Application of SLAMM to Coastal Connecticut

Draft Report

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NOTICE

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Acronyms and Abbreviations List

CT	Connecticut
DEM	Digital Elevation Map
FEMA	US Federal Emergency Management Agency
GCM	General Climate Model
GIS	Geographic Information Systems
GT	Great Diurnal Tide Range
HTU	Half-Tide Units (highest tide each day minus the mean tide level)
IFM	Irregularly-Flooded Marsh
LiDAR	Light Detection and Ranging– method to produce elevation data
LRR	Linear Regression Rate
m	Meters
MEM	Marsh Equilibrium Model
MHHW	Mean Higher High Water (average highest tide each day)
MLLW	Mean Lower Low Water (average lowest tide each day)
MTL	Mean Tide Level
NAVD88	North American Vertical Datum of 1988
NED	USGS National Elevation Dataset
NLD	National Levee Database from the U.S. Army Corps of Engineers
NEIWPCC	New England Interstate Water Pollution Control Commission
NOAA	United States National Oceanic and Atmospheric Administration
NWI	National Wetlands Inventory
NYSERDA	New York State Energy Research and Development Authority
RFM	Regularly-Flooded Marsh
RIM	Rapid Ice Melt
RMSE	Root Mean Standard Error
SD	Standard Deviation
SLAMM	Sea-level Affecting Marshes Model
SLR	Sea-Level Rise
STORET	EPA Data Warehouse
TSS	Total Suspended Solids
UConn	University of Connecticut
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator (UTM) conformal projection
VDATUM	NOAA Product for converting vertical datums
WPC	Warren Pinnacle Consulting, Inc.

1 Background

In 2013 and 2014, the New England Interstate Water Pollution Control Commission (NEIWPCC) and the state of Connecticut funded a marsh-habitat migration study for the entirety of coastal Connecticut. Goals of the project are to identify potential responses of Connecticut's coastal marshes and adjacent upland areas to anticipated increases in mean-tide water level elevations in Long Island Sound (LIS) and Connecticut's estuarine embayments. Results of the study will help identify the most appropriate adaptation strategies for specific areas including land acquisition, marsh restoration, infrastructure development, and other land and facility management actions.

Tidal marshes are dynamic ecosystems that provide significant ecological and economic value. Given that tidal marshes are located at the interface between land and water, they can be among the most susceptible ecosystems to climate change, especially accelerated sea-level rise (SLR). Numerous factors can affect marsh fate including the elevation of marshes relative to the tides, marshes' frequency of inundation, the salinity of flooding waters, the biomass of marsh platforms, land subsidence, marsh substrate, and the settling of suspended sediment into the marshes. Because of these factors, a simple calculation of current marsh elevations as compared to future projections of sea level does not provide an adequate estimation of wetland vulnerability.

The Sea-Level Affecting Marshes Model (SLAMM) is widely recognized as an effective model to study and predict wetland response to long-term sea-level rise (Park et al. 1991). The model simulates the dominant processes that affect shoreline modifications during long-term sea-level rise and has been applied in every coastal US state (Craft et al. 2009; Galbraith et al. 2002; Glick et al. 2007, 2011; National Wildlife Federation and Florida Wildlife Federation 2006; Park et al. 1993; Titus et al. 1991). SLAMM predicts when currently-existing marshes are likely to be vulnerable to SLR as well as predicting locations where marshes will migrate upland in response to changes in water levels. SLAMM provides numerical and spatial outputs; its relative simplicity and modest data requirements allow application at a reasonable cost. Mcleod and coworkers wrote in their review of sea-level rise impact models that "... the SLAMM model provides useful, high-resolution, insights regarding how sea-level rise may impact coastal habitats" (2010).

The SLAMM model was one of the first landscape-scale models to incorporate the effects of vertical marsh accretion rates on predictions of marsh fates, incorporating this process since the mid-1980s (Park et al. 1989). Marsh accretion is the process of wetland elevations changing due to the accumulation of organic and inorganic matter. Since 2010, SLAMM has incorporated dynamic relationships between marsh types, marsh elevations, tide ranges, and predicted accretion rates. The SLAMM application presented here utilizes a mechanistic marsh accretion model to define relationships between tide ranges, water levels, and accretion rates (Morris et al. 2002; Morris 2013).

Other processes that are accounted for within this SLAMM simulation include dry-land inundation, coastal-wetland erosion, and connectivity of wetland habitats. SLAMM is a relatively simple non-hydrodynamic model that relies on predicted future land elevations and tidal ranges to predict the future of wetland habitats. A detailed description of model processes, underlying assumptions, and equations can be found in the SLAMM 6.2 Technical Documentation (available at http://warrenpinnacle.com/prof/SLAMM).

2 Methods

2.1 Study Area

The project study area was divided into 3 individual SLAMM projects (Figure 1) that are loosely identified by county:

- Area 1: Fairfield County
- Area 2: New Haven and Middlesex counties
- Area 3: New London County

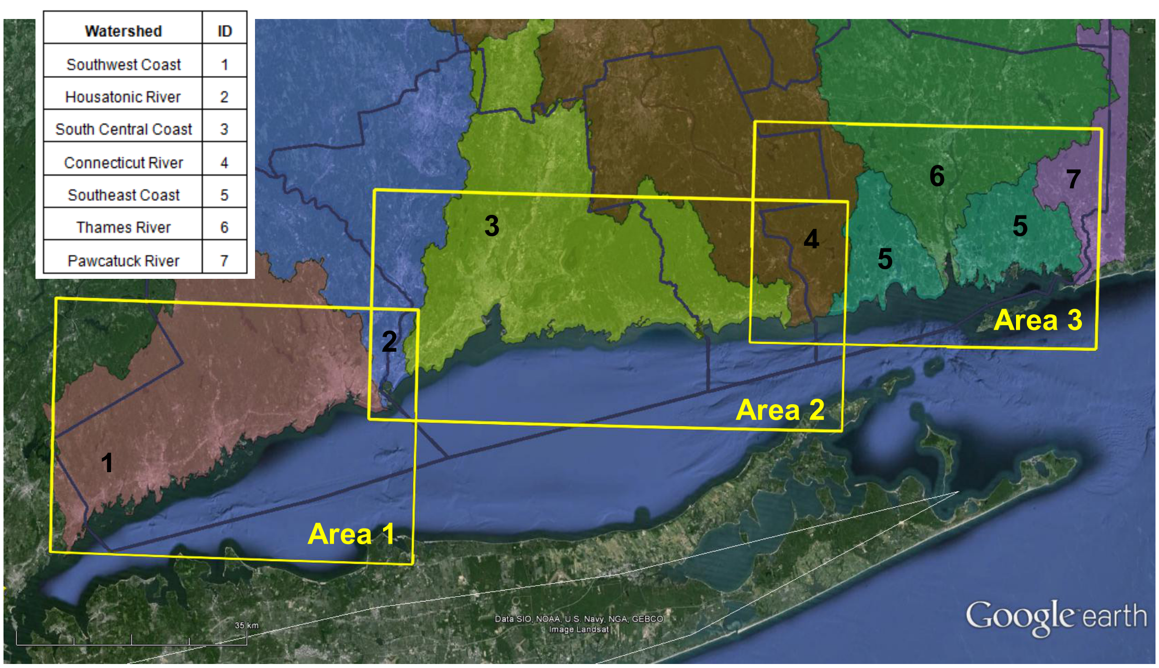

Figure 1. Project study area broken into the three individual SLAMM projects.
Blue lines represent county boundaries. Colored areas are major watershed basins.

SLAMM projections results are summarized by the coastal areas (elevations less than 5 m) of the major watersheds in Connecticut shown in Table 1. The Appendix has also results summarized by county.

Table 1 shows the current land coverage for the entire study area. Of the 436,000 acres that represent the study area, more than 65% is occupied by dry land (developed and undeveloped), and 27.5% by estuarine open water. The remaining 12.5% includes over 23,000 acres of wetland, over 2,500 acres of beaches and tidal flats, and approximately 4,500 acres of inland-fresh open water.

Table 1. Land cover categories for entire Connecticut study area

Land cover type		Area (acres)	%
	Undeveloped Dry Land	196,599	45.1
	Estuarine Open Water	119,683	27.5
	Developed Dry Land	88,504	20.3
	Irreg.-Flooded Marsh	11,211	2.6
	Swamp	8,591	2.0
	Inland Open Water	4,561	1.0
	Estuarine Beach	2,457	0.6
	Regularly-Flooded Marsh	1,182	0.3
	Inland-Fresh Marsh	850	0.2
	Tidal-Fresh Marsh	743	0.2
	Tidal Swamp	667	0.2
	Riverine Tidal	452	0.1
	Trans. Salt Marsh	158	<0.1
	Inland Shore	120	<0.1
	Tidal Flat	98	<0.1
	Rocky Intertidal	62	<0.1
	Total (incl. water)	**435,938**	**100**

2.2 Input Raster Preparation

This section presents the data sources used in this project and the manipulation steps used to create SLAMM input rasters.

2.2.1 Elevation Data

High vertical-resolution elevation data may be the most important SLAMM data requirement. Elevation data demarcate where salt water is predicted to penetrate and, when combined with tidal data, the frequency of inundation for wetlands and marshes.

In order to derive the elevation layers within the study areas, several LiDAR sources were combined (Figure 2):

- 2004 FEMA Bare Earth Topographic LiDAR: Connecticut River;
- 2006 FEMA Topographic LiDAR: Connecticut Coastline Survey;
- 2011 USGS LiDAR for the Northeast;
- 10 m resolution National Elevation Data;
- 2012 Post Sandy LiDAR data; and,
- 2000 DEM (10 foot) from the University of Connecticut derived from Connecticut LiDAR 2000.

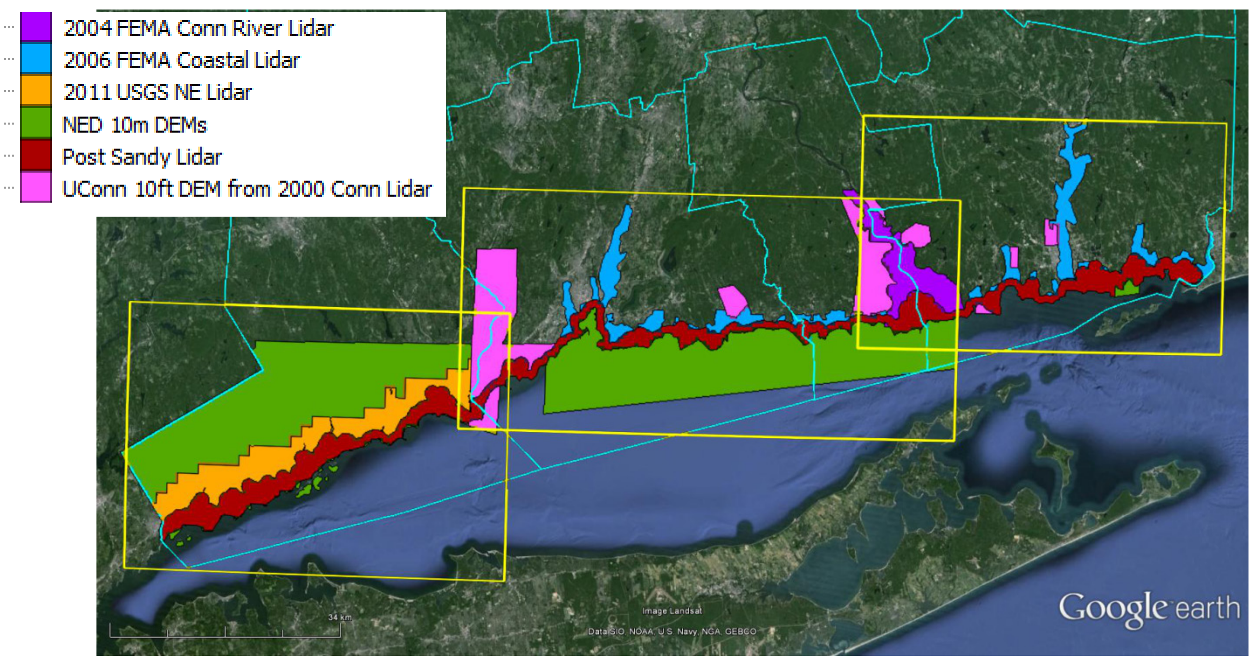

Figure 2. Elevation sources for Connecticut

Multiple steps were used to produce a hydro-enforced DEM for the full Connecticut coastal project area.

- **Project Boundary Derivation**: LiDAR data were reprocessed for locations at or below 5 m above NAVD88 (approximate mean-tide level) to limit the scope of data processed.
- **Data Preparation**: Data were re-projected to project specifications and resampled to the 5 m cell size used in all model runs.
- **Creation of Breaklines for HydroEnforcement:** Water-flow pathways were defined to determine where bridges and culverts DEM may be blocking hydrologic flow. Road centerlines

were intersected with water flow lines to determine locations to examine. Culvert and bridges were positively identified using CT orthoimagery.

- **DEM Hydroenforcement**: Water-flow pathways identified in the steps described above and by examining SLAMM initial inundation conditions were enforced and written into the project DEMs.

More technical details regarding GIS processing can be found in Appendix A.

SLAMM Simulation. When the above procedures were complete, a preliminary inundation and connectivity analysis was run for the study area using SLAMM. This type of analysis illustrates the frequency of tidal inundation for coastal habitats. This analysis, along with correspondence with NEIWPCC project managers, allowed us to identify areas that were either inundated too frequently or not frequently enough. When water pathways were inadequately represented, the combined DEMs were further edited by Warren Pinnacle Consulting. Additional water-flow pathways were manually added if water flows had been improperly impeded based on DEM elevations.

Slope. Slope rasters were derived from the hydro-enforced DEMs created above using ESRI's spatial analyst. The "slope tool" was used to create slope with output values in degrees.

2.2.2 Elevation correction

VDATUM version 3.2 (NOS 2013) was utilized to convert elevation data from the NAVD88 vertical datum to Mean Tide Level (MTL), which is the vertical datum used in SLAMM. This is required as coastal wetlands inhabit elevation ranges in terms of tide ranges as opposed to geodetic datums (McKee and Patrick 1988). VDATUM does not provide vertical corrections over dry land; dry-land elevations were corrected using the VDATUM correction from the nearest open water. Corrections in the study areas ranged from approximately -0.12 m to 0.05 m. A spatial map of corrections is shown in Figure 3.

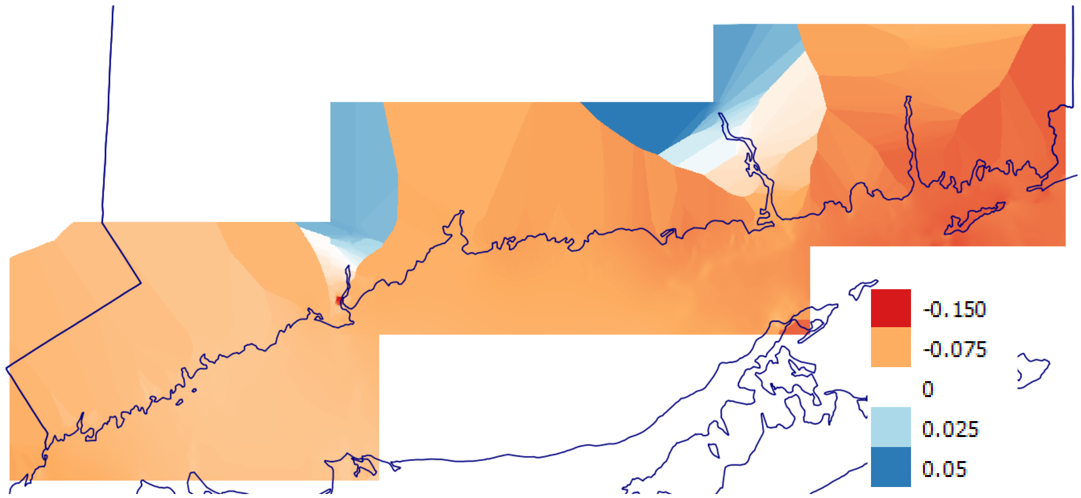

Figure 3. VDATUM-derived correction values (meters)

2.2.3 Wetland Layers and Crosswalk to SLAMM

Wetland rasters were created from a National Wetlands Inventory (NWI) survey dated 2010 for the entire study area. NWI land coverage codes were crosswalked to SLAMM codes using Table 4 of the SLAMM Technical Documentation as produced with assistance from Bill Wilen of the National Wetlands Inventory (Clough et al. 2012). The SLAMM Codes correspond to the following SLAMM Categories:

SLAMM Codes	SLAMM Colors	SLAMM Description
1		Developed Dry Land
2		Undeveloped Dry Land
3		Swamp
4		Cypress Swamp
5		Inland Fresh Marsh
6		Tidal Fresh Marsh
7		Transitional Salt Marsh
8		Regularly-flooded Marsh
9		Mangrove
10		Estuarine Beach
11		Tidal Flat
12		Ocean Beach
13		Ocean Flat
14		Rocky Intertidal
15		Inland Open Water
16		Riverine Tidal
17		Estuarine Open Water
18		Tidal Creek
19		Open Ocean
20		Irregularly-flooded Marsh
21		Tall Spartina
22		Inland Shore
23		Tidal Swamp
24		Blank
25		Flooded Developed Dry Land
26		Backshore

Since dry land (developed or undeveloped) is not classified by NWI, SLAMM classified cells as dry land if they were initially blank but had an elevation assigned. The resulting raster data was checked visually to make sure the projection information is correct, has a consistent number of rows and columns as the other rasters in the project area, and to ensure that the data looked complete based on the source data.

2.2.4 Dikes and Impoundments

Dike rasters were created using different data sources:

- NWI data. All NWI wetland polygons with the "diked or impounded" attribute "h" were selected from the original NWI data layer and these lands were assumed to be permanently protected from flooding. This procedure has the potential to miss dry lands that are protected by dikes and seawalls as contemporary NWI data contains wetlands data only.
- 2013 FEMA Flood Hazard Layers using the attribute of dams. These data were inspected to make sure each feature consisted of a single line drawn on top of the dam structure.
- Connecticut Dams database which consists of point data representing the general location of a dam. A new line feature class was created for each dam feature that could be found within a 500' area surrounding each point.

- National Levee Database (NLD). The U.S. Army Corps of Engineers National Levee Database (2014) (http://nld.usace.army.mil/) was accessed and any additional levees in the study area not included in the NWI, FEMA, and Connecticut Dams database but represented in the NLD were added manually, based on dimensions shown in the on-line mapping interface. Dikes in locations above five meters in elevation were not digitized.

Line and polygon data from the first three datasets listed above were mosaicked together into a final dikes and dams raster with a 5 meter cell size. Raster data were checked visually to make sure the projection information was correct, layers had a consistent number of rows and columns, and that the data captured all features within the source data. NLD data were then manually added through the SLAMM interface using SLAMM wetland layers laid over satellite imagery to ensure locations were digitized as precisely as possible[1].

In Stamford CT, the dike system has a flood gate that may be closed when necessary. Therefore the open water behind this gate was classified as diked. Because of this, SLAMM projections assume that SLR will not occur behind this gate (the gate will be maintained and improved in the event of SLR).

A significant amount of the Connecticut coastline is protected by seawalls. However, if these structures were uniformly designated as "diked" by SLAMM it would be equivalent to having them continually armored against sea-level rise. There will likely be some changes to the structures over time, but there is no reliable way to assess which structures may be altered. In these simulations, current seawalls were generally accounted for only by their current elevation (provided by the LiDAR data) and were allowed to be overtopped when sea levels become high enough. In a few cases where seawalls were visible on satellite imagery and time-zero flooding was predicted, a few cells were designated as "diked" to protect against immediate flooding[2].

2.2.5 Percent Impervious

Percent Impervious rasters were extracted from the 2006 National Land Cover Dataset (Fry et al. 2011). The cell size was resampled from the original 30 m resolution to 5 m resolution in order to match the cell resolution of the other rasters in the project.

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[1] Dikes were manually added in the following locations: Stonington CT, 41.371465°, -71.833078°; New London CT, 41.349526° -72.101089°;

[2] Some seawalls cells were manually set to "diked" in the following locations: Spruce Swamp Pond 41.087893° -73.394471° ; Rocky Point Club 41.016840° -73.558618°; In front of a pond shown as "impounded" in the NWI Layer 41.021223° -73.577665° .

2.3 Model Timesteps

SLAMM simulations were run from the date of the initial wetland cover layer to 2100 with model-solution time steps of 2025, 2040, 2055, 2070, 2085 and 2100. Maps and numerical data were output for the years 2025, 2055, 2085, and 2100.

2.4 Sea Level Rise Scenarios

The accelerated sea-level rise (SLR) scenarios used in this analysis were developed for a similar project undertaken in New York by the New York State Energy Research and Development Authority (NYSERDA) in conjunction with the project's advisory committee. Scenarios correspond to the maximum of the General Climate Model (GCM) and the minimum and maximum of the and Rapid Ice Melt (RIM) estimates as described in the New York State ClimAID report (2011) as well as the intermediate scenario of 1 meter of SLR by 2100 (39.4 inches). The base year for these scenarios is 2002. The "rapid ice-melt scenarios" are based on the potential acceleration of ice-melt rates in the Greenland and West Antarctic ice sheets as well as paleoclimatological studies. Table 2 and Figure 4 show details of SLR relative to the base year of 2002 used in the four scenarios applied to the Connecticut SLAMM projections.

Table 2. SLR under each scenario for each timestep (mm) relative to the base year of 2002

Scenario	2025	2055	2085	2100
General Climate Model Maximum	127	305	584	718
1 m by 2100	129	431	807	1000
Rapid Ice Melt Minimum	127	483	1041	1327
Rapid Ice Melt Maximum	254	737	1397	1721

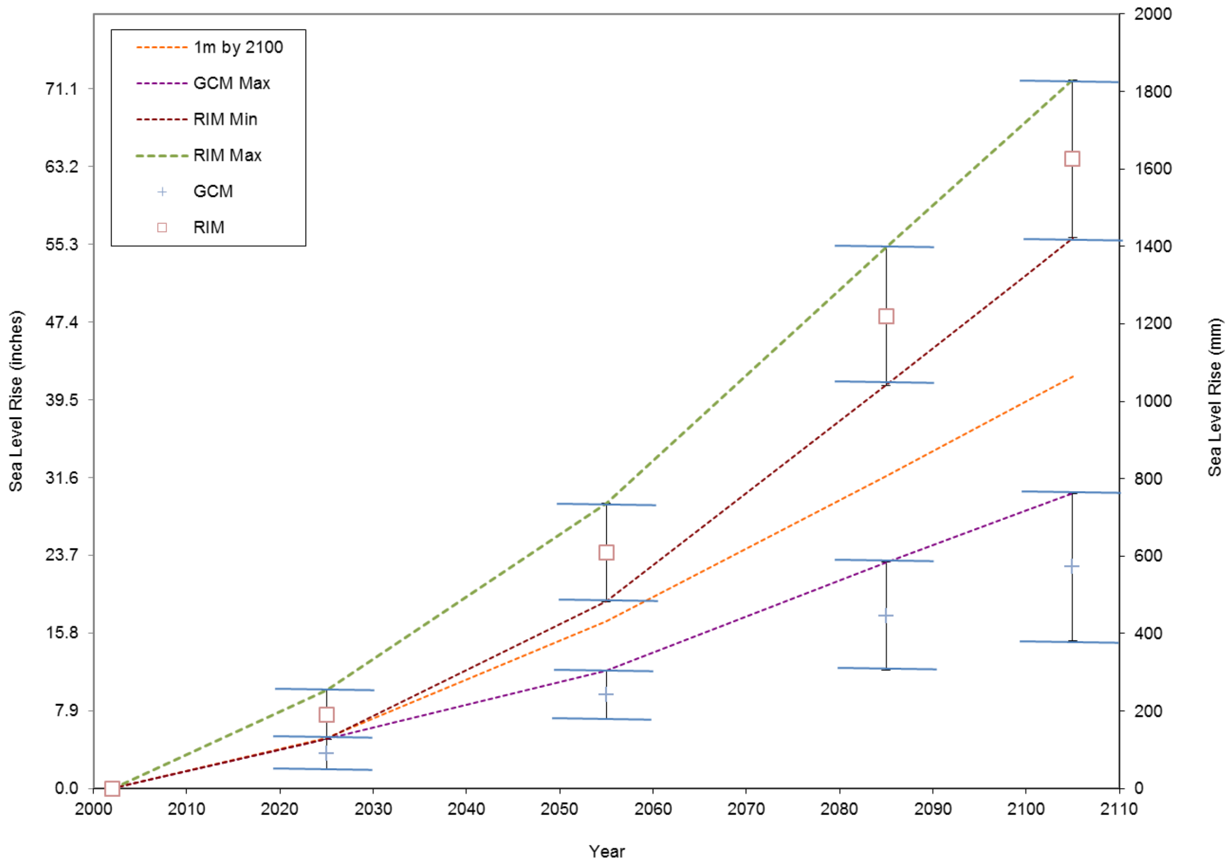


Figure 4. Sea level rise scenarios simulated using SLAMM compared to the General Climate Model and Rapid Ice Melt model predictions.
(Horizontal lines on error bars represent the decadal timescale over which predicted SLR may occur.)

