 presents information on the NOAA tidal datum data used while Table 4 provides details on the tide table data applied.

Table 3. NOAA Tidal Datum Stations used

Station Name (OR)	Station ID	Site/subsite applied to	Great Diurnal Tide Range (m)
Garibaldi	9437540	2 - Entrance	2.54
Netarts, Netarts Bay	9437262	2 - Netarts	2.09
Yaquina USCG Sta, Newport	9435385	4- Yaquina	2.50
South Beach, Yaquina	9435380	4- Yaquina	2.54
Weiser Point, Yaquina River	9435308	4- Yaquina	2.58
Toledo	9435362	4- Yaquina	2.69
North Bend, Coos Bay	9432895	8 – Bay Center	2.57
Sitka Dock, Coos Bay	9432879	8 - Coast	2.35
Charleston	9432780	8 - Coast	2.32
Isthmus Slough, Coos Bay	9432796	8 - Upstream	1.01
Port Orford	9431647	10 - Coast	2.67

Table 4. NOAA Tide Table Stations used

Station Name (OR)	Site/subsite applied to	Great Diurnal Tide Range (m)
Brookings, Chetco Cove	11 - Chetco	2.10
Wedderburn, Rogue River	10 – Upstream	2.04
Port Orford	10 - Coast	2.22
Bandon, Coquille River	9 - Coquille	2.16
Charleston	8 - Coast	2.32
Empire	8 - Coast	2.04
Coos Bay	8 – Bay Center	2.23
Umpqua River Entrance	7- Coast	2.10
Gardiner	7 - Upstream	2.04
Reedsport	7 - Upstream	2.04
Siuslaw River Entrance	6 - Coast	2.23
Florence	6 - Upstream	2.01
Waldport, Alsea Bay	5 - Estuary	2.35
Drift Creek, Alsea River	5 - Upstream	1.97
Bar at entrance	5 - Coast	2.41
Newport	4- Yaquina	2.44
Southbeach	4- Yaquina	2.54
Yaquina	4- Yaquina	2.50
Winant	4- Yaquina	2.50
Toledo	4- Yaquina	2.47
Depoe Bay	4- Yaquina	2.51
Taft, Siletz Bay	4 - Siletz	2.01
Kernville, Siletz River	4 - Siletz	1.86
Nestucca Bay entrance	3 - Nestucca	2.32
Netarts, Netarts Bay	2 - Netarts	2.09
Barview	2 - Coast	2.29
Garibaldi	2 - Entrance	2.54
Miami Cove	2 - Entrance	2.26
Bay City	2 - Center	2.16
Tillamook, Hoquarten Slough	2- Upstream	2.01
Brighton	1 - Coast	2.38
Nehalem	1 – Estuary	2.19
Seaside, Necanicum River	1 - North	1.77

Historic Sea Level Trend

The historic trend for sea level rise represents the amount and direction of land movement in a study area. The historic sea level rise observed along the coast of Oregon ranges from -0.31 mm/yr. in Astoria to 2.72 mm/yr. in South Beach, Yaquina (as shown in Figure 4). Tectonic activity in the

Pacific Northwest leads to significant variations in subsidence and uplift along the Oregon coast and results in a large variability in sea level trends in this region.

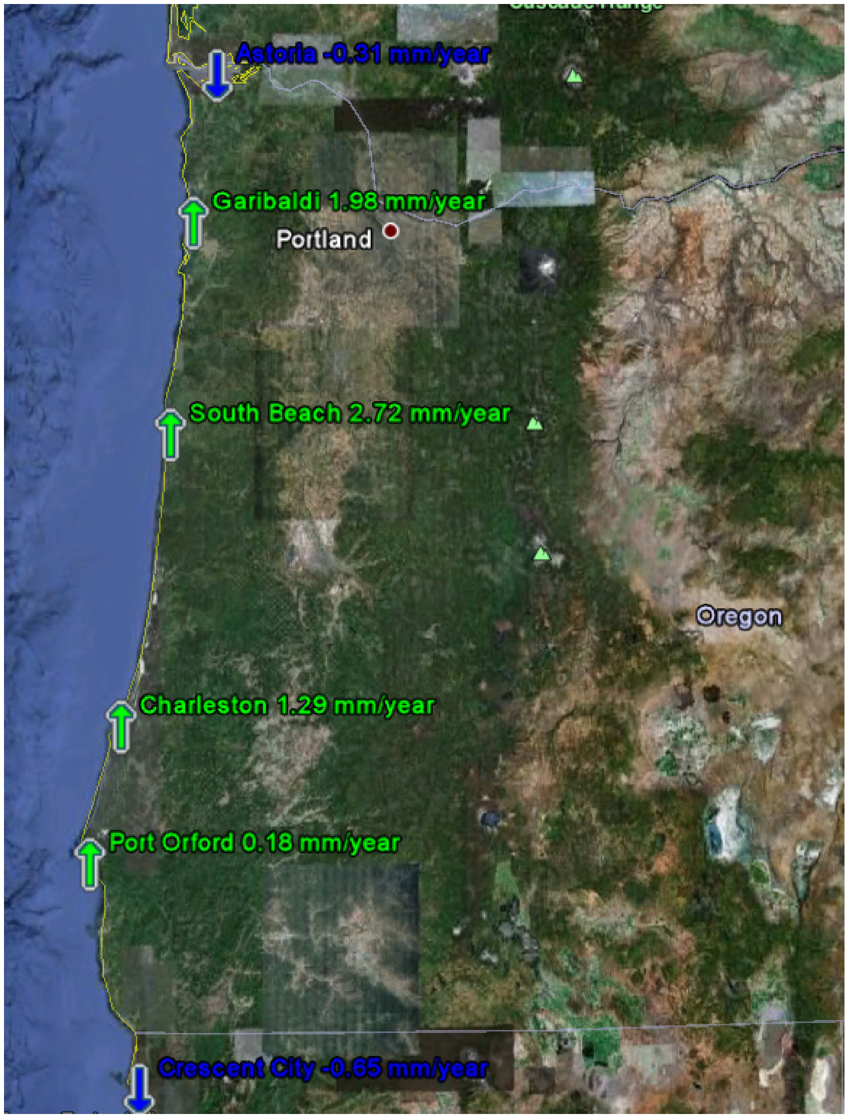

Figure 4. Locations of SLR gauge stations and observed trends on the Oregon coast

Work by Vincent (1989) and Komar and coworkers (2011) suggests a distinct pattern of uplift and subsidence occurring along the OR coast, which is also reflected in the NOAA tide gauge measurements. Figure 5 presents a comparison of the NOAA tide gauge measurements and their 95% confidence intervals, superimposed on the most recent assessment of relative SLR rates published by Komar et al. (2011). The NOAA gauges appear to slightly overestimate the SLR trends when compared to the data of Komar (which uses data from Burgette et al. (2009). In this model application, both datasets were considered in determining the historic SLR, as reflected by the purple triangles in Figure 5. It should be noted that the historic SLR trend values used in this model application fall within the 95% confidence intervals of the NOAA gauge SLR predictions. However, the spatial variability of uplift and subsidence on the Oregon coast leads to increased model uncertainty.

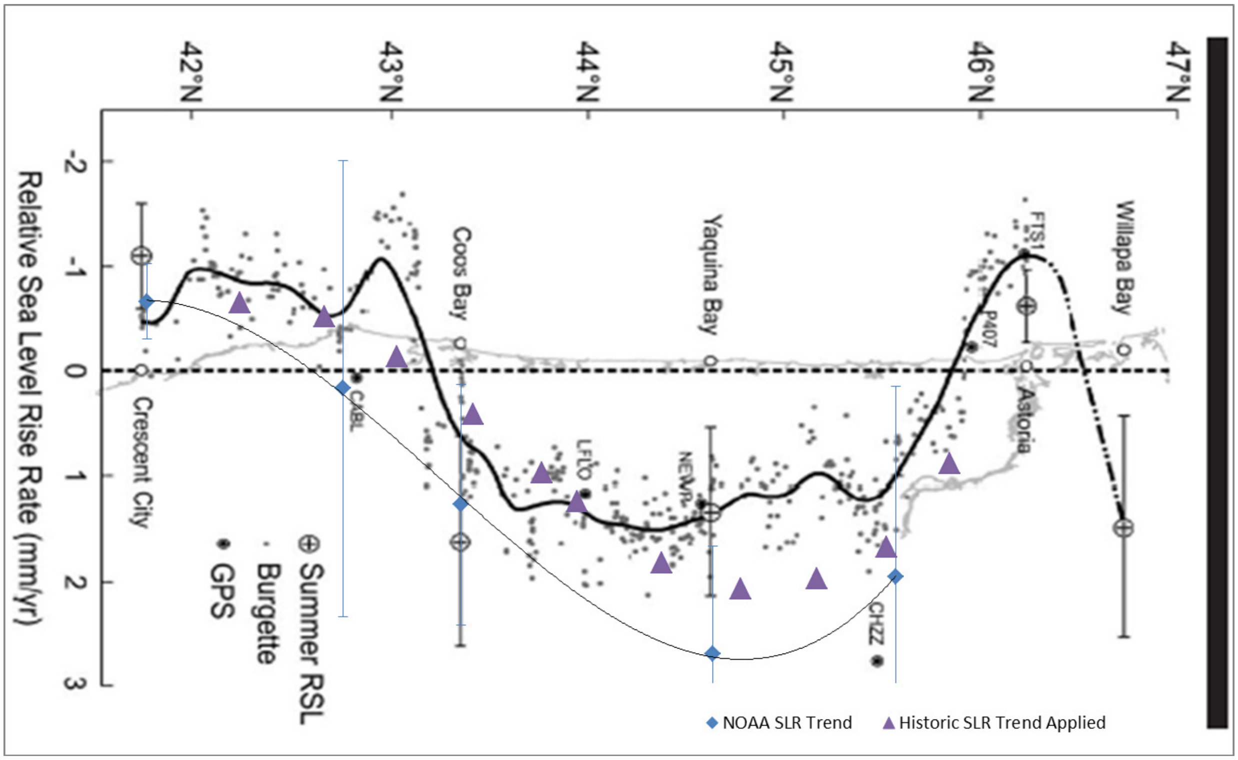

Figure 5. Land movement relative to SLR from Komar and coworkers (2011) with NOAA historic trend gauges (blue diamonds) and the historic trends assigned to the study sites herein (purple triangles).

Salt Elevation

The "salt elevation" parameter within SLAMM designates the boundary between coastal wetlands and dry lands or fresh water wetlands. An estimate of this elevation may be derived by examining historical tide gauge data to determine how frequently different elevations are flooded with ocean water. Within SLAMM modeling simulations this elevation is usually defined as the elevation over which flooding is predicted less than once in every 30 days. The "salt boundary" in SLAMM was set based on analyses of tidal data of coastal Oregon. Sufficient data to determine the 30 day inundation height was available at Garibaldi, South Beach Yaquina, Charleston, and Port Orford tide stations. These heights were then applied to the model by multiplying them by the great diurnal tide range applied for each subsite. Figure 6 shows an example of the results of an inundation analysis conducted for the Garibaldi, OR NOAA gauge.

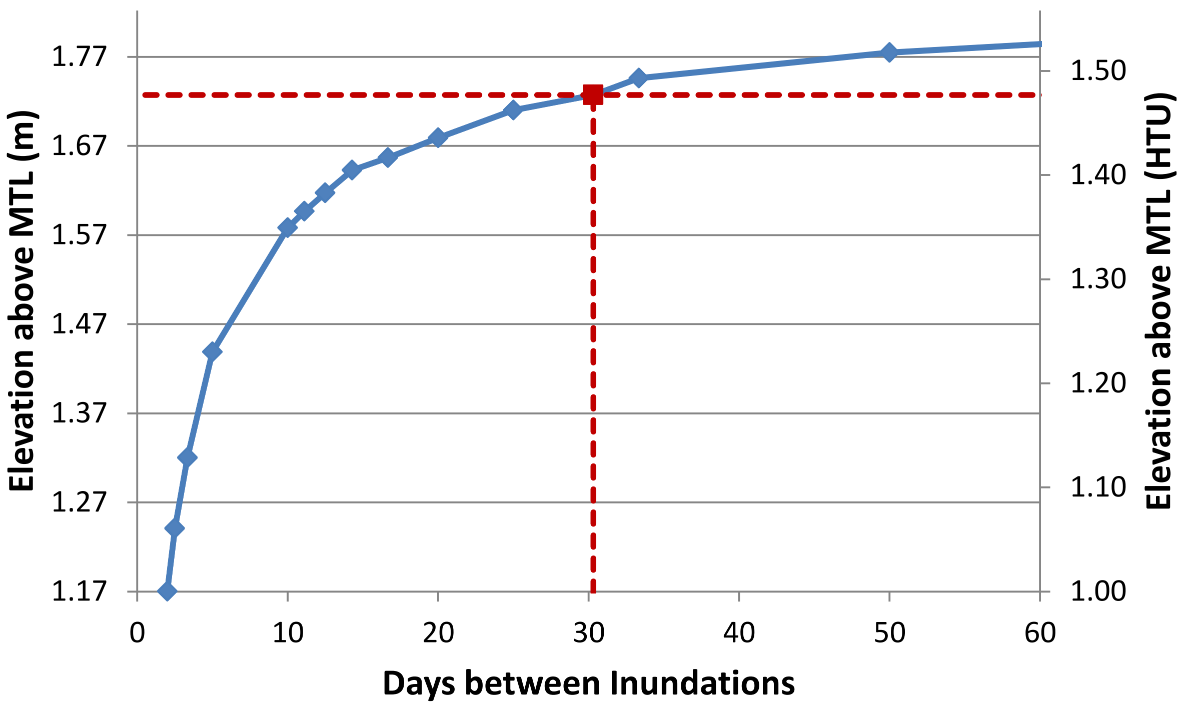

Figure 6. Inundation analysis at Garibaldi, OR

Diked lands
Areas in the study area protected by dikes were derived from a combination of data sources. The primary data source for this parameter was the work of Laura Mattison of Oregon Department of Land Conservation and Development who has performed an exhaustive analysis of dike locations based on existing LiDAR data sets. In addition, diked and impounded areas are listed within the National Wetland Inventory, but this coverage is often incomplete. An examination of USGS topographical maps was also undertaken. Finally, model results were used to see where saline inundation is immediately predicted. Local sources were contacted to determine if these areas are actually protected by dikes. This analysis was primarily performed by Kevin Petrik of Ducks Unlimited. Since SLAMM considers diked areas to be protected from inundation effects until they are 2 m below MTL, it is important to ensure the correct dike assignments are made.

Erosion and Accretion
Little site-specific data were available for accretion and erosion. Therefore, marsh and swamp accretion were set to 3 mm/year for sites 2 through 11 based on an accretion study performed in Salmon River (Thom, 1992). This value is consistent with the regional average of 3.8 mm/year for the Pacific Northwest as described by Thom (1992).

Site 1 was located less than 30 miles due south of Willapa Bay, Washington, which was previously modeled by WPC using SLAMM. In the Willapa Bay study, model marsh accretion values were determined using data from an unpublished study by Young, Atwater and McKee (Reusser, 2010). Cores were taken in the summer of 1995, with low marsh (regularly flooded) accretion estimated at 2.1 mm/year and high marsh (irregularly flooded) accretion estimated at 2.8 mm/year. Therefore in

Site 1, an accretion rate of 2.1 mm/yr. was applied to the regularly-flooded marshes. An accretion rate of 3 mm/yr. of was applied to the irregularly –flooded marsh and swamp based on the publication from Thom (1992) and its similarity to the observation in Willapa Bay. For all other sites, in the absence of site-specific data, accretion rates of 3 mm/yr. were applied to regularly-flooded, irregularly-flooded, tidal fresh and inland fresh marsh.

Direct erosion of marshes was assumed to be negligible for the Oregon coast. SLAMM assumes marsh erosion only when adequate oceanic fetch exists to allow for wave setup. The protected location of the majority of marshes precludes prediction of marsh erosion by SLAMM. Additionally, marsh erosion in several of the study areas may be assumed to be minimal because of the depositional nature of the estuaries due to logging activities (e.g., in the Siletz River Estuary, Pakenham, 2009).

Elevation Conversion

Elevation data were converted to a mean tide level (MTL) basis using data NOAA's VDATUM software. MTL to NAVD88 elevation correction rasters were created for each study site allowing for corrections on a cell-by-cell basis.

Initial model calibration.

Initially, SLAMM simulates a "time zero" step, in which the conceptual model validates the consistency between wetland information, elevation and tidal data. Due to local factors, DEM and NWI uncertainty, and simplifications within the SLAMM conceptual model, some cells inevitably may fall below their lowest allowable elevation category and would be immediately converted by the model to a different land cover category (e.g. an area categorized in the wetland layer as swamp where water has a tidal regime according to its elevation and tidal information will be converted to a tidal marsh). These cells represent outliers on the distribution of elevations for a given land-cover type. Generally, a threshold tolerance of up to 5% change is allowed for in major land cover categories in SLAMM analyses. These threshold values are site specific and they can be calibrated by analyzing the elevation distribution statistics associated to each land cover category.

In order for the SLAMM model to initially reproduce a similar wetland land cover to the available wetland survey, the minimum elevations for some wetland categories were set to the values based on LiDAR data for that particular site. These adjustments to the conceptual model were necessary to prevent SLAMM from predicting immediate inundation of these areas and reflect local dynamic wetland regimes in riverine environments. Within SLAMM, Tidal Swamp and Tidal Fresh Marsh lower-boundary elevations are assumed to be highly dependent on freshwater flow and therefore are generally set based on site-specific data. Any site-specific changes made to the SLAMM conceptual model are described in the individual site sections below.

Table 5. Default minimum wetland elevations in SLAMM conceptual model. HTU = Half-tide unit

SLAMM Category	Min Elev.	Min Unit
Undeveloped Dry Land	1	Salt Elev.
Developed Dry Land	1	Salt Elev.
Swamp	1	Salt Elev.
Ocean Beach	-1	HTU
Inland-Fresh Marsh	1	Salt Elev.
Tidal Flat	-1	HTU
Regularly-Flooded Marsh	0	Meters
Riverine Tidal	1	Salt Elev.
Irreg.-Flooded Marsh	0.5	HTU
Inland Open Water	1	Salt Elev.
Trans. Salt Marsh	1	HTU
Tidal Swamp	1	HTU[†]
Tidal-Fresh Marsh	0.5	HTU[†]
Estuarine Beach	-1	HTU
Rocky Intertidal	-1	HTU
Inland Shore	-1	HTU
Vegetated Tidal Flat	-1	HTU
Backshore	1	Salt Elev.
Cypress Swamp	1	Salt Elev.
Mangrove	0	Meters
Ocean Flat	-1	HTU
Tidal Creek	1	Salt Elev.

† Within SLAMM, Tidal Swamp and Tidal Fresh Marsh lower-boundary elevations are assumed to be highly dependent on freshwater flow and therefore are generally set based on site-specific data

Model Results

All Study Areas Combined

Predicted wetland losses for the entire study area under all the SLR scenarios examined are summarized in Table 6. Simulations predict large gains in transitional and salt marsh habitats. These gains are predicted to be particularly significant at SLR scenarios of 1 m by 2100 and above. Conversely, freshwater tidal wetlands are predicted to sustain the highest losses, followed by low-tidal and freshwater non-tidal habitats. When simulations were run with dikes removed similar results were observed, as shown in Table 7. However, the removal of dikes resulted in larger gains in transitional and saltmarsh habitats and larger losses in freshwater wetlands (both tidal and non-tidal). In addition, low tidal habitat is lost to a much lesser extent when dikes are removed and is predicted to start making small gains at higher SLR scenarios.

Table 6. Predicted Percent Change of Land Categories by 2100 for Entire Study Area Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	0	1	1
Open Water	-7	-11	-16	-23	-32
Freshwater Non-Tidal	4	6	8	12	17
Low Tidal	11	18	25	31	31
Transitional	-48	-60	-74	-77	-85
Saltmarsh	-52	-80	-117	-196	-203
Freshwater Tidal	3	8	20	43	60

Table 7. Predicted Percent Change of Land Categories by 2100 for Entire Study Area Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	1	1	1
Open Water	-7	-12	-18	-29	-42
Freshwater Non-Tidal	24	27	30	36	41
Low Tidal	7	6	3	0	-1
Transitional	-130	-112	-107	-103	-106
Saltmarsh	-318	-354	-354	-355	-305
Freshwater Tidal	5	11	25	53	71

Site 1: Nehalem

The northernmost site is the study area bordered the lower Columbia River in the north and contained the Nehalem estuary. The 140,734 acre site is predominantly upland (91%) and contains approximately 400 acres of salt marsh, as shown in Table 8.

Table 8. Wetland coverage of Site 1 according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	127,877	91
Open Water	4778	3
Freshwater Non-Tidal	3603	3
Low Tidal	2383	2
Transitional	1366	1
Saltmarsh	401	< 1
Freshwater Tidal	326	< 1
Total (incl. water)	**140,734**	**100**

Figure 7 and Figure 8 show the elevation data and location of dikes in this site, respectively. Several tide gauges are located within this site. Tide data was incorporated using subsites as shown in Figure 9. The Northern part of the study area was assigned a tide range of 1.77 m based on Seaside tide table data while the coastline and bay entrance were assigned a tide range of 2.38 based on data from the tide table located at Brighton. The inland portion of the study area was assigned a lower tide range of 2.19 m based on the tide table data from the Nehalem site. The salt elevations were calculated from the inundation analysis conducted at the Garibaldi NOAA gauge station (#9437540) and determined to be 1.31 m for the northern subsite, 1.76 m for the coastal subsite, and 1.62 m for the inland subsite. The historic SLR trend applied to this site was 0.9 mm/yr.

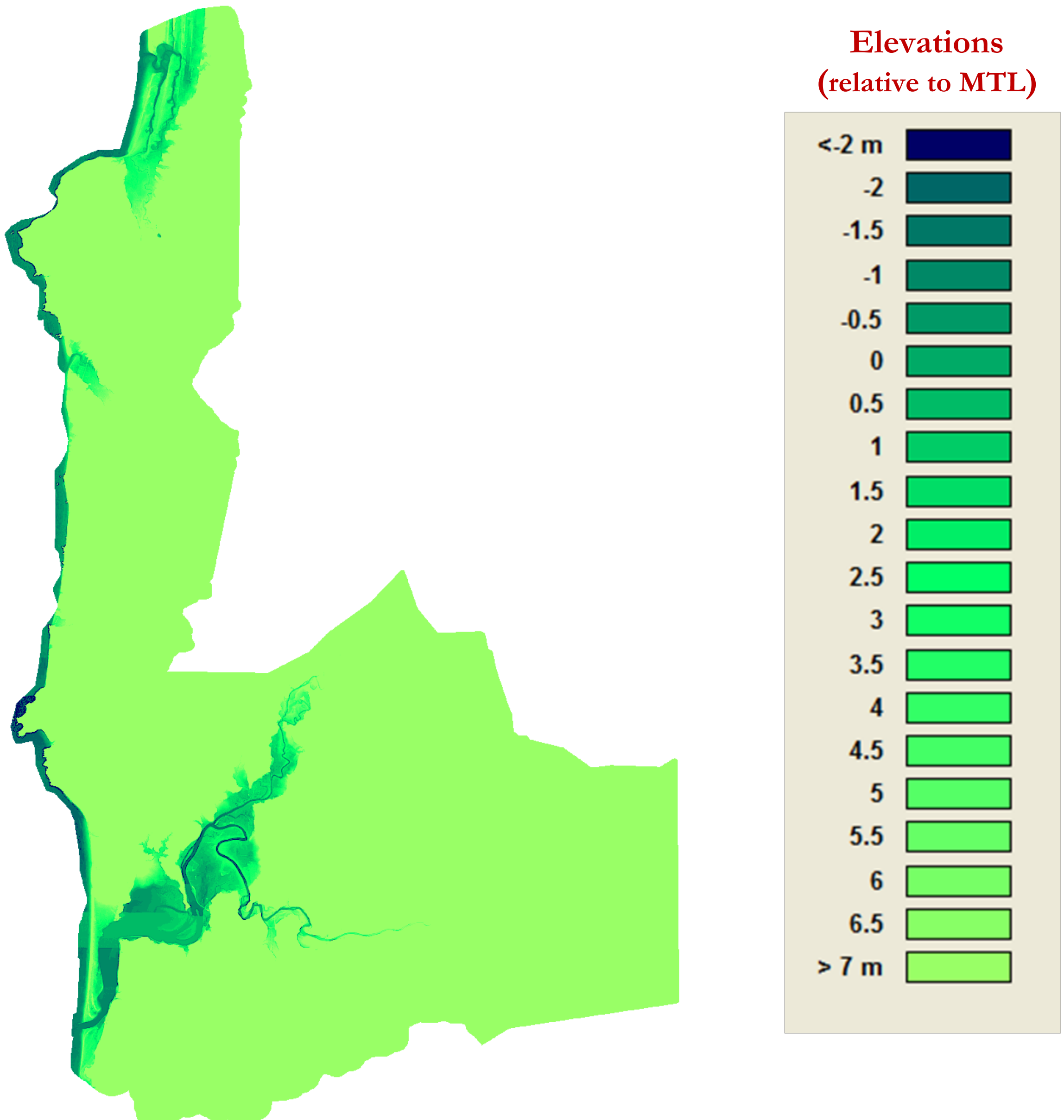

Figure 7. LiDAR elevation data for Site 1 – Nehalem

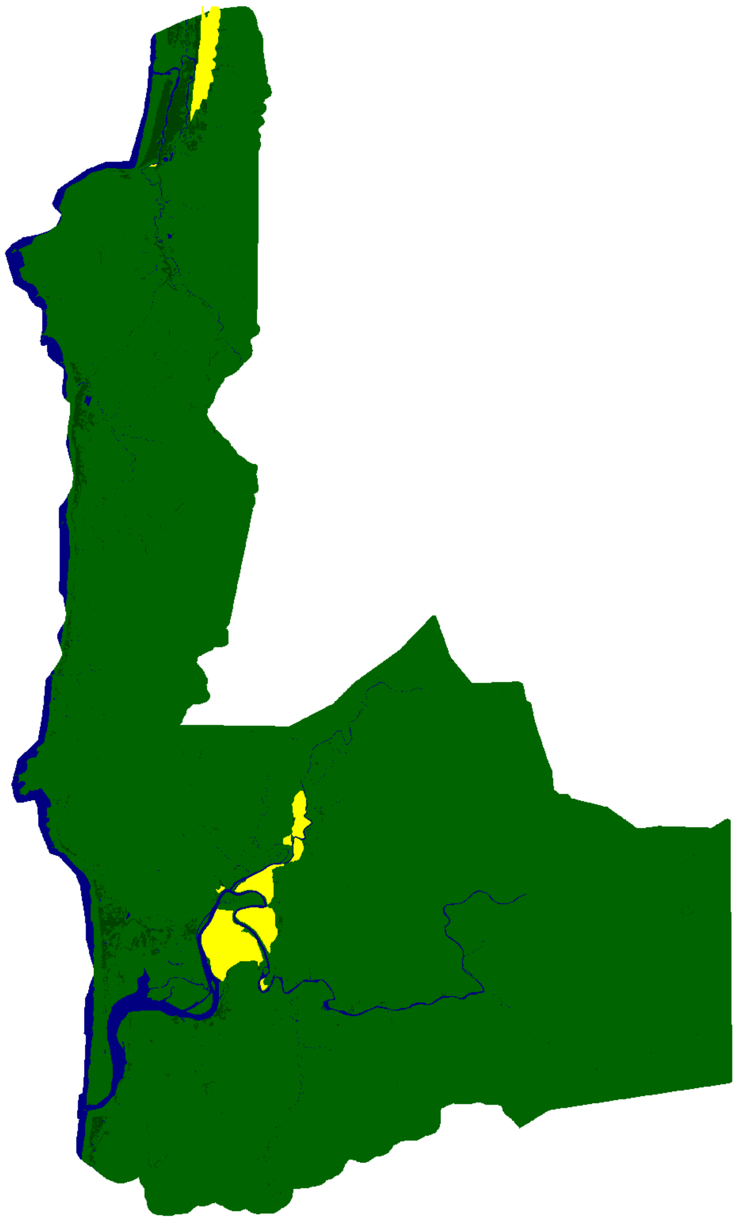

Figure 8. Location of dikes in Site 1 – Nehalem (shown in yellow)

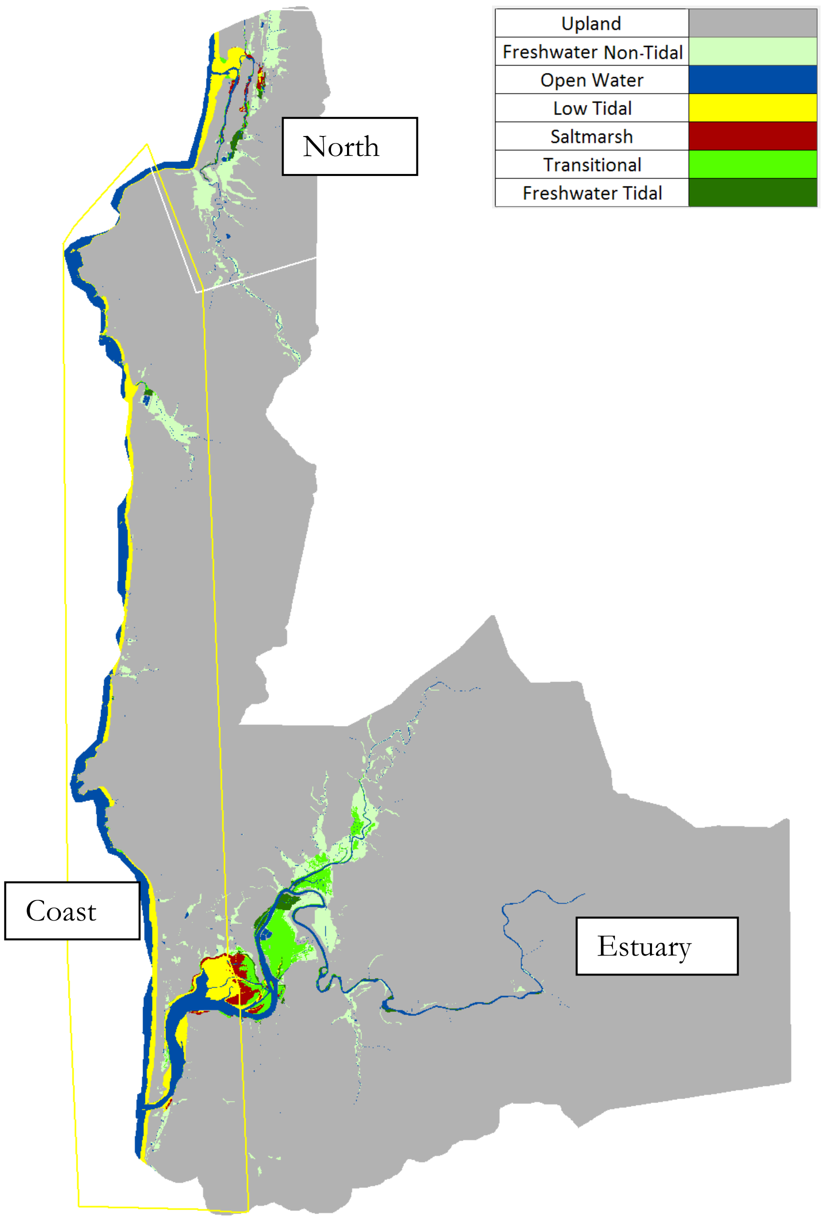

Figure 9. Wetland data for Site 1 – Nehalem, with subsites

Predicted wetland losses for all SLR scenarios are summarized in Table 9. Simulations predict large gains in salt marsh habitats (shown by negative values in Table 9). These gains are predicted to be particularly significant at SLR scenarios of 1.5 m by 2100 and above. These increases in salt marsh are predicted to occur in the Nehalem river estuary that is currently inhabited by non-diked freshwater non-tidal wetlands. The freshwater tidal category is predicted to sustain the highest losses, with a maximum of 65% loss predicted under the 2 m SLR by 2100 scenario.

Table 9. Predicted Percent Change of Land Categories by 2100 at Site 1 – Nehalem Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	0	0	1
Open Water	-6	-7	-11	-20	-29
Freshwater Non-Tidal	2	6	11	17	24
Low Tidal	7	9	13	20	19
Transitional	1	-9	-18	-8	-7
Saltmarsh	-20	-28	-50	-140	-187
Freshwater Tidal	4	8	17	42	65

The same set of SLR scenarios described above was run with the dikes removed to assess the potential effects of dike removal on wetland distribution. The results of this analysis, presented in Table 10, suggest dike removal would lead to greater losses in freshwater tidal, non-tidal and transitional marshes and greater gains in salt marsh.

Table 10. Predicted Percent Change of Land Categories by 2100 at Site 1 – Nehalem Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	0	1	1
Open Water	-6	-8	-11	-21	-32
Freshwater Non-Tidal	8	15	23	34	46
Low Tidal	4	4	5	2	-13
Transitional	17	13	10	23	23
Saltmarsh	-123	-181	-249	-354	-370
Freshwater Tidal	7	11	23	50	73

The predicted land cover maps at 2100 are shown below for each simulated SLR scenario.

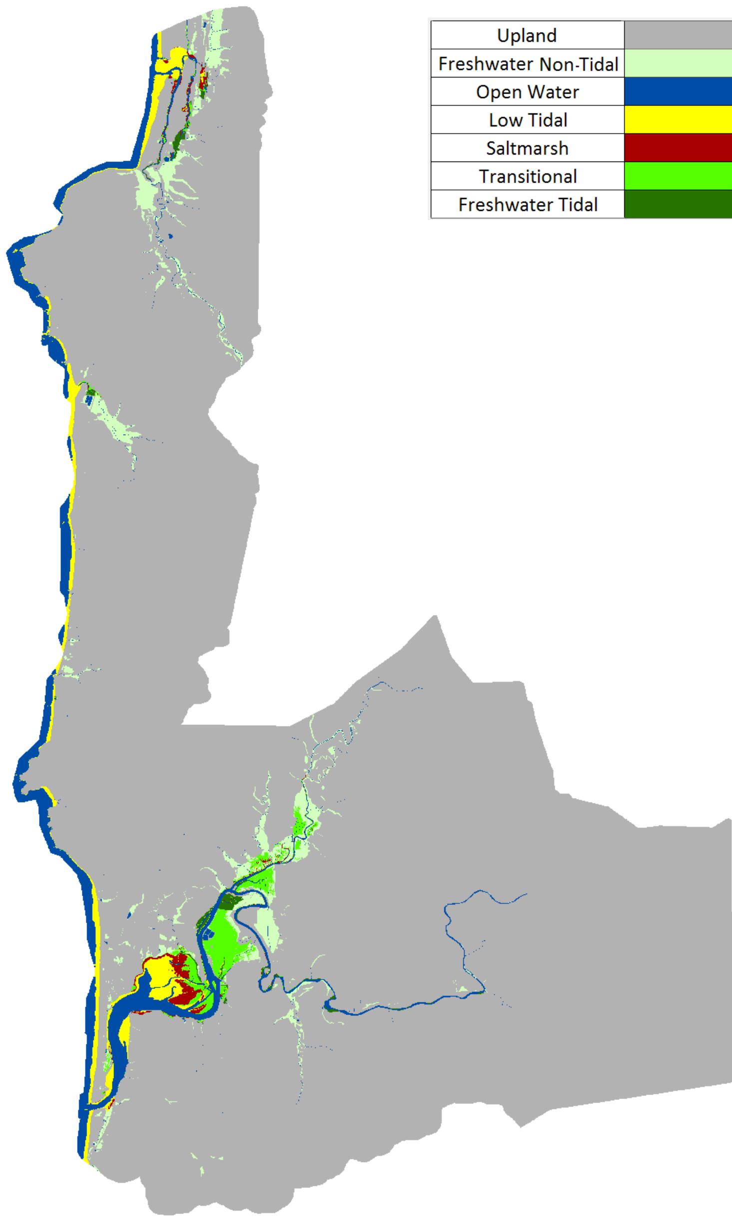

Figure 10. Site 1, 2100, Scenario A1B mean, (0.39 m)

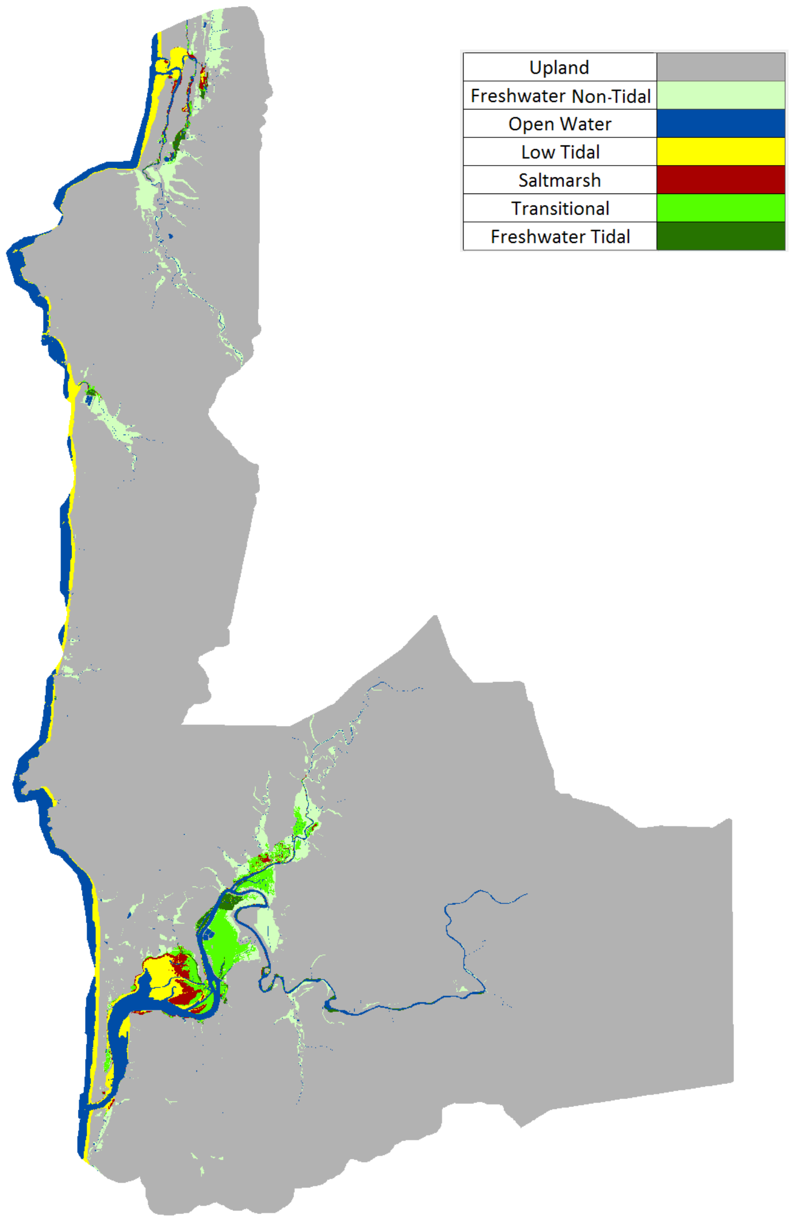

Figure 11. Site 1, 2100, Scenario A1B max, (0.69 m)

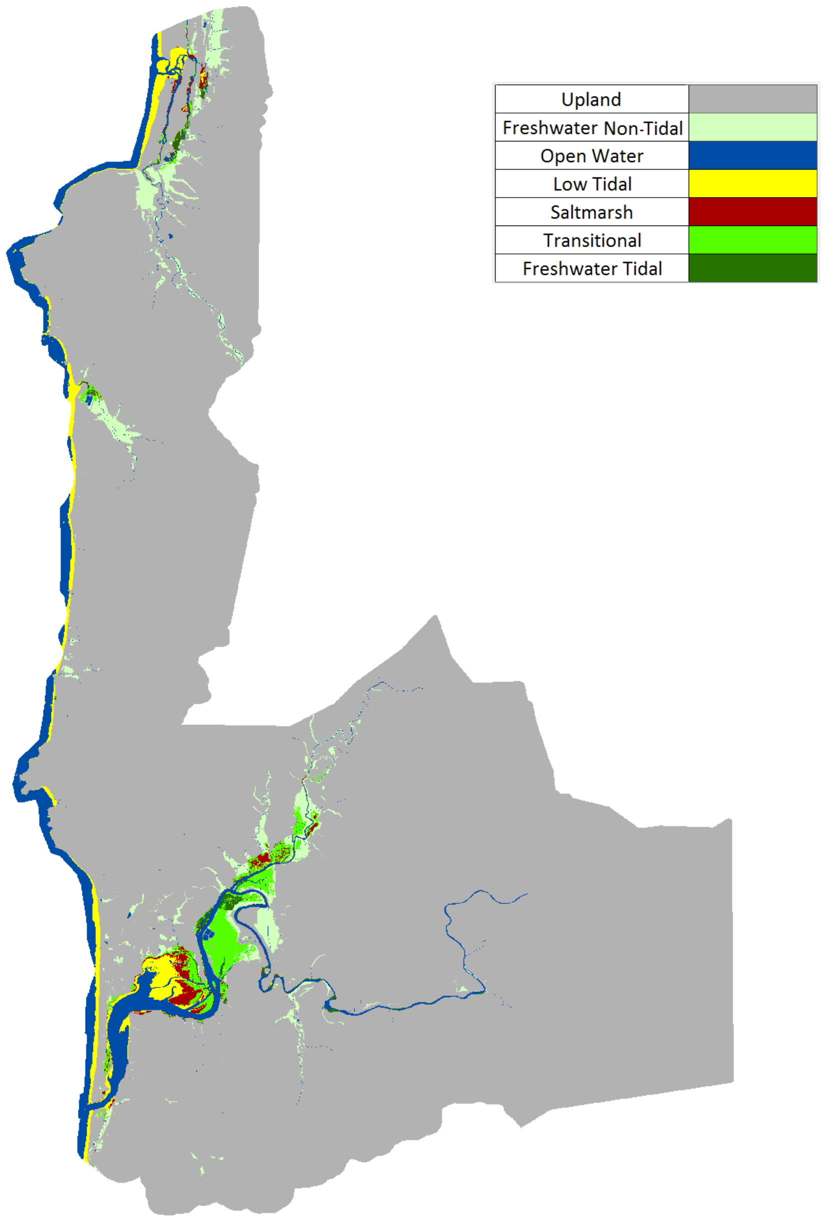

Figure 12. Site 1, 2100, Scenario 1 m

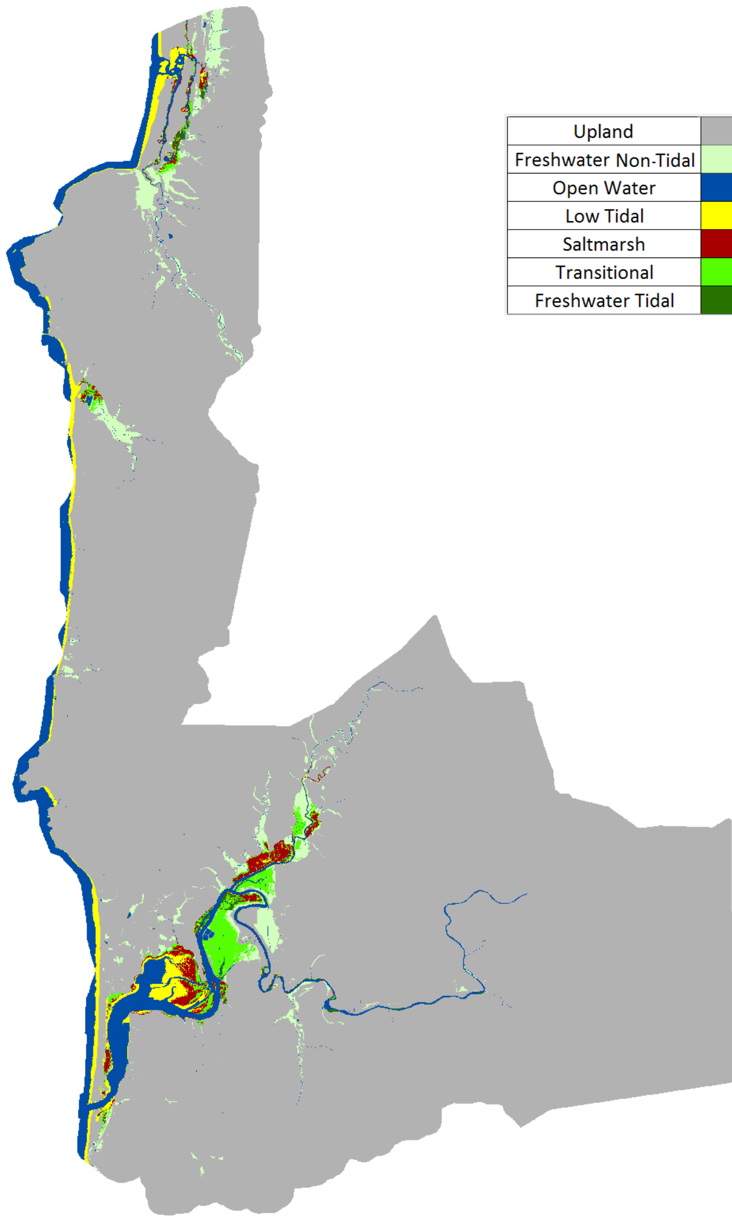

Figure 13. Site 1, 2100, Scenario 1.5 m

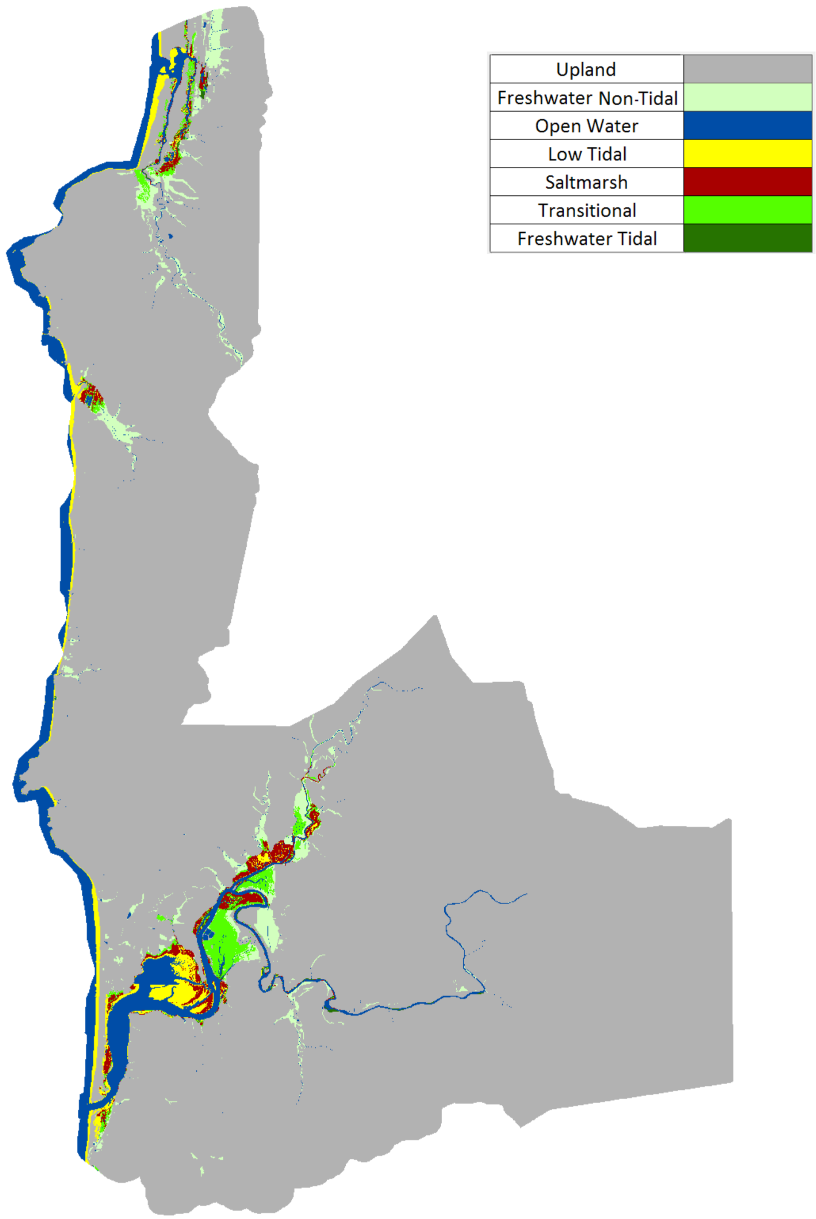

Figure 14. Site 1, 2100, Scenario 2 m

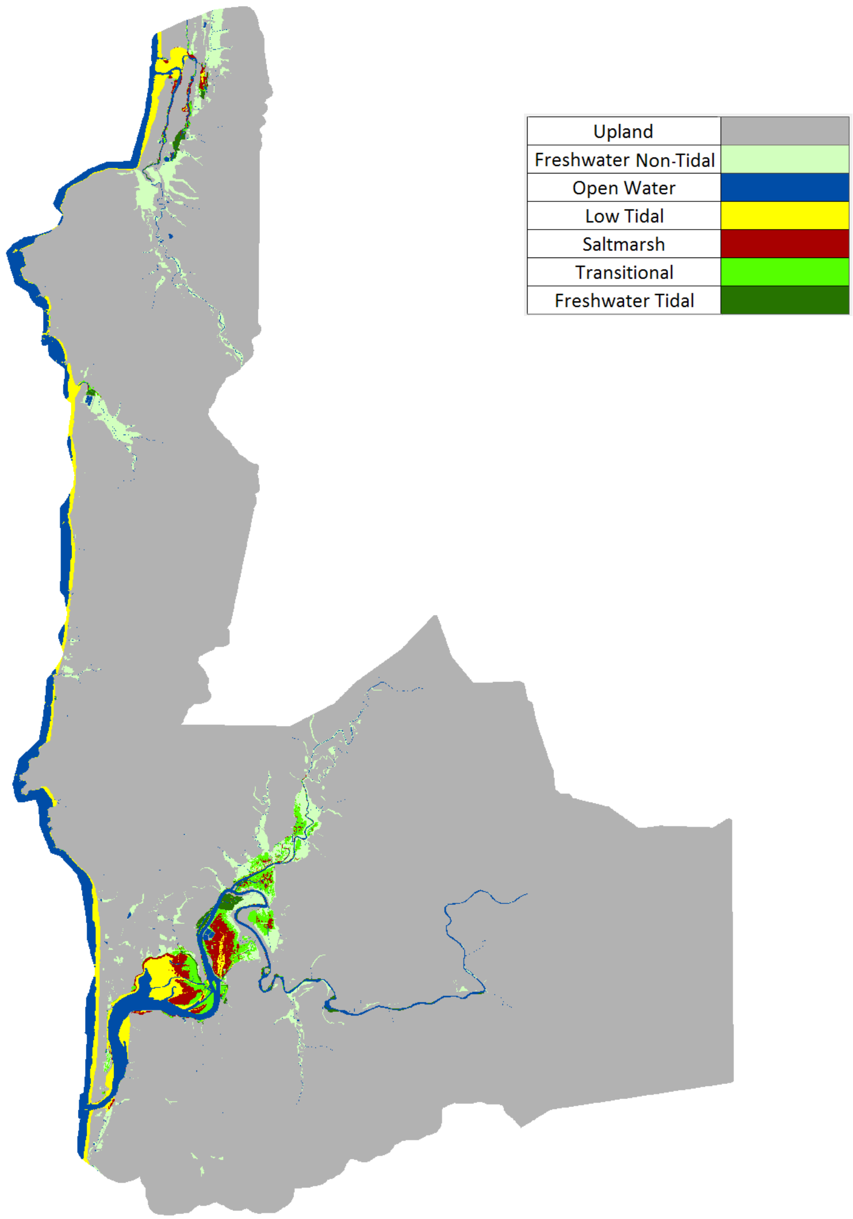

Figure 15. Site 1, 2100, Scenario A1B mean (0.39 m) – No Dikes

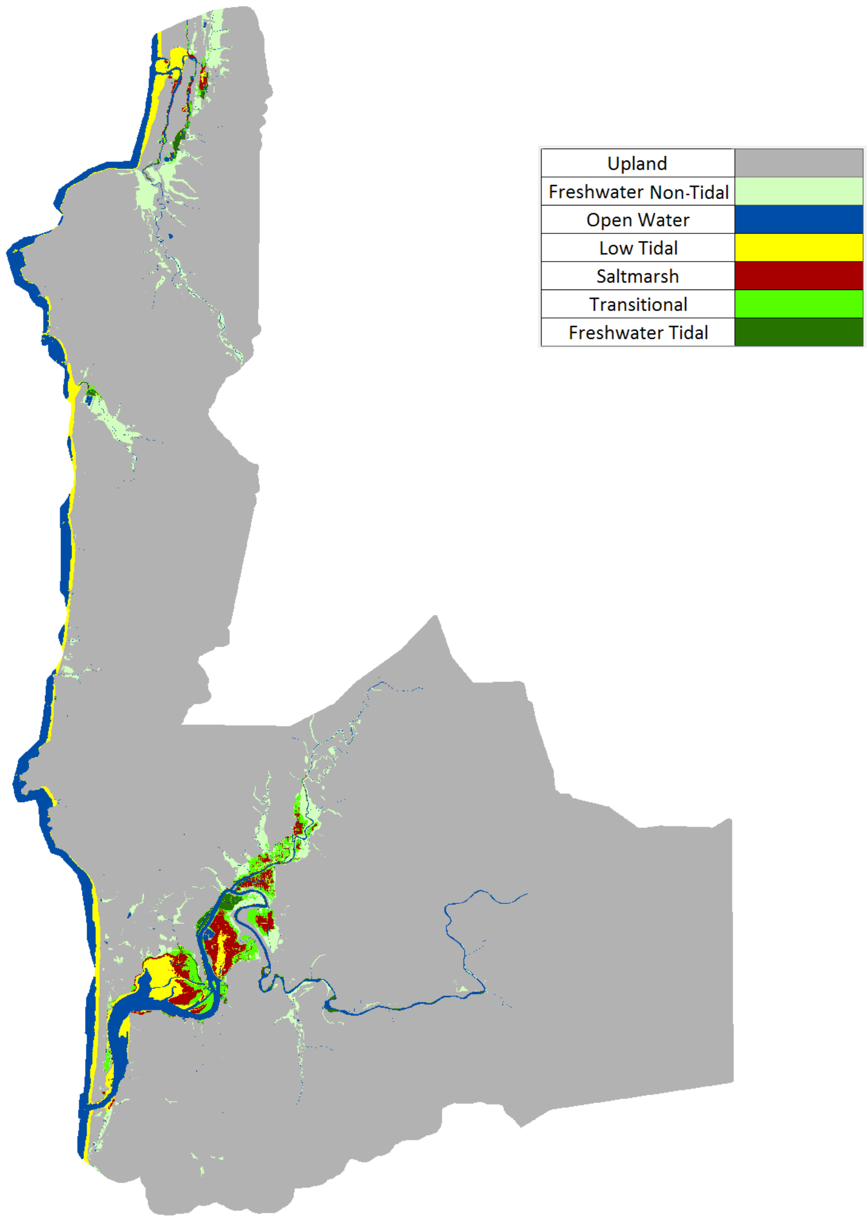

Figure 16. Site 1, 2100, Scenario A1B max (0.69 m) – No Dikes

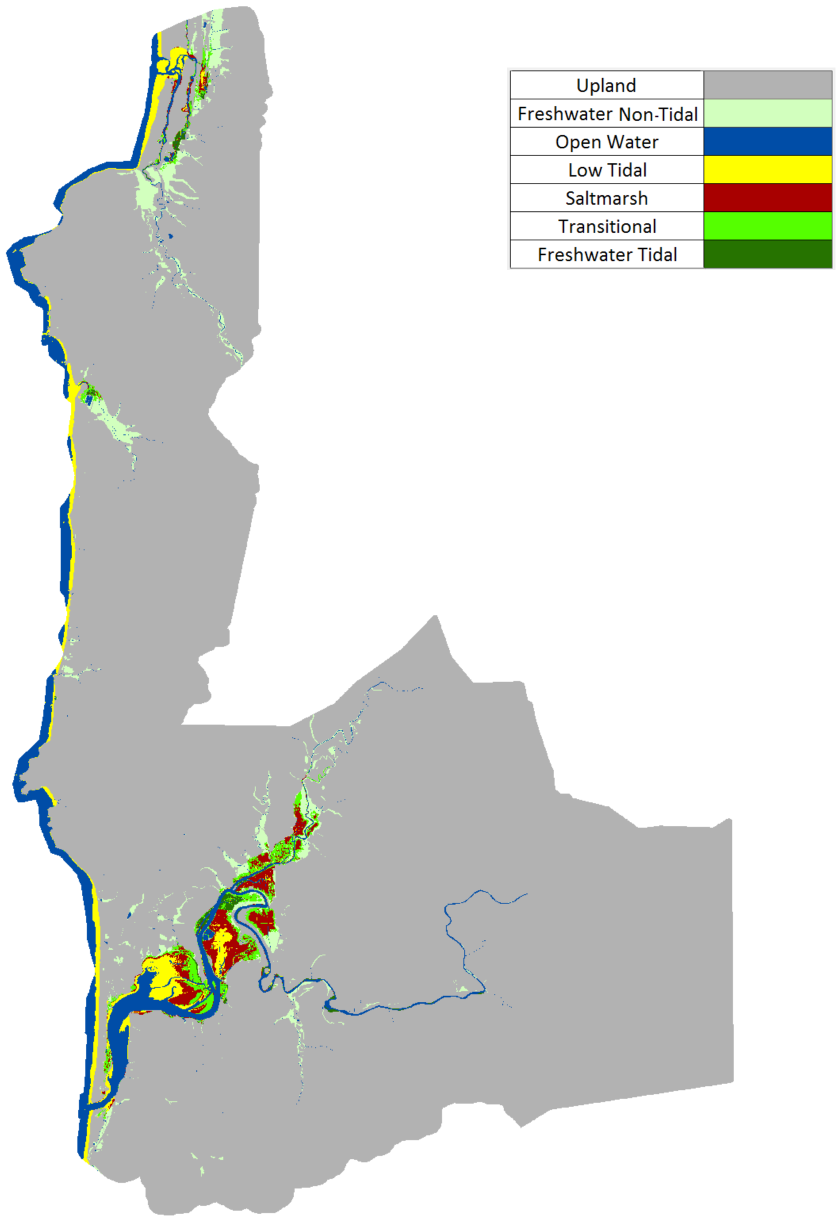

Figure 17. Site 1, 2100, Scenario 1 m – No Dikes

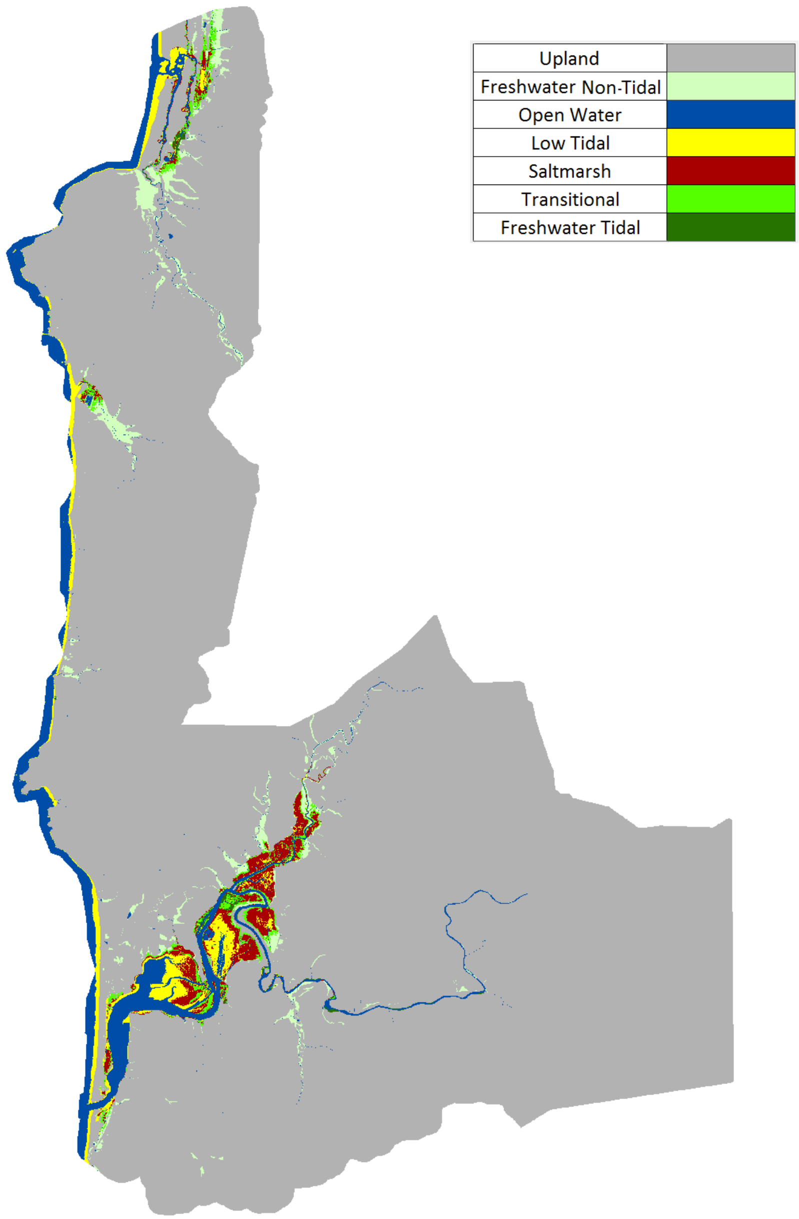

Figure 18. Site 1, 2100, Scenario 1.5 m – No Dikes

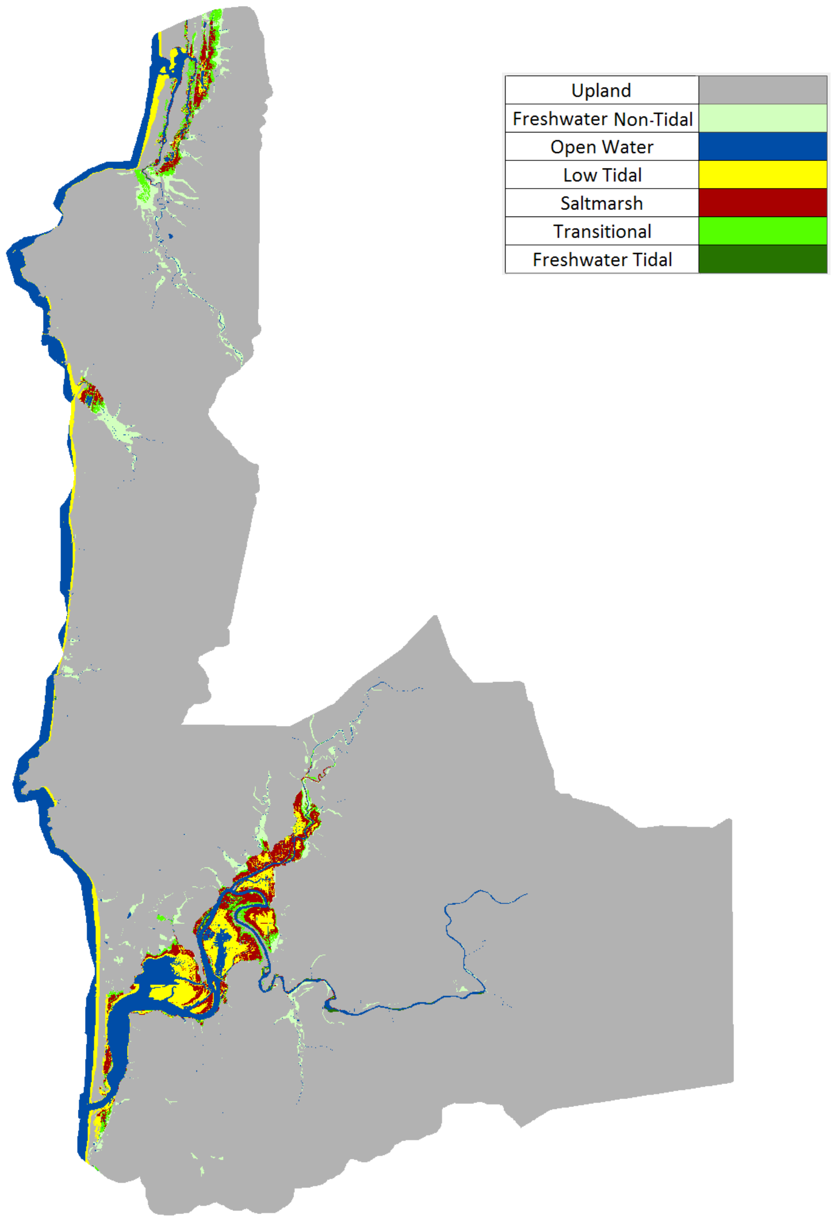

Figure 19. Site 1, 2100, Scenario 2 m – No Dikes

Site 2: Tillamook

The Tillamook estuary wetlands are composed primarily of low tidal and freshwater non- tidal habitats, as shown in Table 11.

Table 11. Wetland coverage of Site 2 according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	79133	76
Open Water	8739	8
Low Tidal	8638	8
Freshwater Non-Tidal	6577	6
Transitional	765	1
Saltmarsh	558	1
Freshwater Tidal	132	< 1
Total (incl. water)	**104541**	**100**

Figure 20 shows the elevation data applied to this site. Elevation data were derived from two data layers: the coastal portion of the site was covered by the 2010 DOGAMI LiDAR dataset while the marshes upstream (near the city of Tillamook) were not covered by LiDAR and therefore filled in with data from the National Elevation Dataset (NED). Both the NED portion of the study area and the tidal flats were subjected to the SLAMM elevation pre-processor (Clough et al. 2010). The pre-processor module is always applied when non-LiDAR elevation data is used. In this application the pre-processor was also applied to the tidal flats (low tidal) areas in Tillamook and Netarts Bays. These areas were covered by LiDAR but appeared to have data processing issues as noted by the striations in the elevation data shown in Figure 20. Figure 21 illustrates the location of dikes within in this site.

Several tide gauges are located within the sites which were incorporated into the study area using multiple subsites, as shown in Figure 22. The coastal part of the study area was assigned a tide range of 2.3 m (Barview tide table data). Netarts Bay was assigned a tide range of 2.1 m based on the Netarts Bay tidal datum (NOAA gauge #9437262). Tillamook Bay was assigned three different tide ranges: 2.4 m near the entrance (based on observations from the Garibaldi NOAA gauge #9437540 and Miami Cove stations), 2.2 m in the center of the bay (based on data collected at the Bay City tide table station), and 2 m upstream at the confluence of the bay and its tributaries based on data from the tide table located at Hoquarten Slough. The salt elevations were calculated from the inundation analysis conducted at the Garibaldi NOAA gauge station (#9437540), which is located within site 2. Salt elevations were determined to be 1.7 m for the coastal subsite, 2.1 m for Netarts, 1.77 m for the Bay entrance, 1.62 for the bay center, and 1.48 for the upstream subsite. The historic SLR trend applied to this site was 1.70 mm/yr. The SLAMM conceptual model was modified by reducing the lower elevation for tidal flats to the negative salt elevation (-1.5 HTU). This represents the extreme low water level, which conforms to the NWI description of the habitat in this area.

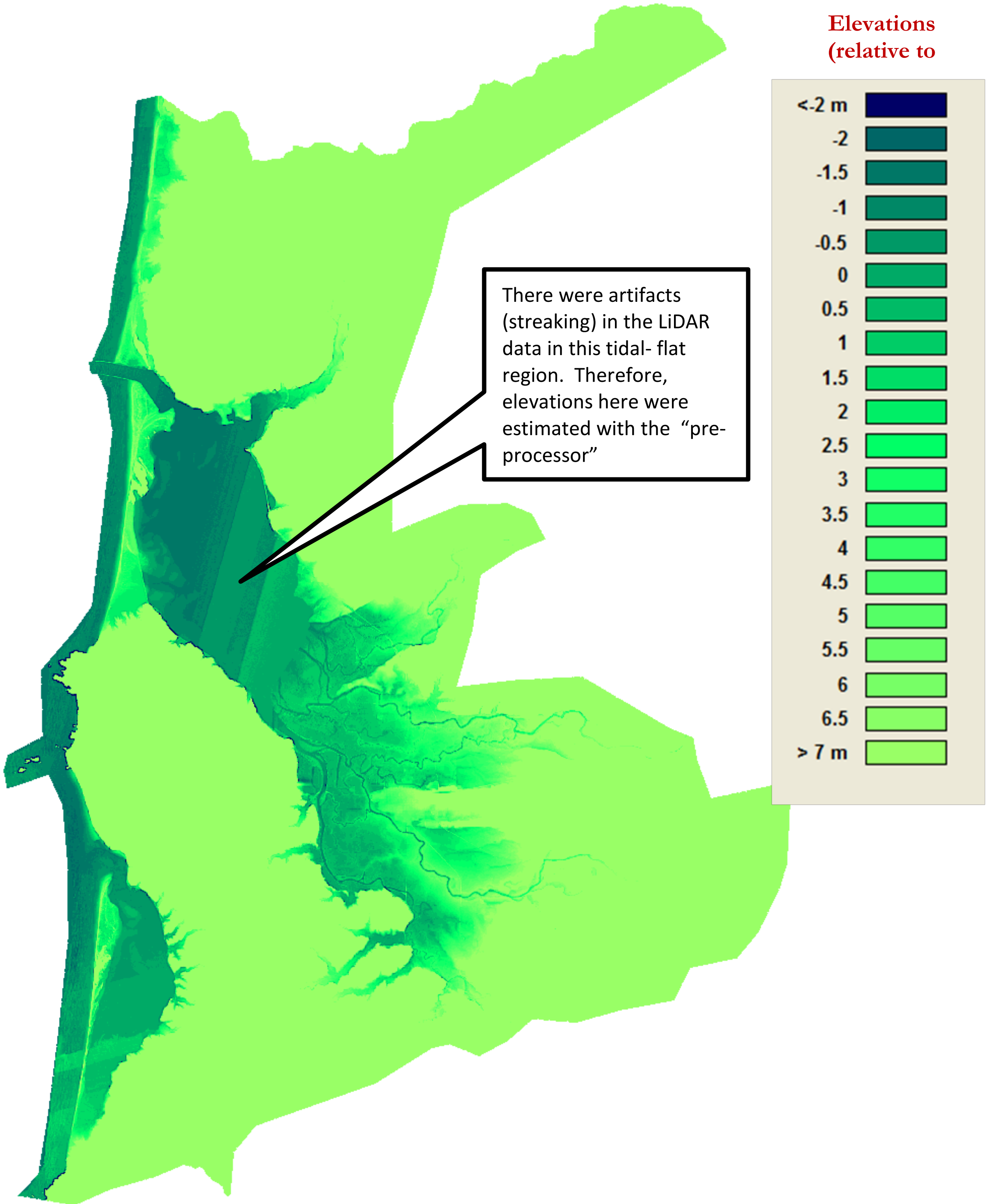

Figure 20. LiDAR and NED elevation data for Site 2 – Tillamook

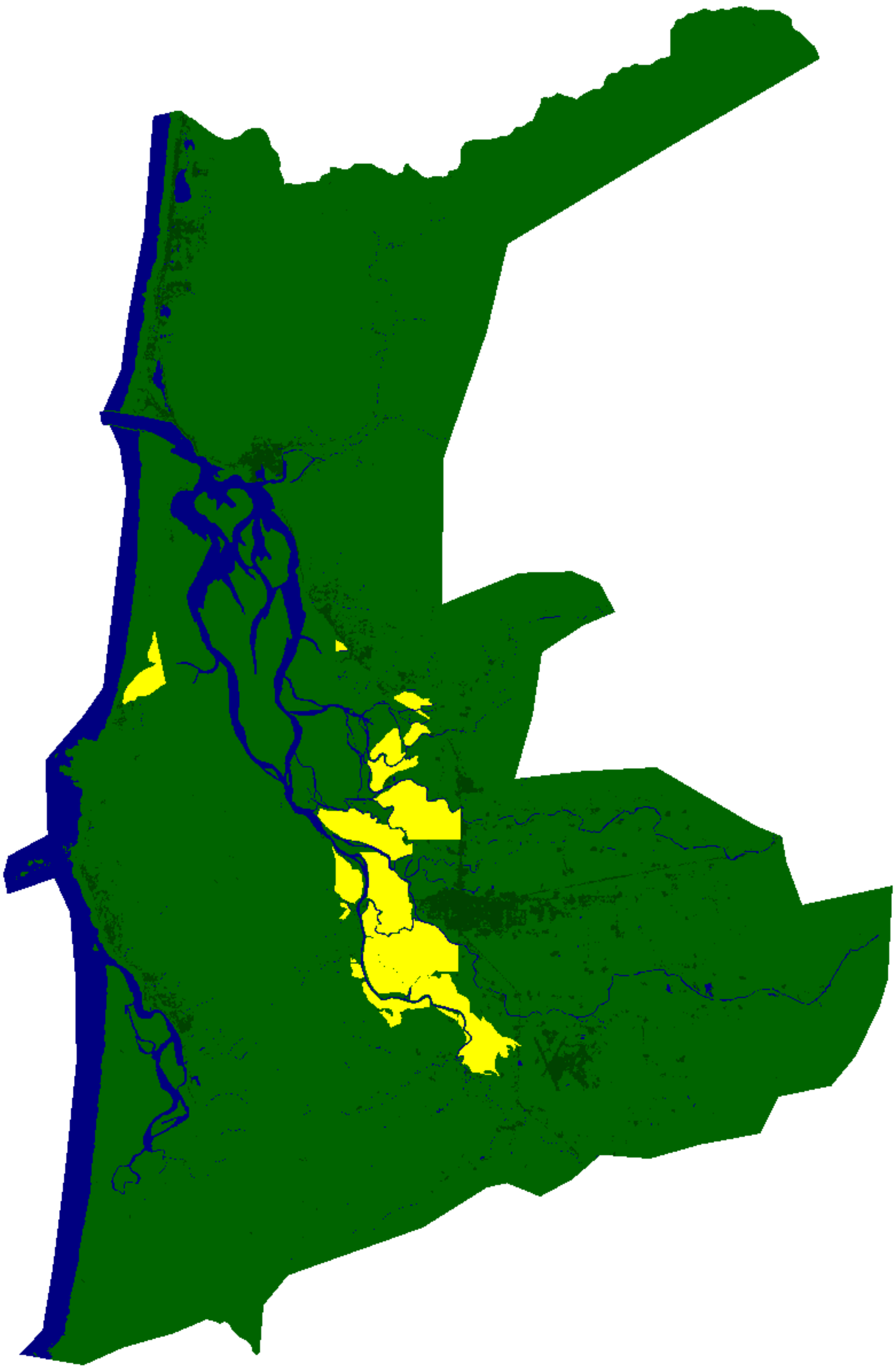

Figure 21. Location of dikes in Site 2 – Tillamook (shown in yellow)

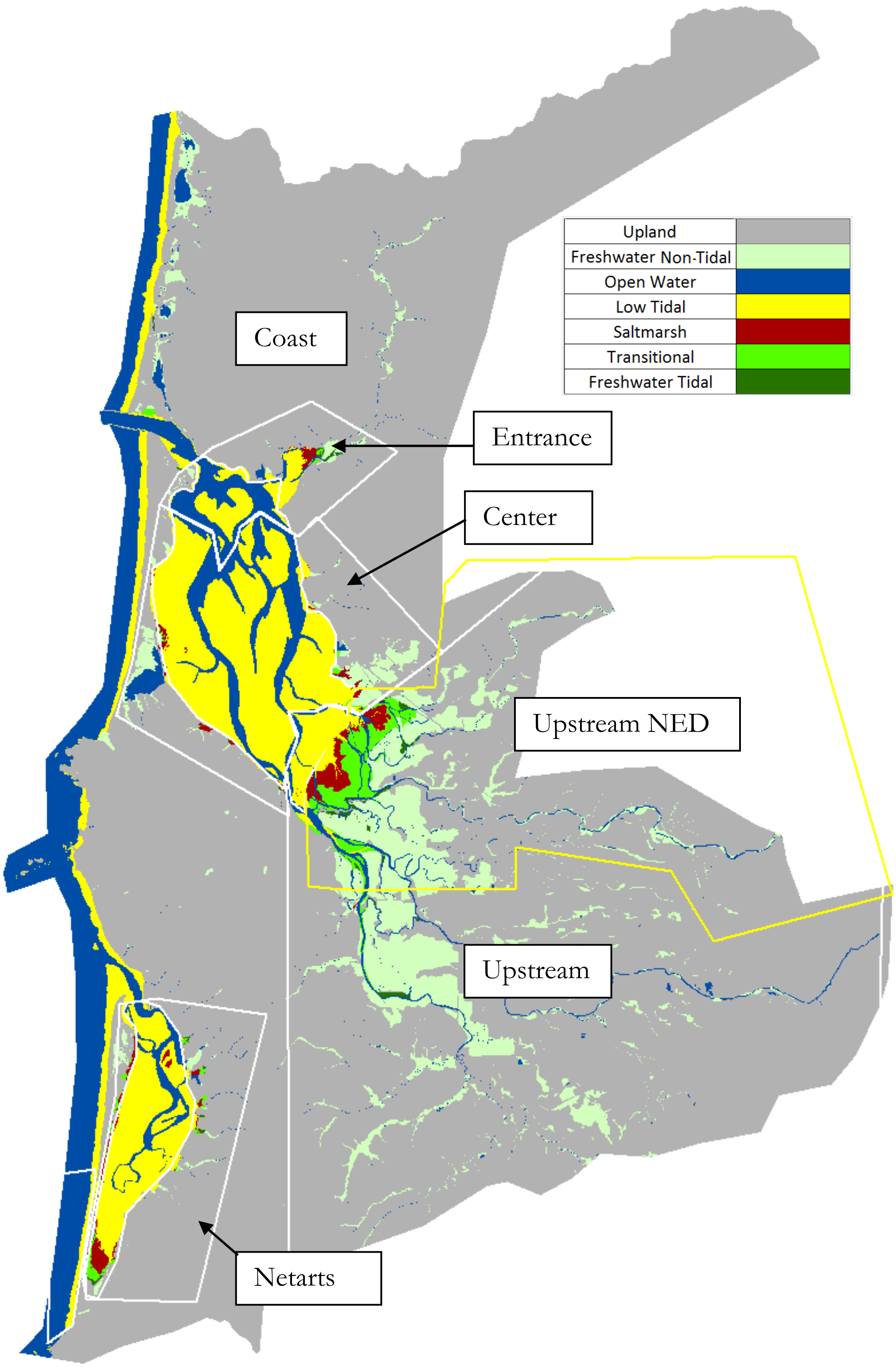

Figure 22. Wetland data for Site 2 – Tillamook

SLAMM simulations predict the Tillamook site to be affected by SLR under all the SLR scenarios examined. Table 12 presents the percentage of each land cover type predicted to be lost under each of the SLR scenarios examined. Low tidal habitat is the most at-risk wetland type, with predicted losses of 49 to 71 percent depending on the SLR scenario, followed by freshwater non-tidal habitat. Gains are predicted in the saltmarsh, transitional, and open water categories.

These results are presented with a few caveats. First, since the low tidal habitats in both Tillamook and Netarts Bays were subjected to the elevation –pre-processor, the timing of losses for this habitat type is fairly uncertain. In addition, low-lying wetlands that are far upstream are predicted to convert to saltwater wetlands even under the lowest SLR scenarios. This result is uncertain since upstream tide data were not available for the rivers that empty into Tillamook Bay.

Simulations run without the dikes included predicted greater losses in freshwater non-tidal habitat than when the dikes were included, as shown in Table 13. However, less loss was predicted for low tidal wetlands. Greater gains were predicted for saltmarsh and fresh marsh habitats.