2.5 Historic sea level rise rates

The SLR scenarios shown in the table and figure above are "relative" sea-level rise estimates. This means that SLAMM scenarios do not need to be corrected for differentials between local (or relative) SLR and global (or eustatic) SLR trends. For this reason, within the model, the historic SLR was set to zero (to model relative sea level rise rather than eustatic SLR).

According to NOAA, historic sea level rise trends along the Connecticut coast range from 2.25 mm/yr at New London to 2.56 mm/yr in Bridgeport. Therefore each of the four scenarios simulated represents a significant acceleration of SLR from the local historical trend observed.

2.6 Tide Ranges

Tide range data was collected from NOAA tidal datums and tide prediction tables for 2011 within the study area. SLAMM requires the great diurnal tide range (GT) as an input, which is provided directly, along with mean tide range and other tidal datum information, by the NOAA tidal datums. NOAA's tide prediction tables provide the mean tide range, which was converted to GT by multiplying by the average ratio between mean tide range and great diurnal tide range derived from the NOAA tidal datums. The GT values in the project area varied from a maximum of 2.5 m at Cos Cobb Harbor to 0.88 m in New London. As discussed in the results section below, this tends to make marshes more vulnerable to SLR in the eastern portion of the study area. A map of GT data throughout the study area is provided in Appendix B.

2.7 Salt Elevation

The salt-elevation parameter in SLAMM defines the boundary between coastal wetlands and dry lands (or fresh-water wetlands). This elevation, relative to mean-tide level, is determined through analysis of "higher high" water levels in NOAA tide records. In practice, we have found that the elevation that differentiates coastal wetlands and dry lands is approximately the height inundated once every 30 days.

Therefore, the 30-day inundation level was determined for the only three locations in Connecticut with NOAA verified water-level data available: Bridgeport, New Haven and New London. Five years of data were analyzed in order to characterize this relationship in each location. Although relatively few data points were available spatially, a linear relationship was determined between the calculated salt elevations versus the great diurnal tide ranges for the entire study area (Salt Elevation = $0.6015 \cdot GT + 0.3205$, see Figure 5.) This relationship was used to derive site-specific salt elevations based on the available local measured GT applied.

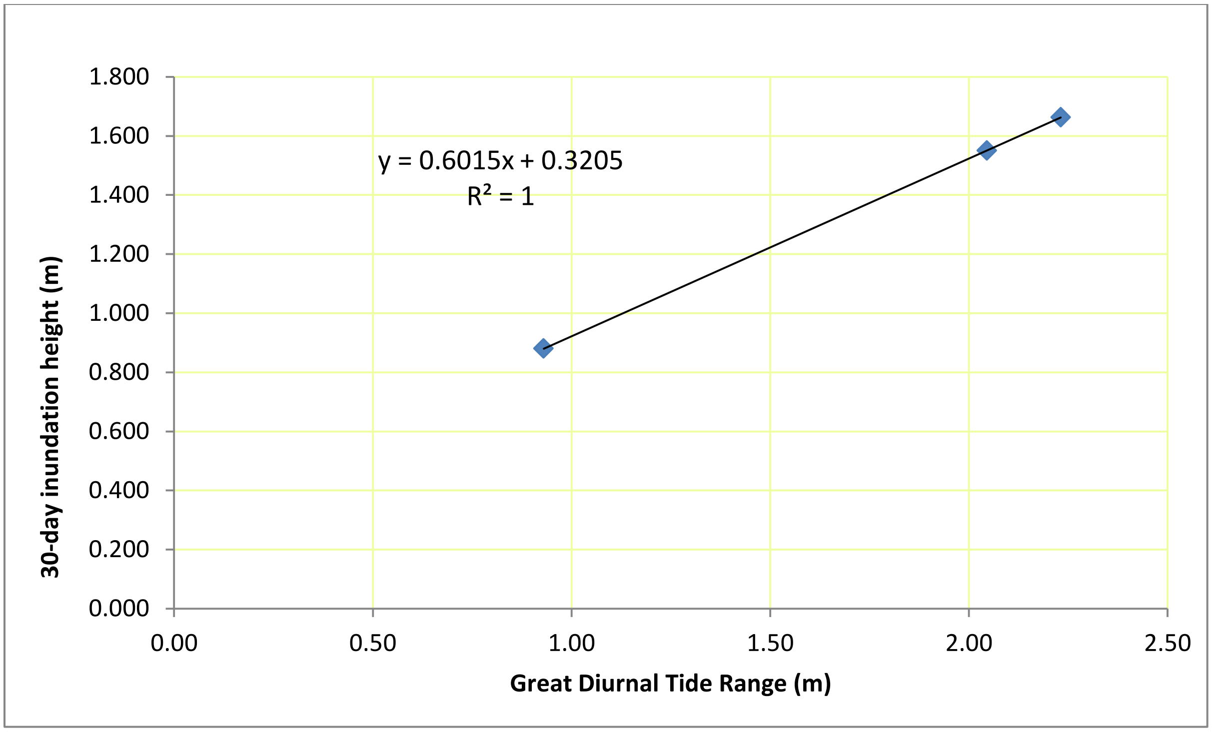


Figure 5. Great Diurnal Tide Range to 30-Day Inundation Height/Salt Elevation relationship derived from NOAA

2.8 Accretion Rates

A full literature search was conducted to collect relevant accretion rates. In addition, unpublished data from members of the project advisory committee were used to determine the accretion rates for the study area.

The current SLAMM application attempts to account for what are potentially critical feedbacks between tidal-marsh accretion rates and SLR (Kirwan et al. 2010). In tidal marshes, increasing inundation can lead to additional deposition of inorganic sediment that can help tidal wetlands keep pace with rising sea levels (Reed 1995) . In addition, salt marshes will often grow more rapidly at lower elevations allowing for further inorganic sediment trapping (Morris et al. 2002).

In this project, feedback relationships were investigated using observed accretion rates as compared to marsh platform elevations. Elevations relative to accretion rates were derived by comparing the location provided in the citations to the corresponding project area DEM. There is significant uncertainty in terms of assigning elevations to these marsh platforms, especially when core data were used to derive accretion rates. Employing this approach we have assumed that the marsh has maintained an equilibrium elevation relative to tide levels for the historical period in question – a debatable but necessary assumption in order to carry out this analysis. Locations were also compared to the input wetland layer to differentiate between low and high marshes.

2.8.1 Available accretion rate data

All available accretion data are summarized in Table 3. Data with known sampling locations are shown with colored backgrounds in Table 3, and these locations are illustrated in Figure 6. When sources did not define the type of marsh being studied, data for regularly-flooded marsh (RFM) vs. irregularly-flooded marsh (IFM) were discerned using the NWI wetland layer.

Figure 6. Locations of Available Accretion Data in Coastal CT. (yellow dots)

Table 3. Accretion database for Connecticut. Shading indicates regions – Red = Fairfield, Green = New Haven, Orange = Barn Island, White = precise locations unknown.

Location	Marsh Type	Accretion (red) or Elevation change (mm/yr)	Accretion (red) or Elevation change Std. Dev. (mm/yr)	elev (m, from LiDAR) NAVD88	GT (m)	Source
Sherwood	RFM	*3.5*		1.55	2.3	Anisfeld 2014
Hoadley	RFM	*3.9*		0.8065	1.9	Anisfeld 2014
Jarvis	RFM	*10.3*		0.337	1.9	Anisfeld 2014
Guilford CT	IFM	*2.5*	*1.4*	1.3692	1.9	Anisfeld et al. (1999)
BP1	IFM	3.2	0.1	0.505	0.85	Barrett and Warren (2014)
BP2	IFM	2.7	0.1	0.4189	0.85	Barrett and Warren (2014)
WC1	IFM	2.3	0.2	0.5	0.85	Barrett and Warren (2014)
HQ1	IFM	1.62	0.07	0.36	0.85	Barrett and Warren (2014)
HQ3	IFM	3.07	0.09	0.68	0.85	Barrett and Warren (2014)
HQ2	IFM	2.4	0.1	0.36	0.85	Barrett and Warren (2014)
IP1	IFM	1.4	0.2	0.4	0.85	Barrett and Warren (2014)
IP2	IFM	1.3	0.4	0.4	0.85	Barrett and Warren (2014)
IP3	IFM	2.8	0.3	0.4	0.85	Barrett and Warren (2014)
CT	IFM	*3.3*		0.39	0.85	Orson, Warren and Niering (1998)
CT	IFM	*2*		0.5	0.85	Orson, Warren and Niering (1998)
CT	IFM	*1.8*		0.455	0.85	Orson, Warren and Niering (1998)
Barn Island		2				Harrison and Bloom, 1977
Great Island		3.8				Harrison and Bloom, 1977
Hammock River marsh, CT		3.6				Harrison and Bloom, 1977
Stony Creek marsh, CT		6.6				Harrison and Bloom, 1977
Nells Island, CT		6				Harrison and Bloom, 1977
Pataguanset		1.1				Orson et al., 1987
Headquarter, CT		1.125				Warren et al., 1993
Wequetequock Cove, CT		2.25				Warren et al., 1993

2.8.2 Irregularly-flooded marsh

The accretion data sampled from locations identified as irregularly-flooded marsh were analyzed to determine if they exhibit spatial trends or underlying feedback relationships with elevations. However, the distribution of the available accretion data as a function of the elevation suggests that there is not a strong relationship between elevation and accretion for this type of marsh, as shown in Figure 7. This may be expected since irregularly-flooded marshes are subject to less frequent flooding and therefore less sedimentation. These high marshes can therefore be assumed to be less sensitive to their vertical elevations. The average of the available measured accretion data is 2.42 mm/year. This accretion rate has been applied for all irregularly-flooded marshes across the entire study area. The uncertainty analysis will explore the effects of other possible accretion-rate relationships by varying maximum and minimum accretion rates based on regional minimum and maximum observed data.

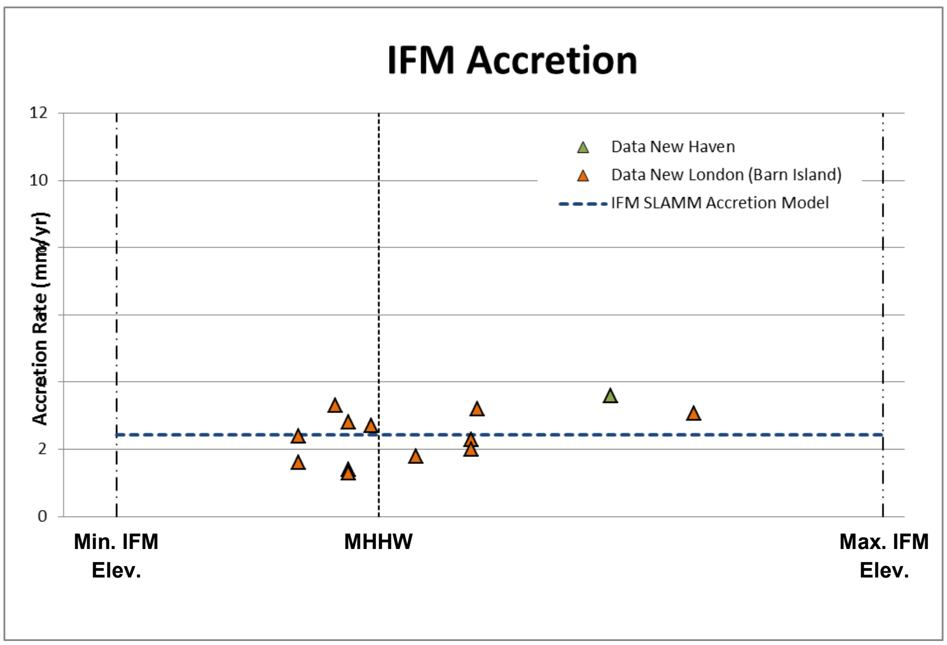


Figure 7. Irregularly-flooded marsh data and models for CT

2.8.3 Regularly-flooded Marsh

For Connecticut low marshes, accretion rates and their relationship with elevation were derived by calibrating the Marsh Equilibrium Model (MEM) developed by Dr. James Morris and coworkers at the University of South Carolina (Morris et al. 2002, 2012; Morris 2013) to site-specific data. The MEM model was chosen for several reasons. MEM describes feedbacks in marsh accretion rates, it is backed up by existing data, and it accounts for physical and biological processes that cause these feedbacks. An alternative approach could be to fit available accretion data with a simple mathematical function. However, as described below, available accretion data often do not span a wide enough set of elevations to be able to derive the required curve. Furthermore, using a mechanistic model such as MEM helps explain the causes for feedbacks between accretion rates and elevation and therefore can tell a more compelling story.

Another important reason to use MEM is that results from this model can be extrapolated to other geographic areas where there is no accretion data available, but other physical/biological parameters are available (e.g. suspended sediment concentrations or tidal regimes). The model can also be extrapolated to vertical positions in the tidal frame where data do not exist. This is often required in areas where there is little marsh low in the tidal frame due to historically low rates of SLR.

The key physical input parameters of the MEM model are tide ranges, suspended sediment concentrations, initial sea-level and marsh platform elevations, and the elevations defining the domain of marsh existence within the tidal frame. Biological input parameters are the peak concentration density of standing biomass at the optimum elevation, organic matter decay rates, and parameters determining the contribution to accretion from belowground biomass. However, several input parameters are not always known (e.g. partition between organic and inorganic components to accretion, peak biomass, settling velocities, trapping coefficients, organic matter decay rate, below ground turnover rate and others). The approach followed was to estimate MEM input parameters based on observations when available and fit the unknown model parameters using observed accretion rates.

The sections below discuss the regional physical and biological input parameters for developing MEM within the study area.

2.8.3.1 Suspended Sediment

Suspended sediment data (in the form of total suspended solids or TSS) were collected from the US EPA STORET Data Warehouse (U.S. Environmental Protection Agency, 2013). Table 4 presents the averages obtained when the TSS data were analyzed by region.

Table 4. Average TSS by Study area

	Fairfield	**New Haven and Middlesex**	**New London**
Average (mg/L)	10	17	8
St.Dev. (mg/L)	13	17	7
N – Sample size	56	45	15

Statistical analyses of the TSS data (Kolmogorov Smirnoff tests) show that the New Haven/Middlesex data set is distinct from the other two data sets, but the Fairfield and New London data sets are not statistically different. Despite this, we have produced three different MEM curves applied to each study region since New London and Fairfield counties are not spatially adjacent and have different tidal range.

2.8.3.2 Marsh Biomass

Relatively few studies on marsh biomass are available within the study area. Values between 700-1000 g/m^2 have been measured at Hoadley, Jarvis and Sherwood marshes in CT by Shimon Anisfeld (2014). These values were used as input parameters for the MEM models developed for the different study areas (Table 5). Based on observed data, a value of 700 g/m^2 was chosen across the study area except for in New Haven and Middlesex counties where available data suggested a higher peak biomass.

Table 5. Peak biomass applied to the MEM models in CT

	Fairfield	New Haven and Middlesex	New London
Peak biomass (g/m^2)	700	995	700

These chosen values are also reasonably in the range of other measured biomass data in the region. Anisfeld and Hill measured a maximum “net aboveground primary production” in a *Spartina alterniflora* marsh in Guilford, CT of 250 grams of Carbon per square meter per year (Anisfeld and Hill 2012). The Aboveground Organic Carbon Content of *Spartina alterniflora* has been observed to be between 39 to 44% (Alexander and Robinson 2006; Gallagher 1975; Middelburg et al. 1997; Osgood and Zieman 1993; Tyler, C 1997). Considering the above ground carbon weight percent of Spartina of 39.2% measured by Middleburg et al. (Middelburg et al. 1997), the peak biomass for the Guilford Marsh is that can be estimated of approximately 625 g/m^2. Hartig et al. measured biomass of *Spartina alterniflora* ranging 700-1450 g/m^2 in Jamaica Bay (2002).

2.8.3.3 MEM Calibration Results.

The final set of regularly-flooded marsh accretion models plotted against data is shown in Figure 8. As discussed above, there is little-to-no data low in the tidal frame, making an empirical derivation of these curves impossible. The Connecticut MEM calibration was achieved starting with a model calibration for the North Shore of Long Island, NY. Tide ranges, peak biomasses, and total suspended solids were then set to Connecticut-specific values. Finally, parameters determining the partition between inorganic and organic contribution to accretion were calibrated in order to better fit available Connecticut accretion data.

In Figure 8 below irregularly-flooded marsh data are also included (triangles), while the model was derived for regularly-flooded marshes. High in the tidal frame (near MHHW), accretion rates for regularly-flooded and irregularly flooded marshes are quite similar. While there is some uncertainty in the National Wetland Inventory between the spatial domains of regularly and irregularly-flooded marshes, overall model uncertainty is reduced as both marshes have very similar accretion rates at their boundaries.

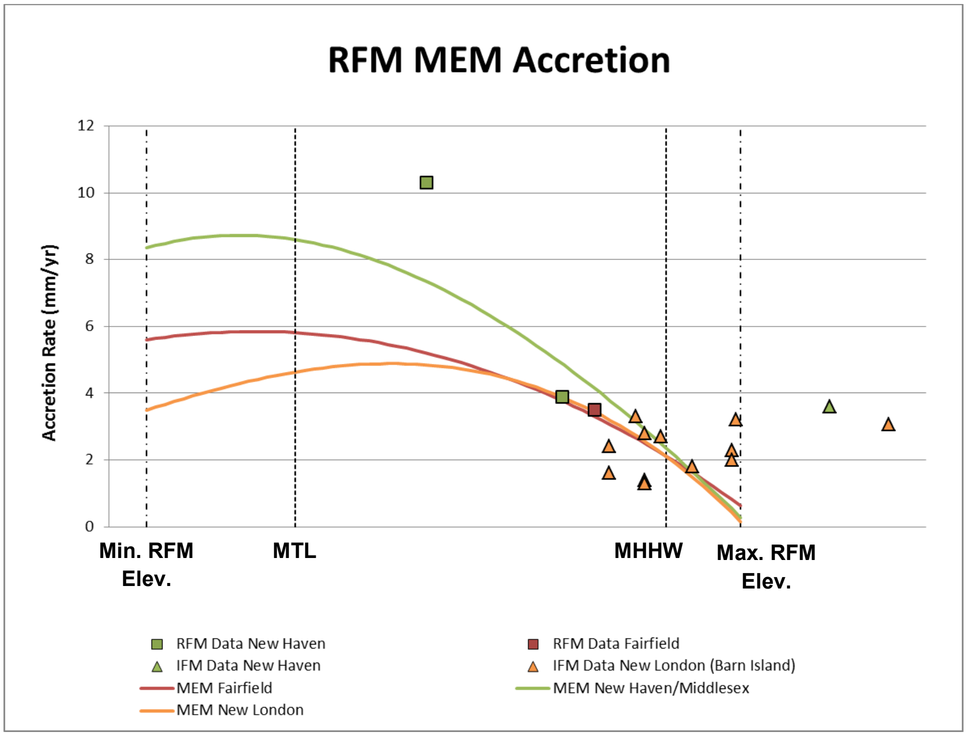


Figure 8. Regularly-flooded marsh accretion models plotted against available data

2.8.4 Accretion for Other Wetlands

The Inland-fresh Marsh accretion rate was set to 1 mm/yr. Studies of fens and freshwater marshes in Michigan and Georgia (Craft and Casey 2000; Graham et al. 2005) suggest this to be an appropriate value based on ^{210}Pb measurements. Tidal Fresh Marsh accretion was set to 5 mm/yr based on data presented by Neubauer (Neubauer 2008; Neubauer et al. 2002). Tidal-fresh marsh accounts for only one half of one percent of coastal wetlands in the study area. Accretion feedbacks were not used for tidal-fresh marshes due to a lack of site-specific data. Lacking site-specific data, values of 1.6 mm/yr and 1.1 mm/yr were assigned for swamp and tidal swamp accretion, respectively which were measured in Georgia by Dr. Christopher Craft (Craft 2008, 2012).

Beach sedimentation was set to 0.5 mm/yr, a commonly used value in SLAMM applications. Average beach sedimentation rates are assumed to be lower than marsh-accretion rates due to the lack of vegetation to trap suspended sediment, though it is known to be highly spatially variable. In addition, it is worth noting that future beach nourishment, should it occur within the study area, is not accounted for in these SLAMM simulations.

2.9 Erosion Rates

In SLAMM average erosion rates are entered for marshes, swamps and beaches. Horizontal erosion is only applied when the wetland type in question is exposed to open water and where considerable wave effects are possible (a 9km fetch). SLAMM models erosion as additive to inundation. In general, SLAMM has been shown to be less sensitive to the marsh erosion parameters than accretion parameters (Chu-Agor et al. 2010).

In order to parameterize the erosion rates required by SLAMM, we relied on recent shoreline change statistics derived for the CT coast by Barrett and Coworkers (2014). This work characterized transects along the entire coast of CT to determine both long (1880 - 2006) and short-term (1983-2006) shoreline change rates. Long term rates were used to calculate the Linear Regression Rate (LRR) by fitting a least-squares regression line to all shoreline points for a particular transect (Barrett et al. 2014). In several cases the LRR showed positive shoreline movement, indicating aggradation. In these areas erosion rates were set to zero. In areas where shorelines had negative LRRs, the rate derived was applied equally to marsh, swamp, and beach categories, though erosion only applies in open-water to wetland boundaries. Specific rates applied, ranging from 0.02 to 0.12 meters per year, are described in the individual model calibration sections below. These rates are lower than the 1 meter per year observed by Fagherazzi (2013) and applied to the NYSERDA-funded SLAMM modeling of the New York Coast.

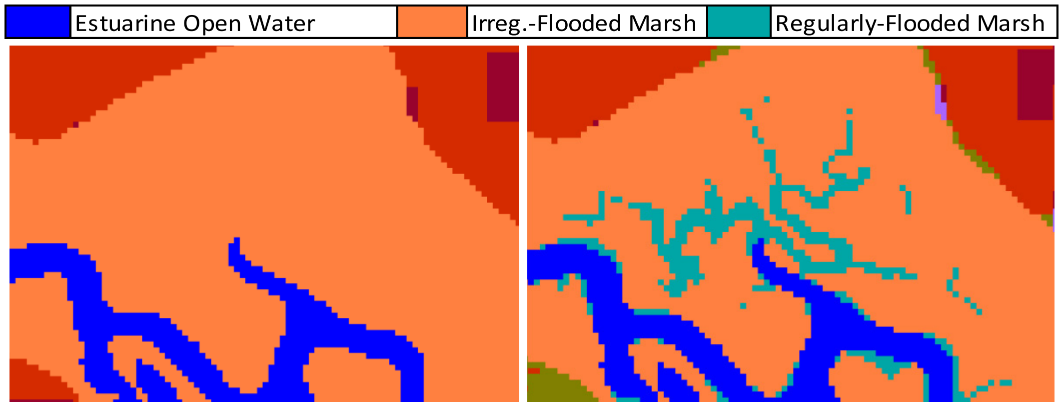
2.10 Model Calibration Approach

Initially, SLAMM simulates a “time zero” step, in which the conceptual model validates the consistency between wetland maps, elevation data, connectivity, and a spatial accounting of tide ranges. Due to local factors, DEM and NWI uncertainty, and simplifications within the SLAMM conceptual model, some cells inevitably can fall below their lowest allowable elevation category and are immediately converted by the model to a different land cover category. For example, an area categorized in the wetland layer as fresh-water swamp but which is subject to regular saline tides (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.

The wetland data used in this study were derived from the National Wetland Inventory (NWI) maps reflecting land coverage in 2010. While the time zero analysis indicated many areas were well represented by these data, in some areas valid changes were noted. In several areas the high horizontal resolution of the elevation data allowed for a more refined wetland map than the original NWI-generated shapefiles. The standard mapping protocol for the NWI maps used in this project is to include wetlands with an area of 0.5 acres (2023 m^2). In addition, "long, narrow rectangles …, such as those following drainage-ways and stream corridors…may or may not be mapped, depending on project objectives" (Federal Geographic Data Committee, 2009). With a 5m cell-size, SLAMM is able to discern wetlands of 25m^2, therefore the time-zero maps sometimes provide a refinement to the initial wetland layers, as shown in Figure 9.

Inundation-frequency maps were used to identify areas that needed further hydro-enforcement. Consequently the DEM was modified, for example by removing a bridge or adding a culvert to correct water flows. In addition, inundation maps were used to validate wetland coverage and tidal information. The wetland coverage layer was also modified where areas initially identified as covered by tidal water were clearly not tidal.

Another issue encountered during model calibration was the immediate flooding of some developed lands. Most often these areas were bridges and piers – areas that are represented as development in the wetland layer but whose elevations are not included in the bare-earth elevation layer. Occasionally SLAMM predicts low-lying residential areas to be flooded at least once every 30 days based on tide data. These occurrences were investigated on a case-by-case basis by examining satellite imagery from Google Earth and Bing Maps and performing web searches for any public records of flooding issues.