Table 12. Predicted Percent Change of Land Categories by 2100 at Site 2 – Tillamook Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	0	1	2	3
Open Water	-52	-27	-72	-84	-93
Low Tidal	49	26	66	68	71
Freshwater Non-Tidal	9	5	13	19	24
Transitional	-38	-30	-45	-71	-88
Saltmarsh	-74	-32	-103	-137	-211
Freshwater Tidal	-10	-7	-8	0	15

Table 13. Predicted Percent Change of Land Categories by 2100 at Site 2 – Tillamook Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses.*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	1	1	3	4
Open Water	-52	-27	-72	-84	-93
Low Tidal	47	25	56	46	41
Freshwater Non-Tidal	48	42	54	61	65
Transitional	-143	-203	-107	-109	-105
Saltmarsh	-404	-265	-418	-331	-309
Freshwater Tidal	-76	-76	-64	-21	19

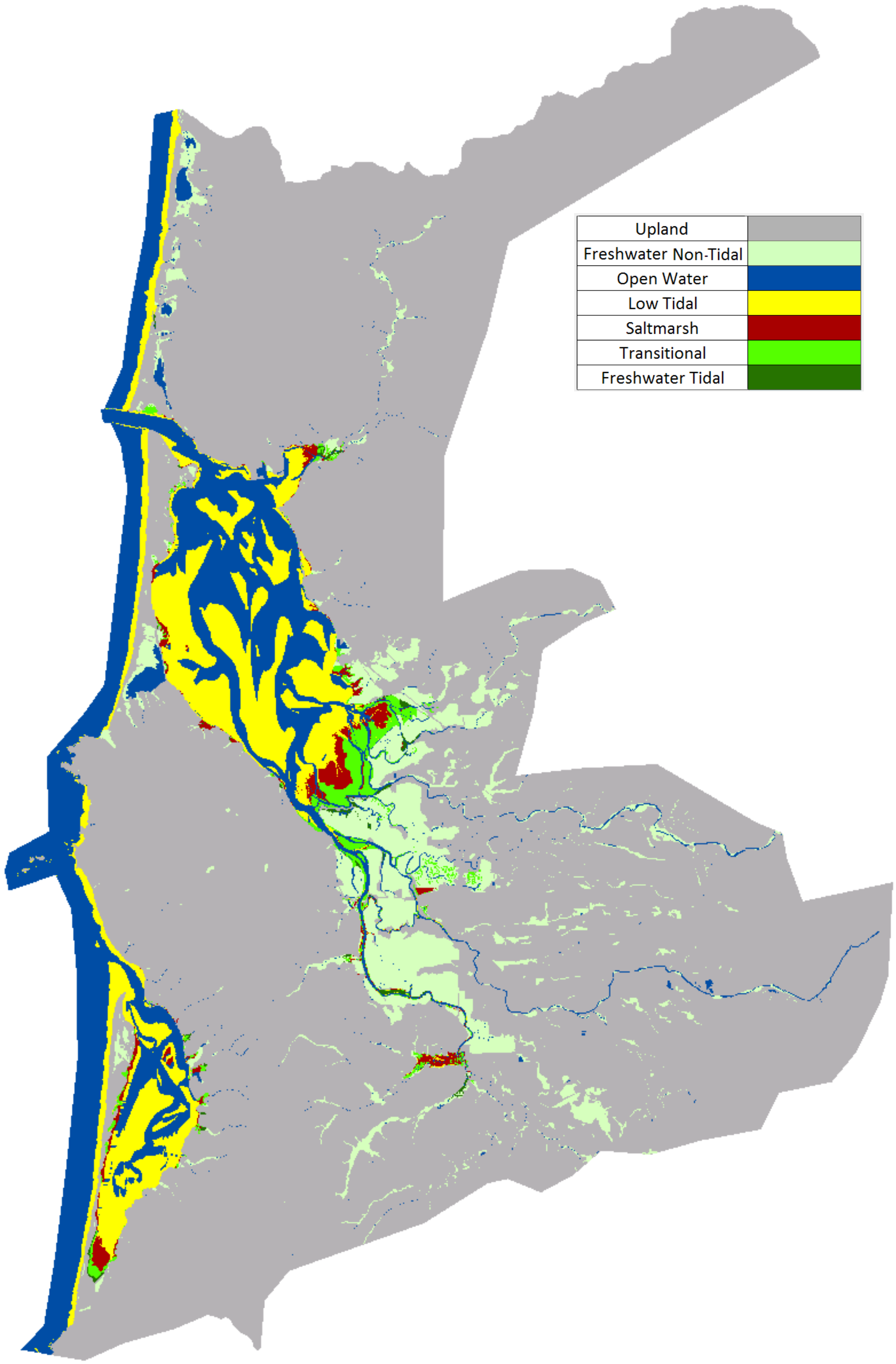

Figure 23. Site 2, 2100, Scenario A1B Mean

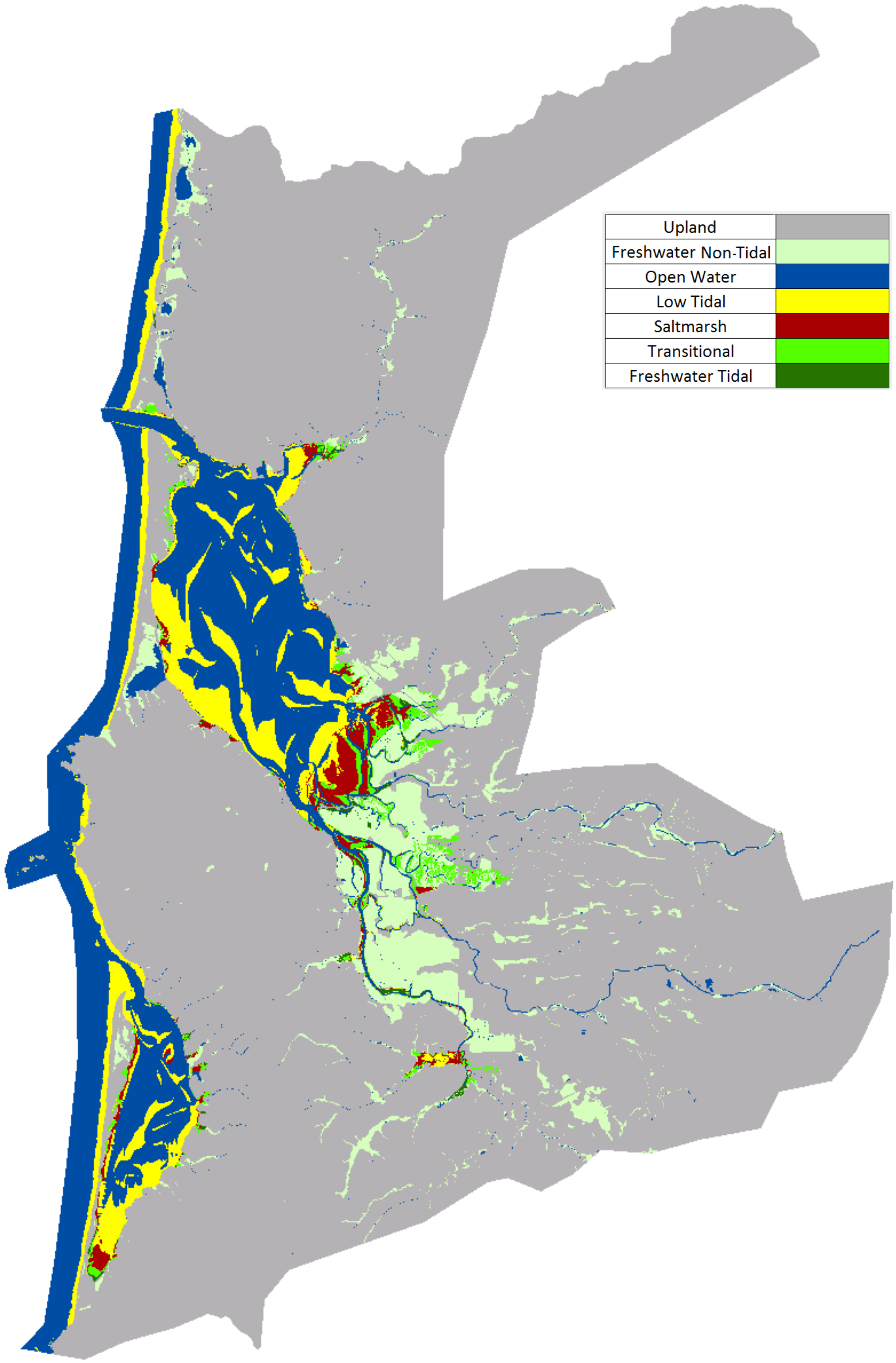

Figure 24. Site 2, 2100, Scenario A1B Max

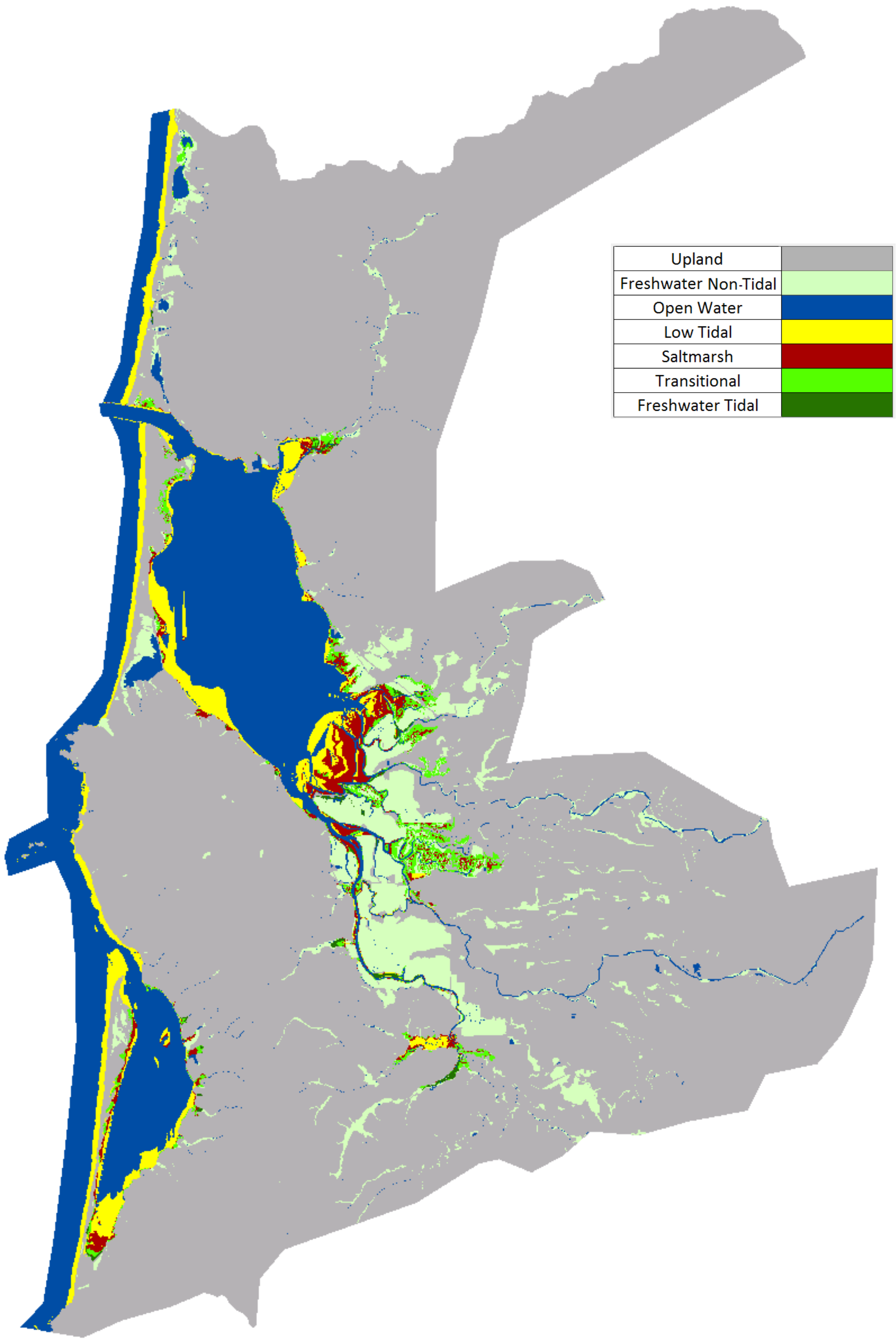

Figure 25. Site 2, 2100, Scenario 1 Meter

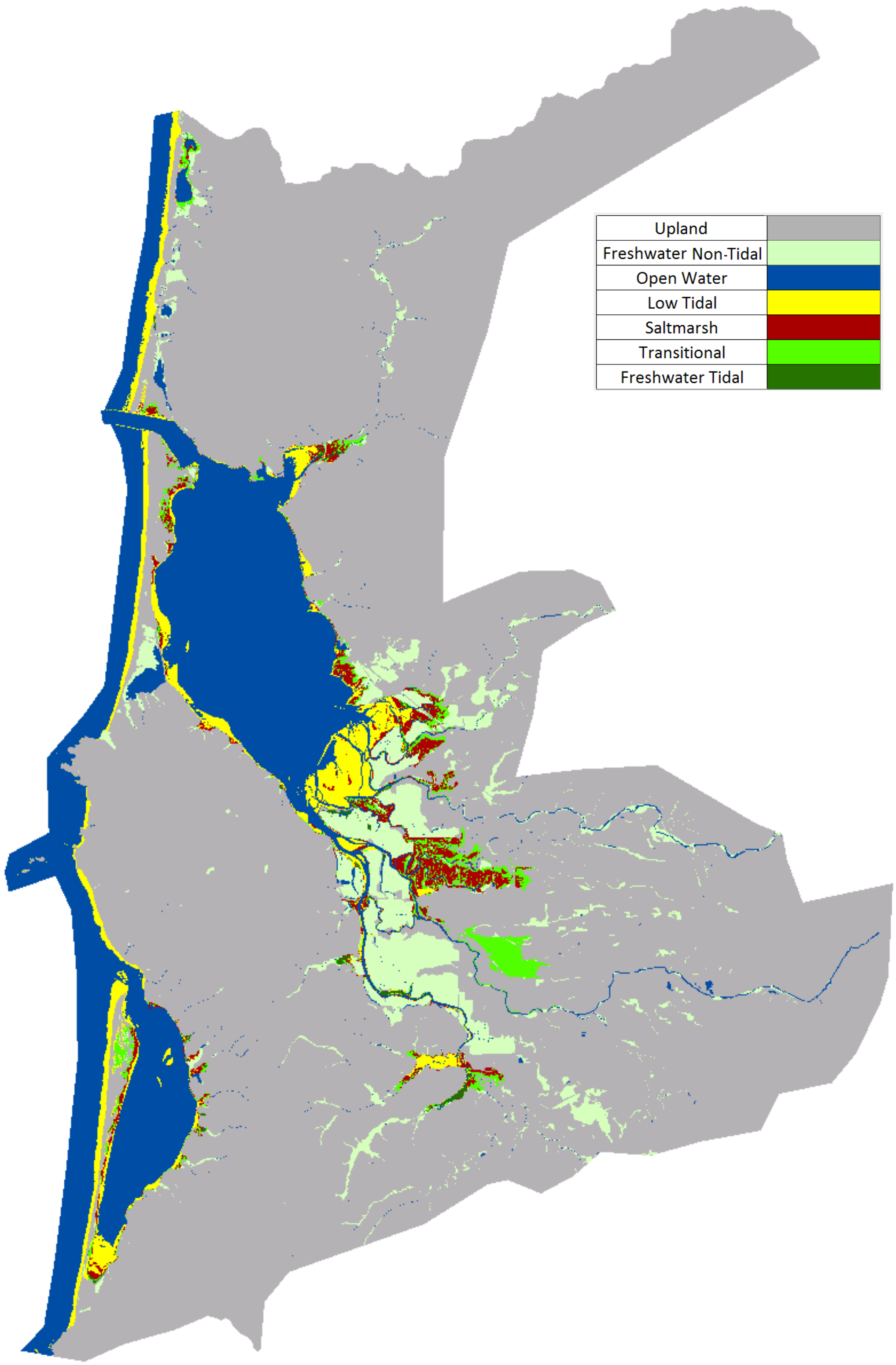

Figure 26. Site 2, 2100, Scenario 1.5 Meters

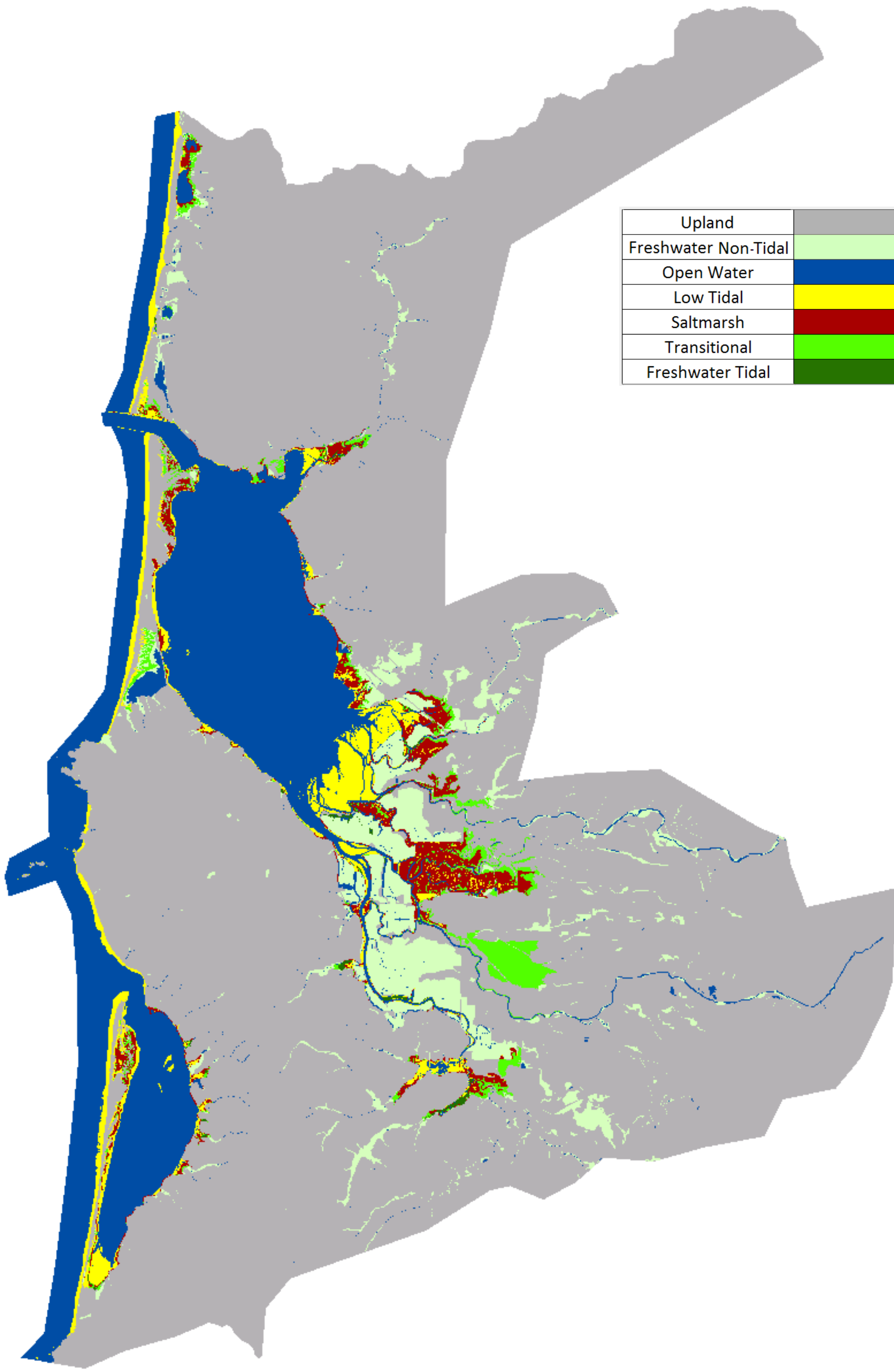

Figure 27. Site 2, 2100, Scenario 2 Meters

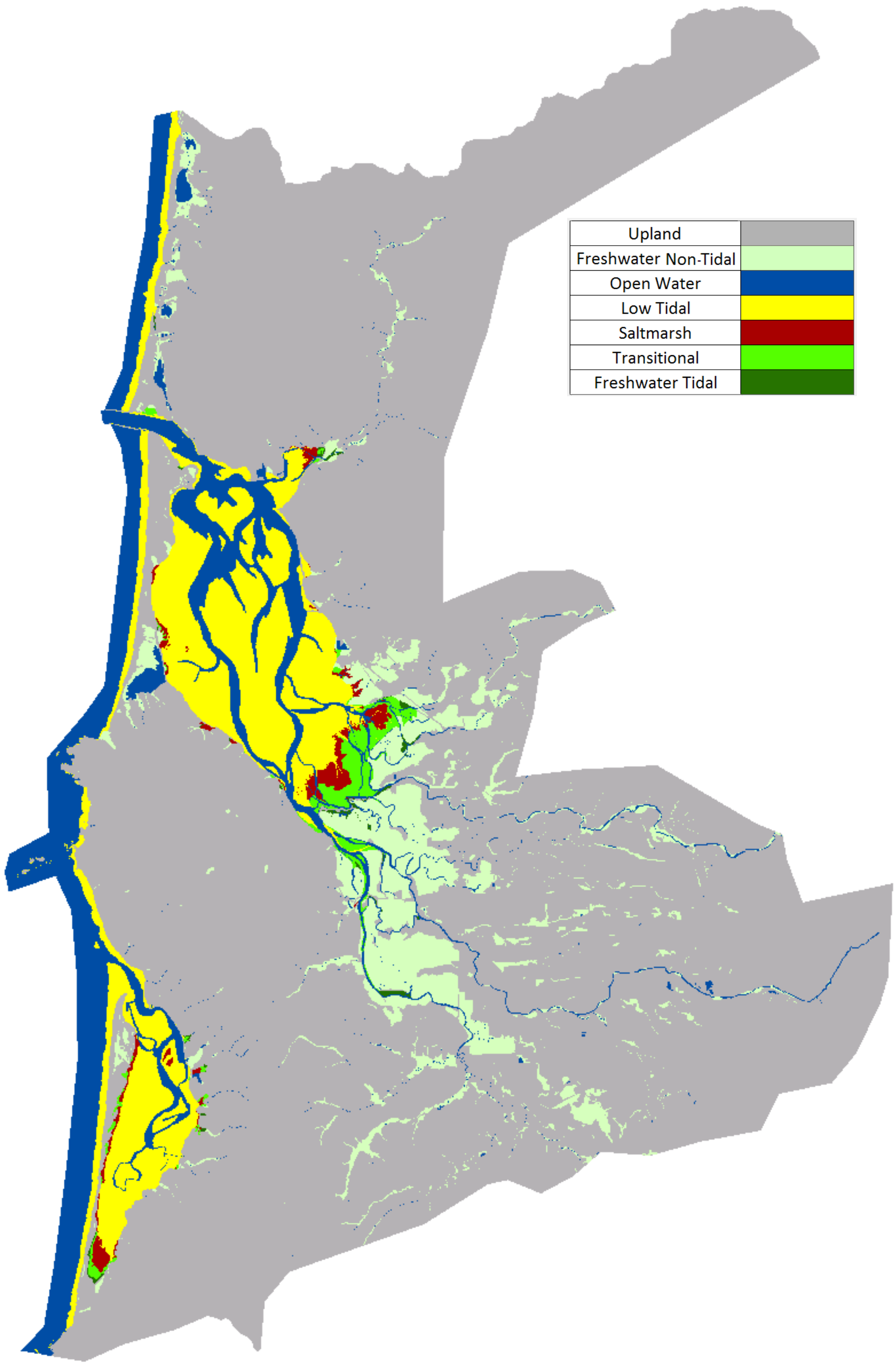

Figure 28. Initial Condition Wetland Data for Site 2 – Tillamook

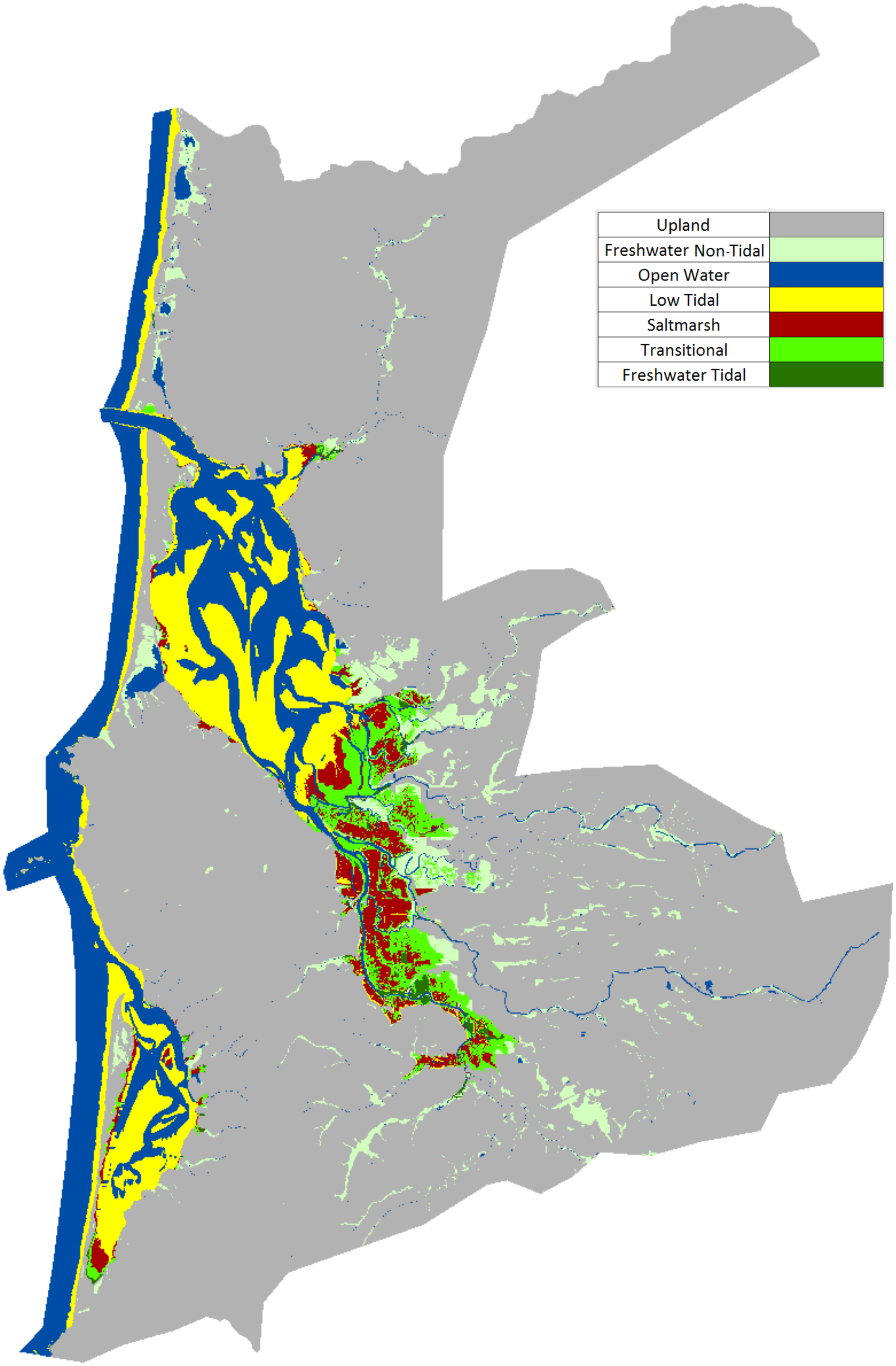

Figure 29. Site 2, 2100, Scenario A1B Mean – No Dikes

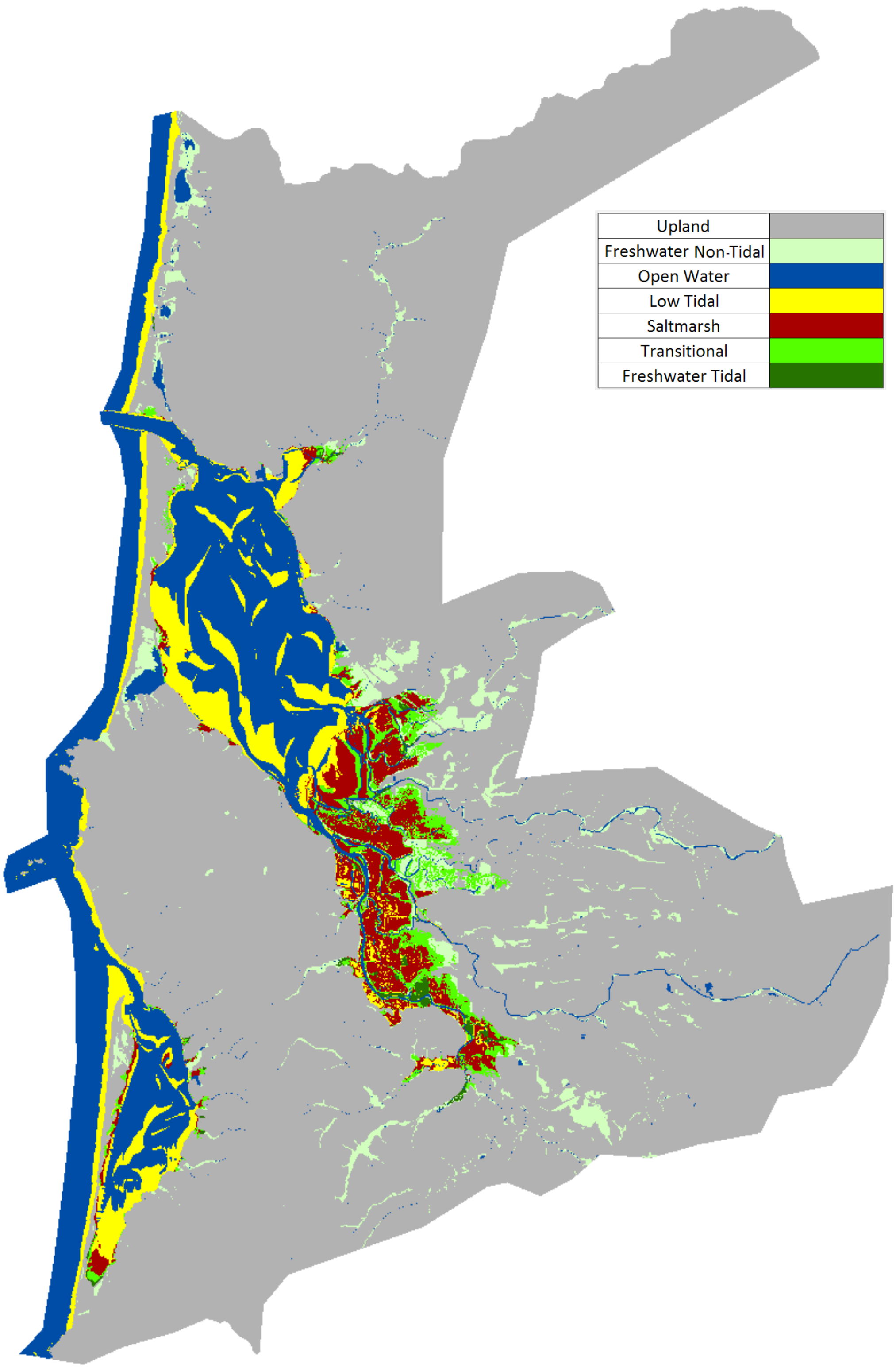

Figure 30. Site 2, 2100, Scenario A1B Max – No Dikes

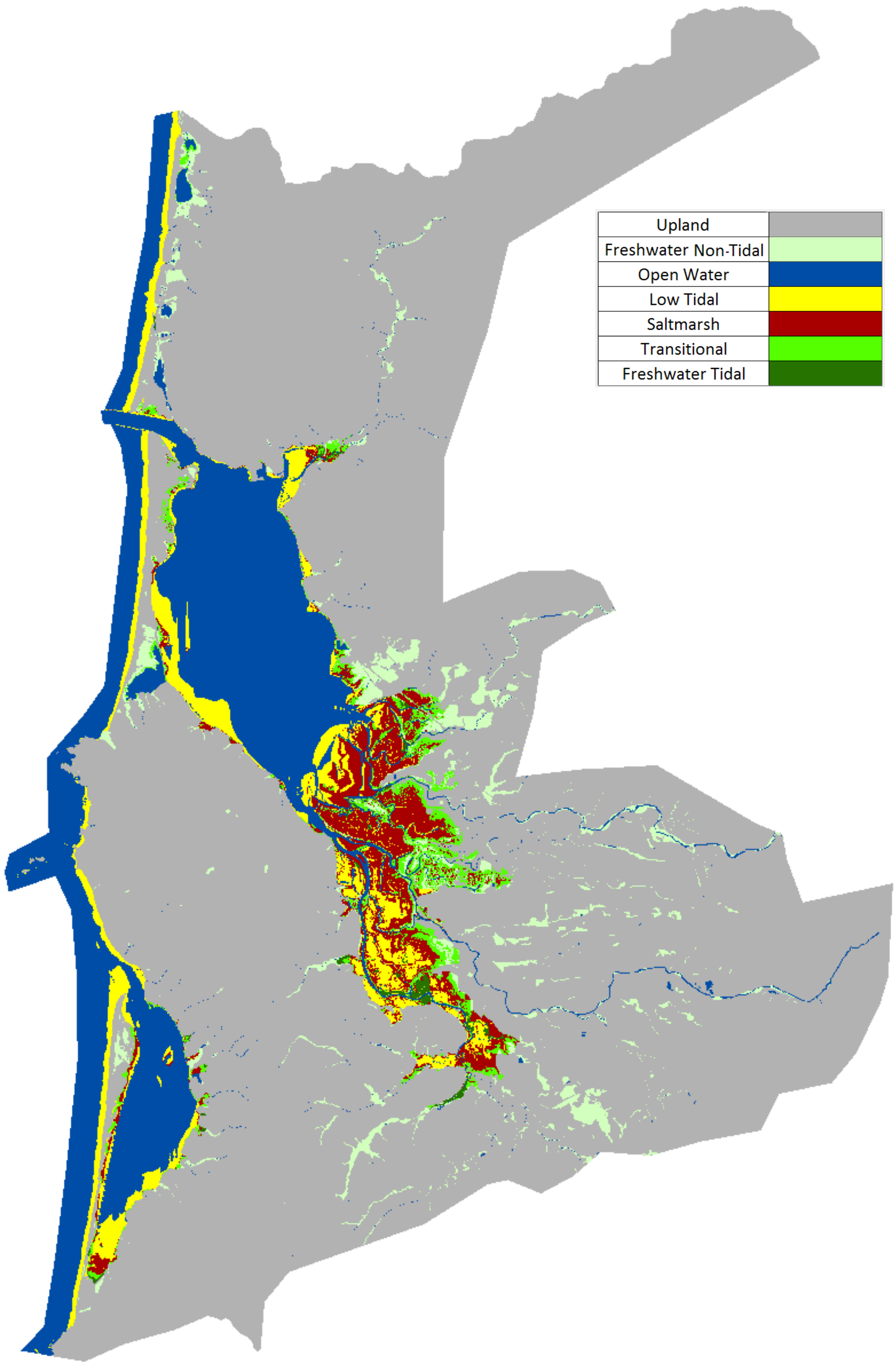

Figure 31. Site 2, 2100, Scenario 1 Meter – No Dikes

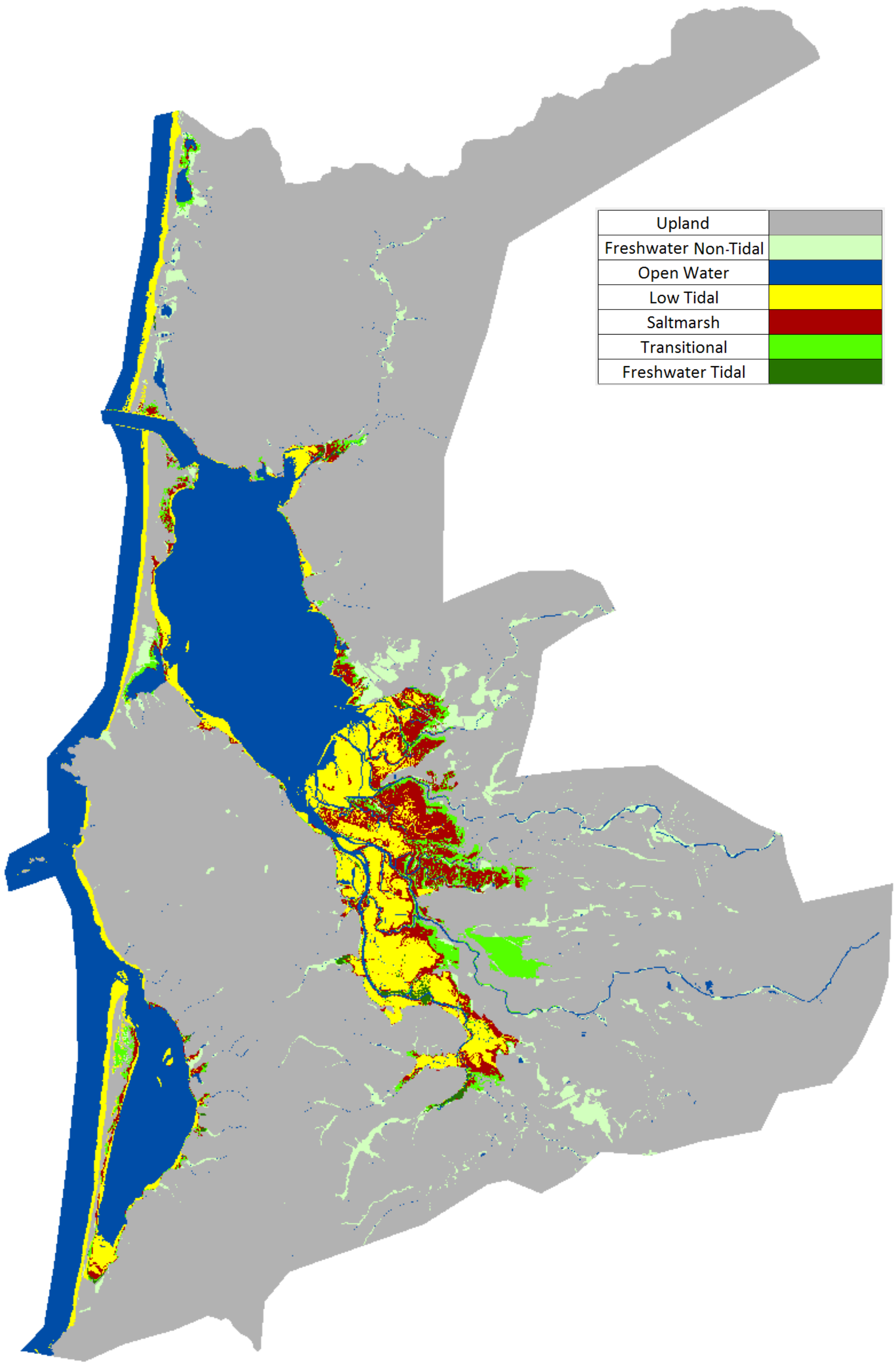

Figure 32. Site 2, 2100, Scenario 1.5 Meters – No Dikes

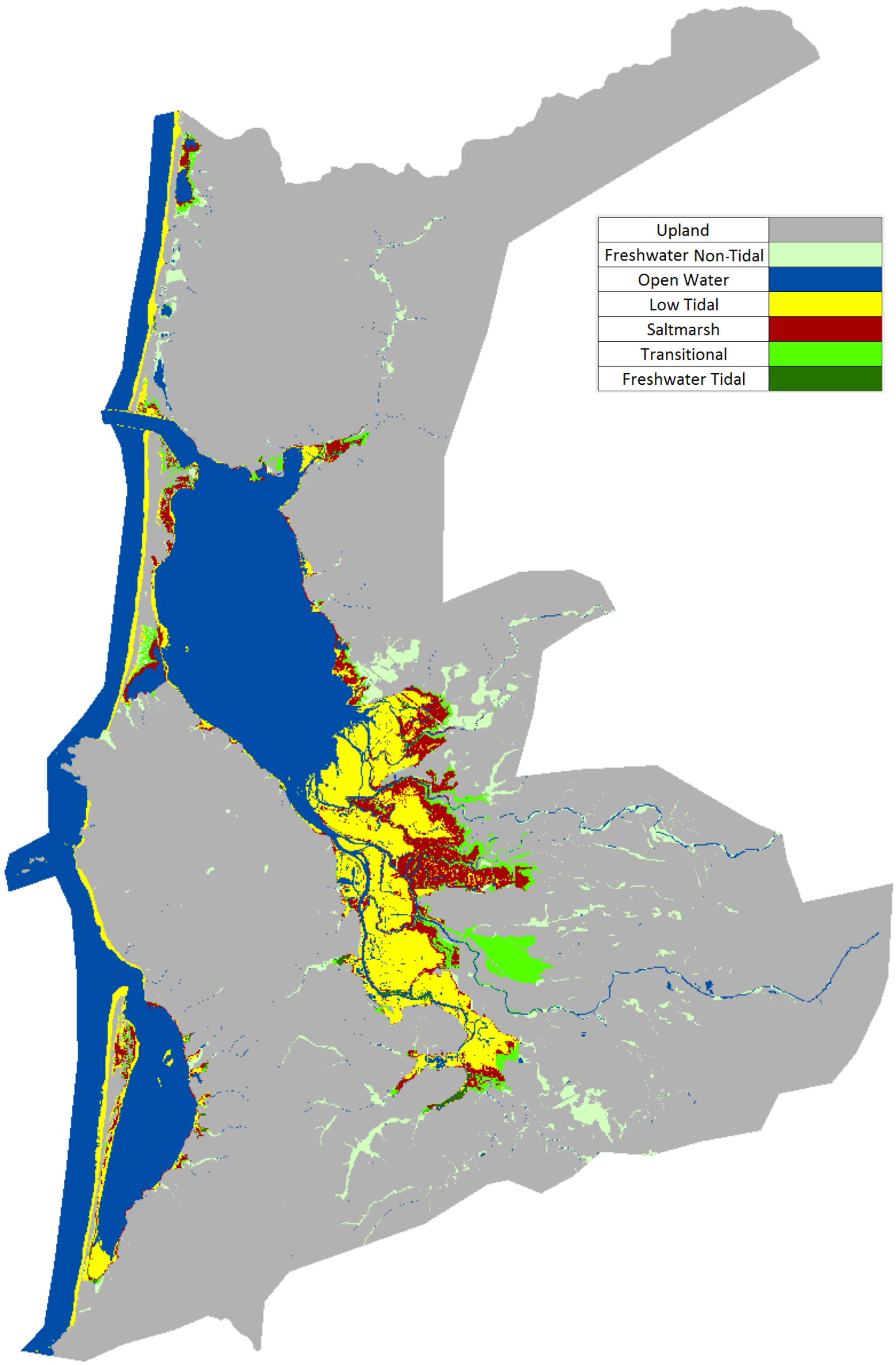

Figure 33. Site 2, 2100, Scenario 2 Meters – No Dikes

Site 3: Sand Lake, Nestucca, and Salmon

Site 3 comprises more than 99,000 acres of the study area. The majority of the site is currently categorized as upland, with four percent categorized as freshwater non-tidal and only one percent as salt marsh, as shown in Table 14. This site includes the Sand Lake, Nestucca and Salmon River estuaries. In order to more effectively assess the potential consequences of SLR on each of these estuaries, Site 3 was divided into three different output subsites. Figure 34 shows the division of site 3 into these subsites and the analysis of each subsite follows the analysis of site 3 in its entirety.

Table 14. Wetland coverage of Site 3 according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	84448	85
Freshwater Non-Tidal	4413	4
Open Water	5997	6
Low Tidal	2818	3
Saltmarsh	641	1
Transitional	691	1
Freshwater Tidal	175	< 1
Total (incl. water)	**99183**	**100**

Only one NOAA tide site, at the Nestucca Bay Entrance, was located within this site. Therefore a GT value of 2.3 m was applied to the entire site. The historic SLR trend applied was 2 mm/yr. The inundation analysis results for the Garibaldi and South Beach Yaquina NOAA stations were averaged to calculate the salt elevation, resulting in a specification of 1.44 m for this parameter. In order to match the site-specific elevation data more closely, the minimum elevation for tidal-fresh swamp was adjusted to 1 HTU.

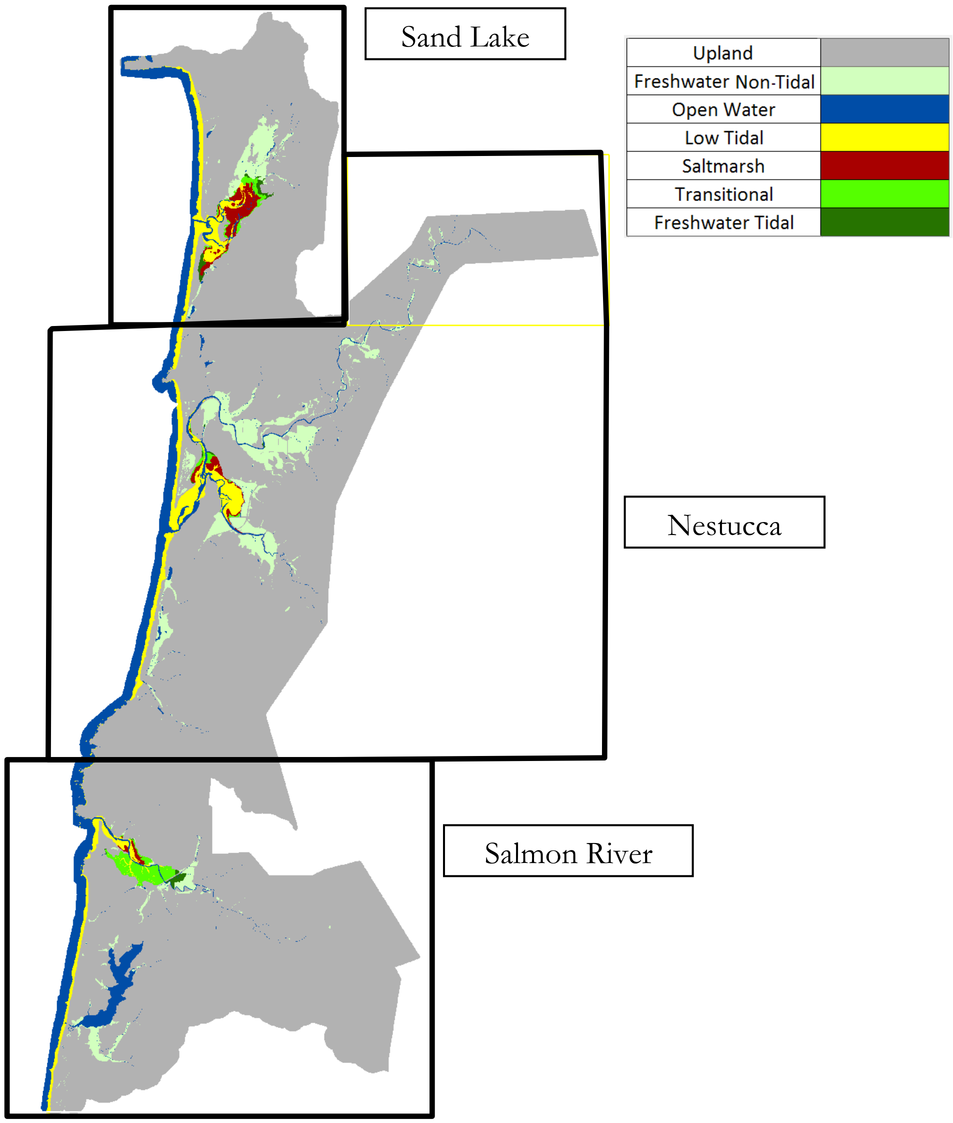

Figure 34. Site 3 output subsites

The DEM map for the entirety of Site 3 as well as the dike layer applied is shown in Figure 35. All of the dikes included the simulation were located in the Nestucca estuary.

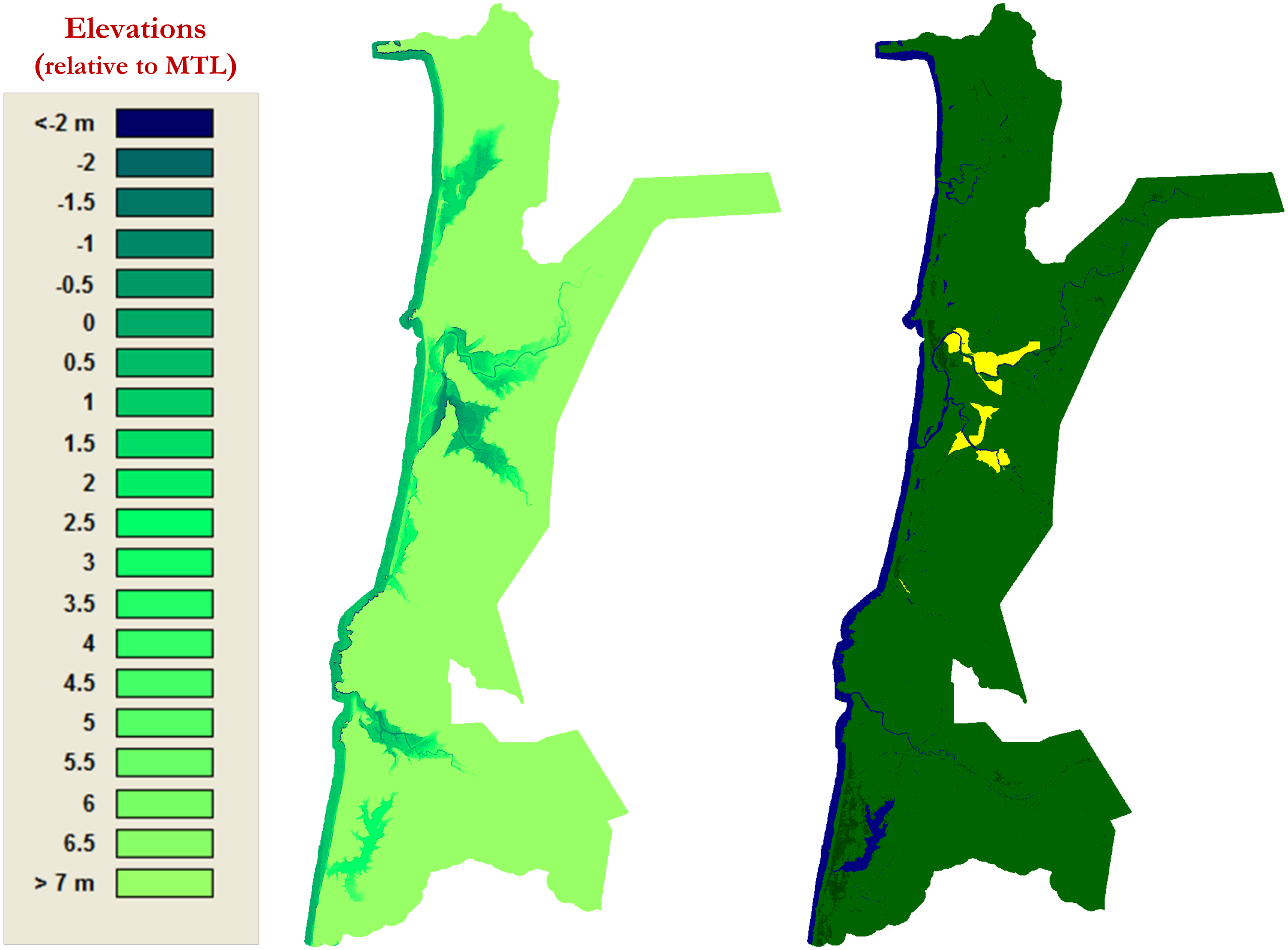

Figure 35. LiDAR elevation data (left) and location of dikes (right, shown in yellow) for Site 3 – Nestucca

Entire Site

The results for Site 3 (shown in Table 15) suggest increases in salt marsh and open water and losses in freshwater tidal wetlands to occur over the coming century. According to Kevin Petrik, the areas that were noted to convert due to low elevations at time zero are labeled as breached or historical/removed levees. The removal of dikes explains the conversion of these areas to salt marsh. The freshwater tidal category is predicted to be most impacted by SLR with losses exceeding 48% at 1 m of SLR by 2100 and above. However, freshwater non-tidal areas are predicted to be rather resilient, with only 12% predicted to be lost at 1 m of SLR by 2100.

Table 15. Predicted Percent Change of Land Categories by 2100 at Site 3 – Nestucca Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	1	1	1
Open Water	-5	-6	-8	-12	-18
Freshwater Non-Tidal	5	6	12	20	25
Low Tidal	6	4	4	1	-19
Transitional	-27	-40	-73	-26	1
Saltmarsh	-25	-32	-54	-151	-124
Freshwater Tidal	11	26	48	75	85

The results of simulations run without including dikes, shown in Table 16, generally showed the same trend of gains and losses predicted by the scenarios where dikes were included. The main difference between the two sets of simulations was the more extreme losses predicted in freshwater non-tidal habitat and extreme gains predicted in transitional and salt marsh categories if dikes are removed.

Table 16. Predicted Percent Change of Land Categories by 2100 at Site 3 – Nestucca Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	1	1	1	2
Open Water	-5	-6	-8	-12	-20
Freshwater Non-Tidal	27	31	38	47	53
Low Tidal	5	3	-4	-20	-47
Transitional	-79	-79	-98	-43	-14
Saltmarsh	-132	-163	-177	-240	-180
Freshwater Tidal	11	26	48	75	85

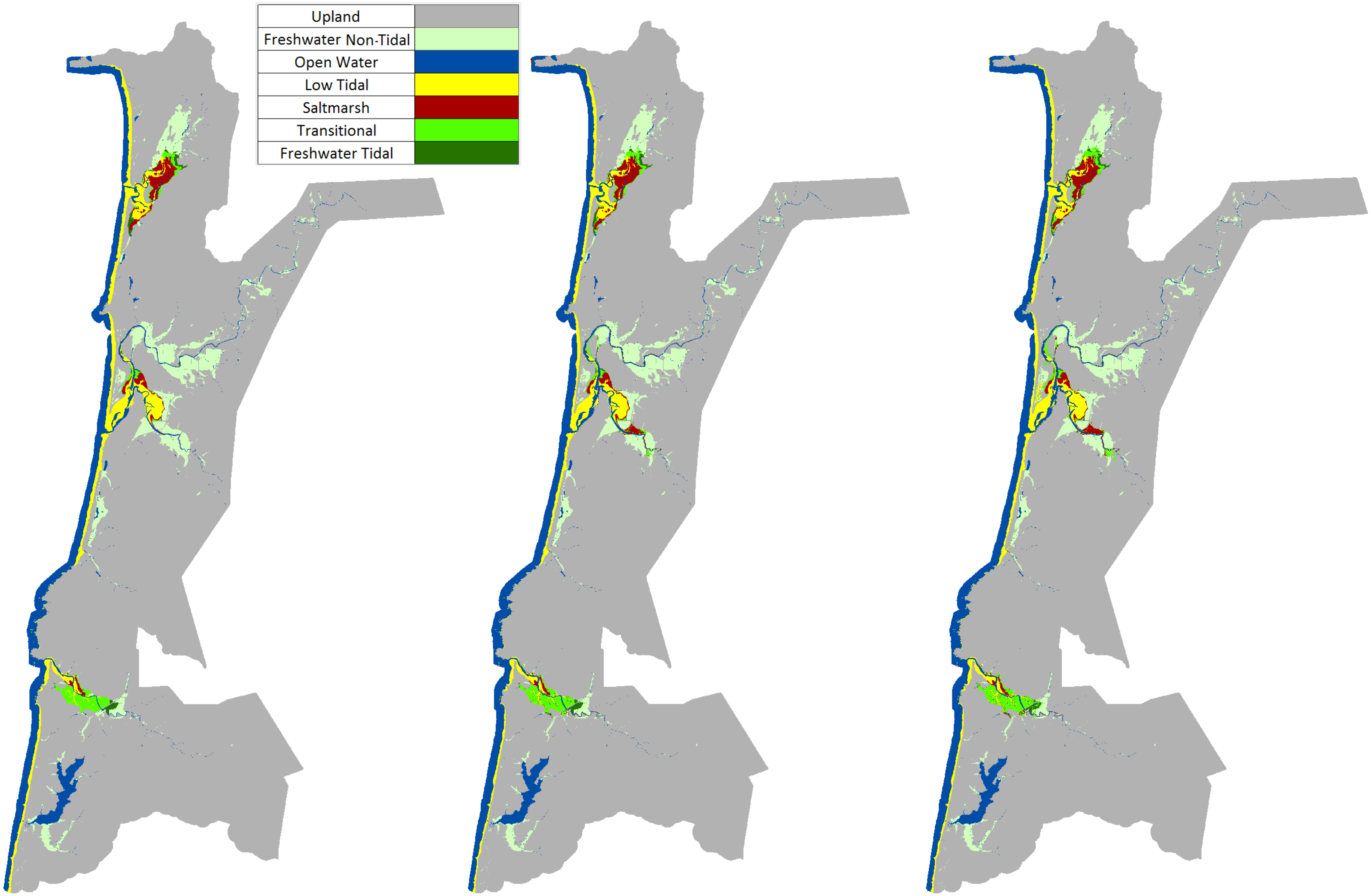

Figure 36. Wetland data for Site 3 – Nestucca. Initial condition - 2002 (left), 2100 under the A1B mean scenario (0.39 m SLR by 2100, middle), 2100 under the A1B max scenario (0.69 m SLR by 2100, right)

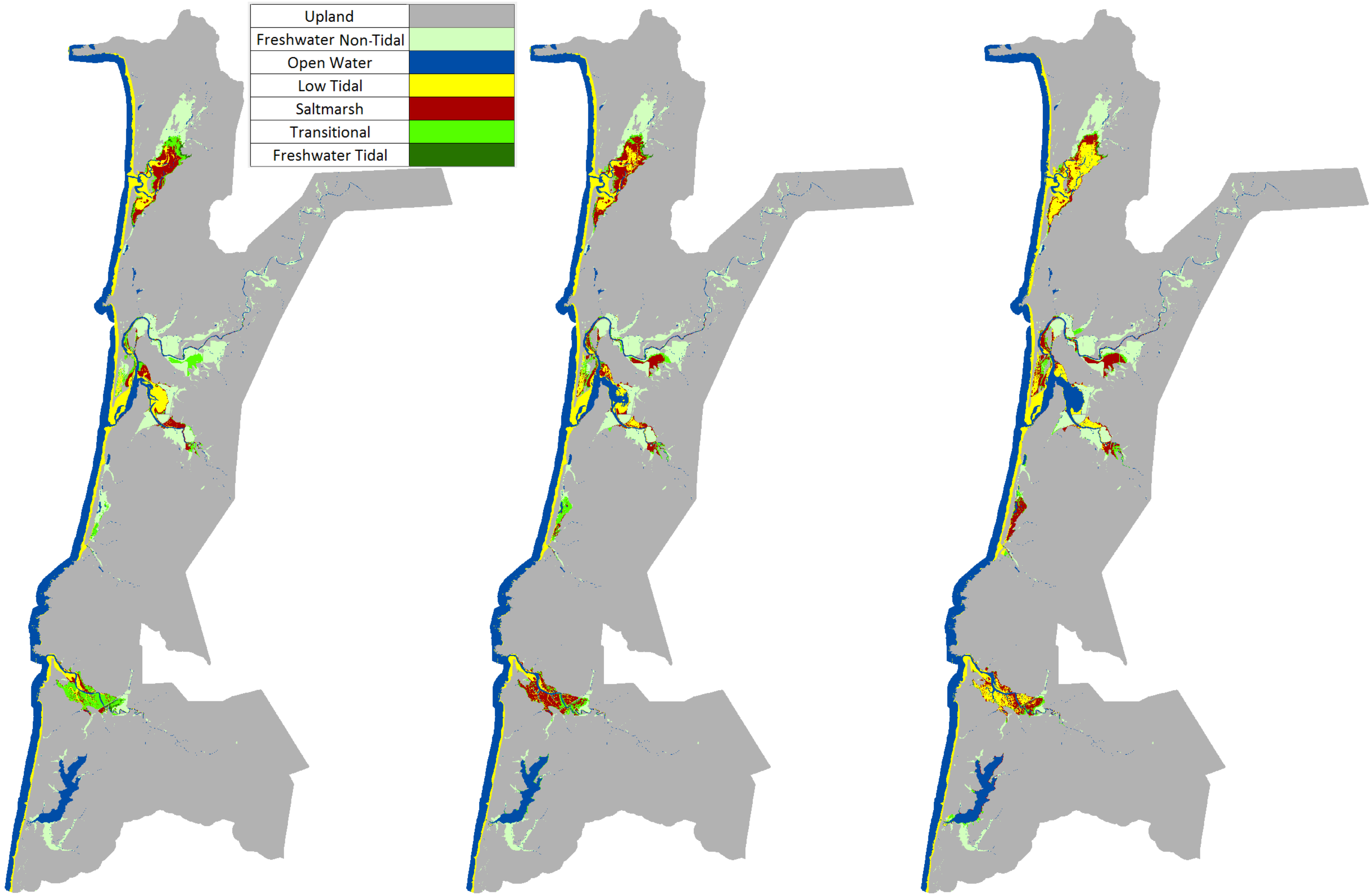

Figure 37. Projected wetland coverage in 2100 under the 1 m (left). 1.5 m (middle), and 2 m (right) SLR by 2100 scenarios

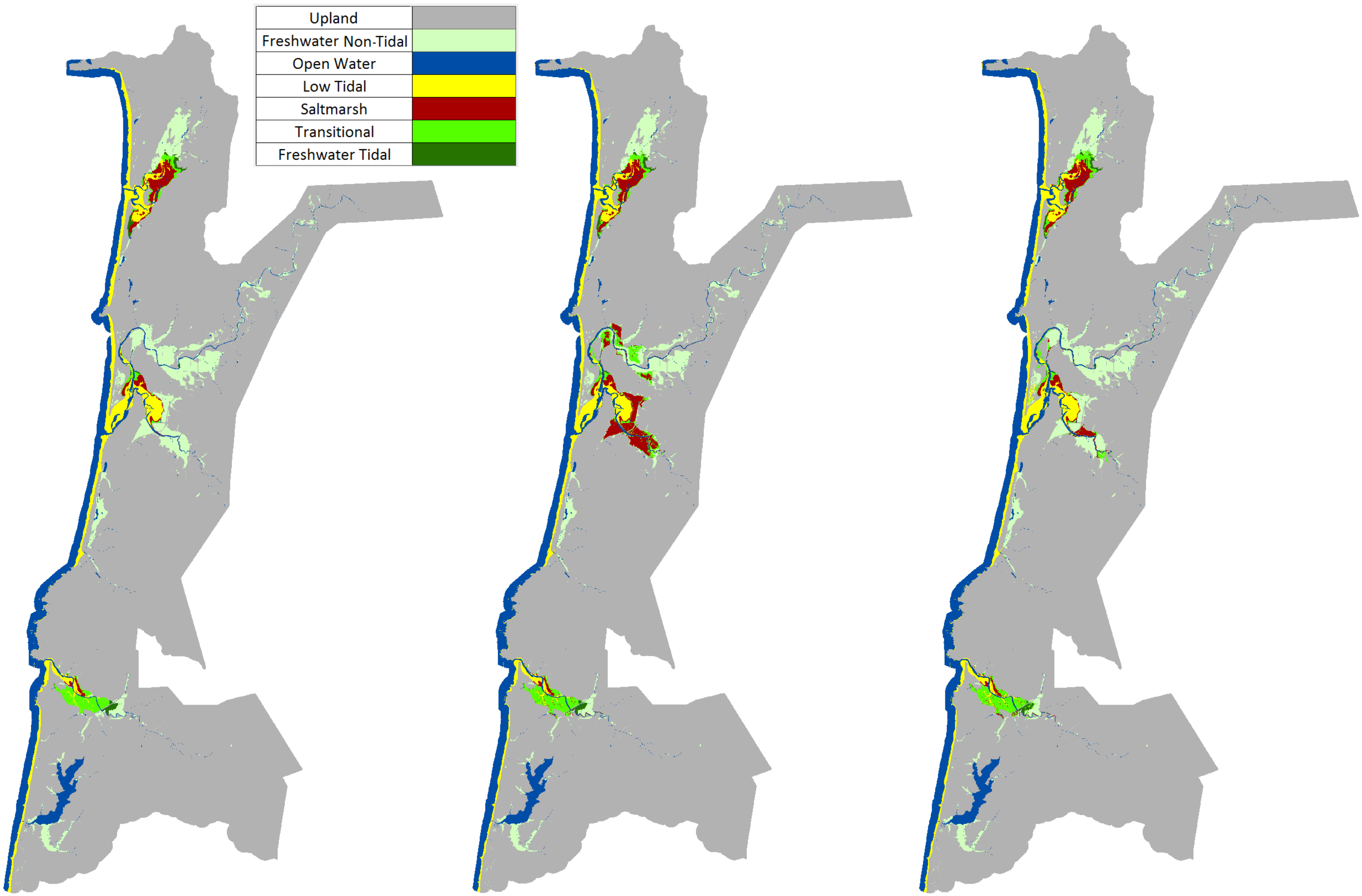

Figure 38. Wetland data for Site 3 – Nestucca. Initial condition - 2002 (left), 2100 under the A1B mean scenario (0.39 m SLR by 2100, middle), 2100 under the A1B max scenario (0.69 m SLR by 2100, right), - No Dikes

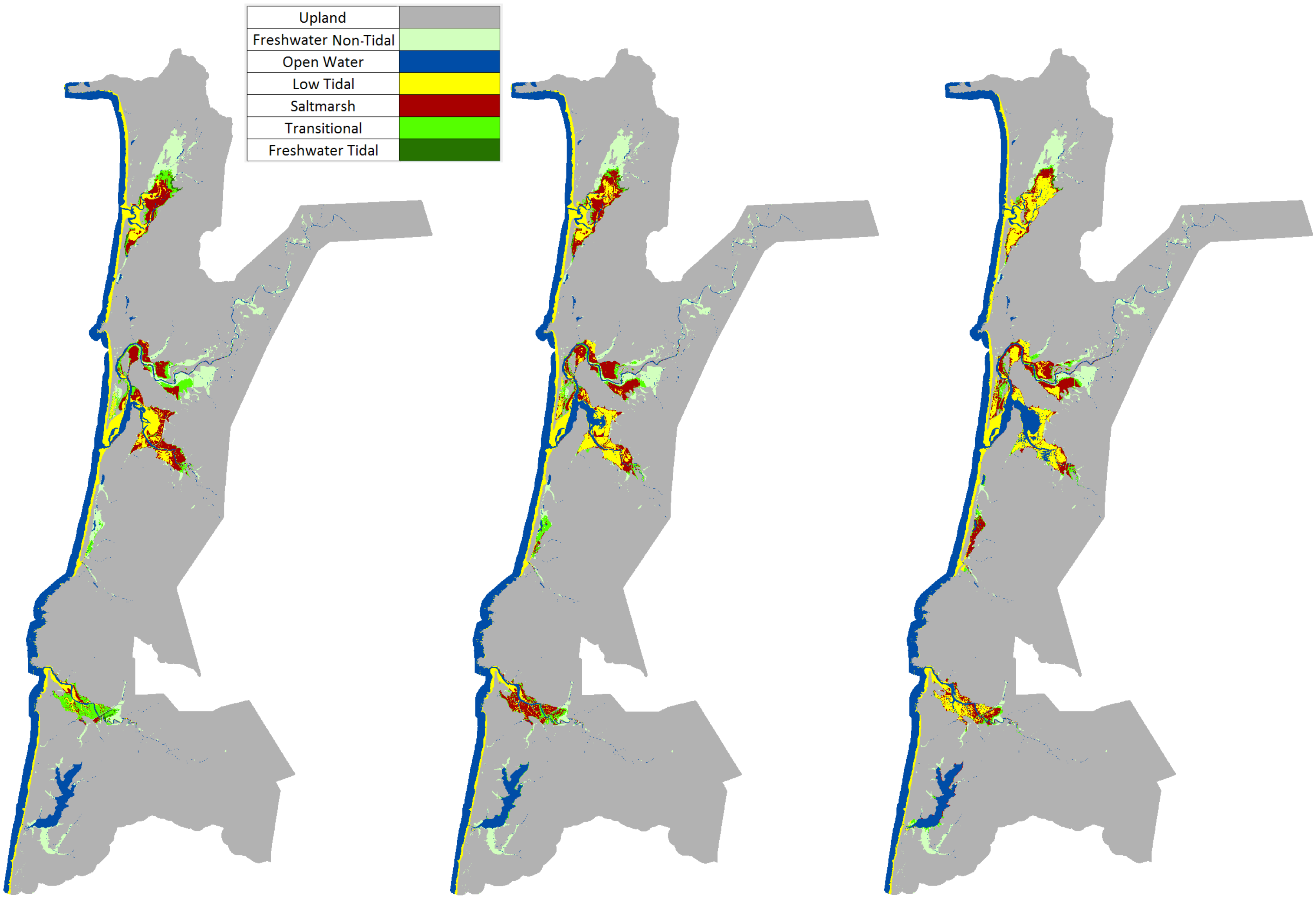

Figure 39. Projected wetland coverage in 2100 under the 1 m (left). 1.5 m (middle), and 2 m (right) SLR by 2100 scenarios - No Dikes

Sand Lake

The Sand Lake estuary is located in the northernmost portion of Site 3 and is composed primarily of low tidal and freshwater non-tidal wetlands, as shown in Table 17.

Table 17. Wetland coverage of Site 3 – Sand Lake according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	14557	80
Open Water	1260	7
Low Tidal	896	5
Freshwater Non-Tidal	775	4
Saltmarsh	439	2
Transitional	150	1
Freshwater Tidal	99	1
Total (incl. water)	**18177**	**100**

The results for the Sand Lake subsites (shown in Table 18) suggest increases in open water and losses in freshwater tidal wetlands to occur over the coming century. Increases in transitional and salt marsh were also predicted at SLR scenarios of 1.5 m by 2100 and below; however, at higher SLR rates these wetlands are predicted to be lost. The freshwater tidal category is predicted to be most impacted by SLR with losses greater than 43% at 1 m of SLR by 2100 and above. However, freshwater non-tidal areas are predicted to be rather resilient, with only 9% predicted to be lost at 1 m of SLR by 2100.

Table 18. Predicted Percent Change of Land Categories by 2100 at Site 3 – Sand Lake Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	1	1	1
Open Water	-6	-6	-6	-7	-16
Low Tidal	6	6	5	-8	-40
Freshwater Non-Tidal	2	6	9	13	17
Saltmarsh	-2	-4	-12	-29	31
Transitional	-33	-59	-64	-5	24
Freshwater Tidal	13	29	43	68	78

This site did not contain any diked areas, precluding simulations run without the dike layer included

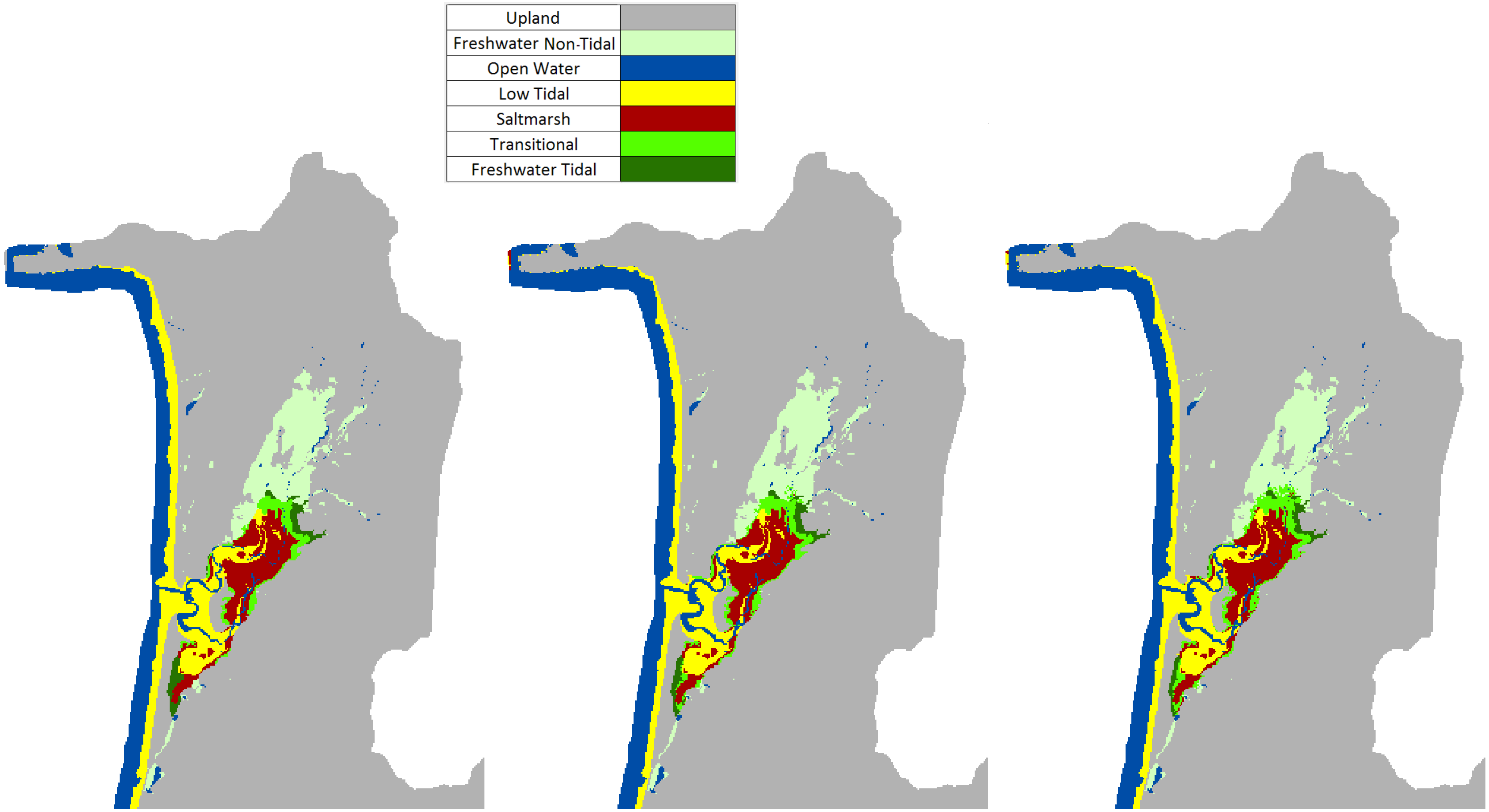

Figure 40. Wetland data for Site 3 – Sand Lake. Initial condition - 2002 (left), 2100 under the A1B mean scenario (0.39 m SLR by 2100, middle), 2100 under the A1B max scenario (0.69 m SLR by 2100, right)

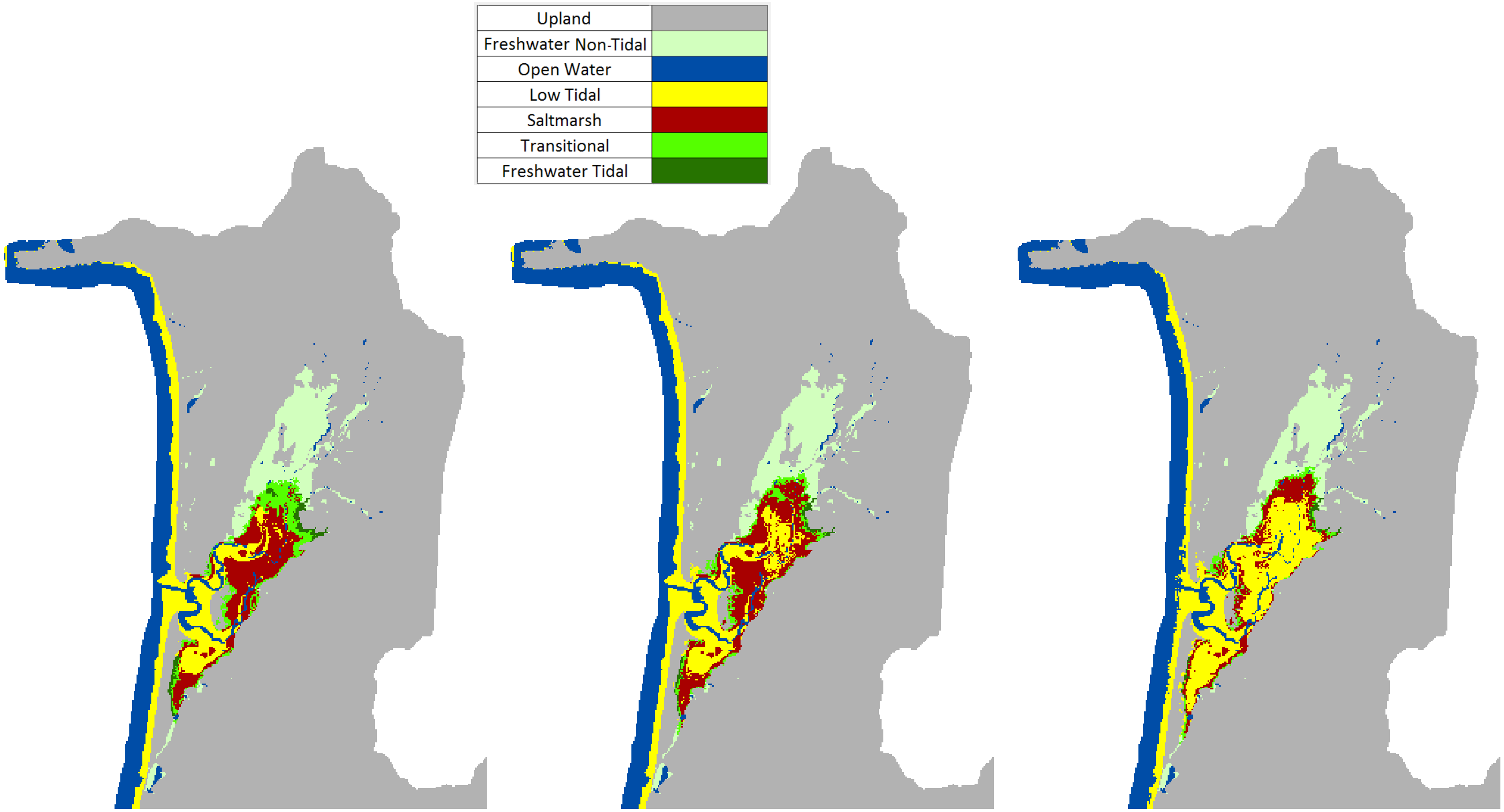

Figure 41. Projected wetland coverage in 2100 under the 1 m (left). 1.5 m (middle), and 2 m (right) SLR by 2100 scenario

Nestucca

The Nestucca estuary is located in the center of Site 3 and is composed primarily of freshwater non-tidal and low tidal wetlands, as shown in Table 19.

Table 19. Wetland coverage of Site 3 – Nestucca according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	36773	84
Freshwater Non-Tidal	3021	7
Open Water	2455	6
Low Tidal	1346	3
Saltmarsh	148	< 1
Transitional	70	< 1
Freshwater Tidal	14	< 1
Total (incl. water)	**43826**	**100**

Results for the Nestucca estuary (shown in Table 20) suggest increases in transitional marsh, salt marsh, and open water and losses in freshwater tidal wetlands will occur. According to Kevin Petrik, the areas that were noted to convert due to low elevations at time zero are on fact breached or historical/removed levees. The removal of dikes explains the conversion of these areas to salt marsh. The freshwater tidal category is predicted to be most impacted by SLR with losses of 44% at 1 m of SLR by 2100 and culminating in 80% loss under the 2 m by 2100 scenario. However, freshwater non-tidal areas are predicted to be fairly resilient, with only 27% predicted to be lost at 2 m of SLR by 2100.

Table 20. Predicted Percent Change of Land Categories by 2100 at Site 3 – Nestucca Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	1	1	1	2
Open Water	-6	-7	-11	-19	-28
Freshwater Non-Tidal	5	6	14	22	27
Low Tidal	5	2	5	7	7
Transitional	-160	-220	-553	-570	-453
Saltmarsh	-77	-91	-123	-279	-423
Freshwater Tidal	13	23	44	62	80

The results of simulations run without including dikes, shown in Table 21, generally showed the same trend of gains and losses predicted by the scenarios where dikes were included. The differences between the two sets of simulations were the loss of low tidal wetlands, larger gains predicted in freshwater non-tidal habitat, and extreme gains predicted in transitional and salt marsh categories if dikes are removed.

Table 21. Predicted Percent Change of Land Categories by 2100 at Site 3 – Nestucca Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed *Negative values indicate gains while positive values indicate losses*

Land cover category	**Simulated SLR by 2100**				
	0.39 m	**0.69 m**	**1 m**	**1.5 m**	**2 m**
Upland	1	1	1	2	2
Open Water	-6	-7	-11	-19	-32
Freshwater Non-Tidal	38	42	51	61	67
Low Tidal	5	0	-12	-37	-51
Transitional	-669	-606	-801	-733	-601
Saltmarsh	-541	-660	-659	-661	-666
Freshwater Tidal	13	23	44	62	80

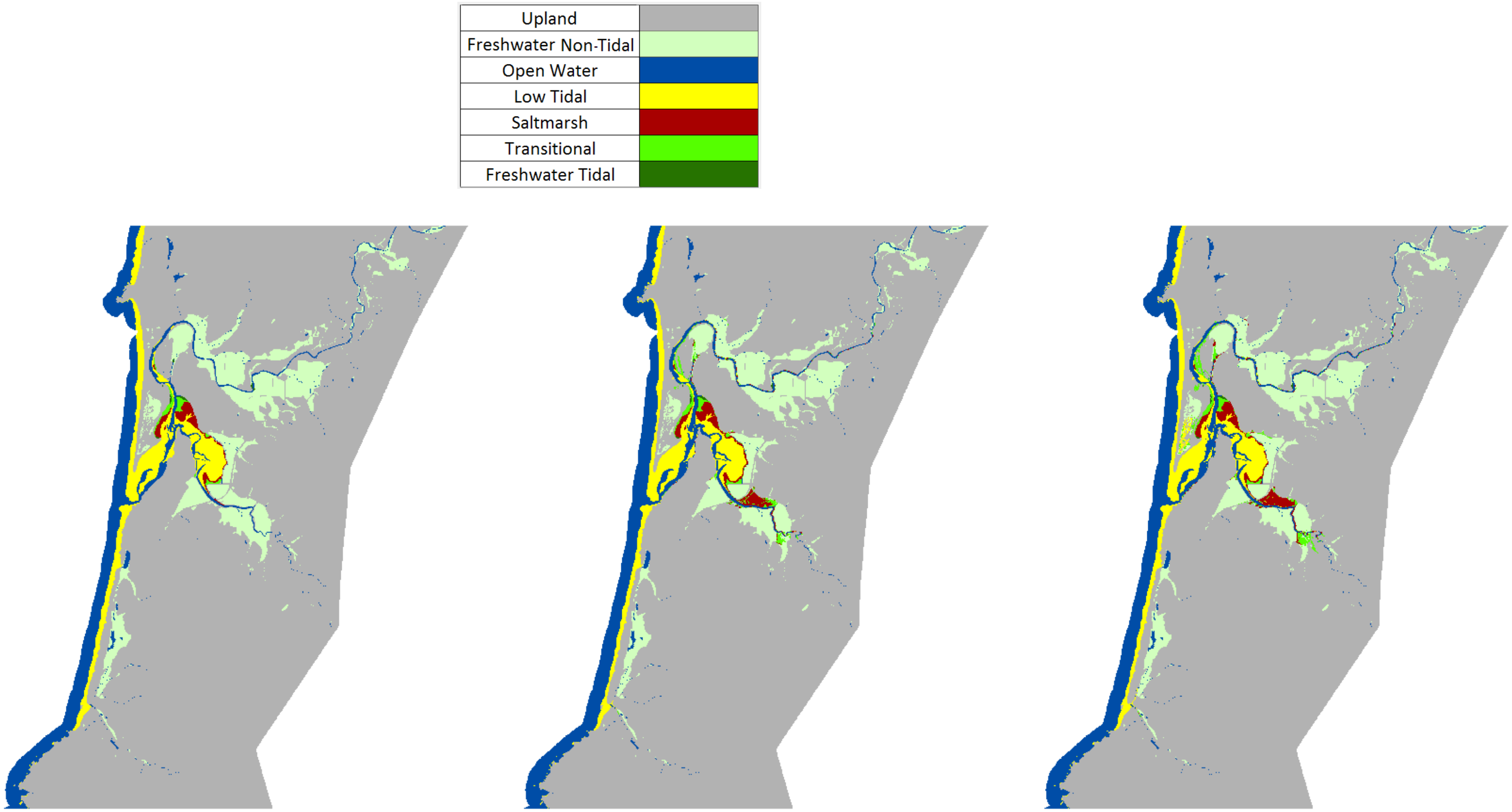

Figure 42. Wetland data for Site 3 – Nestucca. Initial condition - 2002 (left), 2100 under the A1B mean scenario (0.39 m SLR by 2100, middle), 2100 under the A1B max scenario (0.69 m SLR by 2100, right)

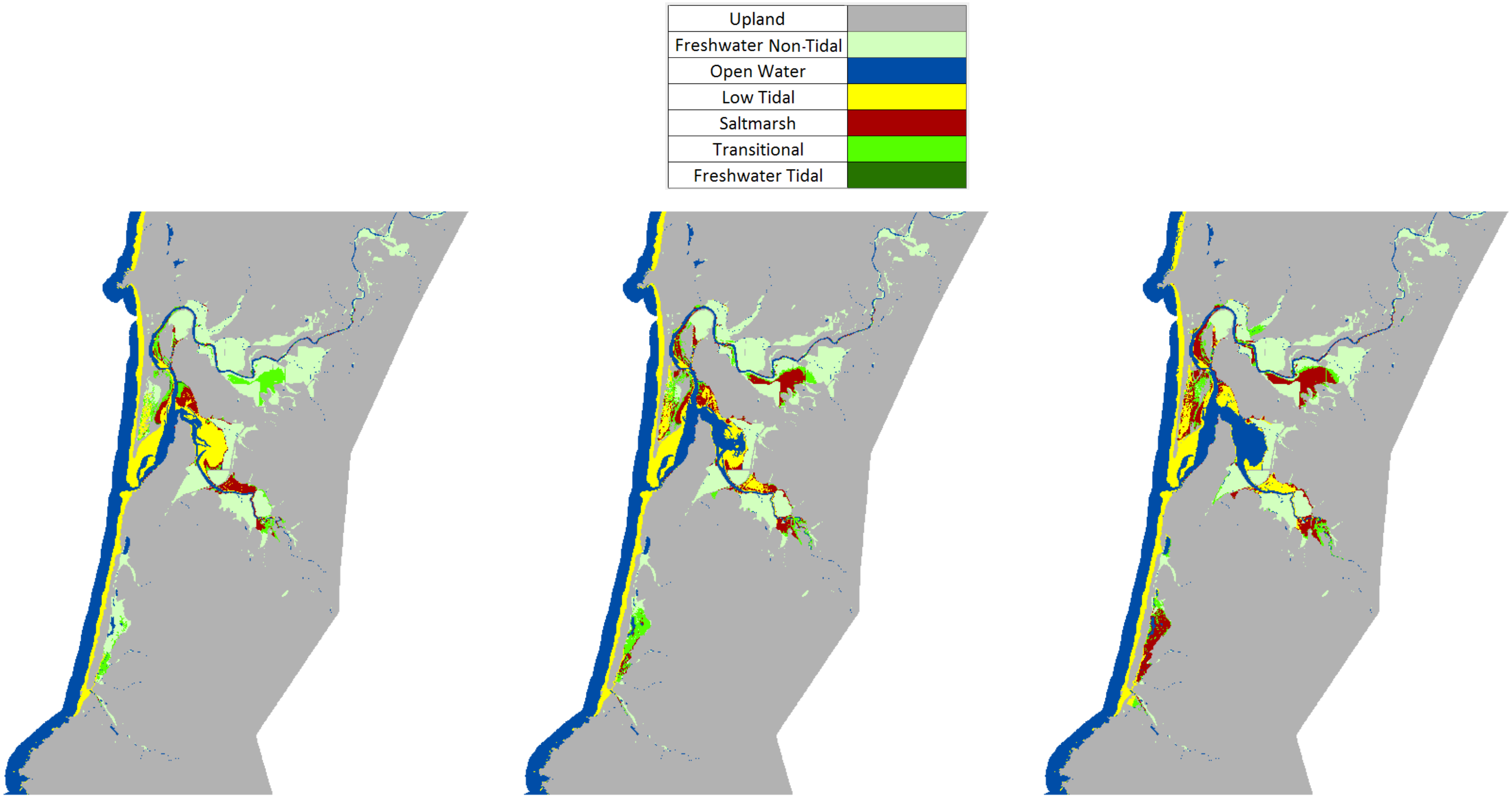

Figure 43. Projected wetland coverage in 2100 under the 1 m (left). 1.5 m (middle), and 2 m (right) SLR by 2100 scenarios

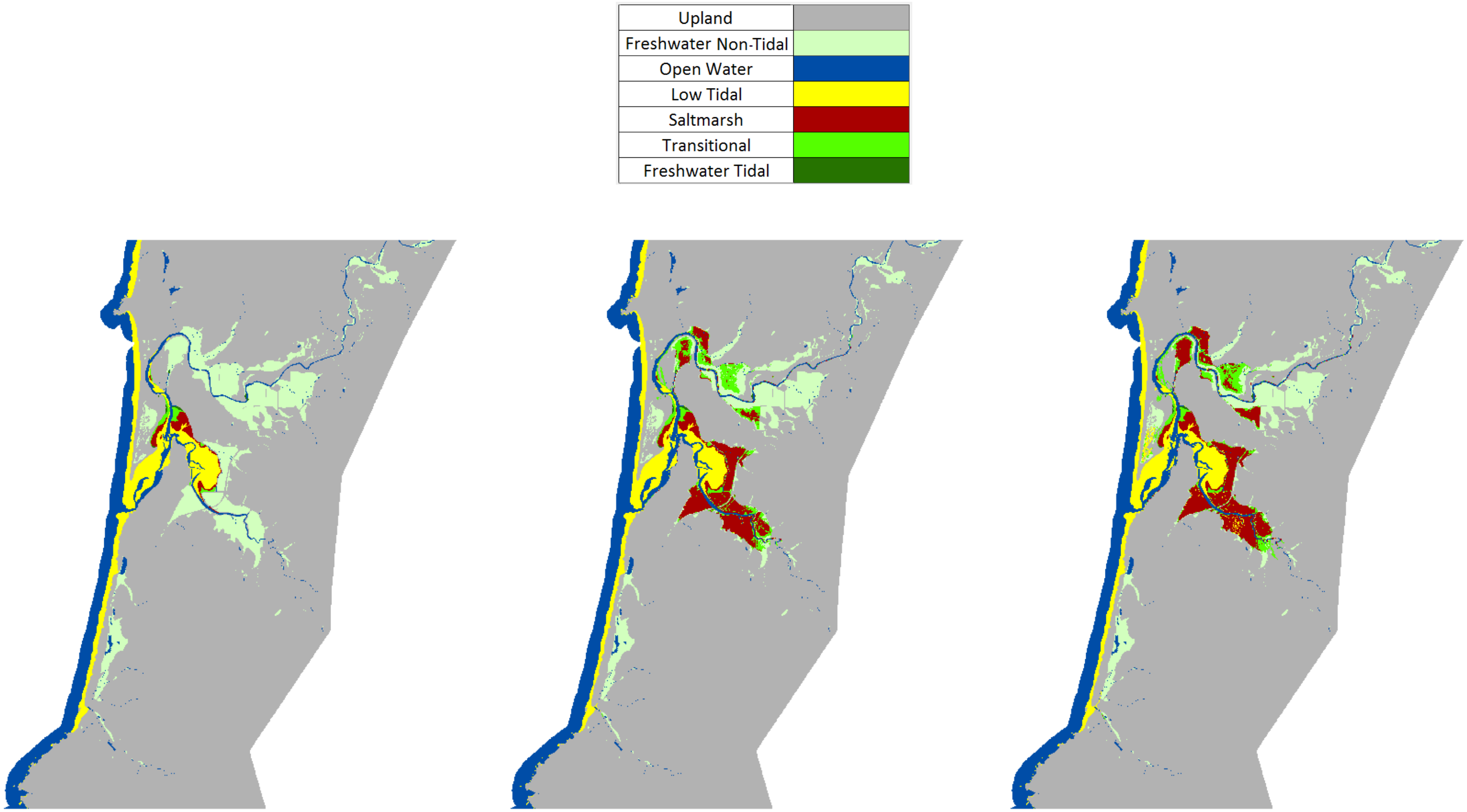

Figure 44. Wetland data for Site 3 – Nestucca. Initial condition - 2002 (left), 2100 under the A1B mean scenario (0.39 m SLR by 2100, middle), 2100 under the A1B max scenario (0.69 m SLR by 2100, right), - No Dikes

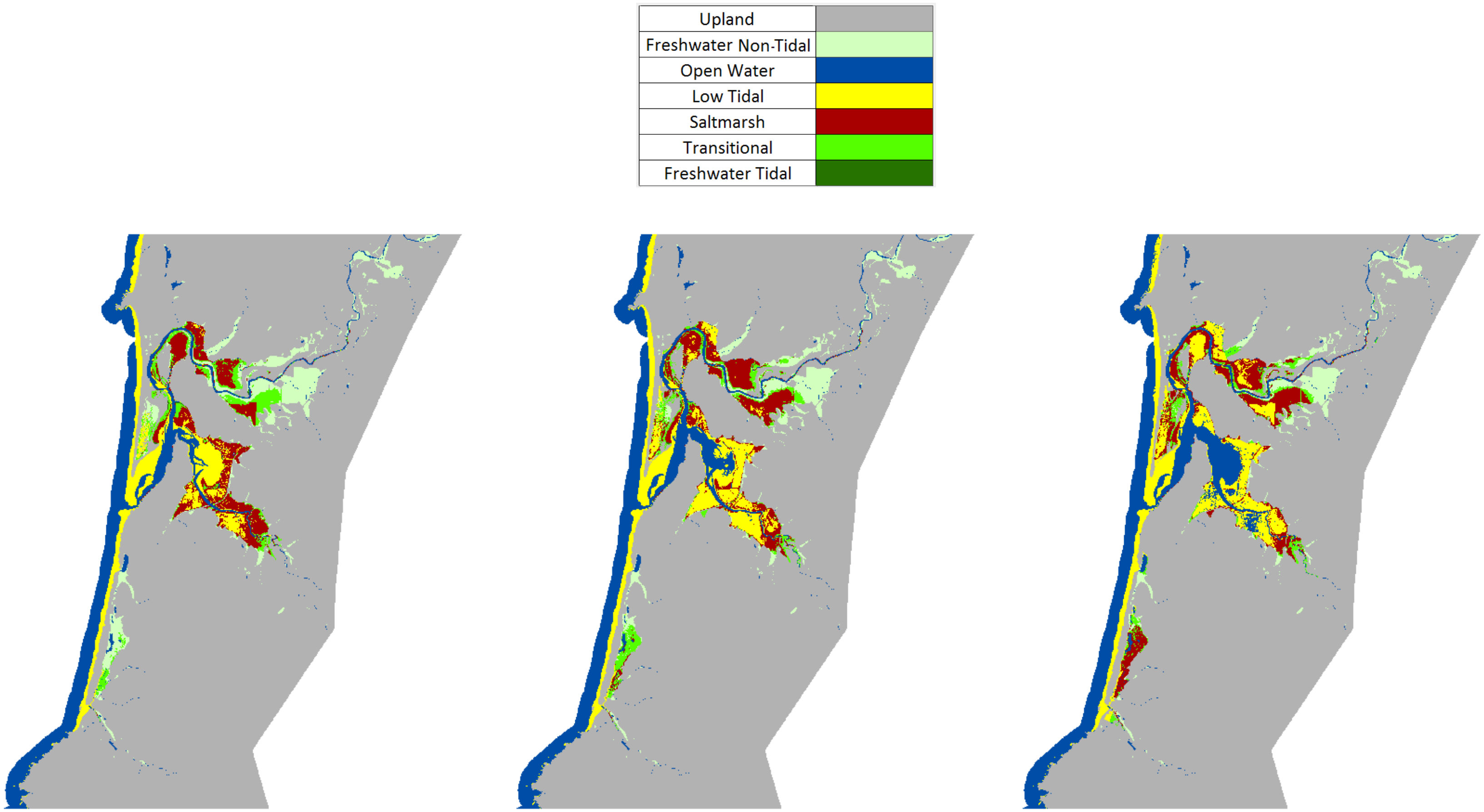

Figure 45. Projected wetland coverage in 2100 under the 1 m (left). 1.5 m (middle), and 2 m (right) SLR by 2100 scenarios, - No Dikes

Salmon River

The Salmon River estuary is composed mainly of freshwater non-tidal and low tidal wetlands as shown in Table 22.