Initial wetland layer **Time-zero predicted wetland layer**

Satellite Imagery (from Google Earth)

Figure 9. Marsh in Sherwood Island State Park

In order for SLAMM 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 site-specific LiDAR data. 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. The minimum elevation of regularly flooded marsh was set to -0.4 half tide units (HTU) based on observations for Long Island by McKee and Patrick (1988). Table 6 presents the minimum elevations applied for the entire study area; site-specific changes made to the SLAMM conceptual model for Tidal Swamp and Tidal Fresh Marsh are described in the individual site sections below.

Table 6. 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	-0.4	HTU
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[3]
Tidal-Fresh Marsh	0.5	HTU[38]
Estuarine Beach	-1	HTU
Rocky Intertidal	-1	HTU
Inland Shore	-1	HTU
Ocean Flat	-1	HTU

In addition to the minor adjustments to minimum wetland elevation discussed above, changes were made to the input parameters on a subsite basis when warranted. Such changes included reducing tide range, or adjusting salt elevation if too much dry-land conversion was observed.

As inundated developed land is unlikely to immediately convert to a coastal wetland, a new landcover category was included in SLAMM: "Flooded Development." This category occurs when developed dry land is inundated by salt water at least once every 30 days. Flooded developed land is not subject to more land-cover conversions. There is some uncertainty as to whether a marsh could inhabit this land cover, so the model is likely somewhat conservative with respect to marsh transgression due to this category.

Time zero maps were compared to the initial condition maps using GIS software and annotated where large conversions of wetland were observed. These issues were consequently explained or fixed by additional calibration or layer refinement. Any calibrations or "allowable" time-zero changes were quality assured by

[3] 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.

an independent team member. Model projections are reported from time-zero forward so that the effect of SLR is accounted for independently of any remaining time-zero changes.

2.11 Model Setup

As noted above, the study area was divided into 3 individual SLAMM projects: Area 1: Fairfield County, Area 2: New Haven and Middlesex Counties, and Area 3: New London County. Within each of these areas the projects were subdivided into seven watersheds, as shown in Figure 10 and summarized in Table 7.

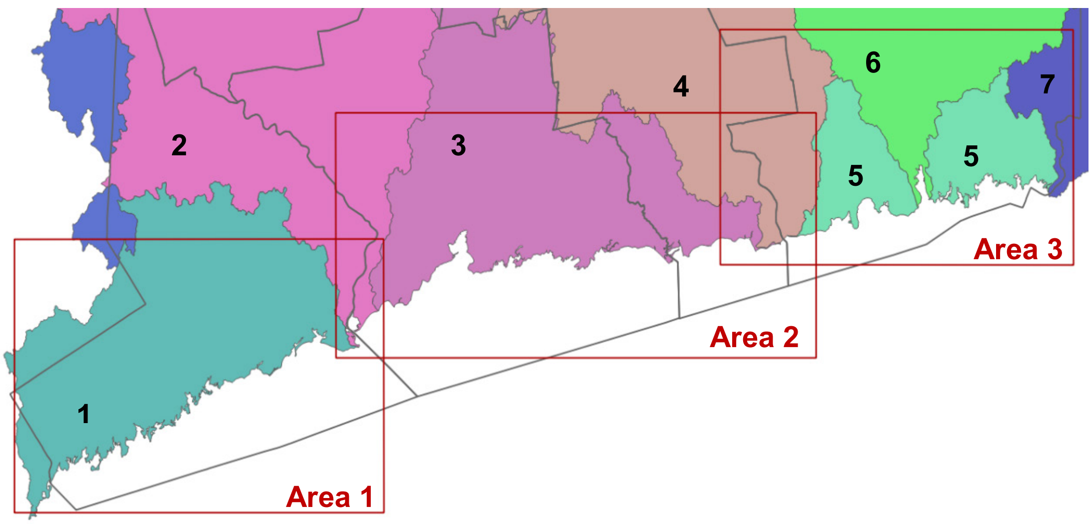


Figure 10. CT SLAMM project areas.

Table 7. Watersheds of coastal CT and the SLAMM project areas where represented

Watershed	Study Area
1 - Southwest Coast	1
2 – Housatonic River	1
3 - South Central Coast	2
4 - Connecticut River	3
5 - Southeast Coast	3
6 - Thames River	3
7 – Pawcatuck River	3

Projects areas were also divided into subsites based on tide range and erosion parameters, as described in the following sections.

2.11.1 Area 1 - Fairfield County

2.11.1.1 Fairfield County Site Description

Study Area 1 was referred to as Fairfield County, although it contains areas beyond the county boundary in order to encompass the Southwestern and Housatonic River Watersheds. Examining the areas with elevations below 5 m above MTL, the Southwest Coast watershed is composed of 237,676 acres, which are primarily dry land. Swamp accounts for nearly 2% (4,423 acres) while the next most prevalent wetland category is irregularly-flooded marsh which makes up only 0.5 % of the study area (1,112 acres). In the Housatonic watershed irregularly-flooded marsh is the most prevalent wetland type, making up 3.5% (710 acres) of the study area (Table 8).

Table 8. Initial Wetland Coverage for the Southwest Coast and Housatonic River watersheds.

Land cover type		Southwest Coast		Housatonic River	
		Area (acres)	**%**	**Area (acres)**	**%**
	Undeveloped Dry Land	120,479	50.7	6,269	30.7
	Estuarine Open Water	58,761	24.7	5,765	28.2
	Developed Dry Land	47,707	20.1	6,584	32.2
	Swamp	4,423	1.9	315	1.5
	Inland Open Water	3,484	1.5	115	0.6
	Irreg.-Flooded Marsh	1,112	0.5	710	3.5
	Estuarine Beach	814	0.3	308	1.5
	Regularly-Flooded Marsh	302	0.1	248	1.2
	Inland-Fresh Marsh	342	0.1	38	0.2
	Inland Shore	119	0.1	-	-
	Trans. Salt Marsh	13	<0.1	44	0.2
	Tidal-Fresh Marsh	15	<0.1	31	0.2
	Tidal Flat	38	<0.1	-	-
	Riverine Tidal	27	<0.1	4	<0.1
	Rocky Intertidal	20	<0.1	-	-
	Tidal Swamp	18	<0.1	9	<0.1
	Total (incl. water)	**237,676**	**100**	**20,441**	**100**

2.11.1.2 Fairfield County Site Parameters

"Area 1" was divided into four input subsites. Three subsites were defined based on tide range while one subsite, around Stratford, was added based on erosion rates. Details for these study areas are shown in Table 9, while the boundaries of each subsite are shown in

Figure 11. The tidal fresh marsh lower bound was set to 0.74 HTU and the Tidal Swamp boundary reduced to 0.77 HTU to reflect site-specific LiDAR data.

Table 9. Input subsites applied to Area 1

Subsite	Description	Great Diurnal Tide Range - GT (m)	Salt Elev. (m above MTL)	Horizontal Erosion Rate (m/yr)
General Area 1	Area 1 not included in the subsites below	2.3	1.66	0
1	Pine Creek	1.5	1.22	0
2	Sikorsky Airport	1.2	1.02	0
3	Stratford	2.3	1.66	0.06

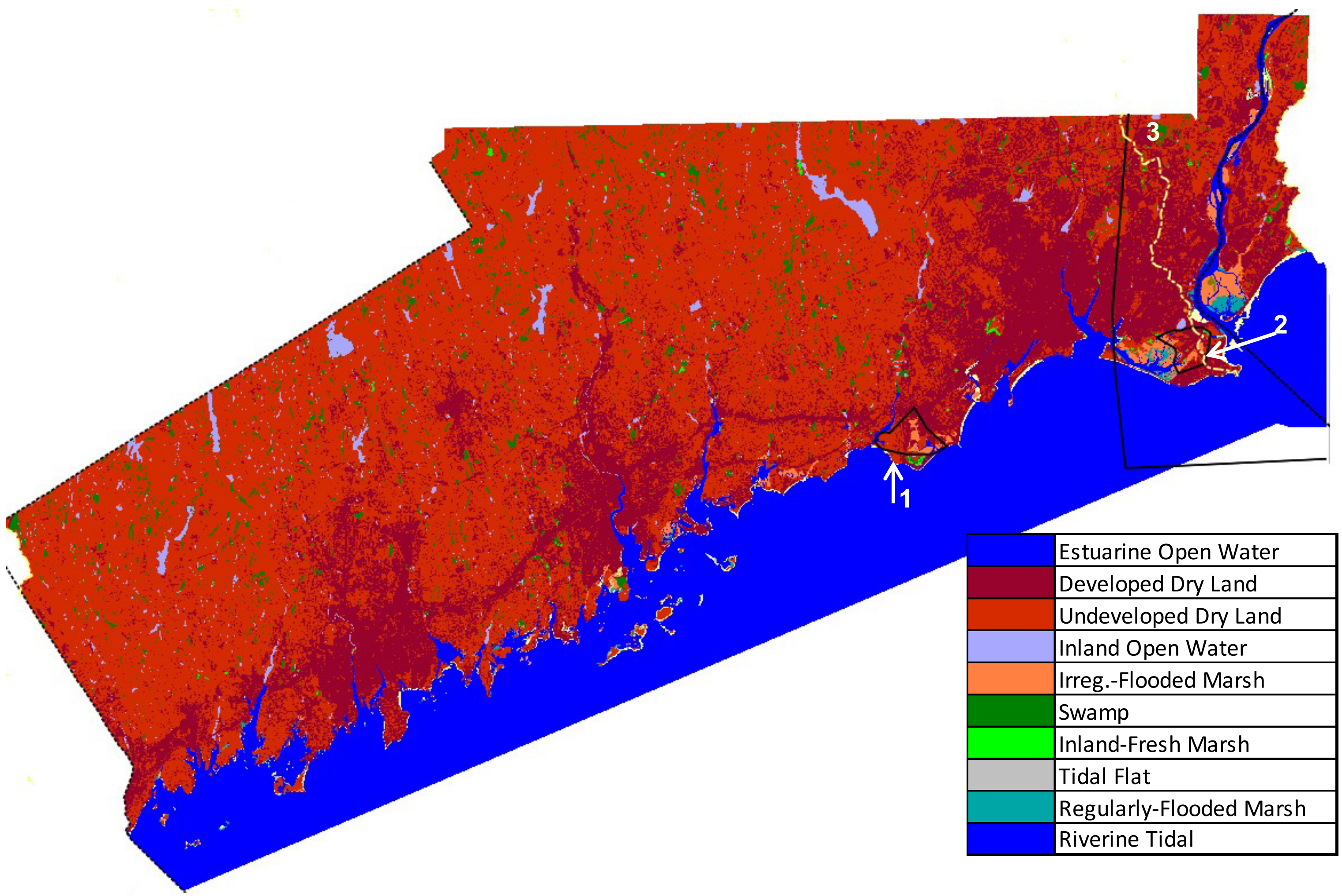


Figure 11. Current land coverage distribution for the Fairfield County Study Area.Numbers correspond to subsites described in Table 9; the yellow dashed line indicates a watershed boundary

2.11.1.3 Fairfield County Site Calibration

Several rounds of calibration were run for the Fairfield County study area. These iterations focused on refining the time zero results for the Pine Creek marsh and around Sikorsky Airport where the initial site parameters led to flooding. After reviewing data available for these areas beyond NOAA gauge records, subsites were added to reflect the reduced tidal ranges in these areas. A study of wetland delineation around the Sikorsky Airport informed the locations of subsite boundaries and model parameters used at that site (Fitzgerald & Halliday, Inc. 2013). Pine Creek Marsh was investigated by Roman and coworkers and that study, as well as data available from the town of Fairfield, provided insight for the probable extent and tide range of the subsite there (Roman et al. 1984; Town of Fairfield CT, 2014). Adjustments were also made to the global subsite. To reduce the amount of wide-spread coastal fringe flooding, particularly in developed areas, the tide range for the global subsite was set to 2.3 m, and salt elevation reduced to 1.66 m, which is the 20-day inundation height given by ($y = 0.5948x + 0.2908$).

Results of model calibration are presented in Table 10 and Table 11. Both of these tables indicate there are conversions of greater than 5% of the initial wetland coverage in several categories. However, these changes occur in land cover categories with coverages of less than 2% of the study area and are explained by wetland layer corrections as discussed in section 2.10, "Model Calibration" on page 19.

Table 10. Southwest Coast Watershed Time-Zero Results (acres)

Land cover type		Initial Coverage (acres)	Time Zero - 2010 (acres)	Change (acres)	% Change (- is loss)
	Undeveloped Dry Land	120,479	120,225	-254	-0.2
	Estuarine Open Water	58,761	58,788	27	<0.1
	Developed Dry Land	47,707	47,567	-140	-0.3
	Swamp	4,423	4,412	-11	-0.3
	Inland Open Water	3,484	3,476	-9	-0.2
	Irreg.-Flooded Marsh	1,112	980	-132	-11.8
	Estuarine Beach	814	802	-13	-1.6
	Inland-Fresh Marsh	342	336	-6	-1.9
	Regularly-Flooded Marsh	302	426	123	40.8
	Inland Shore	119	119	0	0.0
	Tidal Flat	38	49	11	29.2
	Riverine Tidal	27	24	-4	-12.9
	Rocky Intertidal	20	20	-1	-3.9
	Tidal Swamp	18	18	<1	-1.4
	Tidal-Fresh Marsh	15	14	-1	-3.7
	Trans. Salt Marsh	13	282	269	1992.1
	Flooded Developed Dry Land	-	140	140	NA
	Total (incl. water)	**237,676**	**237,676**		

Table 11. Housatonic River Watershed Time-Zero Results (acres)

Land cover type	Initial Coverage (acres)	Time Zero - 2010 (acres)	Change (acres)	% Change (- is loss)
Developed Dry Land	6,584	6,552	-32	-0.5
Undeveloped Dry Land	6,269	6,210	-60	-1.0
Estuarine Open Water	5,765	5,790	25	0.4
Irreg.-Flooded Marsh	710	653	-57	-8.0
Swamp	315	315	0	0.0
Estuarine Beach	308	308	<1	-0.1
Regularly-Flooded Marsh	248	323	74	29.9
Inland Open Water	115	93	-22	-19.5
Trans. Salt Marsh	44	80	37	84.2
Inland-Fresh Marsh	38	36	-2	-5.8
Tidal-Fresh Marsh	31	29	-2	-6.3
Tidal Swamp	9	8	-1	-11.3
Riverine Tidal	4	2	-2	-56.3
Tidal Flat	-	11	11	NA
Flooded Developed Dry Land	-	32	32	NA
Total (incl. water)	**20,441**	**20,441**		

2.11.2 Area 2 - New Haven and Middlesex Counties

2.11.2.1 New Haven and Middlesex Counties Site Description

The Area 2 project encompasses both New Haven and Middlesex counties which in turn make up the South Central Coast Watershed. Within this watershed, over eighty thousand acres were within 5 meters of MTL and therefore included in this analysis. The area is predominantly dry land, with irregularly-flooded marsh and swamp comprising the most dominant wetland types, covering 6.8% (5,480 acres) and 2.8% (2,223 acres) of the study area, respectively. Table 12 presents the wetland coverage of the South Central Coast watershed.

Table 12. Current land coverage distribution in South Central Coast watershed.

Land cover type		South Central Coast Area (acres)	South Central Coast %
	Undeveloped Dry Land	26,585	33.2
	Estuarine Open Water	22,210	27.7
	Developed Dry Land	21,087	26.3
	Irreg.-Flooded Marsh	5,480	6.8
	Swamp	2,223	2.8
	Estuarine Beach	1,021	1.3
	Regularly-Flooded Marsh	507	0.6
	Inland Open Water	474	0.6
	Inland-Fresh Marsh	294	0.4
	Tidal-Fresh Marsh	96	0.1
	Tidal Swamp	82	0.1
	Tidal Flat	50	0.1
	Riverine Tidal	37	<0.1
	Rocky Intertidal	32	<0.1
	Trans. Salt Marsh	12	<0.1
	Inland Shore	1	<0.1
	Total (incl. water)	**80,193**	**100**

2.11.2.2 New Haven and Middlesex Counties Site Parameters

In order to account for variations in tide ranges, erosion rates, and wetland impoundments along the coast, eight input subsites were utilized when setting up this project area. Table 13 presents the subsite areas with the GT, salt elevation, and horizontal erosion rates applied. Subsite areas are shown in Figure 12. The Housatonic subsite (subsite 3) is the furthest west and has the largest tide range applied in this project area. However, when reporting results, this subsite is superseded by the parameters in Area 1. General Area 2, CT River, and Guilford subsites are the largest input subsites and were used to represent the variation in GT (and salt elevation) that occurs moving from east to west in the Long Island Sound. The subsites representing the Hammock River, HVN Airport, Sybil Creek, and a smaller area of muted tide were added during the calibration process. Two adjustments to the SLAMM elevation conceptual model were made: a reduction of the minimum boundary of Tidal Fresh Marsh to -0.18 HTU and Tidal Swamp to 0.4 HTU to reflect site-specific fresh-water flows and LiDAR data.

Table 13. SLAMM input subsites applied to Area 2

Subsite	Description	Great Diurnal Tide Range - GT (m)	Salt Elev. (m above MTL)	Horizontal Erosion Rate (m/yr)
General Area 2	Area 2 not included in the subsites below	2.1	1.1	0
1	CT river	1.1	0.94	0
2	Guilford	1.67	1	0.08
3	Housatonic	2.2	1.6	0
4	Hammock River	1	0.5	0.08
5	HVN airport	1	0.5	0
6	Sybil Creek	0.5	0.35	0
7	Muted Tide	0.88	0.7	0

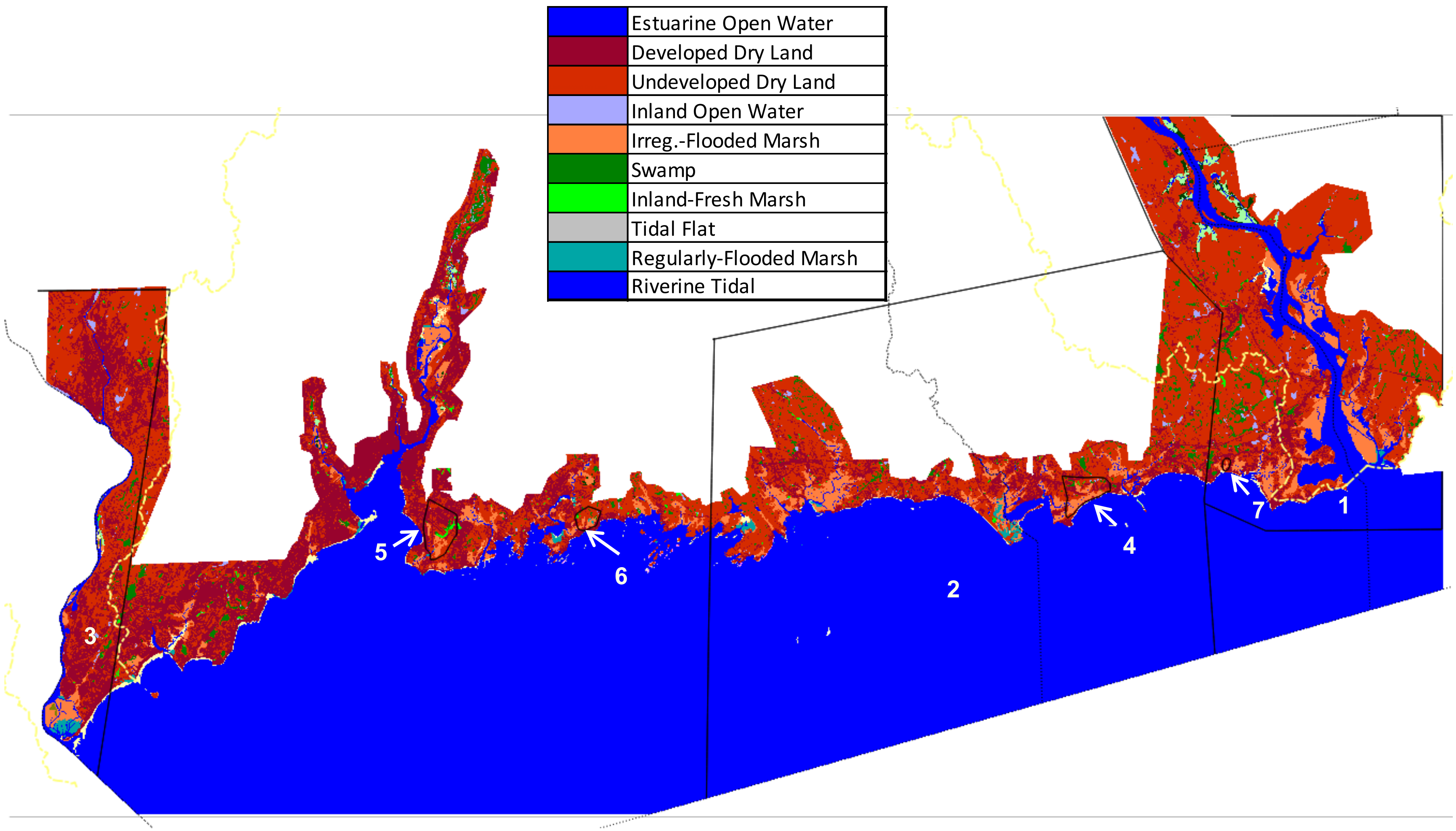


Figure 12. Current land coverage distribution for the New Haven and Middlesex Counties Study Area. Numbers correspond to subsites described in Table 13.

2.11.2.3 New Haven and Middlesex Counties Site Calibration

Several calibration iterations were carried out in order to adjust tide ranges and salt elevations within the New Haven and Middlesex study area. Adjustments were made to the salt elevations in all the large input subsites (General Area 2, CT River, and Guilford), revising them to match the current wetland conditions. Smaller subsites (Hammock River, HVN Airport, Sybil Creek, and Muted Tide) were added during calibration to reflect muted tidal ranges due to tide gates and culverts and to minimize flooding in residential areas. Muted tide ranges were determined based on literature review (Bjerklie et al. 2013; Roman et al. 1984; Rozsa 1995) and examination of marsh elevation profiles using SLAMM. Calibration of this site also included additional hydroenforcement of marshes based on feedback from the CT Department of Energy & Environmental Protection.

Table 14 presents a comparison between the initial observed and time-zero wetland layers for New Haven and Middlesex Counties. Losses in undeveloped dry lands lead to gains in transitional marsh while losses in irregularly-flooded marshes resulted in increases in regularly flooded marsh. Within the 80,193 acre study area, approximately 488 acres of irregularly-flooded marsh converted (to regularly-flooded marsh) in the time-zero analysis. This represents 9% of the initial coverage of irregularly-flooded marsh. As discussed in the Model Calibration section, these changes were accepted based on the approach used by NWI to exclude channels that are included in the LiDAR-derived DEM.

Table 14. South Central Coast Watershed Time-Zero Results (acres)

Land cover type		Initial Coverage (acres)	Time Zero - 2010 (acres)	Change (acres)	% Change (- is loss)
	Undeveloped Dry Land	26,585	26,245	-339	-1.3
	Estuarine Open Water	22,210	22,237	27	0.1
	Developed Dry Land	21,087	20,987	-100	-0.5
	Irreg.-Flooded Marsh	5,480	4,992	-488	-8.9
	Swamp	2,223	2,186	-37	-1.7
	Estuarine Beach	1,021	1,020	-1	-0.1
	Regularly-Flooded Marsh	507	979	472	93.2
	Inland Open Water	474	468	-6	-1.3
	Inland-Fresh Marsh	294	276	-18	-6.2
	Tidal-Fresh Marsh	96	96	<1	-0.5
	Tidal Swamp	82	74	-8	-9.6
	Tidal Flat	50	71	21	42.9
	Riverine Tidal	37	30	-8	-20.9
	Rocky Intertidal	32	30	-3	-8.4
	Trans. Salt Marsh	12	400	388	3271.5
	Inland Shore	1	1	0	0.0
	Flooded Developed Dry Land	-	100	100	NA
	Total (incl. water)	**80,193**	**80,193**		

2.11.3 Area 3 - New London County

2.11.3.1 New London County Site Description

This study area includes New London County in its entirety and covers the coastal areas of the Connecticut River, South East Coast, Thames River and Pawcatuck watersheds. Most of the marshes in this portion of the study area are located on the western shores of the Connecticut River basin and the coastal area that includes Barn Island (a preferred location for marsh ecology studies). However, significant patches of marsh areas also exist along the coast in between.

Table 15 reports the current wetland coverage for each major watershed in New London County. Overall, nearly 58% of the study area (elevations below 5 m) is occupied by dry land, mostly undeveloped, while open water covers almost 34% of the area. The remaining 8% of this area is characterized as follows: 50% is occupied by coastal saline marshes, (equivalent to 4.2% of study Area 3), 46% is occupied by swamps, fresh marshes and fresh open water, and the remaining acreage is occupied by low-tidal non-vegetated land cover such as beaches and tidal flats.

Table 15. Current wetland coverage for Area 3.

		Connecticut River		South East Coast		Thames River		Pawcatuck River (CT only)	
Land cover type		Area (acres)	%	Area (acres)	%	Area (acres)	%	Area (acres)	%
	Undeveloped Dry Land	20,587	60.4	15,805	33.5	6,316	42.4	558	38.8
	Estuarine Open Water	5,951	17.5	22,087	46.8	4,615	31.0	294	20.4
	Developed Dry Land	2,459	7.2	6,456	13.7	3,730	25.1	481	33.4
	Irreg.-Flooded Marsh	2,529	7.4	1,308	2.8	30	0.2	40	2.8
	Swamp	748	2.2	742	1.6	85	0.6	54	3.8
	Tidal-Fresh Marsh	579	1.7	21	0.0	1	<0.1	-	-
	Tidal Swamp	370	1.1	181	0.4	7	<0.1	0.4	<0.1
	Inland Open Water	263	0.8	174	0.4	47	0.3	3	0.2
	Riverine Tidal	377	1.1	-	-	-	-	6	0.4
	Estuarine Beach	107	0.3	189	0.4	18	0.1	-	-
	Inland-Fresh Marsh	55	0.2	95	0.2	24	0.2	1	<0.1
	Regularly-Flooded Marsh	57	0.2	62	0.1	5	<0.1	-	-
	Trans. Salt Marsh	6	<0.1	81	0.2	1	<0.1	1.5	0.1
	Tidal Flat	2	<0.1	8	<0.1	-	-	-	-
	Rocky Intertidal	-	-	8	<0.1	2	<0.1	-	-
	Total (incl. water)	**34,090**	**100**	**47,219**	**100**	**14,881**	**100**	**1,439**	**100**

2.11.3.2 New London County Site Parameters

Area 3 was divided into three subsites in order to accommodate spatial variations in tide ranges and erosion rates. The tidal information used was from the NOAA data as discussed in Section 2.6 and 2.7. Areas with different erosion rates were selected according to the different observed rates in the area as discussed the *Erosion Rates* section on page 19. The input parameters assigned to corresponding subsite boundaries are shown in Table 16 and Figure 13.

Table 16. Tidal ranges and erosion rates for different SLAMM subsites in Area 3

Subsite	Description	Great Diurnal Tide Range - GT (m)	Salt Elev. (m above MTL)	Horizontal Erosion Rate (horz. m /yr)
General Area 3	Area 3 not in the subsites below	0.92	0.84	0
SubSite 1	Connecticut River	1.1	0.94	0.12
SubSite 2	Erosion zone - Stonington	0.92	0.84	0.02

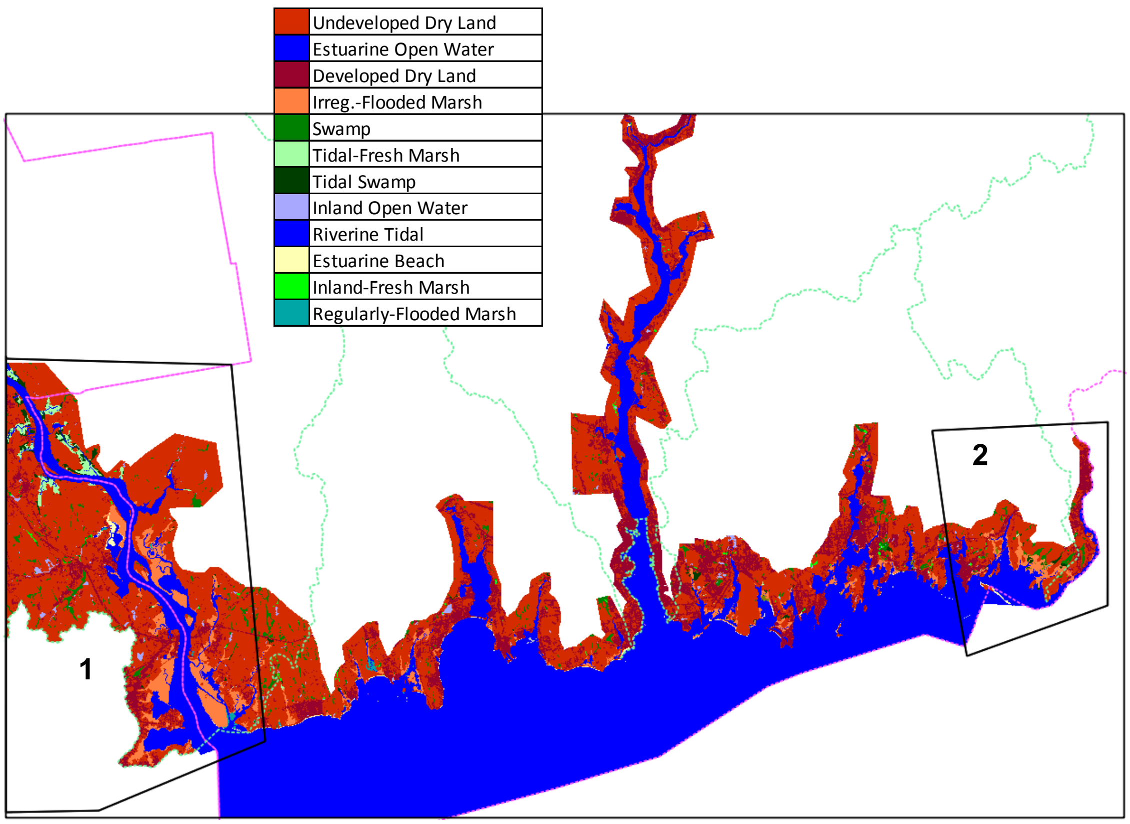


Figure 13. Current land coverage distribution for Area3 and SLAMM analysis subsites in black. Pink lines represent county boundaries while the green lines are watershed boundaries.

2.11.3.3 New London County Site Calibration

Two rounds of calibration were run on study Area 3. These iterations focused on refining the time zero results until the interplay between tide ranges, elevations, and coastal habitat maps in the initial conditions was deemed satisfactory. Results of the calibration of the initial condition are reported in the tables below and broken down by watershed. Overall, initial land cover changes are minimal indicating a strong agreement between spatial data and tidal information. Two main conversions are observed: some dry lands are found by the model to be inundated at least once every 30 days and thus are converted to either wetlands or flooded developed categories. These areas are usually small fringes of dry land bordering open water. This conversion is mostly due to the wetland-layer horizontal resolution and uncertainty in the elevations assigned to these cells. The elevation assigned to each cell is an average of the LiDAR returns in that cell and may include open water and dry land. Another uncertainty stems from the definition of developed vs. undeveloped dry lands. Developed dry lands were derived from data with 30-m resolution data and rescaled to the 5-m cell size of the project.

The second common initial conversion is from irregularly-flooded marsh to regularly-flooded marsh. This result is somewhat expected as the boundary between low and high marsh is a spatially variable buffer area more than a precise line; thus, wetland classification in this interface is affected by significant uncertainty.

Connecticut River watershed. Time-zero calibration results for this area are reported in Table 17. Overall, there are not significant reclassifications of the major land cover types in the area (those occupying more than 5% of the area) except for irregularly-flooded marsh that is converted by 6.6%. A justification of this result has been discussed above.

Table 17. Connecticut River watershed Time-Zero Results (acres)

Connecticut River					
Land Cover		Initial Coverage (acres)	Time Zero 2010 (acres)	Change (acres)	% Change (- is loss)
	Undeveloped Dry Land	20,587	20,304	-283	-1.4
	Estuarine Open Water	5,951	6,028	77	1.3
	Irreg.-Flooded Marsh	2,529	2,362	-167	-6.6
	Developed Dry Land	2,459	2,450	-9	-0.4
	Swamp	748	743	-5	-0.7
	Tidal-Fresh Marsh	579	549	-30	-5.1
	Riverine Tidal	377	328	-50	-13.1
	Tidal Swamp	370	342	-28	-7.5
	Inland Open Water	263	263	0	0.0
	Estuarine Beach	107	79	-27	-25.5
	Regularly-Flooded Marsh	57	260	203	357.5
	Inland-Fresh Marsh	55	55	<1	-0.4
	Trans. Salt Marsh	6	294	288	5121.1
	Tidal Flat	2	24	21	901.8
	Flooded Developed Dry Land	-	9	9	NA
	Total (incl. water)	**34,090**	**34,090**		

South East Coast watershed. Time-zero calibration results for this area are reported in Table 18 below. For this area, initial land cover changes are minimal indicating a very good agreement between spatial data, parameters and tidal information.

Table 18. South East Coast watershed Time-Zero Results (acres)

Southeast Coast					
Land Cover		Initial Coverage (acres)	Time Zero 2010 (acres)	Change (acres)	% Change (- is loss)
	Estuarine Open Water	22,087	22,107	20	0.1
	Undeveloped Dry Land	15,805	15,586	-219	-1.4
	Developed Dry Land	6,456	6,412	-44	-0.7
	Irreg.-Flooded Marsh	1,308	1,253	-55	-4.2
	Swamp	742	737	-6	-0.8
	Estuarine Beach	189	181	-8	-4.1
	Tidal Swamp	181	180	-1	-0.3
	Inland Open Water	174	174	0	0.0
	Inland-Fresh Marsh	95	94	-1	-0.9
	Trans. Salt Marsh	81	300	219	269.4
	Regularly-Flooded Marsh	62	115	52	84.1
	Tidal-Fresh Marsh	21	21	0	0.0
	Tidal Flat	8	5	-3	-38.7
	Rocky Intertidal	8	8	<1	-0.2
	Flooded Developed Dry Land	-	44	44	NA
	Total (incl. water)	**47,219**	**47,219**		

Thames River watershed. Time-zero calibration results for this area are reported in Table 19 below. There is a good agreement between the data and the model for this area.

Table 19. Thames River watershed Time-Zero Results (acres)

Thames River					
Land Cover		**Initial Coverage (acres)**	**Time Zero 2010 (acres)**	**Change (acres)**	**% Change (- is loss)**
	Undeveloped Dry Land	6,316	6,220	-96	-1.5
	Estuarine Open Water	4,615	4,616	2	<0.1
	Developed Dry Land	3,730	3,708	-22	-0.6
	Swamp	85	84	-1	-1.6
	Inland Open Water	47	46	-1	-2.2
	Irreg.-Flooded Marsh	30	25	-5	-18.1
	Inland-Fresh Marsh	24	22	-3	-10.6
	Estuarine Beach	18	18	<1	0.3
	Tidal Swamp	7	7	<1	-0.3
	Regularly-Flooded Marsh	5	11	6	110.1
	Rocky Intertidal	2	1	<1	-29.1
	Trans. Salt Marsh	1	100	99	9911.1
	Tidal-Fresh Marsh	1	1	0	0.0
	Flooded Developed Dry Land	-	22	22	NA
	Total (incl. water)	**14,881**	**14,881**		

Pawcatuck River watershed. Time-zero calibration results for this area are reported in Table 20 below. Also for this area there is a strong agreement between the data and the model.

Table 20. Pawcatuck River watershed Time-Zero Results (acres)

Pawcatuck River (CT only)				
Land Cover	**Initial Coverage (acres)**	**Time Zero 2010 (acres)**	**Change (acres)**	**% Change (- is loss)**
Undeveloped Dry Land	558	548	-11	-1.9
Developed Dry Land	481	478	-3	-0.6
Estuarine Open Water	294	295	1	0.4
Swamp	54	54	<1	-0.1
Irreg.-Flooded Marsh	40	39	-1	-2.7
Riverine Tidal	6	4	-1	-22.8
Inland Open Water	3	3	0	0.0
Trans. Salt Marsh	1	12	11	737.9
Inland-Fresh Marsh	1	1	0	0.0
Tidal Swamp	0	0	0	0.0
Regularly-Flooded Marsh	-	1	1	NA
Flooded Developed Dry Land	-	3	3	NA
Total (incl. water)	**1,439**	**1,439**		

3 Results and Discussion

In the following subsections, deterministic model results (non-uncertainty-analysis results) are presented individually for each of the seven modeled watershed areas, as well as the entire study area. Tables of land-cover acreage at each time step for each SLR scenario simulated are included, as well as summary tables showing the percentage loss and acreage gain for selected land-cover types. It is important to note that changes presented in the summary tables are compared to the 2010 time-zero result and therefore represent projected land-cover changes as a result of sea-level rise excluding any predicted changes that occur when the model is applied to initial-condition data

3.1 Entire Study Area

Within the coastal-Connecticut study area, irregularly-flooded marshes are the most vulnerable category to sea-level rise, with predicted losses ranging from 50% to 97% by 2100 (Table 21). This Connecticut high marsh is also, by far, the most prevalent coastal wetland type in the study area. Other vulnerable habitats include tidal-swamps, tidal-fresh marshes, and estuarine beaches. In addition to these wetland losses, between 2.4 and 8.8 percent of developed dry land within the study area is predicted to be flooded regularly due to SLR.

Table 21. Predicted percentage change in land covers from 2010 to 2100 for the entire study area

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Estuarine Open Water	291,756	0.6	0.8	1.4	2.8
Undeveloped Dry Land	204,591	-1.4	-2.2	-3.1	-4.0
Developed Dry Land	92,006	-2.4	-4.2	-6.4	-8.8
Irreg.-Flooded Marsh	10,302	-50.1	-87.8	-95.1	-97.4
Swamp	8,810	-2.5	-4.1	-5.9	-8.1
Inland Open Water	4,801	-2.2	-2.9	-3.7	-4.3
Estuarine Beach	2,425	-24.1	-34.6	-47.6	-57.6
Regularly-Flooded Marsh	2,115	369.0	603.0	554.0	469.4
Trans. Salt Marsh	1,493	38.5	54.1	62.0	53.9
Inland-Fresh Marsh	835	-13.4	-20.7	-25.1	-28.2
Riverine Tidal	734	-75.8	-78.3	-80.7	-83.1
Tidal-Fresh Marsh	727	-8.5	-27.6	-62.3	-83.8
Tidal Swamp	639	-42.2	-59.9	-72.3	-80.3
Flooded Developed Dry Land	353	619.8	1089.6	1658.3	2283.1
Tidal Flat	189	-0.5	265.9	1551.0	1932.0
Inland Shore	120	0.0	0.0	0.0	0.0
Rocky Intertidal	74	-17.3	-23.6	-37.6	-49.9

Figure 14 shows the interplay between marsh types as SLR increases. Currently in the CT study area irregularly-flooded (high) marsh dominates the intertidal landscape. However, as SLR increases, more frequent inundation will increase the salinity in these marshes and lower their elevation relative to the tides, converting them to the “regularly-flooded” marsh category. When SLR by 2100 exceeds 50 inches, even this lower salt marsh starts to succumb and is largely replaced with non-vegetated tidal flats.

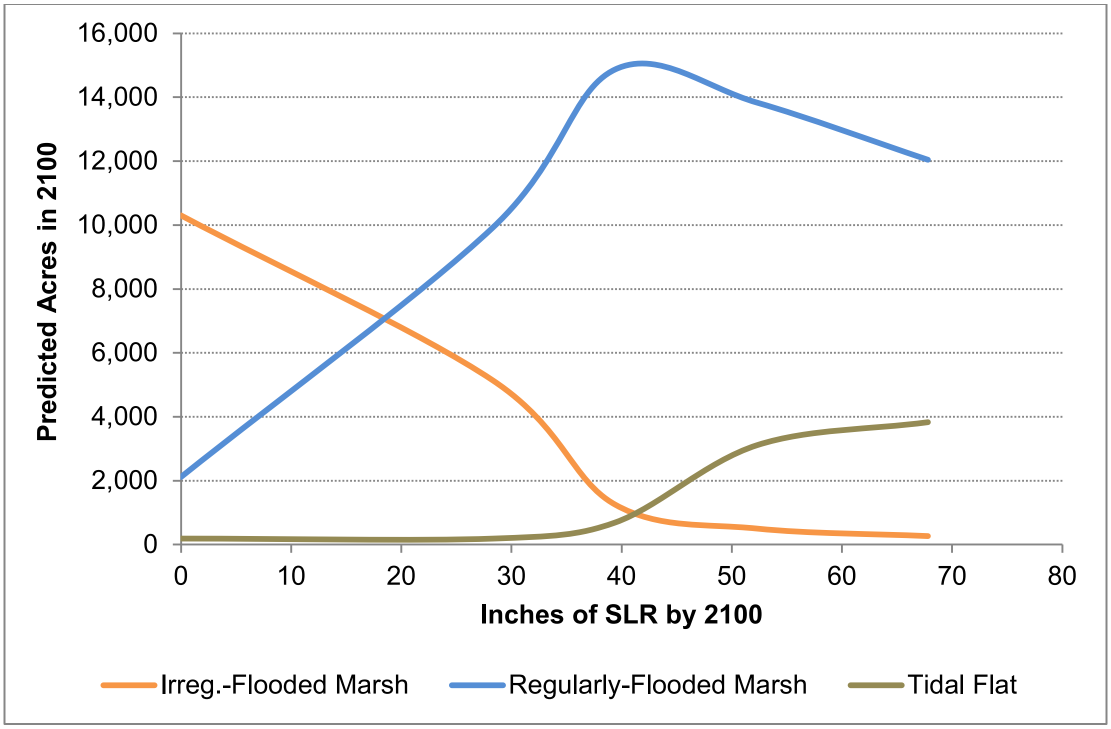


Figure 14. Marsh and Tidal-Flat fate as a function of SLR by 2100

One evident trend across the study area is that as tide ranges get smaller (further east) marshes are predicted to be less resilient. Intertidal marshes in areas with lower tide ranges inhabit a smaller elevation range and lower SLR changes are therefore required before a marsh becomes permanently flooded and is no longer viable. As this report summarizes results from watersheds from west to east, more conversion to open water is evident later in the report.

Dry-land loss rates are somewhat more linear with respect to sea-level rise effects. Up to 9% of developed lands and up to 4% of undeveloped lands have been found to be vulnerable under the SLR scenarios examined (Figure 15).

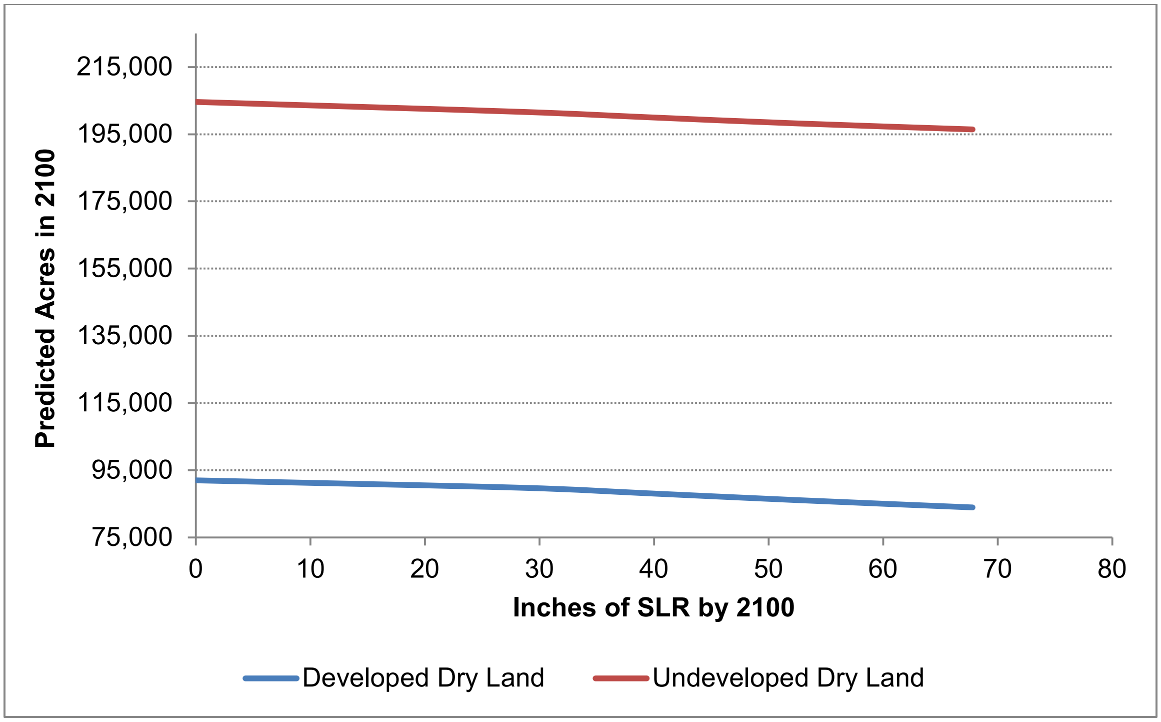


Figure 15. Dry-land fate as a function of SLR by 2100

Presenting results maps for the entire study area, which was mapped at 5 meters cell size, is not practical for this type of report. However, the sections below will discuss results for each of the seven relevant watersheds in the study area and will present maps of some areas of particular interest. Maps presented herein are only a tiny portion of available mapped output, however. As part of this project, GIS maps of the entire study area are being made publicly available for every scenario and time-step simulated along with numerous maps derived from uncertainty analyses (http://warrenpinnacle.com/prof/SLAMM/LISS/). Watershed results are presented below moving from west to east. Tables of results broken down by county are available in Appendix D of this document.

3.2 Southwest Coast Watershed

The Southwest Coast watershed is the largest portion of the study area, and results are similar to the results for the entire study area. Table 22 shows that irregularly-flooded marshes are expected to decline by at least 25% by 2100 and up to 97%. Low marshes, on the other hand, are predicted to increase by a factor of 2 to 5 by 2100 depending on the SLR scenario examined.

Table 22. Southwest Coast Watershed Landcover Change Summary
(positive indicates a gain, negative is a loss)

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Undeveloped Dry Land	120,225	-0.7	-1.0	-1.4	-1.7
Estuarine Open Water	58,788	0.3	0.5	0.7	1.1
Developed Dry Land	47,567	-2.7	-4.6	-6.6	-8.3
Swamp	4,412	-1.3	-1.8	-2.2	-2.4
Inland Open Water	3,476	-1.4	-1.6	-1.8	-2.1
Irreg.-Flooded Marsh	980	-27.1	-79.5	-93.1	-96.6
Estuarine Beach	802	-8.2	-17.4	-28.0	-38.1
Regularly-Flooded Marsh	426	171.1	366.1	482.5	519.2
Inland-Fresh Marsh	336	-10.1	-11.1	-12.8	-12.9
Trans. Salt Marsh	282	139.6	181.0	163.8	107.5
Flooded Developed Dry Land	140	928.7	1568.9	2230.8	2834.6
Inland Shore	119	0.0	0.0	0.0	0.0
Tidal Flat	49	-0.1	57.3	302.7	956.6
Riverine Tidal	24	-84.0	-85.0	-90.5	-90.6
Rocky Intertidal	20	-7.4	-12.1	-18.9	-39.5
Tidal Swamp	18	-9.8	-19.3	-33.3	-40.7
Tidal-Fresh Marsh	14	-10.3	-33.9	-60.0	-75.7

Figure 16 shows predictions for marshes and dry lands in a portion of Bridgeport, CT under one meter of SLR by 2100. In this location, the majority of high marsh has become more-regularly flooded and extensive flooded developed lands are predicted.

Figure 17 shows this same location under rapid ice melt scenarios which results in additional flooded developed lands, but the salt marshes in this region have the potential to remain fairly resilient against this sea-level rise due to their initial-condition elevations and rates of vertical accretion. Some tidal-flats and open-water regions are predicted, however, suggesting that the remaining marshes are on the brink of extensive habitat loss under these higher scenarios.