Table 22. Wetland coverage of Site 3 – Salmon River according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	33267	89
Open Water	2292	6
Freshwater Non-Tidal	620	2
Low Tidal	577	2
Transitional	471	1
Freshwater Tidal	62	< 1
Saltmarsh	54	< 1
Total (incl. water)	**37342**	**100**

The results for Salmon River (shown in Table 23) suggest increases in salt marsh and open water and losses in freshwater tidal wetlands to occur over the coming century. Increases in transitional marsh are predicted under the lower SLR rate scenarios examined and gains in low tidal habitat are predicted at the highest SLR rates simulated. The freshwater tidal category is predicted to be most impacted by SLR with losses greater of 57% at 1 m of SLR by 2100 culminating in a maximum loss of 97% at the 2 m by 2100. However, freshwater non-tidal areas are predicted to be rather resilient, with only 11% predicted to be lost at 1 m of SLR by 2100.

Table 23. Predicted Percent Change of Land Categories by 2100 at Site 3 – Salmon River Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	0	1	1
Open Water	-4	-4	-4	-7	-9
Freshwater Non-Tidal	6	8	11	18	28
Low Tidal	6	4	2	1	-48
Transitional	-6	-7	-4	48	61
Freshwater Tidal	5	21	57	89	97
Saltmarsh	-67	-96	-200	-809	-568

This site did not contain any diked areas, precluding simulations run without the dike layer included.

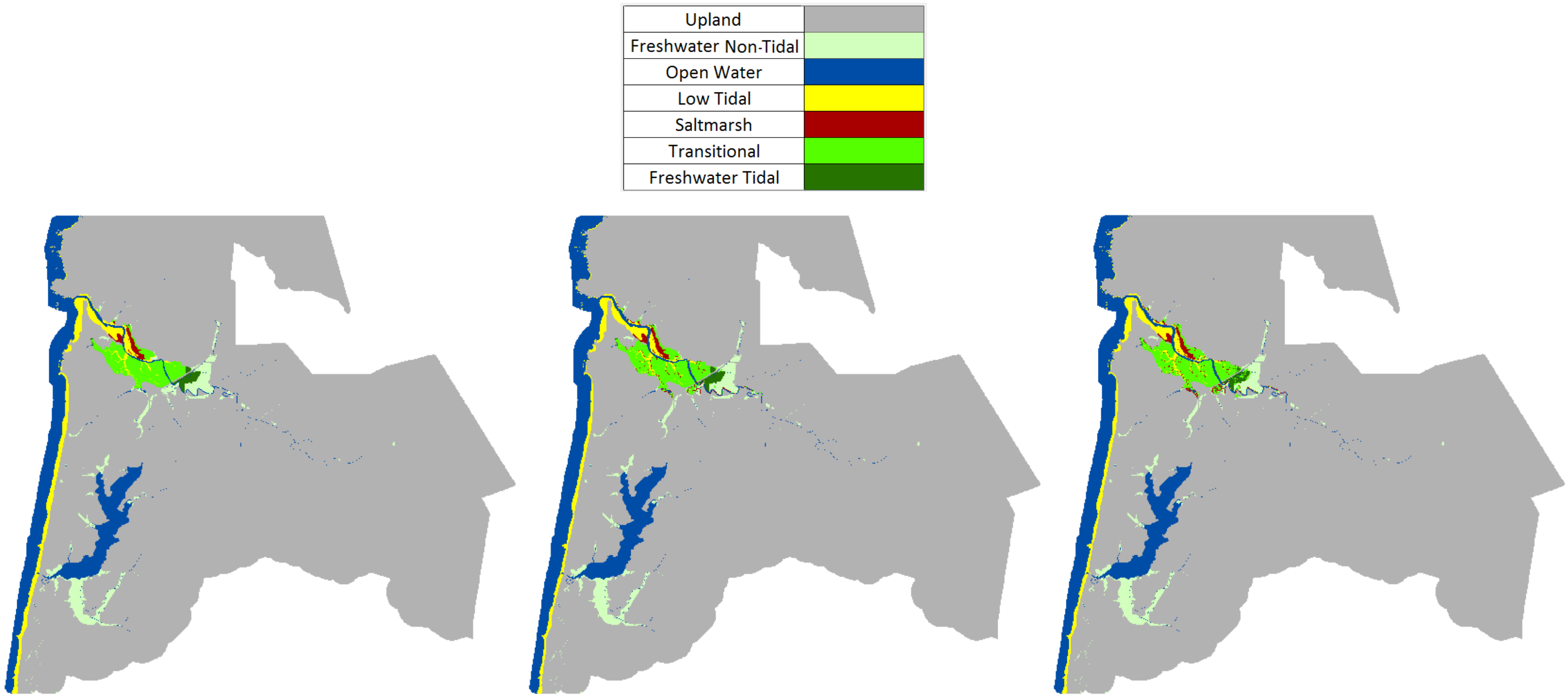

Figure 46. Wetland data for Site 3 – Salmon River. Initial condition - 2002 (left), 2100 under the A1B mean scenario (0.39 m SLR by 2100, middle), 2100 under the A1B max scenario (0.69 m SLR by 2100, right)

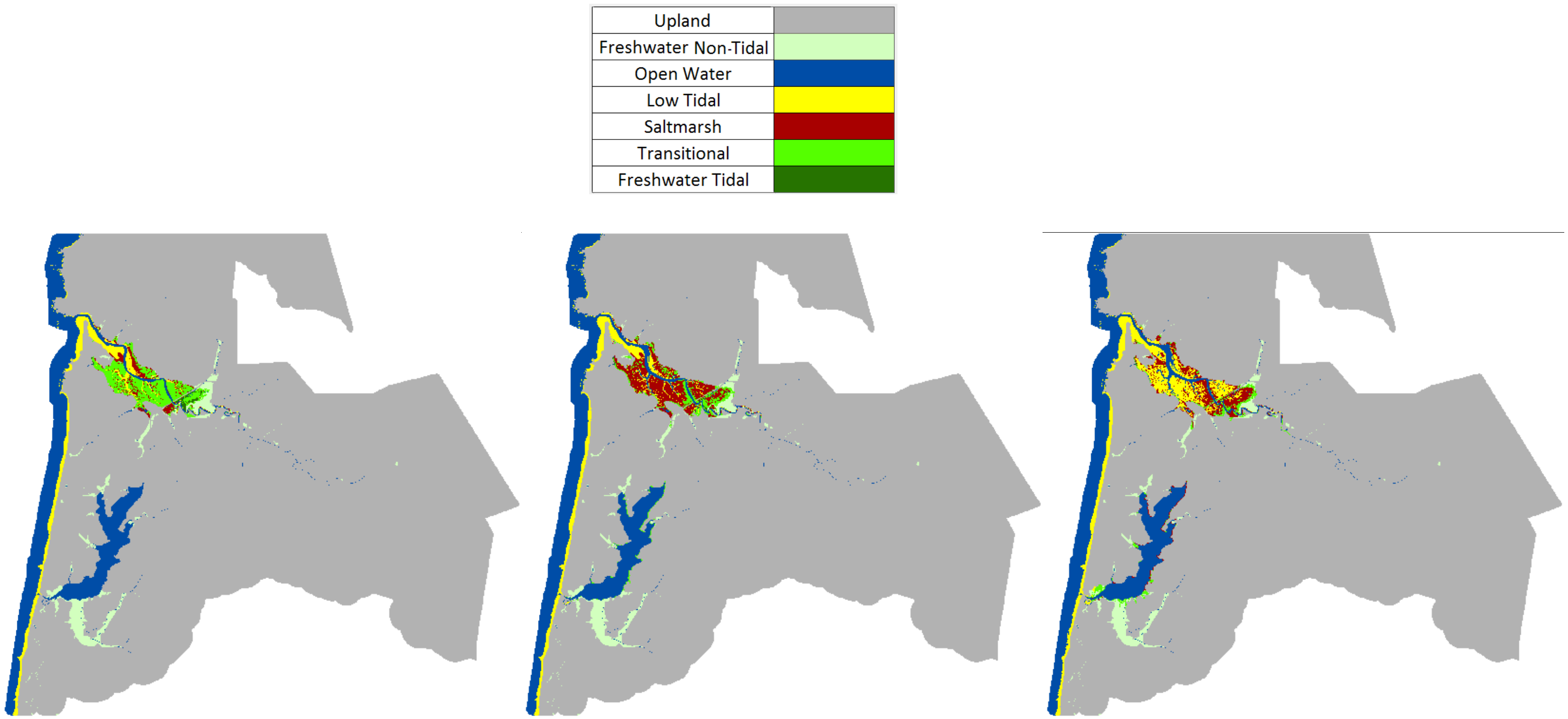

Figure 47. Projected wetland coverage in 2100 under the 1 m (left). 1.5 m (middle), and 2 m (right) SLR by 2100 scenarios

Site 4: Siletz and Yaquina

Site 4 is nearly 150,000 acres in area and contains both the Siletz and Yaquina river estuaries. Although run in the same simulation, the study area was divided into two output subsites (as shown in Figure 48) in order to analyze predictions for each estuary independently.

Table 24. Wetland coverage of Site 4 according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	134023	89
Open Water	6677	4
Freshwater Non-Tidal	4051	3
Low Tidal	3872	3
Transitional	562	< 1
Saltmarsh	397	< 1
Freshwater Tidal	199	< 1
Total (incl. water)	**149782**	**100**

The elevation data and location of dikes in this site are shown in Figure 49 and Figure 50, respectively. Several tide gauges are located within the sites which were incorporated into the study area using multiple input subsites, as shown in Figure 51. The northern part of the study area, which included Siletz Bay was assigned a tide range of 1.94 m, based on the average of the tide observations at Kernville (1.86 m) and Taft (2.01 m). The Yaquina estuary was assigned a tide range of 2.5 m based on the average of several tide table and tidal datum measurements (see Table 3 on page 7 and Table 4on page 8 for more detail). One portion of the Yaquina watershed was assigned a tide range of 0 m to simulate the effect of closed tide gates in this area. The salt elevations were calculated from the inundation analysis conducted at the South Beach NOAA gauge station (#9435380) and determined to be 1.4 m for the Siletz subsite and 1.81m for the Yaquina subsite. The salt elevation for the subsite with a tide range of 0 m was also set to 0 m. The historic SLR trend applied to this site was 2.10 mm/yr.

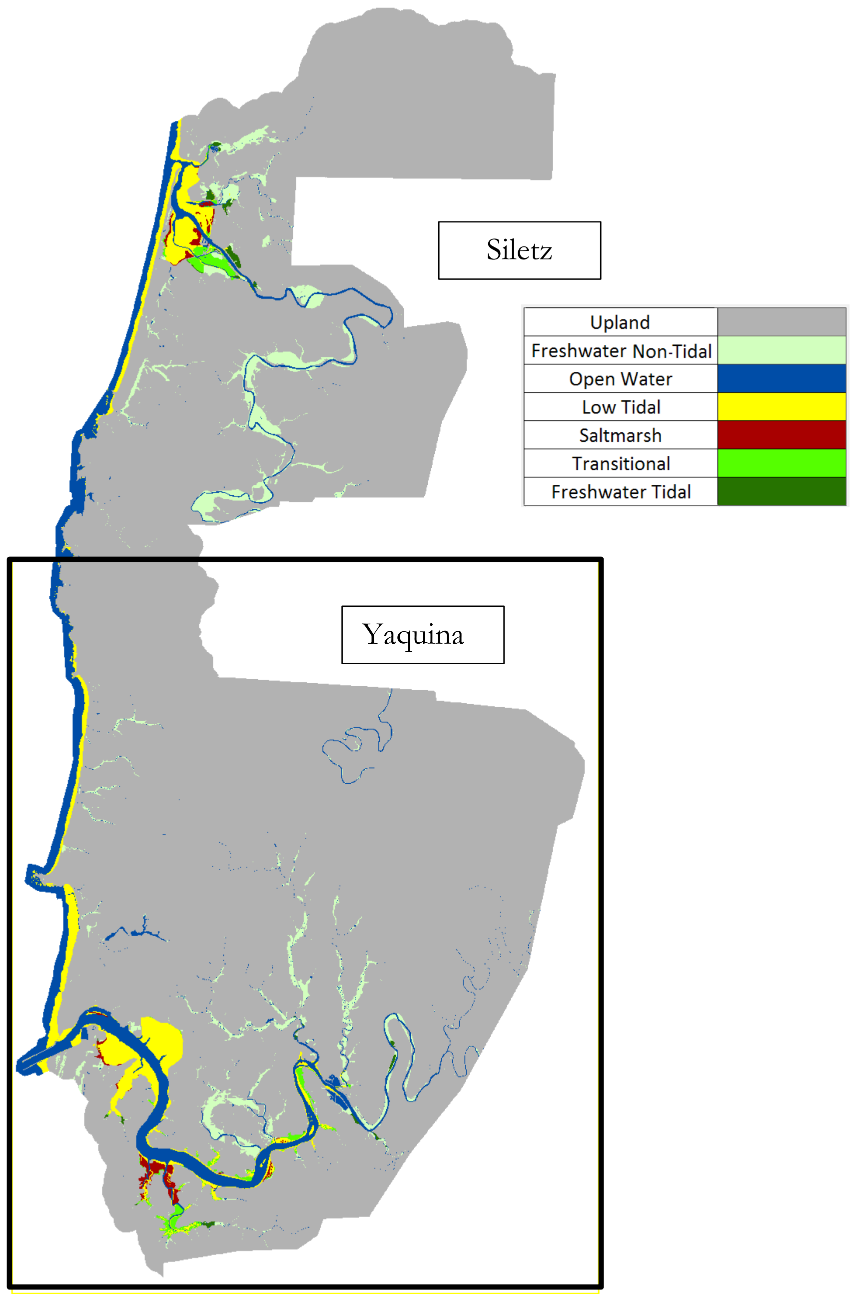

Figure 48. Site 4 subsites

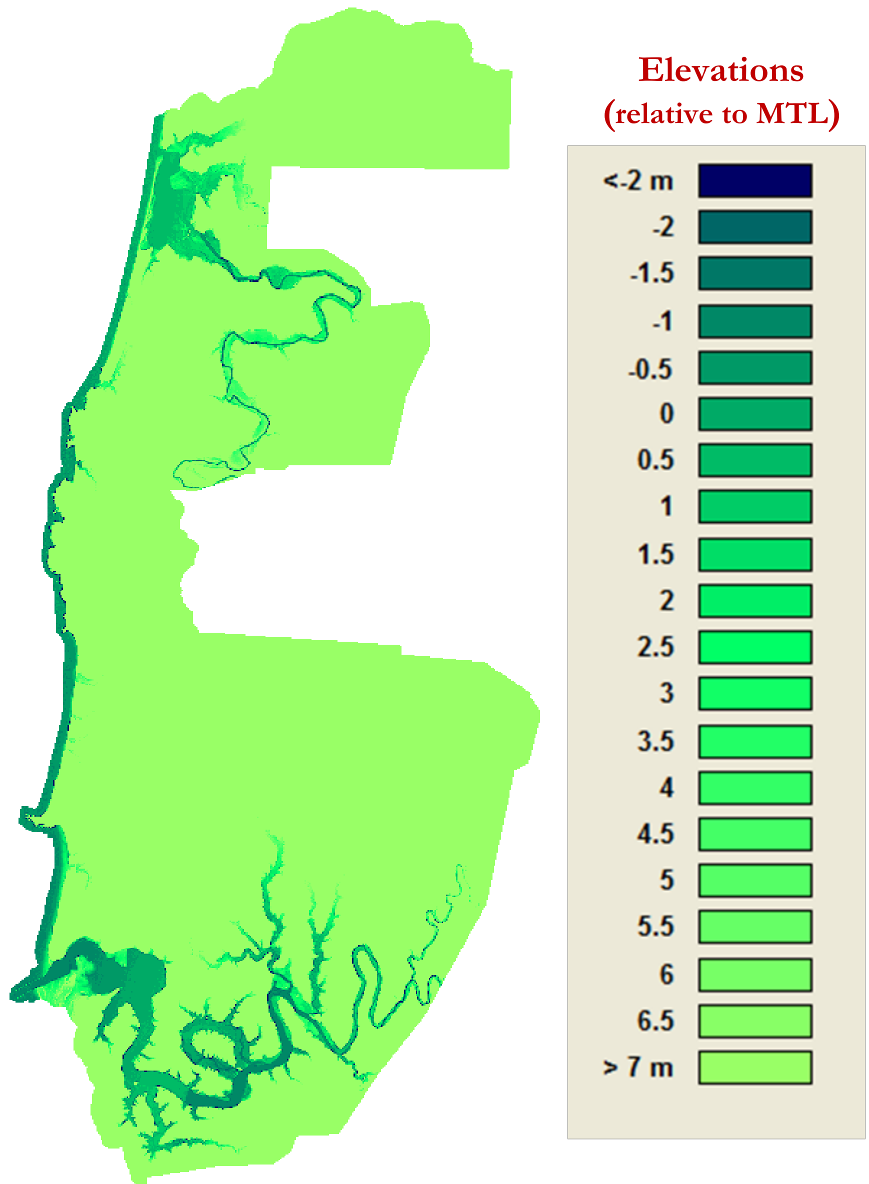

Figure 49. LiDAR elevation data for Site 4

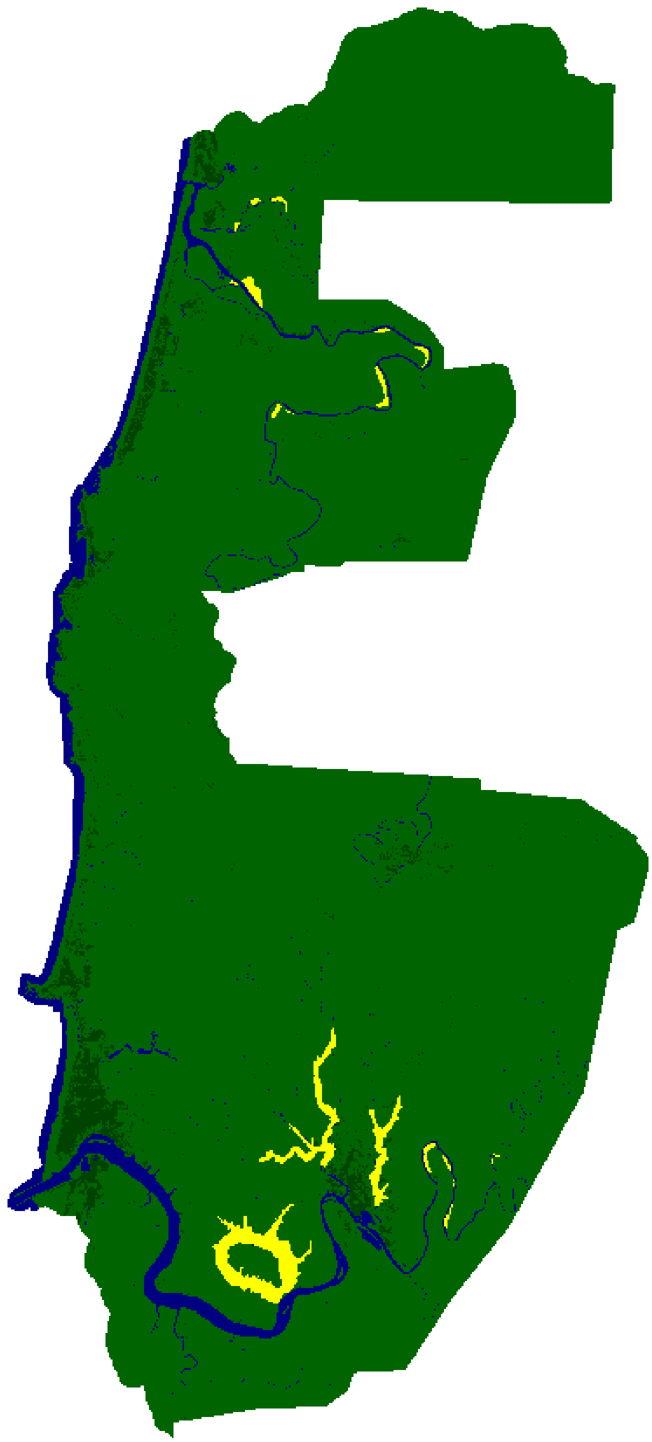

Figure 50. Location of dikes in for Site 4 (shown in yellow)

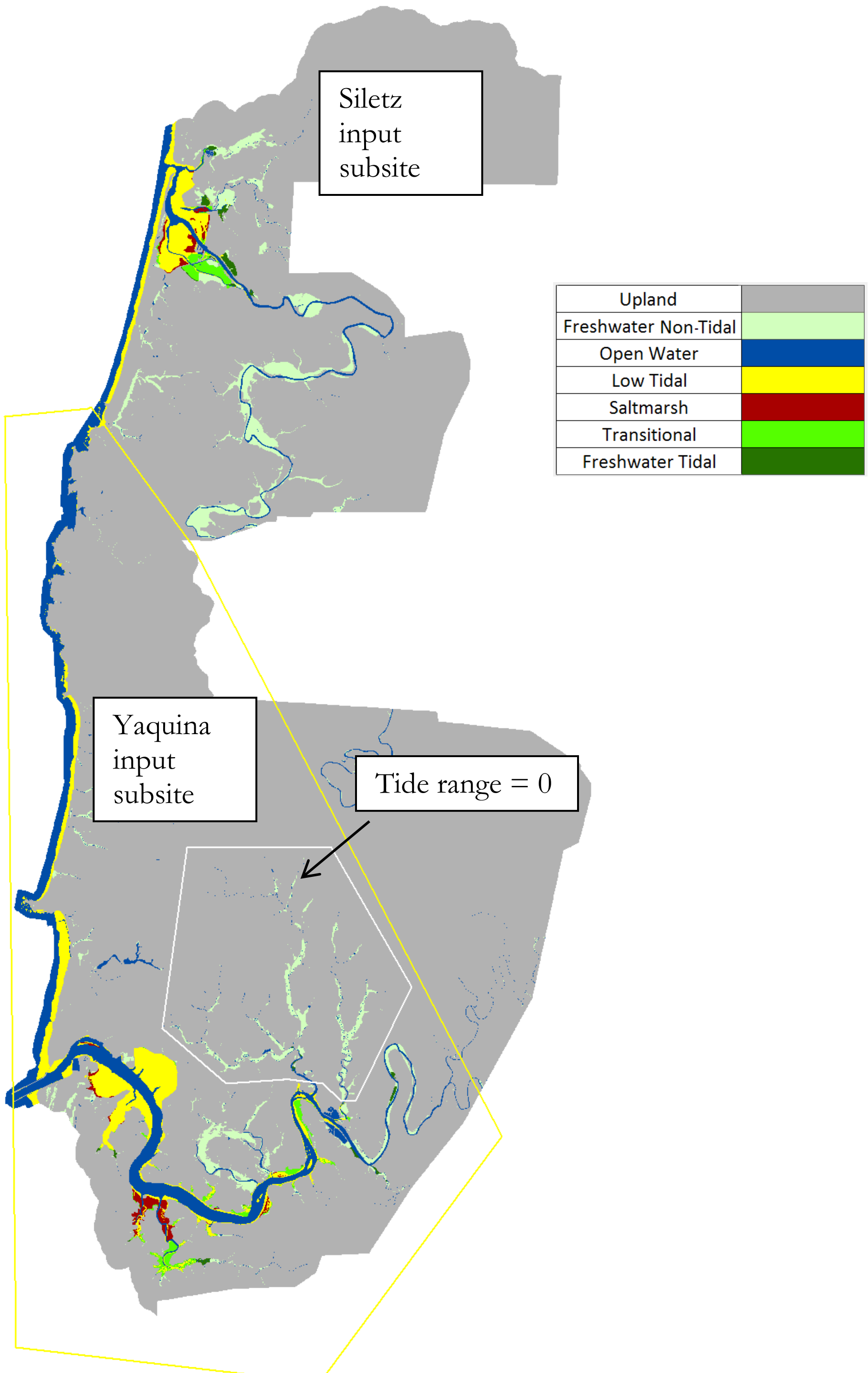

Figure 51. Wetland data with input subsites used for Site 4

Entire Site

The results for Site 4 (shown in Table 25) suggest increases in saltmarsh, transitional marsh, and open water and losses in freshwater tidal wetlands to occur over the coming century. The freshwater tidal category is predicted to be most impacted by SLR with losses of 48% at 2 m of SLR by 2100. However, freshwater non-tidal areas are predicted to be rather resilient, with 17% of the initial wetland coverage predicted to be lost at 1 m of SLR by 2100.

Table 25. Predicted Percent Change of Land Categories by 2100 at Site 4 – Siletz Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	1	1	1	1
Open Water	-6	-8	-13	-27	-51
Freshwater Non-Tidal	10	14	17	21	26
Low Tidal	3	5	8	20	35
Transitional	-68	-89	-81	-36	-23
Saltmarsh	-74	-112	-181	-296	-238
Freshwater Tidal	-38	-32	-17	21	48

When dikes were removed the results of simulations generally showed the same trend of gains and losses predicted by the scenarios where dikes were included, as shown in Table 26. The exception was the freshwater tidal category, in which losses were predicted at lower SLR scenarios rather than gains. Other differences between the two sets of simulations were the prediction of gains in low tidal wetlands, larger losses predicted in freshwater non-tidal habitats, and increased gains predicted in transitional and salt marsh categories if dikes are removed.

Table 26. Predicted Percent Change of Land Categories by 2100 at Site 4 – Siletz Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	1	1	1	2
Open Water	-6	-8	-13	-27	-54
Freshwater Non-Tidal	24	28	33	39	44
Low Tidal	-3	-6	-8	2	23
Transitional	-95	-118	-115	-76	-62
Saltmarsh	-246	-240	-264	-373	-316
Freshwater Tidal	8	12	21	57	84

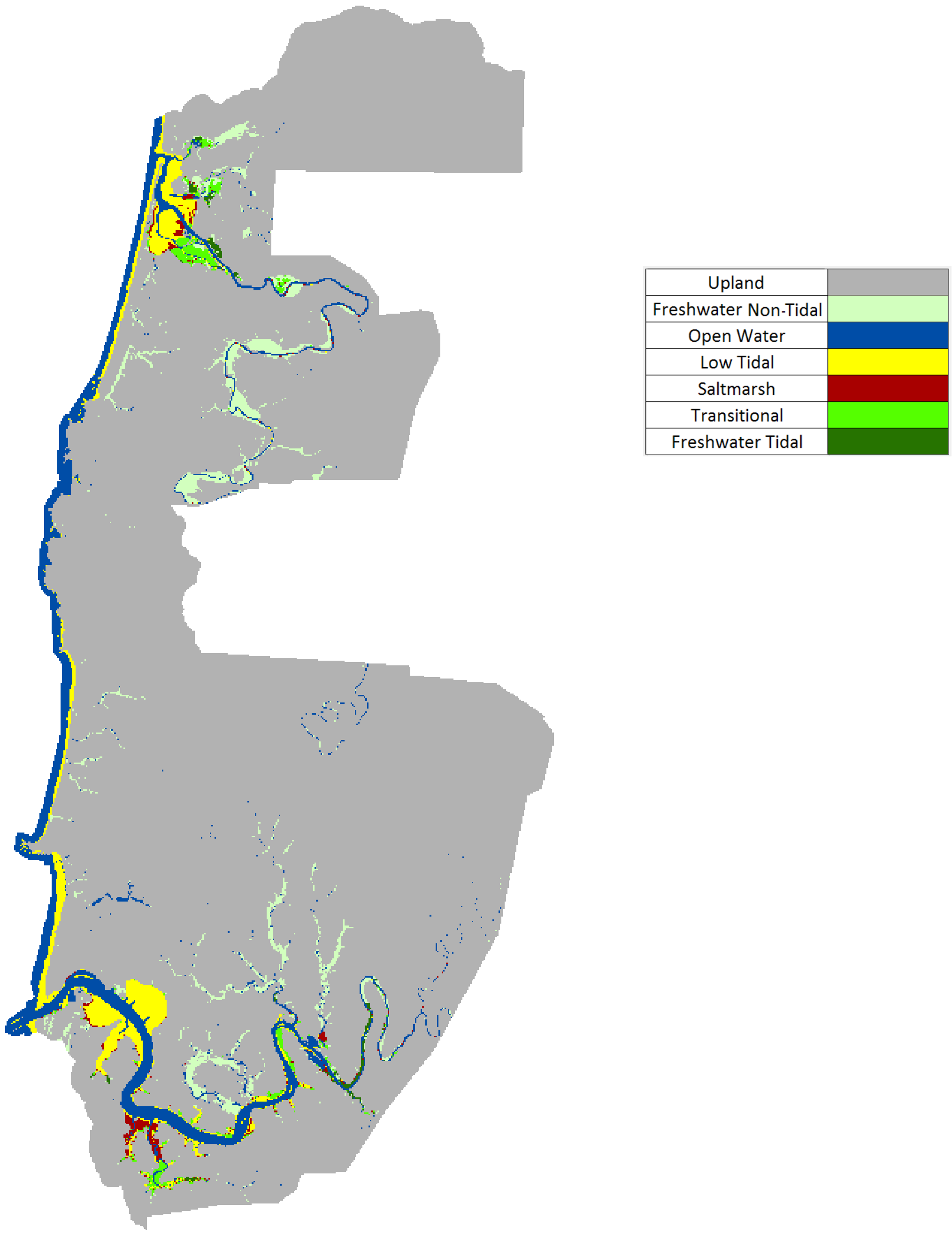

Figure 52. Site 4, 2100, Scenario A1B Mean

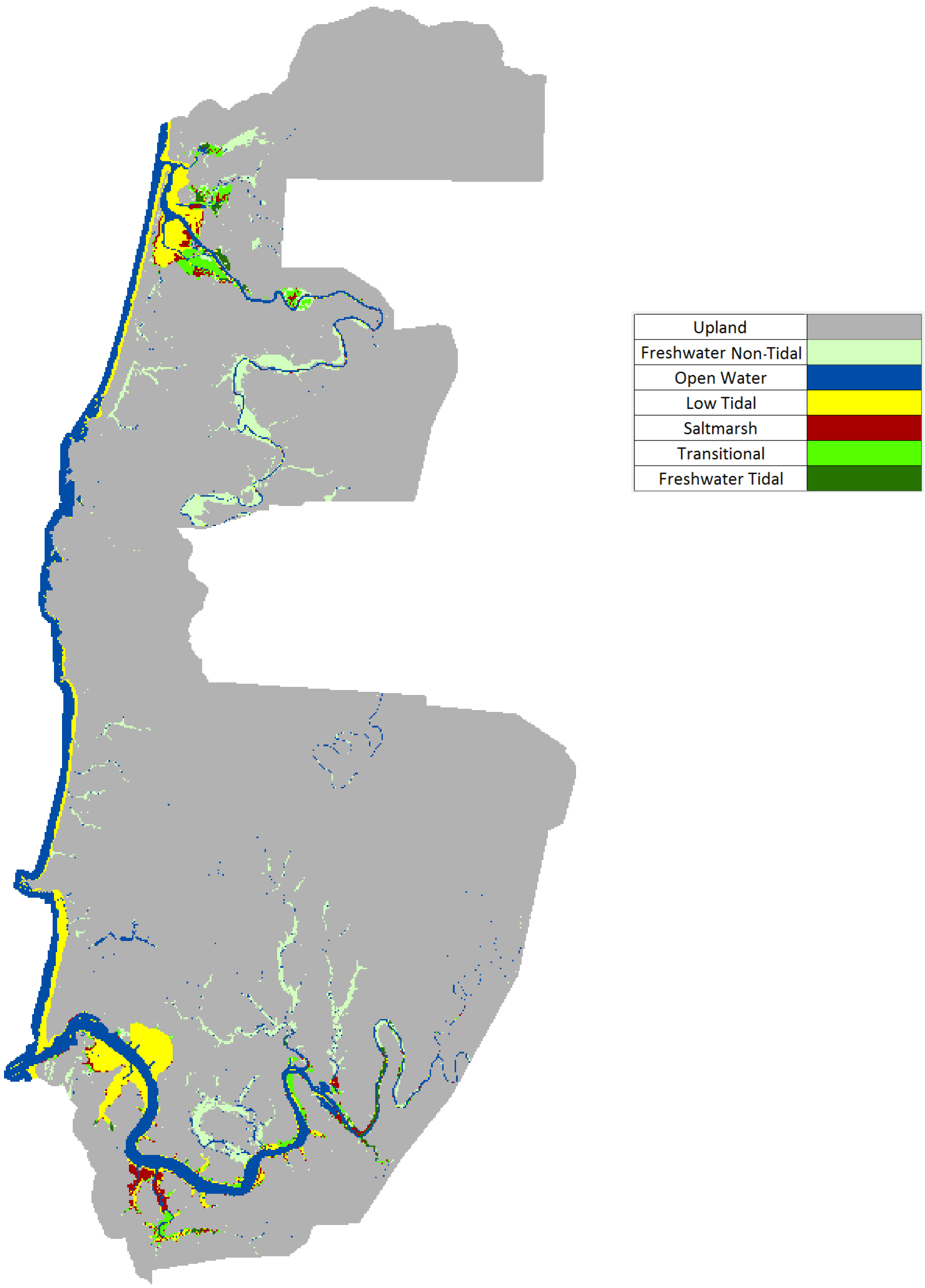

Figure 53. Site 4, 2100, Scenario A1B Max

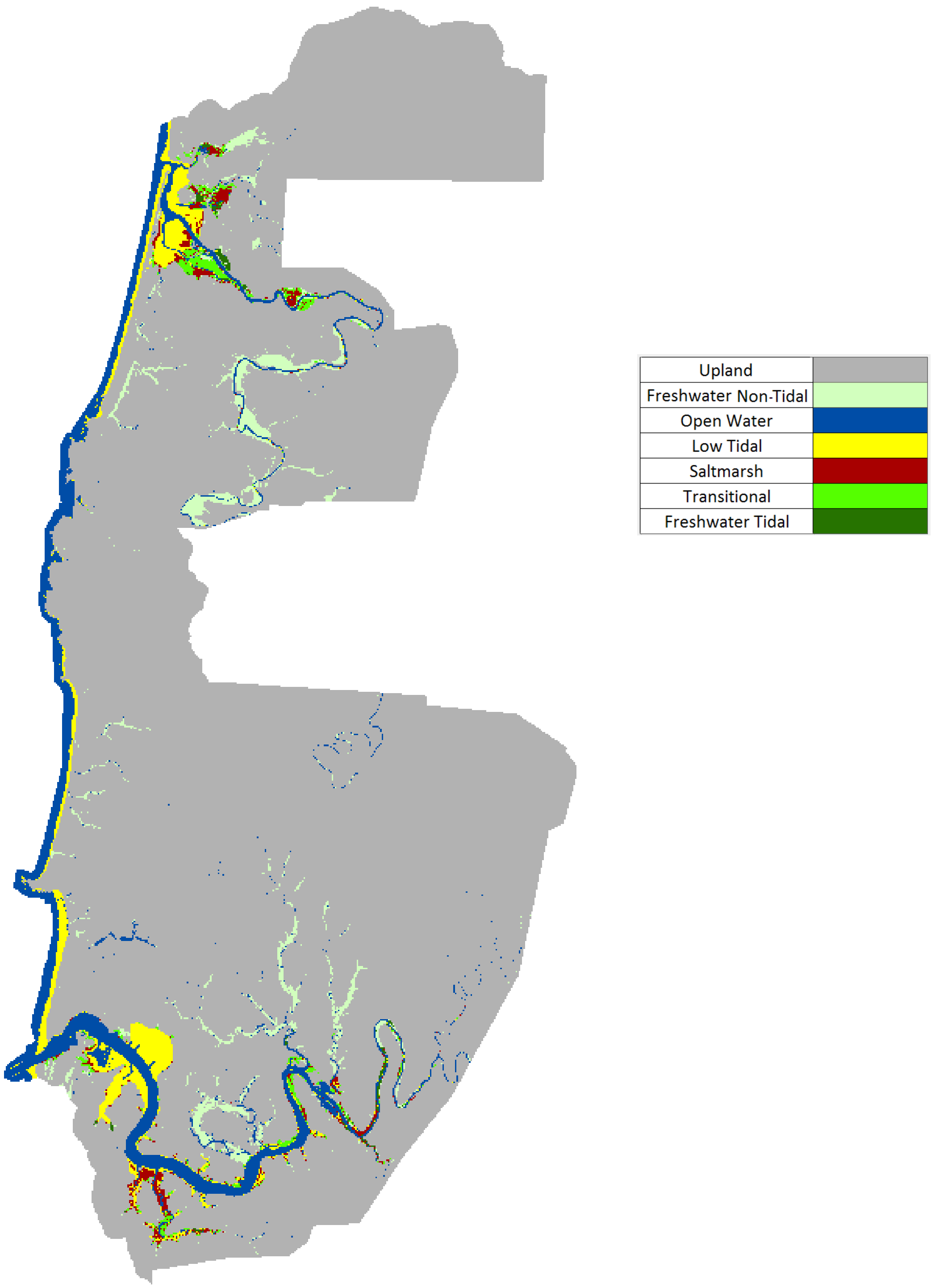

Figure 54. Site 4, 2100, Scenario 1 m

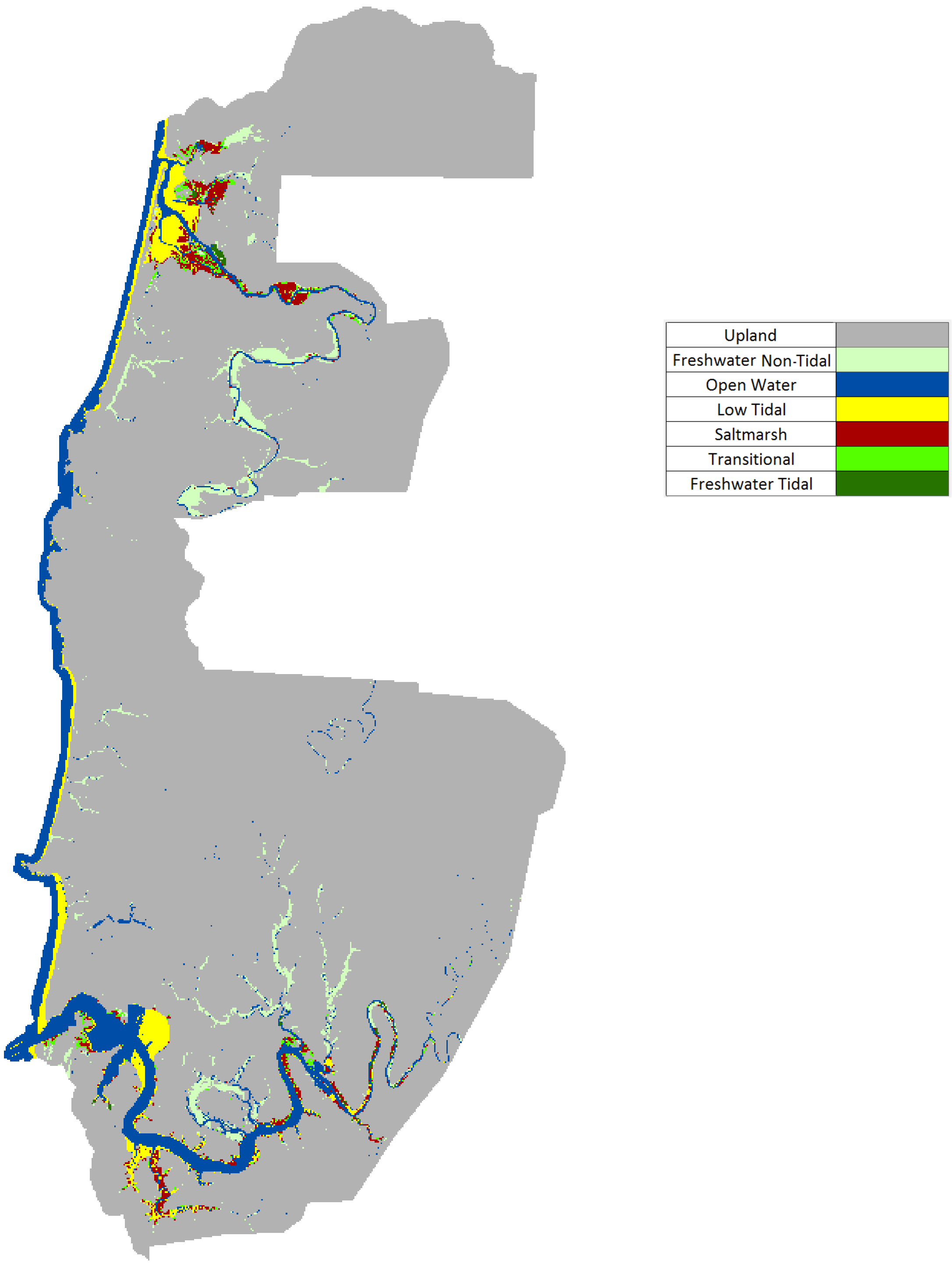

Figure 55. Site 4, 2100, Scenario 1.5 m

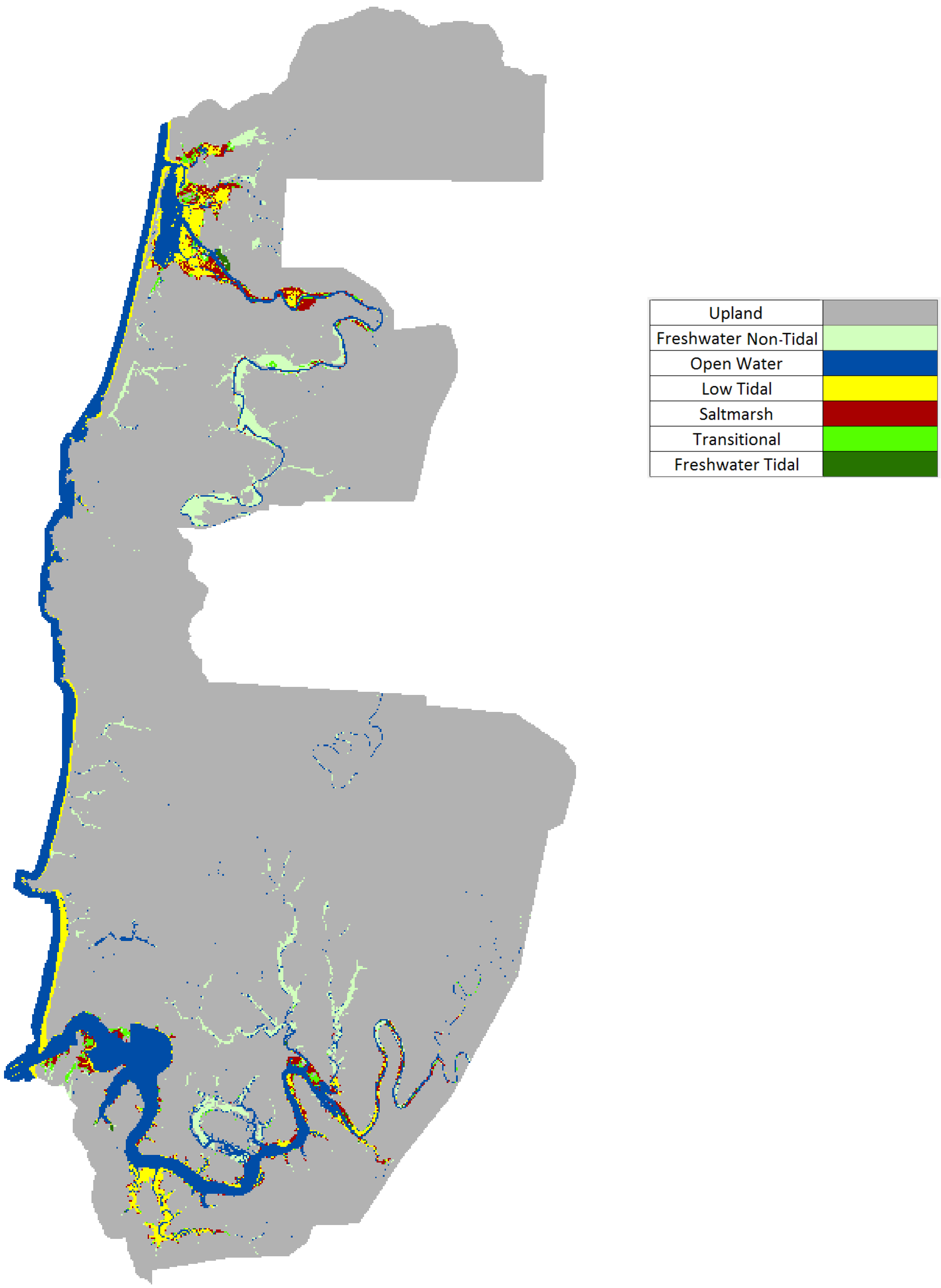

Figure 56. Site 4, 2100, Scenario 2 m

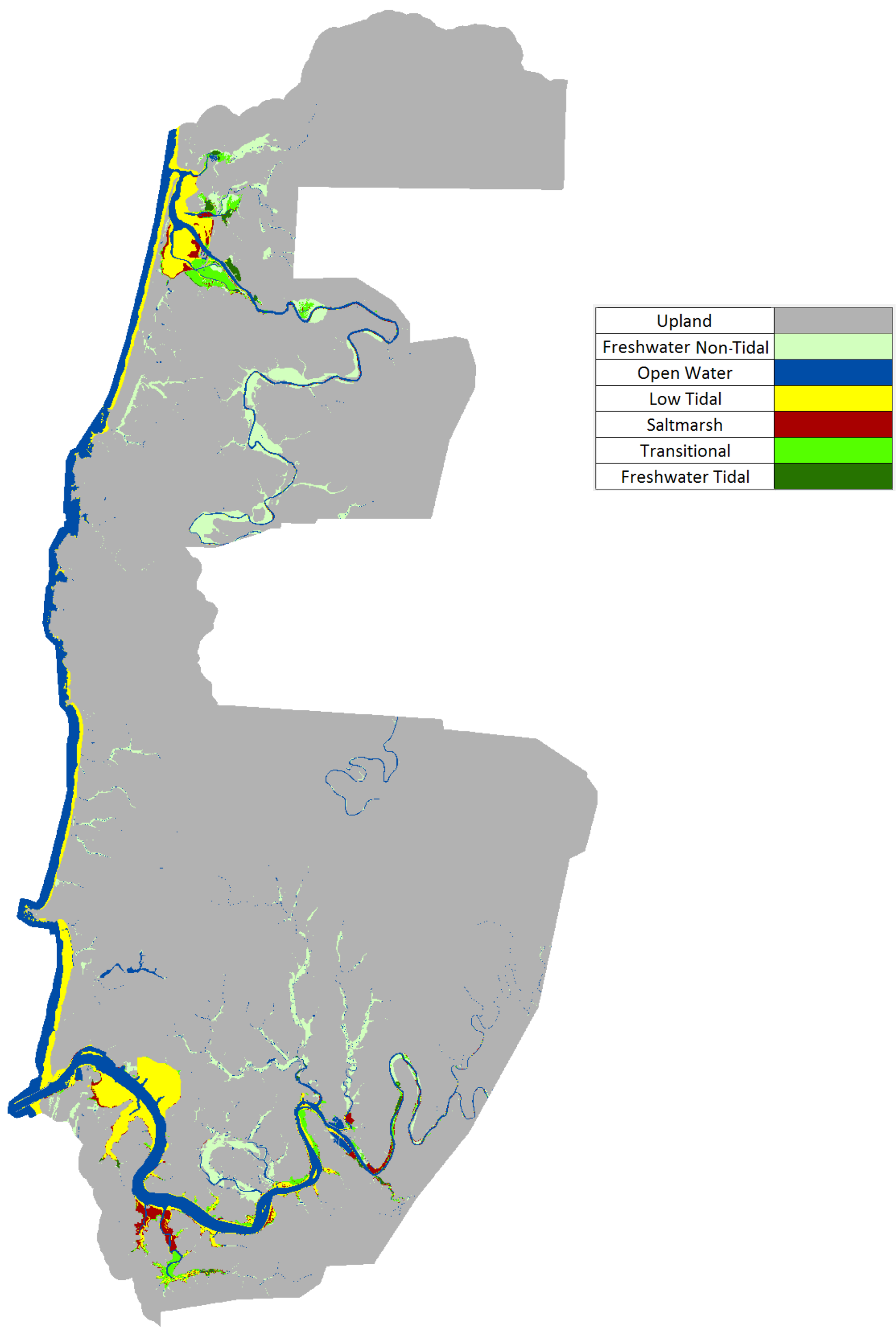

Figure 57. Site 4, 2100, Scenario A1B Mean – No Dikes

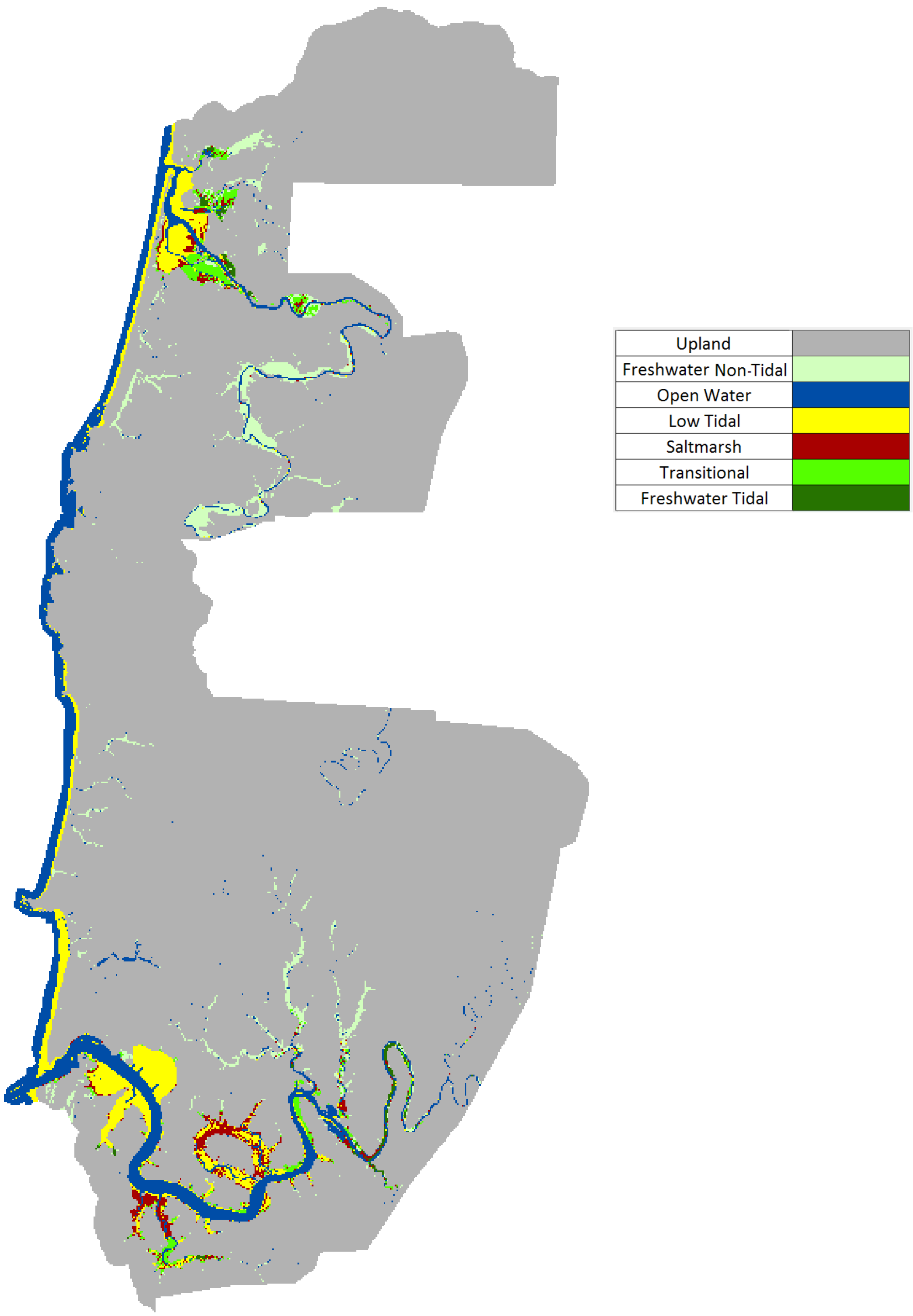

Figure 58. Site 4, 2100, Scenario A1B Max– No Dikes

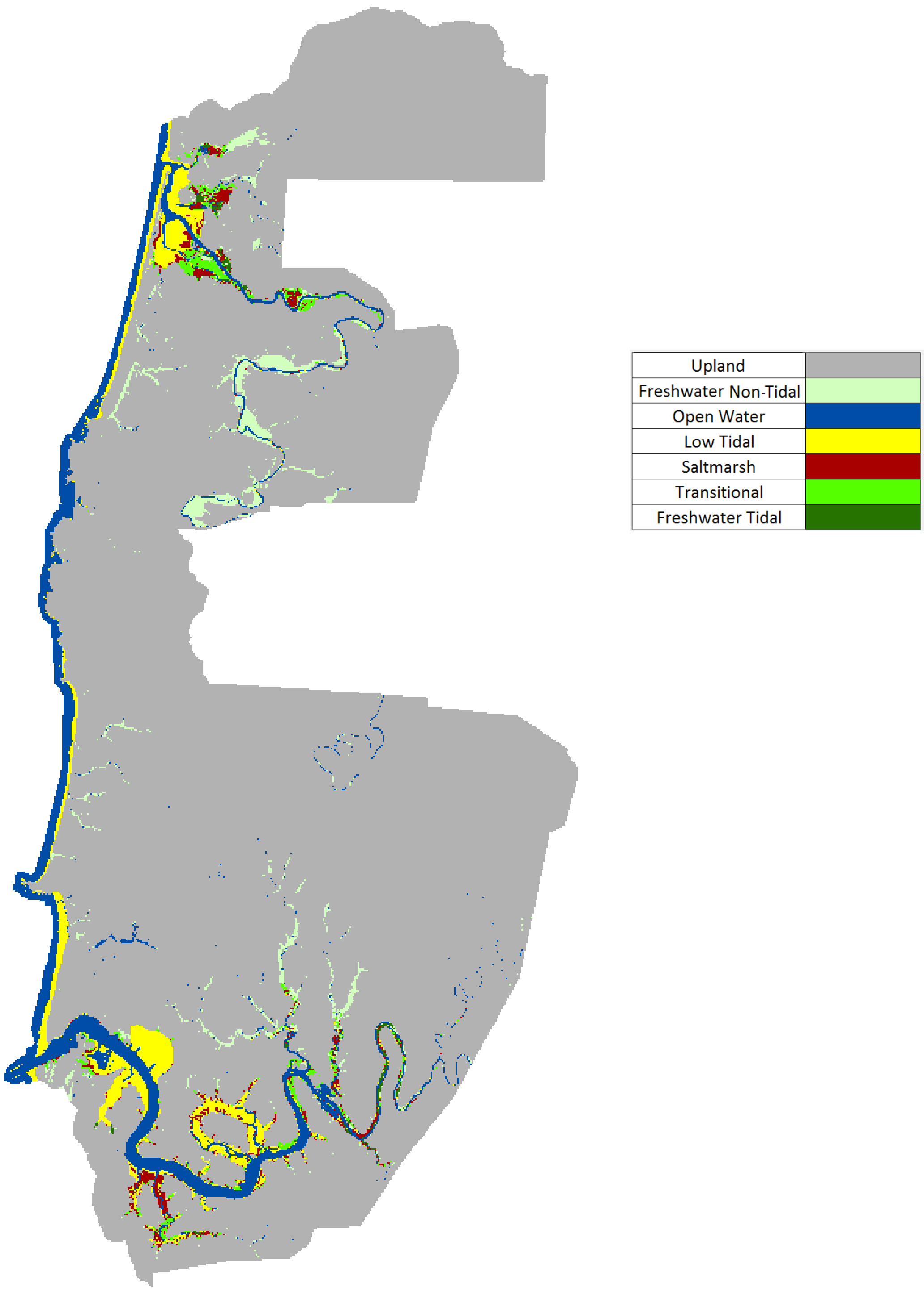

Figure 59. Site 4, 2100, Scenario 1 m– No Dikes

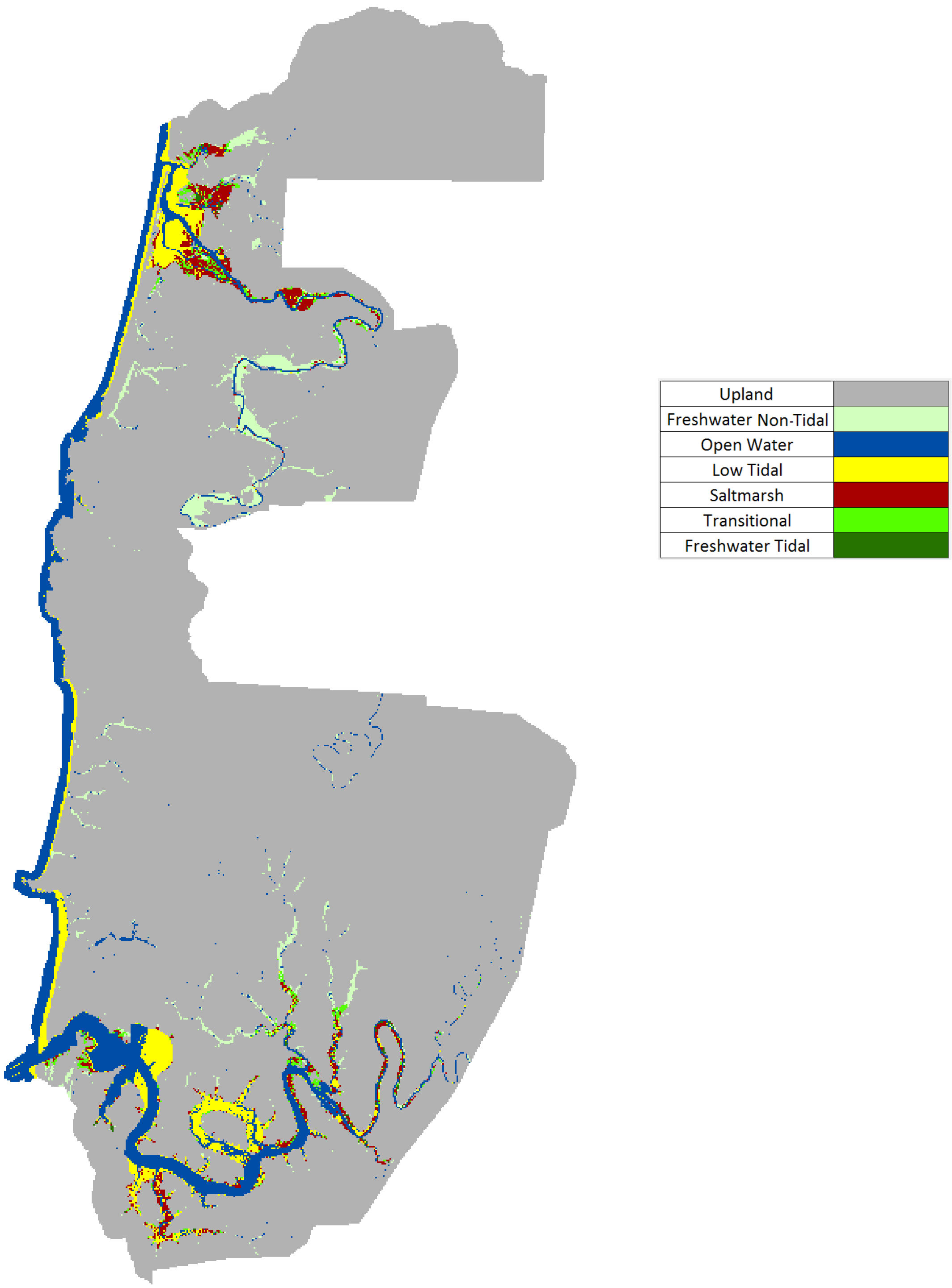

Figure 60. Site 4, 2100, Scenario 1.5 m– No Dikes

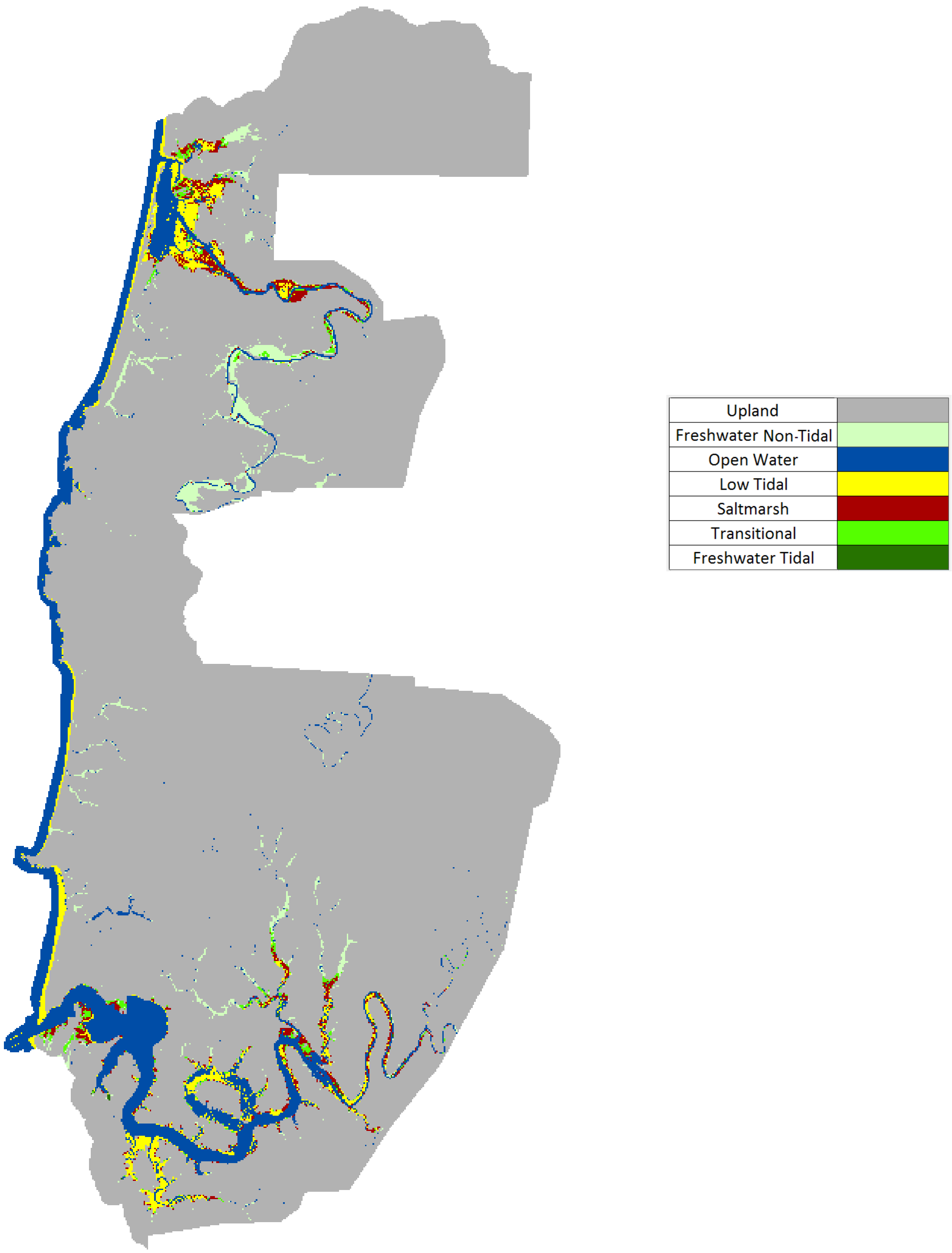

Figure 61. Site 4, 2100, Scenario 2 m– No Dikes

Siletz

The Siletz estuary wetlands are composed primarily of freshwater non-tidal wetlands, which occur in the upstream portion of the estuary, with low tidal and saltmarsh habitats dominating the bay portion.

Table 27. Wetland coverage of Site 4 - Siletz according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	48114	89
Freshwater Non-Tidal	2213	4
Open Water	2171	4
Low Tidal	1275	2
Saltmarsh	129	< 1
Transitional	248	< 1
Freshwater Tidal	125	< 1
Total (incl. water)	**54275**	**100**

Table 28 presents the result of simulations for the Siletz estuary. This estuary appears to be resilient to the effect of SLR under the lower SLR scenarios simulated (1 m by 2100 and lower). However, more than 50% of the freshwater tidal habitat is predicted to be lost under the 2 m by 2100 scenario. Losses in freshwater non-tidal, freshwater tidal, and low tidal habitats are projected to result in gains of transitional and saltmarsh habitats, as well as additional open water.

Table 28. Predicted Percent Change of Land Categories by 2100 at Site 4 – Siletz Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	1	1	1	1
Freshwater Non-Tidal	10	16	21	24	27
Open Water	-5	-6	-7	-11	-40
Low Tidal	2	2	0	-3	8
Transitional	-96	-135	-121	-48	-18
Saltmarsh	-64	-135	-285	-559	-427
Freshwater Tidal	1	3	9	34	53

The same set of SLR scenarios described above was run with the dikes removed to assess the potential effects of dike removal on wetland distribution. The results of this analysis (presented in Table 29) suggest dike removal would not significantly change the predicted coverage if dikes were maintained. The changes noted are greater percentage losses in freshwater tidal and freshwater non-tidal marshes coupled with greater gains in transitional and salt marsh.

Table 29. Predicted Percent Change of Land Categories by 2100 at Site 4 – Siletz Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	**0.69 m**	**1 m**	**1.5 m**	**2 m**
Upland	0	1	1	1	2
Freshwater Non-Tidal	11	17	21	26	30
Open Water	-5	-6	-7	-11	-40
Low Tidal	2	1	0	-6	4
Transitional	-104	-145	-131	-64	-44
Saltmarsh	-68	-145	-305	-592	-471
Freshwater Tidal	3	6	14	56	87