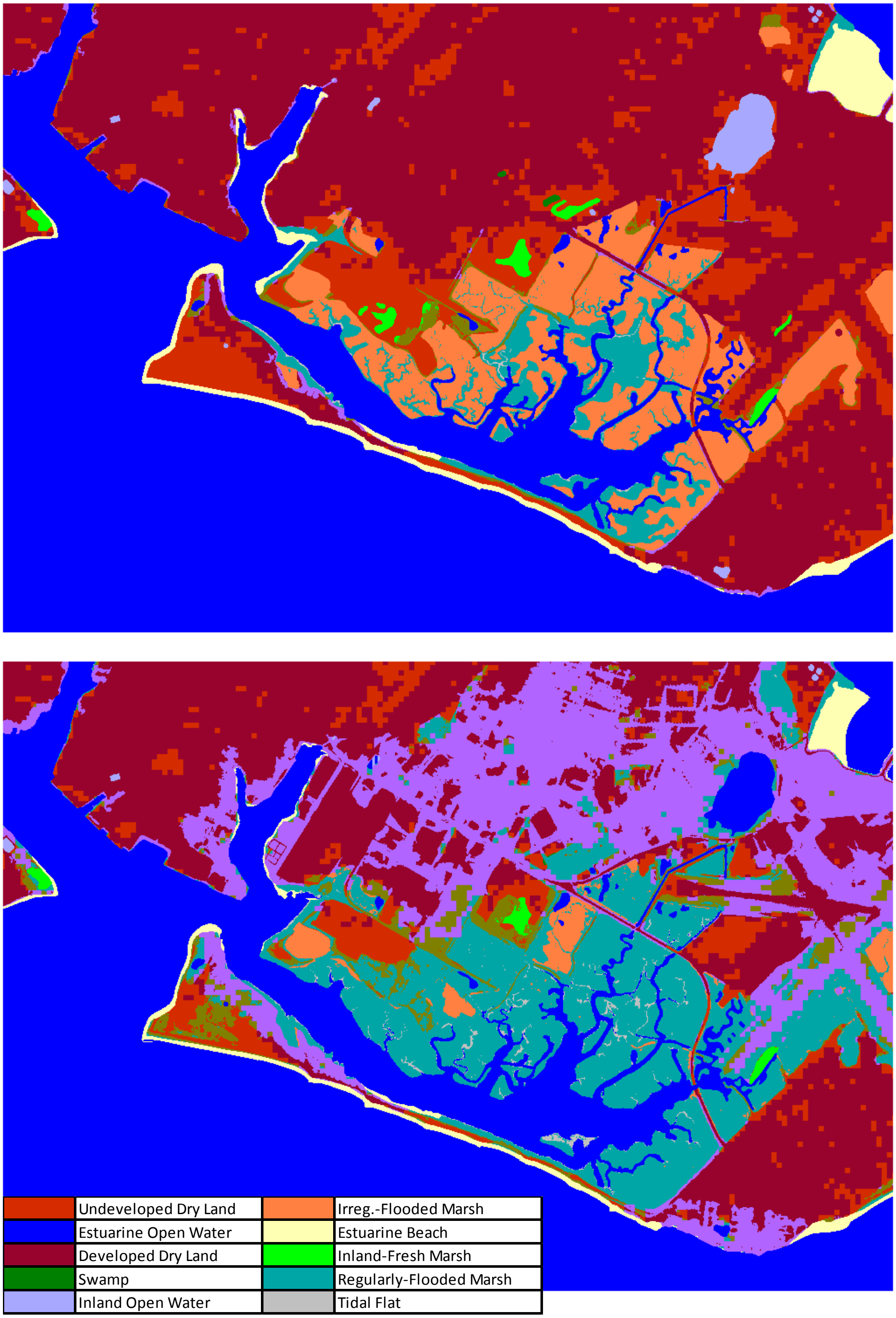


Figure 16. SLAMM predictions for Marshes in Bridgeport Connecticut by Pleasure Beach

Top map shows current conditions and bottom maps in 2100 given 1 meter of SLR

Note, SLAMM output maps show current or predicted land-cover conditions at low tide (MLLW)

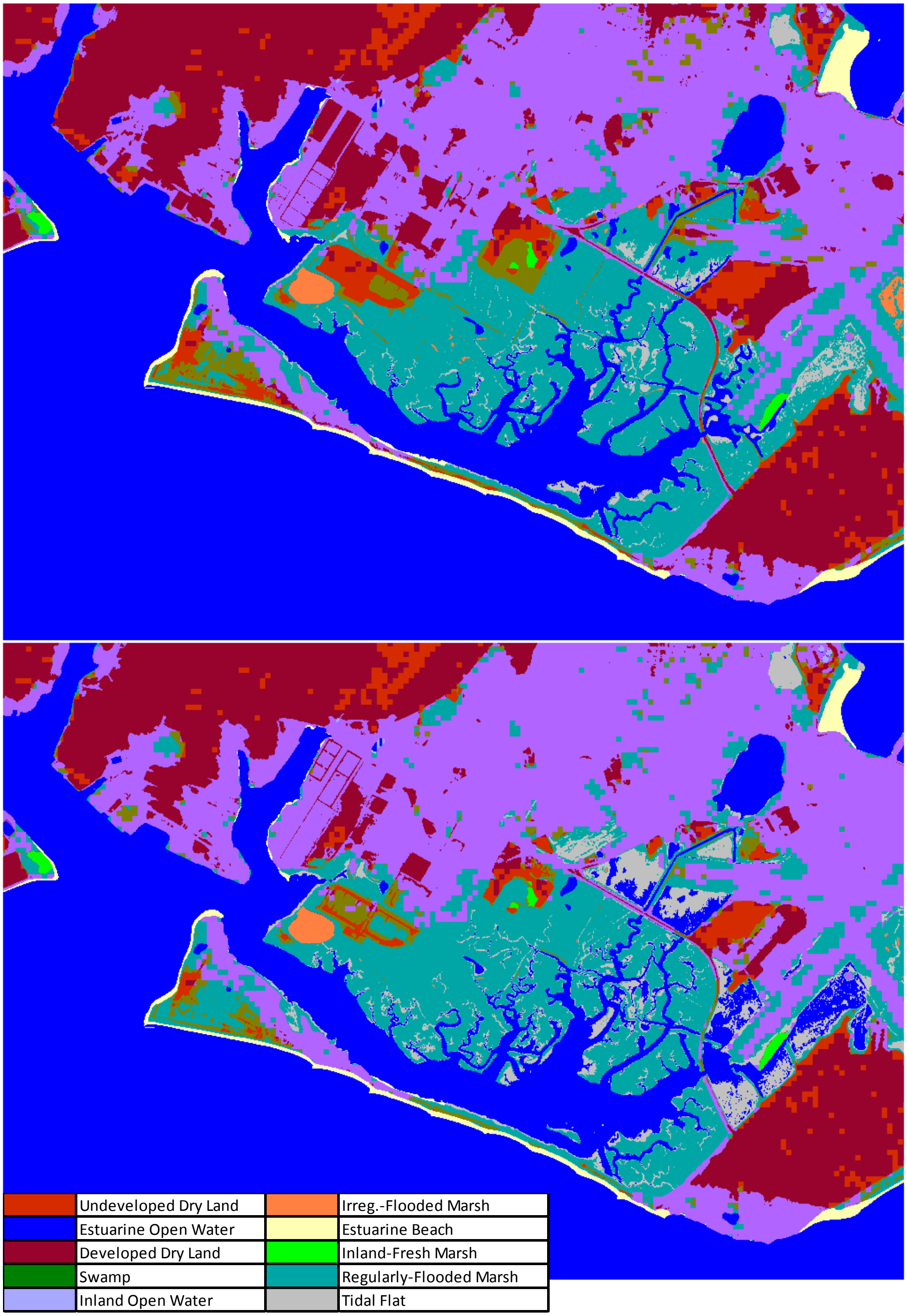


Figure 17. SLAMM predictions for Marshes in Bridgeport Connecticut under Rapid Ice Melt Scenarios

Top map shows RIM Minimum in 2100 (1.4 meters) and the bottom RIM Maximum in 2100 (1.7 meters)

Note, SLAMM output maps show current or predicted land-cover conditions at low tide (MLLW)

Table 23. Southwest Coast Watershed, GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	120,479	120,225	120,174	120,037	119,602	119,421
	Estuarine Open Water	58,761	58,788	58,813	58,836	58,910	58,963
	Developed Dry Land	47,707	47,567	47,533	47,424	46,651	46,266
	Swamp	4,423	4,412	4,411	4,408	4,380	4,356
	Inland Open Water	3,484	3,476	3,470	3,467	3,443	3,428
	Irreg.-Flooded Marsh	1,112	980	966	934	819	715
	Estuarine Beach	814	802	797	789	761	736
	Inland-Fresh Marsh	342	336	334	331	302	302
	Regularly-Flooded Marsh	302	426	571	623	879	1,154
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	54	59	53	49
	Riverine Tidal	27	24	12	8	5	4
	Rocky Intertidal	20	20	19	19	18	18
	Tidal Swamp	18	18	18	17	17	16
	Tidal-Fresh Marsh	15	14	14	14	13	13
	Trans. Salt Marsh	13	282	197	308	647	676
	Flooded Developed Dry Land	0	140	174	283	1,056	1,441
	Total (incl. water)	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**

Table 24. Southwest Coast Watershed 1m (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	120,479	120,225	120,172	119,848	119,283	118,965
	Estuarine Open Water	58,761	58,788	58,813	58,856	58,999	59,074
	Developed Dry Land	47,707	47,567	47,532	47,120	45,989	45,369
	Swamp	4,423	4,412	4,411	4,404	4,347	4,332
	Inland Open Water	3,484	3,476	3,470	3,466	3,426	3,421
	Irreg.-Flooded Marsh	1,112	980	966	866	460	201
	Estuarine Beach	814	802	797	779	713	662
	Inland-Fresh Marsh	342	336	334	326	301	298
	Regularly-Flooded Marsh	302	426	571	725	1,500	1,984
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	54	66	69	76
	Riverine Tidal	27	24	12	7	4	4
	Rocky Intertidal	20	20	19	19	18	17
	Tidal Swamp	18	18	18	17	15	14
	Tidal-Fresh Marsh	15	14	14	13	11	9
	Trans. Salt Marsh	13	282	198	458	705	793
	Flooded Developed Dry Land	0	140	175	586	1,718	2,338
	Total (incl. water)	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**

Table 25. Southwest Coast Watershed RIM MIN (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	120,479	120,225	120,174	119,782	118,901	118,521
	Estuarine Open Water	58,761	58,788	58,813	58,867	59,093	59,205
	Developed Dry Land	47,707	47,567	47,533	47,025	45,222	44,441
	Swamp	4,423	4,412	4,411	4,403	4,329	4,316
	Inland Open Water	3,484	3,476	3,470	3,464	3,421	3,414
	Irreg.-Flooded Marsh	1,112	980	966	838	145	68
	Estuarine Beach	814	802	797	774	648	577
	Inland-Fresh Marsh	342	336	334	326	298	293
	Regularly-Flooded Marsh	302	426	571	776	2,085	2,480
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	54	70	105	196
	Riverine Tidal	27	24	12	7	4	2
	Rocky Intertidal	20	20	19	19	17	16
	Tidal Swamp	18	18	18	17	14	12
	Tidal-Fresh Marsh	15	14	14	13	8	6
	Trans. Salt Marsh	13	282	197	495	783	745
	Flooded Developed Dry Land	0	140	174	682	2,485	3,265
	Total (incl. water)	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**

Table 26. Southwest Coast Watershed RIM MAX (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	120,479	120,225	120,116	119,437	118,477	118,125
	Estuarine Open Water	58,761	58,788	58,822	58,950	59,236	59,430
	Developed Dry Land	47,707	47,567	47,489	46,304	44,363	43,595
	Swamp	4,423	4,412	4,408	4,350	4,315	4,306
	Inland Open Water	3,484	3,476	3,468	3,442	3,414	3,404
	Irreg.-Flooded Marsh	1,112	980	939	532	58	33
	Estuarine Beach	814	802	794	736	568	496
	Inland-Fresh Marsh	342	336	333	302	293	293
	Regularly-Flooded Marsh	302	426	613	1,248	2,461	2,636
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	61	93	270	513
	Riverine Tidal	27	24	11	4	2	2
	Rocky Intertidal	20	20	19	18	16	12
	Tidal Swamp	18	18	17	16	11	10
	Tidal-Fresh Marsh	15	14	14	10	5	3
	Trans. Salt Marsh	13	282	236	712	724	586
	Flooded Developed Dry Land	0	140	218	1,403	3,344	4,111
	Total (incl. water)	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**	**237,676**

3.3 Housatonic River Watershed

The narrow Housatonic River watershed has nearly 1000 acres of intertidal marshes towards its mouth. As usual, the high marshes are most plentiful initially but most vulnerable, with up to 96% loss predicted by 2100. Open water in this portion of the study area can increase by as much as 6%, with up to 145 acres of wetlands converting to open waters. Up to 136 acres of coastal developed land is also predicted to become regularly flooded.

Table 27. Housatonic River Watershed land cover change summary
(positive indicates a gain, negative is a loss)

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Developed Dry Land	6,552	-2.1	-3.3	-5.0	-6.8
Undeveloped Dry Land	6,210	-1.9	-3.0	-4.2	-5.2
Estuarine Open Water	5,790	2.1	3.0	4.2	6.5
Irreg.-Flooded Marsh	653	-26.6	-63.4	-88.6	-96.3
Regularly-Flooded Marsh	323	80.1	154.6	205.6	223.2
Swamp	315	-0.1	-0.2	-0.4	-0.4
Estuarine Beach	308	-33.5	-45.4	-58.9	-69.4
Inland Open Water	93	-4.7	-7.8	-10.9	-11.6
Trans. Salt Marsh	80	37.5	42.8	48.2	11.1
Inland-Fresh Marsh	36	-26.2	-33.2	-46.8	-48.7
Flooded Developed Dry Land	32	428.1	670.1	1038.2	1392.3
Tidal-Fresh Marsh	29	-10.1	-31.4	-60.9	-85.5
Tidal Flat	11	87.4	641.1	1213.2	1147.8
Tidal Swamp	8	-22.7	-44.9	-60.2	-69.0
Riverine Tidal	2	-90.6	-93.9	-97.0	-97.3

Figure 18 shows model outputs for the mouth of the Housatonic River as it empties into Long Island Sound. Given 1 meter of SLR by 2100, regularly-flooded marsh starts to dominate, but given 1.7 meters of SLR by 2100, much of the initial low marshes have converted to open water. Additionally, more frequent inundation is predicted to move up the river converting much of the irregularly-flooded marshes and tidal-fresh marshes into low marshes. However, how far salinity will move up the river is uncertain and is governed as much by changes in fresh water flows as it is by sea-level rise.

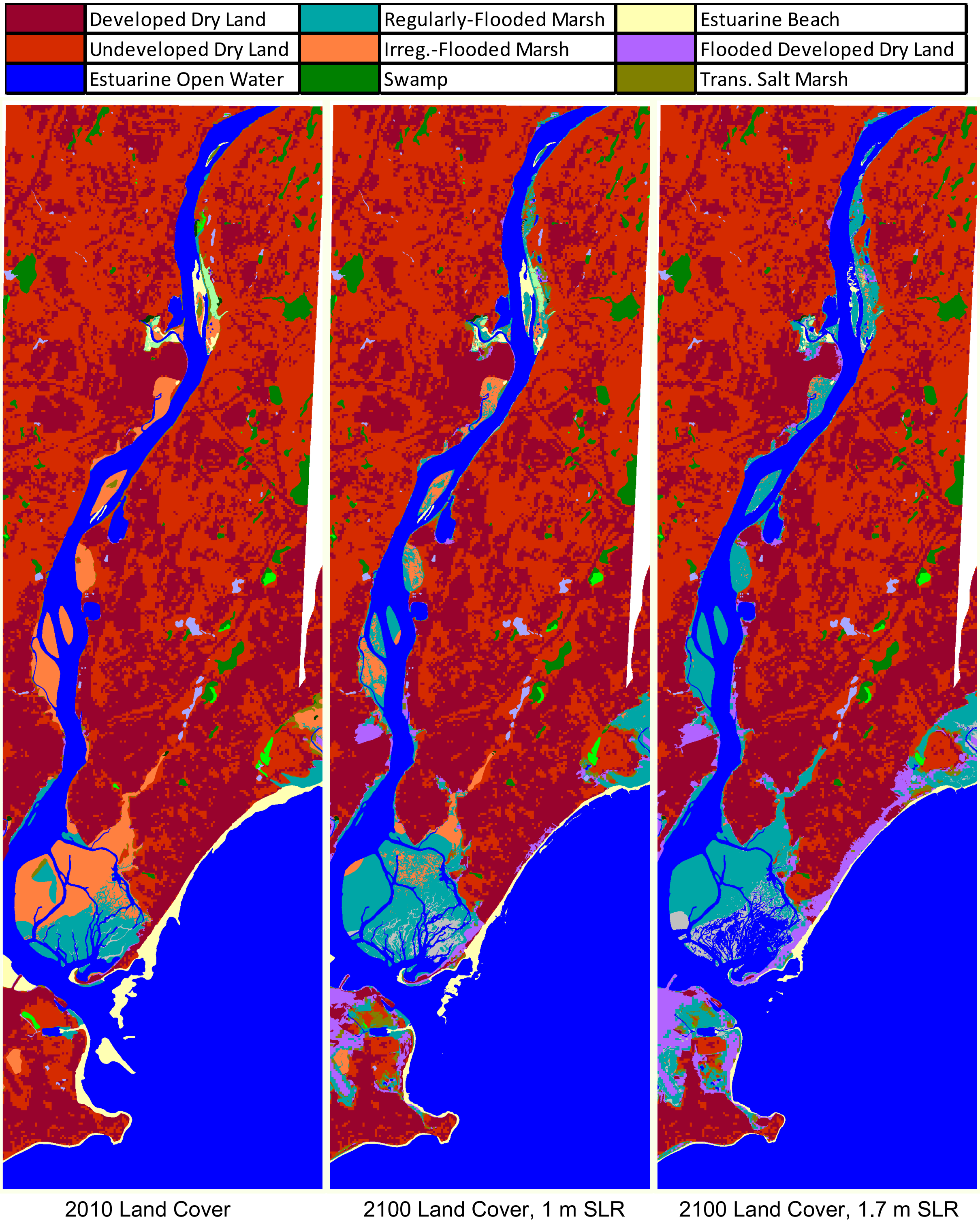


Figure 18. SLAMM predictions for the mouth of the Housatonic River in 2100 compared to initial conditions

Table 28. Housatonic River Watershed GCM Max

		Initial	2010	2025	2055	2085	2100
	Developed Dry Land	6,584	6,552	6,546	6,532	6,448	6,416
	Undeveloped Dry Land	6,269	6,210	6,205	6,182	6,115	6,089
	Estuarine Open Water	5,765	5,790	5,792	5,811	5,877	5,910
	Regularly-Flooded Marsh	248	323	370	395	476	581
	Irreg.-Flooded Marsh	710	653	645	631	563	480
	Swamp	315	315	315	315	314	314
	Estuarine Beach	308	308	307	290	231	205
	Flooded Developed Dry Land	0	32	38	52	136	168
	Trans. Salt Marsh	44	80	43	58	110	110
	Inland Open Water	115	93	93	91	89	88
	Tidal-Fresh Marsh	31	29	29	28	27	27
	Inland-Fresh Marsh	38	36	36	34	28	26
	Tidal Flat	0	11	12	12	18	20
	Tidal Swamp	9	8	8	8	7	6
	Riverine Tidal	4	2	1	0	0	0
	Total (incl. water)	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**

Table 29. Housatonic River Watershed 1 m SLR by 2100

		Initial	2010	2025	2055	2085	2100
	Developed Dry Land	6,584	6,552	6,546	6,518	6,393	6,339
	Undeveloped Dry Land	6,269	6,210	6,205	6,170	6,061	6,026
	Estuarine Open Water	5,765	5,790	5,792	5,839	5,932	5,961
	Regularly-Flooded Marsh	248	323	371	421	662	821
	Irreg.-Flooded Marsh	710	653	645	603	386	239
	Swamp	315	315	315	315	314	314
	Estuarine Beach	308	308	307	264	189	168
	Flooded Developed Dry Land	0	32	38	66	191	245
	Trans. Salt Marsh	44	80	43	63	120	115
	Inland Open Water	115	93	93	91	87	86
	Tidal-Fresh Marsh	31	29	29	27	21	20
	Inland-Fresh Marsh	38	36	36	33	25	24
	Tidal Flat	0	11	12	24	53	79
	Tidal Swamp	9	8	8	7	5	4
	Riverine Tidal	4	2	1	0	0	0
	Total (incl. water)	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**

Table 30. Housatonic River Watershed RIM Min

		Initial	2010	2025	2055	2085	2100
	Developed Dry Land	6,584	6,552	6,546	6,491	6,328	6,222
	Undeveloped Dry Land	6,269	6,210	6,205	6,146	6,017	5,947
	Estuarine Open Water	5,765	5,790	5,792	5,853	5,970	6,036
	Regularly-Flooded Marsh	248	323	370	443	857	986
	Irreg.-Flooded Marsh	710	653	645	579	176	74
	Swamp	315	315	315	315	314	313
	Estuarine Beach	308	308	307	252	162	126
	Flooded Developed Dry Land	0	32	38	93	256	362
	Trans. Salt Marsh	44	80	43	84	118	119
	Inland Open Water	115	93	93	90	86	83
	Tidal-Fresh Marsh	31	29	29	27	18	12
	Inland-Fresh Marsh	38	36	36	30	20	19
	Tidal Flat	0	11	12	31	114	139
	Tidal Swamp	9	8	8	7	4	3
	Riverine Tidal	4	2	1	0	0	0
	Total (incl. water)	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**

Table 31. Housatonic River Watershed RIM Max

		Initial	2010	2025	2055	2085	2100
	Developed Dry Land	6,584	6,552	6,538	6,419	6,210	6,110
	Undeveloped Dry Land	6,269	6,210	6,190	6,091	5,941	5,886
	Estuarine Open Water	5,765	5,790	5,801	5,912	6,068	6,168
	Regularly-Flooded Marsh	248	323	384	590	991	1,042
	Irreg.-Flooded Marsh	710	653	634	412	60	24
	Swamp	315	315	315	314	313	313
	Estuarine Beach	308	308	299	203	123	94
	Flooded Developed Dry Land	0	32	46	165	374	474
	Trans. Salt Marsh	44	80	53	114	113	89
	Inland Open Water	115	93	93	88	83	82
	Tidal-Fresh Marsh	31	29	27	21	9	4
	Inland-Fresh Marsh	38	36	34	26	19	18
	Tidal Flat	0	11	20	79	135	132
	Tidal Swamp	9	8	8	6	3	3
	Riverine Tidal	4	2	1	0	0	0
	Total (incl. water)	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**	**20,441**

3.4 South Central Coast Watershed

Within the south central coast watershed tide ranges are starting to decrease compared to the watersheds to the west. Therefore, while low marshes are predicted to thrive under many SLR scenarios, more tidal flats and open waters start to be predicted, especially under rapid-ice-melt scenarios.

Table 32. South Central Coast Watershed Landcover Change Summary
(positive indicates a gain, negative is a loss)

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Undeveloped Dry Land	26,245	-3.5	-5.4	-7.8	-10.4
Estuarine Open Water	22,237	2.3	3.2	4.7	8.0
Developed Dry Land	20,987	-2.0	-4.0	-6.7	-10.7
Irreg.-Flooded Marsh	4,992	-48.1	-89.5	-95.4	-97.3
Swamp	2,186	-4.5	-7.4	-11.2	-17.3
Estuarine Beach	1,020	-31.6	-43.9	-58.8	-68.8
Regularly-Flooded Marsh	979	353.3	604.9	637.1	543.6
Inland Open Water	468	-7.5	-10.6	-12.5	-15.2
Trans. Salt Marsh	400	-16.2	12.5	59.5	101.3
Inland-Fresh Marsh	276	-17.2	-32.9	-40.5	-46.9
Flooded Developed Dry Land	100	428.3	836.0	1409.0	2248.2
Tidal-Fresh Marsh	96	-1.7	-5.0	-19.7	-55.0
Tidal Swamp	74	-23.2	-49.4	-64.4	-77.2
Tidal Flat	71	-44.7	52.7	566.9	2167.0
Rocky Intertidal	30	-29.4	-38.5	-54.4	-62.8
Riverine Tidal	30	-85.3	-86.0	-86.0	-86.4
Inland Shore	1	0.0	0.0	0.0	0.0

Figure 19 illustrates the effects of SLR on the Hammock River marshes behind the town beaches of Clinton CT, towards the eastern portion of this watershed. High marshes are universally converted to low marshes under the 1-meter scenario and under the higher scenarios, considerable unvegetated tidal flats and open water are predicted.

	Undeveloped Dry Land		Irreg.-Flooded Marsh		Regularly-Flooded Marsh		Tidal-Fresh Marsh
	Estuarine Open Water		Swamp		Flooded Developed Land		Trans. Salt Marsh
	Developed Dry Land		Estuarine Beach		Inland-Fresh Marsh		Tidal Flat

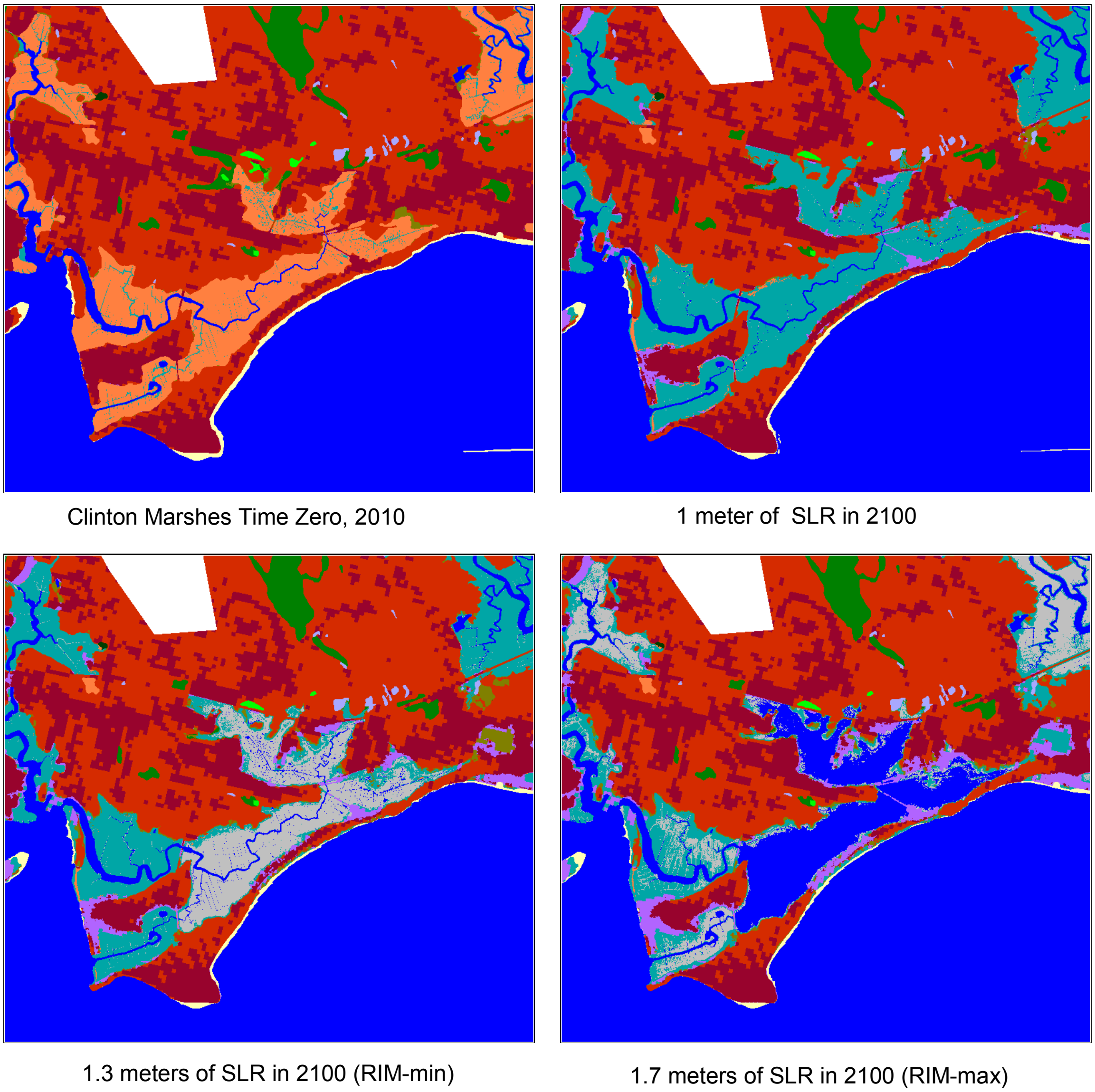


Figure 19. SLAMM predictions for Hammock River Marshes, Clinton CT in 2100 compared to initial conditions

Note, SLAMM output maps show current or predicted land-cover conditions at low tide (MLLW)

Table 33. South Central Coast GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	26,585	26,245	26,171	25,981	25,565	25,337
	Estuarine Open Water	22,210	22,237	22,315	22,421	22,634	22,741
	Developed Dry Land	21,087	20,987	20,962	20,887	20,700	20,558
	Irreg.-Flooded Marsh	5,480	4,992	4,899	4,641	3,541	2,591
	Swamp	2,223	2,186	2,177	2,156	2,111	2,089
	Estuarine Beach	1,021	1,020	997	925	772	698
	Regularly-Flooded Marsh	507	979	1,374	1,773	3,239	4,436
	Inland Open Water	474	468	448	447	441	433
	Inland-Fresh Marsh	294	276	270	261	235	229
	Tidal-Fresh Marsh	96	96	96	96	95	94
	Tidal Swamp	82	74	73	70	60	57
	Tidal Flat	50	71	107	104	58	39
	Riverine Tidal	37	30	5	5	4	4
	Rocky Intertidal	32	30	29	26	22	21
	Trans. Salt Marsh	12	400	144	198	326	335
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	100	126	200	387	529
	Total (incl. water)	**80,193**	**80,193**	**80,193**	**80,193**	**80,193**	**80,193**

Figure 20. High Marsh Habitat in Clinton CT looking east from Town Beach, (photo credit J.Clough)

Table 34. South Central Coast 1m (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	26,585	26,245	26,170	25,811	25,166	24,820
	Estuarine Open Water	22,210	22,237	22,316	22,511	22,816	22,950
	Developed Dry Land	21,087	20,987	20,961	20,814	20,428	20,150
	Irreg.-Flooded Marsh	5,480	4,992	4,896	4,086	1,162	527
	Swamp	2,223	2,186	2,176	2,133	2,064	2,024
	Estuarine Beach	1,021	1,020	997	862	655	572
	Regularly-Flooded Marsh	507	979	1,377	2,444	5,925	6,899
	Inland Open Water	474	468	448	444	429	419
	Inland-Fresh Marsh	294	276	270	243	217	185
	Tidal-Fresh Marsh	96	96	96	95	93	91
	Tidal Swamp	82	74	73	64	50	38
	Tidal Flat	50	71	107	99	75	108
	Riverine Tidal	37	30	5	5	4	4
	Rocky Intertidal	32	30	29	24	20	18
	Trans. Salt Marsh	12	400	145	284	428	450
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	100	126	273	659	938
	Total (incl. water)	**80,193**	**80,193**	**80,193**	**80,193**	**80,193**	**80,193**

Table 35. South Central Coast RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	26,585	26,245	26,171	25,734	24,747	24,210
	Estuarine Open Water	22,210	22,237	22,315	22,555	23,026	23,282
	Developed Dry Land	21,087	20,987	20,962	20,781	20,078	19,576
	Irreg.-Flooded Marsh	5,480	4,992	4,899	3,755	421	232
	Swamp	2,223	2,186	2,177	2,120	2,012	1,941
	Estuarine Beach	1,021	1,020	997	832	554	420
	Regularly-Flooded Marsh	507	979	1,374	2,810	6,820	7,213
	Inland Open Water	474	468	448	443	419	410
	Inland-Fresh Marsh	294	276	270	239	180	164
	Tidal-Fresh Marsh	96	96	96	94	88	77
	Tidal Swamp	82	74	73	62	35	26
	Tidal Flat	50	71	107	104	163	473
	Riverine Tidal	37	30	5	5	4	4
	Rocky Intertidal	32	30	29	23	18	14
	Trans. Salt Marsh	12	400	144	328	618	638
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	100	126	306	1,010	1,512
	Total (incl. water)	80,193	80,193	80,193	80,193	80,193	80,193

Table 36. South Central Coast RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	26,585	26,245	26,083	25,380	24,160	23,504
	Estuarine Open Water	22,210	22,237	22,352	22,743	23,414	24,012
	Developed Dry Land	21,087	20,987	20,930	20,594	19,529	18,735
	Irreg.-Flooded Marsh	5,480	4,992	4,705	1,552	209	133
	Swamp	2,223	2,186	2,163	2,081	1,929	1,807
	Estuarine Beach	1,021	1,020	969	712	410	319
	Regularly-Flooded Marsh	507	979	1,577	5,159	6,845	6,298
	Inland Open Water	474	468	447	433	410	397
	Inland-Fresh Marsh	294	276	265	228	163	147
	Tidal-Fresh Marsh	96	96	95	92	70	43
	Tidal Swamp	82	74	72	56	25	17
	Tidal Flat	50	71	117	174	724	1,608
	Riverine Tidal	37	30	5	4	4	4
	Rocky Intertidal	32	30	28	21	13	11
	Trans. Salt Marsh	12	400	226	469	729	805
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	100	157	494	1,558	2,352
	Total (incl. water)	**80,193**	**80,193**	**80,193**	**80,193**	**80,193**	**80,193**

3.5 Connecticut River Watershed

The narrow Connecticut River watershed continues the trend of increasing vulnerability (from west to east) with 94% to 99% of high marsh habitat predicted to be lost in SLR scenarios of over 1 meter (Table 37). As many as 3,600 acres of additional open water is predicted if SLR reaches 1.7 meters. Tidal fresh habitats are predicted to be flooded more frequently and likely converted on the basis of increased salinity.

Table 37 Connecticut River Watershed Landcover Change Summary
(positive indicates a gain, negative is a loss)

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Undeveloped Dry Land	20,304	-2.2	-3.1	-4.1	-5.0
Estuarine Open Water	6,028	8.1	10.4	19.1	58.6
Developed Dry Land	2,450	-1.7	-2.8	-4.3	-5.9
Irreg.-Flooded Marsh	2,362	-57.6	-93.9	-98.1	-98.9
Swamp	743	-0.9	-1.7	-2.1	-2.5
Tidal-Fresh Marsh	549	-10.2	-32.1	-72.4	-93.4
Tidal Swamp	342	-63.6	-77.1	-85.1	-90.1
Riverine Tidal	328	-83.6	-86.0	-88.0	-89.9
Trans. Salt Marsh	294	17.9	1.2	-11.3	-18.5
Inland Open Water	263	-2.0	-2.7	-4.1	-5.4
Regularly-Flooded Marsh	260	702.7	1055.6	460.6	163.8
Estuarine Beach	79	-82.8	-86.5	-89.8	-92.3
Inland-Fresh Marsh	55	-6.1	-7.4	-10.5	-12.5
Tidal Flat	24	251.0	1195.1	8091.8	2882.4
Flooded Developed Dry Land	9	469.3	772.0	1196.3	1637.0

Figure 21 illustrates predictions at the mouth of the Connecticut River. Open water and tidal flats are predicted to become prevalent under 1.3 meters of SLR and nearly all marshes are lost and converted to open water by 2100. The relatively steep shorelines of the CT River mean that there are few locations for marsh transgression. Much of the dry lands that could offer new marsh habitat are developed and thus unlikely to offer a smooth marsh-migration process.

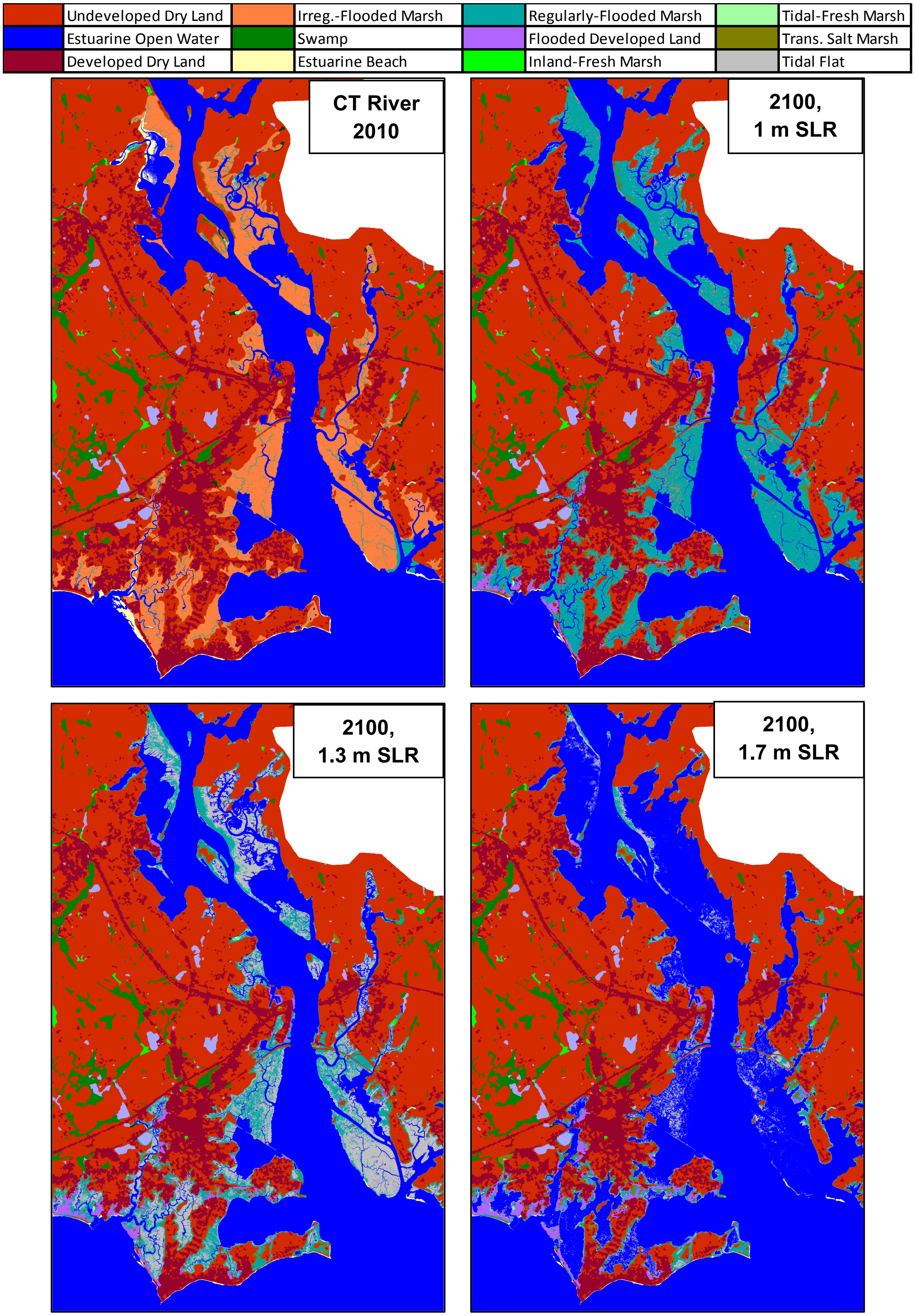


Figure 21. SLAMM Predictions for the Mouth of the CT River, Initial Condition vs. 2100

Table 38. Connecticut River Watershed GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	20,587	20,304	20,260	20,143	19,950	19,862
	Estuarine Open Water	5,951	6,028	6,293	6,394	6,487	6,518
	Irreg.-Flooded Marsh	2,529	2,362	2,324	2,237	1,682	1,002
	Developed Dry Land	2,459	2,450	2,448	2,440	2,420	2,409
	Swamp	748	743	742	741	737	736
	Tidal-Fresh Marsh	579	549	547	542	510	493
	Riverine Tidal	377	328	94	73	59	54
	Tidal Swamp	370	342	329	290	165	125
	Inland Open Water	263	263	261	261	260	257
	Estuarine Beach	107	79	56	26	16	14
	Regularly-Flooded Marsh	57	260	363	504	1,281	2,090
	Inland-Fresh Marsh	55	55	55	54	52	52
	Trans. Salt Marsh	6	294	222	291	365	346
	Tidal Flat	2	24	87	75	67	83
	Flooded Developed Dry Land	0	9	11	19	39	51
	Total (incl. water)	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**

Table 39. Connecticut River Watershed 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	20,587	20,304	20,259	20,052	19,800	19,676
	Estuarine Open Water	5,951	6,028	6,293	6,444	6,569	6,655
	Irreg.-Flooded Marsh	2,529	2,362	2,323	2,048	415	143
	Developed Dry Land	2,459	2,450	2,448	2,433	2,400	2,382
	Swamp	748	743	742	738	735	730
	Tidal-Fresh Marsh	579	549	547	511	430	373
	Riverine Tidal	377	328	94	68	53	46
	Tidal Swamp	370	342	329	228	104	78
	Inland Open Water	263	263	261	260	257	255
	Estuarine Beach	107	79	56	19	12	11
	Regularly-Flooded Marsh	57	260	364	805	2,750	3,009
	Inland-Fresh Marsh	55	55	55	52	52	51
	Trans. Salt Marsh	6	294	222	317	300	297
	Tidal Flat	2	24	87	87	154	305
	Flooded Developed Dry Land	0	9	11	26	59	77
	Total (incl. water)	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**

Table 40. Connecticut River Watershed RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	20,587	20,304	20,260	20,018	19,651	19,478
	Estuarine Open Water	5,951	6,028	6,293	6,462	6,722	7,178
	Irreg.-Flooded Marsh	2,529	2,362	2,324	1,870	112	45
	Developed Dry Land	2,459	2,450	2,448	2,429	2,377	2,344
	Swamp	748	743	742	738	730	727
	Tidal-Fresh Marsh	579	549	547	496	316	151
	Riverine Tidal	377	328	94	66	47	39
	Tidal Swamp	370	342	329	199	71	51
	Inland Open Water	263	263	261	260	255	252
	Estuarine Beach	107	79	56	18	10	8
	Regularly-Flooded Marsh	57	260	363	1,031	2,771	1,460
	Inland-Fresh Marsh	55	55	55	52	51	49
	Trans. Salt Marsh	6	294	222	322	278	260
	Tidal Flat	2	24	87	100	617	1,932
	Flooded Developed Dry Land	0	9	11	30	82	115
	Total (incl. water)	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**

Table 41. Connecticut River Watershed RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	20,587	20,304	20,206	19,878	19,465	19,286
	Estuarine Open Water	5,951	6,028	6,316	6,556	7,418	9,559
	Irreg.-Flooded Marsh	2,529	2,362	2,276	602	45	25
	Developed Dry Land	2,459	2,450	2,444	2,410	2,342	2,305
	Swamp	748	743	741	736	727	725
	Tidal-Fresh Marsh	579	549	530	415	94	36
	Riverine Tidal	377	328	93	59	40	33
	Tidal Swamp	370	342	308	119	48	34
	Inland Open Water	263	263	261	258	252	248
	Estuarine Beach	107	79	37	14	8	6
	Regularly-Flooded Marsh	57	260	459	2,467	1,054	687
	Inland-Fresh Marsh	55	55	54	52	49	48
	Trans. Salt Marsh	6	294	240	287	259	239
	Tidal Flat	2	24	109	190	2,172	703
	Flooded Developed Dry Land	0	9	15	49	118	154
	Total (incl. water)	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**	**34,090**

3.6 Southeast Coast Watershed

The coastal Southeast Coast watershed is split into two pieces with the narrow Thames watershed cutting in the middle. This watershed has the most vulnerable developed dry land in the study area with up to 16% of these lands vulnerable to regular flooding by 2100. Up to 27% of coastal fresh-water swamps and up to 69% of tidal swamps are also predicted to be vulnerable

Table 42 Southeast Coast Watershed Landcover Change Summary
(positive indicates a gain, negative is a loss)

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Estuarine Open Water	22,107	0.4	0.7	4.6	7.8
Undeveloped Dry Land	15,586	-3.6	-5.6	-8.1	-10.5
Developed Dry Land	6,412	-3.7	-6.9	-11.3	-15.7
Irreg.-Flooded Marsh	1,253	-73.9	-88.7	-93.8	-96.1
Swamp	737	-8.2	-14.1	-21.0	-27.0
Trans. Salt Marsh	300	77.5	84.8	83.8	55.9
Estuarine Beach	181	-9.6	-17.4	-29.4	-43.8
Tidal Swamp	180	-20.0	-41.4	-58.2	-69.0
Inland Open Water	174	-4.5	-9.1	-18.6	-18.8
Regularly-Flooded Marsh	115	1122.7	1444.7	850.9	802.8
Inland-Fresh Marsh	94	-20.0	-31.1	-37.0	-39.0
Flooded Developed Dry Land	44	536.2	996.9	1630.7	2263.6
Tidal-Fresh Marsh	21	-0.4	-2.5	-13.1	-31.4
Rocky Intertidal	8	-10.6	-18.5	-29.8	-38.4
Tidal Flat	5	287.8	3827.6	11827.3	10259.8

Figure 21 and Figure 22 show maps of SLAMM predictions from the mouth of the Thames River east into the Southeast Coast watershed. Loss of high-marsh habitat is predicted in this region as well as some conversion of marshes to open water under rapid ice melt scenarios. Parts of the Groton-New London airport are also predicted to be regularly flooded under all sea-level scenarios examined.

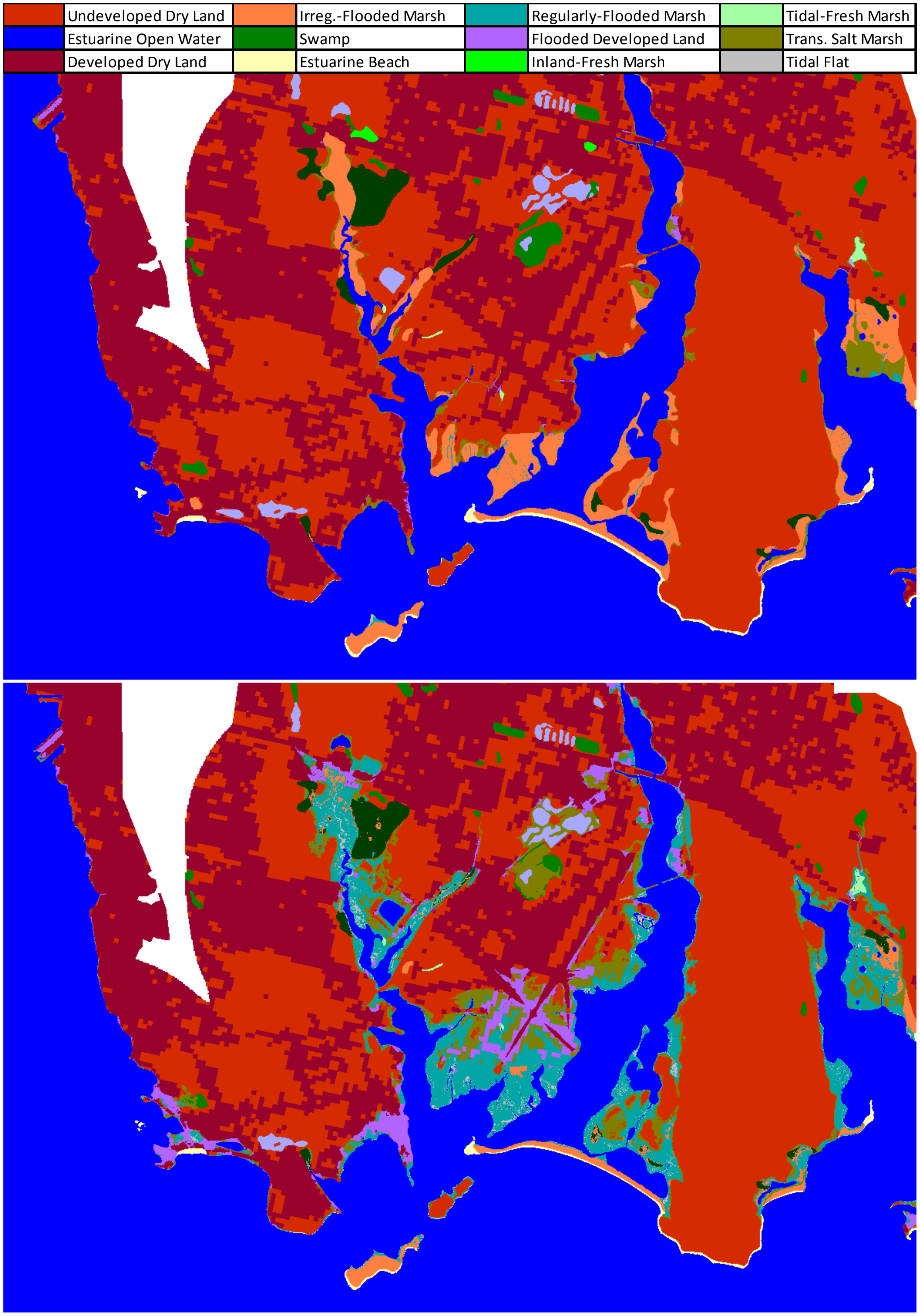


Figure 22. Predictions from the Eastern Mouth of the Thames River to Bluff Point State Park

Top figure shows 2010 conditions and bottom 2100 under 1 meter of SLR

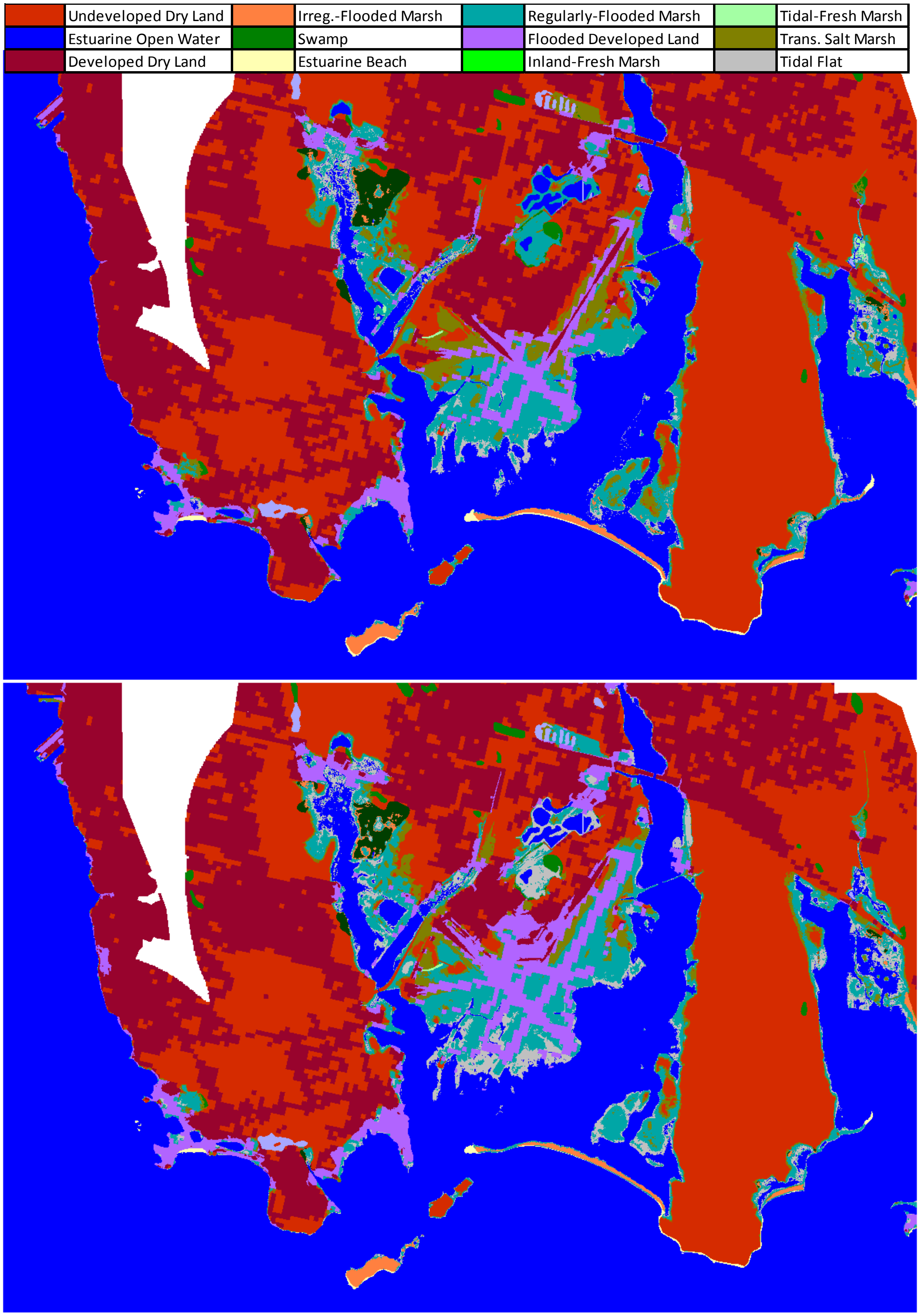


Figure 23. Rapid Ice Melt Predictions from the Eastern Mouth of the Thames River to Bluff Point State Park