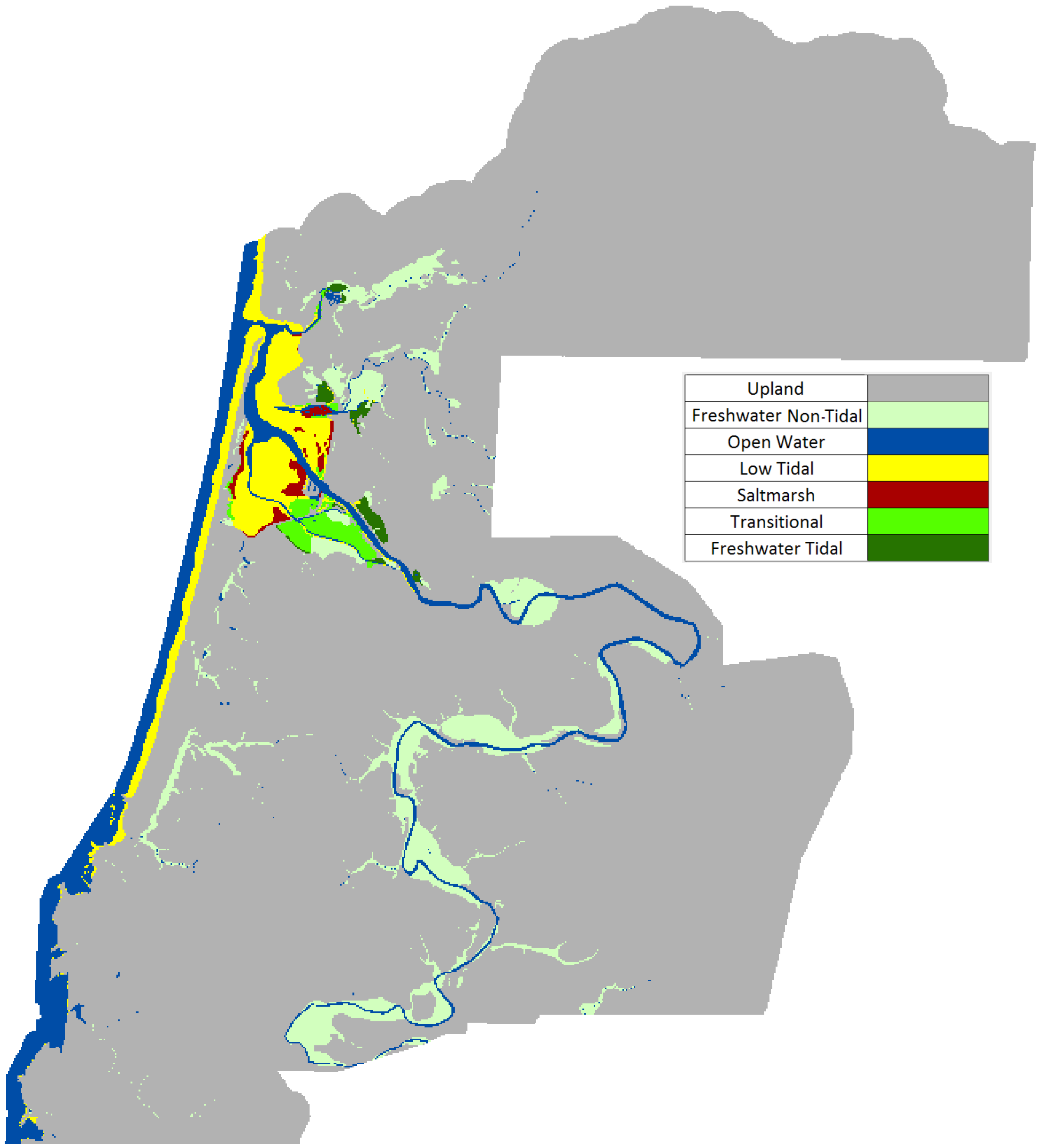

Figure 62. Initial Condition Wetland Data for 4 – Siletz

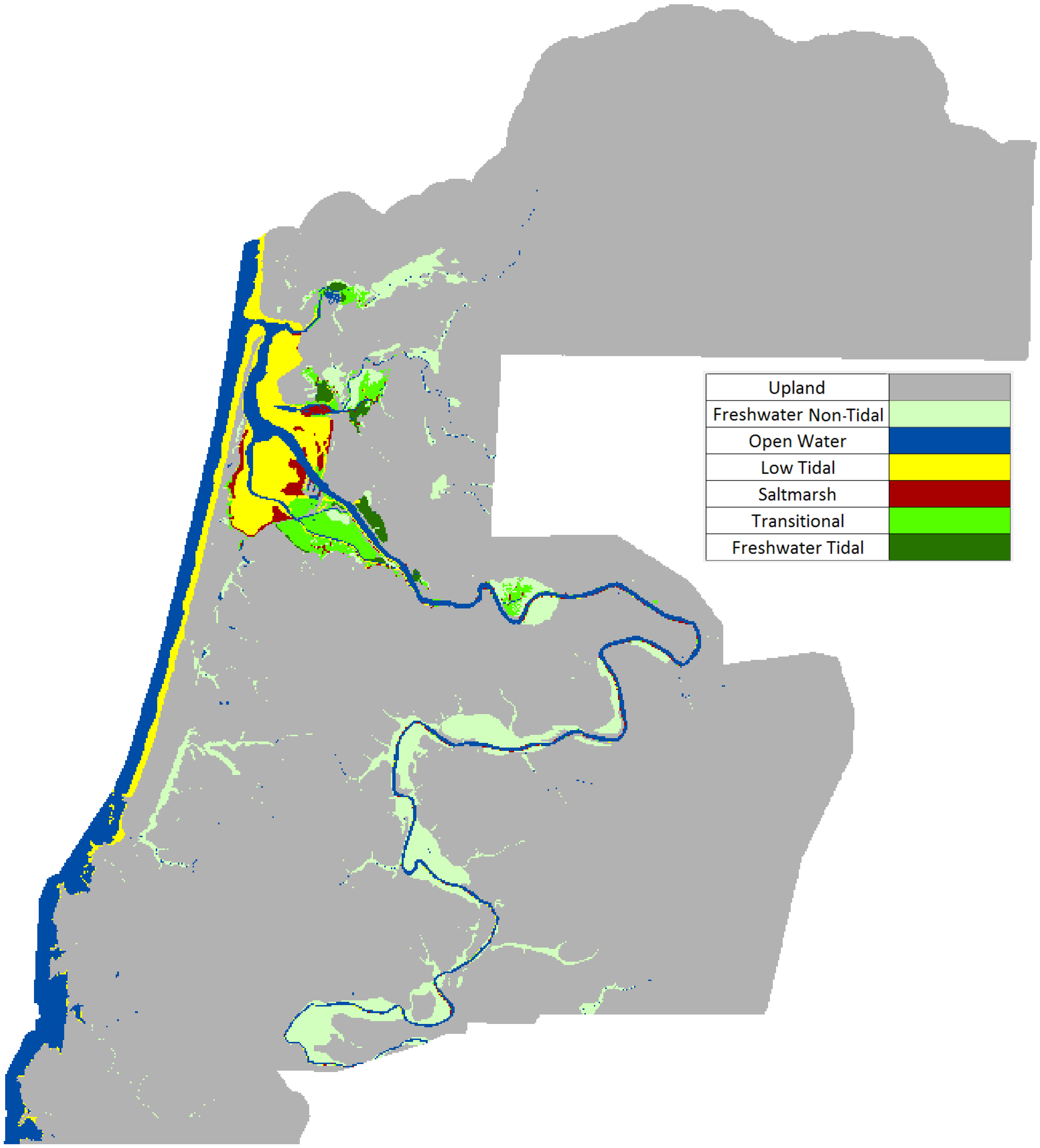

Figure 63. Site 4 – Siletz, 2100, Scenario A1B Mean

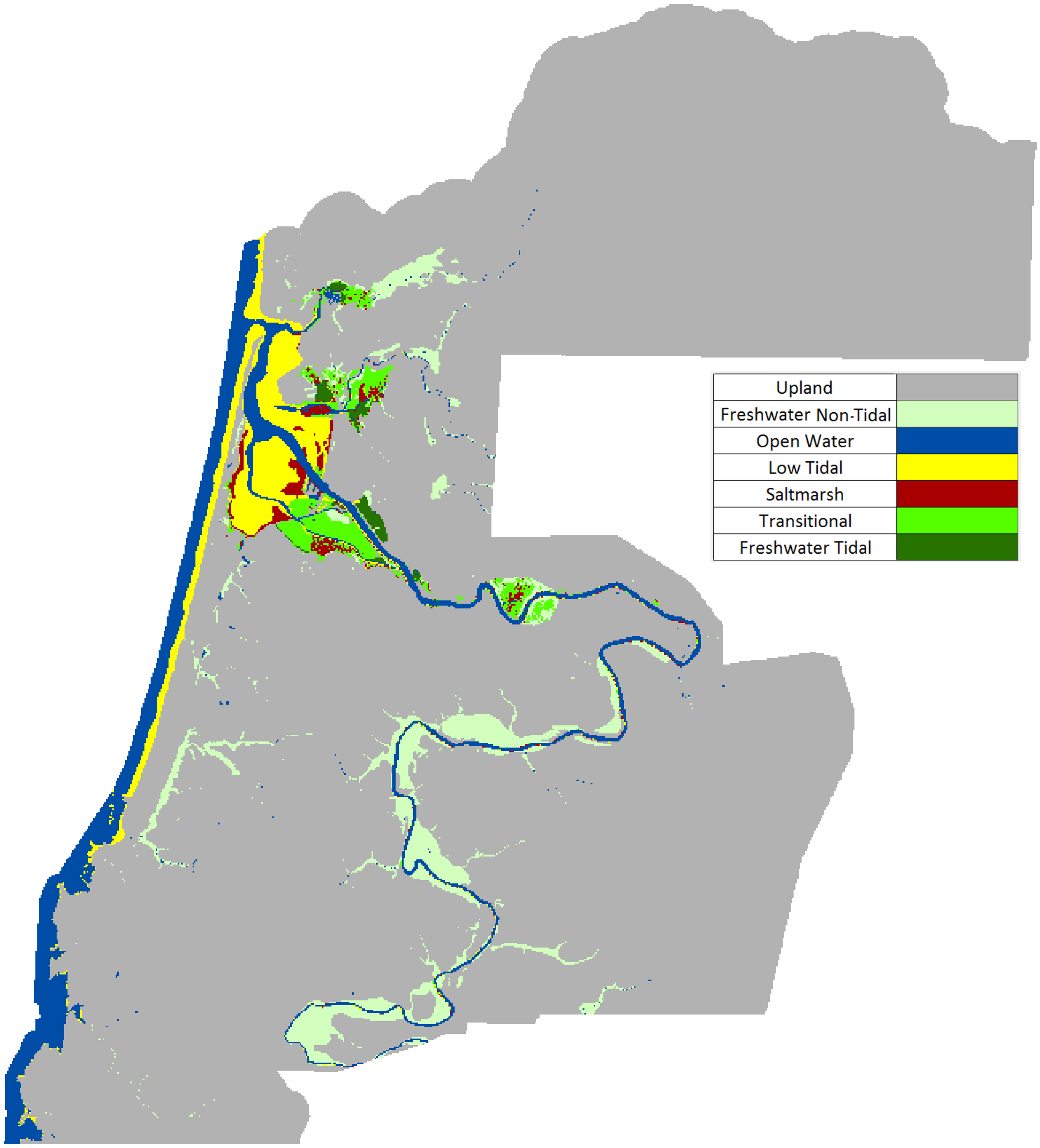

Figure 64. Site 4 – Siletz, 2100, Scenario A1B Max

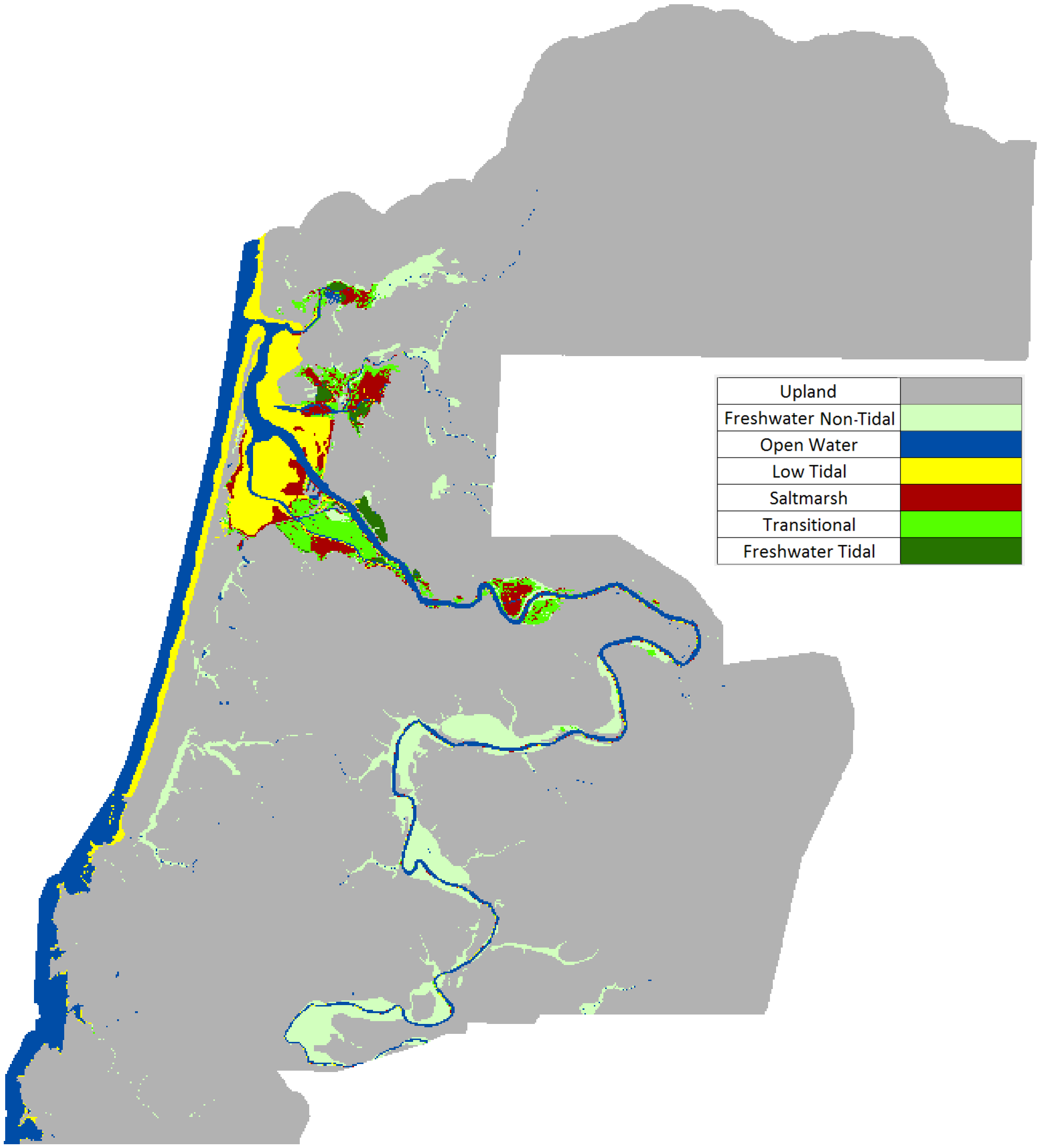

Figure 65. Site 4 – Siletz, 2100, Scenario 1 m

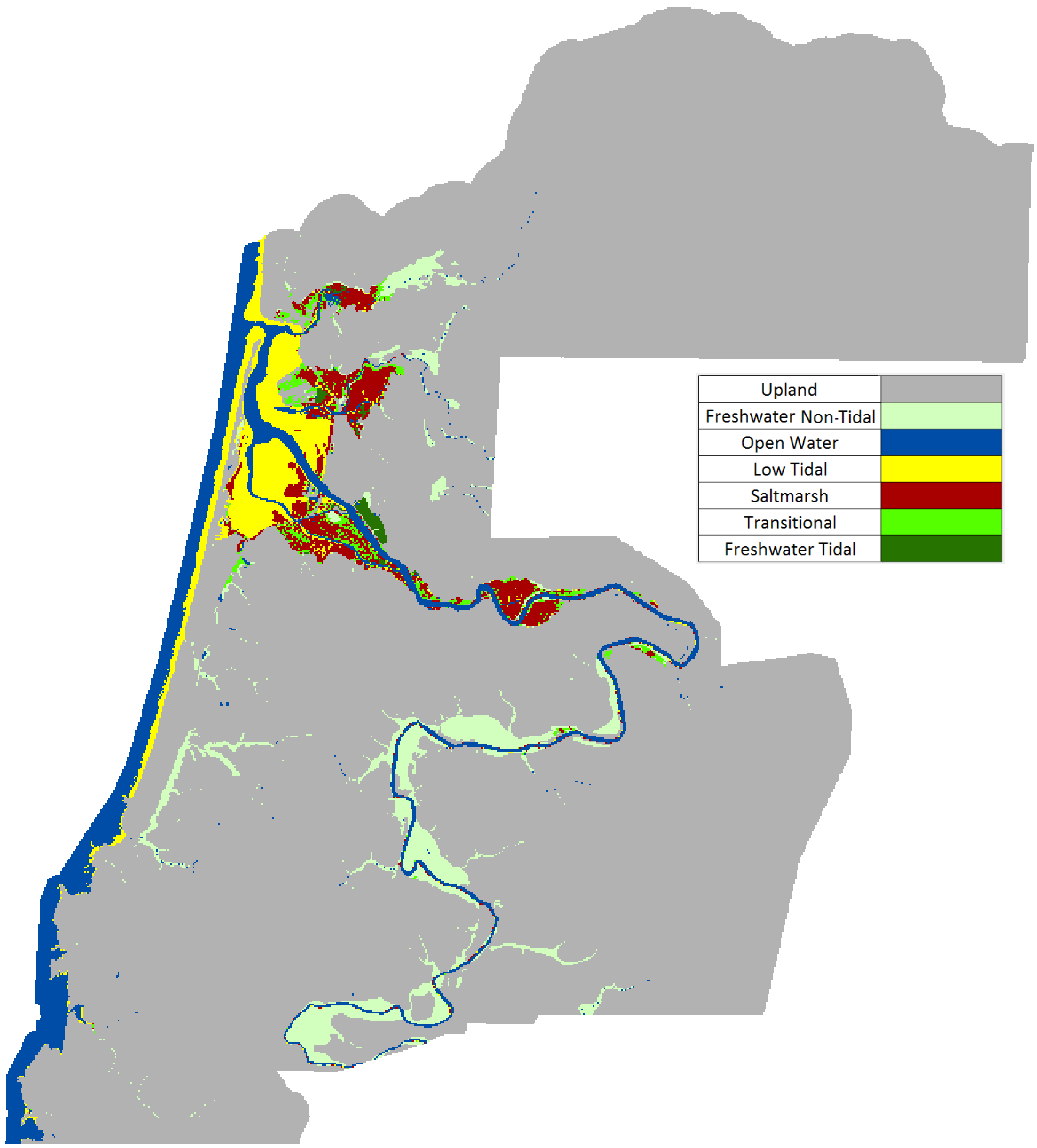

Figure 66. Site 4 – Siletz, 2100, Scenario 1.5 m

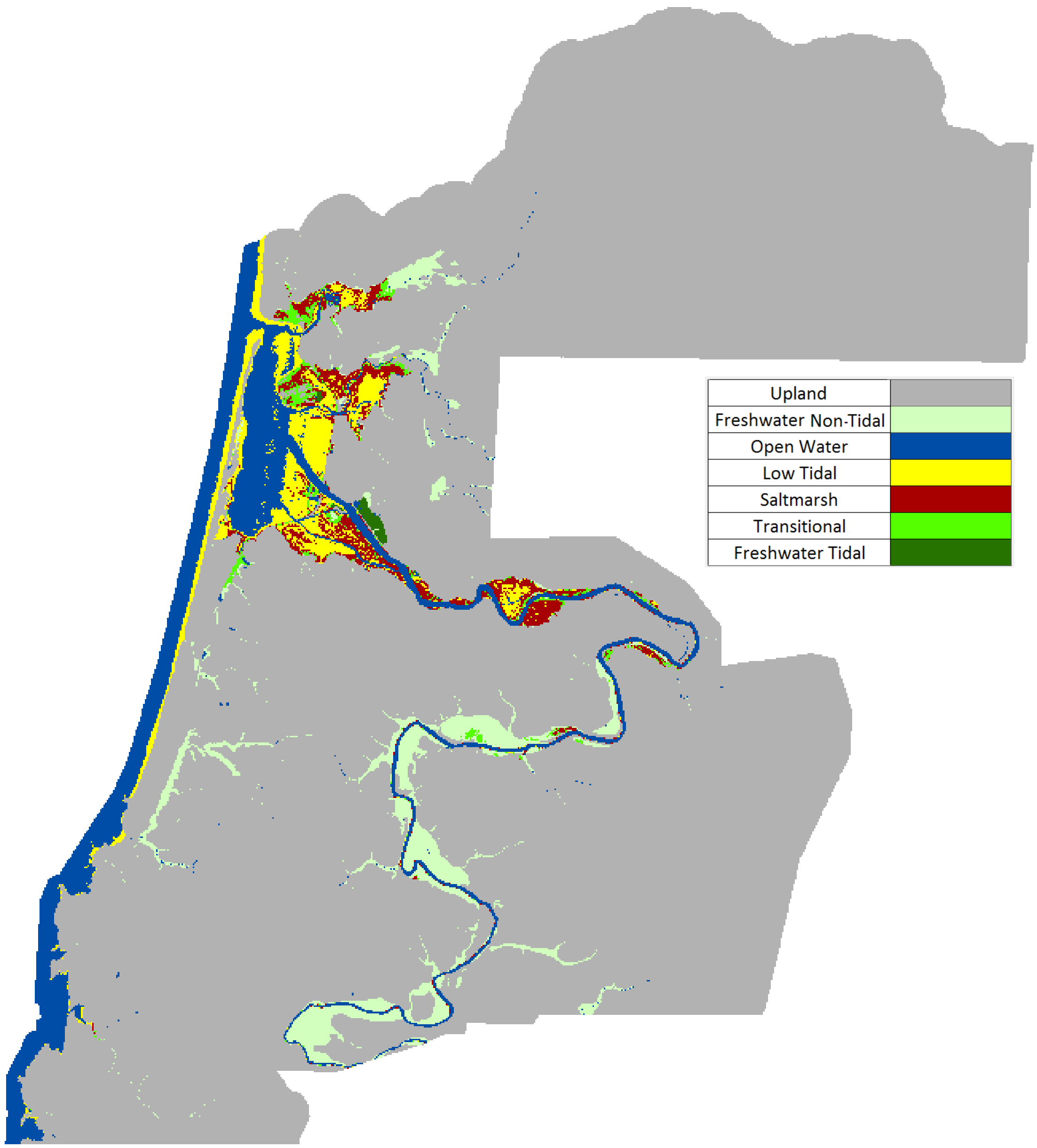

Figure 67. Site 4 – Siletz, 2100, Scenario 2 m

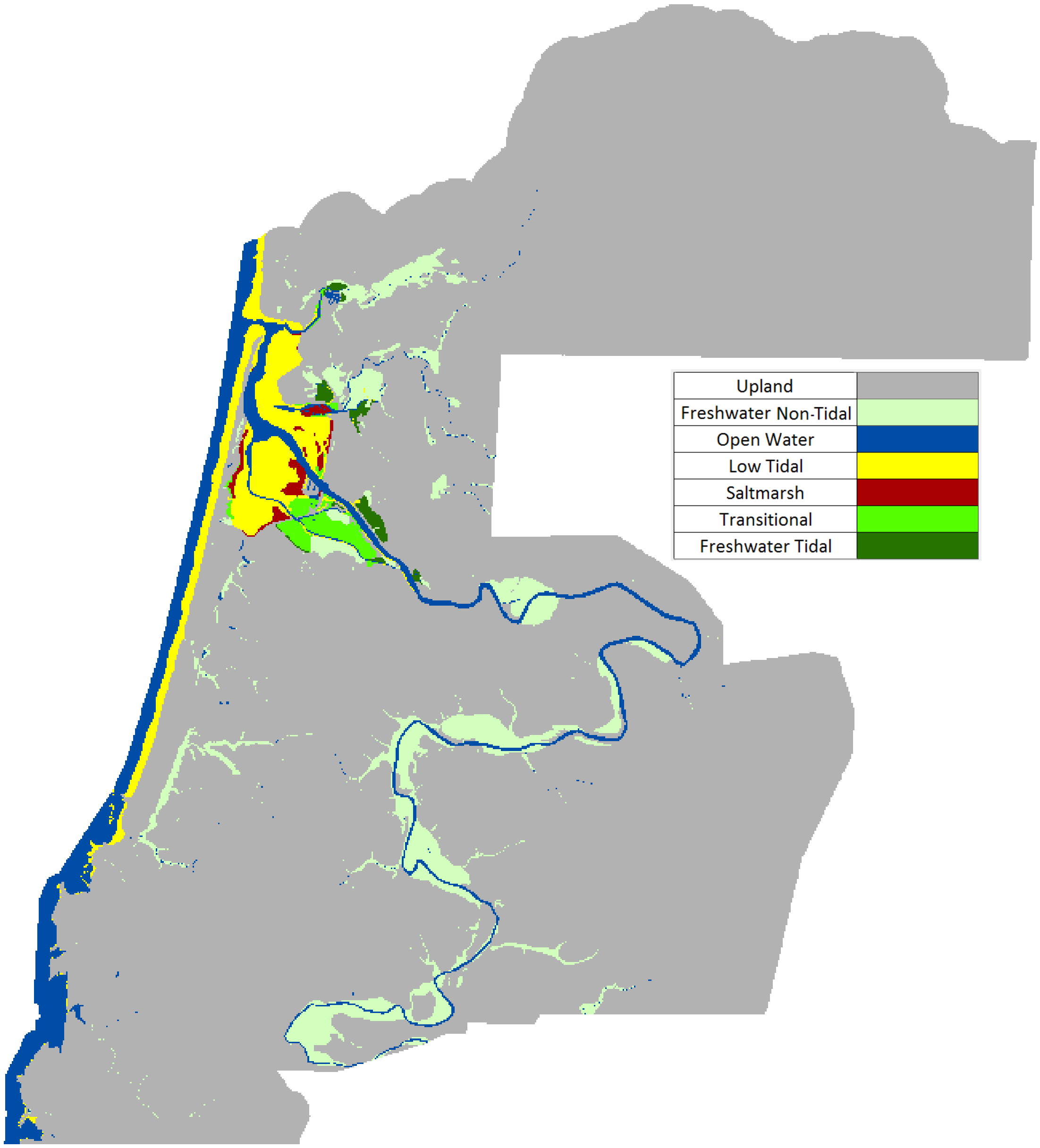

Figure 68. Initial Condition Wetland Data for 4 – Siletz

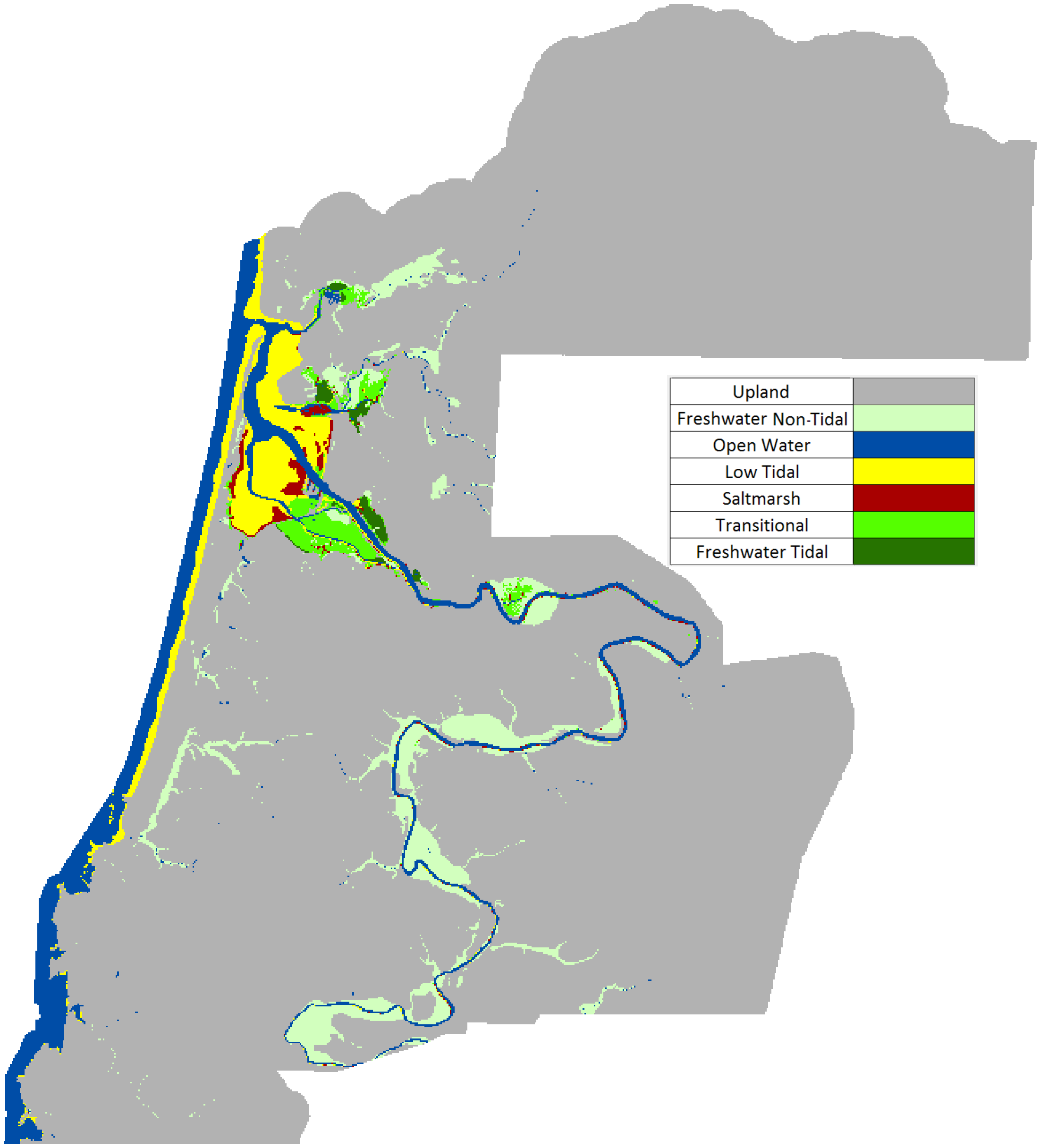

Figure 69. Site 4 – Siletz, 2100, Scenario A1B Mean – No Dikes

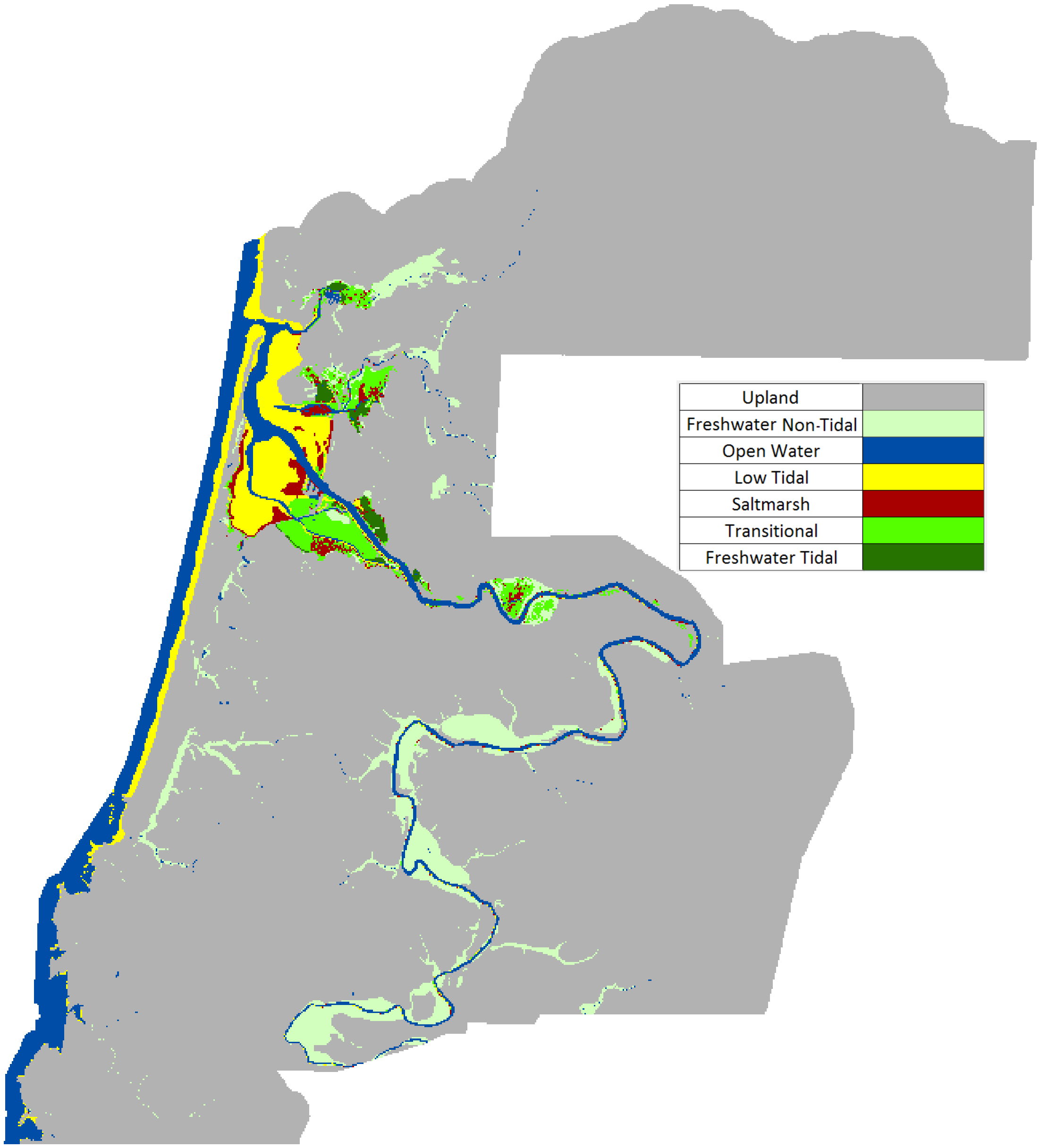

Figure 70. Site 4 – Siletz, 2100, Scenario A1B Max – No Dikes

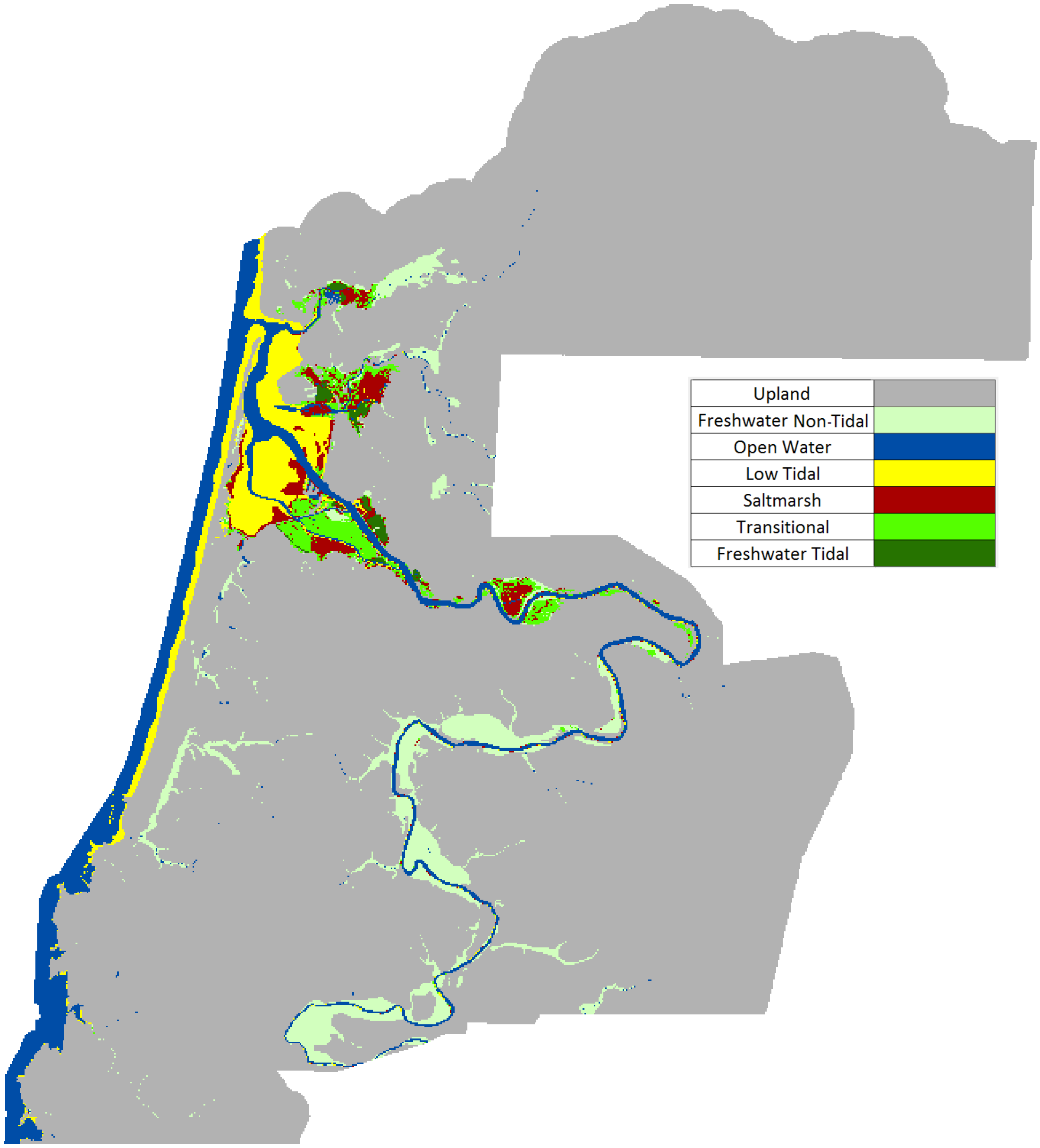

Figure 71. Site 4 – Siletz, 2100, Scenario 1 m – No Dikes

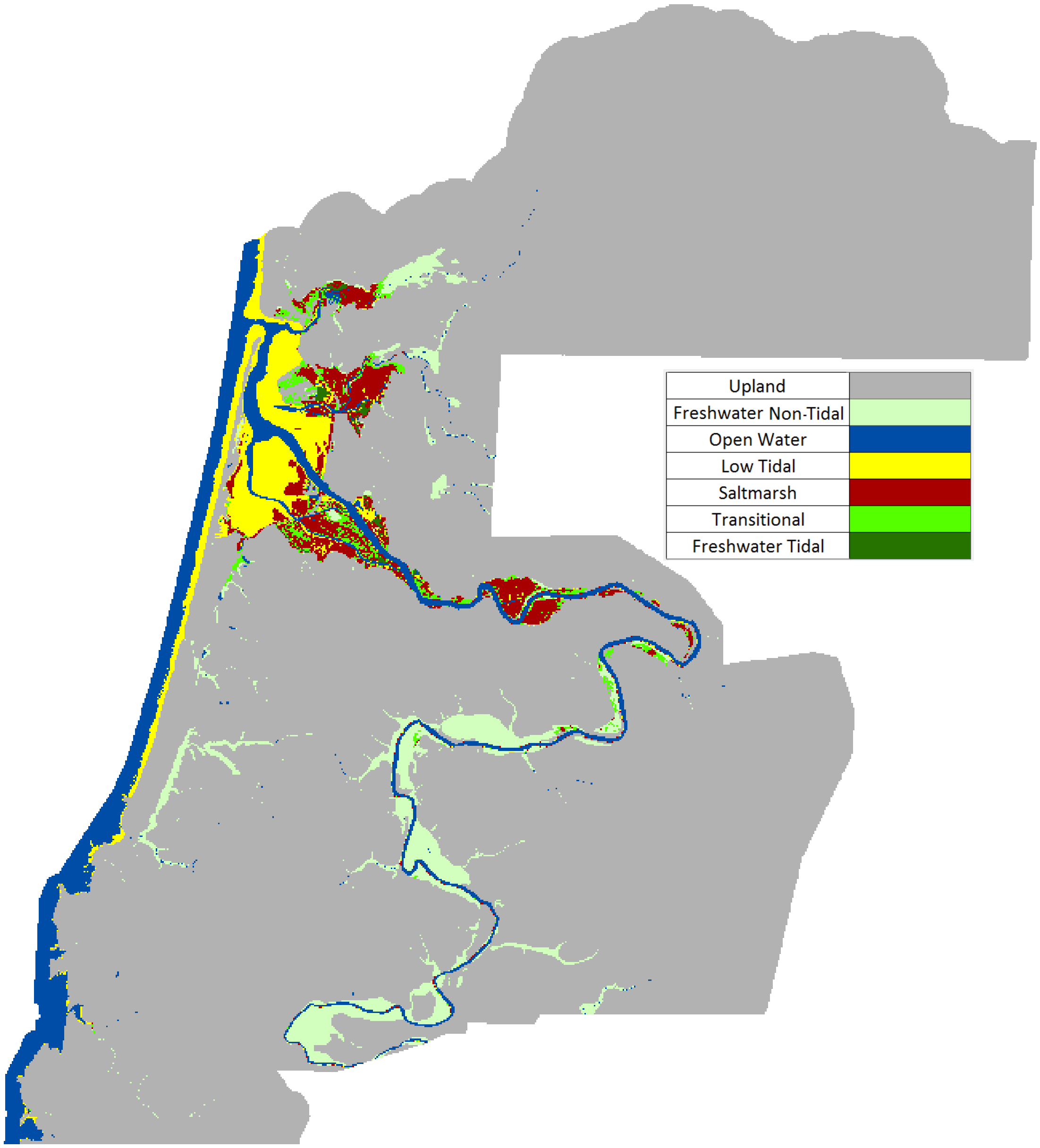

Figure 72. Site 4 – Siletz, 2100, Scenario 1.5 m – No Dikes

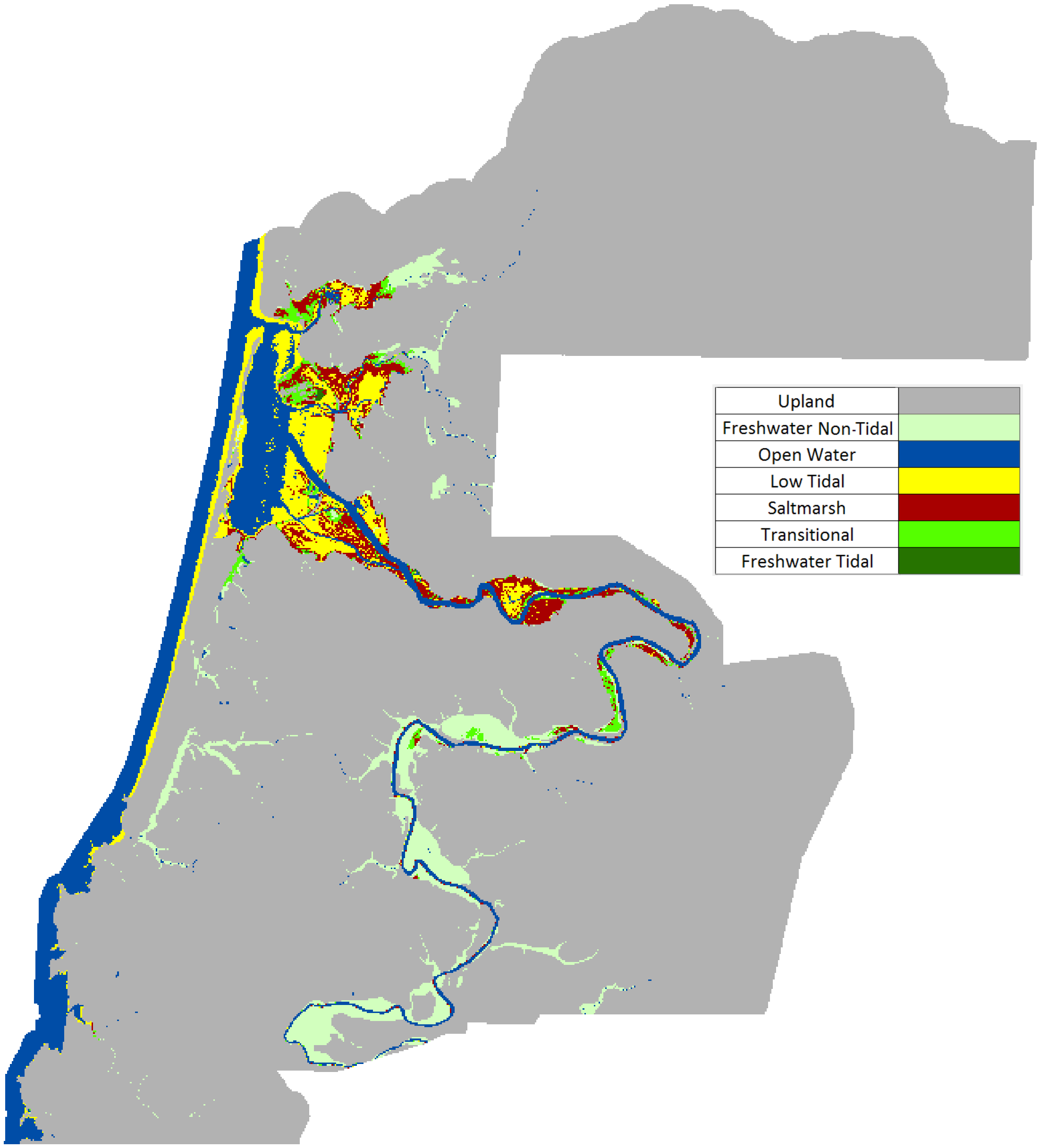

Figure 73. Site 4 – Siletz, 2100, Scenario 2 m – No Dikes

Yaquina

The wetlands in the Yaquina estuary are dominated by freshwater non-tidal and low tidal wetlands. This site was particularly challenging to model since the influence of tides is known to extend far upriver. However, little specific data on upstream tides were available to add to the model parameterization.

Table 30. Wetland coverage of Site 4 - Yaquina according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	85942	90
Open Water	4509	5
Freshwater Non-Tidal	1838	2
Low Tidal	2597	3
Transitional	314	< 1
Saltmarsh	269	< 1
Freshwater Tidal	74	< 1

Simulations indicated the Yaquina estuary is relatively resilient to the effects of SLR. As shown in Table 31, the largest losses of habitat occurred in the Low Tidal wetland category, in which 12% was projected to be lost under the 1 m of SLR by 2100 scenario and culminating in 48% loss under the 2 m by 2100 scenario. Saltmarsh habitats were predicted to gain the most acreage, increasing by 170% under the 1.5 m of SLR by 2100 scenario. For higher SLR rates, gains of this wetland type begin to decrease.

Table 31. Predicted Percent Change of Land Categories by 2100 at Site 4 – Yaquina Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	1	1	1	1
Open Water	-6	-10	-16	-35	-56
Low Tidal	3	6	12	31	48
Freshwater Non-Tidal	9	11	13	17	25
Transitional	-46	-52	-50	-27	-27
Saltmarsh	-78	-101	-131	-170	-148
Freshwater Tidal	-104	-90	-62	-1	40

The same set of SLR scenarios described above was run with the dikes removed to assess the potential effects of dike removal on wetland distribution. The results of this analysis (presented in Table 32) suggest dike removal would lead to greater losses in the freshwater tidal, freshwater non-tidal and low tidal wetland categories with greater gains in transitional and salt marsh.

Table 32. Predicted Percent Change of Land Categories by 2100 at Site 4 – Yaquina Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	**0.69 m**	**1 m**	**1.5 m**	**2 m**
Upland	1	1	1	2	2
Open Water	-6	-10	-16	-36	-61
Low Tidal	-5	-10	-12	5	32
Freshwater Non-Tidal	40	42	47	55	61
Transitional	-88	-96	-102	-85	-77
Saltmarsh	-331	-286	-244	-268	-241
Freshwater Tidal	16	22	32	59	79

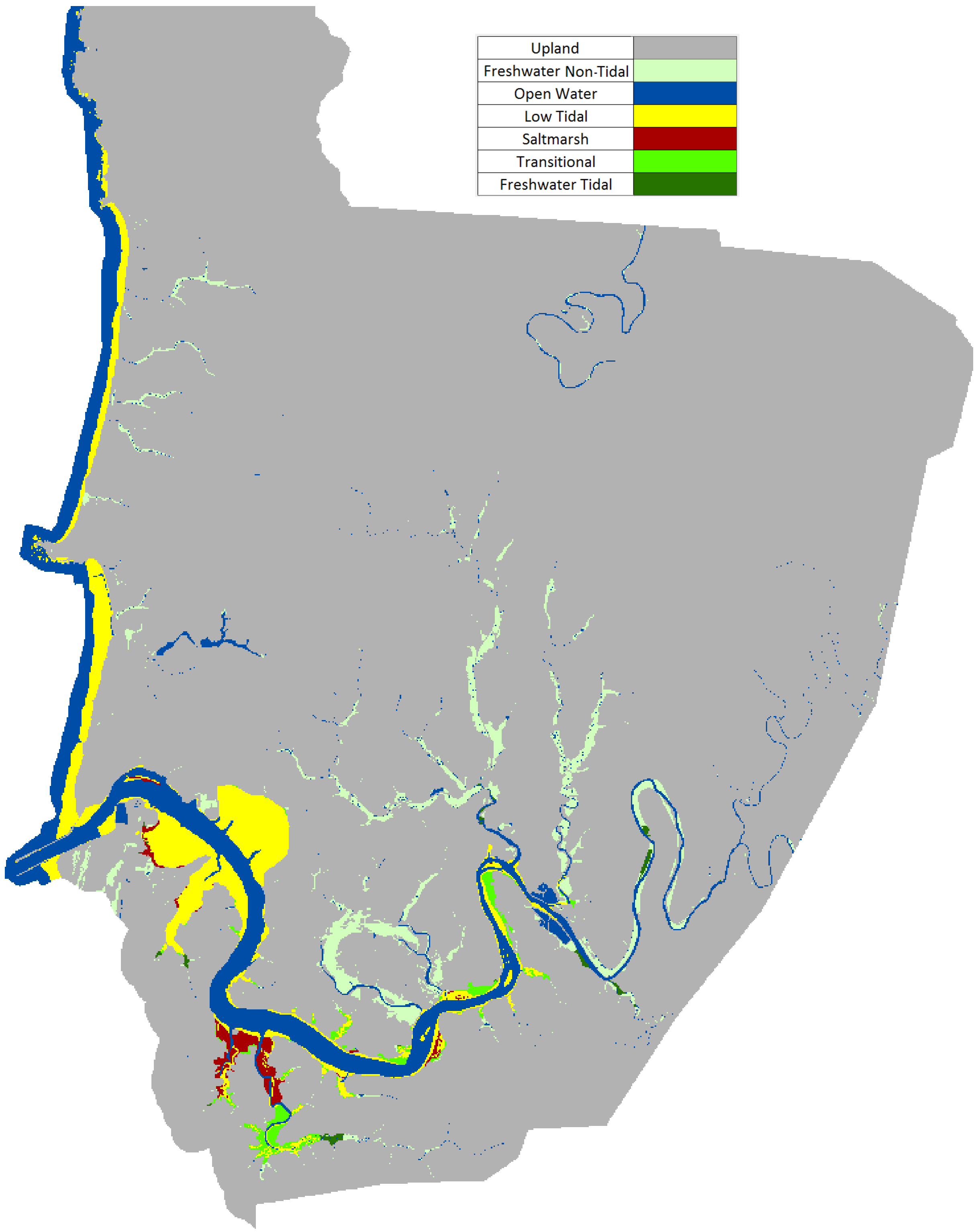

Figure 74. Site 4– Yaquina, 2100, Initial Condition

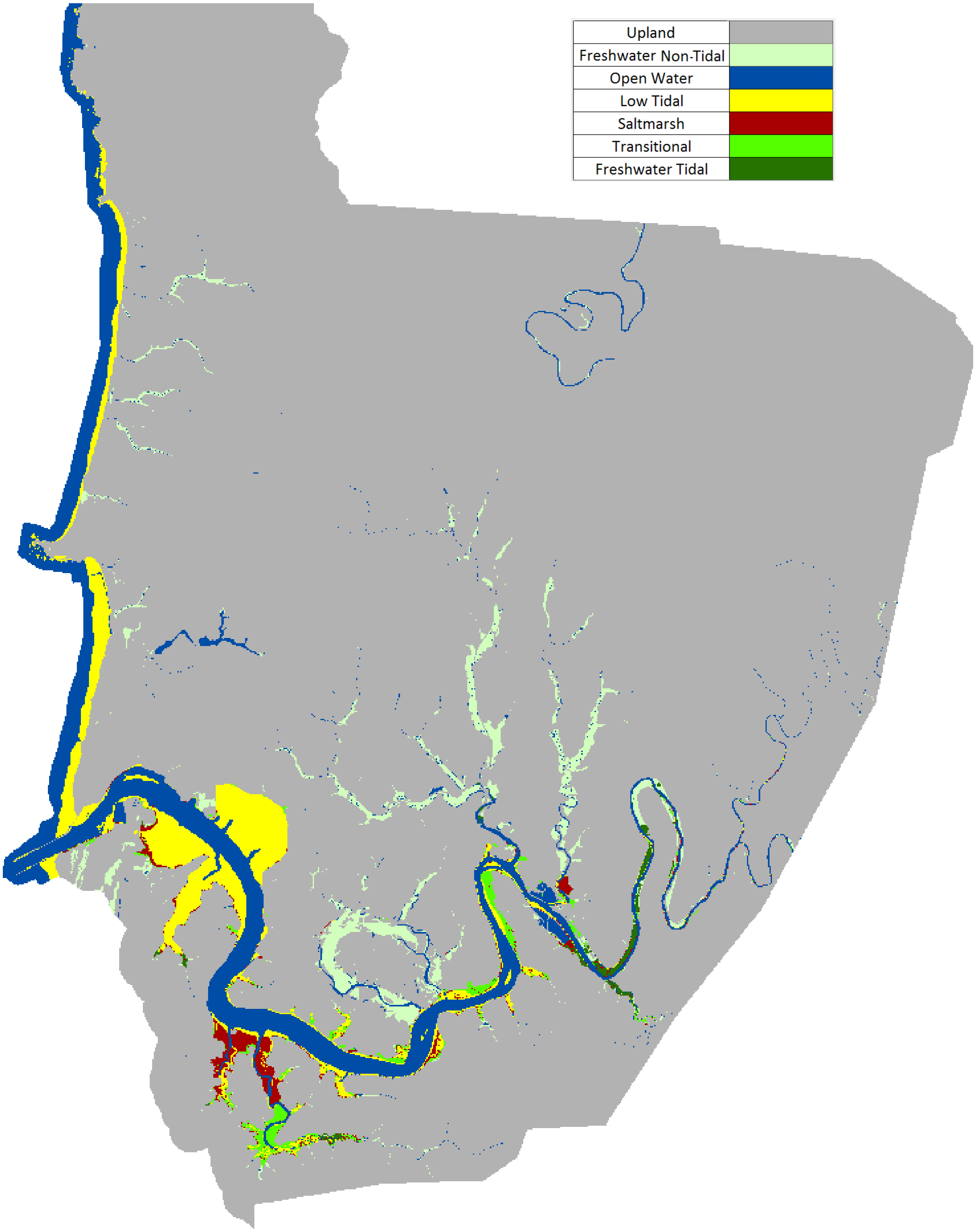

Figure 75. Site 4– Yaquina, 2100, Scenario A1B Mean

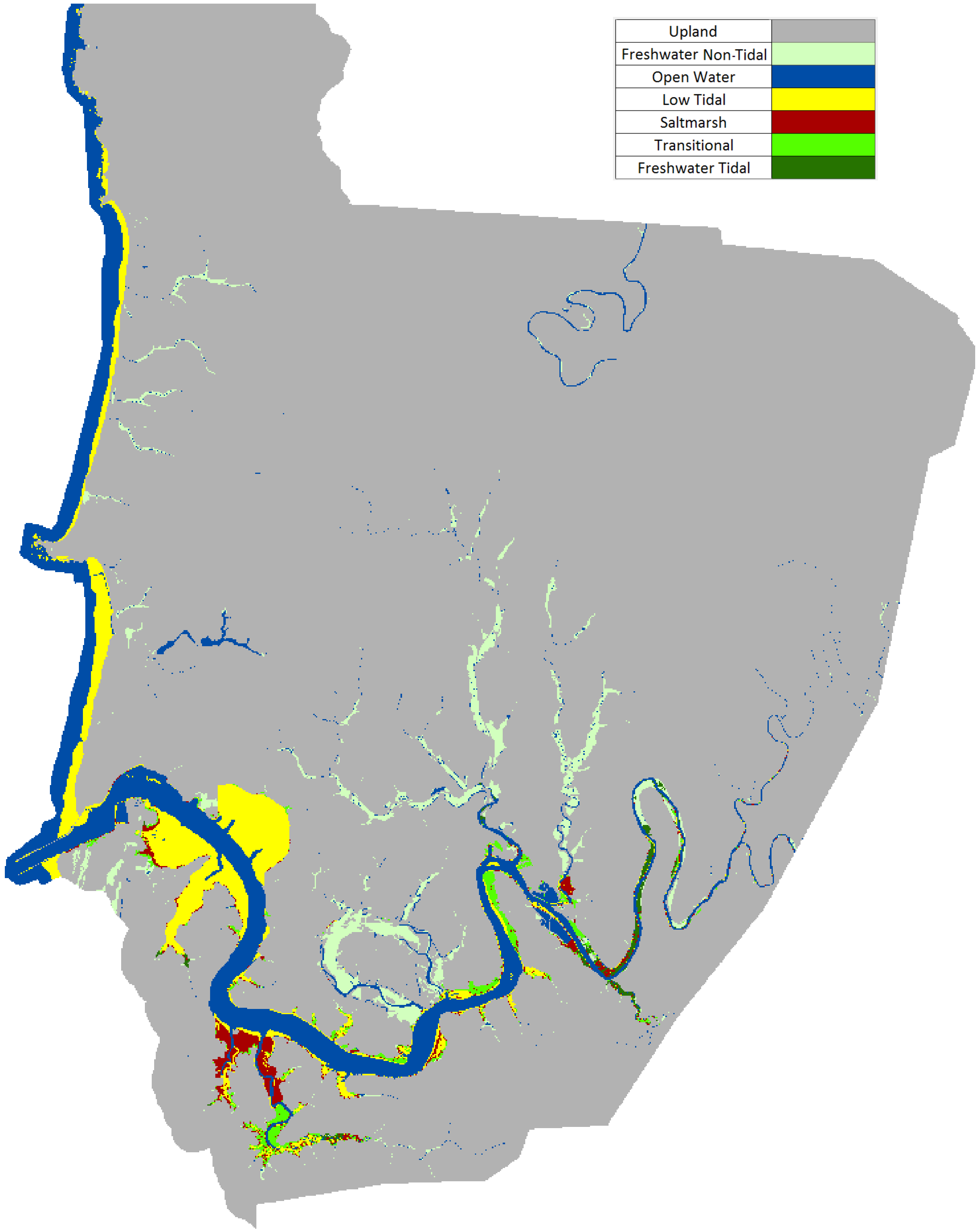

Figure 76. Site 4– Yaquina, 2100, Scenario A1B Max

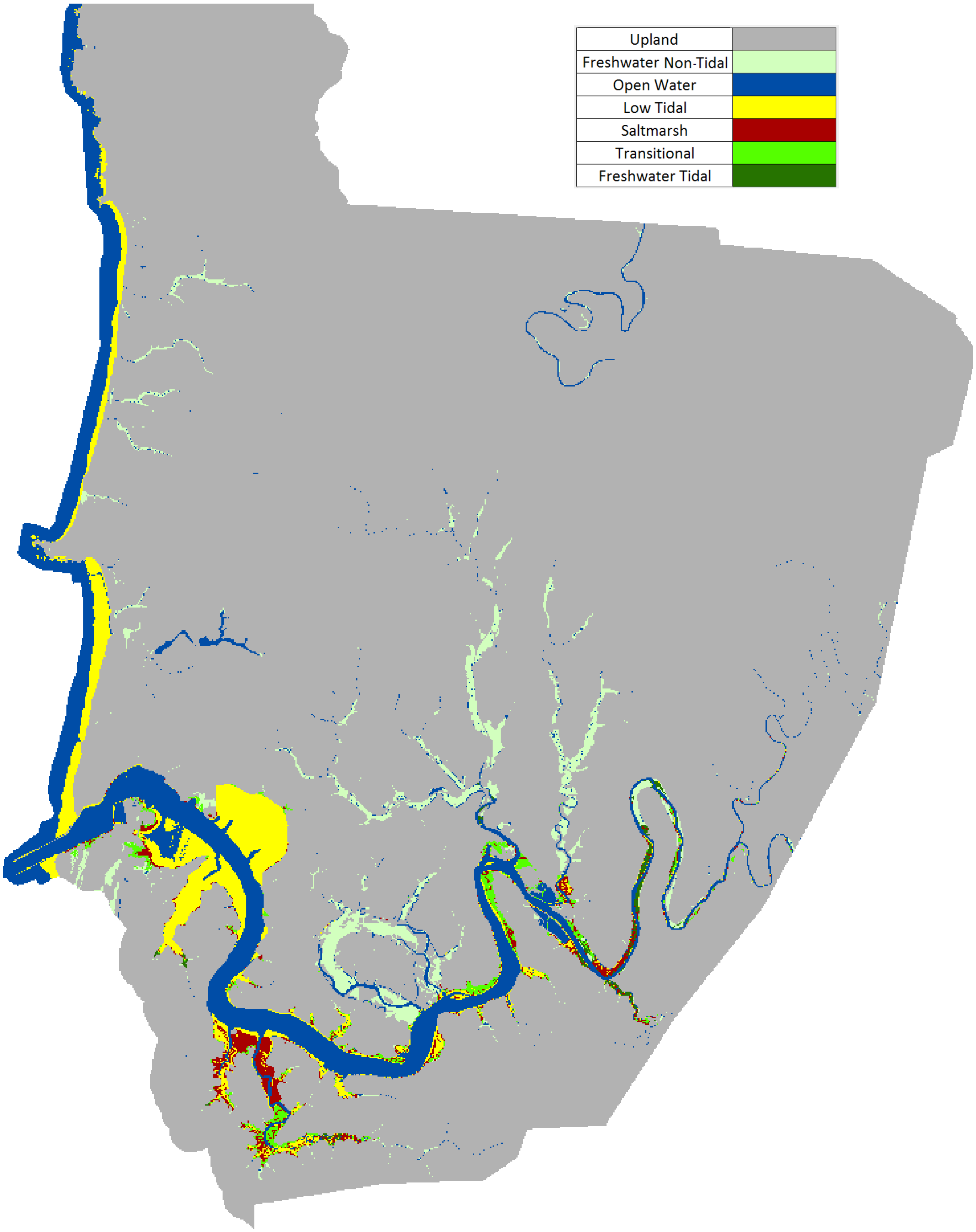

Figure 77. Site 4– Yaquina, 2100, Scenario 1 m

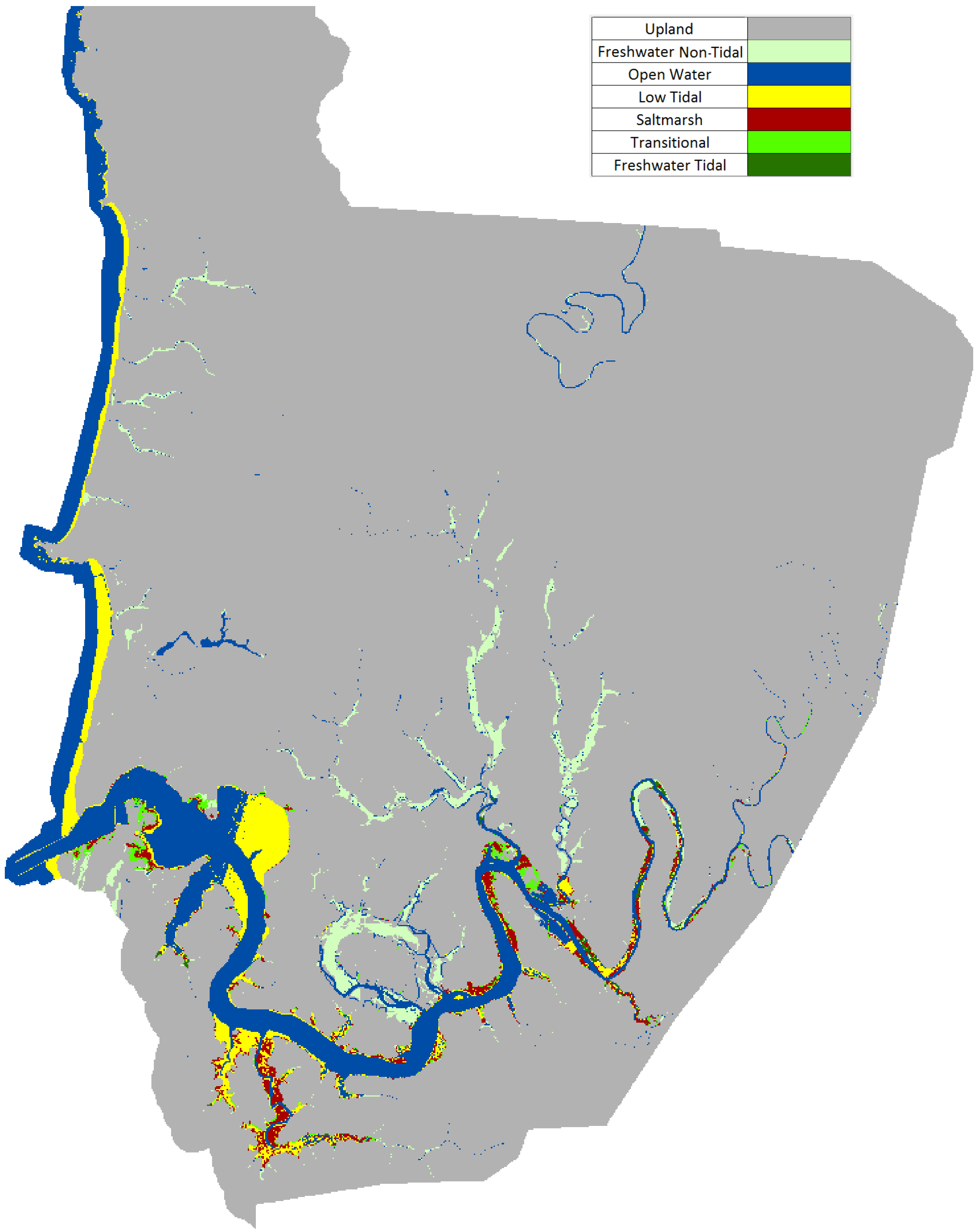

Figure 78. Site 4– Yaquina, 2100, Scenario 1.5 m

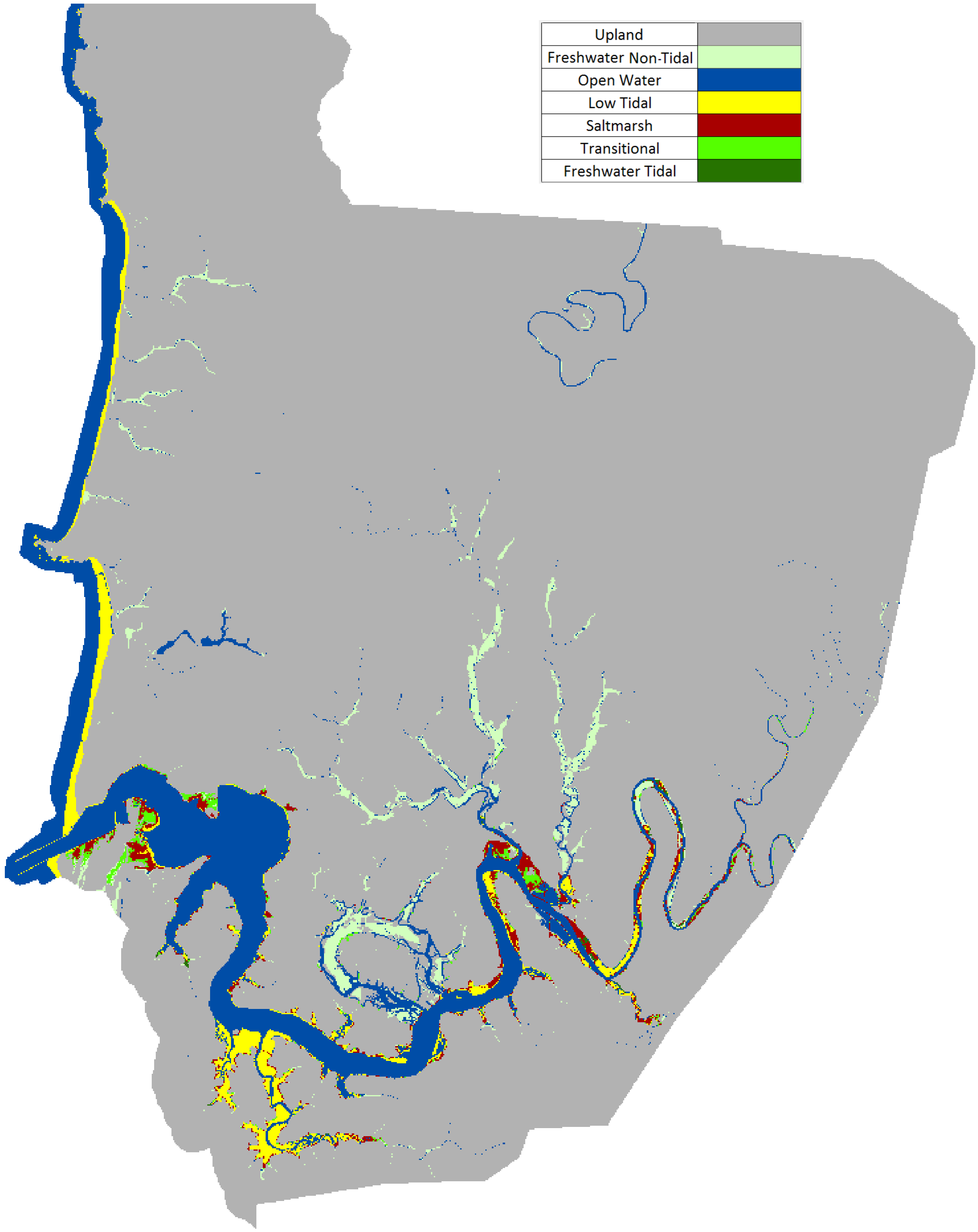

Figure 79. Site 4– Yaquina, 2100, Scenario 2 m

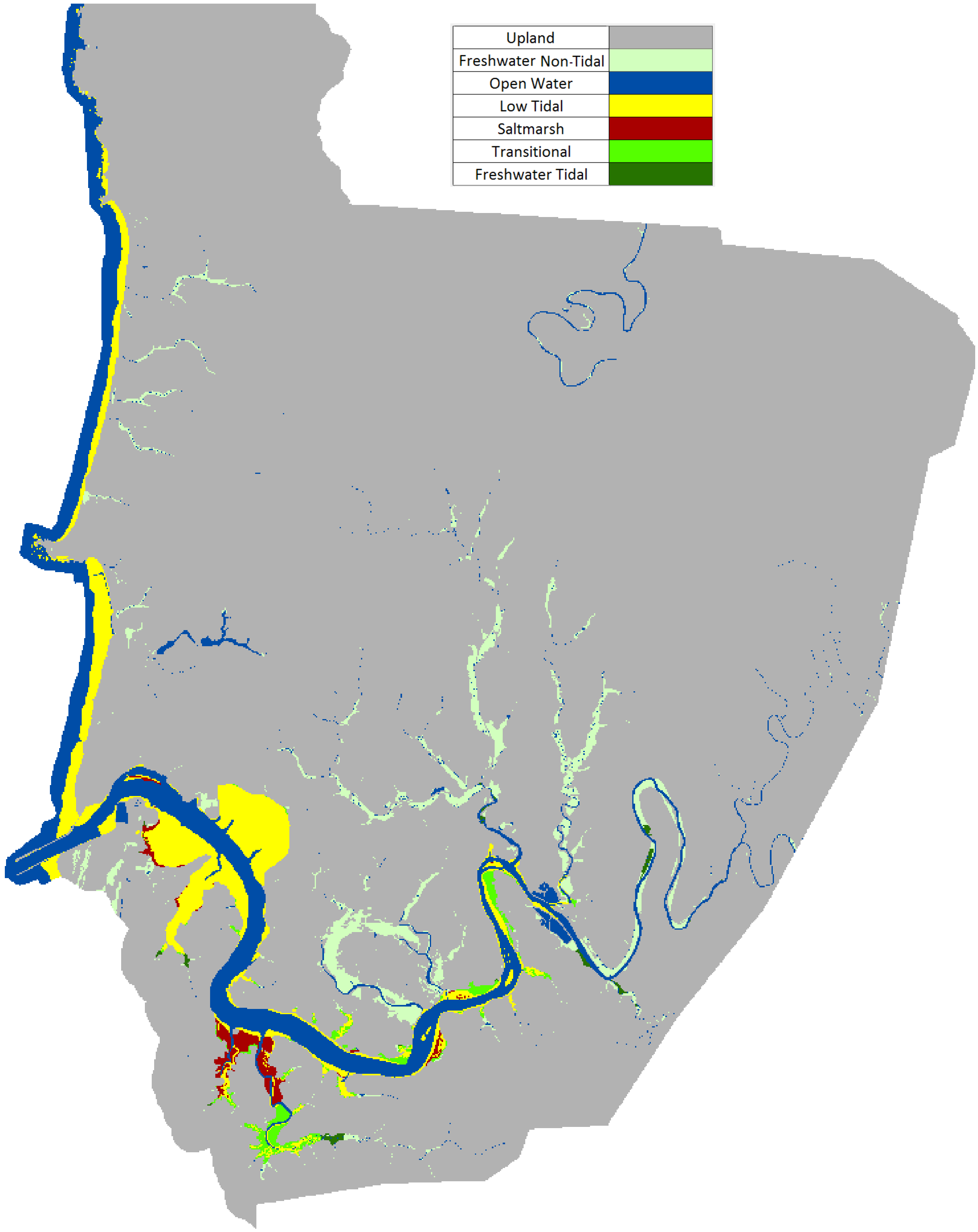

Figure 80. Initial Condition Wetland Data for 4 – Yaquina

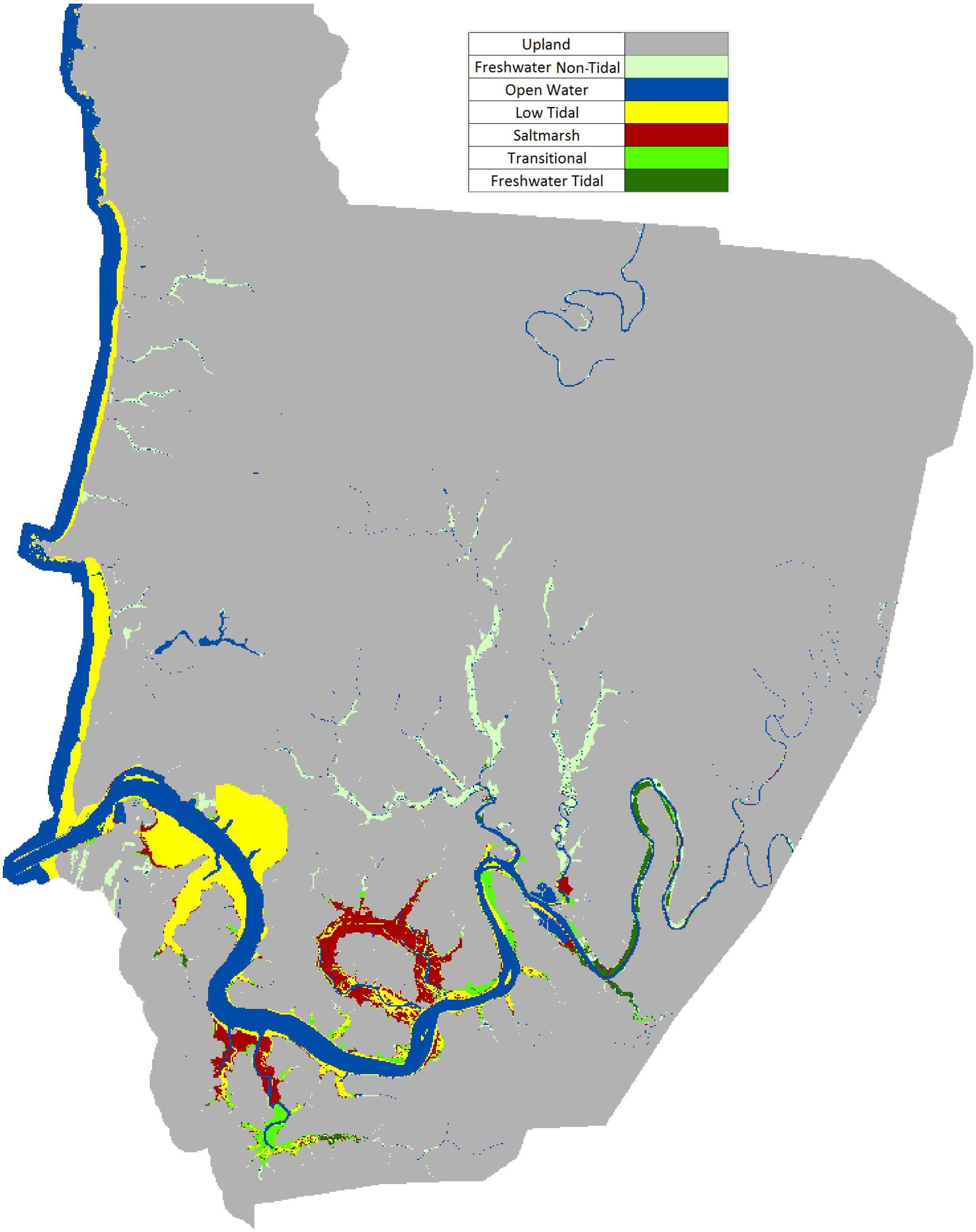

Figure 81. Site 4 – Yaquina, 2100, Scenario A1B Mean – No Dikes

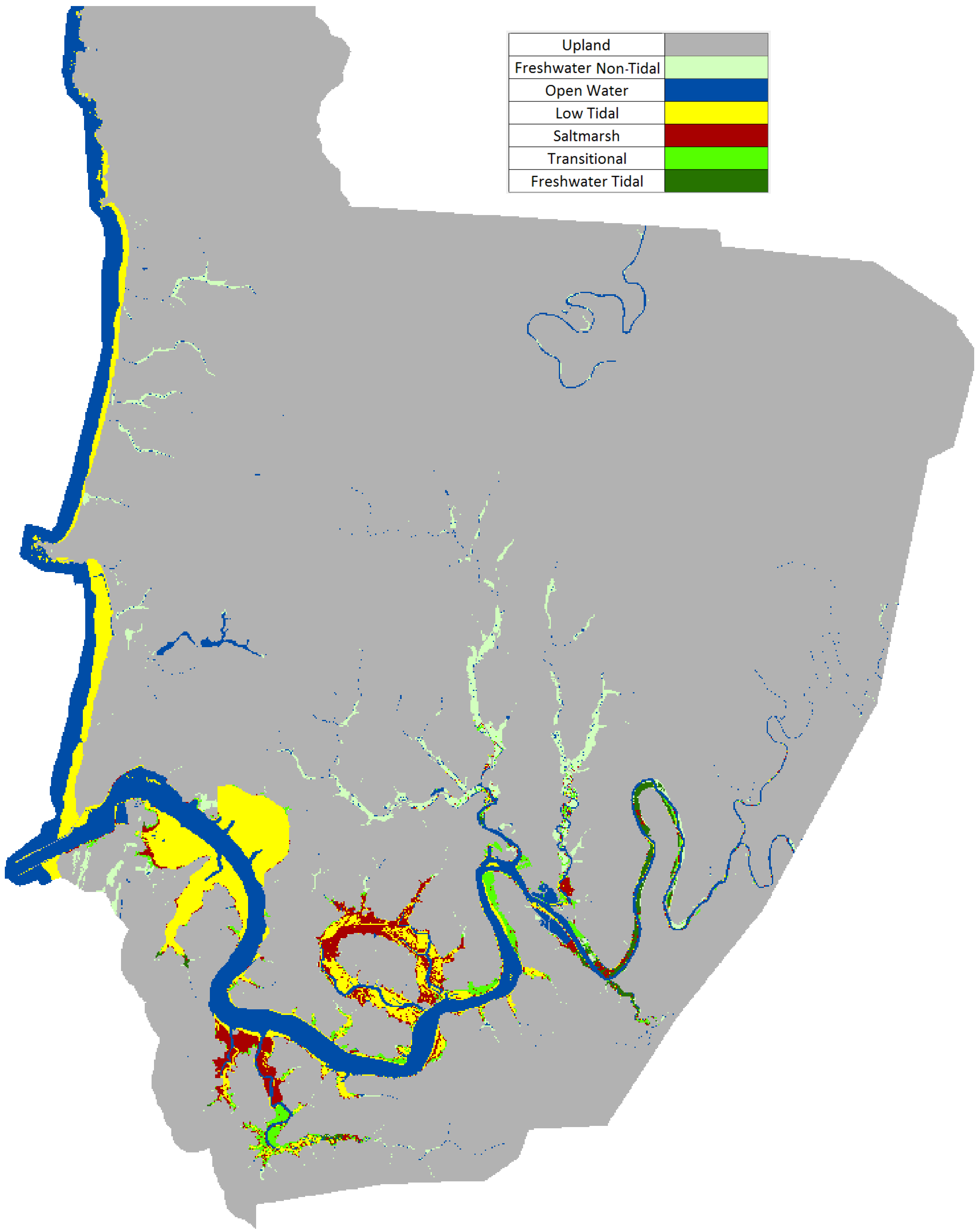

Figure 82. Site 4 – Yaquina, 2100, Scenario A1B Max – No Dikes

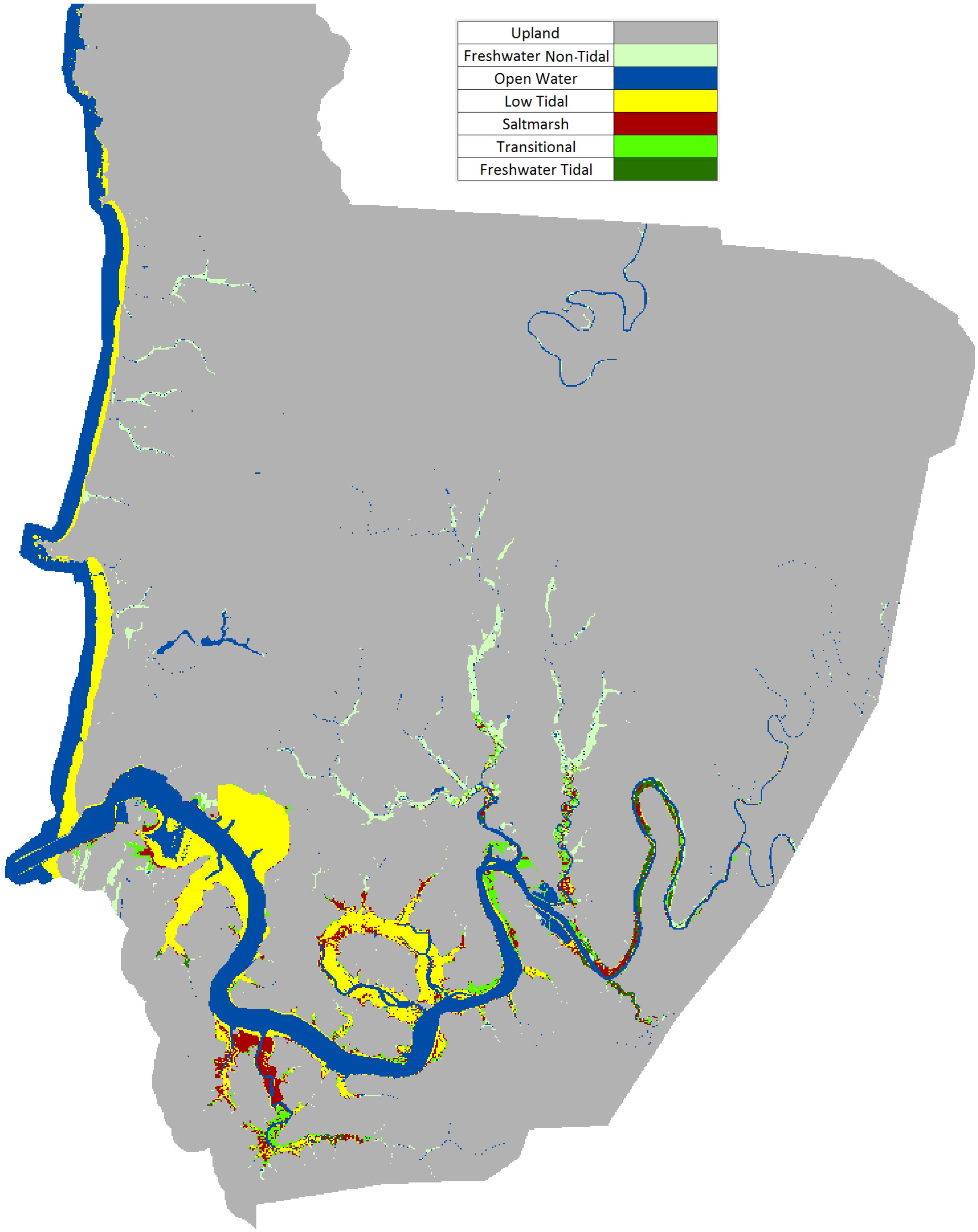

Figure 83. Site 4 – Yaquina, 2100, Scenario 1 m – No Dikes

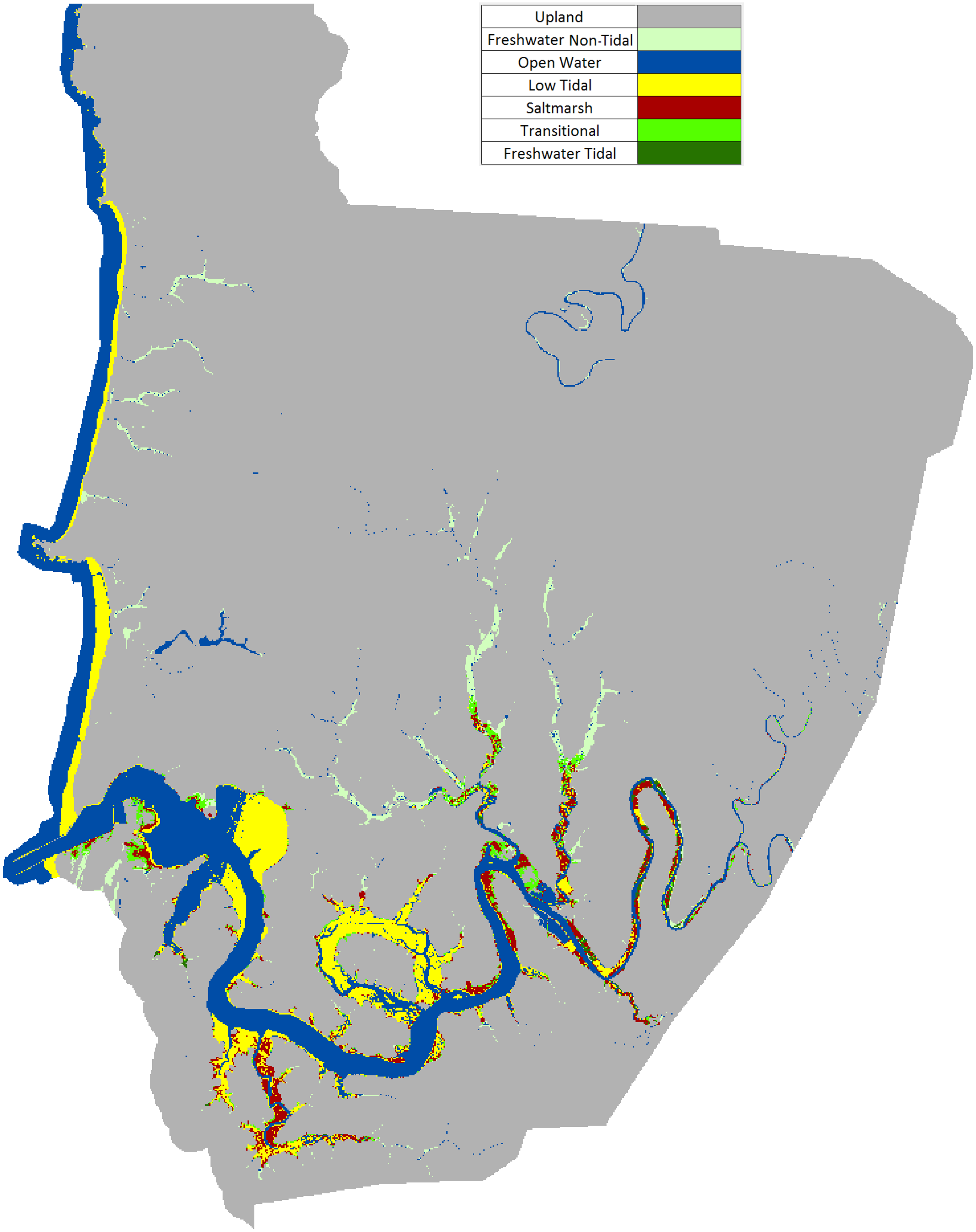

Figure 84. Site 4 – Yaquina, 2100, Scenario 1.5 m – No Dikes

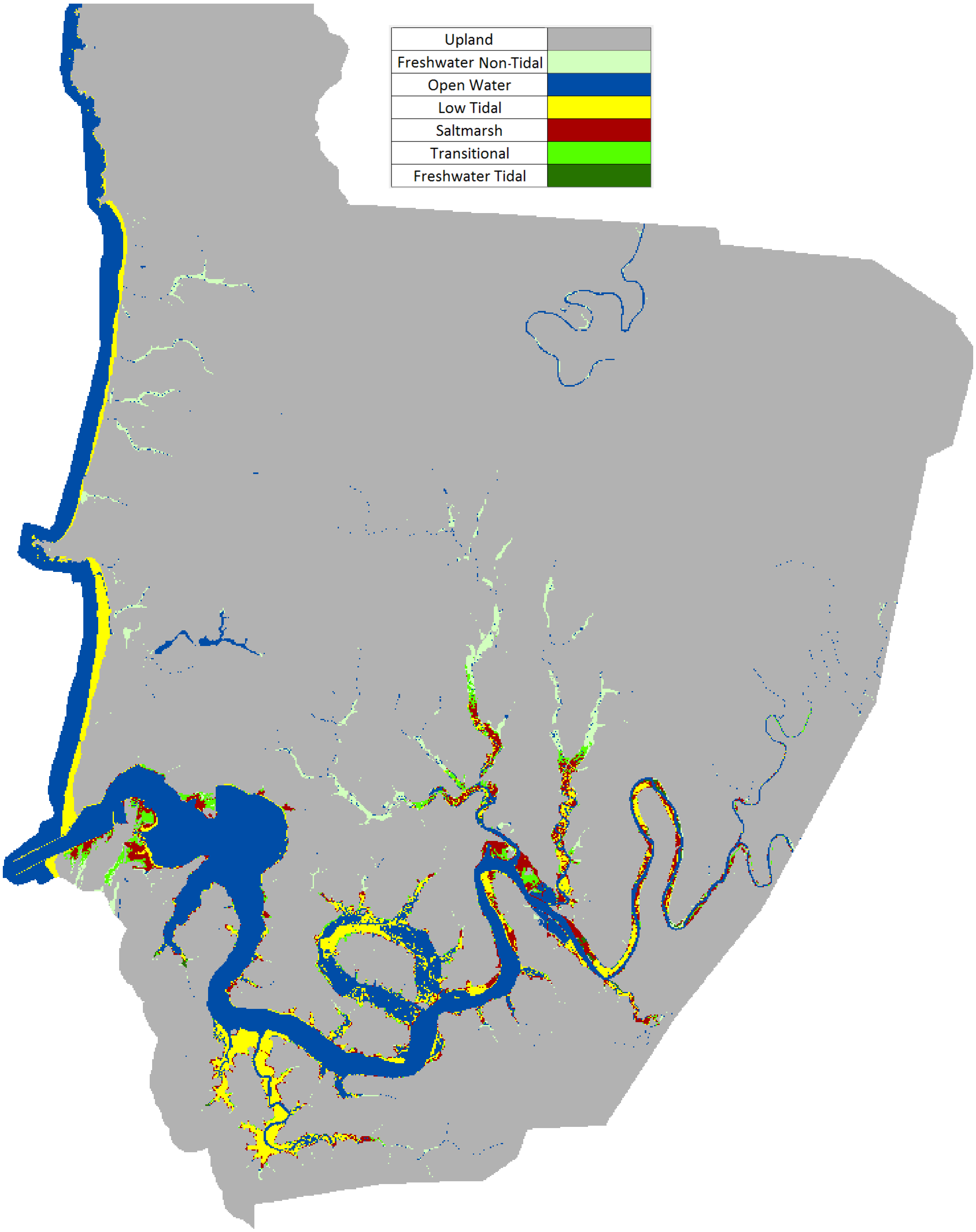

Figure 85. Site 4 – Yaquina, 2100, Scenario 2 m – No Dikes

Site 5: Alsea

Site 5 contained roughly 94,000 acres of the study area. The majority of this is upland (88%) followed by low tidal (4%) and freshwater non-tidal habitats (2%). Saltmarsh comprises less than 1% of the study area.

Table 33. Wetland coverage of Site 5 according to the 2002 Wetland data

Land cover type	**Area (acres)**	**Percentage (%)**
Upland	82758	88
Open Water	4688	5
Low Tidal	3768	4
Freshwater Non-Tidal	1902	2
Saltmarsh	352	< 1
Freshwater Tidal	262	< 1
Transitional	217	< 1
Total (incl. water)	**93947**	**100**

Several NOAA tide sites are located within this site therefore three input subsites were used to account for the tidal variability in the site. The coastal area was applied a GT value of 2.41 m, the area containing Alsea Bay was applied a value of 2.35 m, and a value of 1.97 m was applied to the upriver portion of Alsea River. Salt elevations applied were calculated from the inundation analysis results from the South Beach NOAA station, resulting in a specification of 1.7 m for the coastal and estuary subsites and 1.4 m for the inland subsite. The historic trend applied was 1.85 mm/yr. The elevation data and location of dikes in this project are depicted in Figure 86 and Figure 87, respectively.

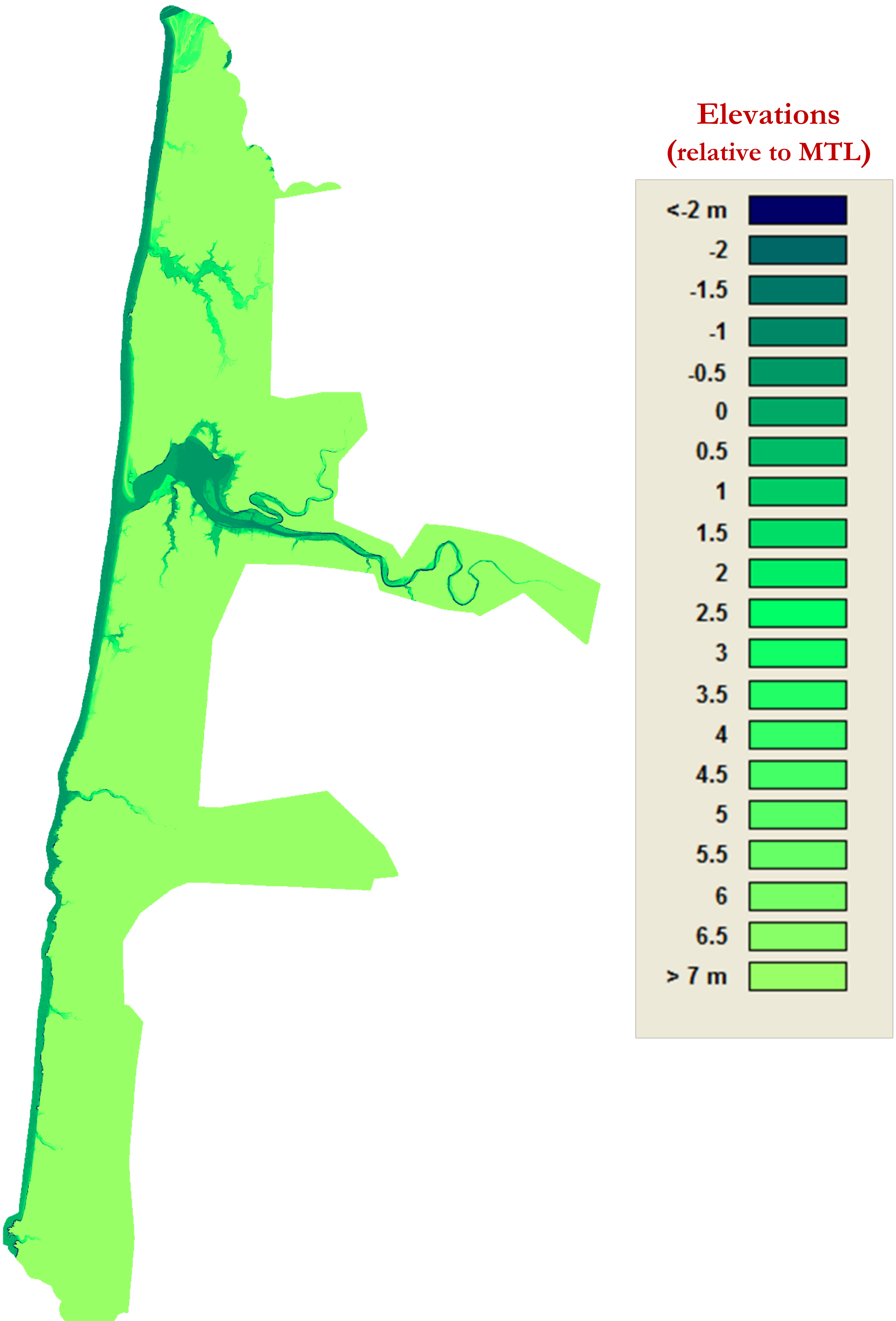

Figure 86. LiDAR elevation data for Site 5 – Alsea

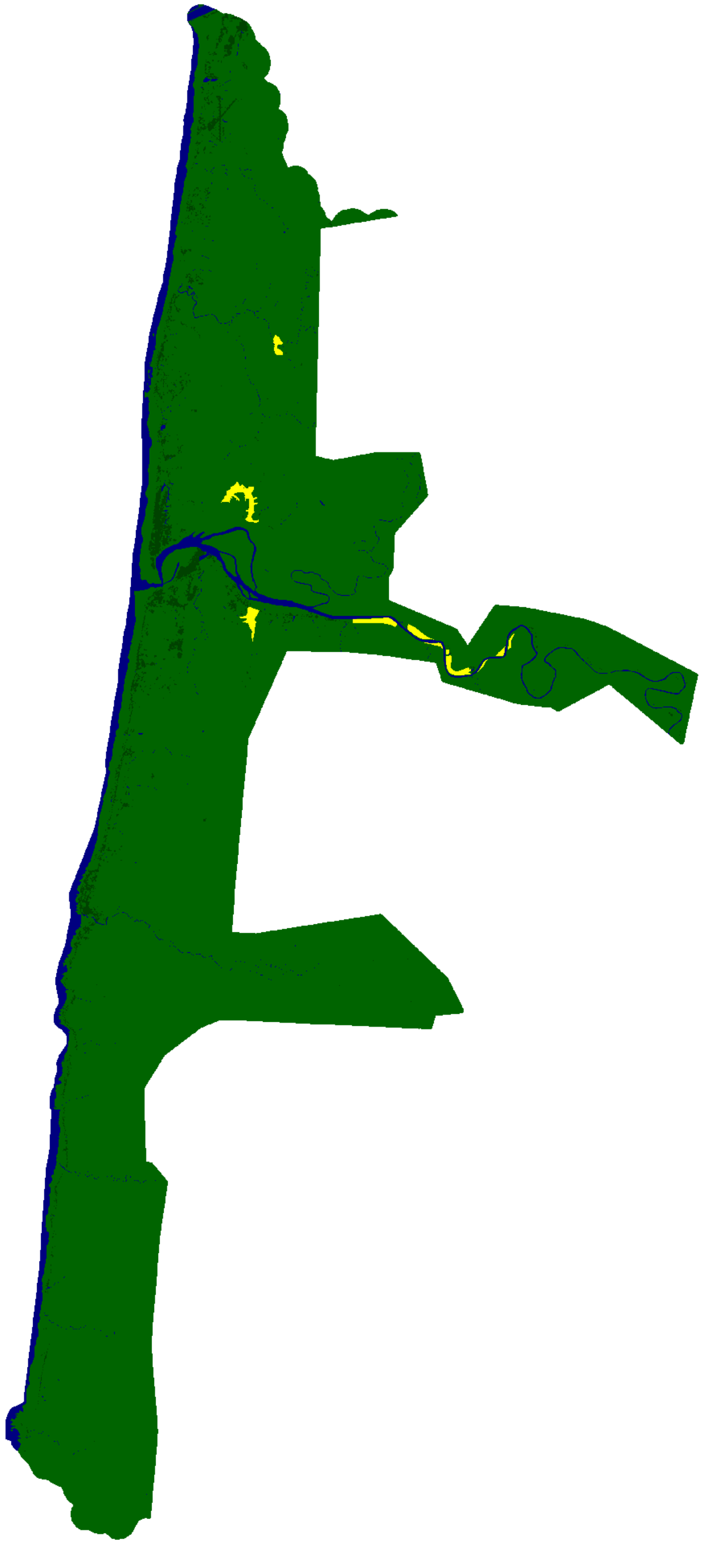

Figure 87. Location of dikes in for 5 – Alsea (shown in yellow)

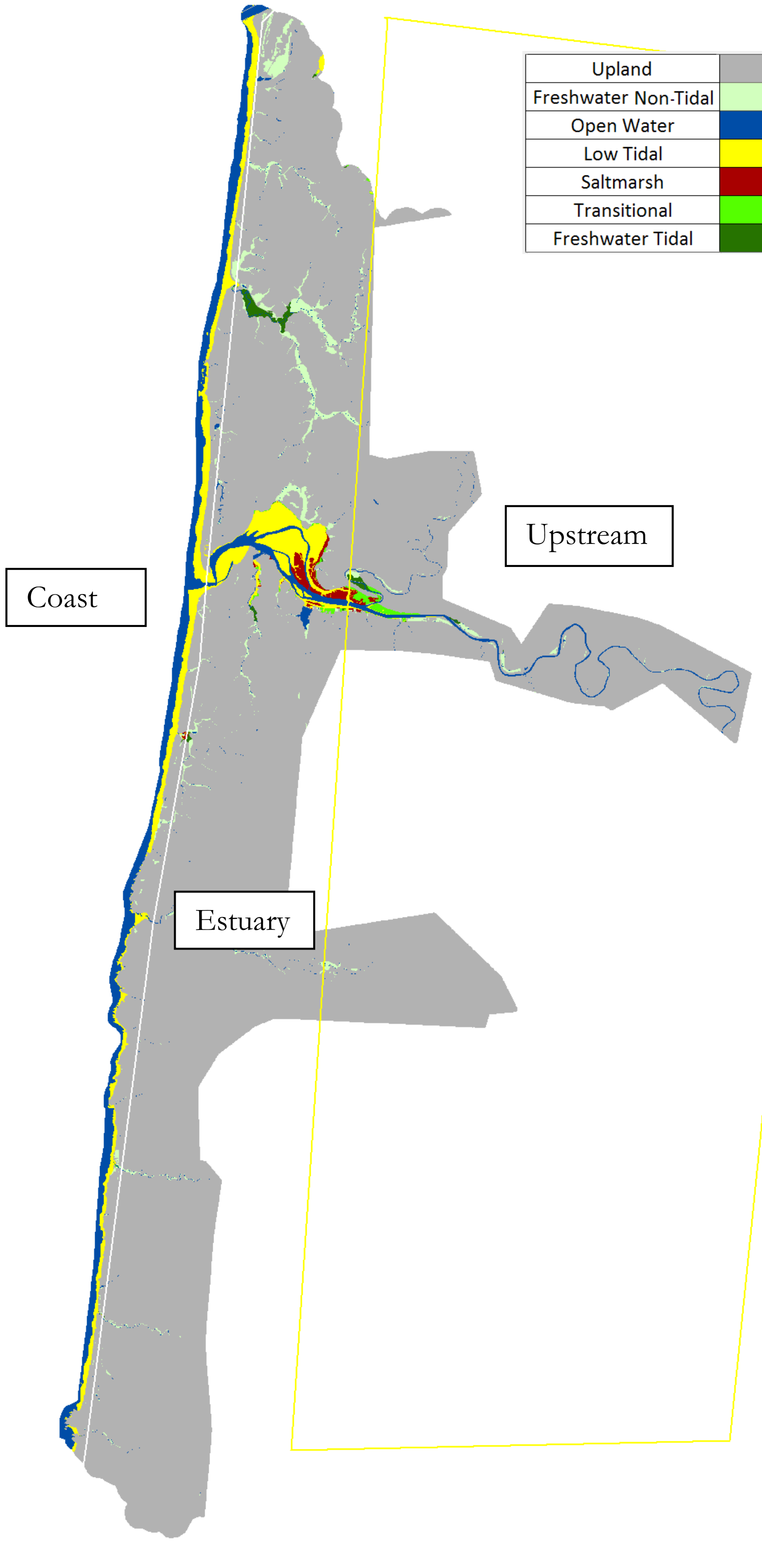

Figure 88. Wetland data for Site 5 – Alsea, with subsites

SLAMM simulations predict the low and freshwater tidal habitats to be the most susceptible to SLR, with losses in these categories countered by gains in saltmarsh, open water, and transitional habitat. Under the mid-range scenario of 1 m of SLR by 2100, 53% of the freshwater tidal habitat and 9% of the low tidal habitat is predicted to be lost.

Table 34. Predicted Percent Change of Land Categories by 2100 at Site 5 – Alsea Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	1	1	1	1
Open Water	-7	-9	-15	-44	-65
Low Tidal	3	4	9	41	53
Freshwater Non-Tidal	4	7	12	20	25
Saltmarsh	-29	-35	-56	-150	-145
Freshwater Tidal	9	19	53	84	94
Transitional	-62	-115	-186	-156	-81

As the dikes areas in site 5 predominantly occurred upriver and in small sloughs, simulations run to forecast the effects of SLR if dikes were removed resulted in small differences from those run with dikes included. SLAMM predicts dike removal would result in increased losses in freshwater non-tidal habitat, with smaller gains observed in saltmarsh and transitional habitat as compared to simulations where dikes were included.

Table 35. Predicted Percent Change of Land Categories by 2100 at Site 5 – Alsea Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	1	1	1	1
Open Water	-7	-9	-15	-44	-65
Low Tidal	3	3	9	39	48
Freshwater Non-Tidal	12	17	23	31	37
Saltmarsh	-61	-80	-114	-201	-180
Freshwater Tidal	9	19	53	84	94
Transitional	-116	-160	-218	-179	-109

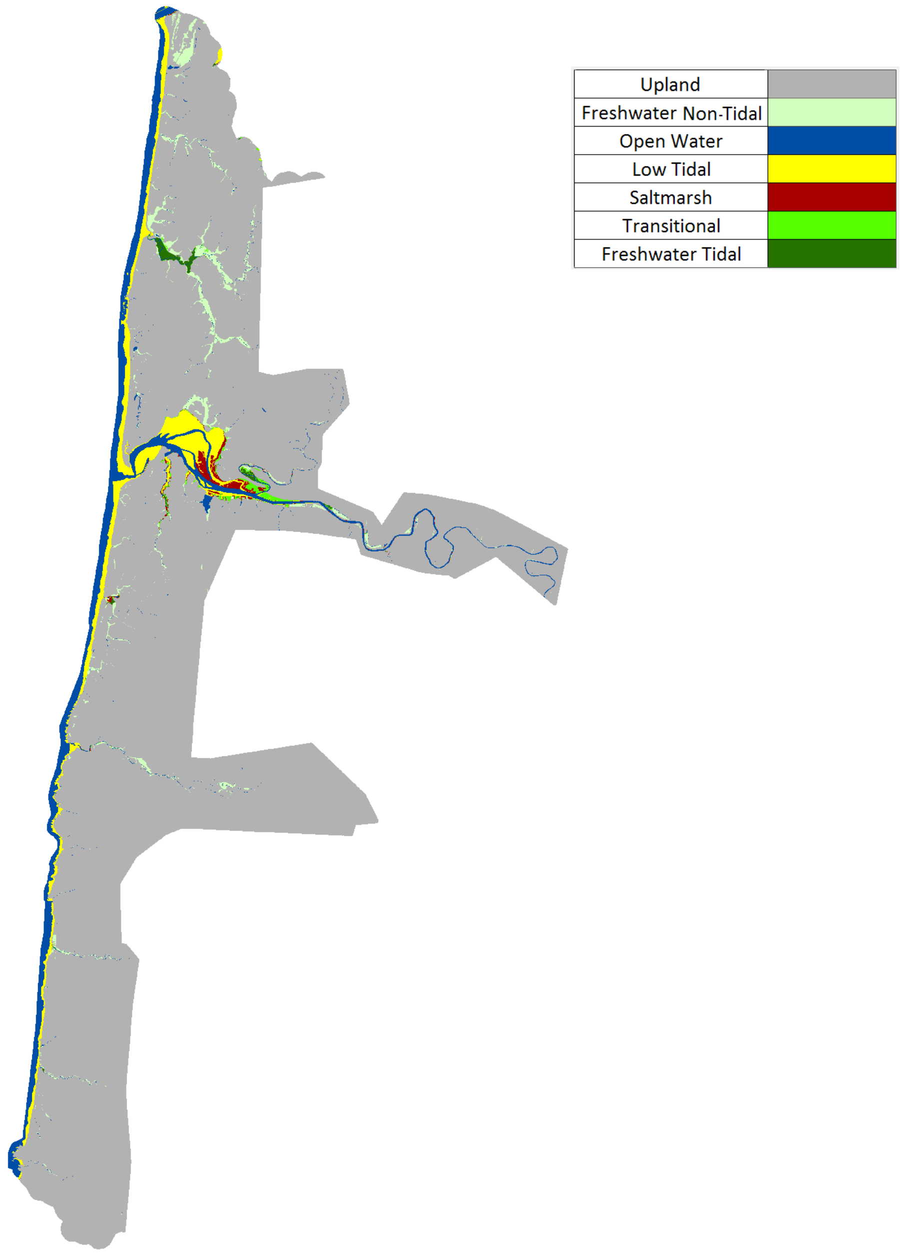

Figure 89. Site 5, 2100, Scenario A1B mean (0.39 m)

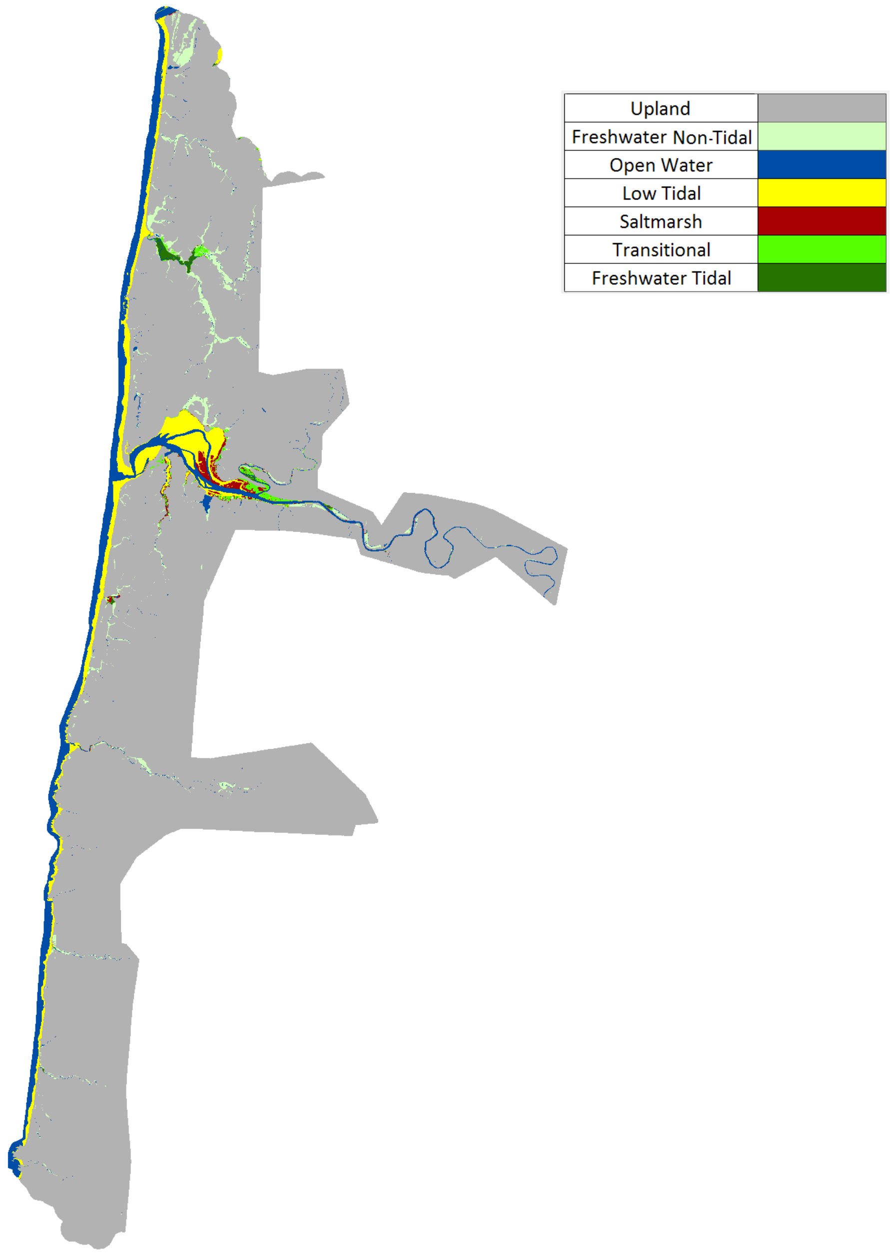

Figure 90. Site 5, 2100, Scenario A1B max (0.69 m)

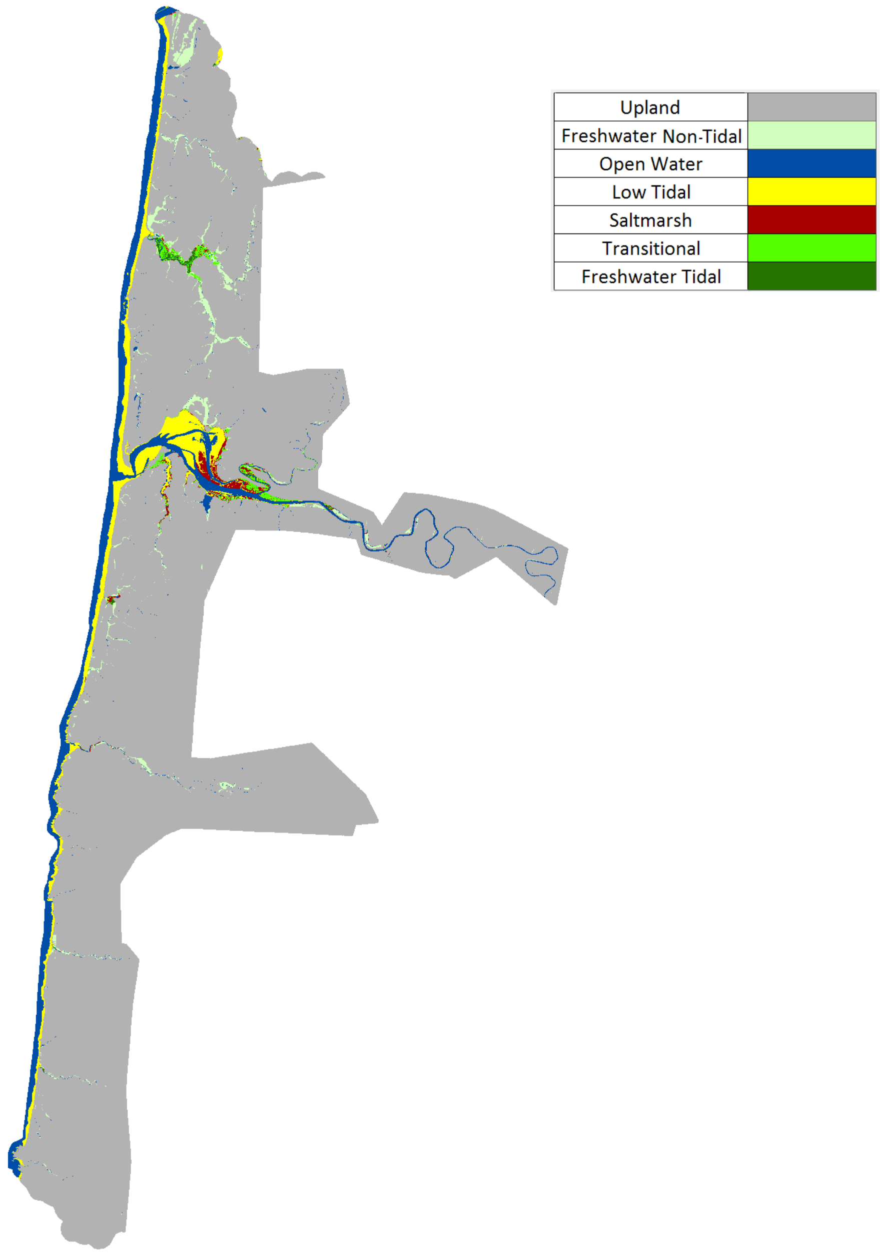

Figure 91. Site 5, 2100, Scenario 1 m

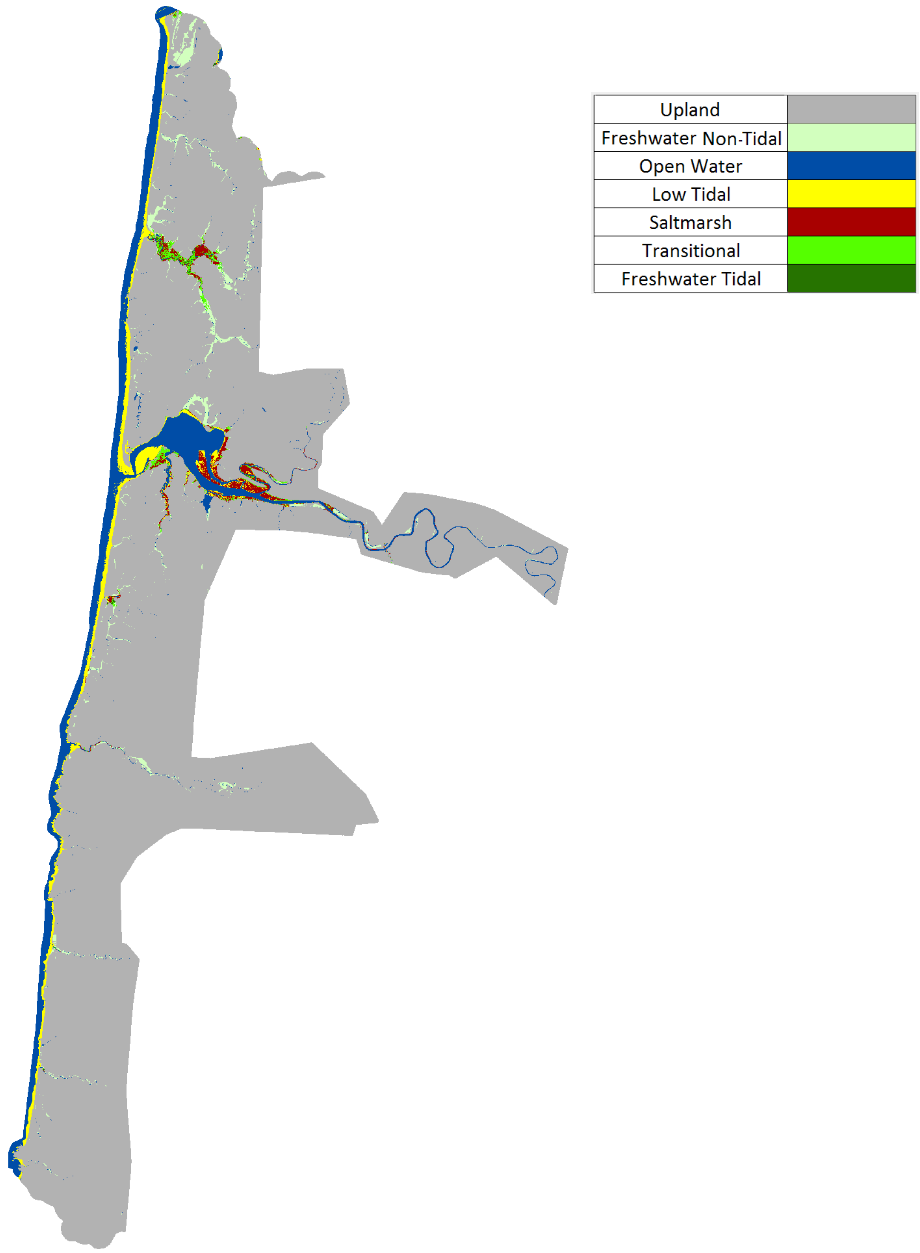

Figure 92. Site 5, 2100, Scenario 1.5 m

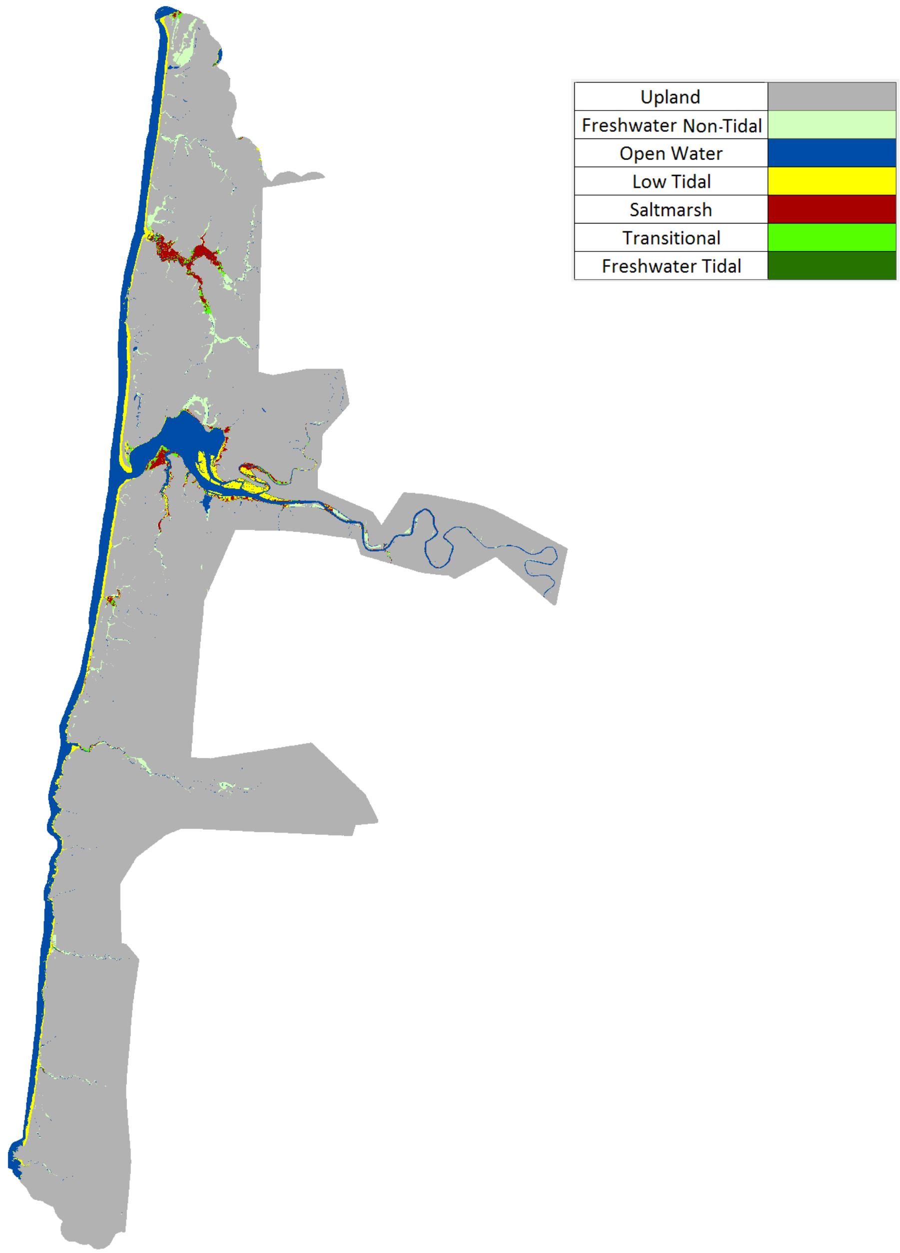

Figure 93. Site 5, 2100, Scenario 2 m

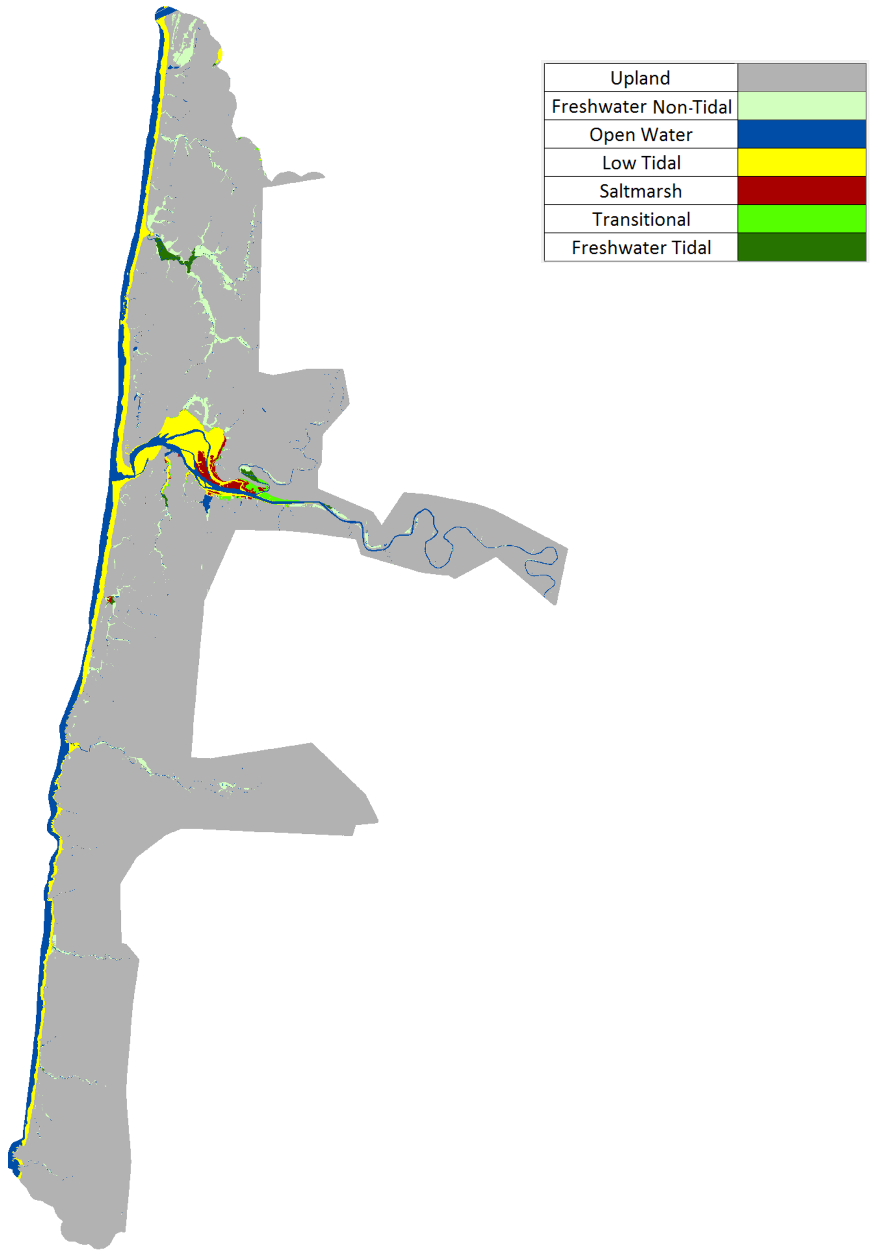

Figure 94. Initial condition wetland data for Site 5 – Alsea

Figure 95. Site 5, 2100, Scenario A1B mean (0.39 m) – No Dikes

Figure 96. Site 5, 2100, Scenario A1B max (0.69 m) – No Dikes

Figure 97. Site 5, 2100, Scenario 1 m – No Dikes

Figure 98. Site 5, 2100, Scenario 1.5 m – No Dikes

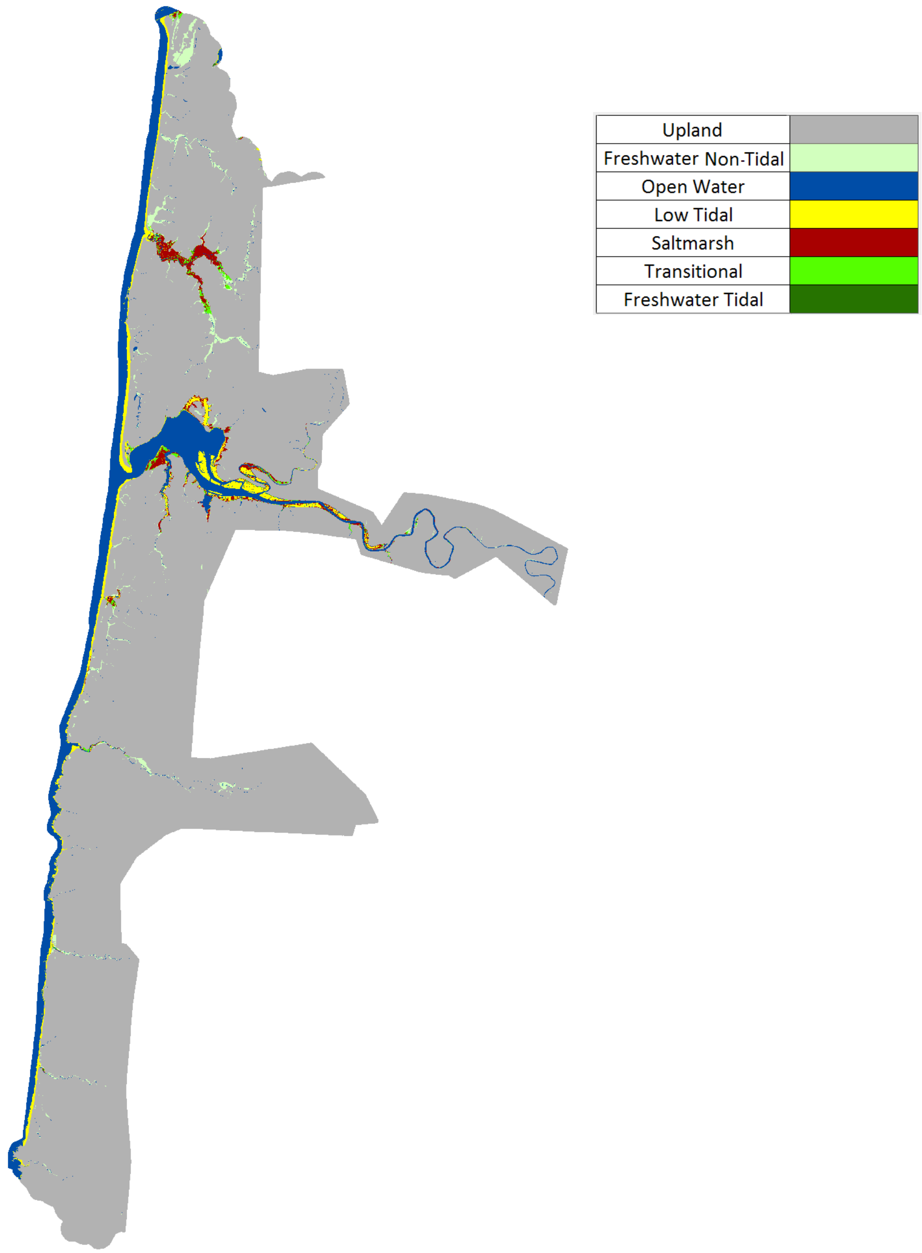

Figure 99. Site 5, 2100, Scenario 2 m – No Dikes

Site 6: Siuslaw

Site 6 contains128,934 acres, equivalent to 6%, of the total study area. The marshes in site 6 are predominantly freshwater non-tidal, with much smaller amounts of freshwater tidal, salt, and transitional marshes, as shown in Table 36.

Table 36. Wetland coverage of Site 6 according to the 2002 wetland data

Land cover type	**Area (acres)**	**Percentage (%)**
Upland	103352	80
Open Water	13116	10
Freshwater Non-Tidal	8418	7
Low Tidal	2556	2
Freshwater Tidal	645	1
Saltmarsh	458	< 1
Transitional	389	< 1
Total (incl. water)	**128934**	**100**

One change was made to the wetland coverage layer. A wetland polygon designated as inland fresh marsh was converted to tidal fresh marsh after confirming with Kevin Petrik that the levee that previously protected this area from tidal influence was breached. The changed polygon is indicated by an arrow in Figure 102.

Two NOAA tide stations are located in this site, one near the mouth of the Siuslaw Bay (GT = 2.23 m) and another upstream at Florence, OR (GT = 2.01 m). Based on these tide measurements, two input subsites were applied to the study area (coast and upriver, as shown in Figure 102. The historic trend applied to this site was 1.26 mm/yr. Observations from the Garibaldi station were used to derive the salt elevation for this site, resulting in the application of 1.62 m for the coastal subsite and 1.48 m for the upstream portion of the study area. Within the SLAMM conceptual model, the lower boundary was changed for the tidal fresh marsh and tidal swamp wetland categories in order to more closely conform to the site-specific data noted for site 6. Tidal fresh marsh was allowed to extend down to -0.16 HTU and tidal swamp to 0.215 HTU.

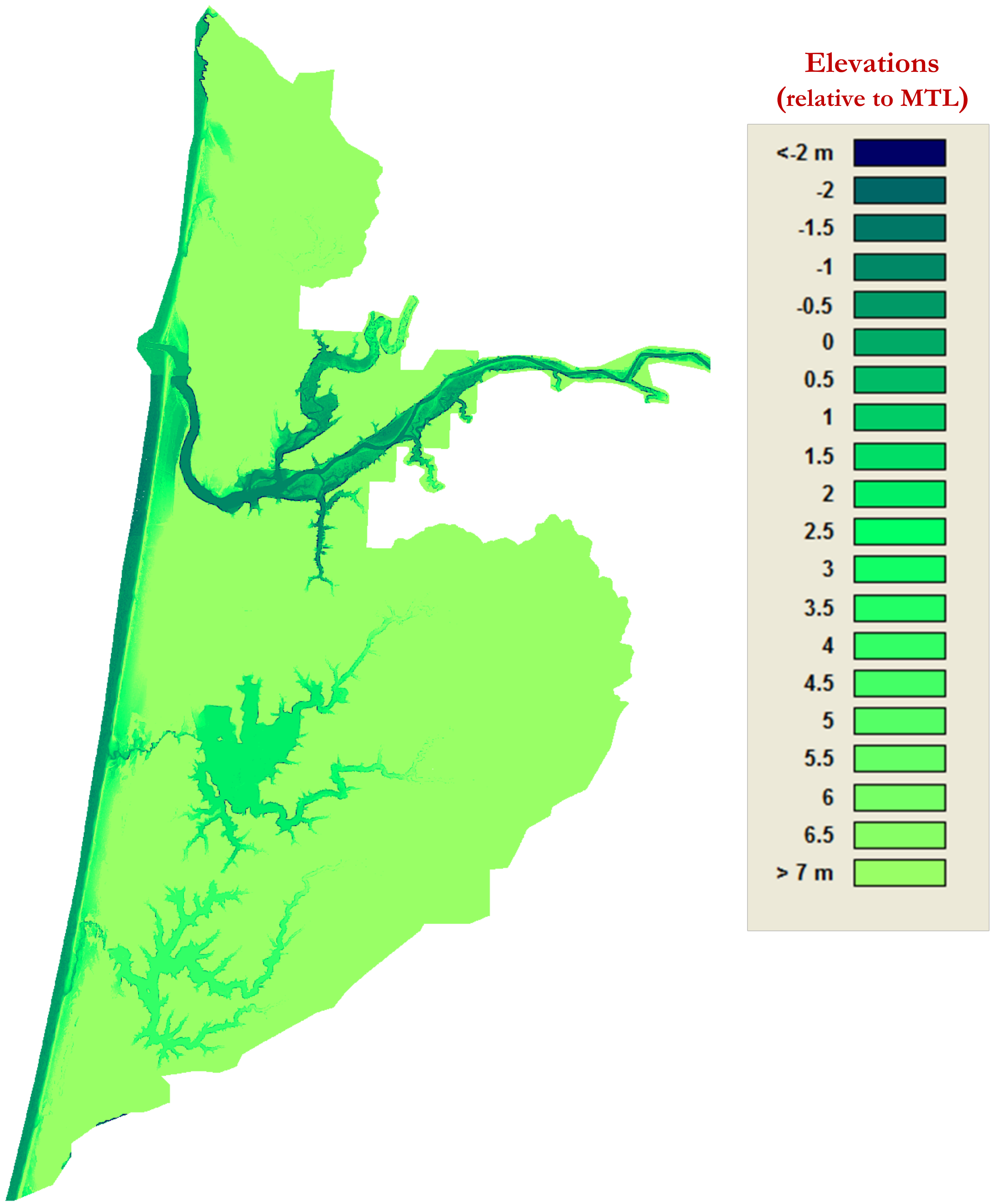

Figure 100. LiDAR elevation data for Site 6 – Siuslaw

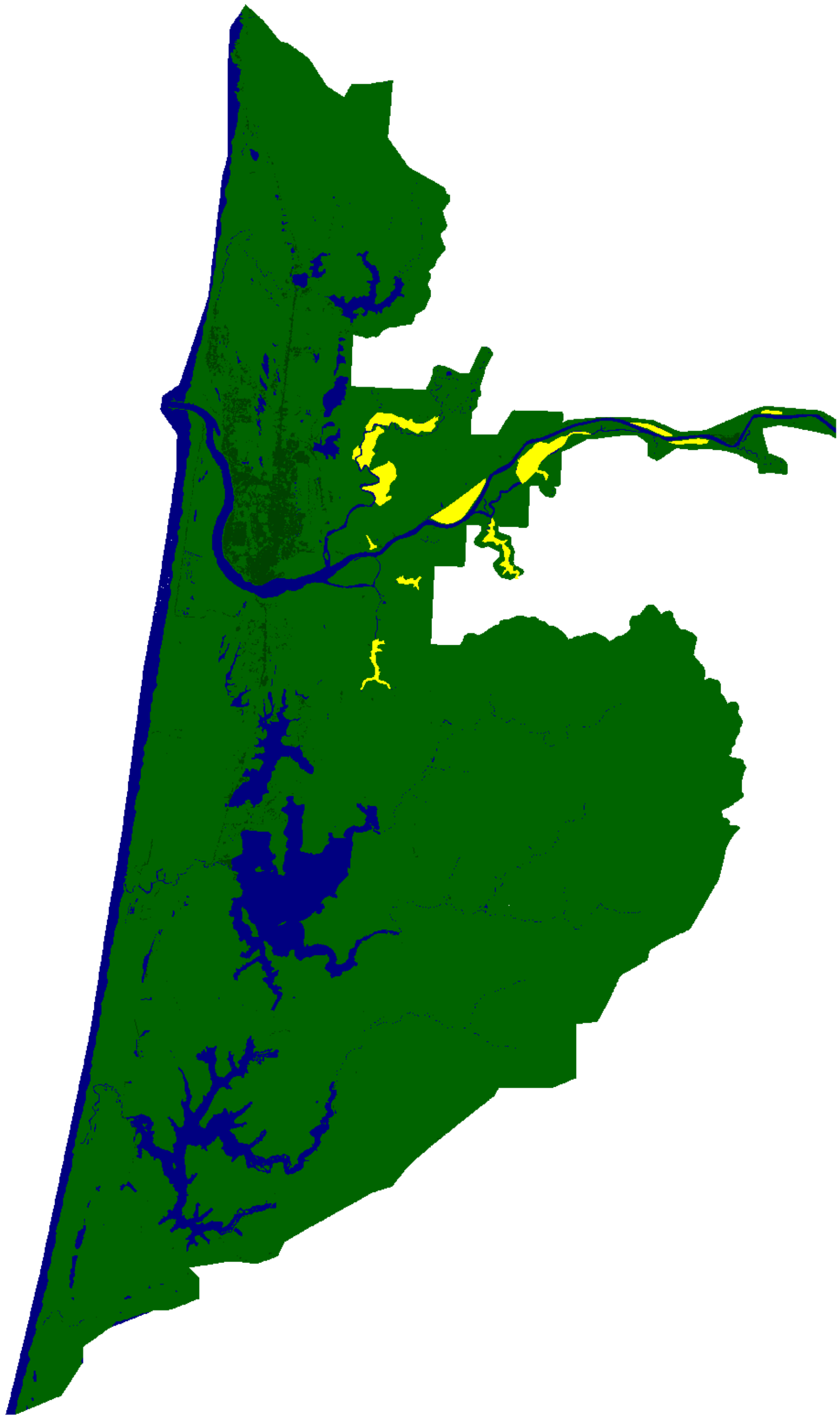

Figure 101. Location of dikes in Site 6 – Siuslaw (shown in yellow)

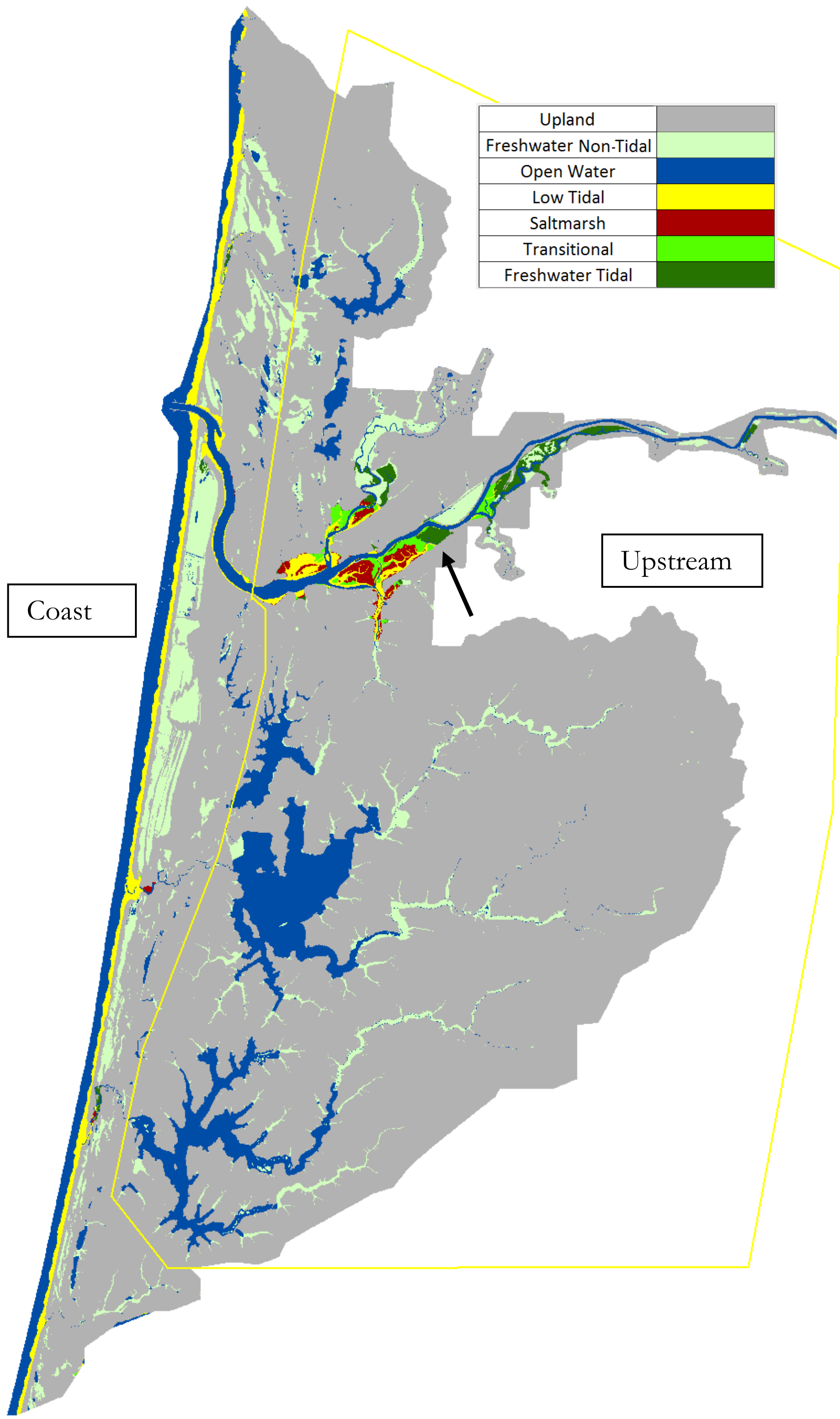

Figure 102. Initial condition wetland data for Site 6 – Siuslaw, with input subsites. Black arrow indicates where inland fresh marsh was changed to tidal-fresh marsh.

For the Siuslaw site, SLAMM predicts losses in the freshwater non-tidal, low tidal, and freshwater tidal marsh habitats and gains in salt and transitional marsh. Table 37 presents the percentage of each land cover type predicted to be lost under each of the SLR scenarios examined. Dry land (upland) is predicted to be relatively unaffected by SLR, while freshwater tidal habitats are predicted to be lost at a higher percentage, particularly under the higher SLR scenarios (1.5 m SLR by 2100 and above). As observed in other sites, these losses are balanced by gains in saltmarsh and transitional habitats. Some of the predicted losses of freshwater wetlands shown in Table 38 are due to the removal of dikes as mentioned above.

Table 37. Predicted Percent Change of Land Categories by 2100 at Site 6 – Siuslaw Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	1	1	1	1
Open Water	-4	-6	-8	-13	-18
Freshwater Non-Tidal	4	6	7	10	14
Low Tidal	6	10	15	9	5
Freshwater Tidal	5	7	11	29	51
Saltmarsh	-54	-73	-113	-128	-118
Transitional	-85	-91	-65	-40	-37

Simulations run without the dikes included suggested gains in low tidal habitat especially at rates of SLR of 1 and 1.5 m by 2100. Conversely, larger losses in freshwater tidal habitats are predicted if dikes are removed.

Table 38. Predicted Percent Change of Land Categories by 2100 at Site 6 – Siuslaw Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	1	1	1	2
Open Water	-4	-6	-8	-14	-21
Freshwater Non-Tidal	11	12	14	17	19
Low Tidal	-2	-6	-7	-8	-4
Freshwater Tidal	7	14	26	57	79
Saltmarsh	-143	-127	-137	-149	-134
Transitional	-105	-117	-92	-67	-57

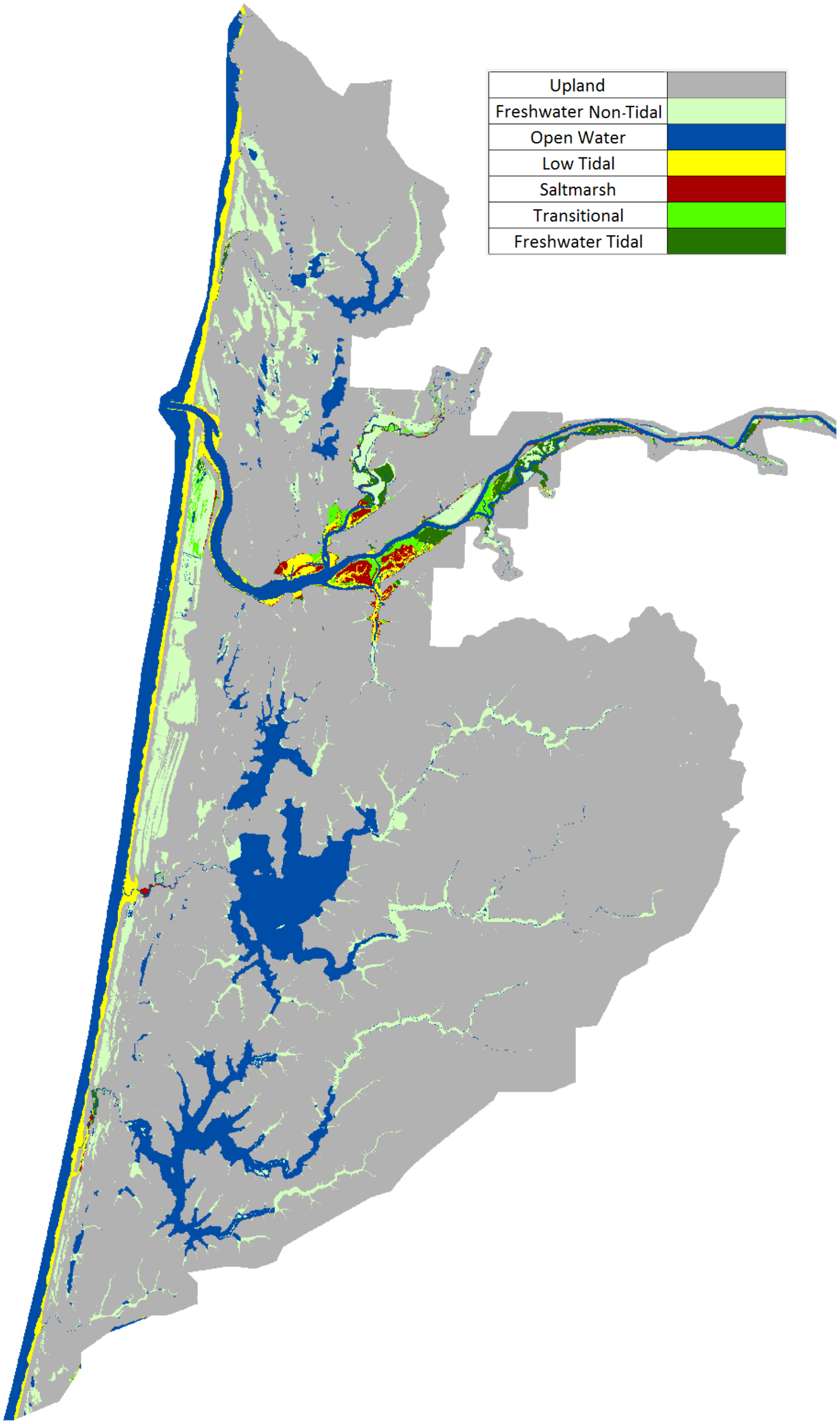

Figure 103. Site 6, 2100, Scenario A1B mean (0.39 m)

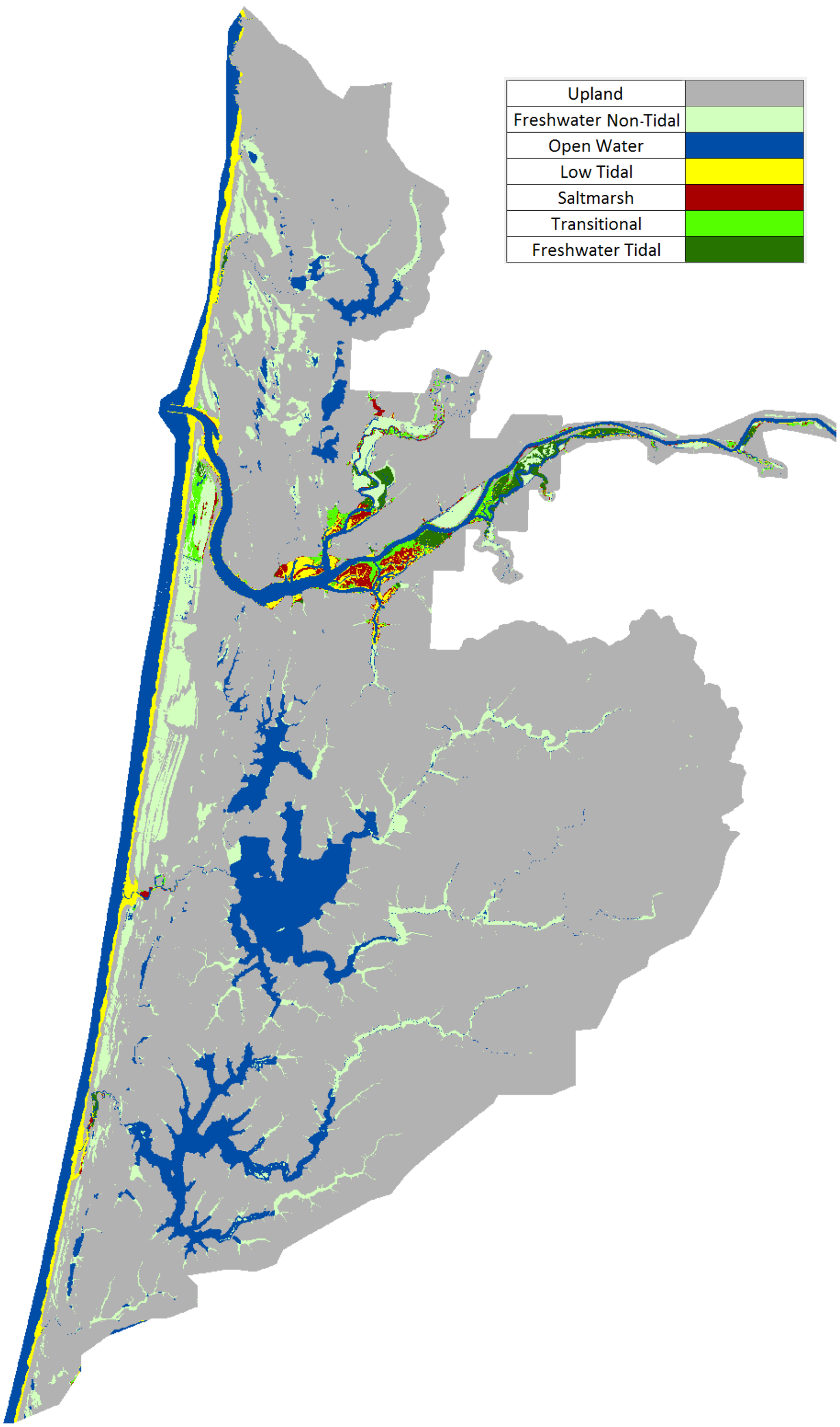

Figure 104. Site 6, 2100, Scenario A1B max (0.69 m)

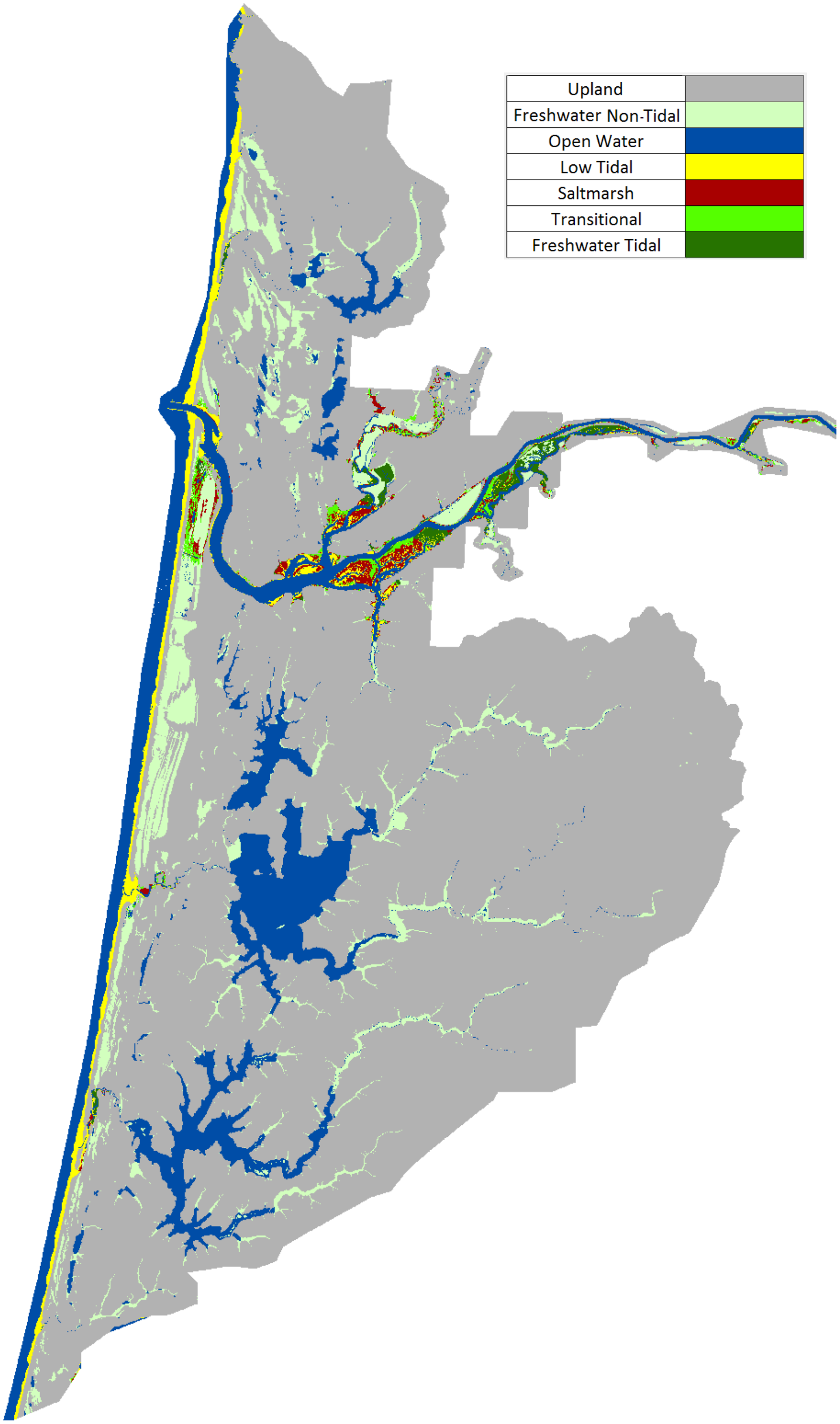

Figure 105. Site 6, 2100, Scenario 1 m

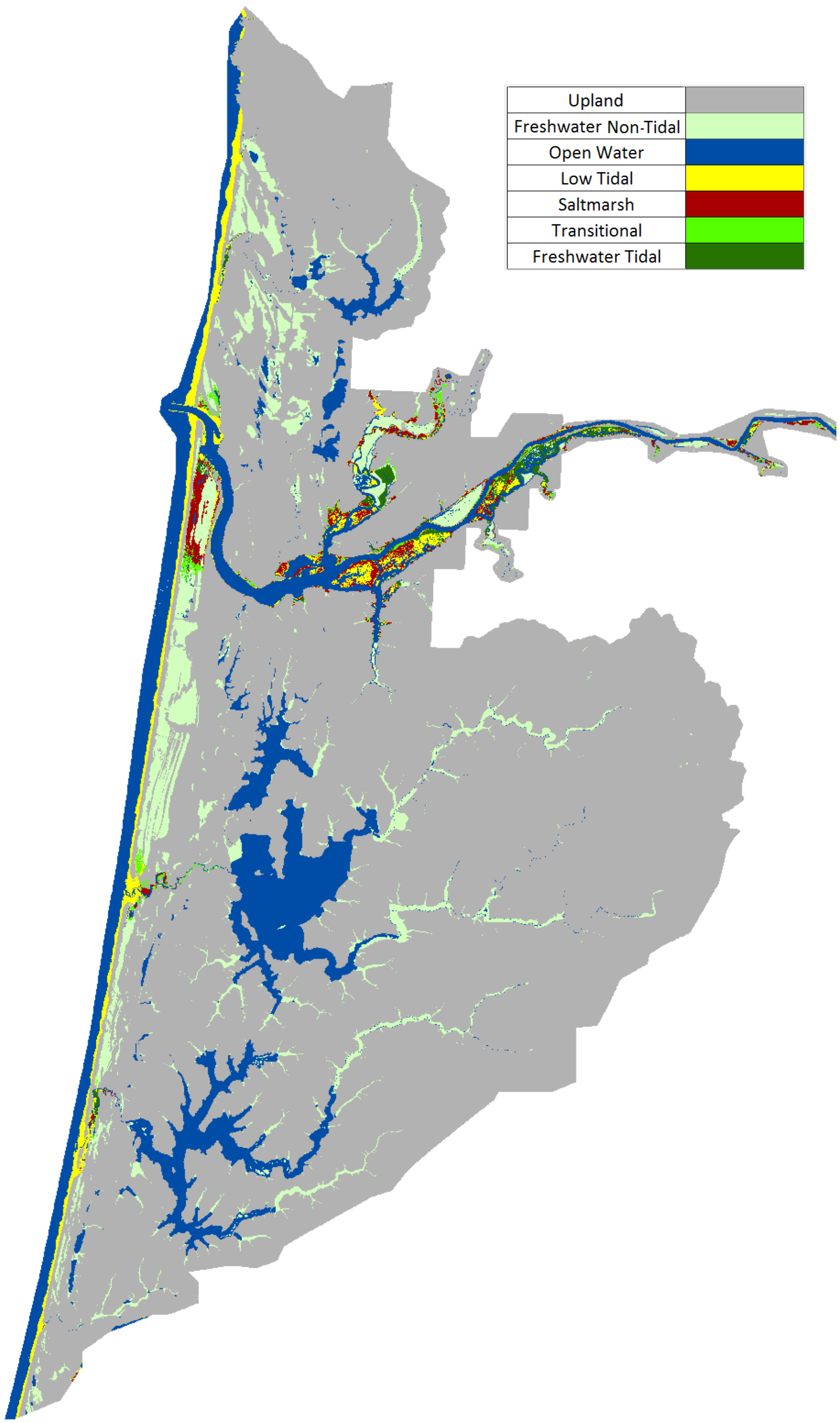

Figure 106. Site 6, 2100, Scenario 1.5 m

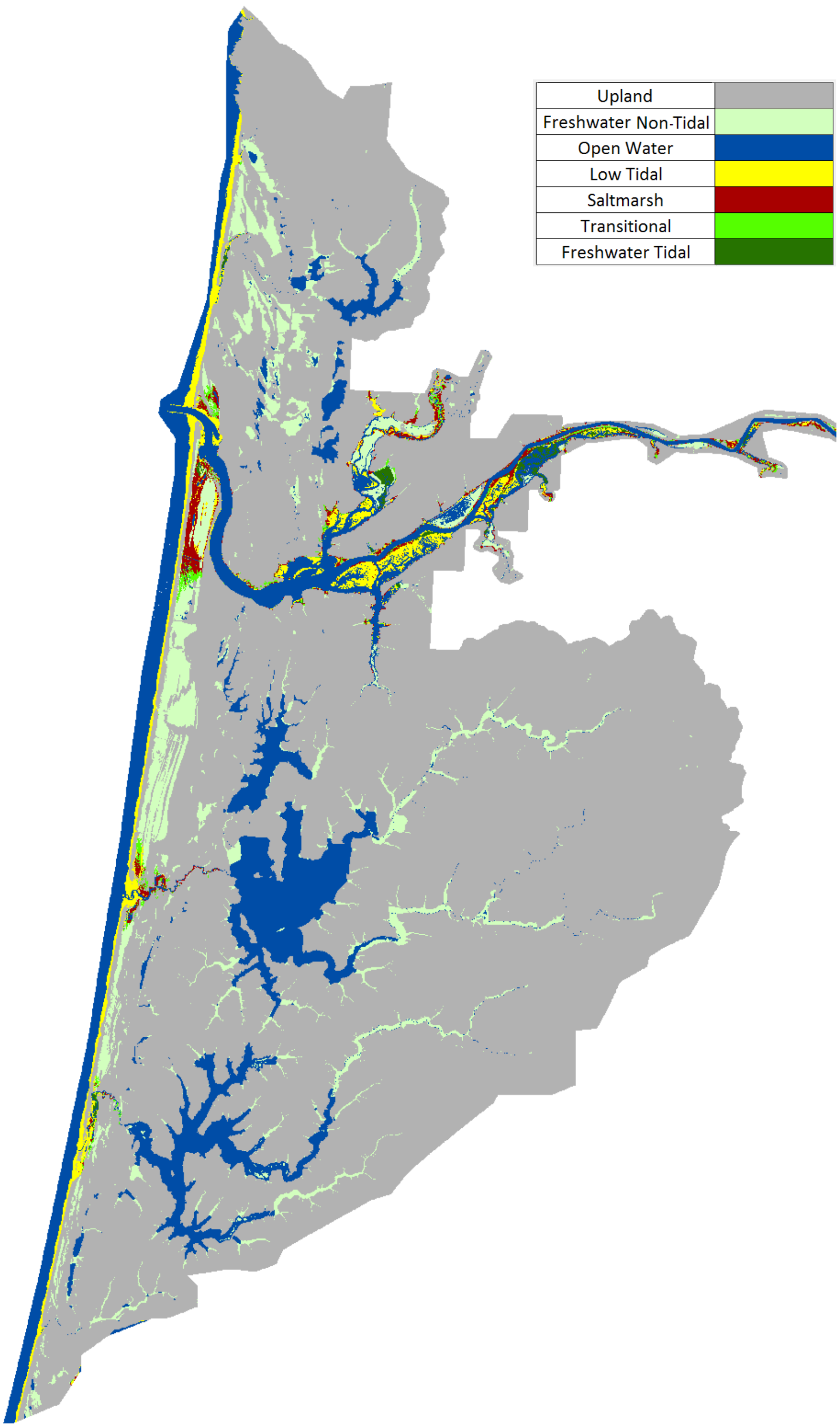

Figure 107. Site 6, 2100, Scenario 2 m

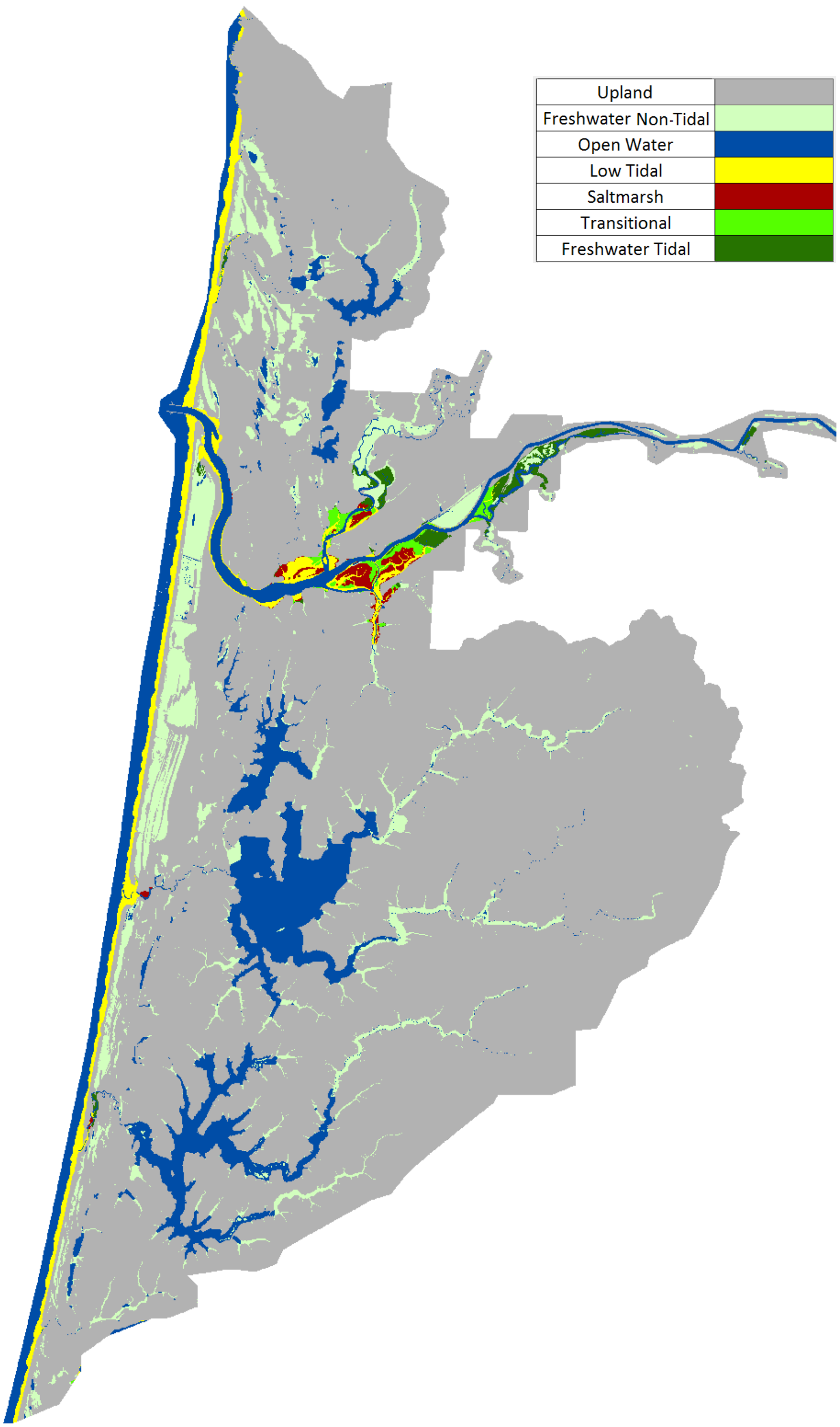

Figure 108. Initial condition wetland data for Site 6 – Siuslaw

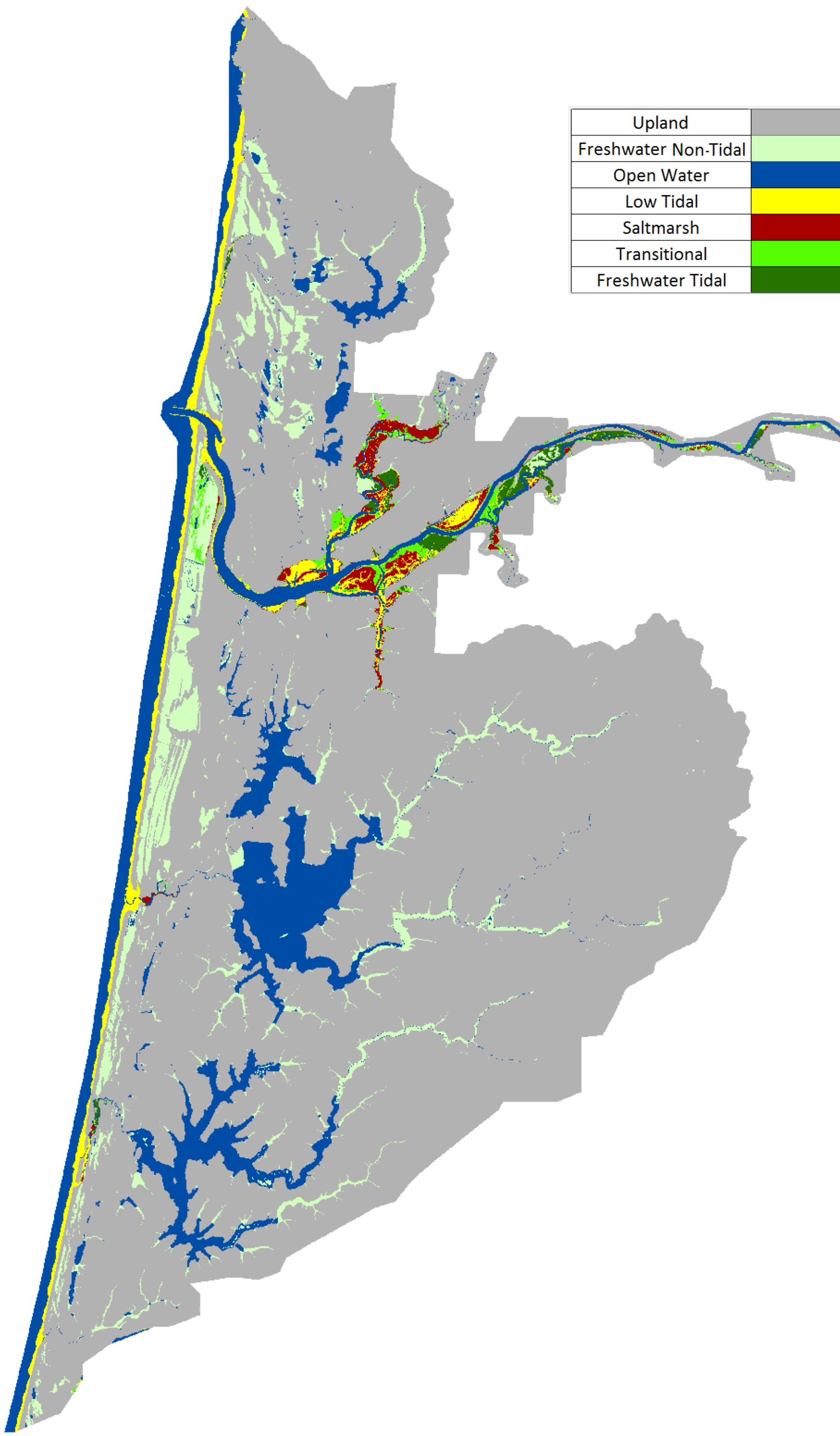

Figure 109. Site 6, 2100, Scenario A1B mean (0.39 m) – No Dikes

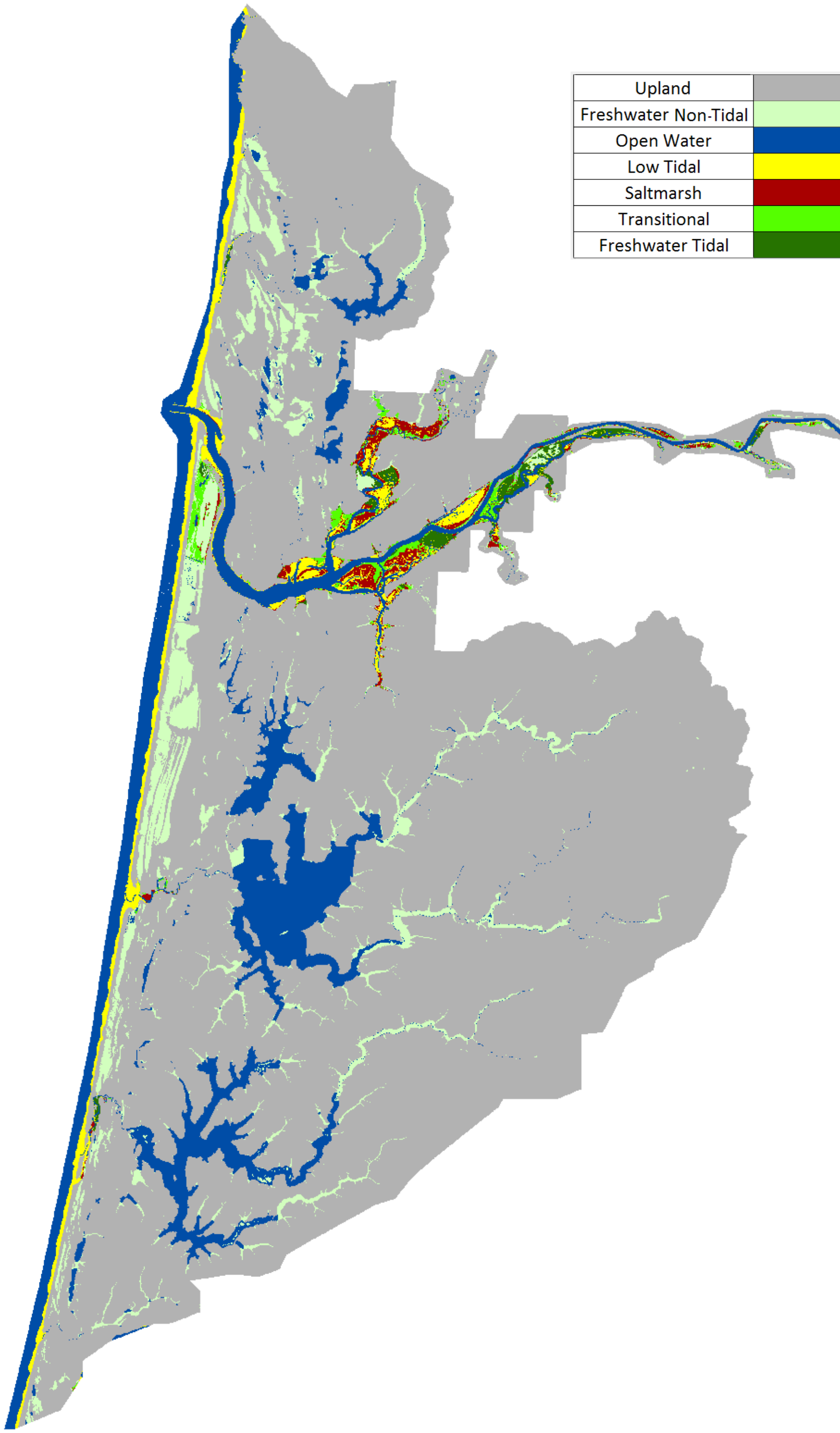

Figure 110. Site 6, 2100, Scenario A1B max (0.69 m) – No Dikes

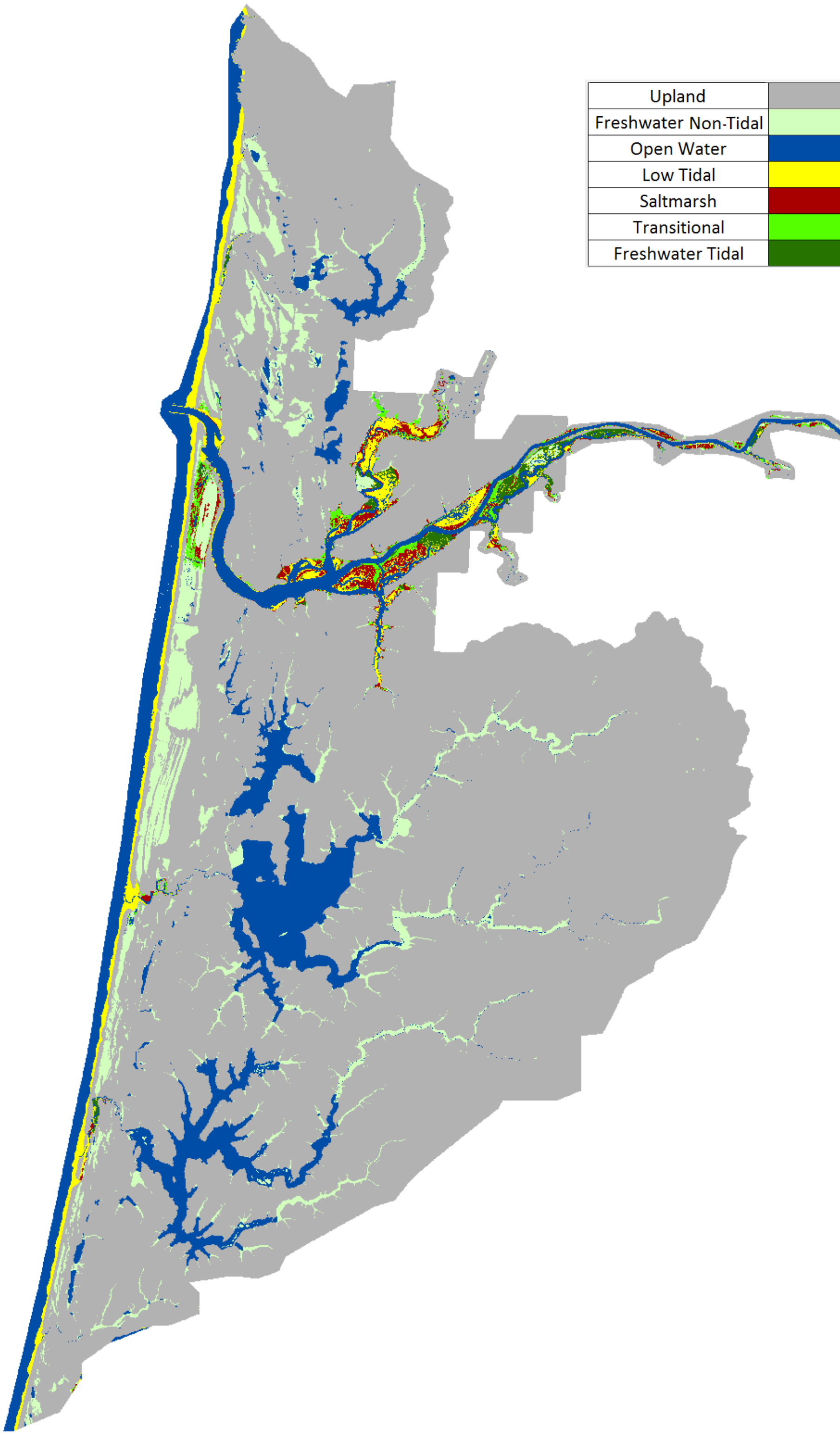

Figure 111. Site 6, 2100, Scenario 1 m – No Dikes

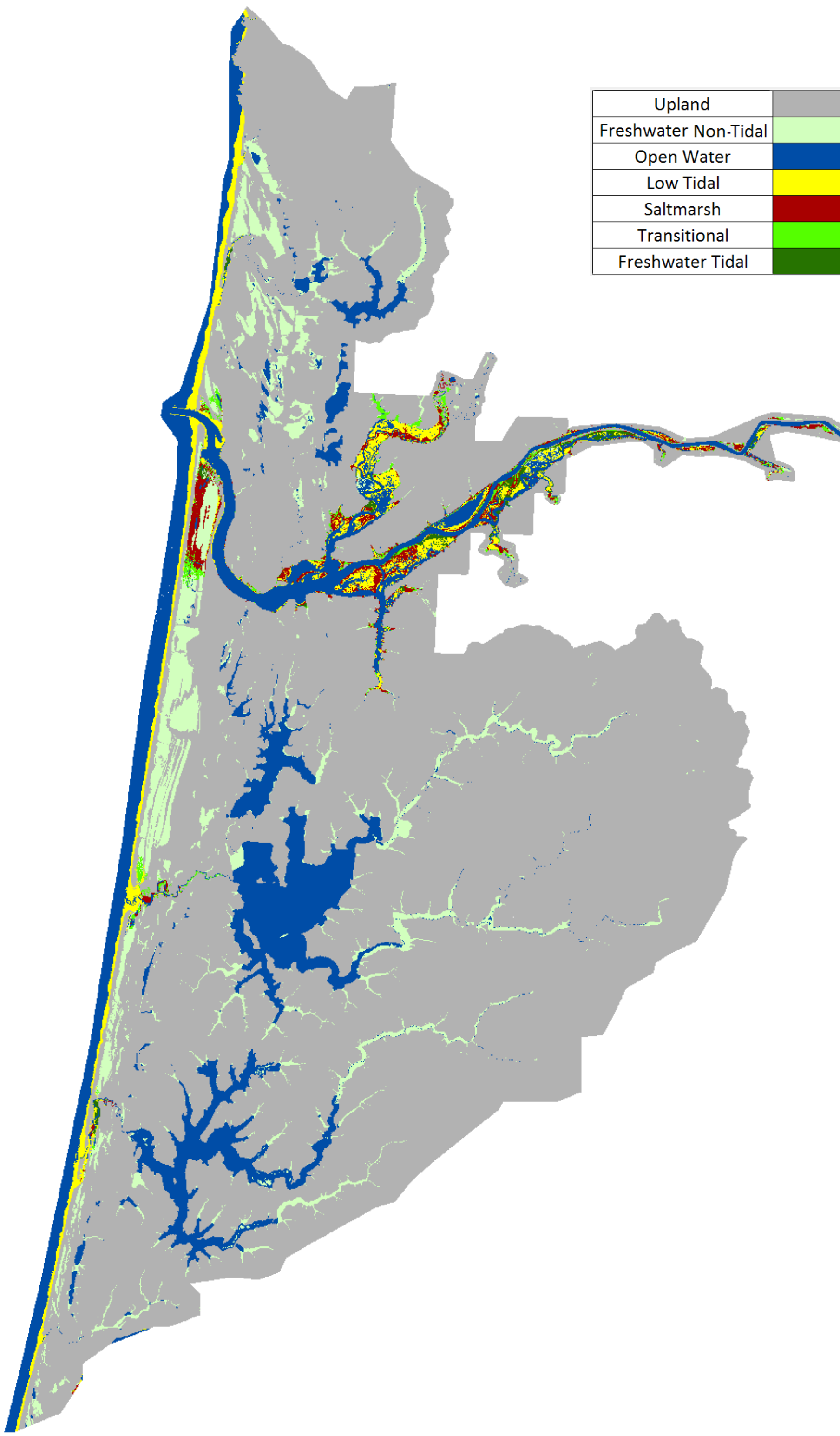

Figure 112. Site 6, 2100, Scenario 1.5 m – No Dikes

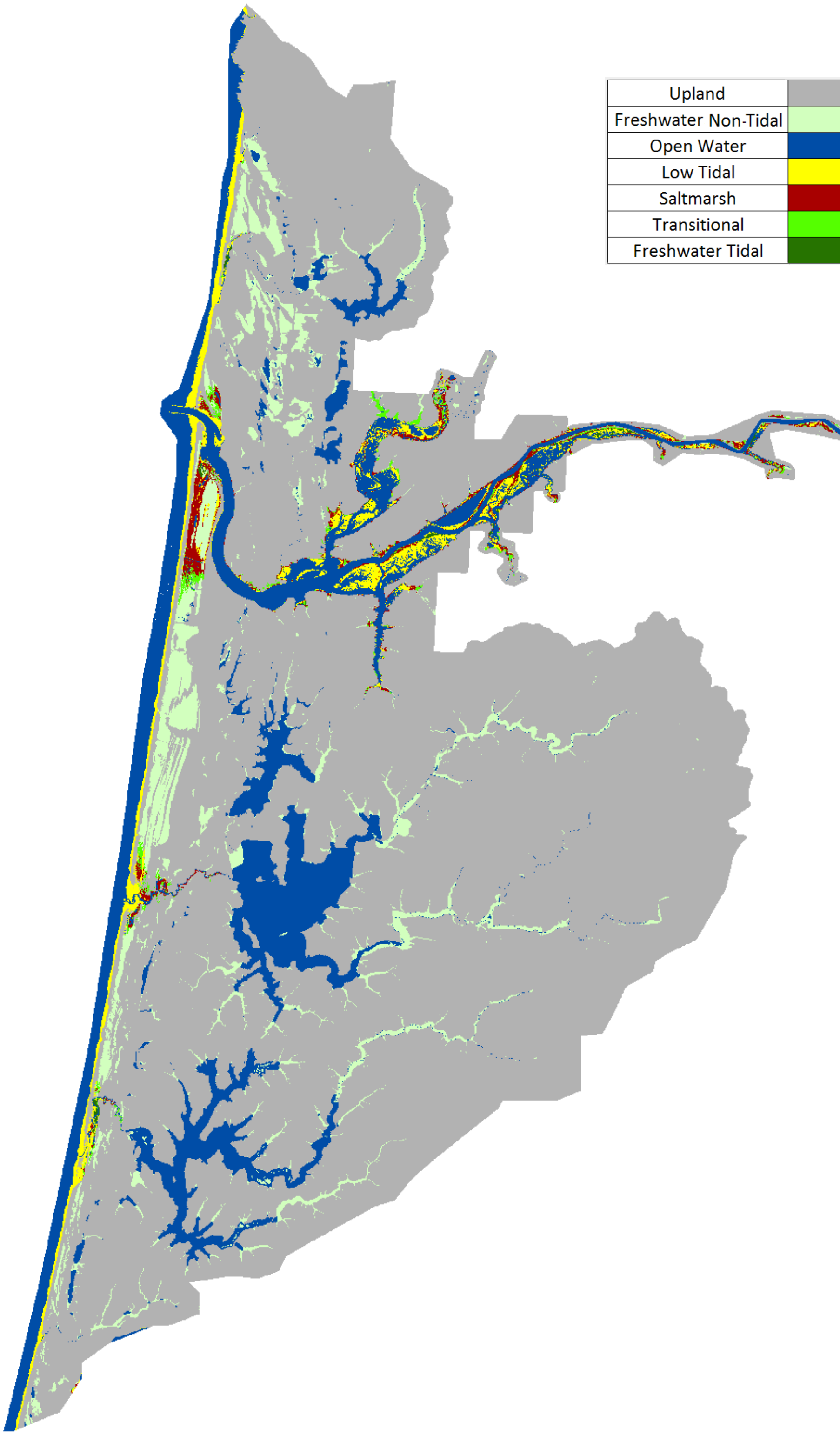

Figure 113. Site 6, 2100, Scenario 2 m – No Dikes

Site 7: Umpqua

Marshes in site 7 are predominantly freshwater non-tidal, with much smaller amounts of freshwater tidal, salt, and transitional marshes, as shown in Table 39.

Table 39. Wetland coverage of Site 7 according to the 2002 wetland data

Land cover type	**Area (acres)**	**Percentage (%)**
Upland	116776	89
Open Water	6115	5
Freshwater Non-Tidal	5090	4
Low Tidal	1738	1
Freshwater Tidal	914	1
Saltmarsh	505	< 1
Transitional	348	< 1
Total (incl. water)	**131485**	**100**

Three NOAA tide table stations are located in this site, which led to the division of the site into two input subsites, Coast and Upstream, as shown in Figure 117. One station was located at the Umpqua River Entrance (GT = 2.1 m, used for the Coast subsite) and the two others are upstream at Gardiner and Reedsport (GT = 2.04 m for both, used for the upstream subsite). The historic trend applied to this site was 0.98 mm/yr. Observations from the Charleston station were used to derive the salt elevation for this site, resulting in the application of 1.48 m for the coastal subsite and 1.41 m for the upstream portion of the study area. Within the SLAMM conceptual model, the lower boundary was changed for the tidal fresh marsh and tidal swamp wetland categories in order to more closely conform to the site-specific data noted for site 6. Tidal fresh marsh was allowed to extend down to 0.501 HTU and tidal swamp to 0.638 HTU.

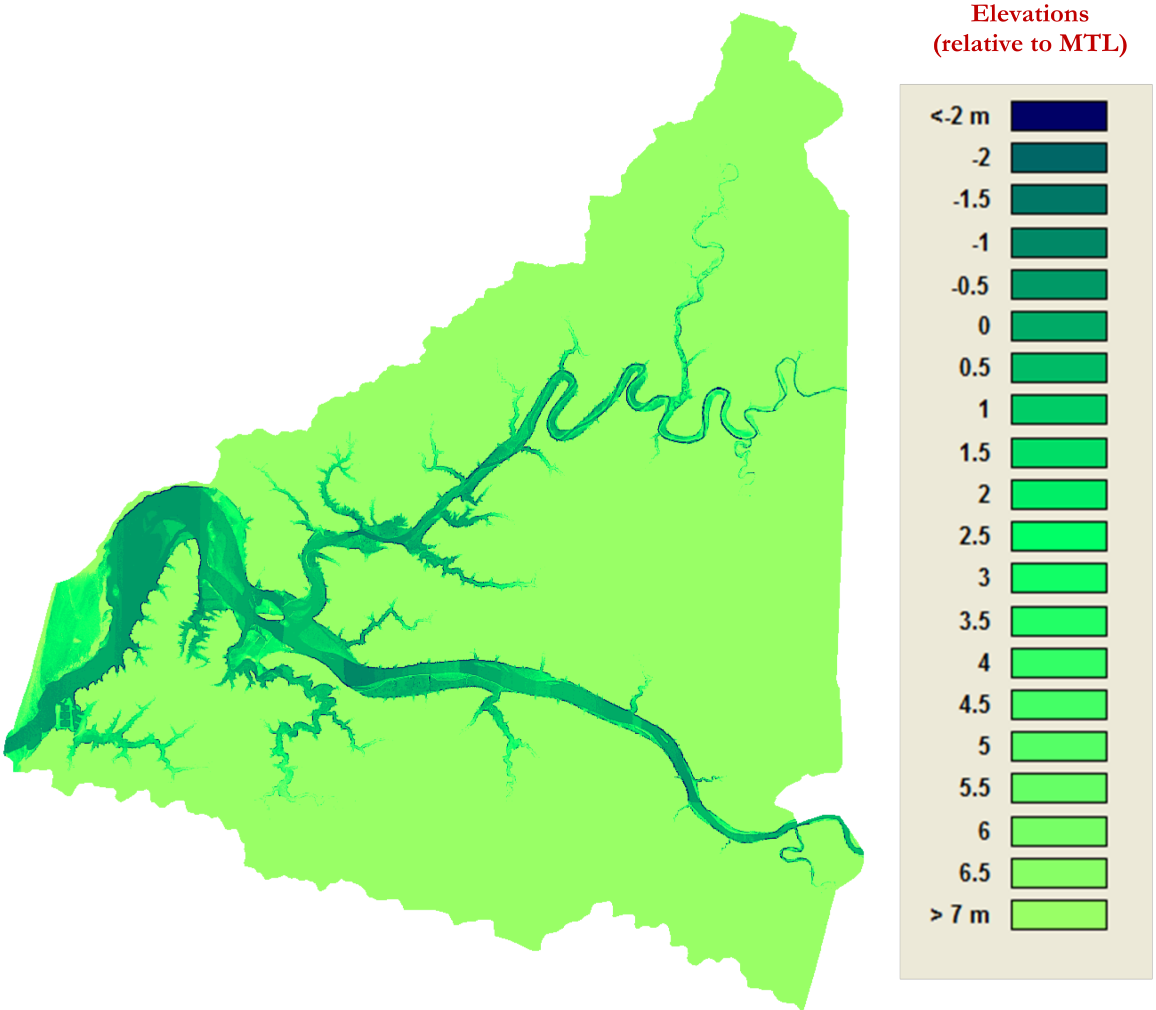

Figure 114. LiDAR elevation data for Site 7 – Umpqua

Figure 115. Location of dikes in Site 7 – Umpqua (shown in yellow)

In addition to the dikes included in Figure 115, the town of Reedsport is protected by a levee system. This was incorporated into simulations of site seven by specifying the developed dry land to be protected from the effects of SLR under each scenario.