Top figure shows 2100 conditions under 1.3 meters of SLR and the bottom 2100 under 1.7 meters of SLR

Table 43. Southeast Coast Watershed GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	22,087	22,107	22,113	22,144	22,181	22,197
	Undeveloped Dry Land	15,805	15,586	15,541	15,420	15,162	15,029
	Developed Dry Land	6,456	6,412	6,401	6,360	6,244	6,174
	Irreg.-Flooded Marsh	1,308	1,253	1,246	1,207	587	328
	Swamp	742	737	729	716	687	676
	Estuarine Beach	189	181	180	176	170	164
	Tidal Swamp	181	180	180	179	162	144
	Inland Open Water	174	174	174	174	167	166
	Inland-Fresh Marsh	95	94	93	91	77	76
	Trans. Salt Marsh	81	300	271	368	522	533
	Regularly-Flooded Marsh	62	115	183	236	1,000	1,403
	Tidal-Fresh Marsh	21	21	21	21	21	21
	Tidal Flat	8	5	24	24	18	19
	Rocky Intertidal	8	8	7	7	7	7
	Flooded Developed Dry Land	0	44	56	96	213	283
	Total (incl. water)	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**

Table 44. Southeast Coast Watershed 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	22,087	22,107	22,113	22,164	22,215	22,251
	Undeveloped Dry Land	15,805	15,586	15,540	15,304	14,938	14,711
	Developed Dry Land	6,456	6,412	6,400	6,315	6,122	5,969
	Irreg.-Flooded Marsh	1,308	1,253	1,246	917	215	142
	Swamp	742	737	729	696	669	633
	Estuarine Beach	189	181	180	174	160	150
	Tidal Swamp	181	180	180	175	128	106
	Inland Open Water	174	174	174	172	164	158
	Inland-Fresh Marsh	95	94	93	83	75	65
	Trans. Salt Marsh	81	300	272	444	492	555
	Regularly-Flooded Marsh	62	115	184	583	1,636	1,772
	Tidal-Fresh Marsh	21	21	21	21	21	20
	Tidal Flat	8	5	24	24	44	193
	Rocky Intertidal	8	8	7	7	7	6
	Flooded Developed Dry Land	0	44	56	141	334	487
	Total (incl. water)	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**

Table 45. Southeast Coast Watershed RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	22,087	22,107	22,113	22,169	22,289	23,129
	Undeveloped Dry Land	15,805	15,586	15,541	15,253	14,665	14,316
	Developed Dry Land	6,456	6,412	6,401	6,291	5,941	5,688
	Irreg.-Flooded Marsh	1,308	1,253	1,246	692	132	78
	Swamp	742	737	729	692	626	582
	Estuarine Beach	189	181	180	173	147	128
	Tidal Swamp	181	180	180	171	99	75
	Inland Open Water	174	174	174	172	159	142
	Inland-Fresh Marsh	95	94	93	82	64	60
	Trans. Salt Marsh	81	300	271	460	530	552
	Regularly-Flooded Marsh	62	115	183	845	1,223	1,091
	Tidal-Fresh Marsh	21	21	21	21	20	18
	Tidal Flat	8	5	24	26	803	585
	Rocky Intertidal	8	8	7	7	6	5
	Flooded Developed Dry Land	0	44	56	165	516	769
	Total (incl. water)	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**

Table 46. Southeast Coast Watershed RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	22,087	22,107	22,115	22,209	23,199	23,834
	Undeveloped Dry Land	15,805	15,586	15,489	15,055	14,283	13,954
	Developed Dry Land	6,456	6,412	6,387	6,187	5,659	5,407
	Irreg.-Flooded Marsh	1,308	1,253	1,222	250	75	48
	Swamp	742	737	720	676	565	538
	Estuarine Beach	189	181	178	165	126	102
	Tidal Swamp	181	180	179	140	73	56
	Inland Open Water	174	174	174	167	142	141
	Inland-Fresh Marsh	95	94	93	75	59	58
	Trans. Salt Marsh	81	300	302	450	571	468
	Regularly-Flooded Marsh	62	115	230	1,501	1,037	1,036
	Tidal-Fresh Marsh	21	21	21	20	17	14
	Tidal Flat	8	5	30	47	610	508
	Rocky Intertidal	8	8	7	7	5	5
	Flooded Developed Dry Land	0	44	69	269	798	1,050
	Total (incl. water)	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**	**47,219**

3.7 Thames Watershed

The area of the Thames Watershed that is below 5 meters elevation is somewhat limited. Within this study area, from 1% to 6% of developed lands are predicted to be flooded by 2100 depending on the SLR scenario evaluated. This watershed has few intertidal wetlands, with under 250 total acres of habitat. Within these habitats a similar pattern of high marsh loss and low marsh increases are predicted as found throughout the entire study area.

Table 47 Thames Watershed Landcover Change Summary

(positive indicates a gain, negative is a loss)

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Undeveloped Dry Land	6,220	-1.0	-1.6	-2.6	-3.7
Estuarine Open Water	4,616	0.7	1.1	2.2	3.4
Developed Dry Land	3,708	-1.0	-2.0	-4.1	-6.1
Trans. Salt Marsh	100	-50.5	-45.5	-23.3	-16.3
Swamp	84	-3.4	-5.8	-7.8	-9.3
Inland Open Water	46	-6.4	-6.8	-7.4	-8.2
Irreg.-Flooded Marsh	25	-55.3	-82.7	-91.8	-92.1
Flooded Developed Dry Land	22	162.6	339.8	676.6	1019.9
Inland-Fresh Marsh	22	-7.1	-7.7	-7.7	-7.8
Estuarine Beach	18	-25.2	-32.5	-45.1	-57.9
Regularly-Flooded Marsh	11	881.4	1009.4	850.6	972.5
Tidal Swamp	7	-14.5	-26.5	-42.5	-62.6
Rocky Intertidal	1	-36.3	-54.2	-71.1	-89.5
Tidal-Fresh Marsh	1	-5.8	-23.7	-61.5	-64.7

Table 48. Thames Watershed GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	6,316	6,220	6,213	6,198	6,172	6,159
	Estuarine Open Water	4,615	4,616	4,617	4,620	4,642	4,649
	Developed Dry Land	3,730	3,708	3,705	3,699	3,683	3,672
	Swamp	85	84	84	83	82	81
	Inland Open Water	47	46	46	45	43	43
	Irreg.-Flooded Marsh	30	25	24	23	17	11
	Inland-Fresh Marsh	24	22	21	21	20	20
	Estuarine Beach	18	18	18	18	14	14
	Tidal Swamp	7	7	7	7	6	6
	Regularly-Flooded Marsh	5	11	75	69	87	104
	Rocky Intertidal	2	1	1	1	1	1
	Trans. Salt Marsh	1	100	43	48	52	50
	Tidal-Fresh Marsh	1	1	1	1	1	1
	Flooded Developed Dry Land	0	22	25	31	47	59
	Tidal Flat	0	0	1	18	13	12
	Total (incl. water)	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**

Table 49. Thames Watershed 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	6,316	6,220	6,213	6,186	6,148	6,123
	Estuarine Open Water	4,615	4,616	4,617	4,631	4,658	4,669
	Developed Dry Land	3,730	3,708	3,705	3,692	3,663	3,632
	Swamp	85	84	83	82	80	79
	Inland Open Water	47	46	46	44	43	43
	Irreg.-Flooded Marsh	30	25	24	20	7	4
	Inland-Fresh Marsh	24	22	21	20	20	20
	Estuarine Beach	18	18	18	15	13	12
	Tidal Swamp	7	7	7	7	6	5
	Regularly-Flooded Marsh	5	11	75	75	110	118
	Rocky Intertidal	2	1	1	1	1	1
	Trans. Salt Marsh	1	100	43	47	47	55
	Tidal-Fresh Marsh	1	1	1	1	1	1
	Flooded Developed Dry Land	0	22	25	38	67	98
	Tidal Flat	0	0	1	21	17	22
	Total (incl. water)	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**

Table 50. Thames Watershed RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	6,316	6,220	6,213	6,182	6,115	6,057
	Estuarine Open Water	4,615	4,616	4,617	4,637	4,678	4,716
	Developed Dry Land	3,730	3,708	3,705	3,690	3,621	3,557
	Swamp	85	84	84	82	79	77
	Inland Open Water	47	46	46	44	43	43
	Irreg.-Flooded Marsh	30	25	24	18	4	2
	Inland-Fresh Marsh	24	22	21	20	20	20
	Estuarine Beach	18	18	18	15	12	10
	Tidal Swamp	7	7	7	6	5	4
	Regularly-Flooded Marsh	5	11	75	79	104	101
	Rocky Intertidal	2	1	1	1	1	0
	Trans. Salt Marsh	1	100	43	47	55	77
	Tidal-Fresh Marsh	1	1	1	1	1	0
	Flooded Developed Dry Land	0	22	25	41	110	173
	Tidal Flat	0	0	1	20	36	43
	Total (incl. water)	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**

Table 51. Thames Watershed RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	6,316	6,220	6,206	6,161	6,050	5,989
	Estuarine Open Water	4,615	4,616	4,617	4,658	4,721	4,773
	Developed Dry Land	3,730	3,708	3,703	3,675	3,551	3,480
	Swamp	85	84	83	81	77	76
	Inland Open Water	47	46	46	43	43	42
	Irreg.-Flooded Marsh	30	25	23	8	2	2
	Inland-Fresh Marsh	24	22	21	20	20	20
	Estuarine Beach	18	18	18	14	10	8
	Tidal Swamp	7	7	7	6	4	3
	Regularly-Flooded Marsh	5	11	83	99	95	114
	Rocky Intertidal	2	1	1	1	0	0
	Trans. Salt Marsh	1	100	42	41	80	84
	Tidal-Fresh Marsh	1	1	1	1	0	0
	Flooded Developed Dry Land	0	22	27	55	179	250
	Tidal Flat	0	0	3	18	49	40
	Total (incl. water)	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**	**14,881**

3.8 Pawcatuck Watershed (CT portion)

The portion of the Pawcatuck watershed within the Connecticut study area is limited to 1144 total acres (land covers below 5 meters of elevation). However, within this region, undeveloped dry lands are predicted to be quite vulnerable with 5% to 18% losses predicted by 2100. Developed-dry land losses range from 2% to 8% by 2100.

Table 52 Pawcatuck Watershed (CT) Landcover Change Summary
(positive indicates a gain, negative is a loss)

Land cover category	Acres in 2010	Percentage Land cover change from 2010 to 2100 for different SLR scenarios			
		GCM Max	1m	RIM Min	RIM Max
Undeveloped Dry Land	548	-5.5	-9.7	-15.2	-18.4
Developed Dry Land	478	-1.7	-3.3	-5.9	-8.4
Estuarine Open Water	295	1.4	1.9	7.4	18.4
Swamp	54	-0.2	-0.9	-1.9	-6.1
Irreg.-Flooded Marsh	39	-62.1	-87.9	-95.8	-98.1
Trans. Salt Marsh	12	99.2	169.9	198.0	101.5
Riverine Tidal	4	-40.4	-53.4	-59.0	-70.4
Flooded Developed Dry Land	3	273.3	535.3	954.1	1364.1
Inland Open Water	3	-18.5	-20.0	-20.0	-20.7
Regularly-Flooded Marsh	1	3665.6	5647.8	4688.9	5573.3
Inland-Fresh Marsh	1	0.0	-100.0	-100.0	-100.0
Tidal Swamp	<1	-44.9	-100.0	-100.0	-100.0

Table 53. Pawcatuck Watershed GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	558	548	545	537	525	517
	Developed Dry Land	481	478	477	476	472	470
	Estuarine Open Water	294	295	296	297	298	299
	Swamp	54	54	54	54	54	54
	Irreg.-Flooded Marsh	40	39	39	38	28	15
	Riverine Tidal	6	4	3	3	3	3
	Inland Open Water	3	3	3	3	3	2
	Trans. Salt Marsh	1	12	11	17	23	24
	Inland-Fresh Marsh	1	1	1	1	1	1
	Tidal Swamp	0	0	0	0	0	0
	Regularly-Flooded Marsh	0	1	5	6	23	42
	Flooded Developed Dry Land	0	3	3	5	9	11
	Tidal Flat	0	0	0	1	1	1
	Total (incl. water)	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**

Table 54. Pawcatuck Watershed in Connecticut; 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	558	548	545	533	511	494
	Developed Dry Land	481	478	477	474	468	462
	Estuarine Open Water	294	295	296	298	299	301
	Swamp	54	54	54	54	54	54
	Irreg.-Flooded Marsh	40	39	39	36	8	5
	Riverine Tidal	6	4	3	3	3	2
	Inland Open Water	3	3	3	3	2	2
	Trans. Salt Marsh	1	12	11	18	25	33
	Inland-Fresh Marsh	1	1	1	1	0	0
	Tidal Swamp	0	0	0	0	0	0
	Regularly-Flooded Marsh	0	1	5	12	53	64
	Flooded Developed Dry Land	0	3	3	7	13	19
	Tidal Flat	0	0	0	1	1	3
	Total (incl. water)	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**

Table 55. Pawcatuck Watershed in Connecticut; RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	558	548	545	530	488	465
	Developed Dry Land	481	478	477	474	461	450
	Estuarine Open Water	294	295	296	298	301	317
	Swamp	54	54	54	54	54	53
	Irreg.-Flooded Marsh	40	39	39	32	4	2
	Riverine Tidal	6	4	3	3	2	2
	Inland Open Water	3	3	3	3	2	2
	Trans. Salt Marsh	1	12	11	19	35	36
	Inland-Fresh Marsh	1	1	1	1	0	0
	Tidal Swamp	0	0	0	0	0	0
	Regularly-Flooded Marsh	0	1	5	18	56	53
	Flooded Developed Dry Land	0	3	3	7	20	31
	Tidal Flat	0	0	0	1	15	28
	Total (incl. water)	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**

Table 56. Pawcatuck Watershed in Connecticut; RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	558	548	543	519	462	447
	Developed Dry Land	481	478	477	470	449	438
	Estuarine Open Water	294	295	296	299	320	349
	Swamp	54	54	54	54	52	51
	Irreg.-Flooded Marsh	40	39	39	10	1	1
	Riverine Tidal	6	4	3	3	2	1
	Inland Open Water	3	3	3	2	2	2
	Trans. Salt Marsh	1	12	12	20	37	25
	Inland-Fresh Marsh	1	1	1	1	0	0
	Tidal Swamp	0	0	0	0	0	0
	Regularly-Flooded Marsh	0	1	7	48	52	63
	Flooded Developed Dry Land	0	3	4	11	32	43
	Tidal Flat	0	0	0	1	29	19
	Total (incl. water)	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**	**1,439**

4 Conclusions

This application of the Sea-Level Affecting Marshes Model was funded by the New England Interstate Water Pollution Control Commission (NEIWPCC) and the state of Connecticut with the goal of identifying potential responses of Connecticut's coastal marshes and adjacent upland areas to accelerated Sea-Level Rise. The model application and results reported herein can be useful in identifying and prioritizing potential adaptation strategies including land acquisition, marsh restoration, infrastructure development, and other land and facility management actions. This study focused on coastal regions of Connecticut with elevations of below five meters and looks at sea-level effects through the year 2100.

Results of this model application find that high marshes (irregularly-flooded marshes), the most prevalent coastal wetland type in the study area, are the most vulnerable category to sea-level rise, with predicted losses ranging from 50% to 97% by 2100. Marsh losses occur at an earlier date and are more likely to become conversions to open water in the eastern portion of the study area, where lower tide ranges result in higher predictions of marsh vulnerability. SLAMM predictions of significant marsh vulnerability to SLR, particularly that of high marsh habitat, are in-line with observations of marsh status in this area over the last 30 to 40 years (Tiner et al. 2006). In addition to wetland losses, up to 9% of developed dry land in the study area is also predicted to be regularly flooded.

In considering these results, it is important to consider the limitations of the study. While SLAMM is a useful tool for visualizing potential effects of SLR, the model only predicts changes due to long-term changes in sea levels. Anthropogenic changes such as beach nourishment, shoreline armoring, construction of levees, and changing tide gate configurations are not included in simulations presented here. In addition, the effects of large storms on landcover conversion and marsh loss are not considered. Given that many of these changes or events can be injurious to marsh habitats, the results of this model application can be considered optimistic.

SLAMM also predicts that high marsh habitat that is regularly flooded will successfully transition into a viable low-marsh habitat. It is possible that adding significant salinity to high marsh habitats will result in peat collapse and direct conversion of irregularly-flooded marshes into open water.

There are also important data limitations to consider. This study employed a developed-land footprint with a 30 meter resolution which was much lower than the resolution of the elevation data layers. The consequence of this course resolution may be an over prediction of flooded-developed lands and an uncertainty in the available corridors for marsh migration. Furthermore, accretion rates are critical input parameters to SLAMM. As discussed in section 2.8, the derivation of precise accretion-feedback curves for regularly-flooded marshes was limited by several factors. Data limitations included little accretion-rate data collected low in the tidal frame, a lack of marsh-platform elevations at the time of accretion measurement, and limited information on marsh biomass within the study area. Accretion-data limitations introduce considerable uncertainty to marsh response patterns predicted by SLAMM. However, this uncertainty will be addressed by the stochastic uncertainty analysis conducted for the final model application report for this project.

Despite model and data limitations, SLAMM results can provide useful insight to scientists, managers, and policy makers. As high marsh is observed to be particularly vulnerable throughout the study area, species that rely on these habitats should be assessed with future habitat limitations in mind. Finally, simulation results indicate locations of vulnerable developed lands and the timescales at which flooding may occur providing data for policymakers as to where and when intervention may be needed.

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Appendix A: GIS Methods

DEM Preparation:

Multiple steps were used to produce a hydro-enforced DEM for the Connecticut coastal project area. The 2011 and 2012 LiDAR dataset ground points were converted to DEMs with 5m cell resolution. The earlier NED and UConn DEM data were resampled to a 5m cell resolution. The DEMs were mosaicked together. The Post Sandy DEM elevation data were used wherever cells overlapped with the other datasets. The other datasets were used to fill in gaps in the Post Sandy data, or to extend coverage inland (i.e., 2011 USGS LiDAR data), to islands along the coast (NED), and along the Housatonic River (UConn DEM). The mosaicked DEM was reclassified to create the hydro-enforcement extent, which is limited to elevated areas at or below 5.5 m above mean tide level.

Pre-processing. The LiDAR datasets were downloaded in laz format. The files were extracted and re-projected from geographic to UTM coordinate systems. Post Sandy heights are referenced to ellipsoidal heights using Geoid12a. USGS LiDAR heights are referenced to ellipsoidal heights using Geoid09. The NED data were downloaded and reprojected from geographic to UTM coordinate systems. NED heights are referenced to NAVD88. The 10ft UConn DEM was downloaded and reprojected from State Plane US_ft to UTM meters coordinate systems. There is no height information for the 10ft UConn DEM. The FEMA Structures database was used as the primary source of data to locate all bridges and culverts in the project area. If a bridge or culvert existed, the LiDAR data and publicly available orthoimagery (i.e., ESRI online imagery) was used as reference data to digitize a line through the bridge or culvert. If the stream was greater than 5m wide then a polygon was digitized through the bridge or culvert along with a centerline. All lines were digitized in the downstream direction. Elevation values were then conflated to the end points of the lines using the hybrid elevation dataset. A custom ArcGIS tool was used to verify the start point of each artificial path was higher than or the same elevation of the endpoint. Vertices were edited as needed to ensure a downstream constraint. The vertices of each line and polygon were then densified to 5m spacing. Another custom tool conflated elevation values to the interior vertices of all lines using the start point and end point elevations. If the start point and end point had the same elevation value then all interior vertices will have the same elevation value. If the start point and end point had different elevation values then the value of each interior vertex was calculated using a linear algorithm based on the values of the two endpoints. We used the LP360 Flatten River Polygon tool to conflate the elevation values of each artificial path to each vertex of the polygons that were digitized at each bridge/culvert location, resulting in 3d polygon breaklines that cut through every culvert/bridge location in the study area.

DEM Hydroenforcement: The mosaicked DEM was converted to a multipoint feature class. Points were then erased from the multipoint feature class that fell inside the bridge/culvert polygons. Multipoint feature class and polygon breaklines were then used to create an ESRI terrain dataset. The terrain dataset was converted to a raster DEM with a 5m cell resolution. The breakline polygon areas were inspected to make sure they were represented in the final DEM. For bridges/culverts represented by lines only, the vertices of the lines were converted to points. Points were converted to raster and mosaicked onto the DEM that was converted from the ESRI terrain.

Wetland-Layer Preparation:

The preparation for all wetland layers required the following steps:

- The projection for each data source was checked/converted to NAD83 UTM Zone 18N.
- ESRI's ArcGIS Union tool was used to join each wetland data layer in order of priority.
- The attributes for the priority layer were updated with each subsequent join operation.
- This process was repeated until all the data sources were combined in the order of priority.
- ESRI's Dissolve tool was used to merge adjacent polygons with the same attribute.
- The wetland polygons for individual project areas were merged together into one single dataset representing the full extent of the project using ESRI's Merge tool.
- ESRI's Conversion tool was used to convert the polygon data to raster format with 5 m cell resolution.
- Each project area was then extracted from the full extent raster using the ESRI's Spatial Analyst tool "Extract by Mask".