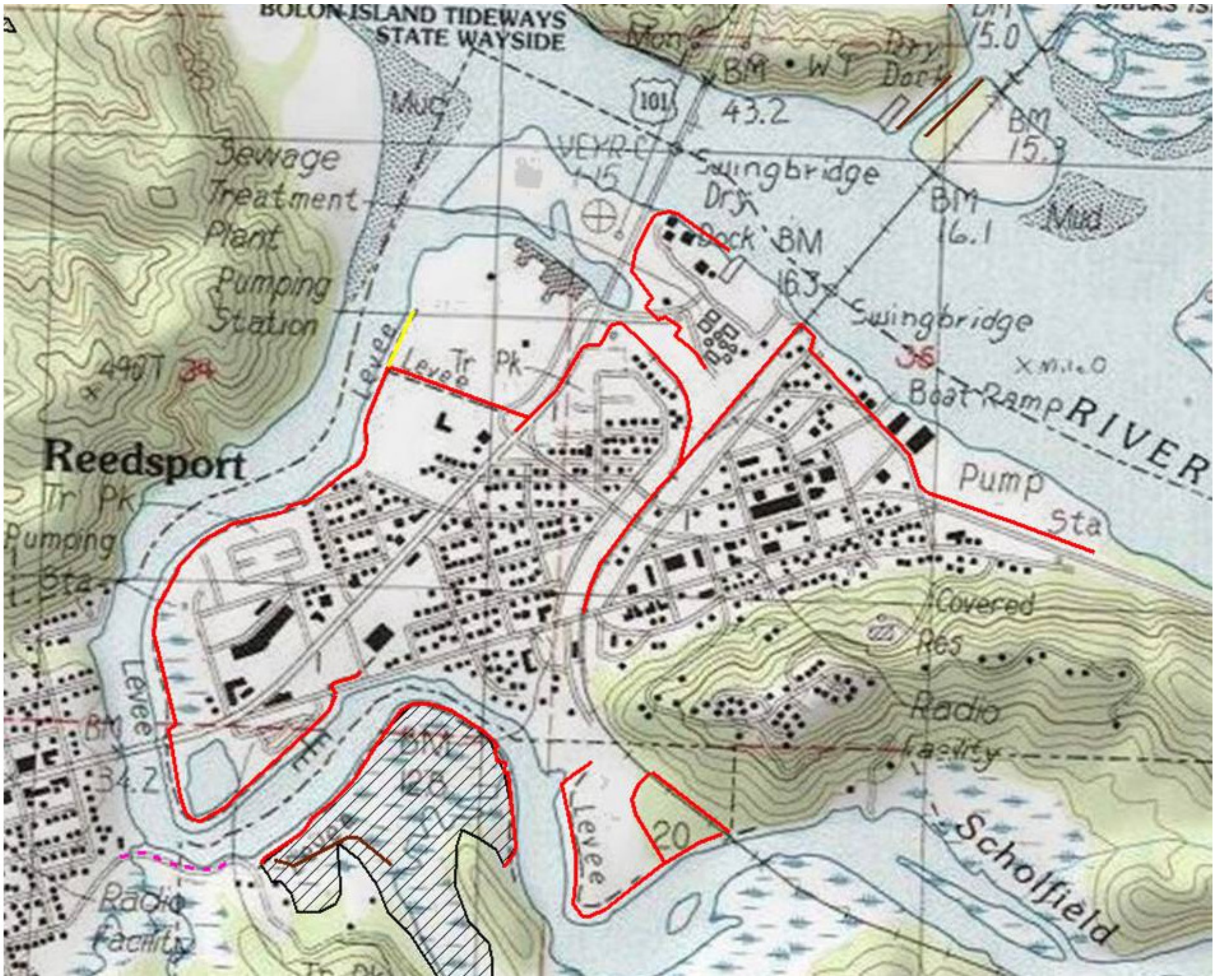

Figure 116. Dikes protecting Reedsport, OR (in red and pink)

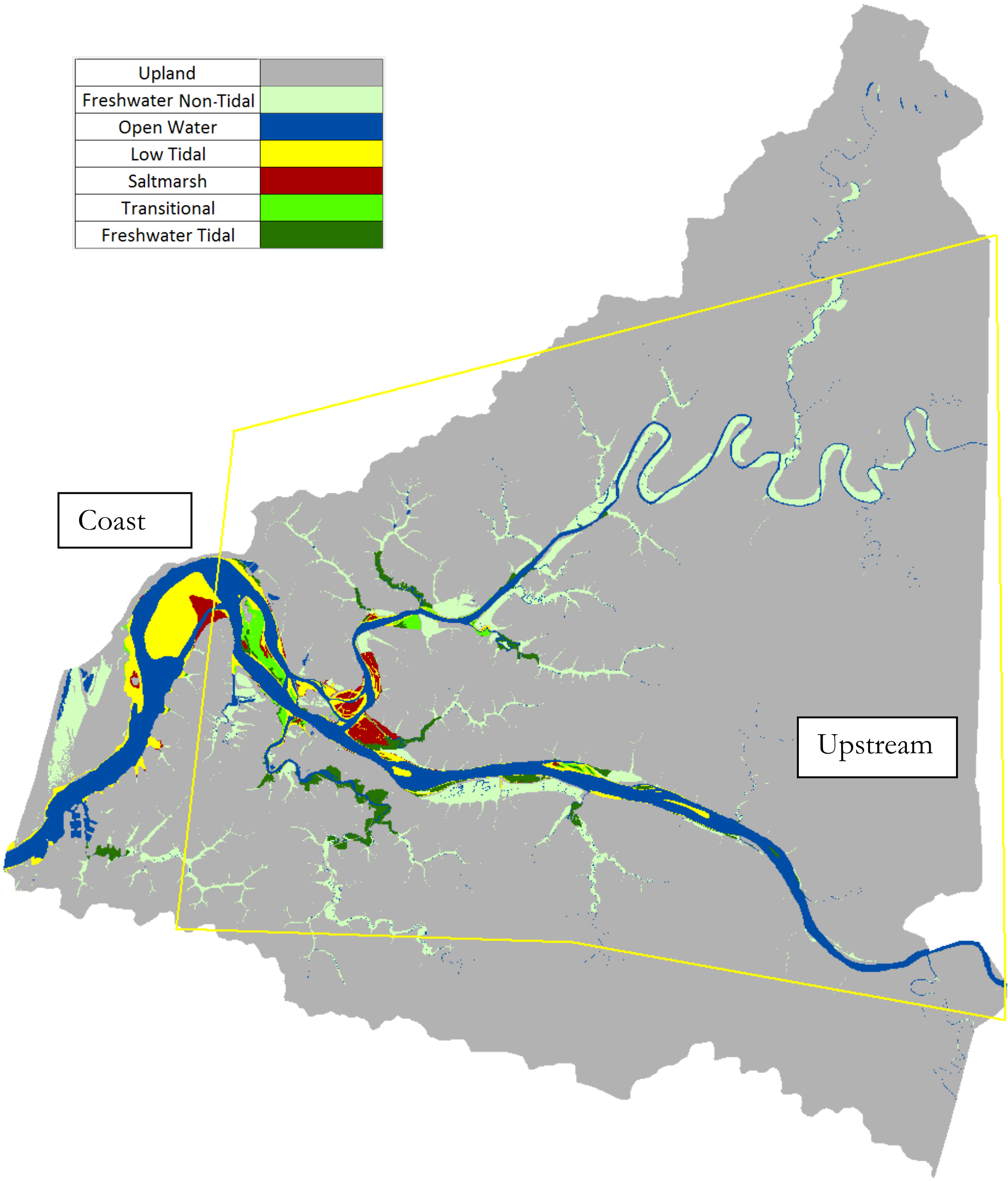

Figure 117. Wetland data for Site 7 – Umpqua

SLAMM simulations predict the Umpqua river estuary to be affected by SLR at higher SLR scenarios. Table 40 presents the percentage of each land cover type predicted to be lost under each of the SLR scenarios examined. The freshwater tidal category appears to be the most at-risk wetland type, with predicted losses of 8 to 85 percent depending on the SLR scenario. Losses in the freshwater tidal and freshwater non-tidal categories are paired with gains in the saltmarsh, transitional, and open water categories.

Simulations run without the dikes included (but with developed dry land still protected) predicted a 30% greater loss than when the dikes were included, as shown in Table 41. In addition, greater gains were predicted in the low tidal, saltmarsh, and fresh marsh categories.

Table 40. Predicted Percent Change of Land Categories by 2100 at Site 7 – Umpqua Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	1	1	1	2
Open Water	-5	-6	-11	-25	-37
Freshwater Non-Tidal	6	8	10	17	22
Low Tidal	0	-3	5	24	8
Freshwater Tidal	8	16	34	69	85
Saltmarsh	-62	-92	-145	-232	-217
Transitional	-90	-105	-128	-168	-150

Table 41. Predicted Percent Change of Land Categories by 2100 at Site 7 – Umpqua Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	1	1	1	1	2
Open Water	-5	-6	-11	-26	-45
Freshwater Non-Tidal	36	39	42	49	55
Low Tidal	-7	-17	-29	-43	-50
Freshwater Tidal	9	16	35	71	88
Saltmarsh	-304	-355	-365	-349	-286
Transitional	-216	-182	-187	-215	-195

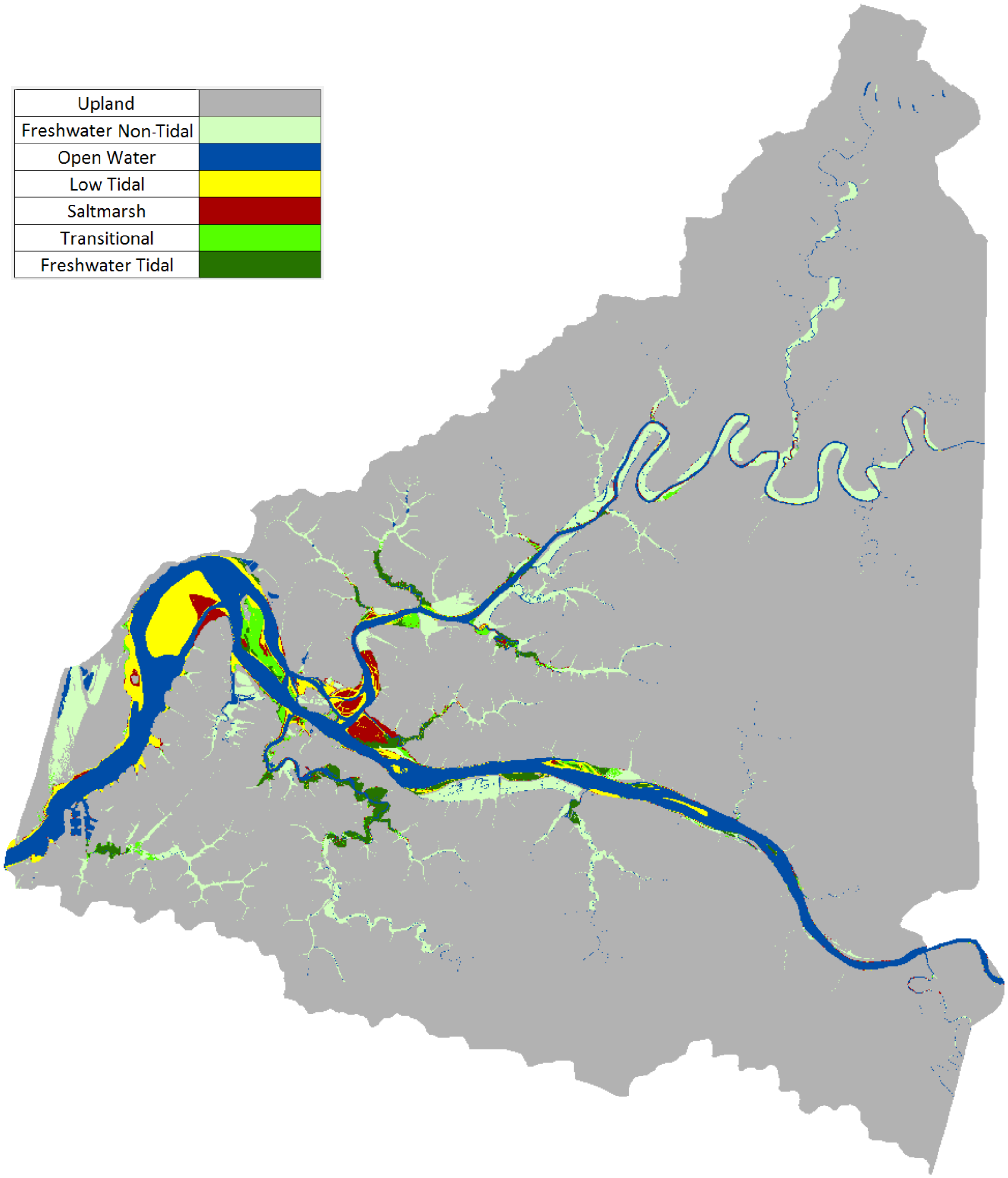

Figure 118. Site 7, 2100, Scenario A1B mean (0.39 m)

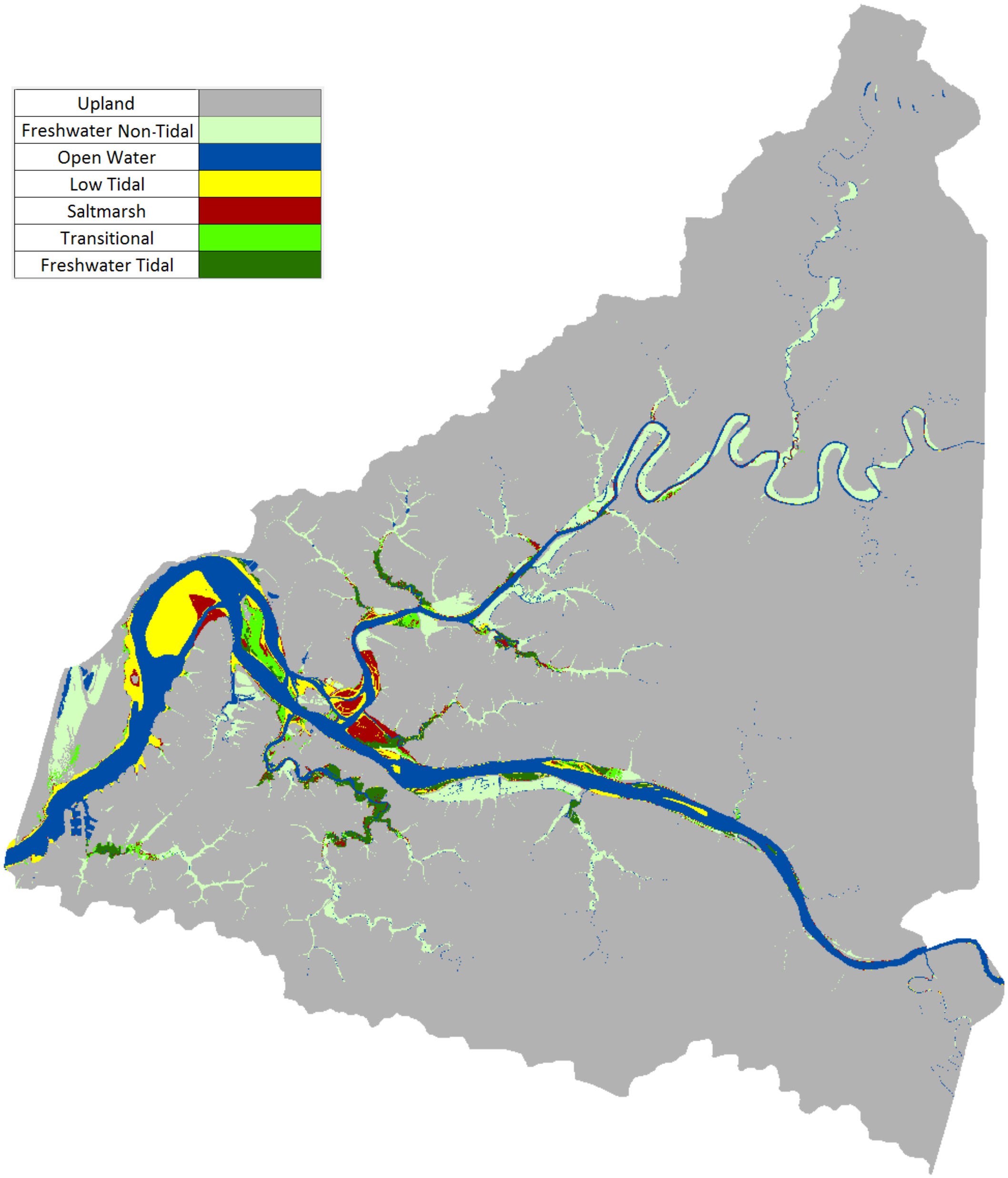

Figure 119. Site 7, 2100, Scenario A1B max (0.69 m)

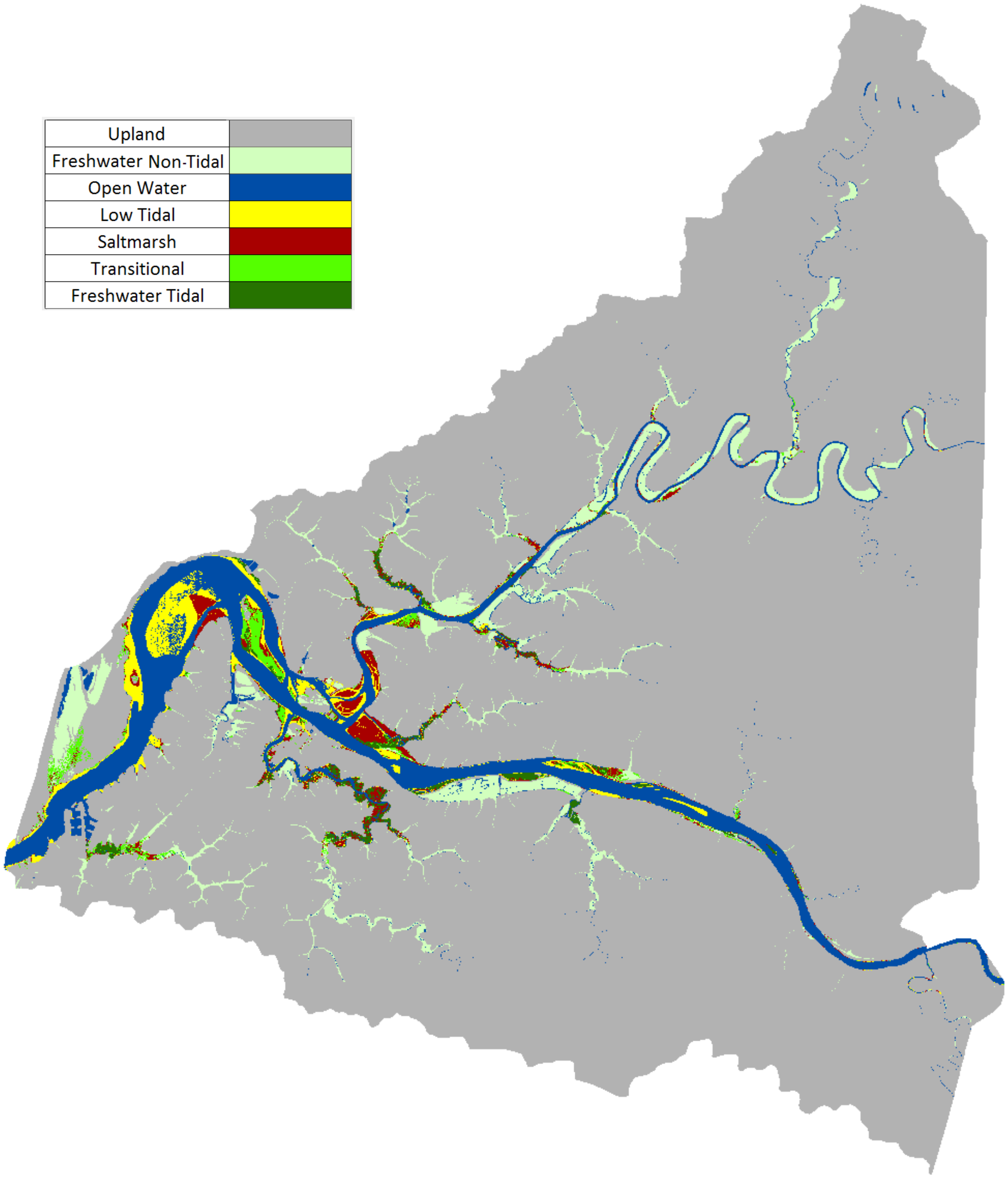

Figure 120. Site 7, 2100, Scenario 1 m

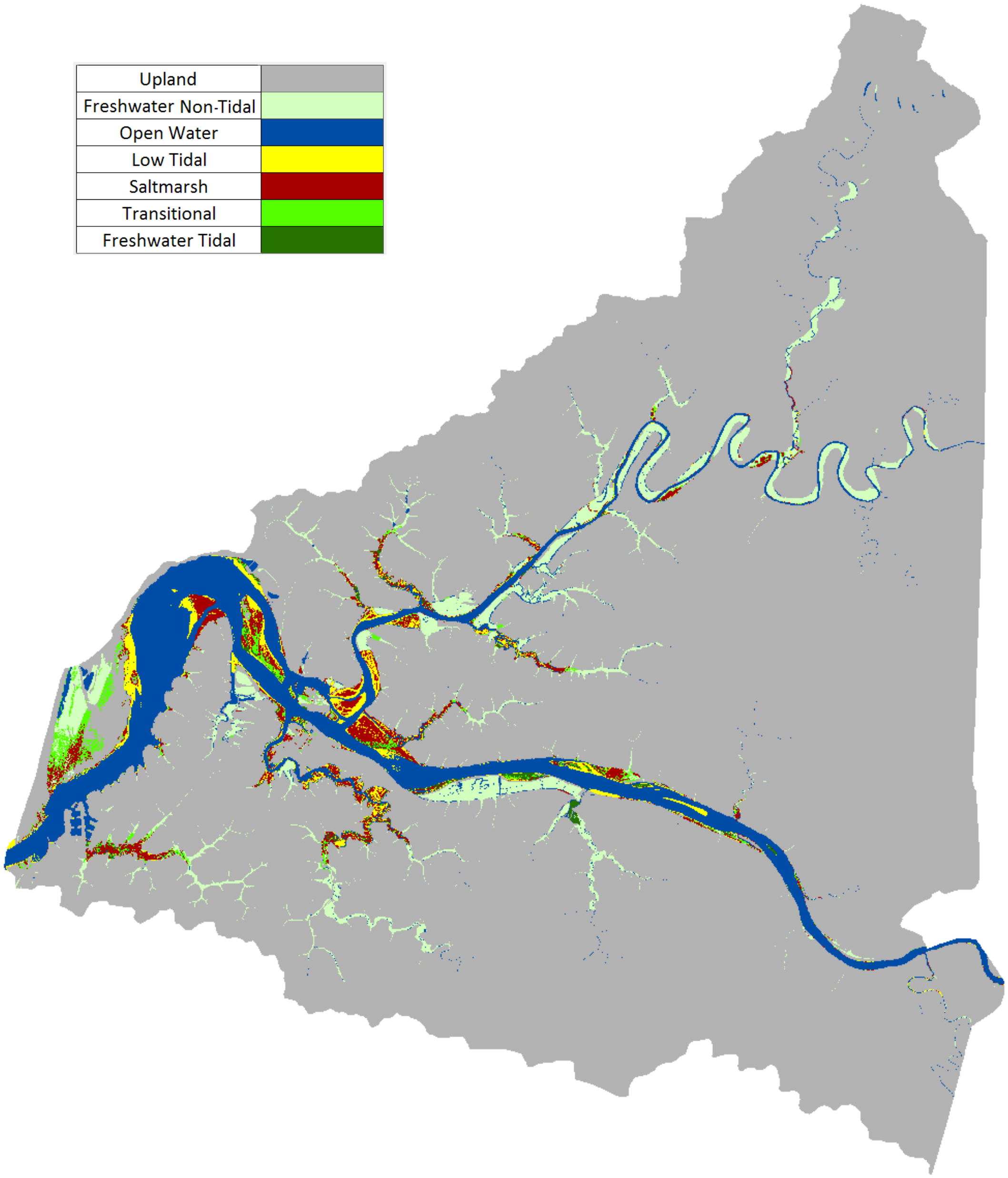

Figure 121. Site 7, 2100, Scenario 1.5 m

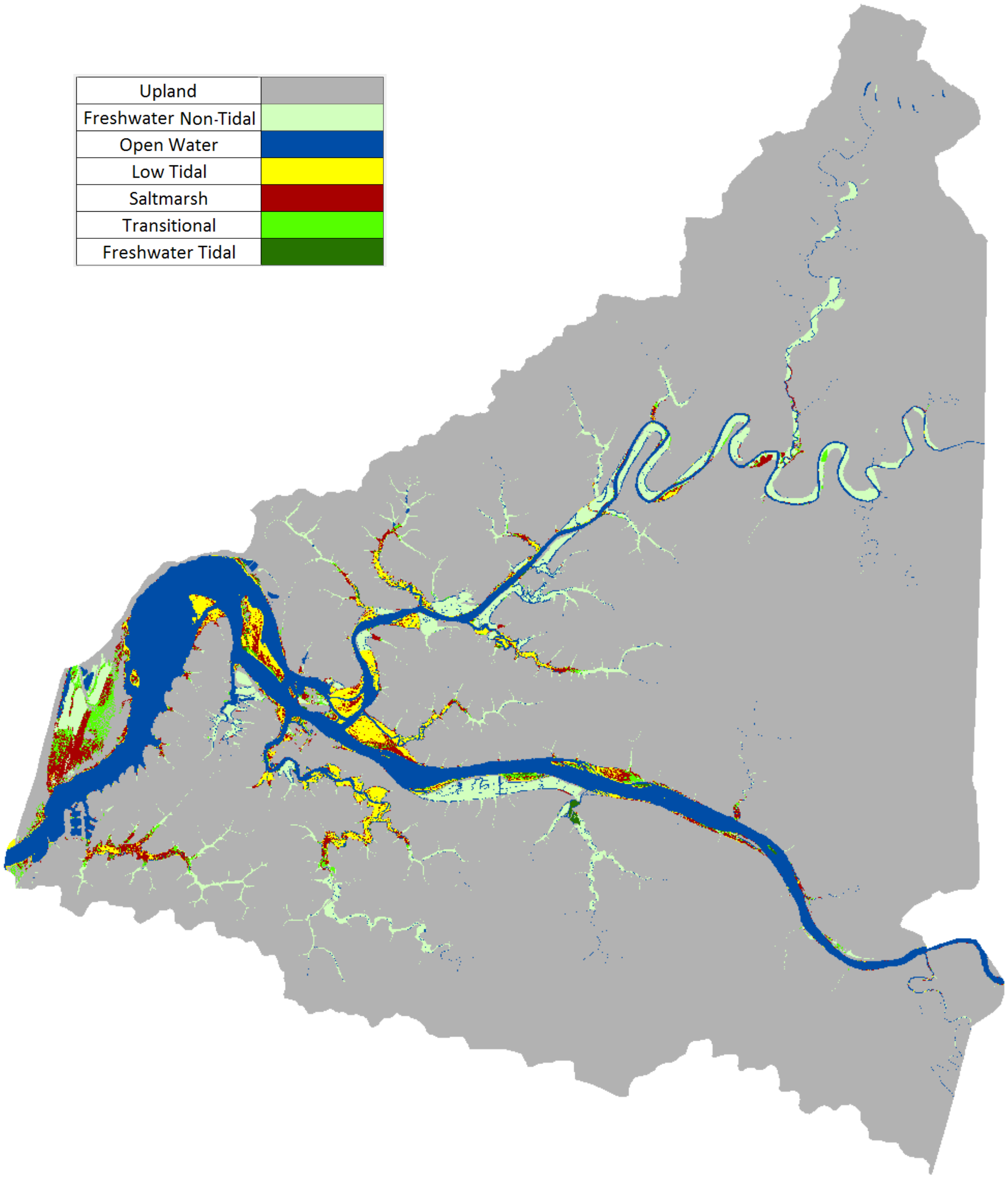

Figure 122. Site 7, 2100, Scenario 2 m

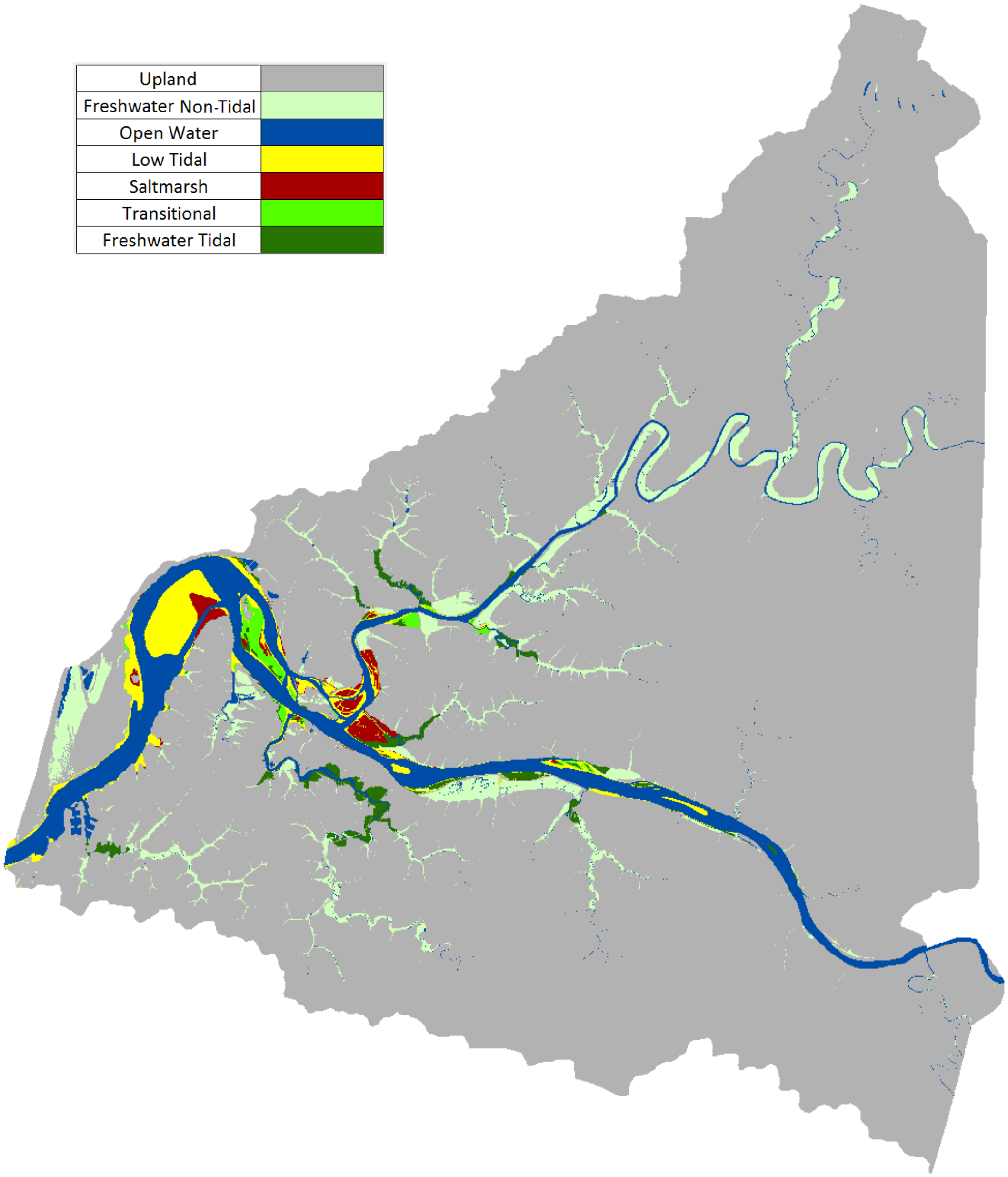

Figure 123. Initial condition wetland data for Site 7 – Umpqua

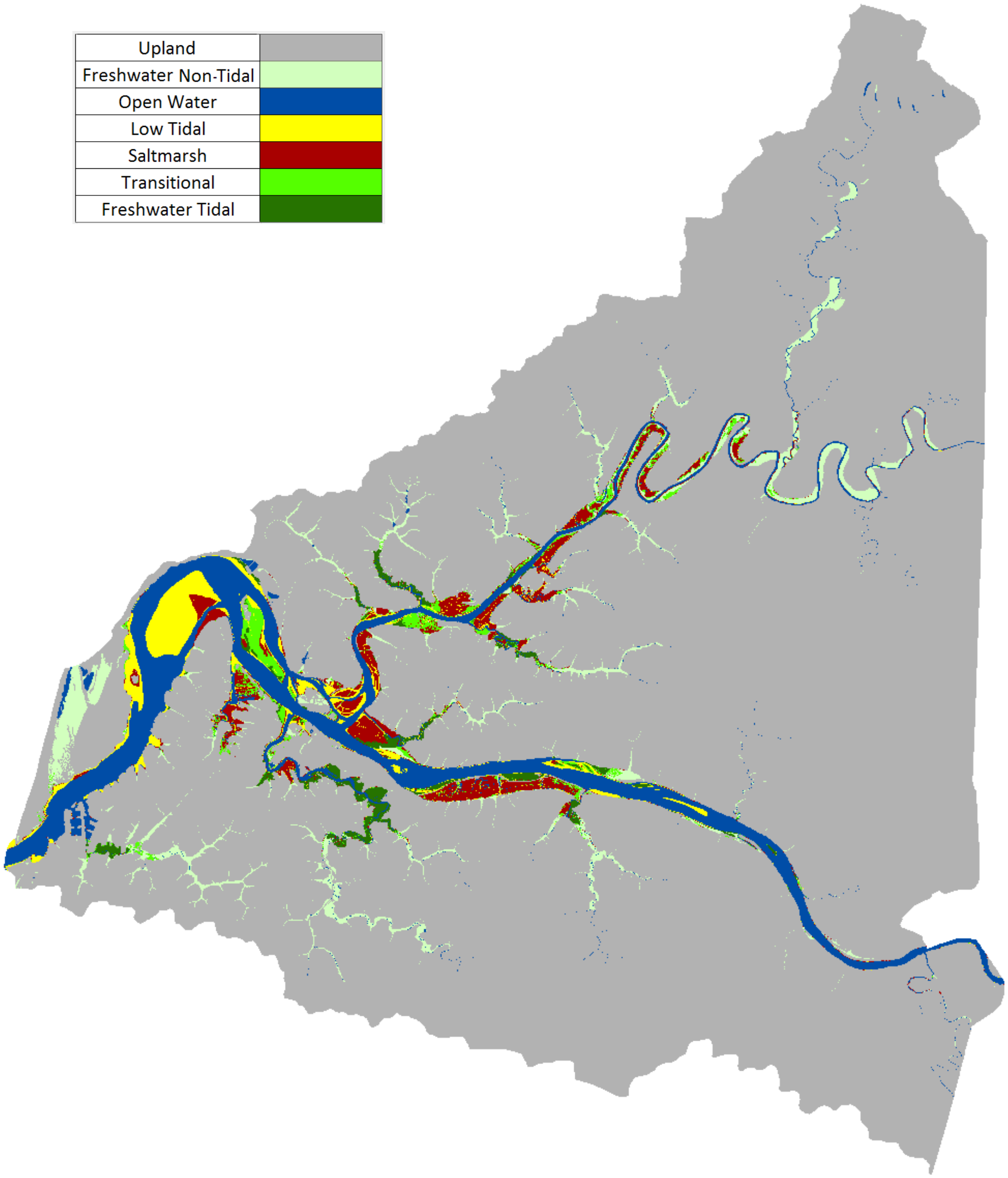

Figure 124. Site 7, 2100, Scenario A1B mean (0.39 m) – No Dikes

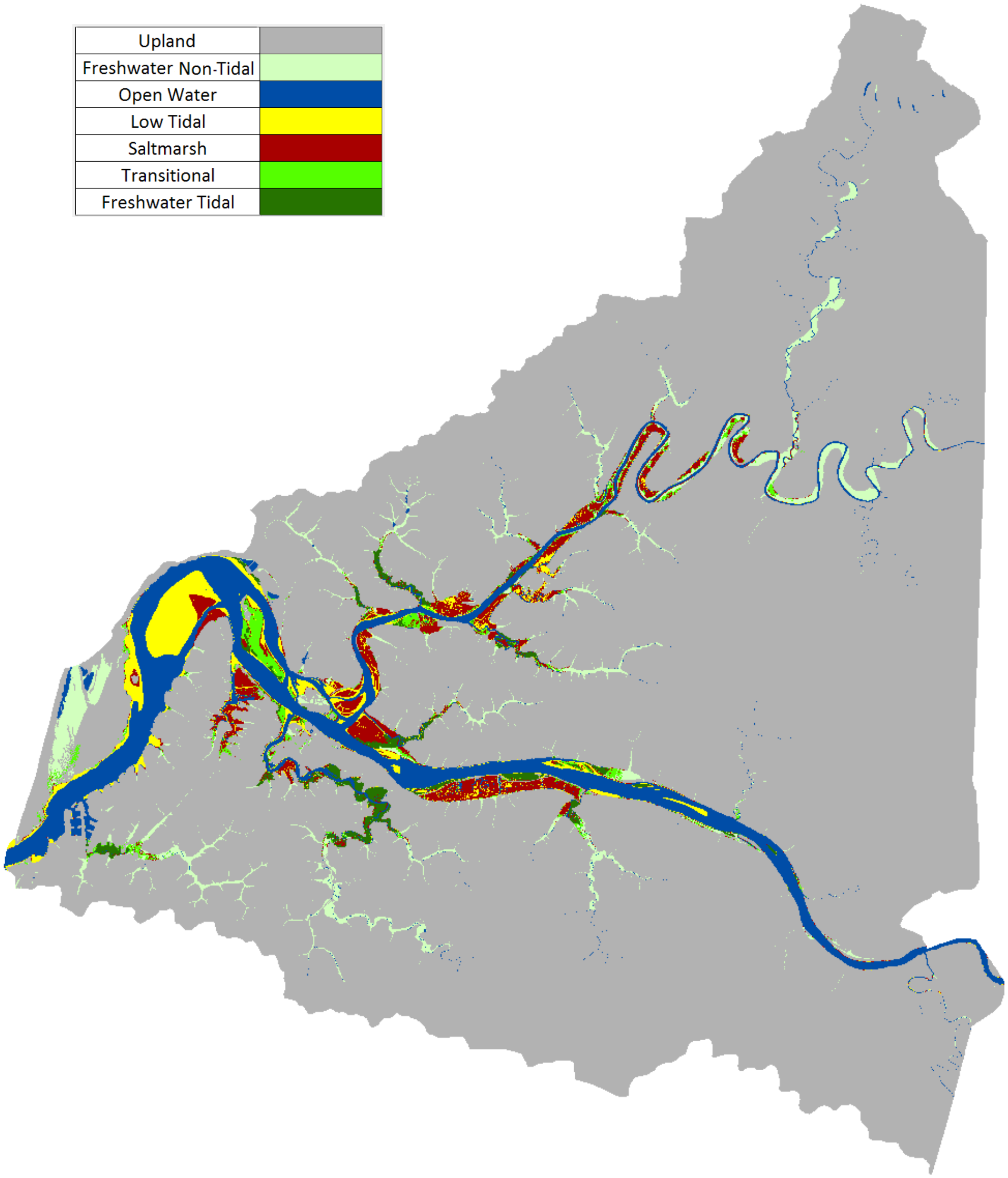

Figure 125. Site 7, 2100, Scenario A1B max (0.69 m) – No Dikes

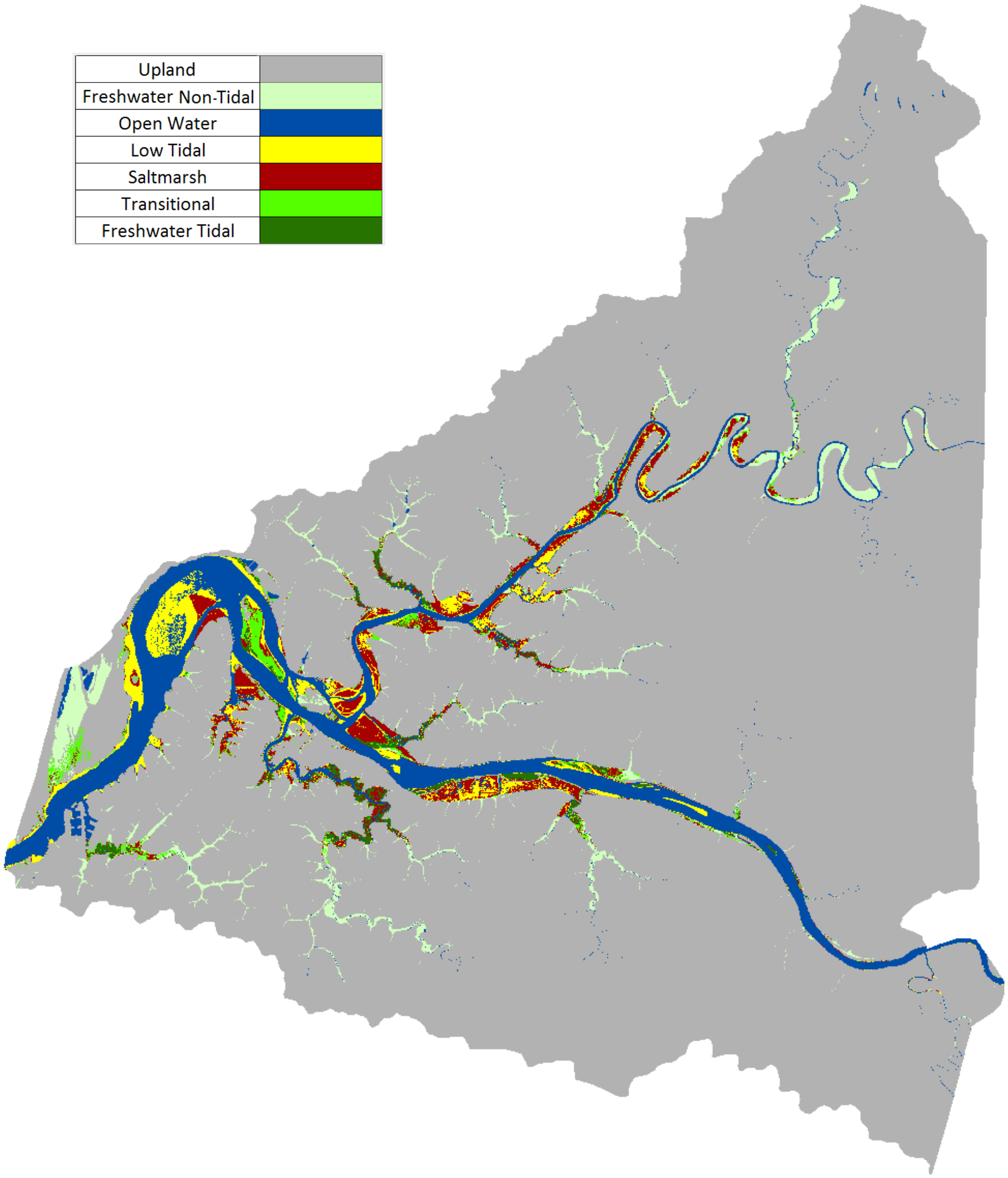

Figure 126. Site 7, 2100, Scenario 1 m – No Dikes

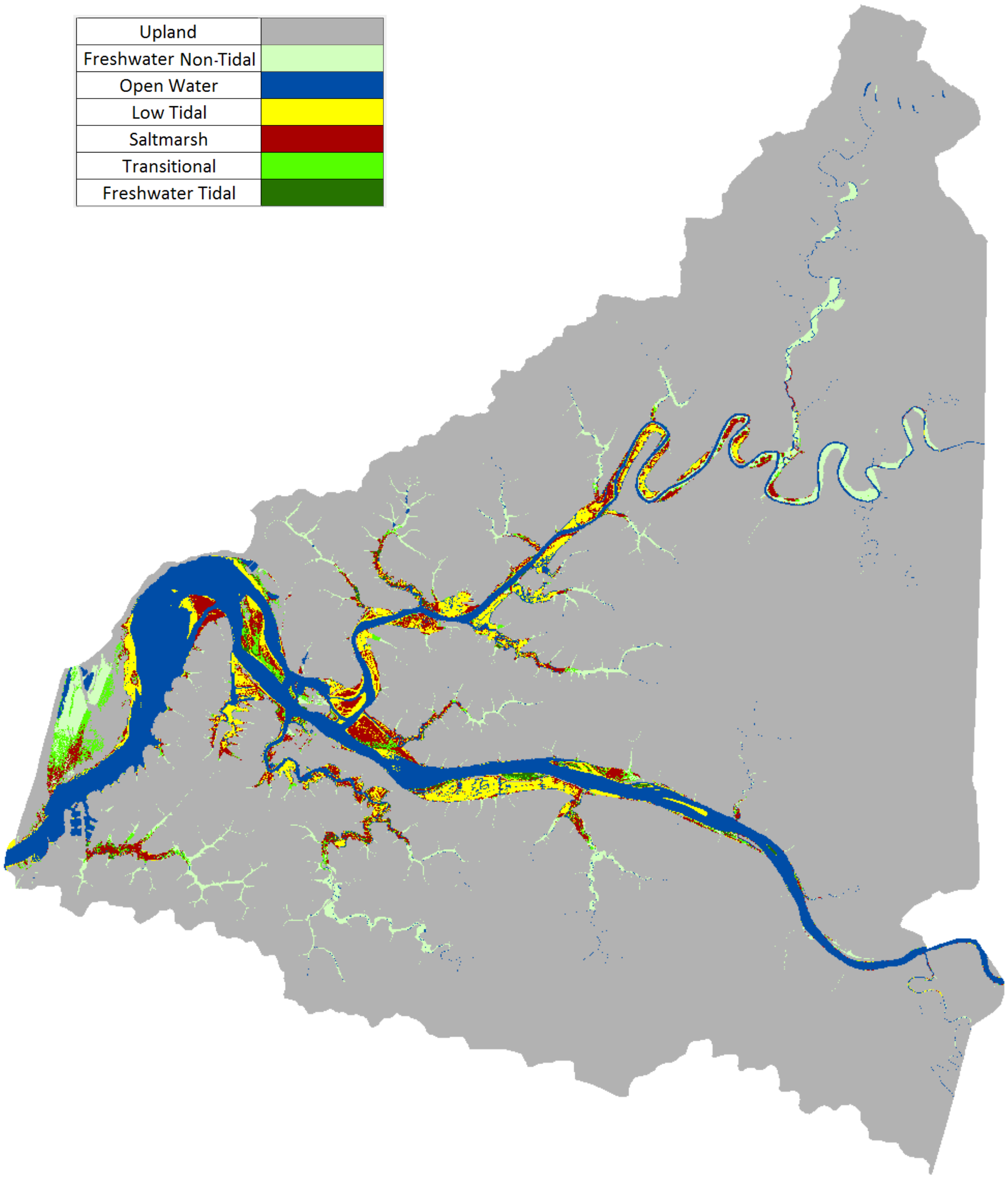

Figure 127. Site 7, 2100, Scenario 1.5 m – No Dikes

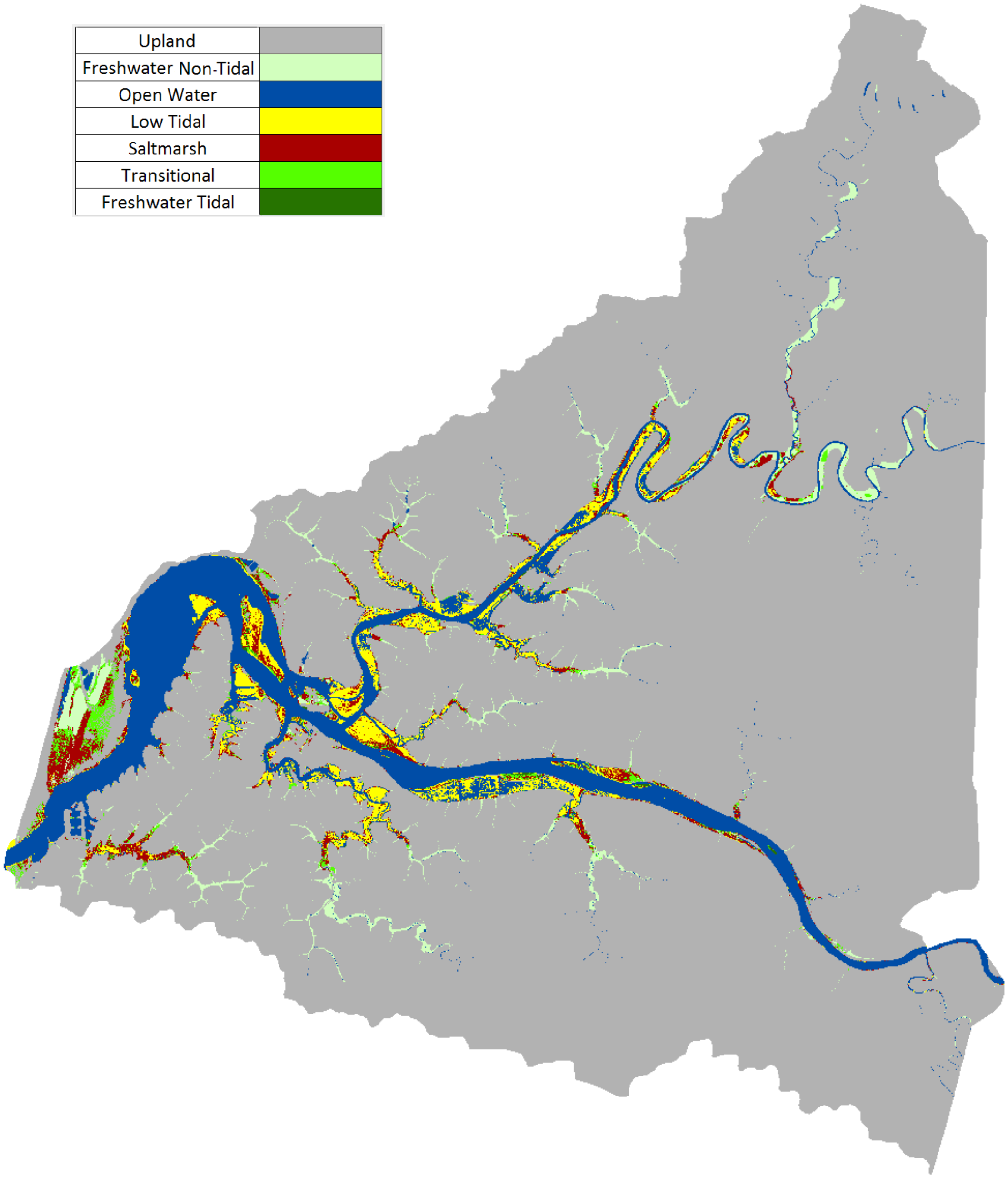

Figure 128. Site 7, 2100, Scenario 2 m – No Dikes

Site 8: Coos

Site 8, covering Coos Bay, composed 16% of the study area. Freshwater non-tidal habitats are the most prevalent wetland type, coving 5% of the study area.

Table 42. Wetland coverage of Site 8 according to the 2002 wetland data

Land cover type	**Area (acres)**	**Percentage (%)**
Upland	286747	88
Open Water	17316	5
Freshwater Non-Tidal	15287	5
Low Tidal	4435	1
Saltmarsh	776	< 1
Transitional	757	< 1
Freshwater Tidal	385	< 1
Total (incl. water)	**325704**	**100**

Several tide gauges are located within the sites which were incorporated into the study area using subsites (see Figure 131). The coastal portion of the study area was assigned a tide range of 2.2 m based on data from the Sitka Dock and Charleston tidal datum stations. The center of Coos Bay was assigned a tide range of 2.4 m based on data from the North Bend tidal datum and Coos Bay tide table predictions. The upstream subsite was assigned a tide range of 1 m based on data collected at Isthmus Slough. Finally, a subsite where the great diurnal tide range was set to zero for the tributaries north of Haynes inlet to reflect the effects of a tide gate near Hauser. The salt elevations were calculated from the inundation analysis conducted at the Charleston NOAA gauge station (#9432780) which was located in this subsite. The salt elevations assigned were: determined to be 1.6 m for the coastal subsite, 0.71 m for the upstream subsite, 1.8 m for the bay center subsite and zero for the subsite where the tide range was set to zero. The historic SLR trend applied to this site was 0.43 mm/yr.

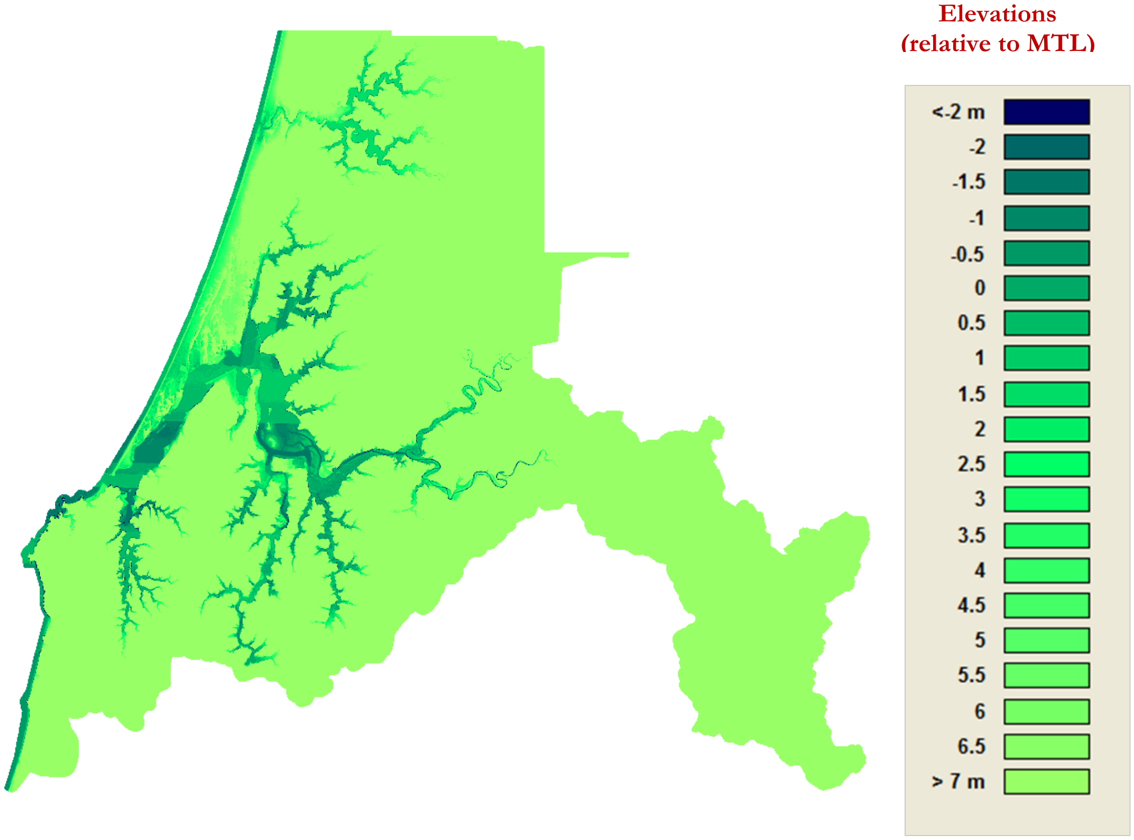

Figure 129. LiDAR elevation data for Site 8 – Coos

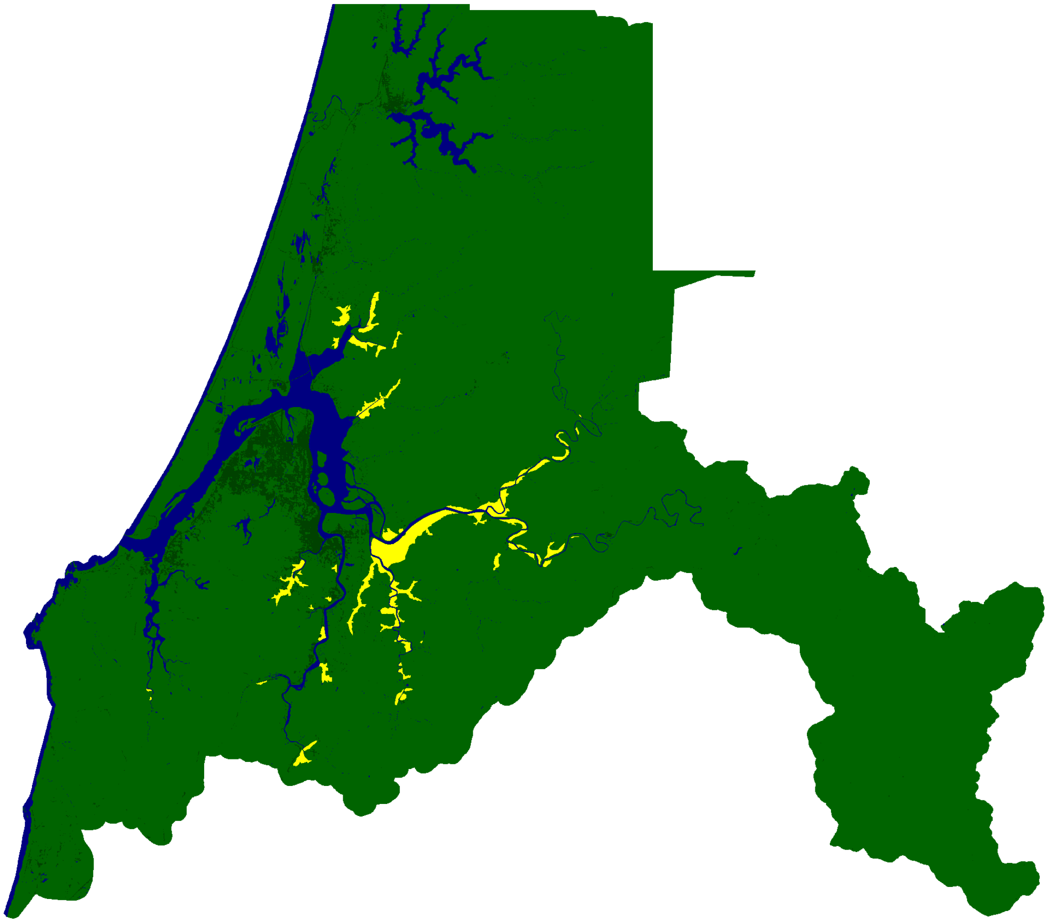

Figure 130. Location of dikes in Site 8 – Coos (shown in yellow)

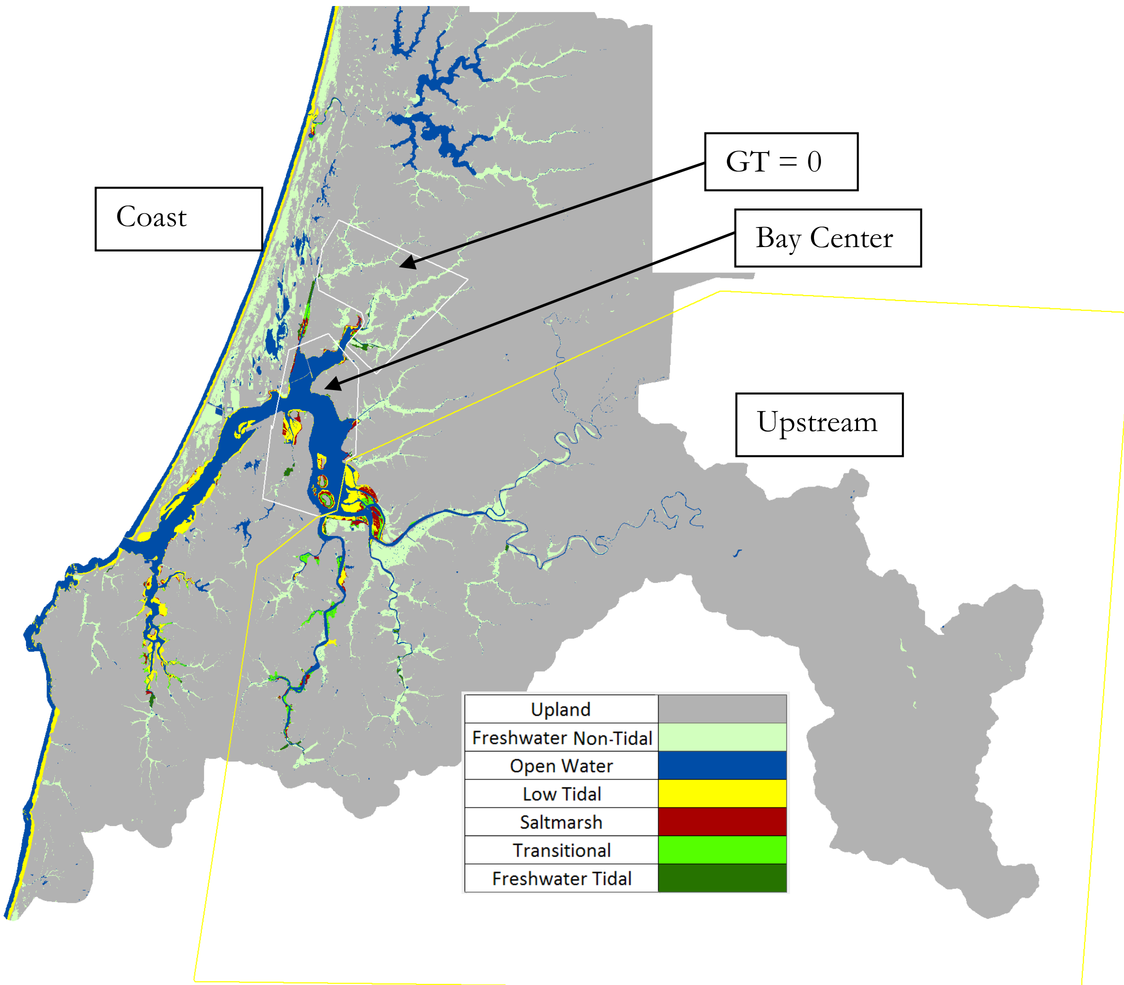

Figure 131. Wetland data for Site 8 – Coos

SLAMM simulations of the Coos Bay estuary indicate the freshwater tidal habitat is the most at-risk wetland type to being lost due to sea-level rise, followed by freshwater non-tidal wetlands. Low tidal wetlands exhibited the largest losses at the mid-range SLR scenarios of 0.69, 1, and 1.5 m by 2100.

Table 43. Predicted Percent Change of Land Categories by 2100 at Site 8 – Coos Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	1	1	1
Open Water	-5	-7	-10	-16	-25
Freshwater Non-Tidal	5	6	8	14	21
Low Tidal	9	14	14	14	11
Freshwater Tidal	6	8	10	19	38
Saltmarsh	-64	-92	-112	-175	-193
Transitional	-69	-81	-116	-182	-237

Simulations run without the dikes included suggest greater losses of the freshwater wetland categories compared to simulations run when dikes were included. In addition, gains of low tidal wetlands are predicted at the mid-range SLR scenarios of 0.69, 1, and 1.5 m by 2100, whereas simulations of these scenarios with dikes included suggested gains.

Table 44. Predicted Percent Change of Land Categories by 2100 at Site 8 – Coos Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	1	1	1
Open Water	-6	-9	-15	-27	-36
Freshwater Non-Tidal	21	23	26	33	38
Low Tidal	1	-11	-14	-2	1
Freshwater Tidal	10	15	20	30	47
Saltmarsh	-270	-242	-205	-219	-231
Transitional	-138	-131	-152	-223	-278

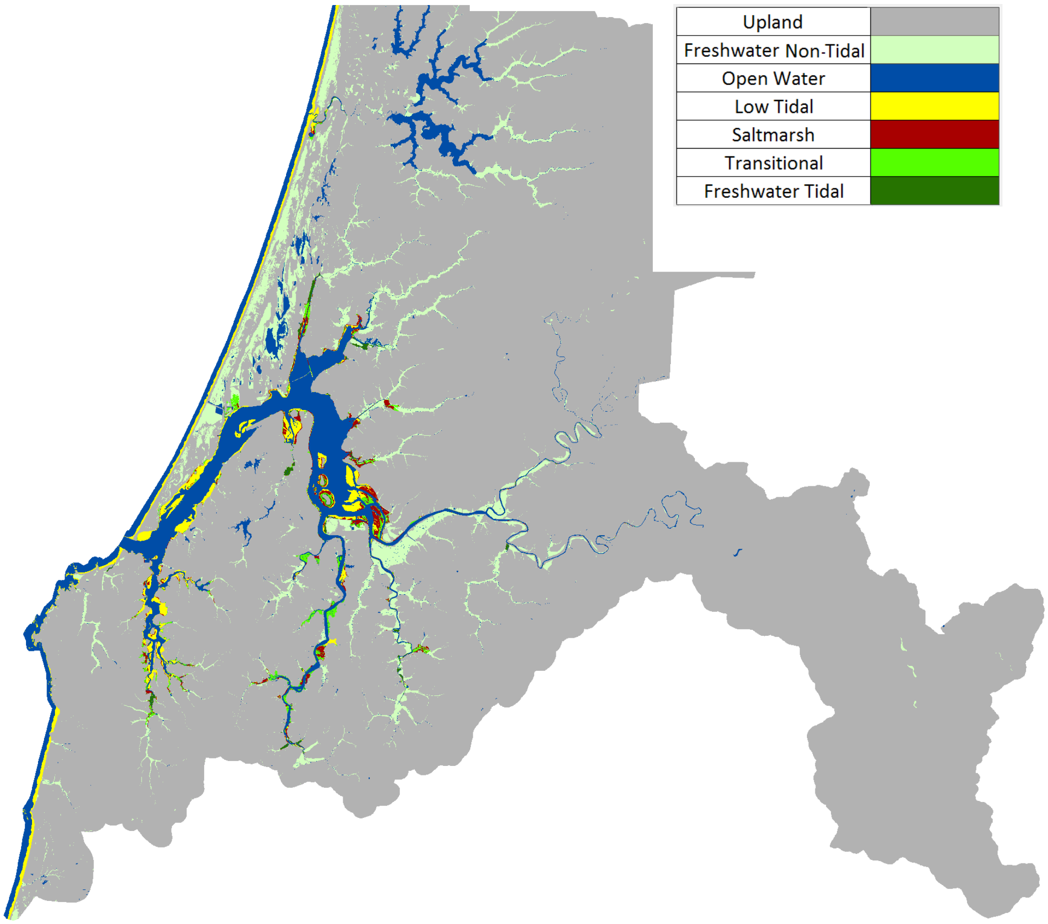

Figure 132. Site 8, 2100, Scenario A1B mean (0.39 m)

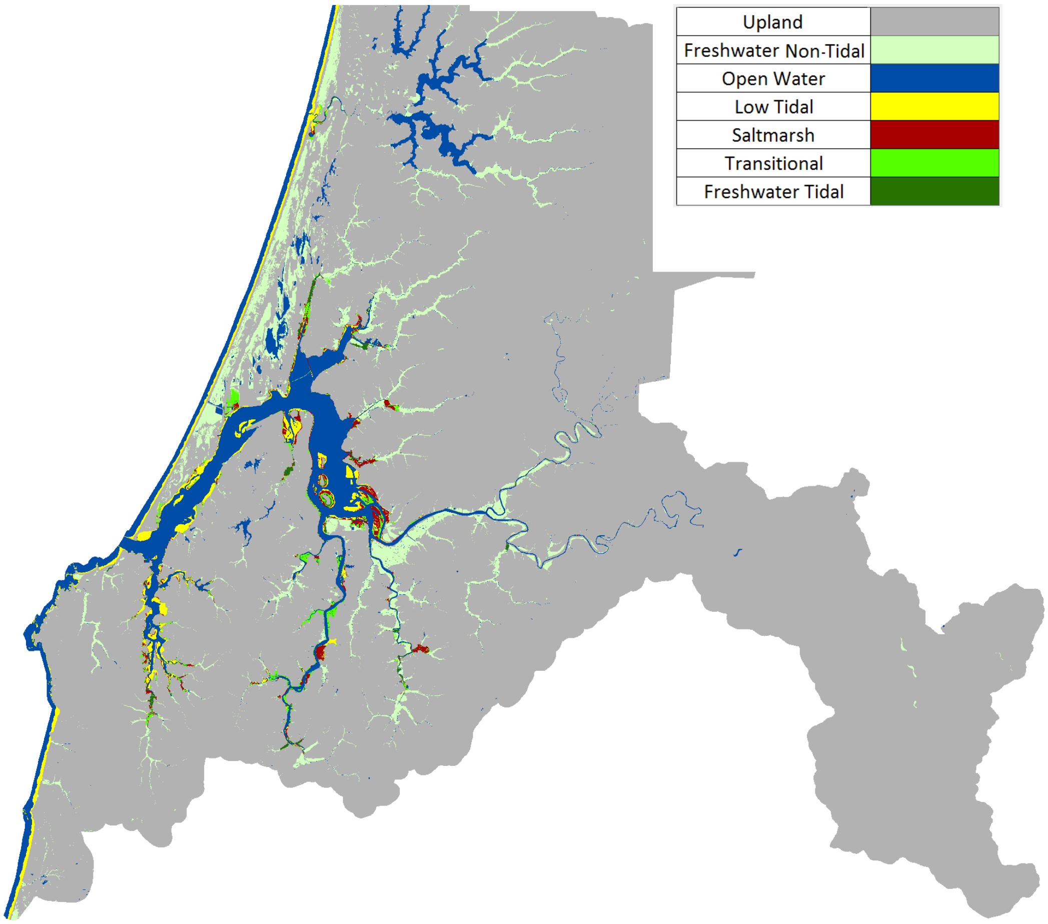

Figure 133. Site 8, 2100, Scenario A1B max (0.69 m)

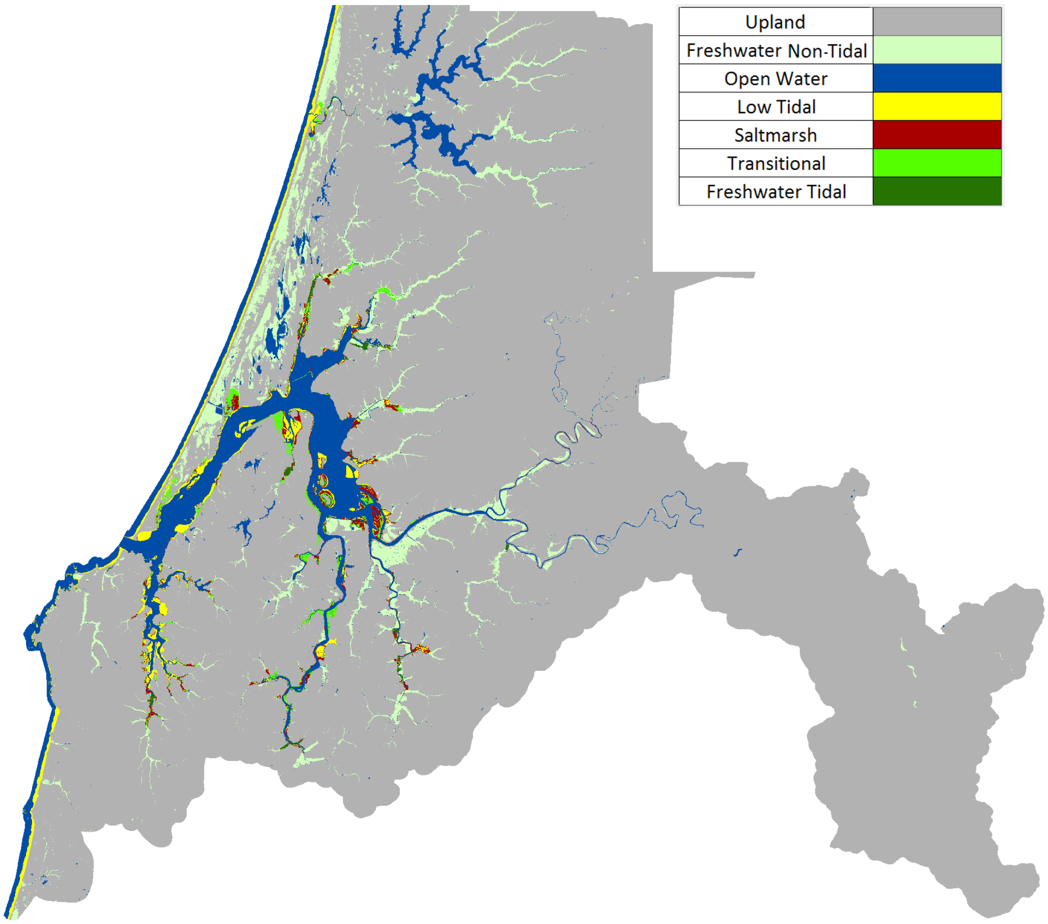

Figure 134. Site 8, 2100, Scenario 1 m

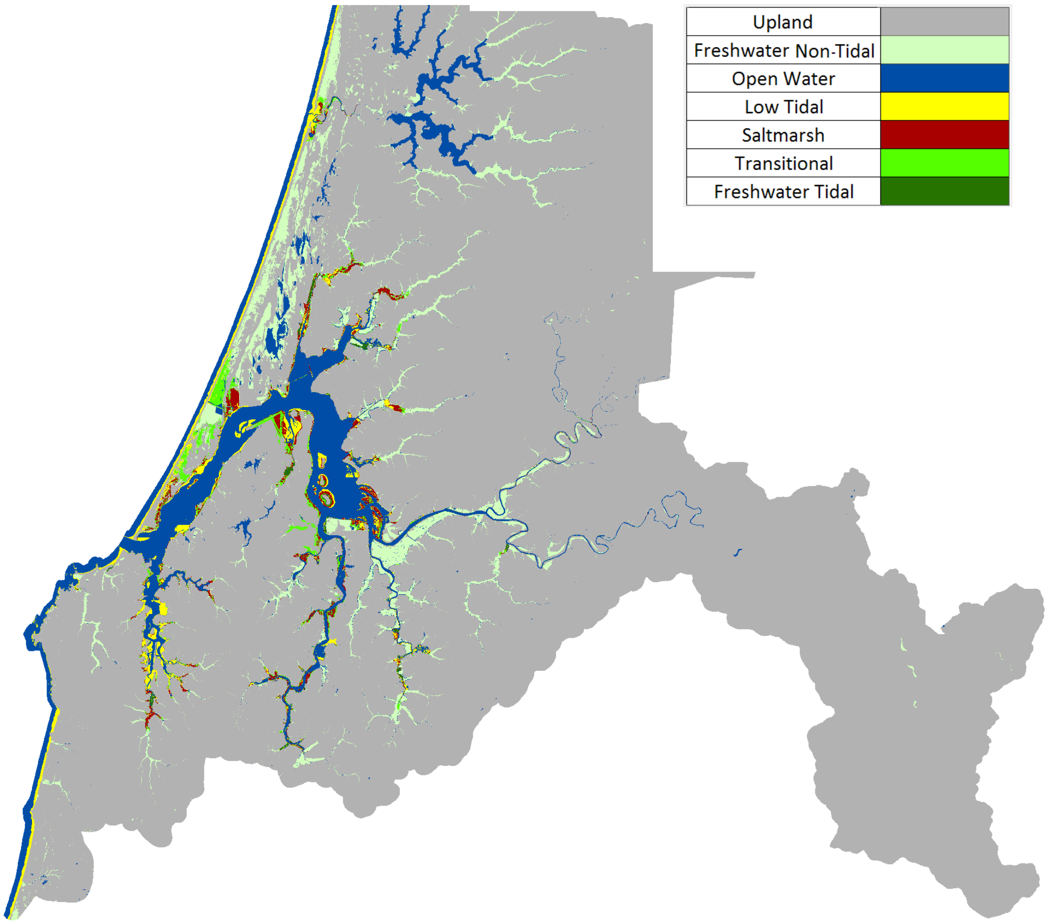

Figure 135. Site 8, 2100, Scenario 1.5 m

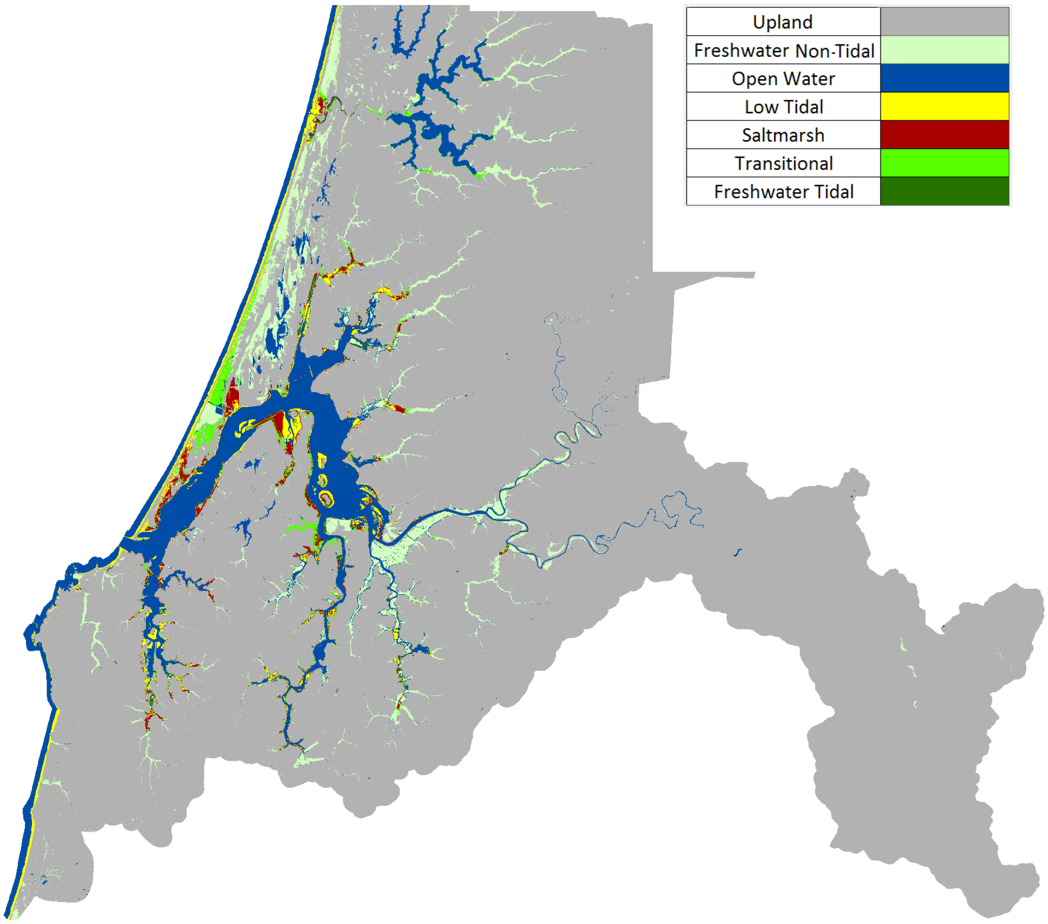

Figure 136. Site 8, 2100, Scenario 2 m

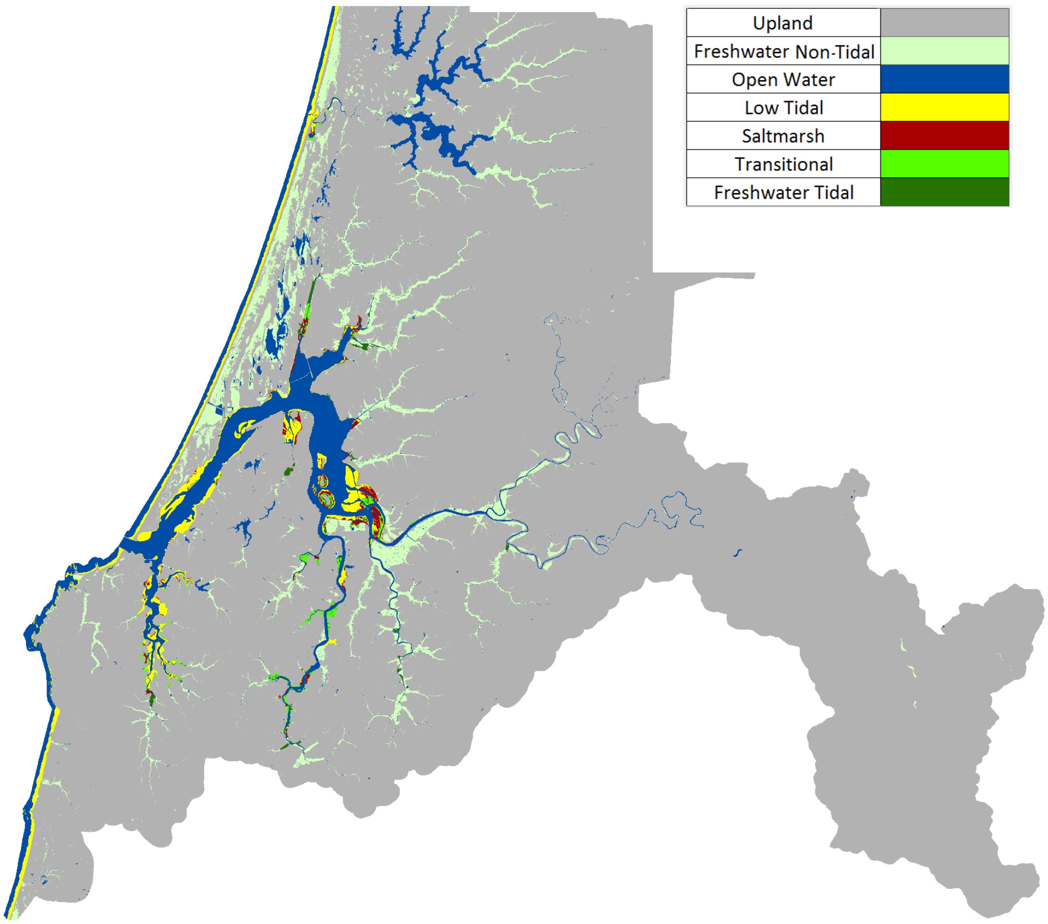

Figure 137. Initial condition wetland data for Site 8 – Coos

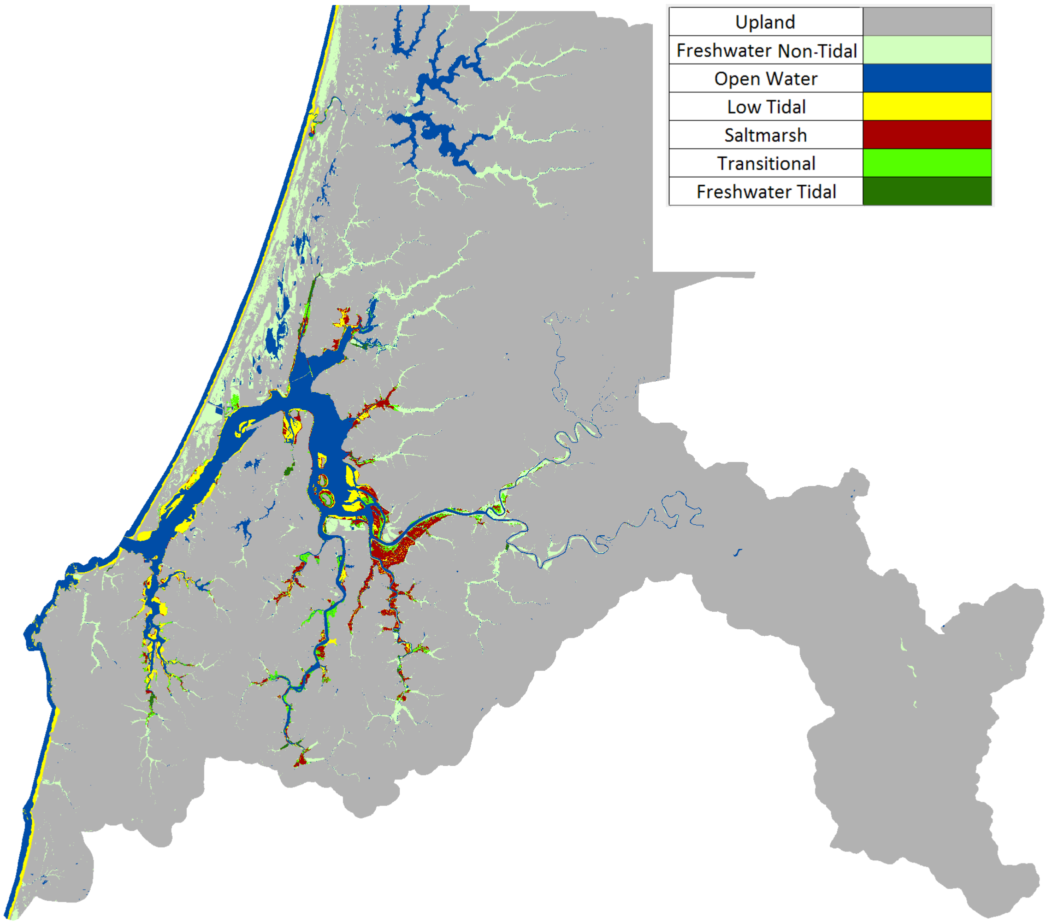

Figure 138. Site 8, 2100, Scenario A1B mean (0.39 m) – No Dikes

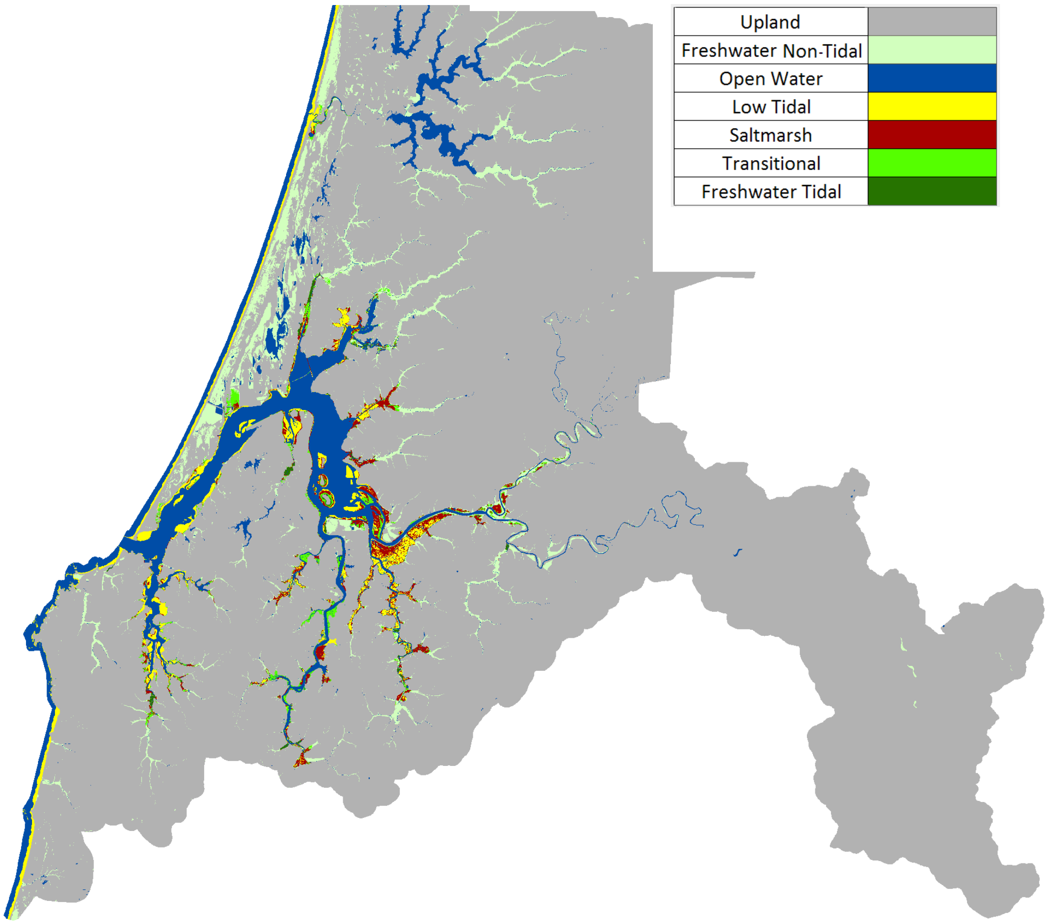

Figure 139. Site 8, 2100, Scenario A1B max (0.69 m) – No Dikes

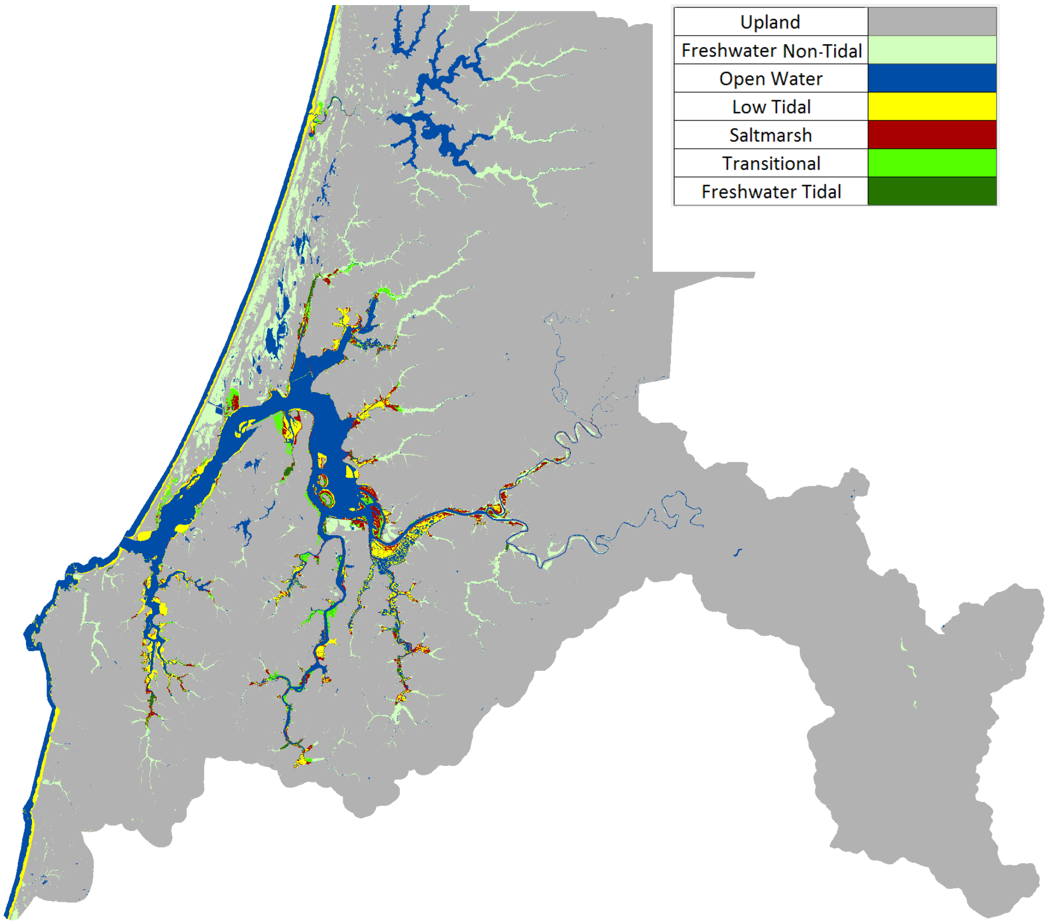

Figure 140. Site 8, 2100, Scenario 1 m – No Dikes

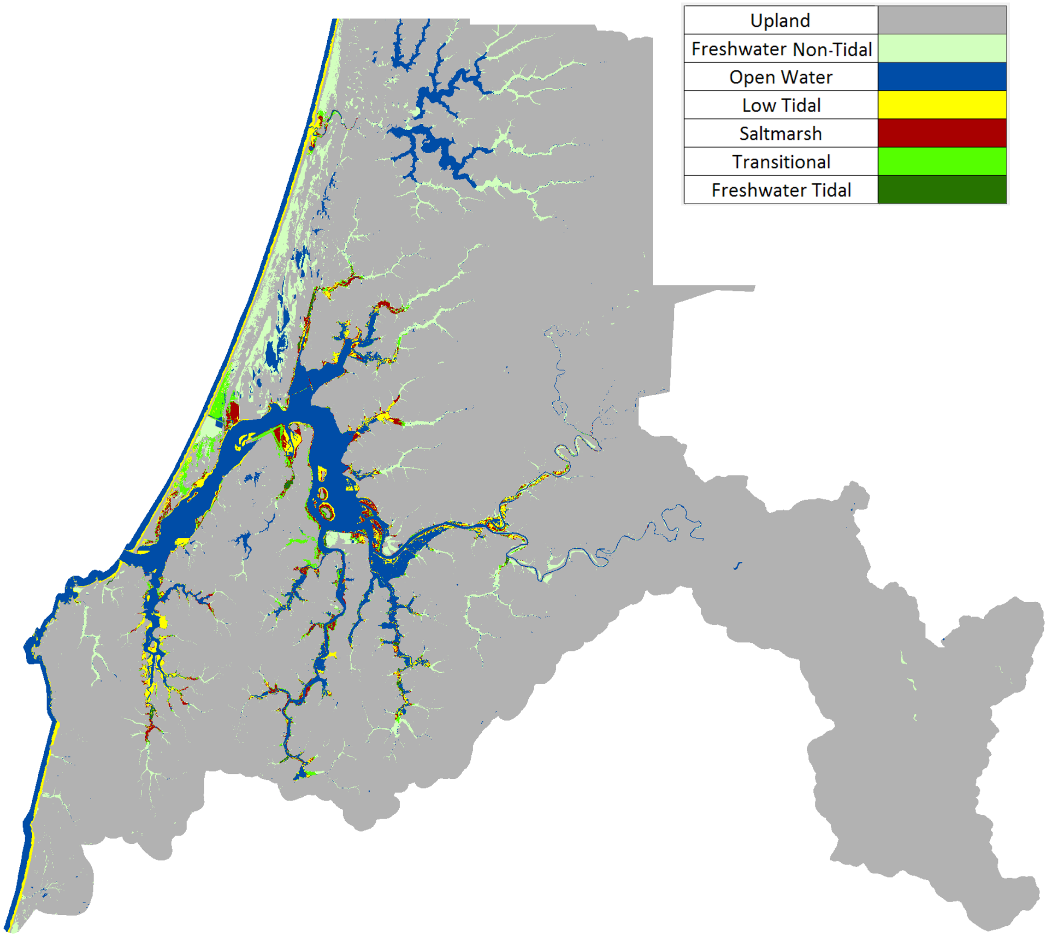

Figure 141. Site 8, 2100, Scenario 1.5 m – No Dikes

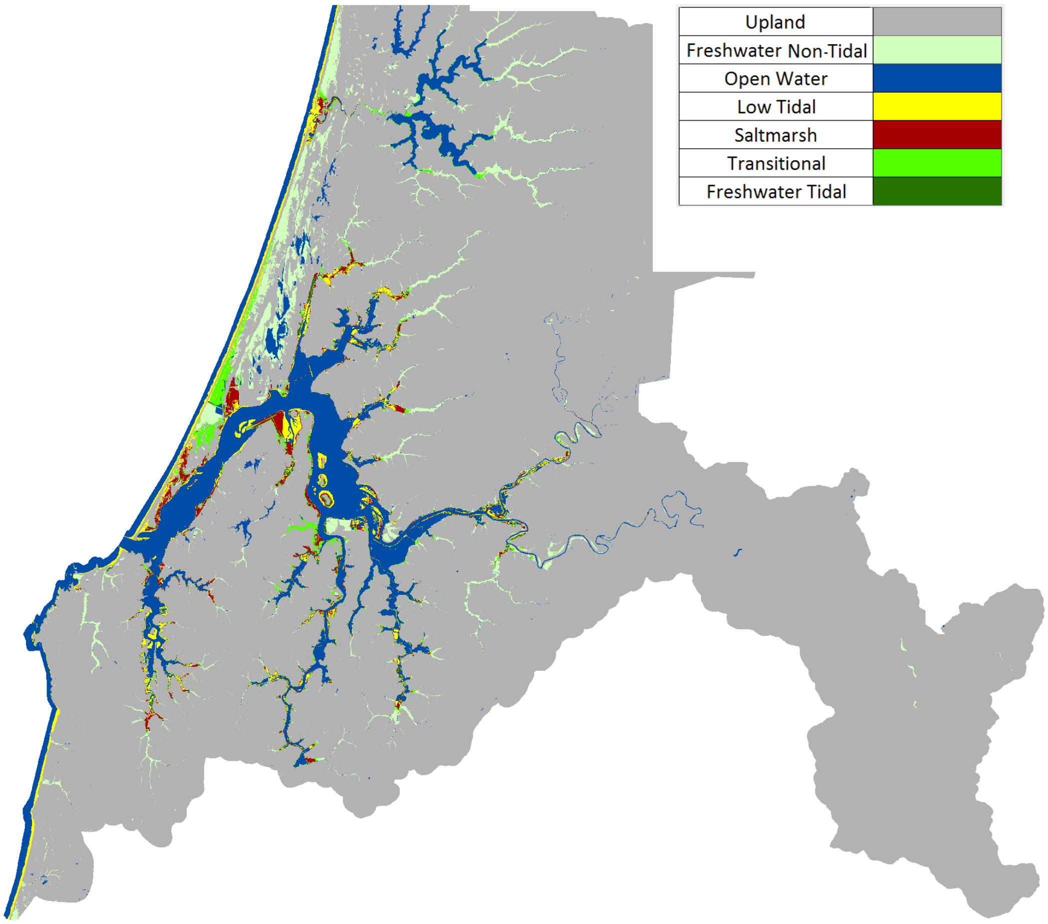

Figure 142. Site 8, 2100, Scenario 2 m – No Dikes

Site 9: Coquille

The wetlands in site 9 – Coquille are dominated by freshwater non-tidal habitat (4% of the study area) followed by much smaller amounts of low tidal, transitional, freshwaters tidal, and salt marsh, as shown in Table 45.

Table 45. Wetland coverage of Site 9 according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	621409	95
Freshwater Non-Tidal	25760	4
Open Water	6133	1
Low Tidal	1413	< 1
Transitional	268	< 1
Freshwater Tidal	245	< 1
Saltmarsh	148	< 1
Total (incl. water)	**655376**	**100**

The elevation data and location of dikes in this site are shown in Figure 49 and Figure 50, respectively. Figure 51 presents the initial wetland data. Only one tide gauge was located in site 9, resulting in the entire study are being assigned a tide range of 2.19 m based on observations made at Bandon marsh on the Coquille River. The salt elevation was calculated from the inundation analysis conducted on data collected from the Charleston NOAA gauge station (#9432780). The historic SLR trend applied to this site was -0.13 mm/yr., suggesting uplift is occurring along this portion of the coast. The SLAMM conceptual model was modified by reducing the lower elevations for tidal swamp (to -0.469 HTU) and tidal-fresh marsh (to 0.491 HTU) based on site –specific elevation data.

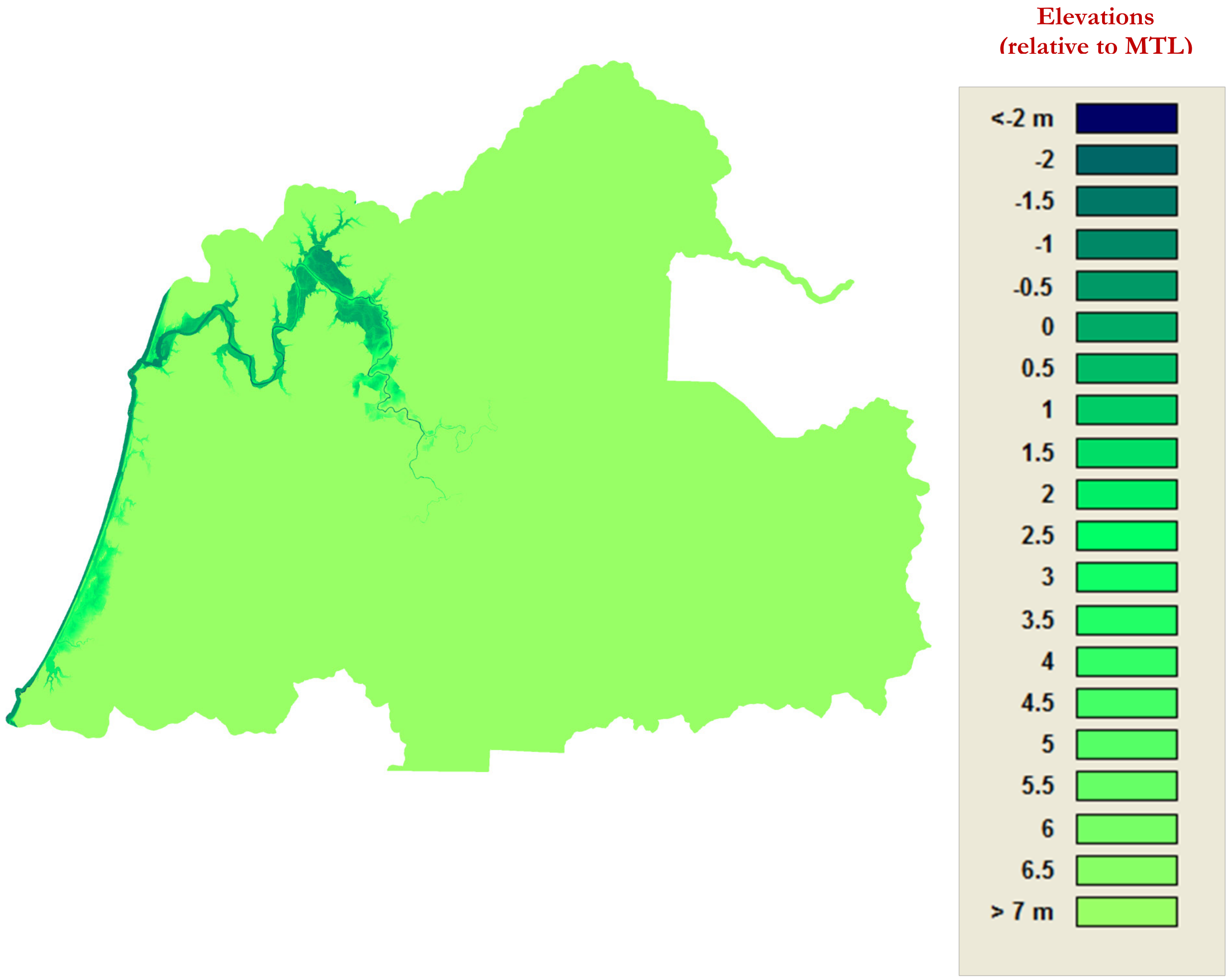

Figure 143. LiDAR elevation data for Site 9 – Coquille

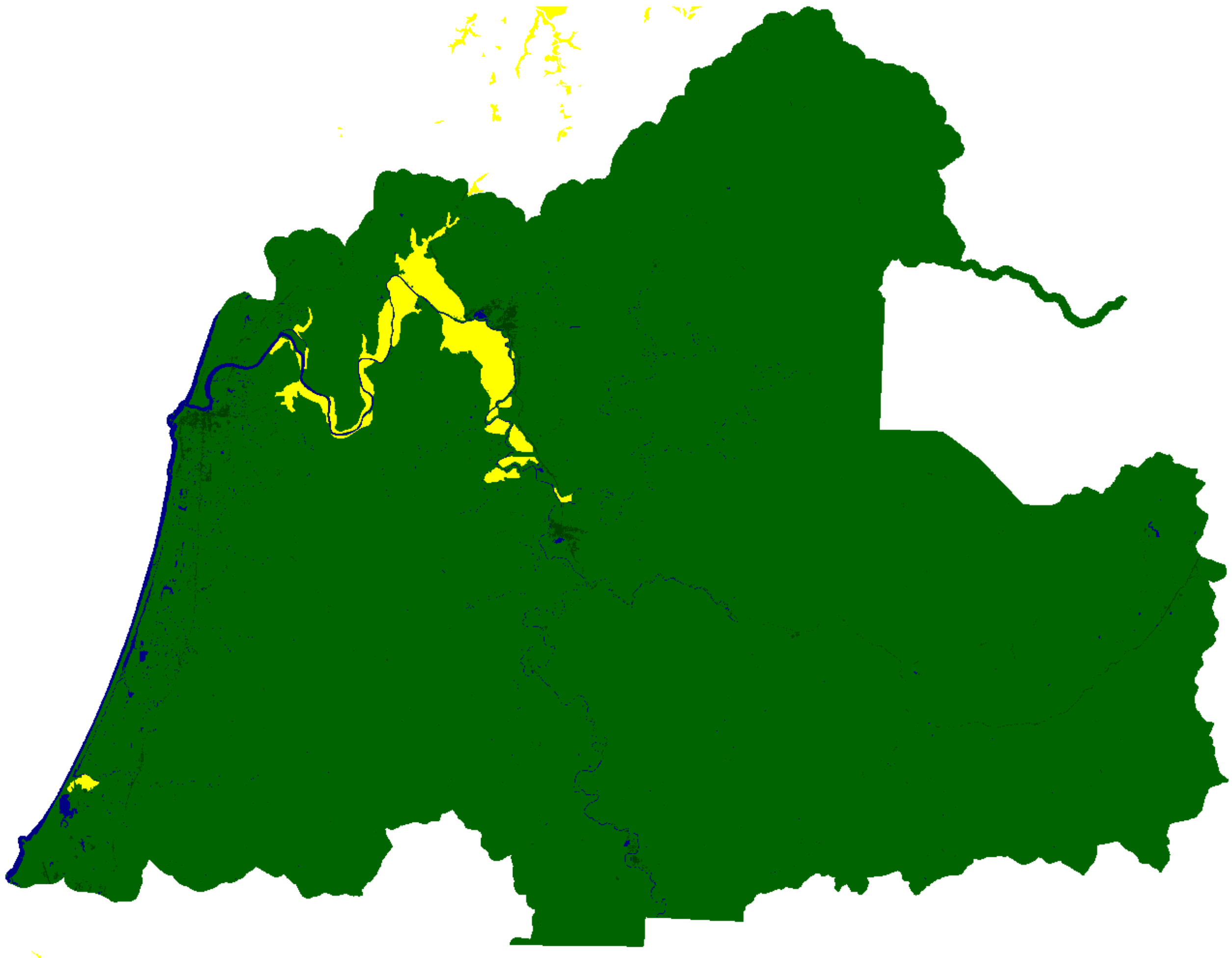

Figure 144. Location of dikes in Site 9– Coquille (shown in yellow)

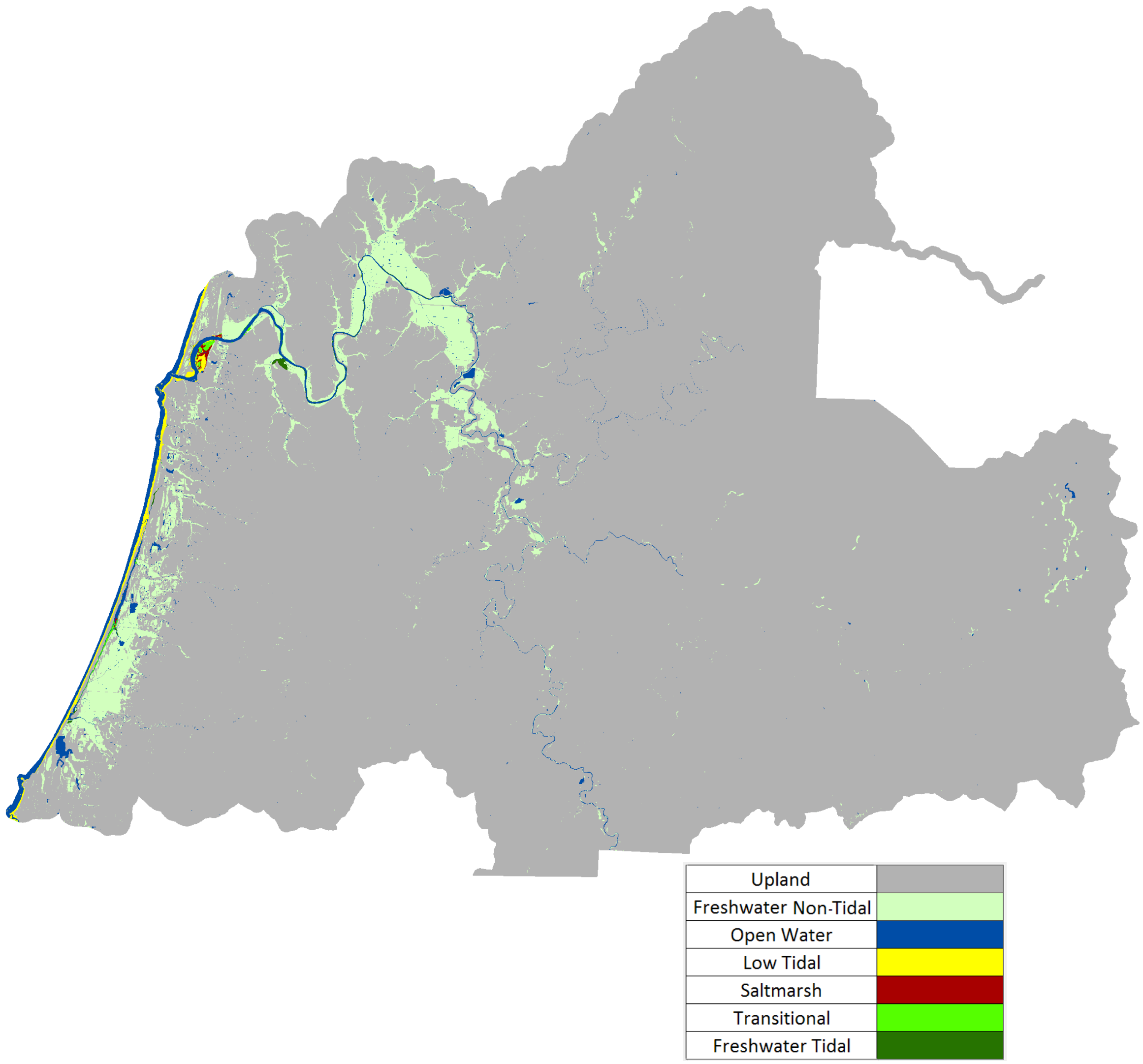

Figure 145. Wetland data for Site 9 – Coquille

SLAMM simulations of the wetlands surrounding the Coquille River indicate the freshwater tidal habitat is the most at-risk wetland type to being lost due to sea-level rise, followed by freshwater non-tidal wetlands.

Table 46. Predicted Percent Change of Land Categories by 2100 at Site 9 – Coquille Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	**Simulated SLR by 2100**				
	0.39 m	**0.69 m**	**1 m**	**1.5 m**	**2 m**
Upland	0	0	0	0	0
Freshwater Non-Tidal	3	4	4	6	10
Open Water	-3	-4	-6	-10	-17
Low Tidal	4	1	-1	-9	-46
Transitional	-203	-158	-131	-195	-286
Freshwater Tidal	5	8	11	17	24
Saltmarsh	-247	-425	-567	-713	-682

The same set of SLR scenarios was run with the dikes removed to assess the potential effects of dike removal on wetland distribution. The results of this analysis, presented in Table 47, indicate dike removal would lead to greater losses in freshwater tidal, non-tidal and greater gains in low tidal, transitional and salt marshes.

Table 47. Predicted Percent Change of Land Categories by 2100 at Site 9 – Coquille Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	**Simulated SLR by 2100**				
	0.39 m	**0.69 m**	**1 m**	**1.5 m**	**2 m**
Upland	0	0	0	0	0
Freshwater Non-Tidal	30	31	33	37	41
Open Water	-4	-4	-6	-20	-53
Low Tidal	-32	-92	-188	-300	-325
Transitional	-810	-548	-407	-414	-490
Freshwater Tidal	6	10	14	22	40
Saltmarsh	-3465	-3668	-3358	-2572	-1778

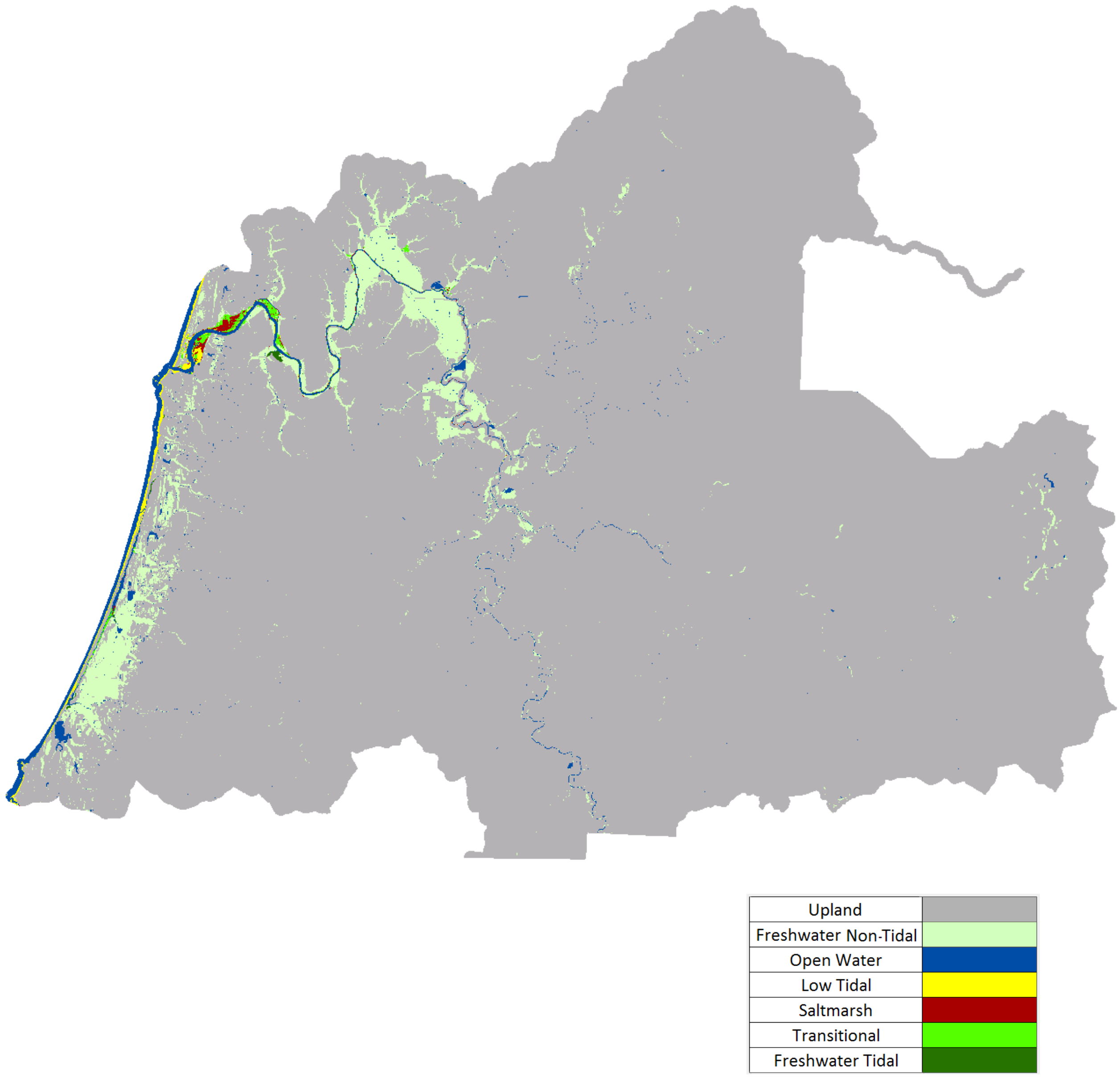

Figure 146. Site 9, 2100, Scenario A1B Mean

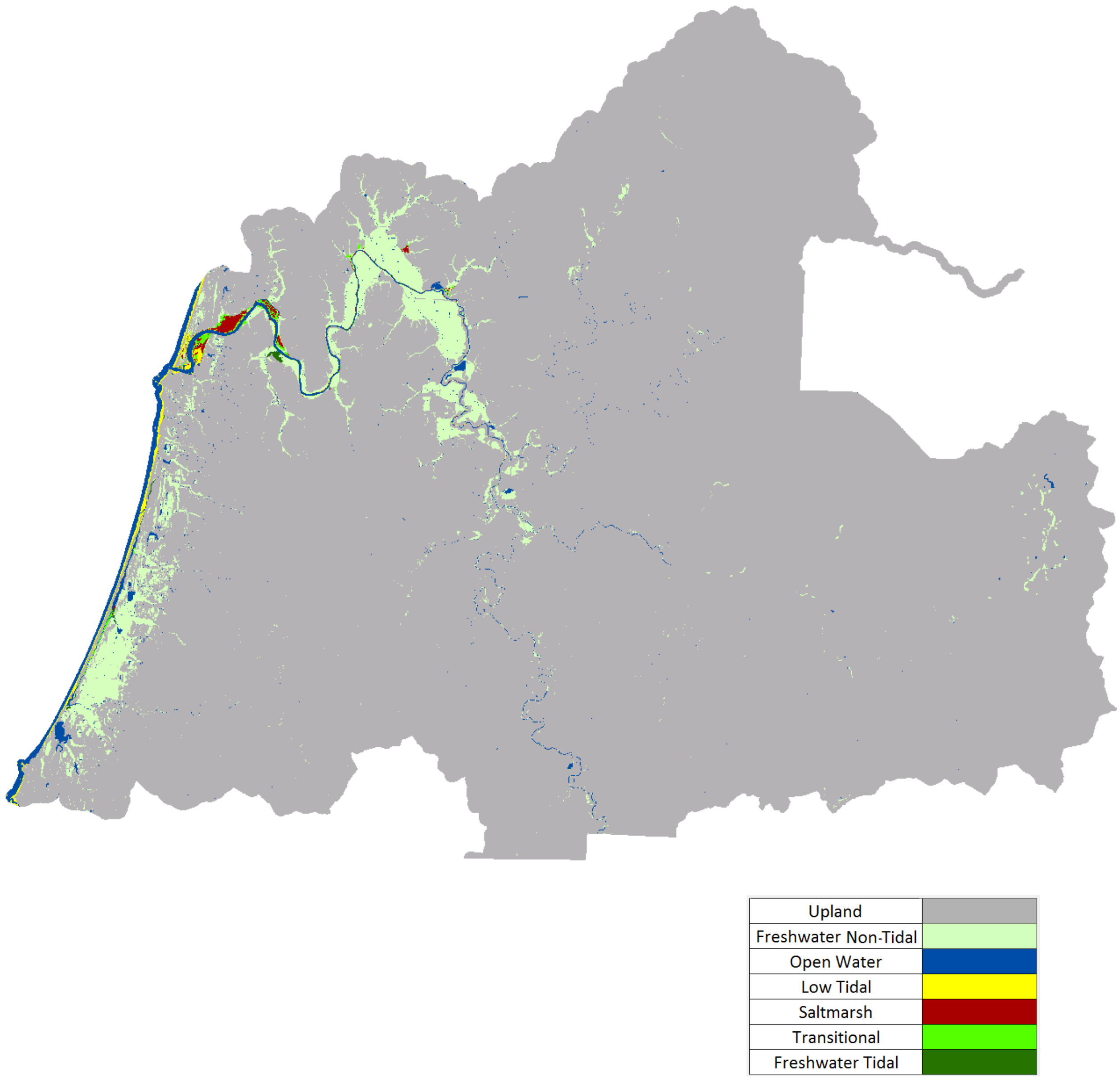

Figure 147. Site 9, 2100, Scenario A1B Max

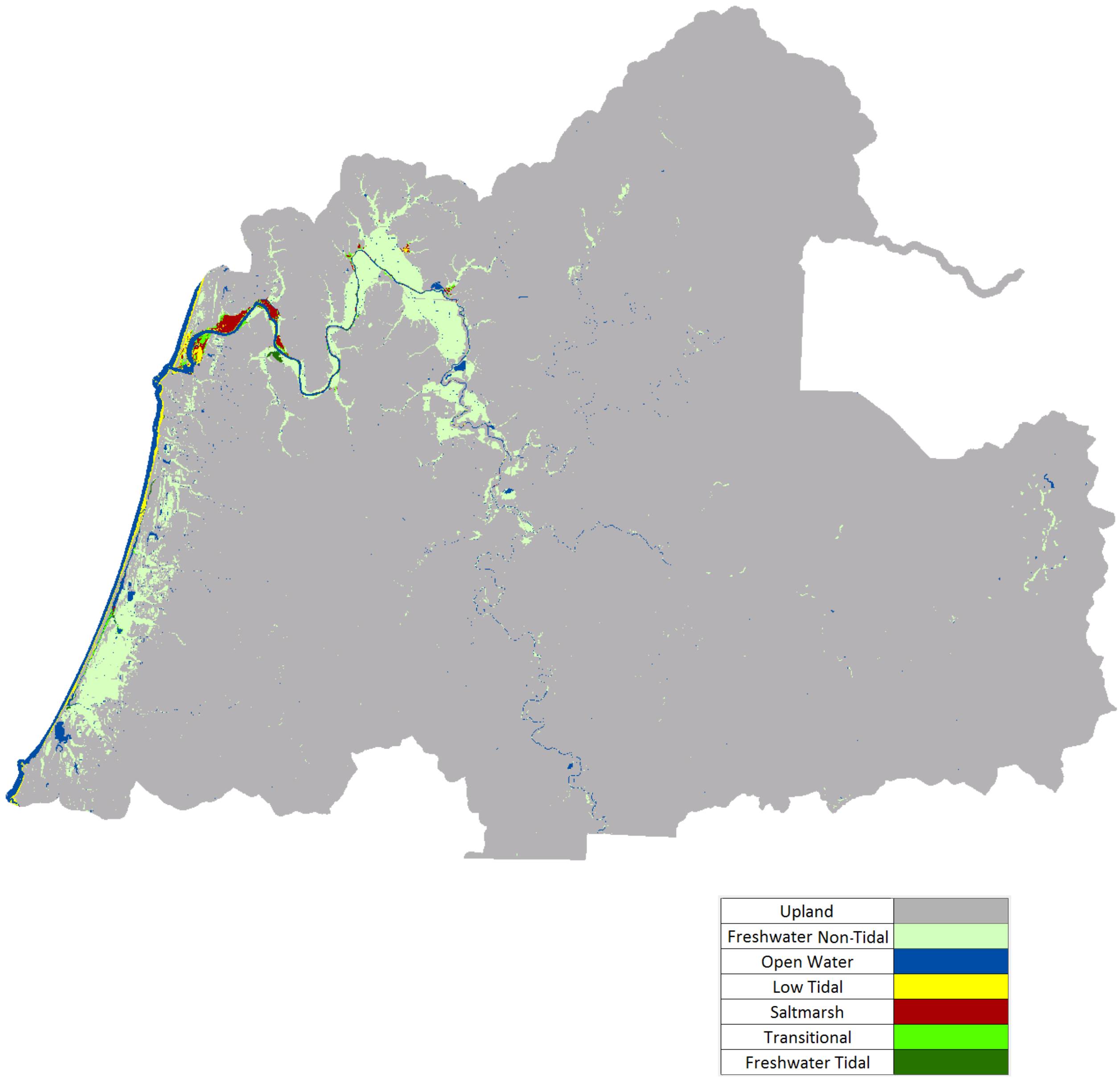

Figure 148. Site 9, 2100, Scenario 1 m

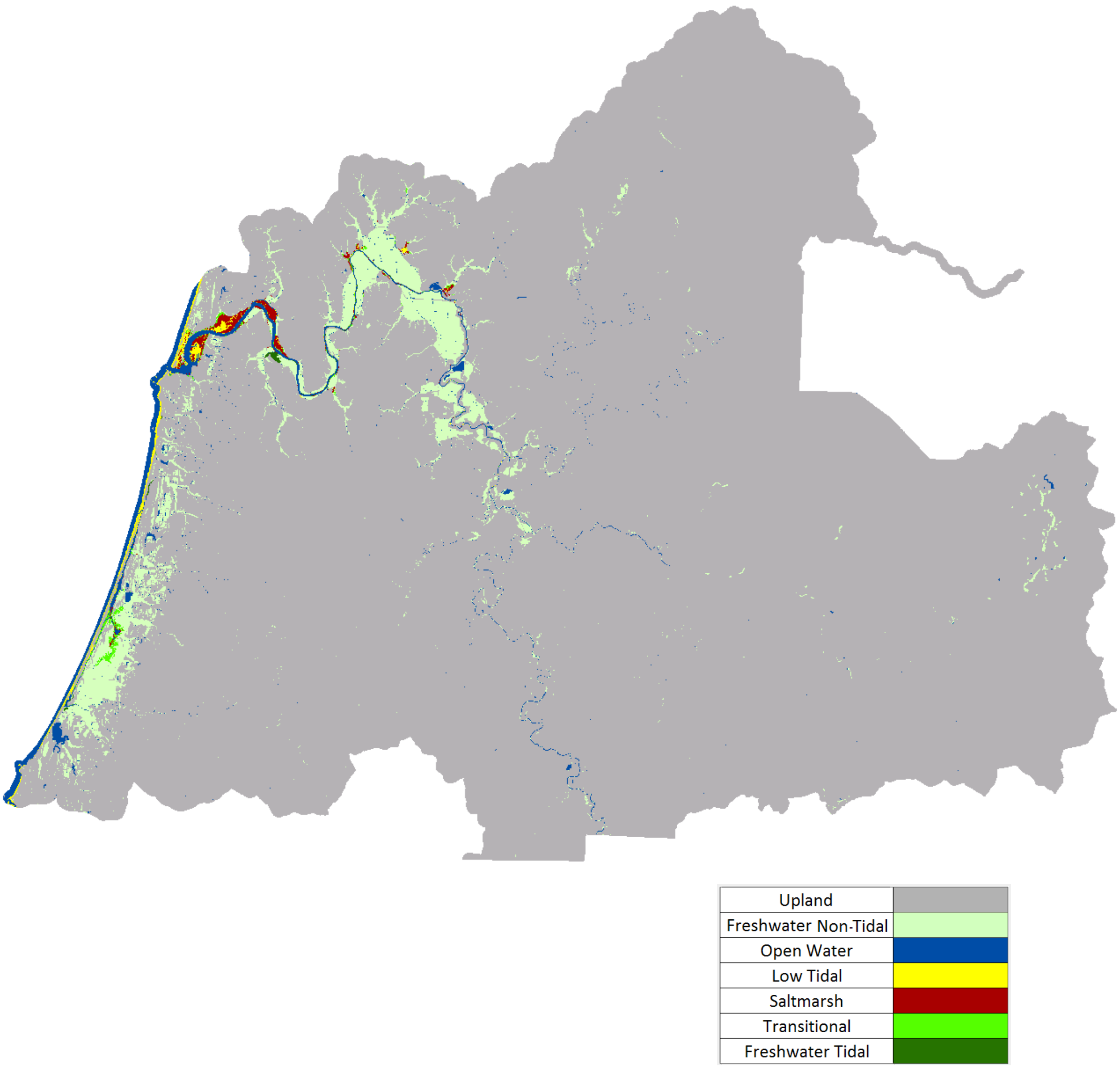

Figure 149. Site 9, 2100, Scenario 1.5 m

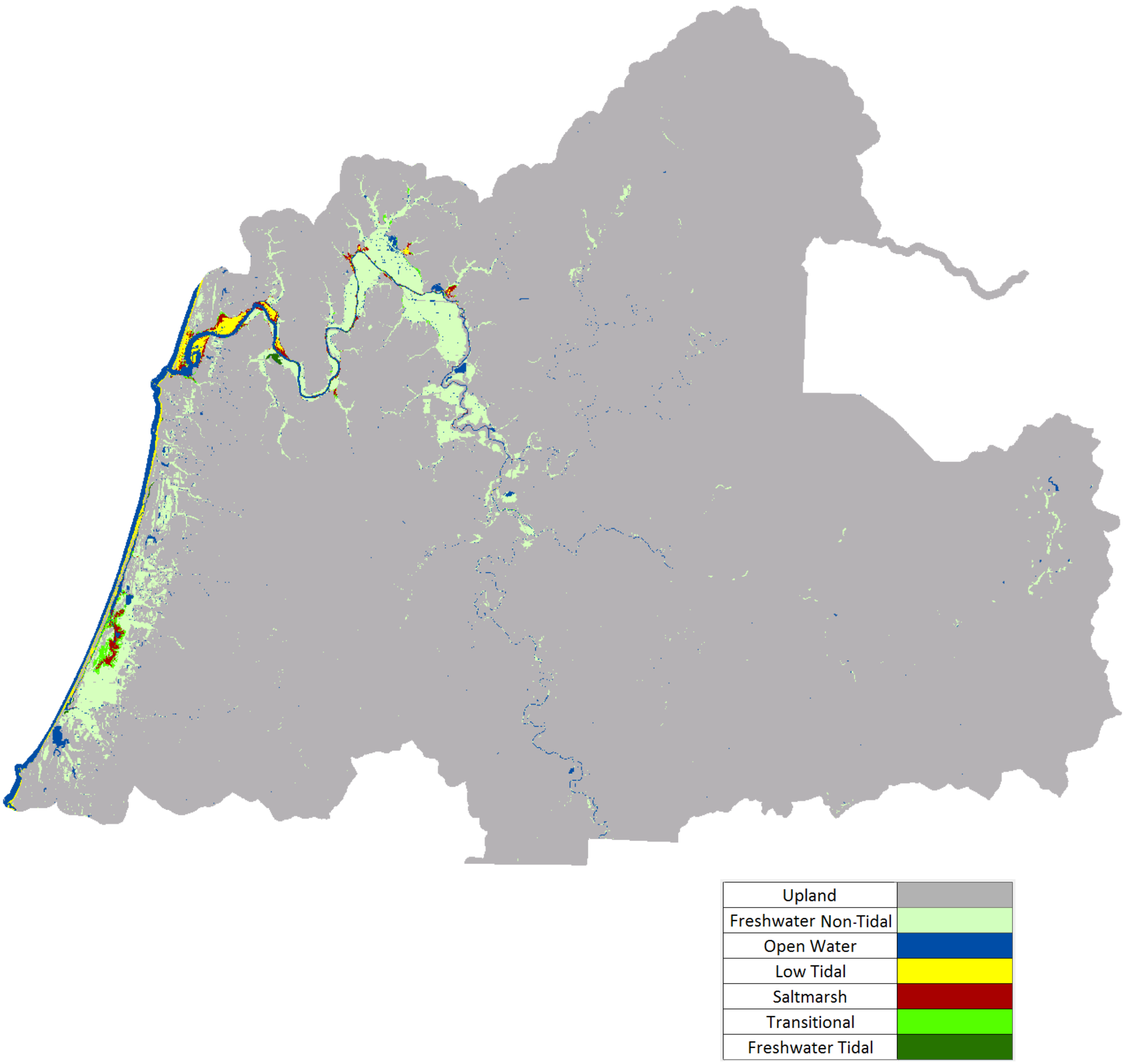

Figure 150. Site 9, 2100, Scenario 2 m

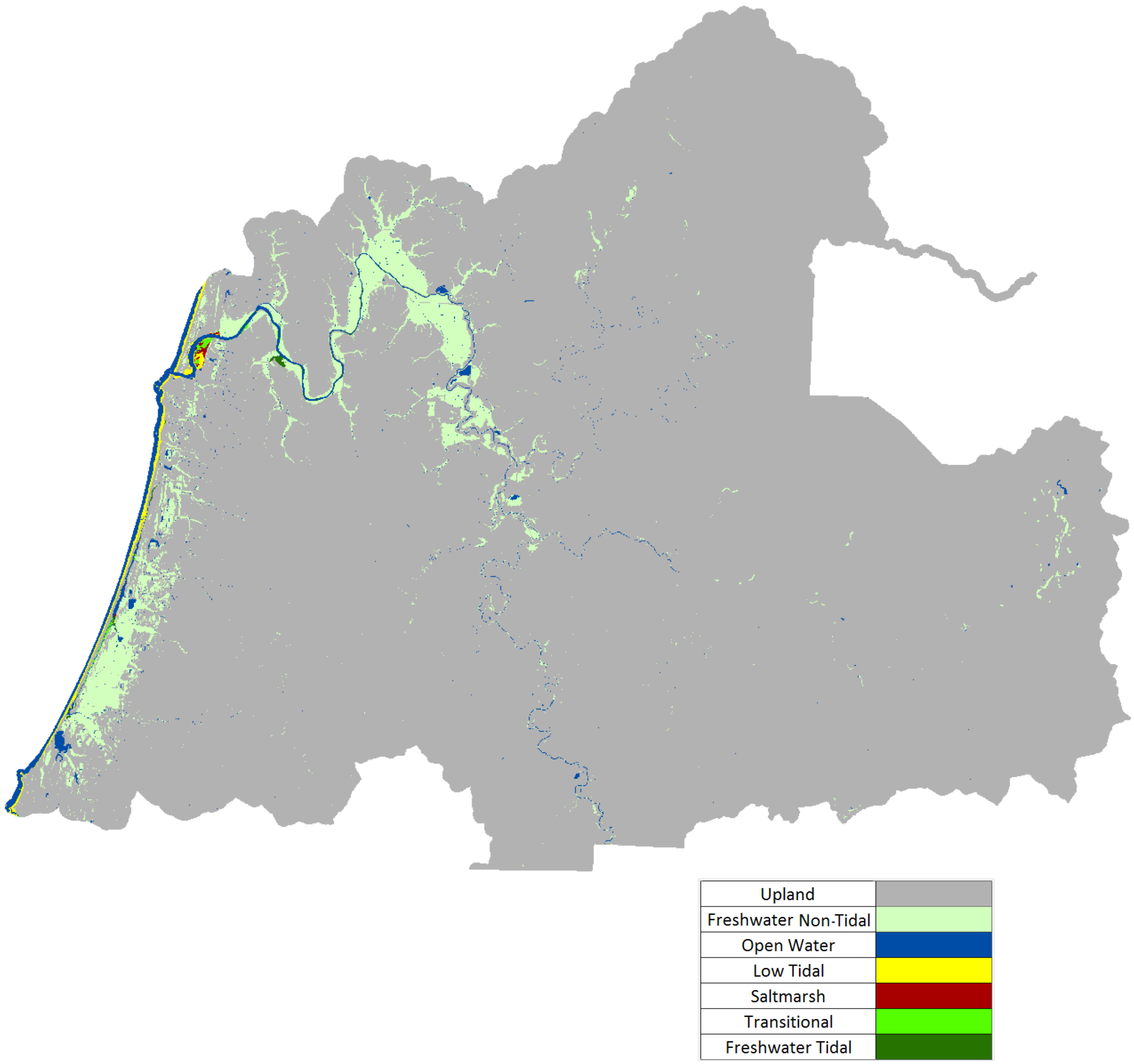

Figure 151. Initial Condition Wetland Data for 9 – Coquille

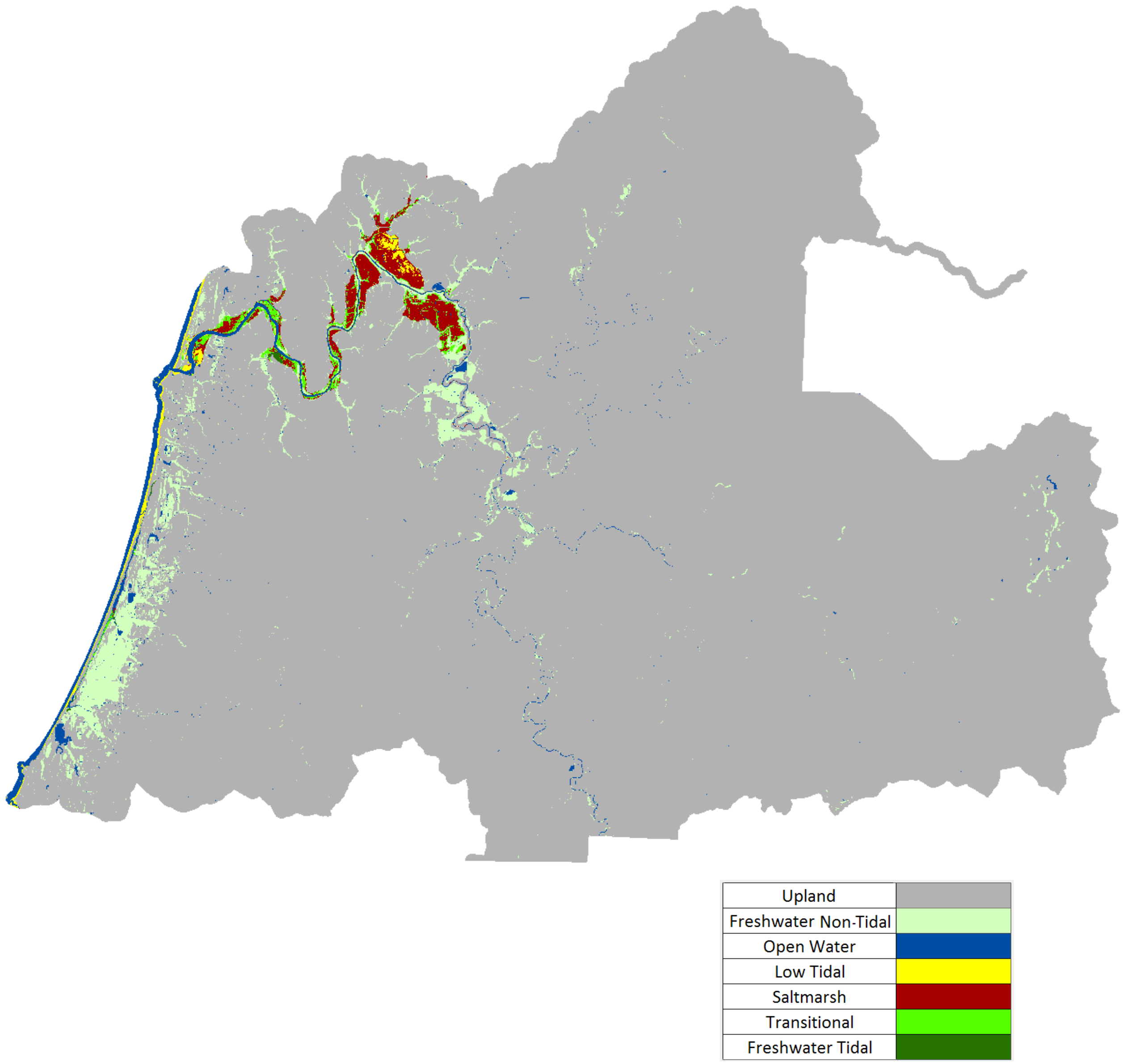

Figure 152. Site 9, 2100, Scenario A1B Mean – No Dikes

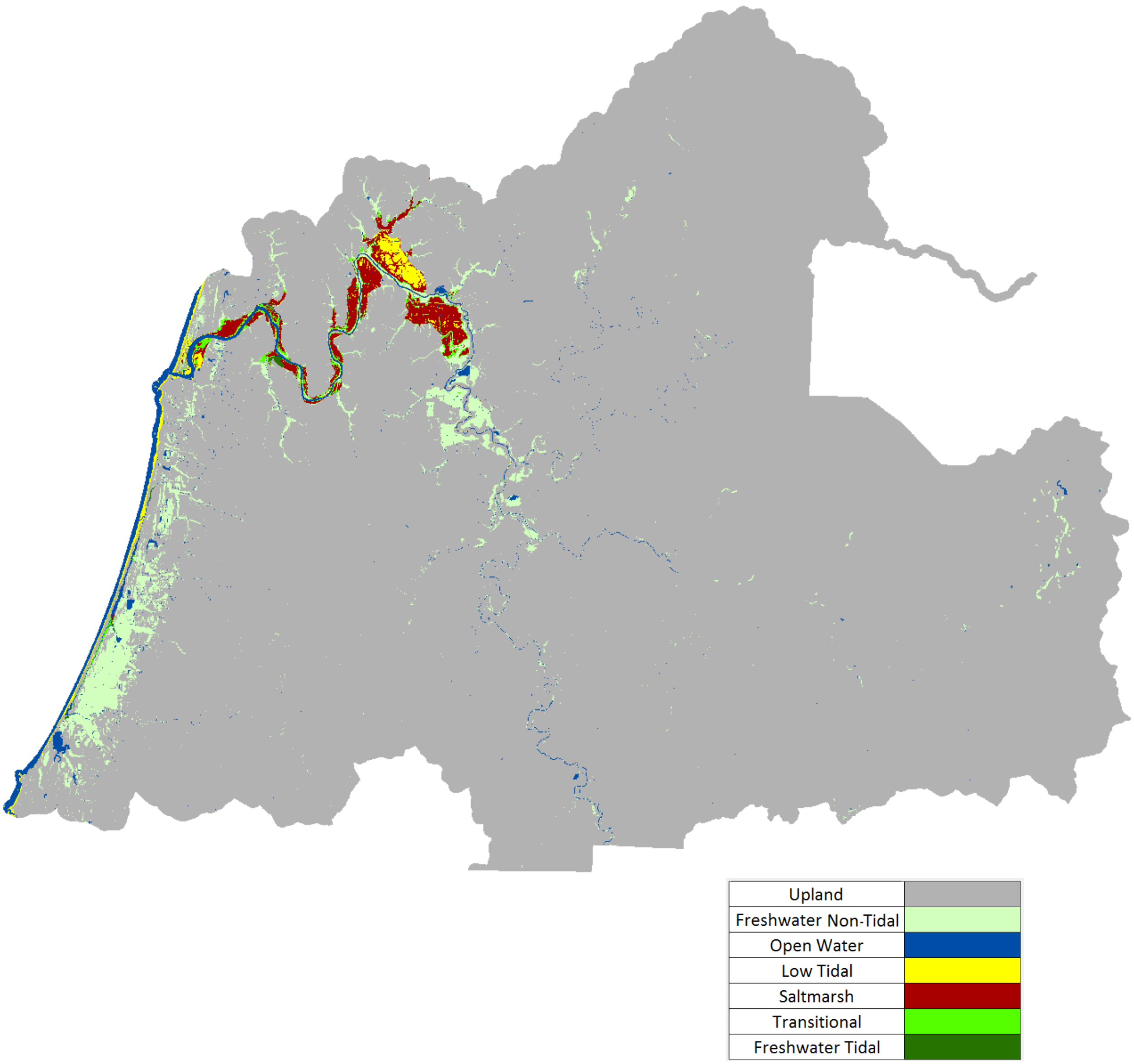

Figure 153. Site 9, 2100, Scenario A1B Max – No Dikes

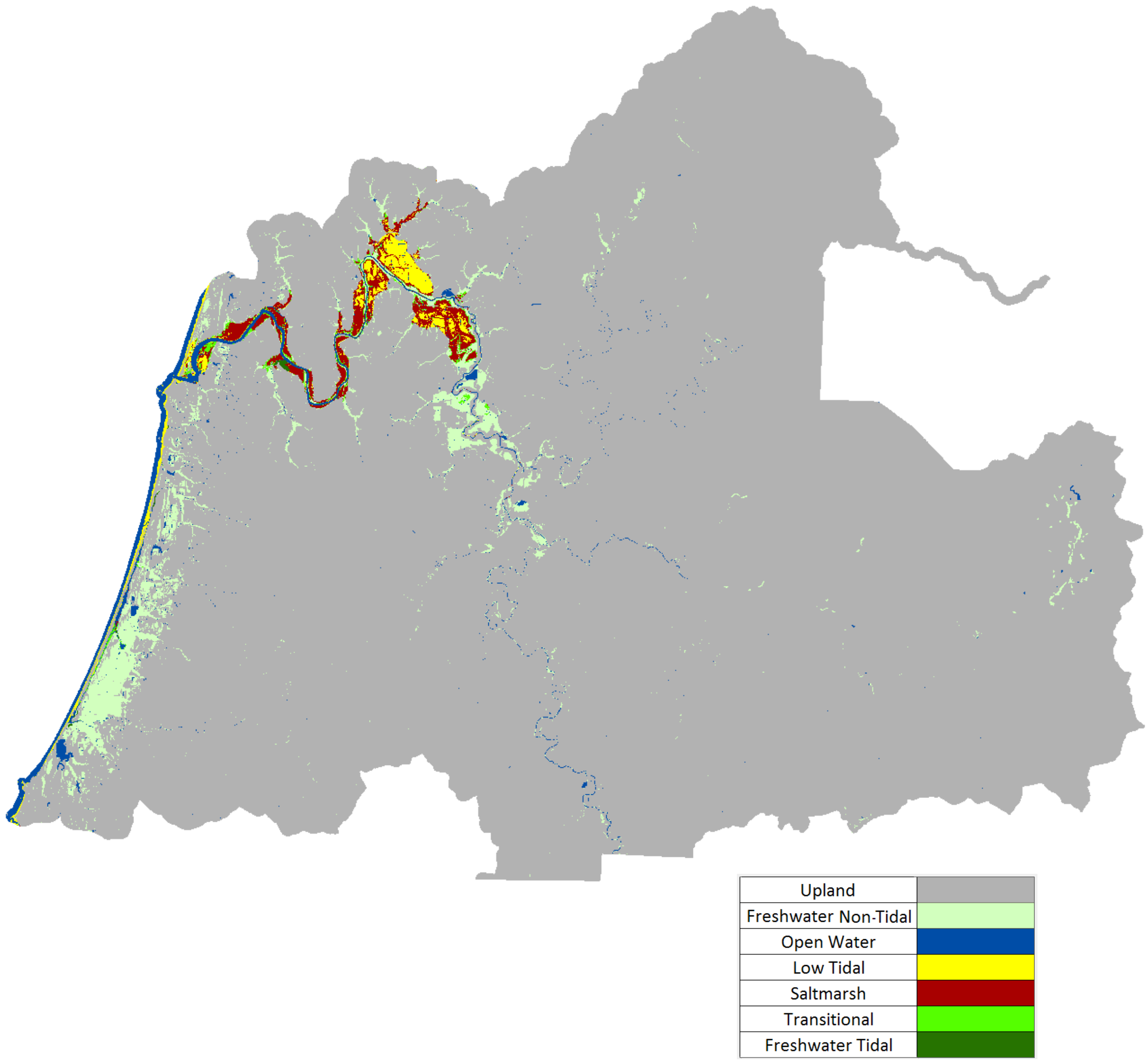

Figure 154. Site 9, 2100, Scenario 1 m – No Dikes

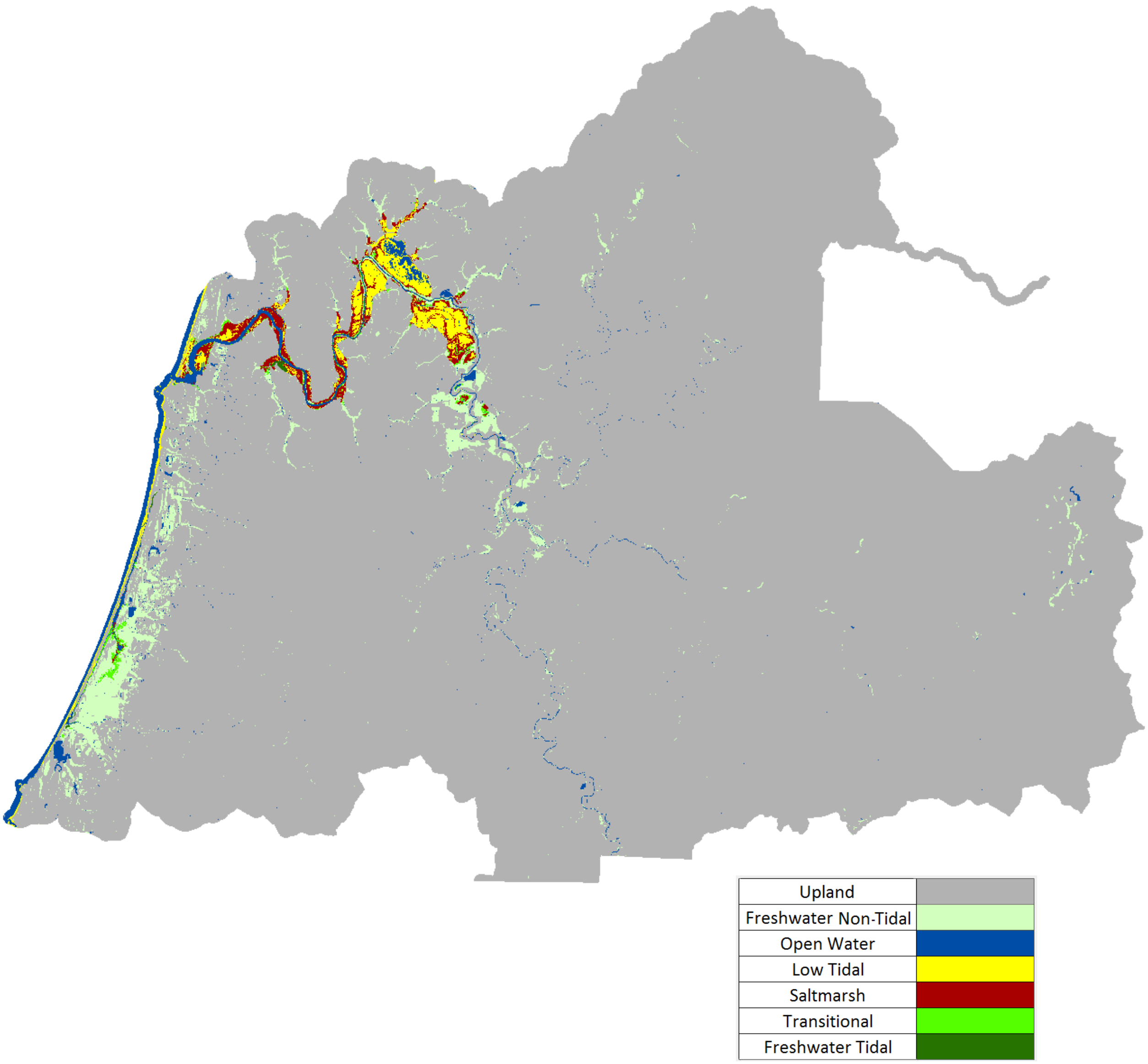

Figure 155. Site 9, 2100, Scenario 1.5 m – No Dikes

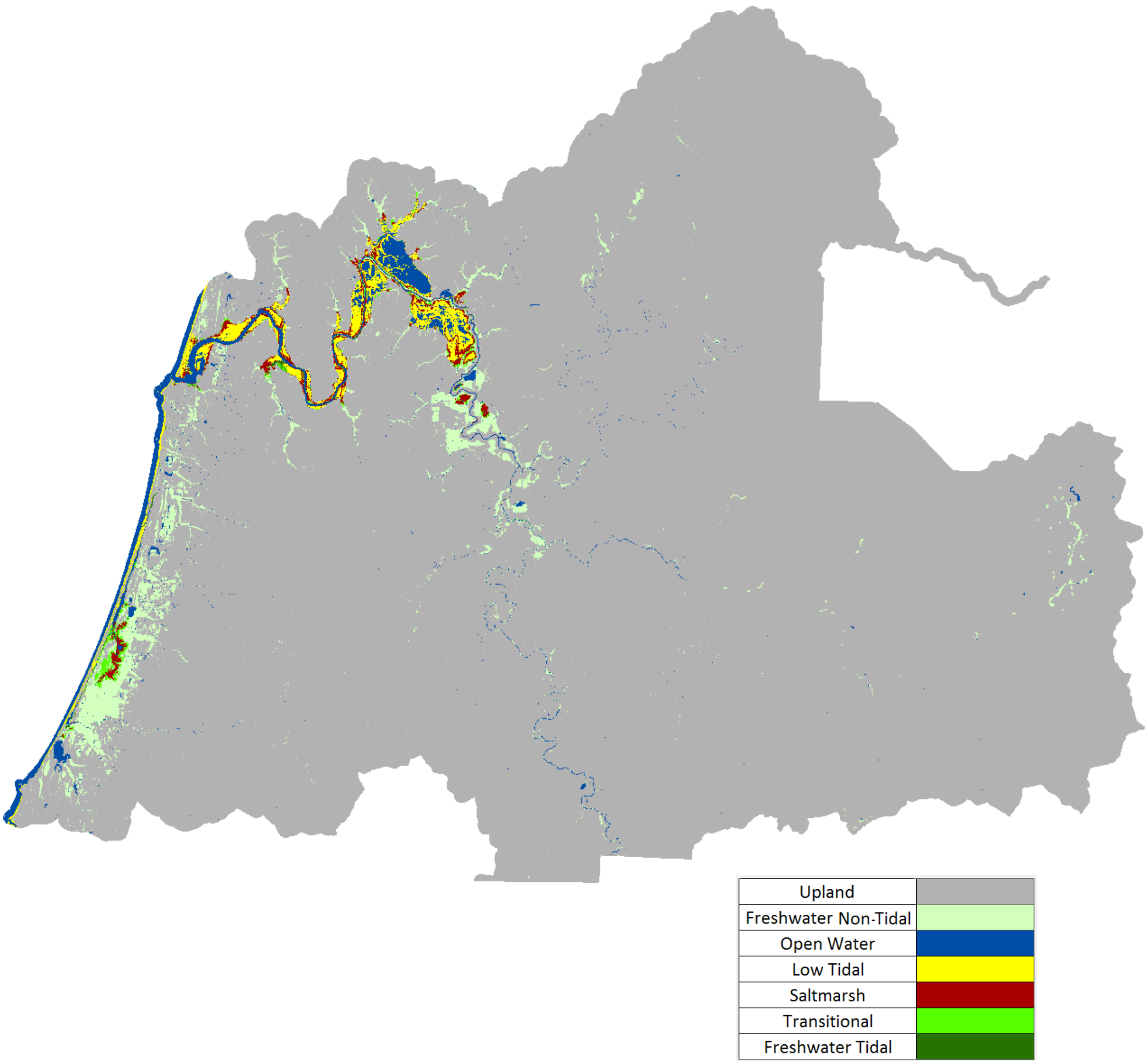

Figure 156. Site 9, 2100, Scenario 2 m – No Dikes

Site 10: Rogue

In site 10 wetlands are dominated by freshwater non-tidal habitat, followed by low tidal and freshwater tidal. This site contained only 44 acres of transitional wetlands and a negligible amount of saltmarsh.

Table 48. Wetland coverage of Site 10 according to the 2002 Wetland data

Land cover type	**Area (acres)**	**Percentage (%)**
Upland	119650	93
Open Water	4686	4
Freshwater Non-Tidal	3069	2
Low Tidal	1212	1
Freshwater Tidal	180	< 1
Transitional	44	< 1
Saltmarsh	2	< 1
Total (incl. water)	**128843**	**100**

Two tide gauges are located within the Rogue River estuary. These were incorporated into the study area using subsites (see Figure 159). The coastal portion of the site was assigned a tide range of 2.4 m based on data from the Port Orford gauge station. The inland portion of the study area was assigned a lower tide range of 2.04 m based on the tide table data from the Wedderburn, Rogue River site. The salt elevations were calculated from the inundation analysis conducted at the Port Orford NOAA gauge station (#9431647) which is located within this site. Salt elevations were determined to be 1.7 m for the coastal subsite and 1.46 m for the inland subsite. The historic SLR trend applied to this site was -0.5 mm/yr., suggesting uplift is occurring within this site. The SLAMM conceptual model was adjusted for site 10 by reducing the tidal swamp minimum elevation to 0.036 HTU and the tidal fresh marsh minimum elevation to -0.03 HTU.

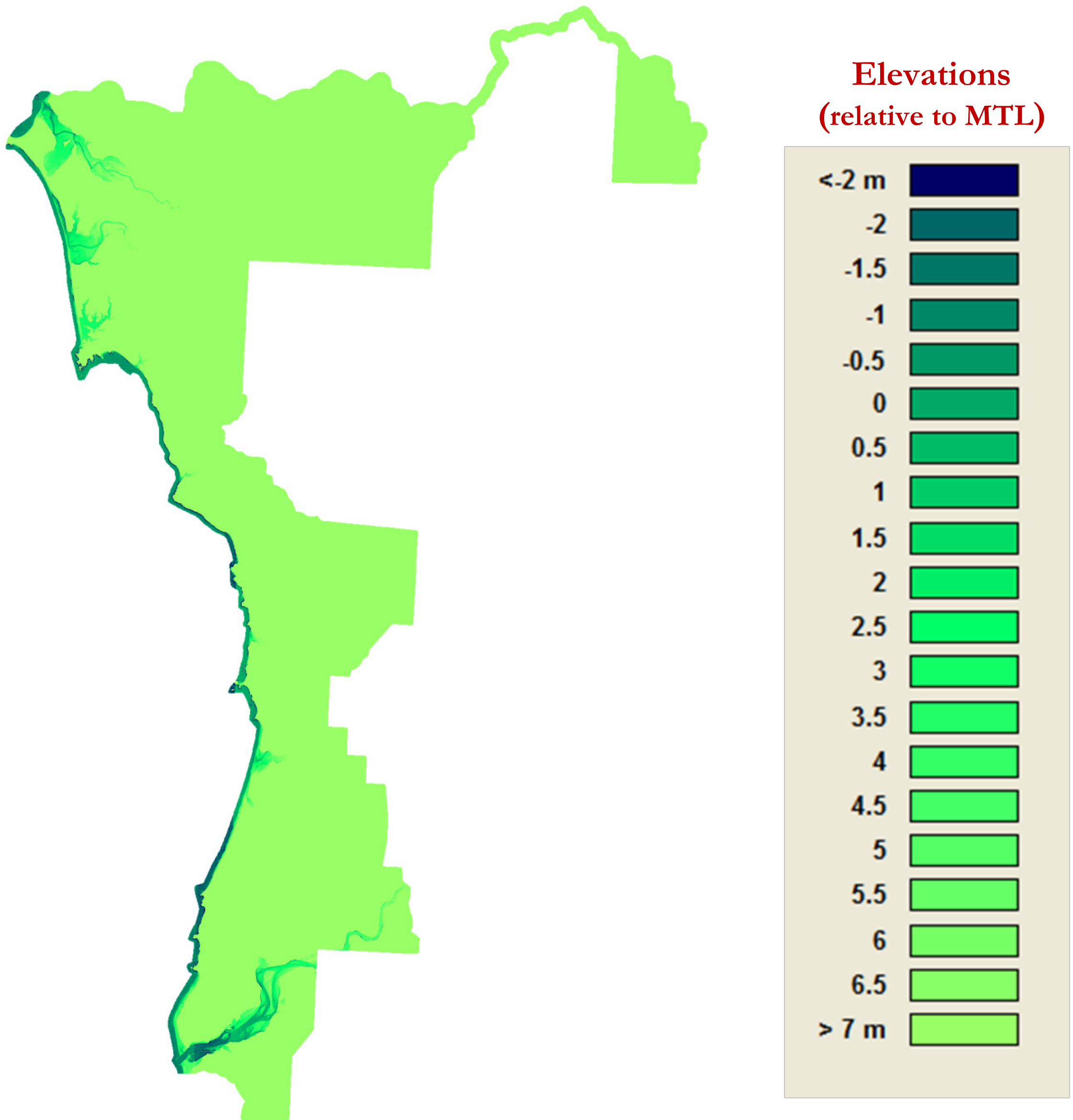

Figure 157. LiDAR elevation data for Site 10 – Rogue

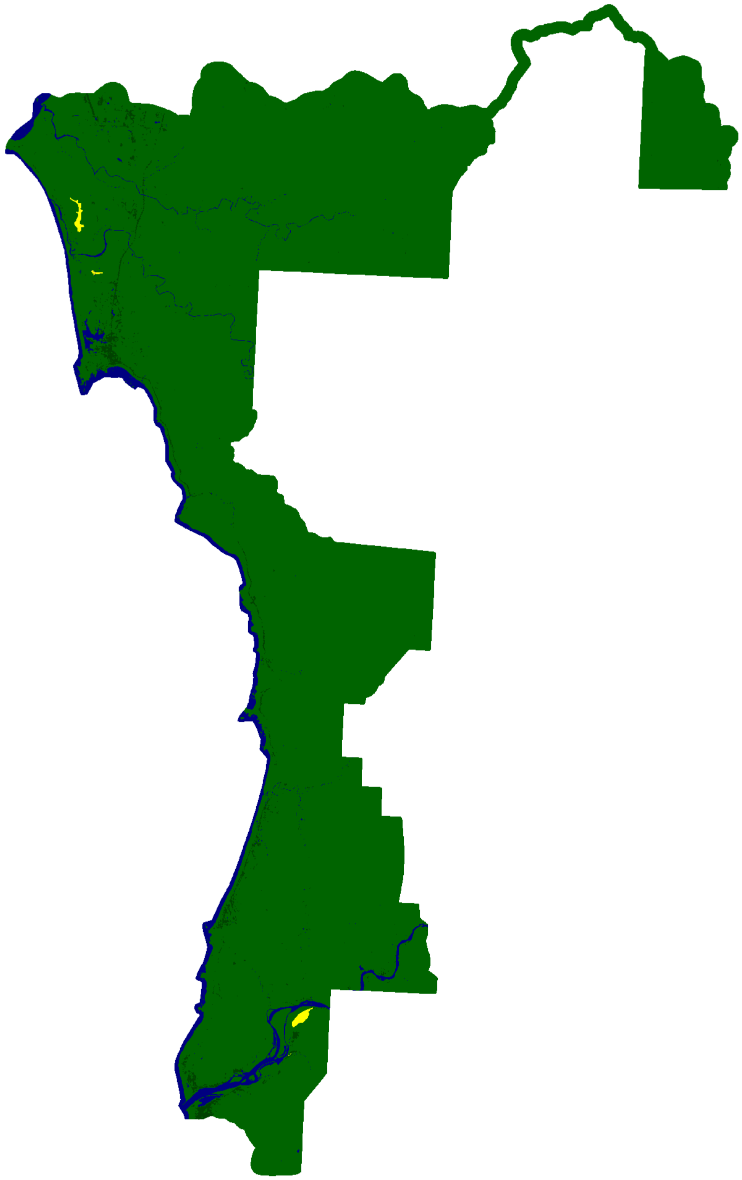

Figure 158. Location of dikes in Site 10 – Rogue (shown in yellow)

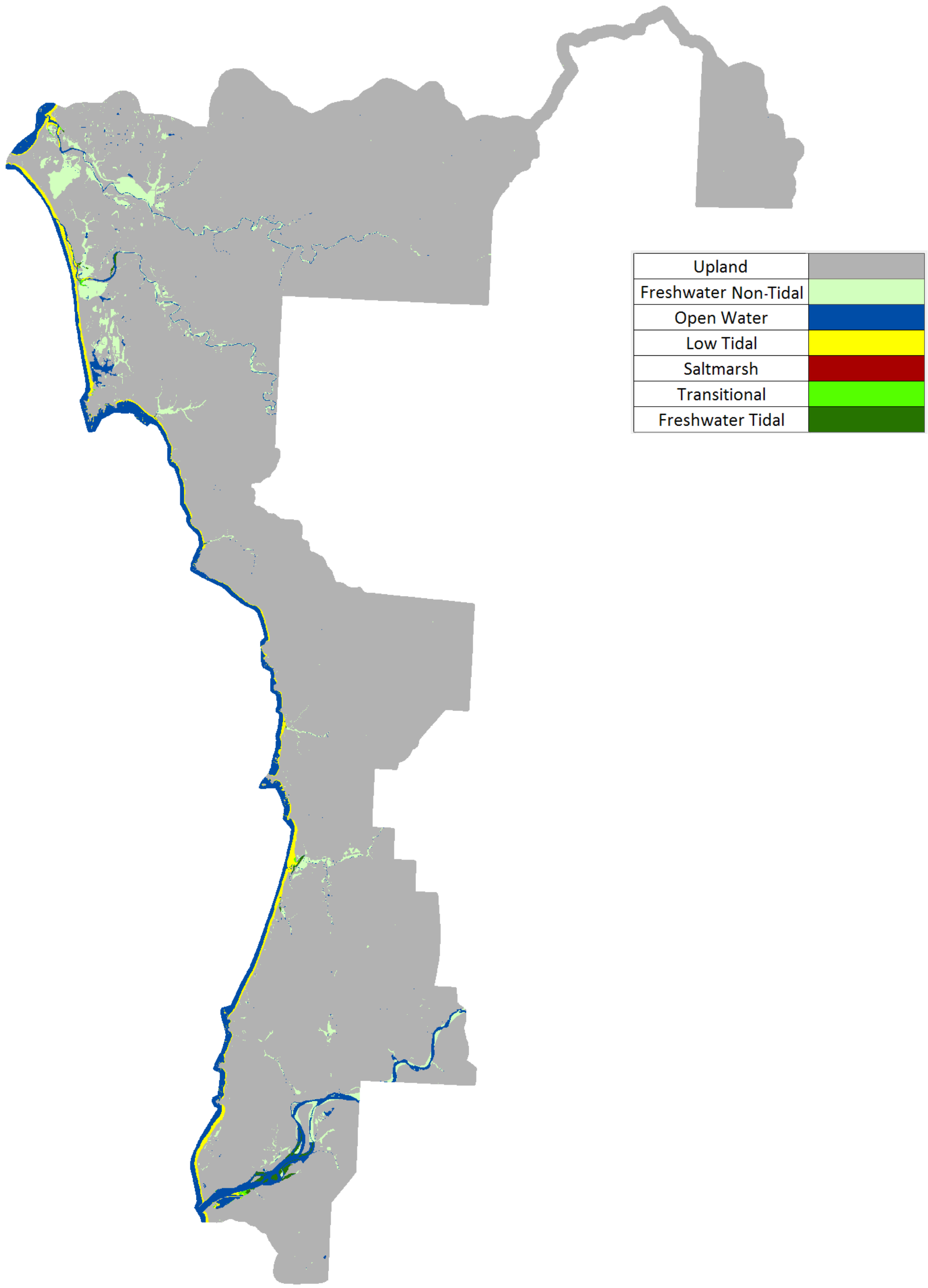

Figure 159. Wetland data for Site 10 – Rogue

Simulations of site 10 indicate the freshwater non-tidal wetlands (the dominant wetland category in this site) are relatively resilient to SLR. Under the 2 m of SLR by 2100 scenario, only 6% of this wetland type is predicted to be lost. Low and freshwater tidal habitats are also predicted to be fairly resilient, with losses not exceeding 30%. Conversely, large gains are predicted in transitional and saltmarsh habitats. The large percentage gains are due in part to the small initial acreages of these wetland categories.

Table 49. Predicted Percent Change of Land Categories by 2100 at Site 10 – Rogue Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	0	0	0
Open Water	-6	-6	-7	-9	-12
Freshwater Non-Tidal	0	0	1	2	6
Low Tidal	18	18	20	24	30
Freshwater Tidal	3	6	10	19	30
Saltmarsh	-1721	-2082	-2883	-6225	-11795
Transitional	-45	-85	-146	-246	-484

Simulations run without dikes included predict slight increases in gains of transitional and saltmarsh habitats as compared simulations run with dikes. However, no appreciable increases in losses are noted in the other wetland categories when dike are removed.

Table 50. Predicted Percent Change of Land Categories by 2100 at Site 10 – Rogue Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	Simulated SLR by 2100				
	0.39 m	0.69 m	1 m	1.5 m	2 m
Upland	0	0	0	0	0
Open Water	-6	-6	-7	-9	-12
Freshwater Non-Tidal	0	0	1	2	6
Low Tidal	18	18	20	24	30
Freshwater Tidal	3	6	10	19	30
Saltmarsh	-1723	-2085	-2890	-6244	-11835
Transitional	-45	-85	-147	-247	-485

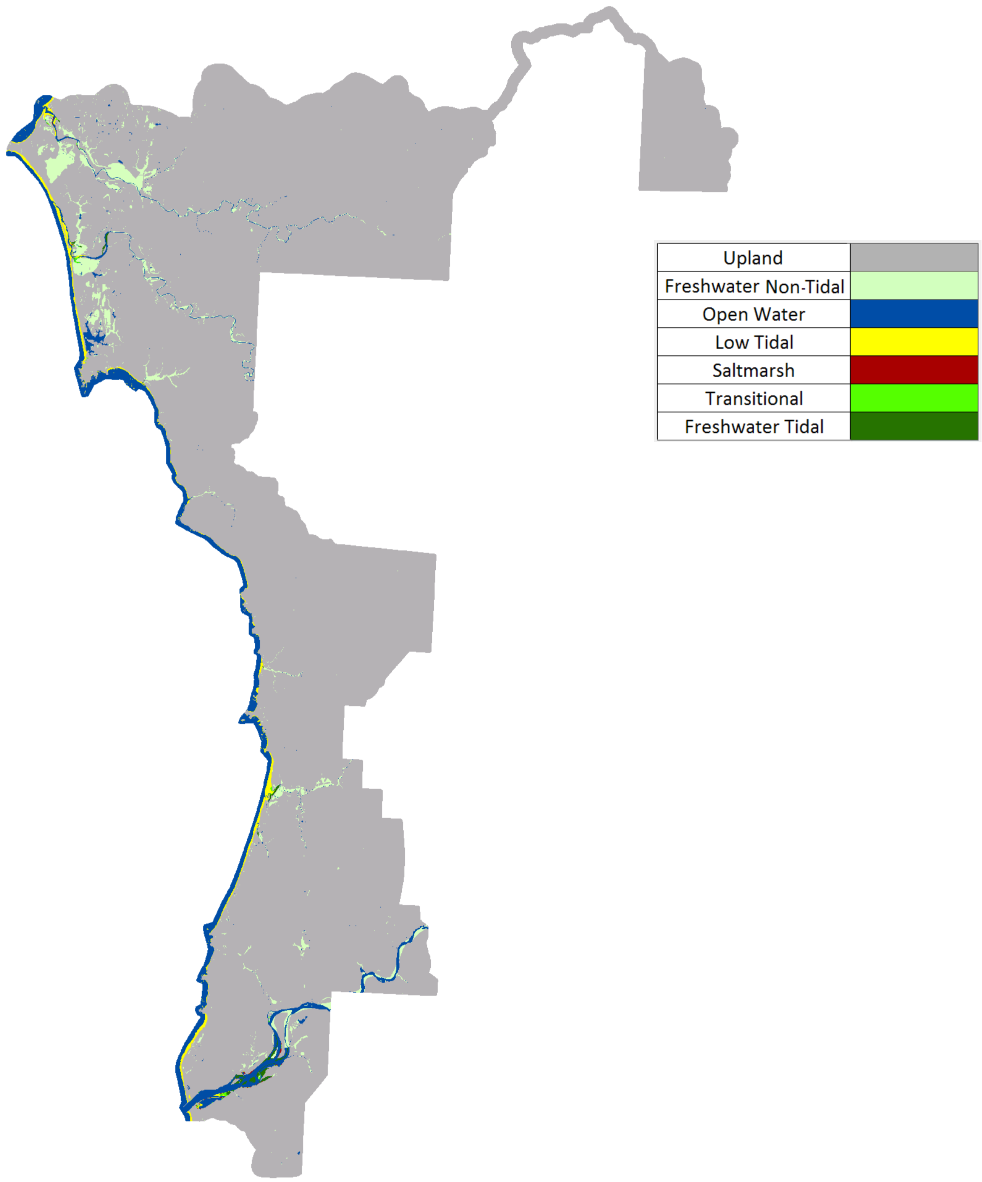

Figure 160. Site 10, 2100, Scenario A1B mean (0.39 m)

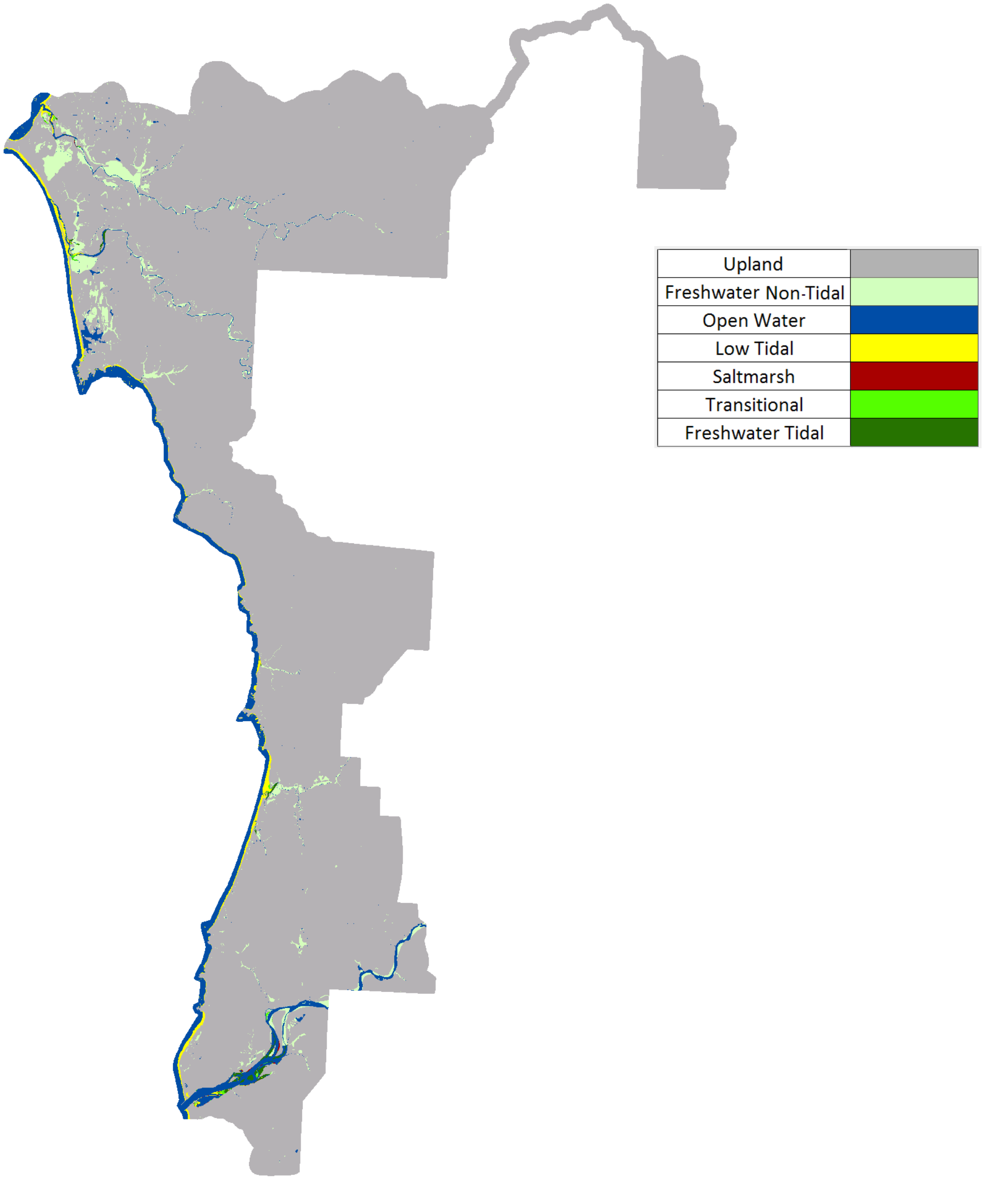

Figure 161. Site 10, 2100, Scenario A1B max (0.69 m)

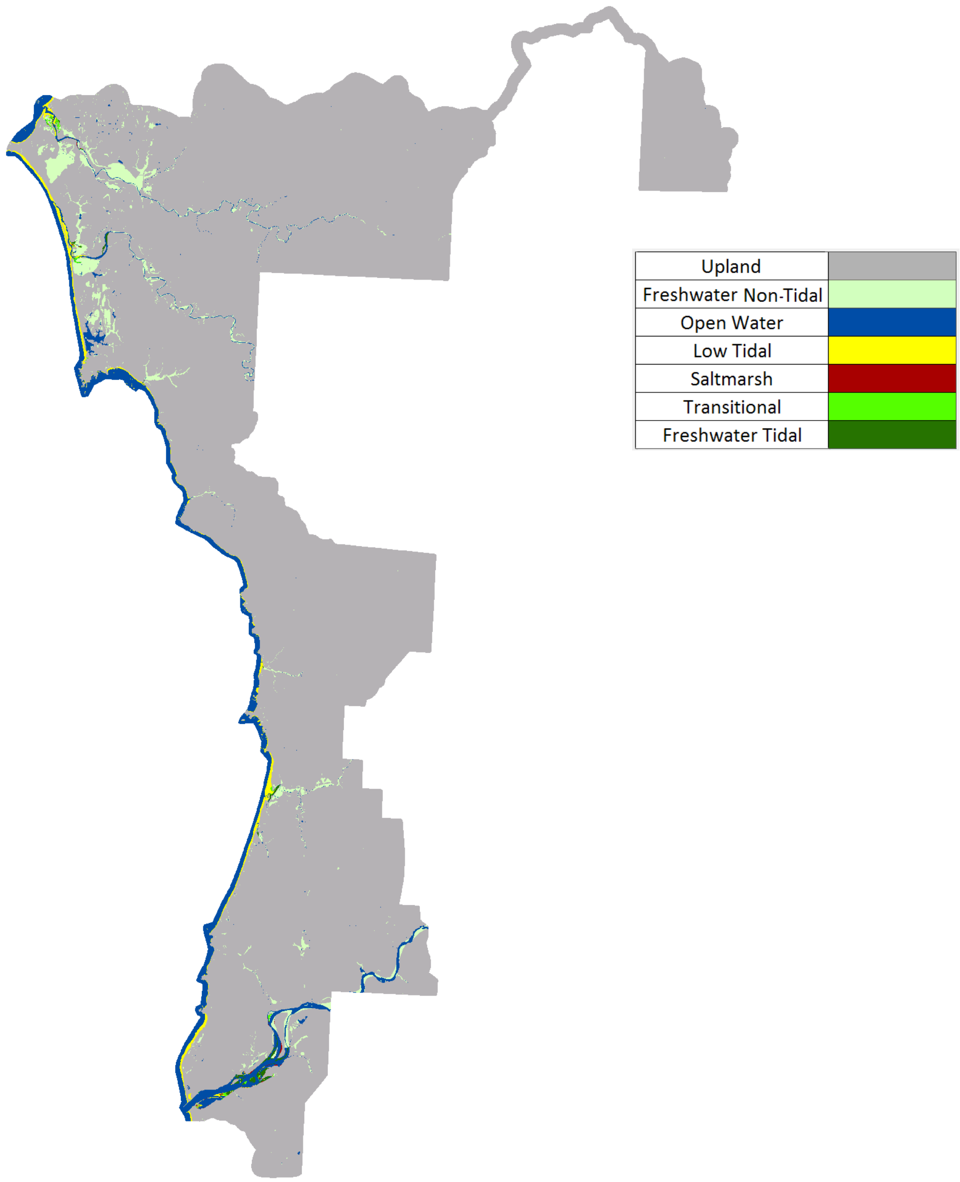

Figure 162. Site 10, 2100, Scenario 1 m

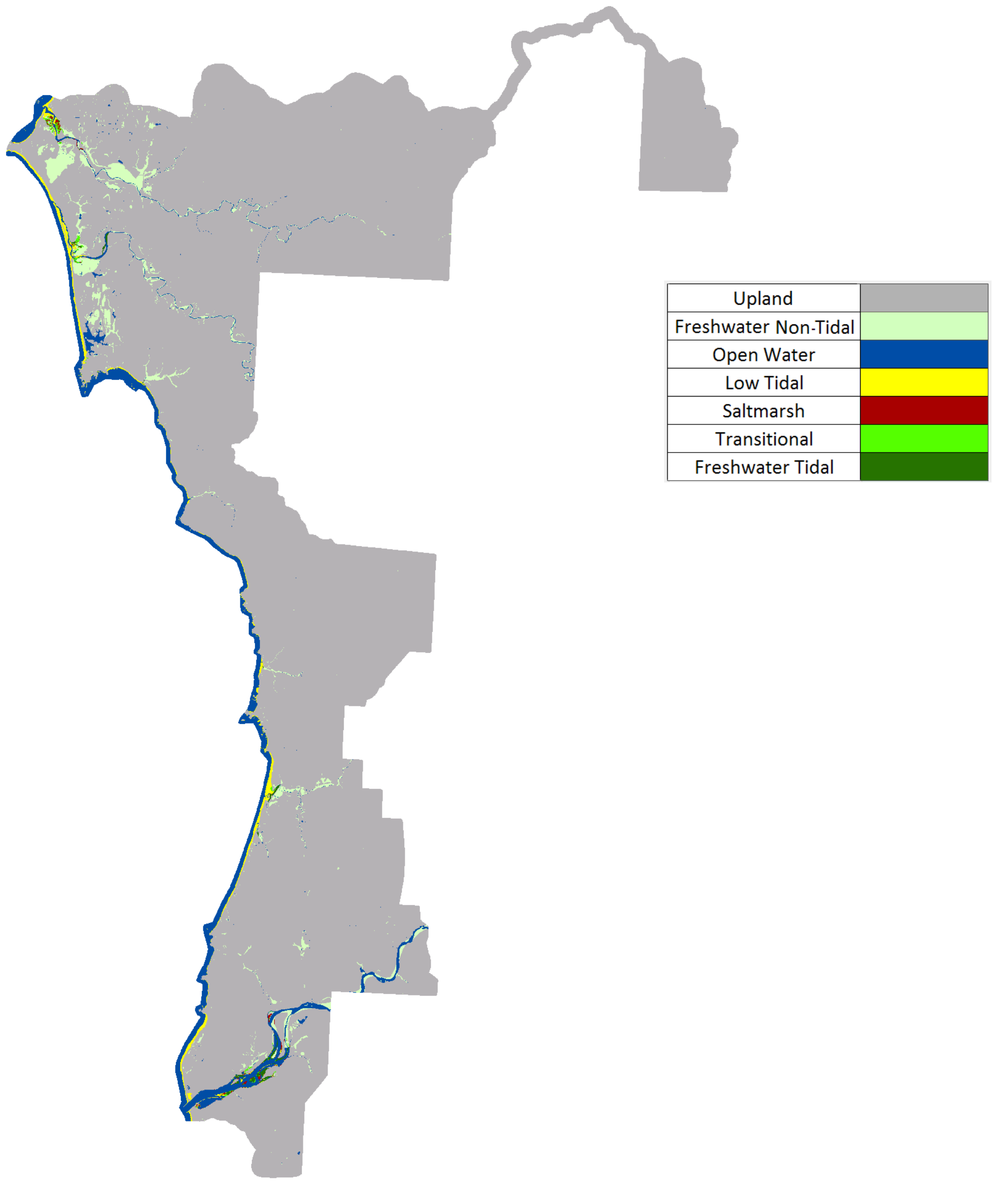

Figure 163. Site 10, 2100, Scenario 1.5 m

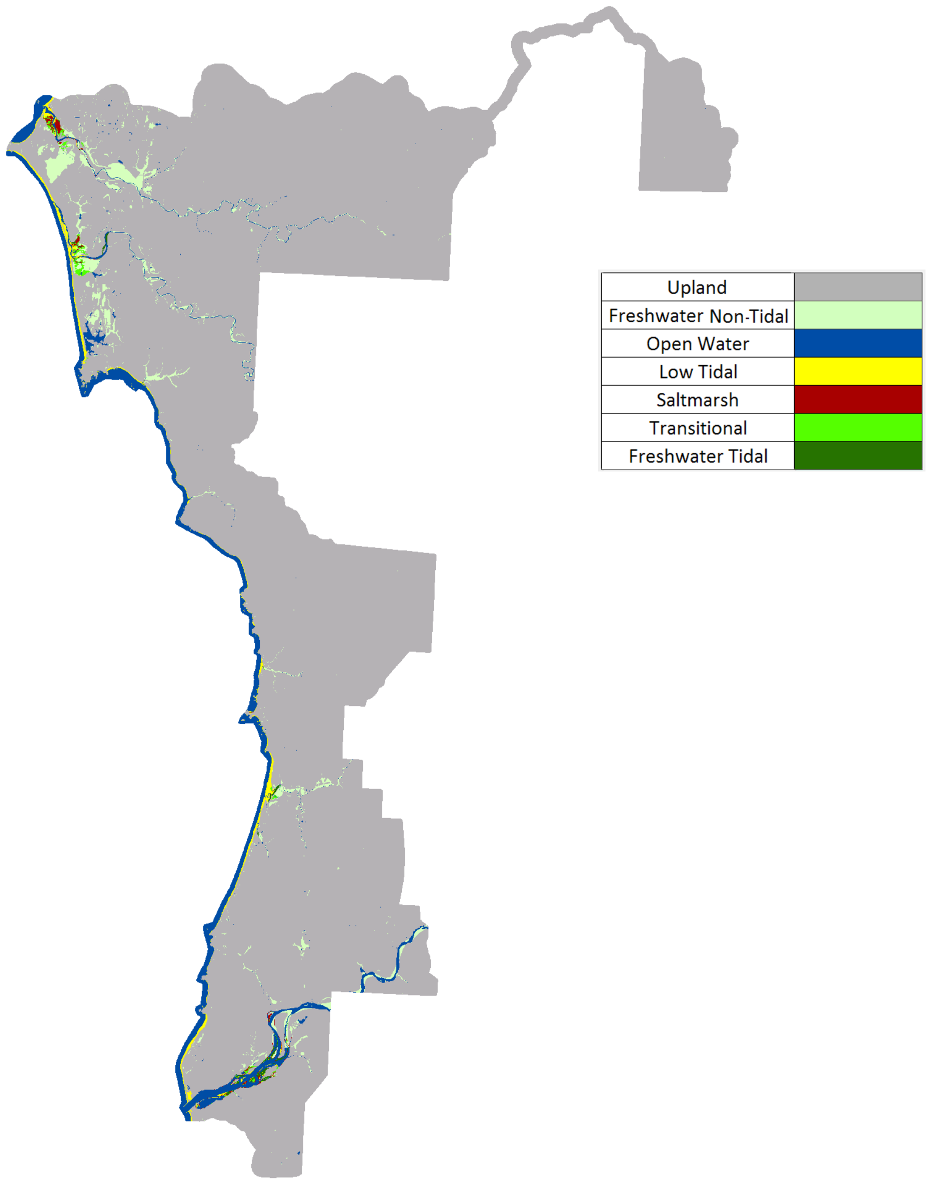

Figure 164. Site 10, 2100, Scenario 2 m

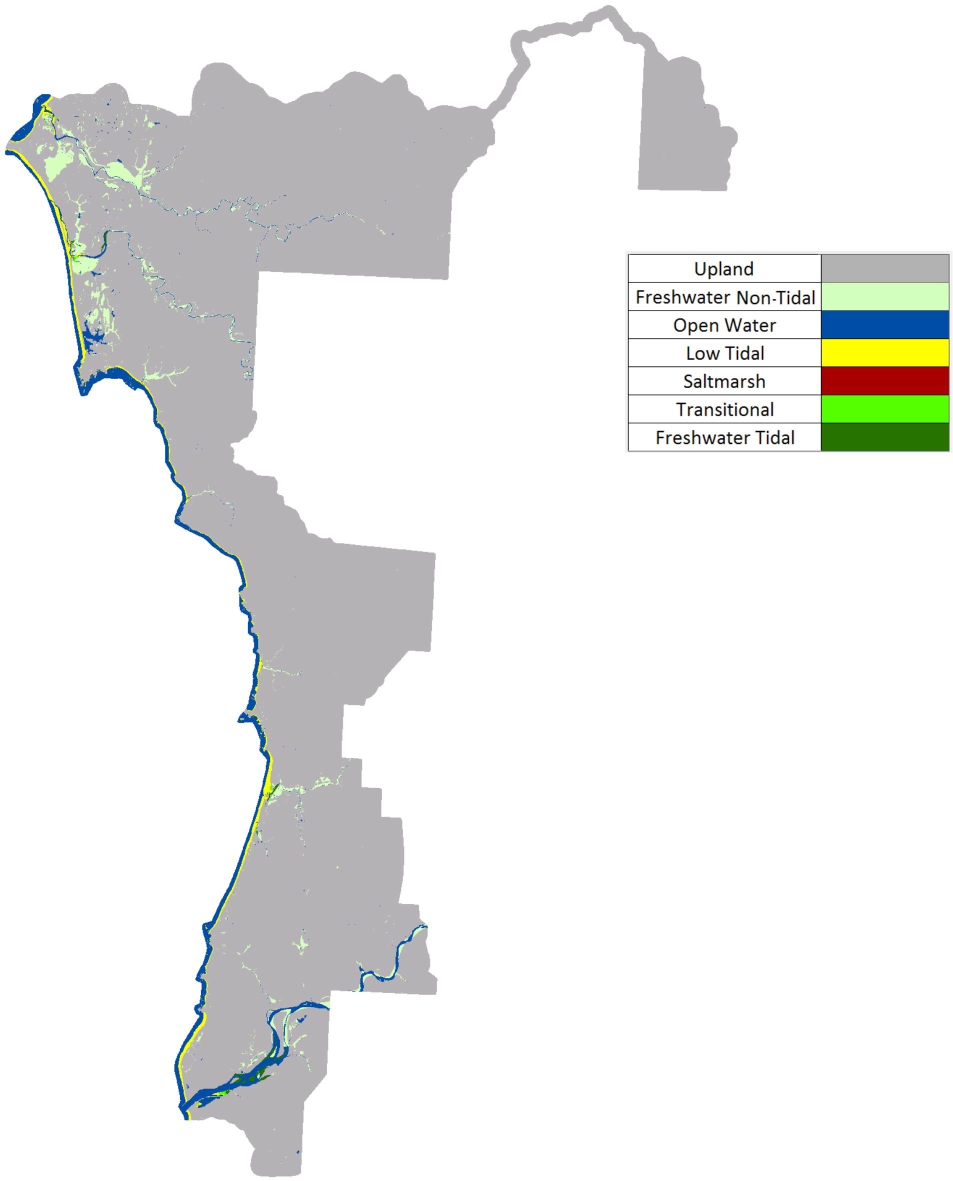

Figure 165. Initial condition wetland data for Site 10 – Rogue

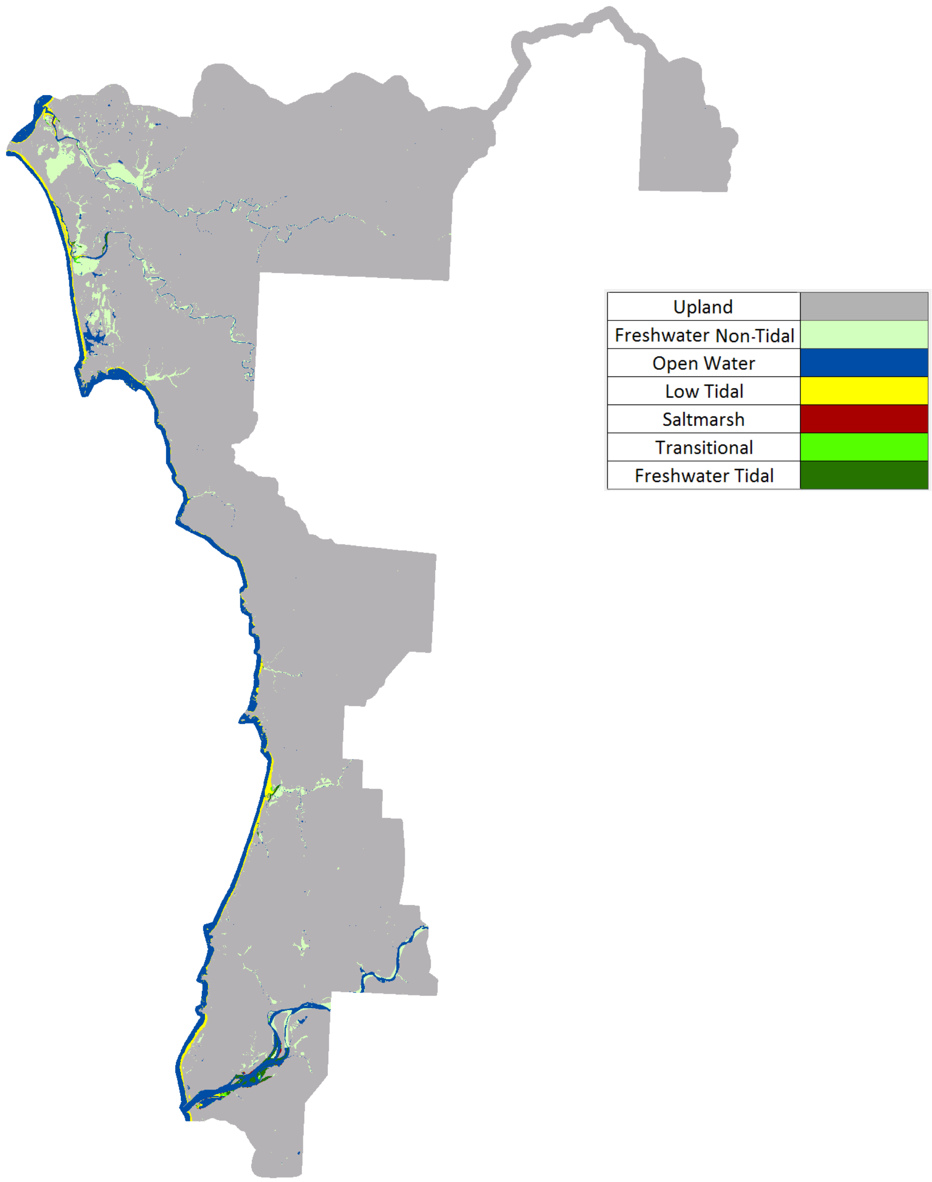

Figure 166. Site 10, 2100, Scenario A1B mean (0.39 m) – No Dikes

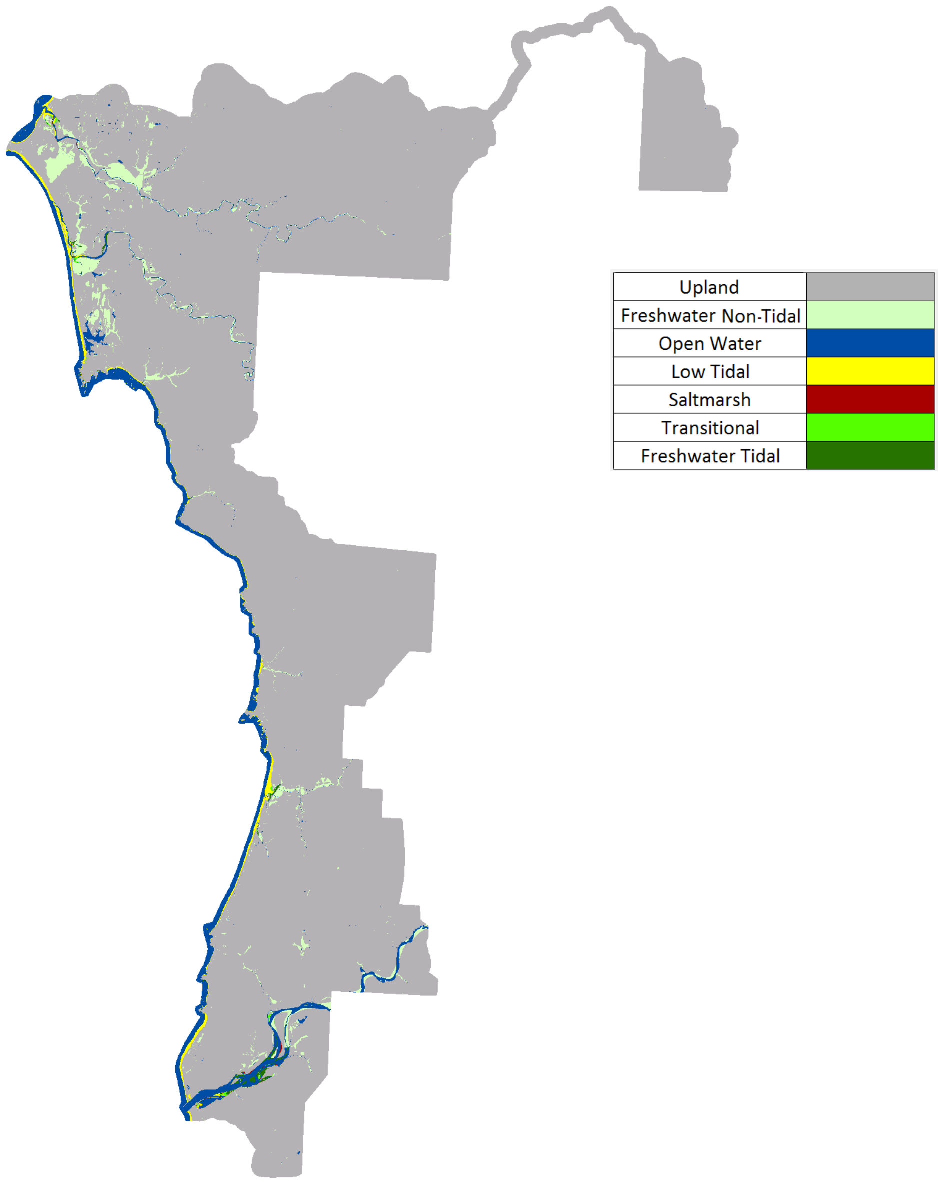

Figure 167. Site 10, 2100, Scenario A1B max (0.69 m) – No Dikes

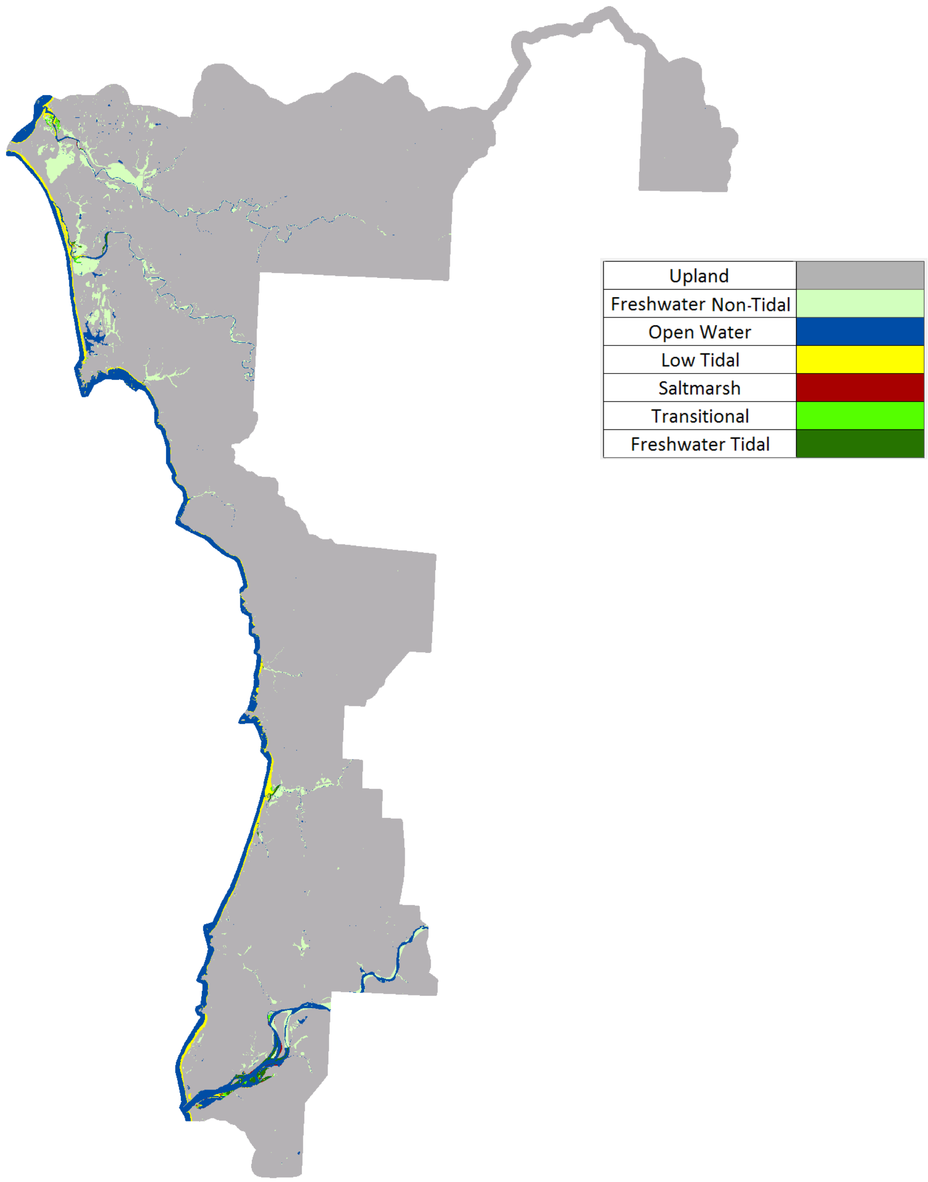

Figure 168. Site 10, 2100, Scenario 1 m – No Dikes

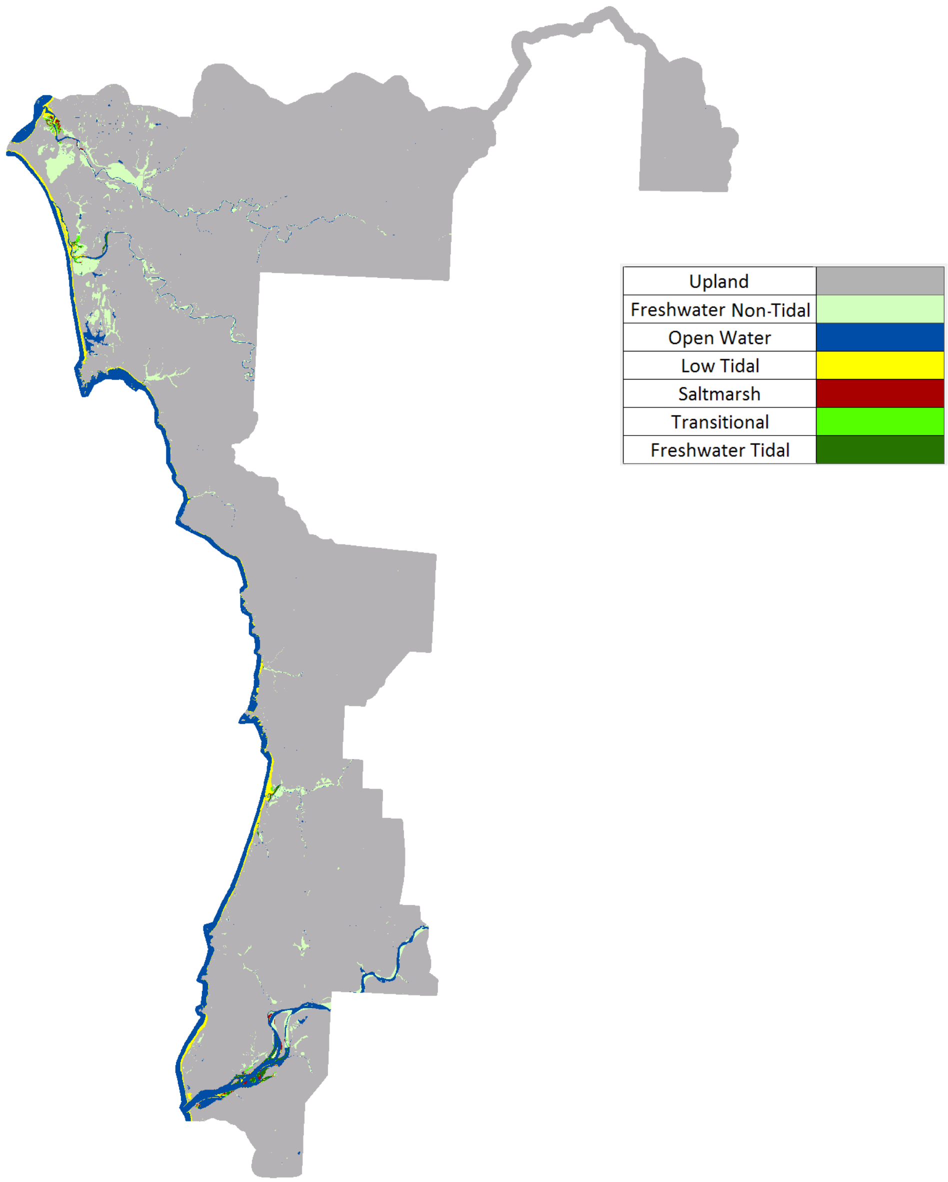

Figure 169. Site 10, 2100, Scenario 1.5 m – No Dikes

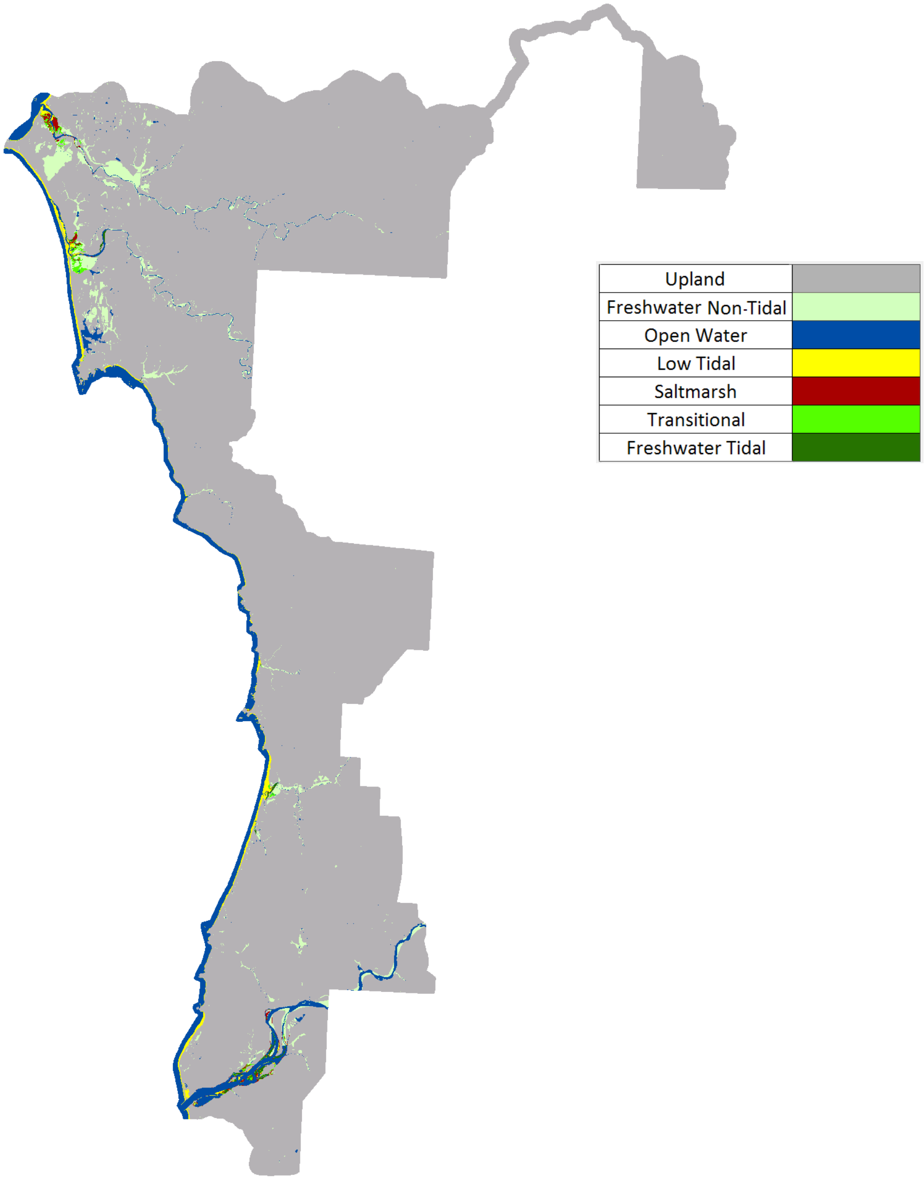

Figure 170. Site 8, 2100, Scenario 2 m – No Dikes

Site 11: Chetco

Site 11, the southernmost site in the study, contained only 2408 acres of wetland. The most prevalent wetland types are low tidal and freshwater non-tidal.

Table 51. Wetland coverage of Site 11 according to the 2002 wetland data

Land cover type	Area (acres)	Percentage (%)
Upland	135629	92
Open Water	9129	6
Low Tidal	1235	1
Freshwater Non-Tidal	1126	1
Freshwater Tidal	38	< 1
Transitional	8	< 1
Saltmarsh	3	< 1
Total (incl. water)	**147167**	**100**

Only one tide measurement was available within this site, located at Brookings in Chetco Cove. Based on this tide measurement, a tide range of 2.1 m was applied to the entire site. Observations from the Port Orford station were used to derive the salt elevation for this site, resulting in the application of 1.5 m for this parameter. The historic trend applied was -0.64 mm/yr., reflecting uplift in this portion of the Oregon coast. Within the SLAMM conceptual model, the lower boundary was changed for the tidal fresh marsh and tidal swamp wetland categories in order to more closely conform to the site-specific data noted for site 11. The tidal swamp minimum elevation was changed to -0.65 HTU and the minimum elevation for tidal-fresh marsh was changed to 0.08 HTU.

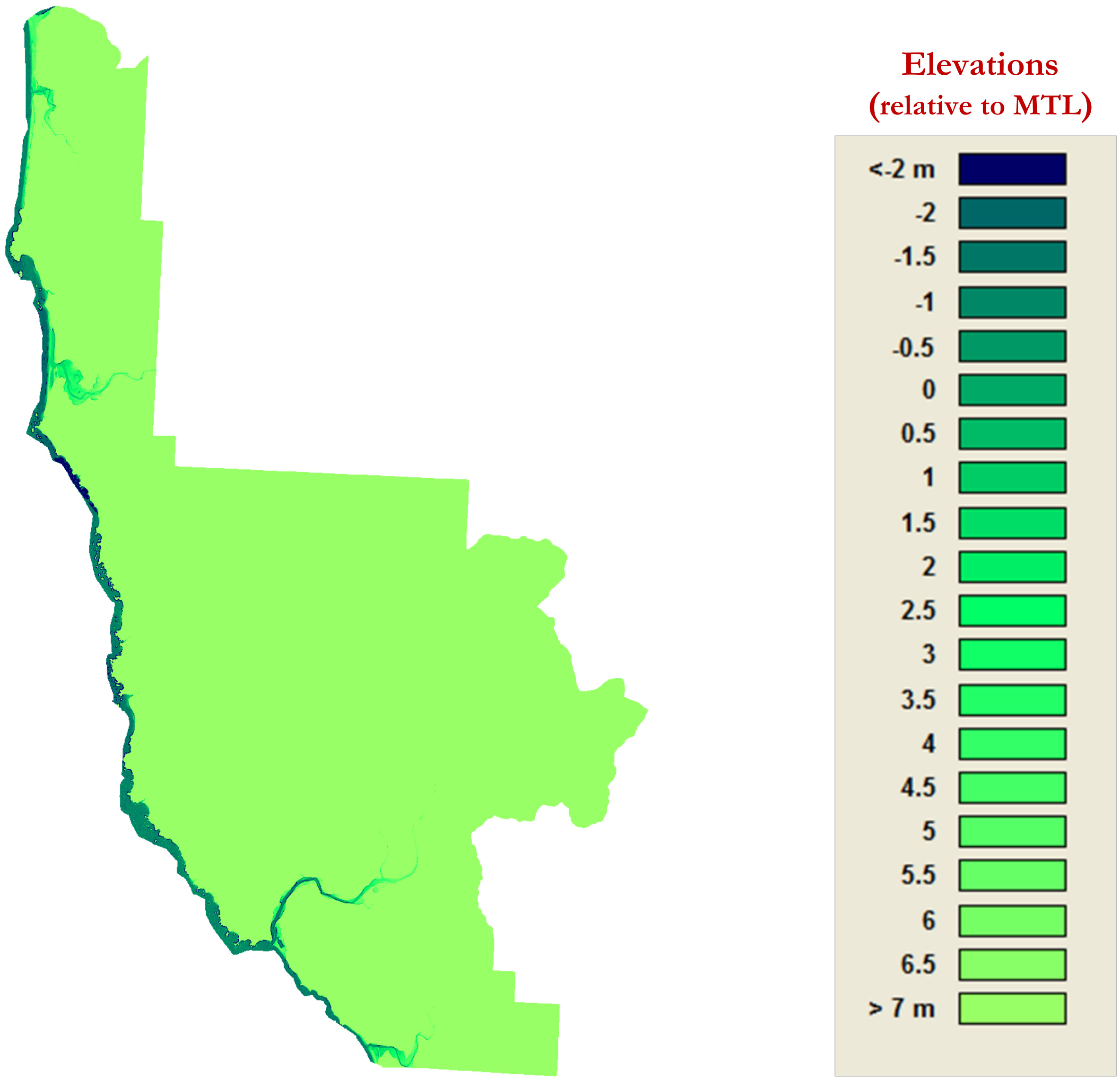

Figure 171. LiDAR elevation data for Site 11 – Chetco

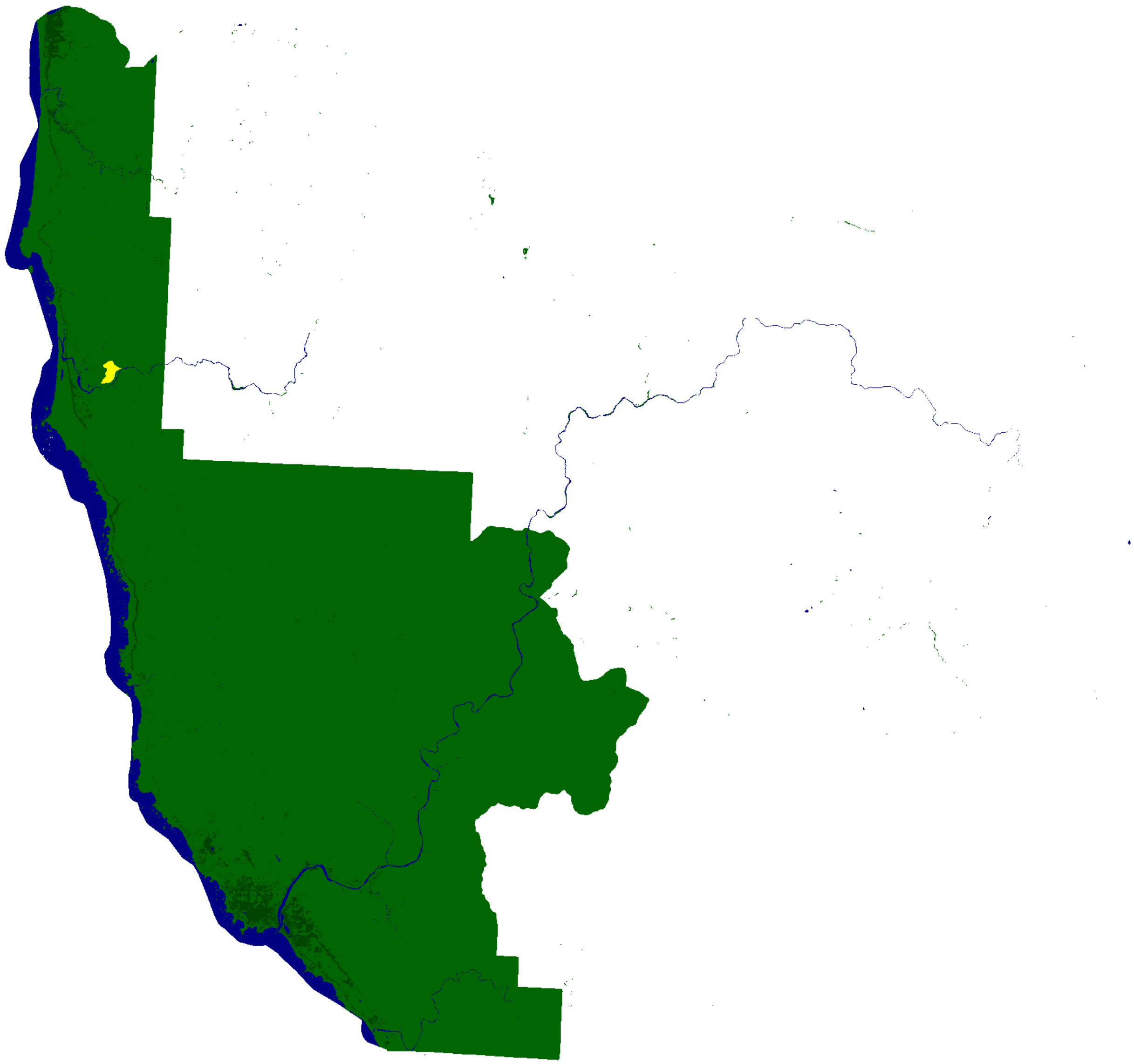

Figure 172. Location of dikes in Site 11 – Chetco (shown in yellow)

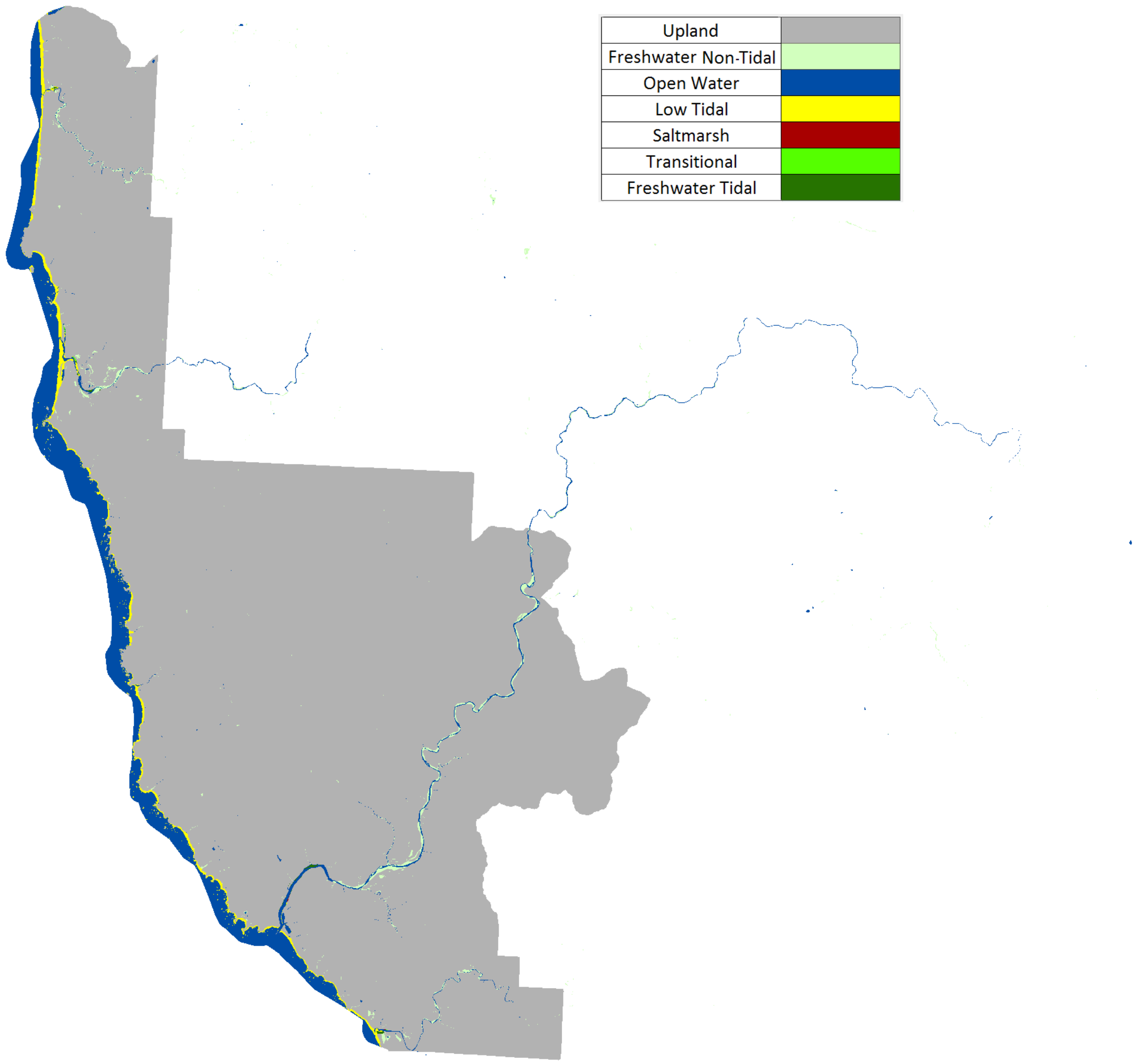

Figure 173. Wetland data for Site 11 – Chetco

Results for site 11 indicate the low tidal habitat, which is the most prevalent wetland type in this site, is susceptible to SLR, with potential losses ranging from 21 to 46% depending on the SLR scenario. Freshwater non-tidal habitats are predicted to be relatively resilient, with a maximum of 16% loss projected under the 2 m of SLR by 2100 scenario. As observed in other sites, losses are balanced with gains in transitional and saltmarsh habitat, which show significant gains particularly at the 1.5 and 2 m SLR by 2100 scenarios.

Table 52. Predicted Percent Change of Land Categories by 2100 at Site 11 - Chetco Given Simulated Scenarios of Eustatic Sea Level Rise. *Negative values indicate gains while positive values indicate losses*

Land cover category	**Simulated SLR by 2100**				
	0.39 m	**0.69 m**	**1 m**	**1.5 m**	**2 m**
Upland	0	0	0	0	0
Open Water	-5	-6	-7	-8	-10
Low Tidal	21	26	32	40	46
Freshwater Non-Tidal	11	12	12	14	16
Freshwater Tidal	7	11	15	22	28
Transitional	-145	-272	-482	-812	-1370
Saltmarsh	-363	-426	-684	-1592	-3287

As there is very little diked land present in this site, results of simulations run without dikes included show only slight differences from those collected when dikes were considered.

Table 53. Predicted Percent Change of Land Categories by 2100 at Site 11 - Chetco Given Simulated Scenarios of Eustatic Sea Level Rise and Dikes Removed. *Negative values indicate gains while positive values indicate losses*

Land cover category	**Simulated SLR by 2100**				
	0.39 m	**0.69 m**	**1 m**	**1.5 m**	**2 m**
Upland	0	0	0	0	0
Open Water	-5	-6	-7	-8	-10
Low Tidal	21	26	32	40	46
Freshwater Non-Tidal	11	12	12	14	16
Freshwater Tidal	7	11	15	22	28
Transitional	-145	-273	-482	-814	-1374
Saltmarsh	-363	-427	-685	-1595	-3294

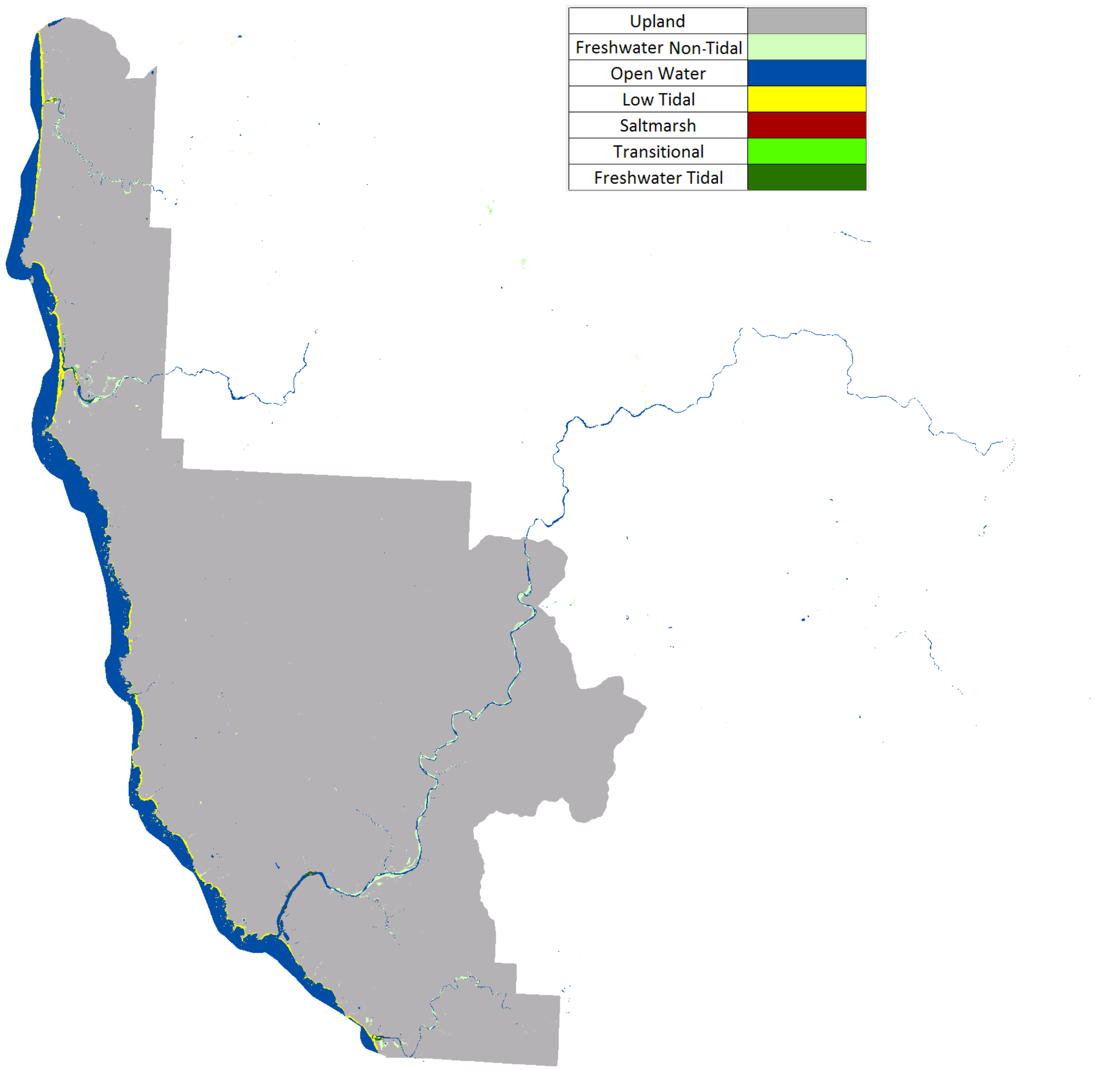

Figure 174. Site 11, 2100, Scenario A1B mean (0.39 m)

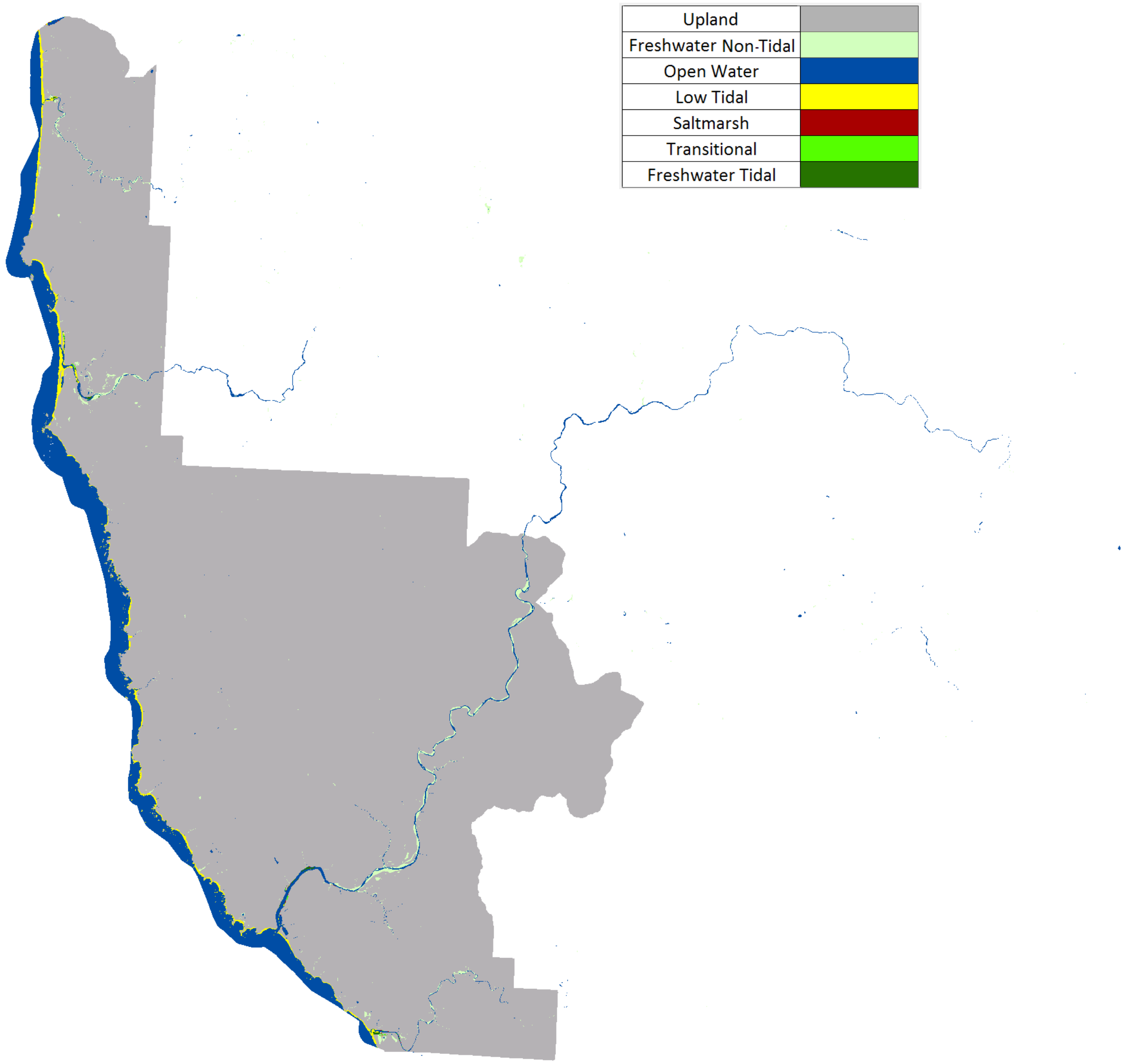

Figure 175. Site 11, 2100, Scenario A1B max (0.69 m)

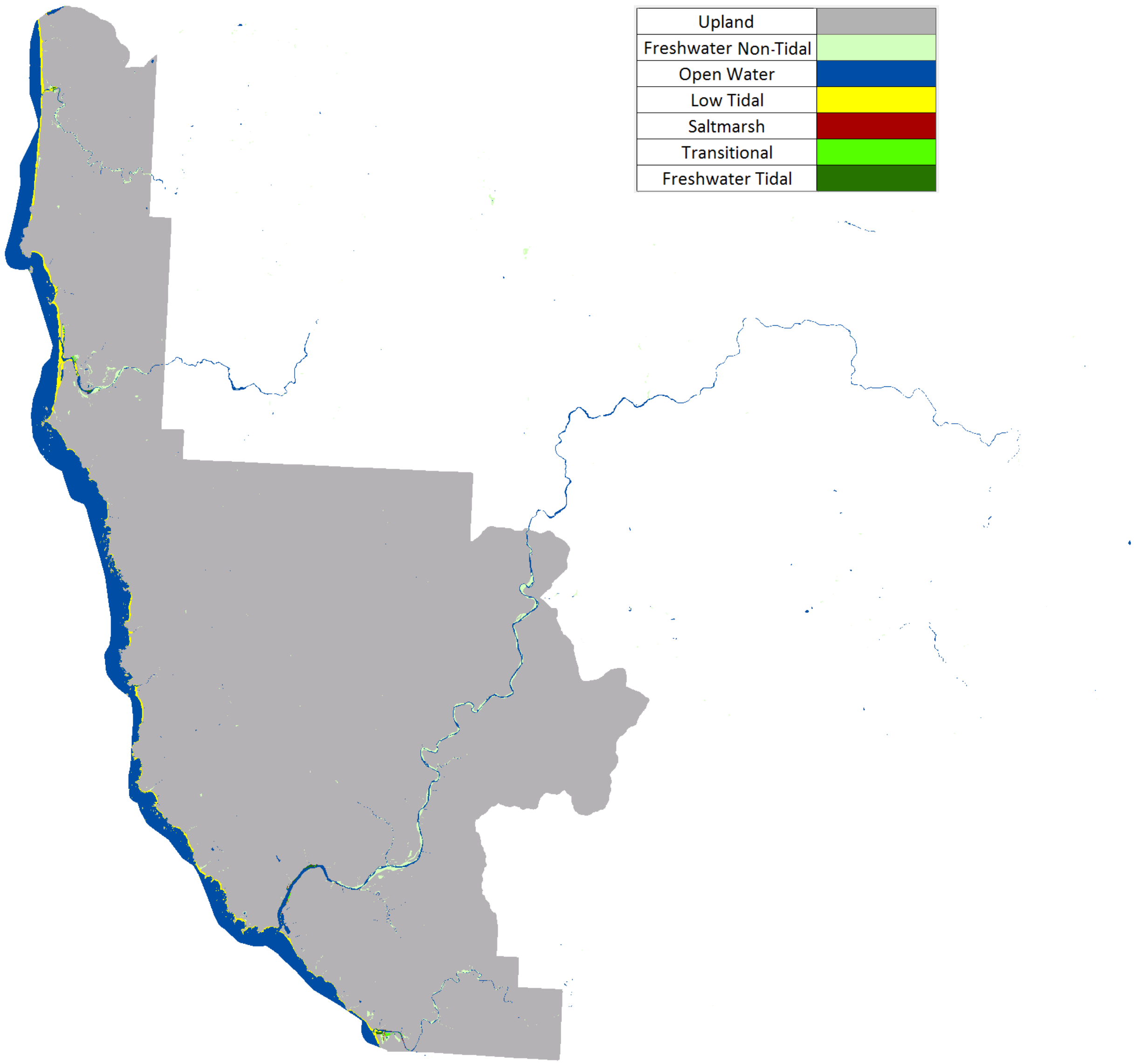

Figure 176. Site 11, 2100, Scenario 1 m

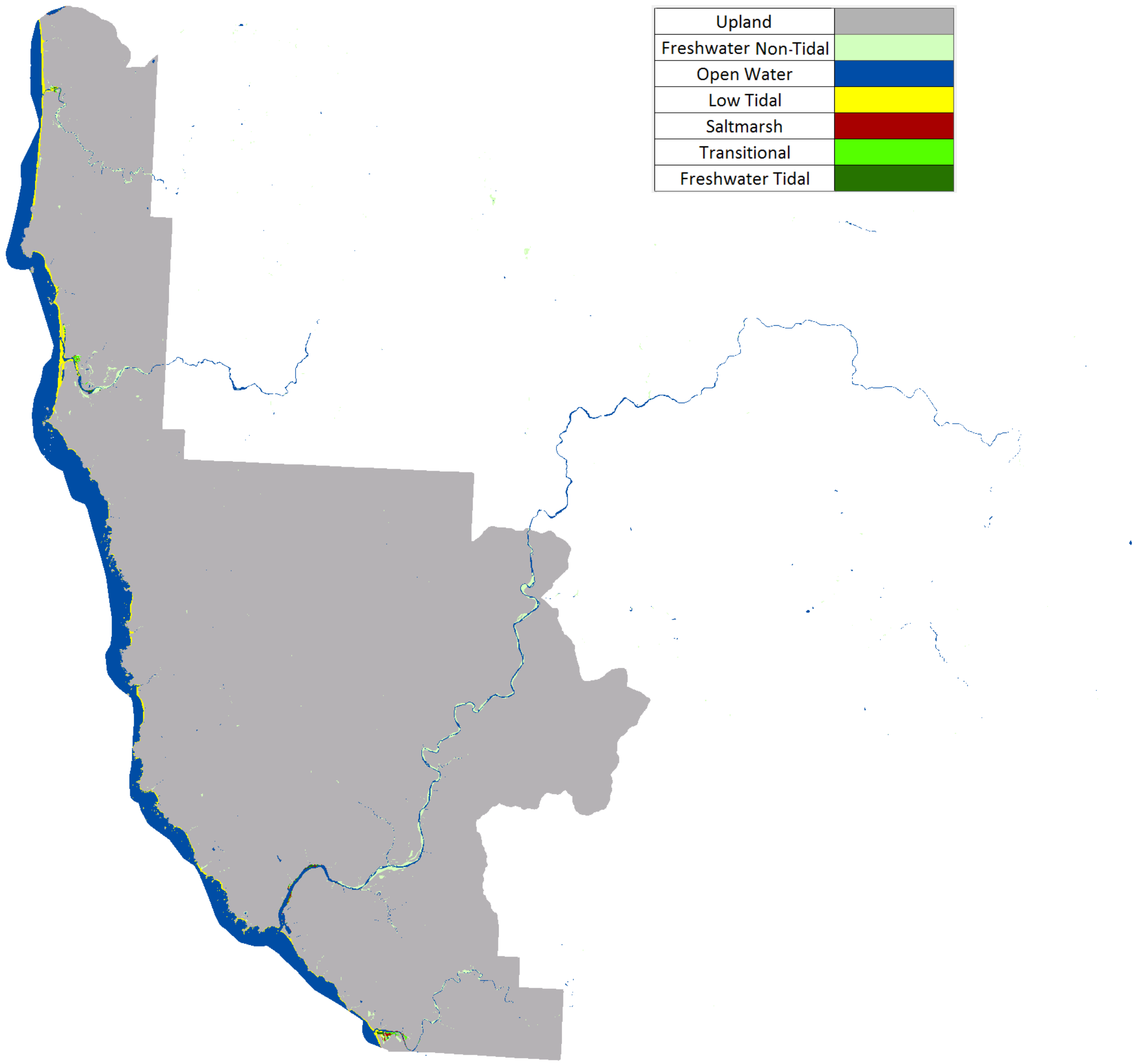

Figure 177. Site 11, 2100, Scenario 1.5 m

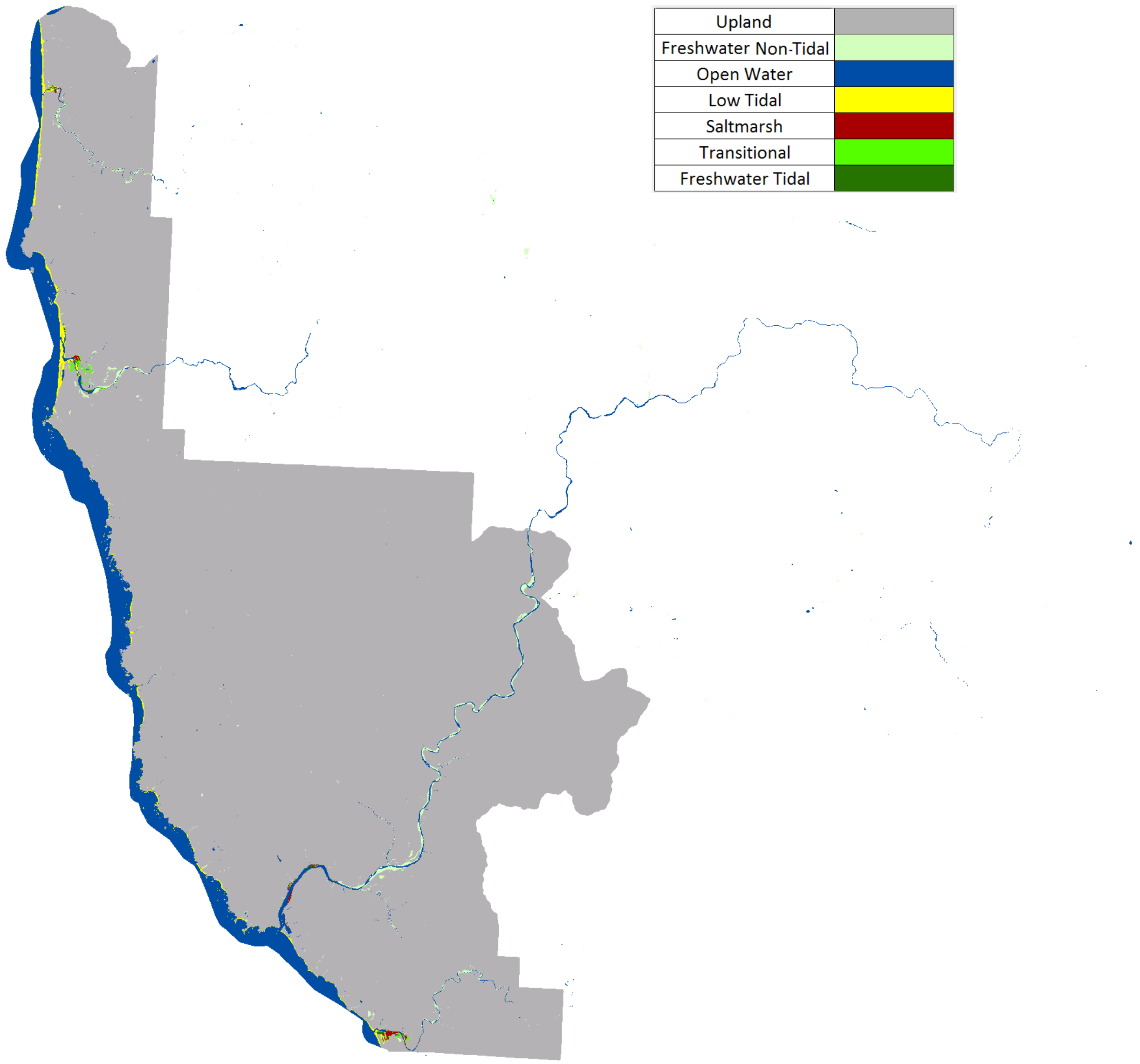

Figure 178. Site 11, 2100, Scenario 2 m

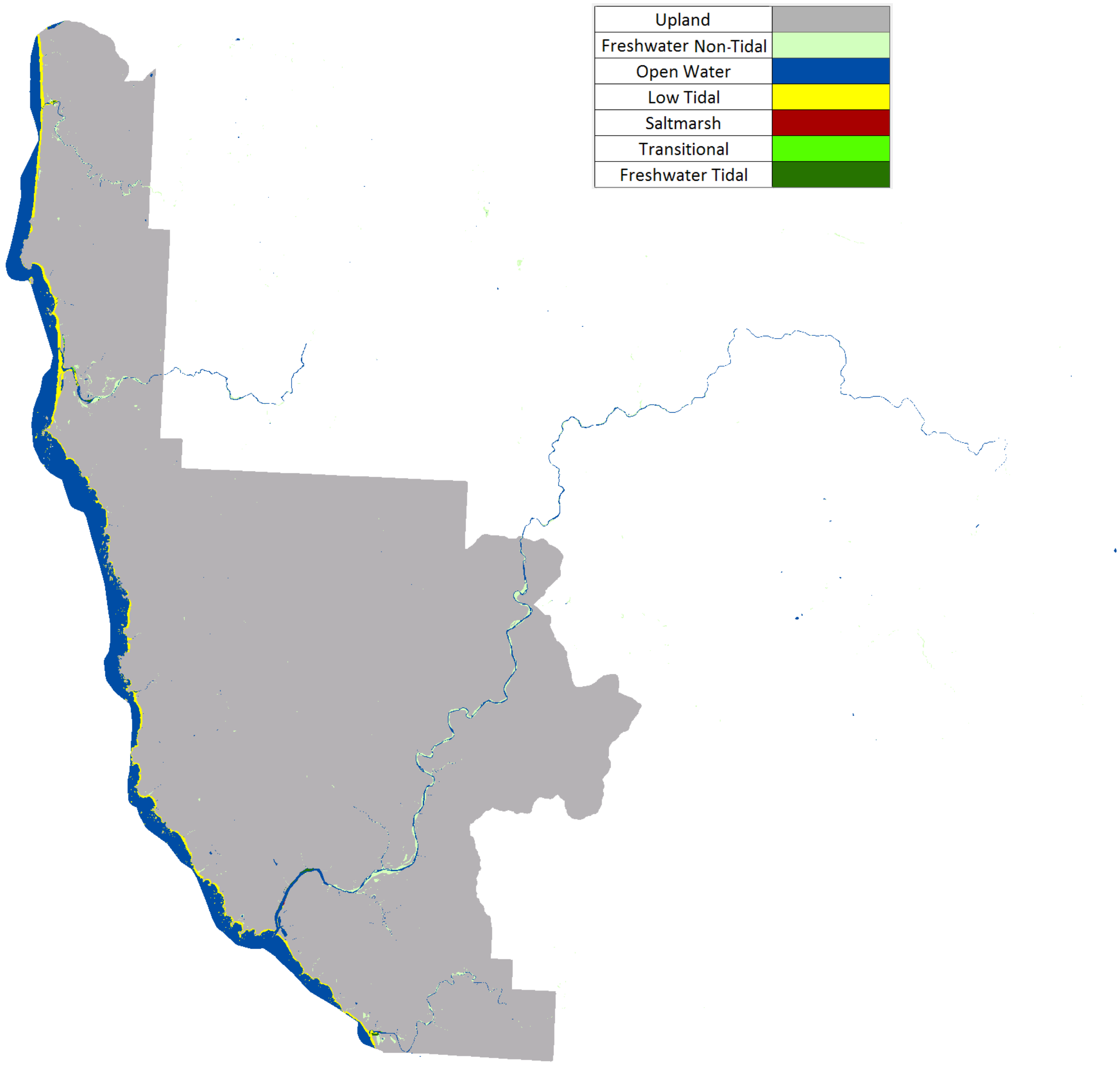

Figure 179. Initial condition wetland data for Site 11 – Chetco

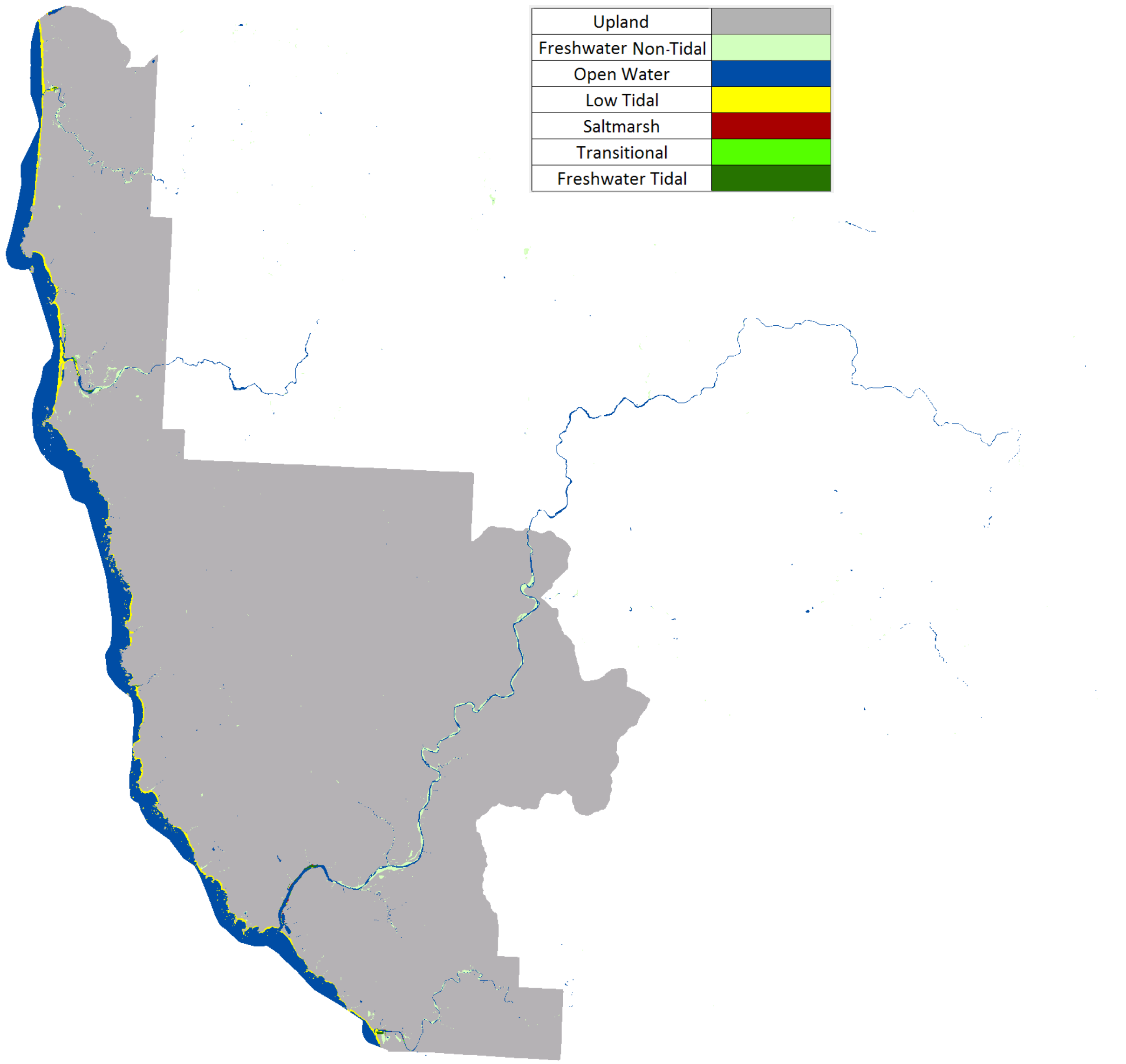

Figure 180. Site 11, 2100, Scenario A1B mean (0.39 m) – No Dikes

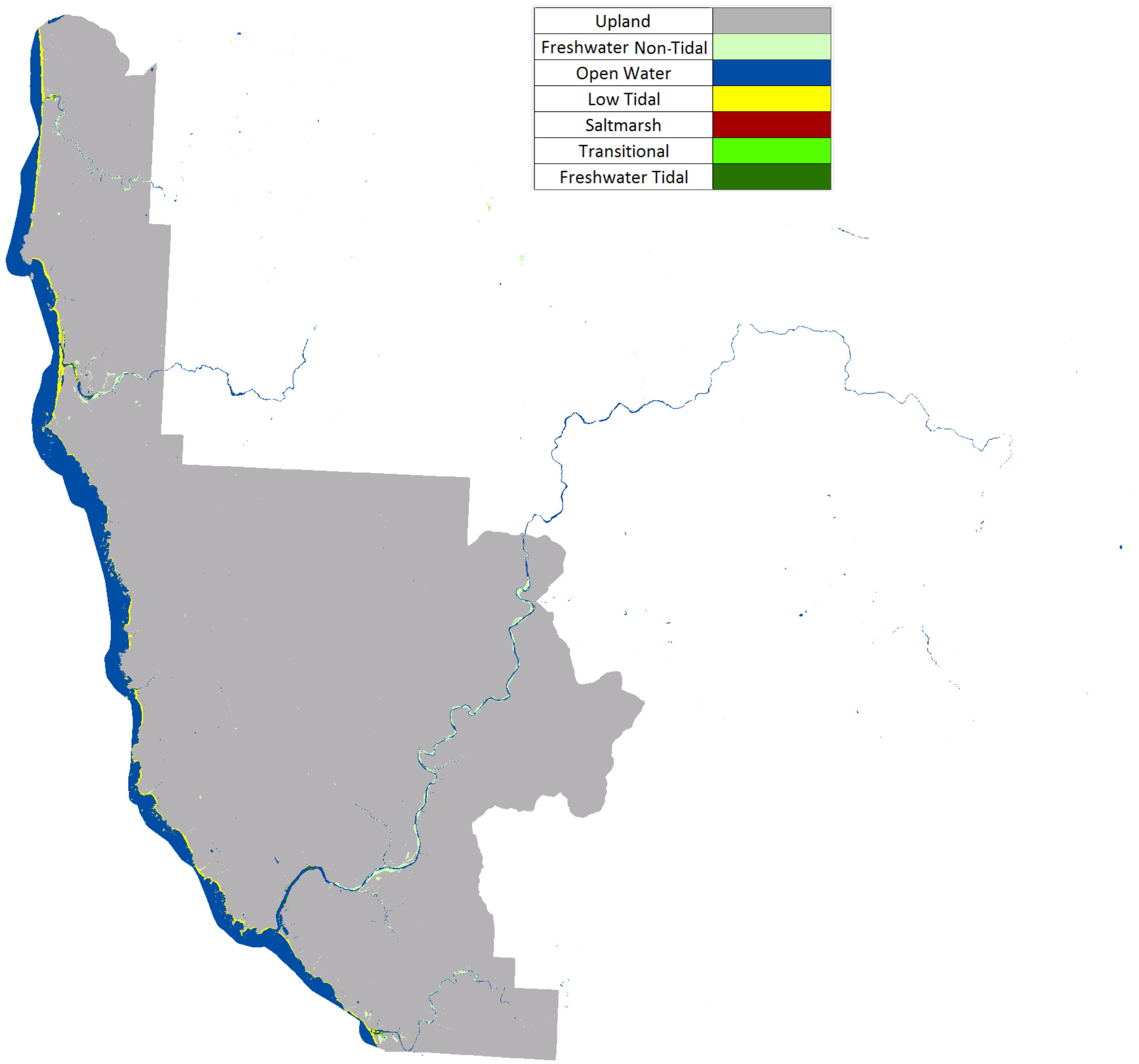

Figure 181. Site 11, 2100, Scenario A1B max (0.69 m) – No Dikes

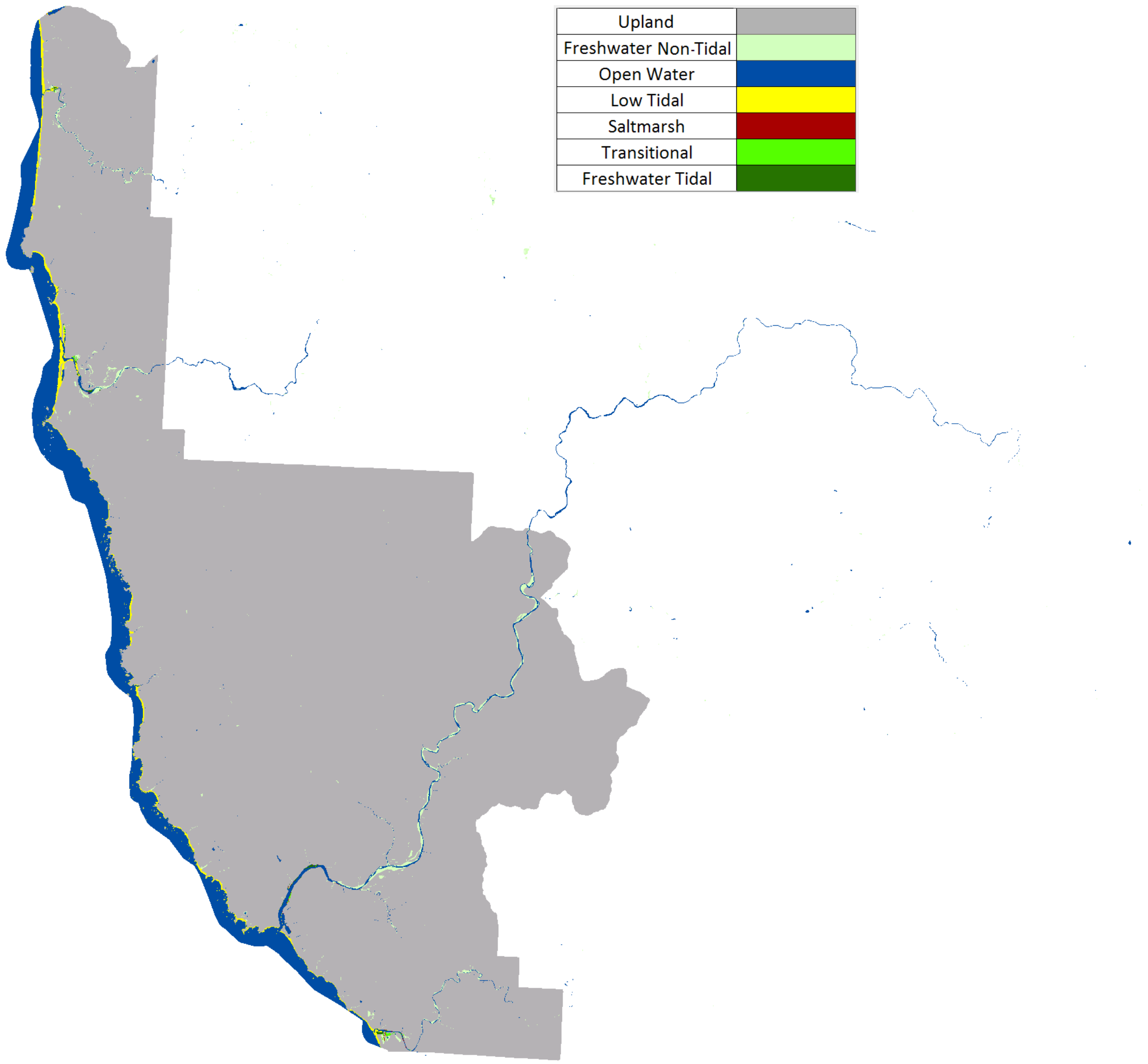

Figure 182. Site 11, 2100, Scenario 1 m – No Dikes

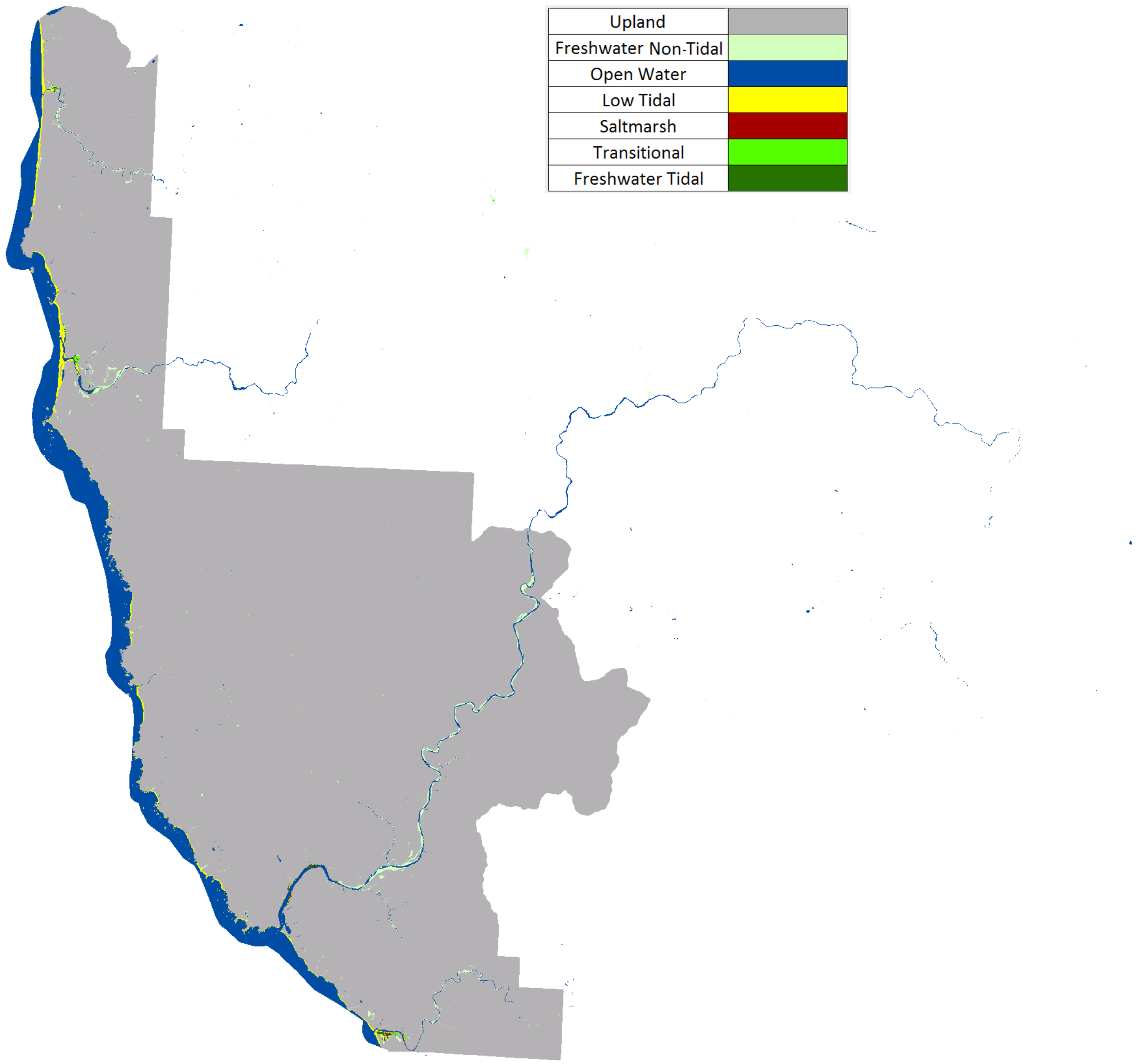

Figure 183. Site 11, 2100, Scenario 1.5 m – No Dikes

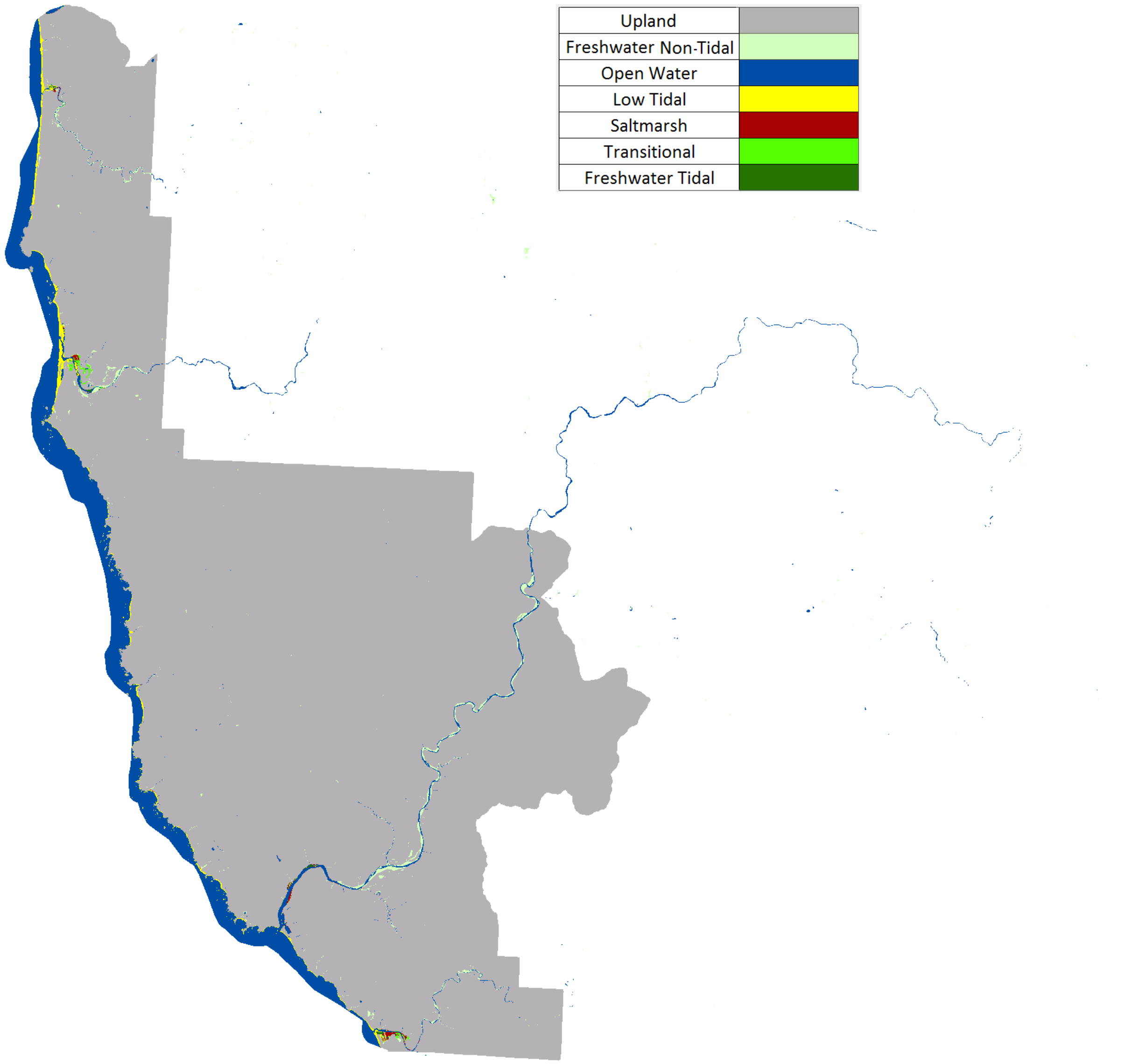

Figure 184. Site 8, 2100, Scenario 2 m – No Dikes

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