Appendix B: Great Diurnal Tide Ranges in CT (m)

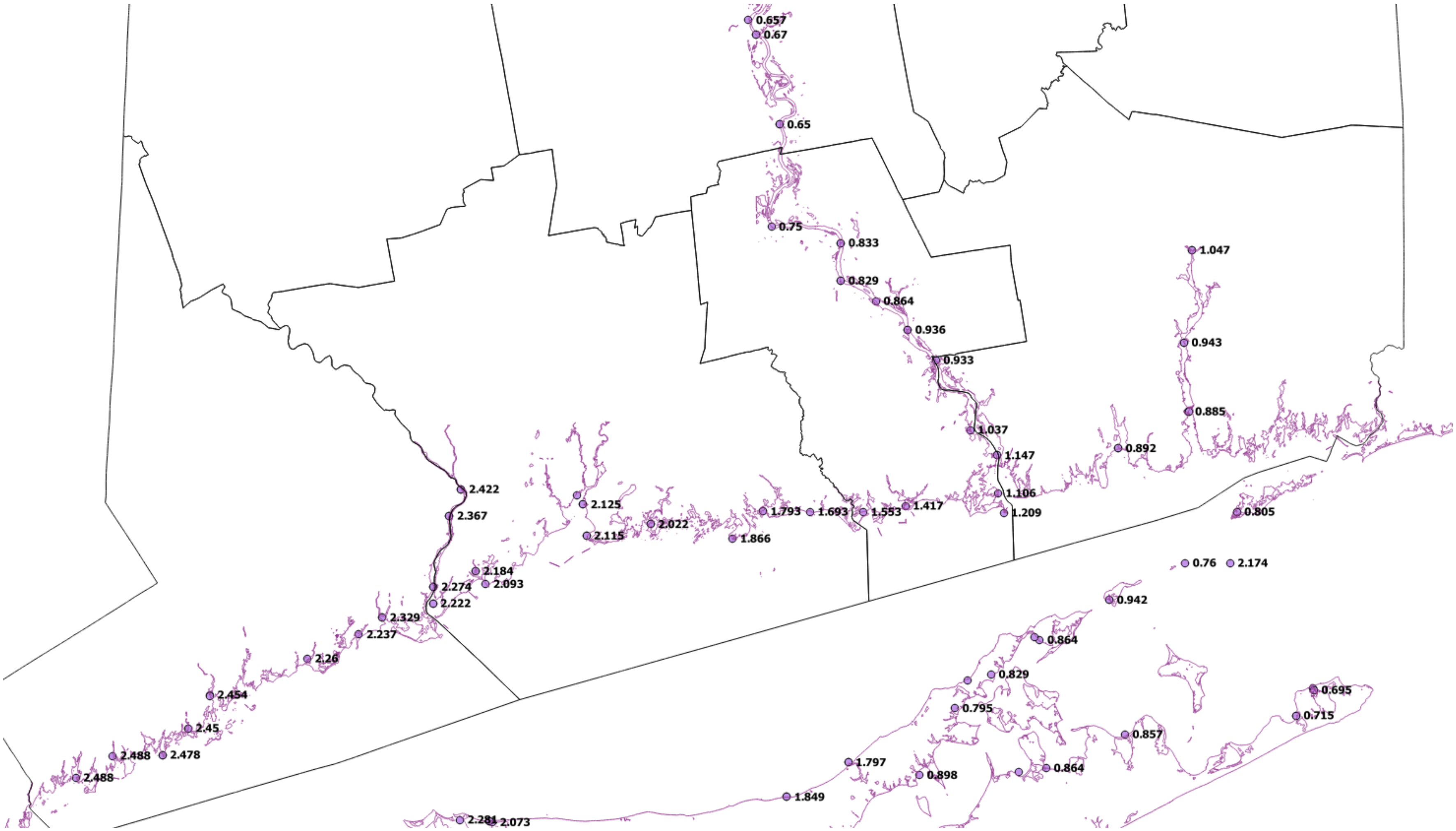

Figure 24. Great diurnal tide ranges in CT (m)

Appendix C: Comprehensive Tables of Input Parameters

Table 57. Area 1 Input Parameters

Subsite	**General Area 1**	**1**	**2**	**3**
Description		**Pine Creek**	**Erosion Zone - Stratford**	**Sikorsky Airport**
NWI Photo Date (YYYY)	2010	2010	2010	2010
DEM Date (YYYY)	2012	2012	2012	2012
Direction Offshore [n,s,e,w]	South	South	South	South
Historic Trend (mm/yr)	0	0	0	0
Historic Eustatic Trend (mm/yr)	0	0	0	0
MTL-NAVD88 (m)	0	0	0	0
GT Great Diurnal Tide Range (m)	2.3	1.5	2.3	1.2
Salt Elev. (m above MTL)	1.66	1.22	1.66	1.02
Marsh Erosion (horz. m /yr)	0	0	0.06	0
Swamp Erosion (horz. m /yr)	0	0	0.06	0
T.Flat Erosion (horz. m /yr)	0	0	0.06	0
Reg.-Flood Marsh Accr (mm/yr)	0	0	0	0
Irreg.-Flood Marsh Accr (mm/yr)	2.422	2.422	2.422	2.422
Tidal-Fresh Marsh Accr (mm/yr)	5	5	5	5
Inland-Fresh Marsh Accr (mm/yr)	1	1	1	1
Mangrove Accr (mm/yr)	0	0	0	0
Tidal Swamp Accr (mm/yr)	1.1	1.1	1.1	1.1
Swamp Accretion (mm/yr)	1.6	1.6	1.6	1.6
Beach Sed. Rate (mm/yr)	0.5	0.5	0.5	0.5
Freq. Overwash (years)	0	0	0	0
Use Elev Pre-processor [True,False]	FALSE	FALSE	FALSE	FALSE
Reg Flood Use Model [True,False]	TRUE	TRUE	TRUE	TRUE
Reg Flood Max. Accr. (mm/year)	5.8474	5.8474	5.8474	5.8474
Reg Flood Min. Accr. (mm/year)	0.6378	0.6378	0.6378	0.6378
Reg Flood Elev a (mm/(year HTU^3))	-0.0304	-0.0304	-0.0304	-0.0304
Reg Flood Elev b (mm/(year HTU^2))	-3.015	-3.015	-3.015	-3.015
Reg Flood Elev c (mm/(year*HTU))	-0.6502	-0.6502	-0.6502	-0.6502
Reg Flood Elev d (mm/year)	5.8123	5.8123	5.8123	5.8123

Table 58. Area 2 Input Parameters (partial)

Subsite	General Area 2	1	2	3	4	5
Description		CT river	Guilford	Housatonic	Hammock River	HVN airport
NWI Photo Date (YYYY)	2010	2010	2010	2010	2010	2010
DEM Date (YYYY)	2012	2012	2012	2012	2012	2012
Direction Offshore [n,s,e,w]	South	South	South	South	South	South
Historic Trend (mm/yr)	0	0	0	0	0	0
Historic Eustatic Trend (mm/yr)	0	0	0	0	0	0
MTL-NAVD88 (m)	0	0	0	0	0	0
GT Great Diurnal Tide (m)	2.1	1.1	1.67	2.2	1	1
Salt Elev. (m above MTL)	1.1	0.94	1	1.6	0.5	0.5
Marsh Erosion (horz. m /yr)	0	0	0.08	0	0.08	0
Swamp Erosion (horz. m /yr)	0	0	0.08	0	0.08	0
T.Flat Erosion (horz. m /yr)	0	0	0.08	0	0.08	0
Reg.-Flood Marsh Accr (mm/yr)	0	0	0	0	0	0
Irreg.-Flood Marsh Accr (mm/yr)	2.422	2.422	2.422	2.422	2.422	2.422
Tidal-Fresh Marsh Accr (mm/yr)	5	5	5	5	5	5
Inland-Fresh Marsh Accr (mm/yr)	1	1	1	1	1	1
Mangrove Accr (mm/yr)	0	0	0	0	0	0
Tidal Swamp Accr (mm/yr)	1.1	1.1	1.1	1.1	1.1	1.1
Swamp Accretion (mm/yr)	1.6	1.6	1.6	1.6	1.6	1.6
Beach Sed. Rate (mm/yr)	0.5	0.5	0.5	0.5	0.5	0.5
Freq. Overwash (years)	0	0	0	0	0	0
Use Elev Pre-processor	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
Reg Flood Use Model	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Reg Flood Max. Accr. (mm/year)	8.7271	8.7271	8.7271	8.7271	8.7271	8.7271
Reg Flood Min. Accr. (mm/year)	0.2791	0.2791	0.2791	0.2791	0.2791	0.2791
Reg Flood Elev a	0.9191	0.9191	0.9191	0.9191	0.9191	0.9191
Reg Flood Elev b	-5.4485	-5.4485	-5.4485	-5.4485	-5.4485	-5.4485
Reg Flood Elev c (mm/(year*HTU))	-1.7157	-1.7157	-1.7157	-1.7157	-1.7157	-1.7157
Reg Flood Elev d (mm/year)	8.5954	8.5954	8.5954	8.5954	8.5954	8.5954

Table 59. Area 2 Input Parameters, continued, and Area 3 Input Parameters

Subsite	Area 2, Site 6	Area 2, Site 7	Area 3, General	Area 3, Site 1	Area 3, Site 2
Parameter Description	**Sybil Creek**	**Muted Tide**		**CT river**	**Erosion zone - Stonington**
NWI Photo Date (YYYY)	2010	2010	2010	2010	2010
DEM Date (YYYY)	2012	2012	2012	2012	2012
Direction Offshore [n,s,e,w]	South	South	South	South	South
Historic Trend (mm/yr)	0	0	0	0	0
Historic Eustatic Trend (mm/yr)	0	0	0	0	0
MTL-NAVD88 (m)	0	0	0	0	0
GT Great Diurnal Tide Range (m)	0.5	0.88	0.92	1.1	0.92
Salt Elev. (m above MTL)	0.35	0.7	0.84	0.94	0.84
Marsh Erosion (horz. m /yr)	0	0	0	0.12	0.02
Swamp Erosion (horz. m /yr)	0	0	0	0.12	0.02
T.Flat Erosion (horz. m /yr)	0	0	0	0.12	0.02
Reg.-Flood Marsh Accr (mm/yr)	0	0	0	0	0
Irreg.-Flood Marsh Accr (mm/yr)	2.422	2.422	2.422	2.422	2.422
Tidal-Fresh Marsh Accr (mm/yr)	5	5	5	5	5
Inland-Fresh Marsh Accr (mm/yr)	1	1	1	1	1
Mangrove Accr (mm/yr)	0	0	0	0	0
Tidal Swamp Accr (mm/yr)	1.1	1.1	1.1	1.1	1.1
Swamp Accretion (mm/yr)	1.6	1.6	1.6	1.6	1.6
Beach Sed. Rate (mm/yr)	0.5	0.5	0.5	0.5	0.5
Freq. Overwash (years)	0	0	0	0	0
Use Elev Pre-processor [True,False]	FALSE	FALSE	FALSE	FALSE	FALSE
Reg Flood Use Model [True,False]	TRUE	TRUE	TRUE	TRUE	TRUE
Reg Flood Max. Accr. (mm/year)	8.7271	8.7271	4.8859	4.8859	4.8859
Reg Flood Min. Accr. (mm/year)	0.2791	0.2791	0.1571	0.1571	0.1571
Reg Flood Elev a (mm/(year HTU^3))	0.9191	0.9191	-1.3211	-1.3211	-1.3211
Reg Flood Elev b (mm/(year HTU^2))	-5.4485	-5.4485	-3.0723	-3.0723	-3.0723
Reg Flood Elev c (mm/(year*HTU))	-1.7157	-1.7157	1.8588	1.8588	1.8588
Reg Flood Elev d (mm/year)	8.5954	8.5954	4.6335	4.6335	4.6335

Appendix D: Tables of Results by County

The following tables present results by county and SLR scenario run. Coastal areas with elevations less than 5 m are included in the SLAMM study area.

Table 60. Fairfield County, GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	124,204	123,925	123,871	123,724	123,248	123,050
	Estuarine Open Water	59,675	59,726	59,752	59,786	59,899	59,967
	Developed Dry Land	51,610	51,449	51,411	51,296	50,453	50,043
	Swamp	4,617	4,606	4,605	4,601	4,574	4,550
	Inland Open Water	3,555	3,524	3,519	3,516	3,490	3,475
	Irreg.-Flooded Marsh	1,292	1,160	1,144	1,112	986	872
	Estuarine Beach	940	927	923	905	839	800
	Inland-Fresh Marsh	357	350	349	346	314	313
	Regularly-Flooded Marsh	342	468	629	686	961	1,263
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	55	60	54	49
	Riverine Tidal	32	26	13	8	5	4
	Tidal-Fresh Marsh	26	24	24	24	22	22
	Tidal Swamp	22	21	21	21	20	19
	Rocky Intertidal	20	20	19	19	18	18
	Trans. Salt Marsh	13	307	209	327	703	733
	Flooded Developed Dry Land	0	161	199	314	1,157	1,567
	Total (incl. water)	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**

Table 61. Fairfield County, 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	124,204	123,925	123,870	123,529	122,898	122,557
	Estuarine Open Water	59,675	59,726	59,753	59,824	60,008	60,090
	Developed Dry Land	51,610	51,449	51,411	50,984	49,751	49,096
	Swamp	4,617	4,606	4,605	4,598	4,540	4,526
	Inland Open Water	3,555	3,524	3,519	3,514	3,473	3,466
	Irreg.-Flooded Marsh	1,292	1,160	1,143	1,041	601	300
	Estuarine Beach	940	927	923	878	771	715
	Inland-Fresh Marsh	357	350	349	341	312	308
	Regularly-Flooded Marsh	342	468	630	794	1,637	2,184
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	55	67	70	78
	Riverine Tidal	32	26	13	7	4	4
	Tidal-Fresh Marsh	26	24	24	22	18	15
	Tidal Swamp	22	21	21	20	18	17
	Rocky Intertidal	20	20	19	19	18	17
	Trans. Salt Marsh	13	307	210	481	766	856
	Flooded Developed Dry Land	0	161	200	626	1,859	2,514
	Total (incl. water)	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**

Table 62. Fairfield County, RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	124,204	123,925	123,871	123,450	122,490	122,077
	Estuarine Open Water	59,675	59,726	59,752	59,843	60,111	60,234
	Developed Dry Land	51,610	51,449	51,411	50,865	48,942	48,107
	Swamp	4,617	4,606	4,605	4,597	4,523	4,510
	Inland Open Water	3,555	3,524	3,519	3,512	3,466	3,459
	Irreg.-Flooded Marsh	1,292	1,160	1,144	1,009	224	109
	Estuarine Beach	940	927	923	864	700	620
	Inland-Fresh Marsh	357	350	349	339	308	302
	Regularly-Flooded Marsh	342	468	629	852	2,313	2,779
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	55	70	107	199
	Riverine Tidal	32	26	13	7	4	2
	Tidal-Fresh Marsh	26	24	24	22	13	10
	Tidal Swamp	22	21	21	20	17	14
	Rocky Intertidal	20	20	19	19	17	16
	Trans. Salt Marsh	13	307	209	530	842	804
	Flooded Developed Dry Land	0	161	199	745	2,669	3,503
	Total (incl. water)	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**

Table 63 Fairfield County; RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Undeveloped Dry Land	124,204	123,925	123,807	123,067	122,030	121,652
	Estuarine Open Water	59,675	59,726	59,766	59,954	60,266	60,471
	Developed Dry Land	51,610	51,449	51,364	50,082	48,023	47,214
	Swamp	4,617	4,606	4,602	4,544	4,508	4,500
	Inland Open Water	3,555	3,524	3,517	3,489	3,459	3,449
	Irreg.-Flooded Marsh	1,292	1,160	1,117	678	92	46
	Estuarine Beach	940	927	915	799	609	529
	Inland-Fresh Marsh	357	350	348	313	302	302
	Regularly-Flooded Marsh	342	468	675	1,363	2,770	2,993
	Inland Shore	119	119	119	119	119	119
	Tidal Flat	38	49	61	94	276	531
	Riverine Tidal	32	26	11	5	2	2
	Tidal-Fresh Marsh	26	24	23	17	8	6
	Tidal Swamp	22	21	21	19	14	13
	Rocky Intertidal	20	20	19	18	16	12
	Trans. Salt Marsh	13	307	253	775	780	628
	Flooded Developed Dry Land	0	161	247	1,528	3,587	4,397
	Total (incl. water)	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**	**246,864**

Table 64. New Haven County, GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	139,226	139,264	139,378	139,483	139,688	139,804
	Undeveloped Dry Land	27,636	27,315	27,258	27,104	26,753	26,565
	Developed Dry Land	24,650	24,550	24,531	24,470	24,327	24,214
	Irreg.-Flooded Marsh	4,554	4,112	4,026	3,808	3,093	2,412
	Swamp	1,720	1,685	1,678	1,663	1,625	1,605
	Estuarine Beach	1,040	1,041	1,022	960	820	748
	Regularly-Flooded Marsh	692	1,131	1,517	1,856	2,866	3,764
	Inland Open Water	537	531	510	510	503	495
	Inland-Fresh Marsh	277	261	256	246	221	215
	Riverine Tidal	207	186	122	111	101	93
	Tidal-Fresh Marsh	115	115	115	115	114	113
	Tidal Swamp	74	66	65	62	53	50
	Tidal Flat	71	100	124	120	80	57
	Rocky Intertidal	49	46	45	41	37	36
	Trans. Salt Marsh	47	391	128	165	292	290
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	99	119	179	323	436
	Total (incl. water)	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**

Table 65. New Haven County, 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	139,226	139,264	139,379	139,573	139,875	140,010
	Undeveloped Dry Land	27,636	27,315	27,257	26,969	26,425	26,128
	Developed Dry Land	24,650	24,550	24,530	24,416	24,107	23,863
	Irreg.-Flooded Marsh	4,554	4,112	4,024	3,456	1,252	589
	Swamp	1,720	1,685	1,678	1,644	1,583	1,546
	Estuarine Beach	1,040	1,041	1,022	900	704	617
	Regularly-Flooded Marsh	692	1,131	1,520	2,298	4,968	5,911
	Inland Open Water	537	531	510	506	491	480
	Inland-Fresh Marsh	277	261	256	228	203	172
	Riverine Tidal	207	186	122	104	93	91
	Tidal-Fresh Marsh	115	115	115	114	112	110
	Tidal Swamp	74	66	65	57	44	32
	Tidal Flat	71	100	124	115	92	131
	Rocky Intertidal	49	46	45	39	35	33
	Trans. Salt Marsh	47	391	129	243	370	396
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	99	120	233	543	786
	Total (incl. water)	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**

Table 66. New Haven County, RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	139,226	139,264	139,378	139,611	140,095	140,365
	Undeveloped Dry Land	27,636	27,315	27,258	26,908	26,067	25,627
	Developed Dry Land	24,650	24,550	24,531	24,392	23,799	23,363
	Irreg.-Flooded Marsh	4,554	4,112	4,026	3,244	467	241
	Swamp	1,720	1,685	1,678	1,633	1,534	1,486
	Estuarine Beach	1,040	1,041	1,022	873	586	437
	Regularly-Flooded Marsh	692	1,131	1,517	2,534	5,846	6,438
	Inland Open Water	537	531	510	505	480	469
	Inland-Fresh Marsh	277	261	256	225	166	149
	Riverine Tidal	207	186	122	103	92	86
	Tidal-Fresh Marsh	115	115	115	113	107	97
	Tidal Swamp	74	66	65	55	30	21
	Tidal Flat	71	100	124	122	198	282
	Rocky Intertidal	49	46	45	38	32	25
	Trans. Salt Marsh	47	391	128	281	545	523
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	99	119	257	851	1,287
	Total (incl. water)	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**

Table 67 New Haven County; RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	139,226	139,264	139,415	139,787	140,448	140,768
	Undeveloped Dry Land	27,636	27,315	27,191	26,600	25,586	25,040
	Developed Dry Land	24,650	24,550	24,507	24,243	23,321	22,595
	Irreg.-Flooded Marsh	4,554	4,112	3,859	1,603	216	132
	Swamp	1,720	1,685	1,669	1,597	1,476	1,390
	Estuarine Beach	1,040	1,041	996	758	425	327
	Regularly-Flooded Marsh	692	1,131	1,696	4,262	6,217	6,149
	Inland Open Water	537	531	510	495	469	457
	Inland-Fresh Marsh	277	261	252	214	147	128
	Riverine Tidal	207	186	122	103	86	79
	Tidal-Fresh Marsh	115	115	114	111	89	62
	Tidal Swamp	74	66	64	49	20	12
	Tidal Flat	71	100	129	213	439	1,019
	Rocky Intertidal	49	46	43	36	24	21
	Trans. Salt Marsh	47	391	185	416	601	664
	Inland Shore	1	1	1	1	1	1
	Flooded Developed Dry Land	0	99	143	407	1,329	2,055
	Total (incl. water)	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**	**200,896**

Table 68. Middlesex County, GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	37,005	37,071	37,325	37,421	37,521	37,549
	Undeveloped Dry Land	21,262	21,075	21,036	20,932	20,752	20,661
	Developed Dry Land	4,990	4,970	4,961	4,931	4,858	4,815
	Irreg.-Flooded Marsh	2,401	2,241	2,218	2,149	1,604	1,059
	Swamp	1,267	1,265	1,262	1,256	1,250	1,248
	Inland Open Water	442	442	441	441	441	441
	Riverine Tidal	321	286	66	47	36	30
	Tidal-Fresh Marsh	292	261	260	256	238	230
	Estuarine Beach	277	247	218	169	123	106
	Tidal Swamp	198	190	186	172	119	93
	Inland-Fresh Marsh	92	88	87	85	82	81
	Regularly-Flooded Marsh	30	205	301	430	1,187	1,854
	Trans. Salt Marsh	9	201	139	194	239	245
	Tidal Flat	3	28	60	49	7	3
	Flooded Developed Dry Land	0	21	30	59	132	176
	Total (incl. water)	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**

Table 69. Middlesex County, 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	37,005	37,071	37,326	37,472	37,580	37,637
	Undeveloped Dry Land	21,262	21,075	21,036	20,852	20,593	20,458
	Developed Dry Land	4,990	4,970	4,960	4,902	4,781	4,712
	Irreg.-Flooded Marsh	2,401	2,241	2,217	1,888	409	161
	Swamp	1,267	1,265	1,262	1,253	1,245	1,242
	Inland Open Water	442	442	441	441	440	440
	Riverine Tidal	321	286	66	43	30	20
	Tidal-Fresh Marsh	292	261	260	239	201	168
	Estuarine Beach	277	247	217	149	99	86
	Tidal Swamp	198	190	186	150	77	59
	Inland-Fresh Marsh	92	88	87	83	80	79
	Regularly-Flooded Marsh	30	205	302	785	2,552	2,952
	Trans. Salt Marsh	9	201	139	211	241	242
	Tidal Flat	3	28	60	34	52	55
	Flooded Developed Dry Land	0	21	30	88	209	279
	Total (incl. water)	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**

Table 70. Middlesex County, RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	37,005	37,071	37,325	37,494	37,669	37,814
	Undeveloped Dry Land	21,262	21,075	21,036	20,817	20,430	20,221
	Developed Dry Land	4,990	4,970	4,961	4,888	4,696	4,570
	Irreg.-Flooded Marsh	2,401	2,241	2,218	1,721	124	52
	Swamp	1,267	1,265	1,262	1,251	1,241	1,219
	Inland Open Water	442	442	441	441	440	438
	Riverine Tidal	321	286	66	42	21	16
	Tidal-Fresh Marsh	292	261	260	232	136	63
	Estuarine Beach	277	247	218	140	85	71
	Tidal Swamp	198	190	186	137	53	38
	Inland-Fresh Marsh	92	88	87	82	79	78
	Regularly-Flooded Marsh	30	205	301	983	2,877	2,638
	Trans. Salt Marsh	9	201	139	218	252	280
	Tidal Flat	3	28	60	43	192	673
	Flooded Developed Dry Land	0	21	30	102	294	421
	Total (incl. water)	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**

Table 71 Middlesex County; RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	37,005	37,071	37,354	37,571	37,973	38,812
	Undeveloped Dry Land	21,262	21,075	20,988	20,679	20,203	19,974
	Developed Dry Land	4,990	4,970	4,948	4,824	4,559	4,405
	Irreg.-Flooded Marsh	2,401	2,241	2,173	575	48	27
	Swamp	1,267	1,265	1,258	1,247	1,217	1,180
	Inland Open Water	442	442	441	441	438	437
	Riverine Tidal	321	286	65	37	16	11
	Tidal-Fresh Marsh	292	261	248	190	45	20
	Estuarine Beach	277	247	192	112	71	58
	Tidal Swamp	198	190	179	89	36	27
	Inland-Fresh Marsh	92	88	86	81	78	76
	Regularly-Flooded Marsh	30	205	374	2,241	2,248	1,317
	Trans. Salt Marsh	9	201	169	229	295	301
	Tidal Flat	3	28	72	109	933	1,361
	Flooded Developed Dry Land	0	21	43	166	431	586
	Total (incl. water)	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**	**68,590**

Table 72. New London County, GCM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	55,657	55,694	55,860	55,936	56,041	56,082
	Undeveloped Dry Land	32,773	32,276	32,194	31,984	31,580	31,379
	Developed Dry Land	11,108	11,037	11,022	10,973	10,833	10,747
	Irreg.-Flooded Marsh	2,970	2,789	2,755	2,640	1,548	796
	Swamp	1,266	1,254	1,244	1,229	1,196	1,183
	Tidal Swamp	377	361	353	333	248	207
	Tidal-Fresh Marsh	330	326	326	324	310	300
	Inland Open Water	305	304	302	301	291	288
	Riverine Tidal	251	236	80	63	54	51
	Estuarine Beach	217	209	207	203	193	186
	Inland-Fresh Marsh	139	136	135	131	117	115
	Regularly-Flooded Marsh	118	311	513	671	2,050	3,038
	Trans. Salt Marsh	88	595	463	606	807	801
	Tidal Flat	10	12	71	79	68	78
	Rocky Intertidal	9	9	9	8	8	7
	Flooded Developed Dry Land	0	71	86	136	275	361
	Total (incl. water)	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**

Table 73. New London County, 1m by 2100 (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	55,657	55,694	55,860	55,990	56,137	56,240
	Undeveloped Dry Land	32,773	32,276	32,192	31,798	31,239	30,901
	Developed Dry Land	11,108	11,037	11,022	10,918	10,683	10,489
	Irreg.-Flooded Marsh	2,970	2,789	2,754	2,177	395	203
	Swamp	1,266	1,254	1,244	1,206	1,174	1,132
	Tidal Swamp	377	361	353	298	182	148
	Tidal-Fresh Marsh	330	326	326	310	260	232
	Inland Open Water	305	304	302	297	284	278
	Riverine Tidal	251	236	80	60	50	44
	Estuarine Beach	217	209	207	199	181	169
	Inland-Fresh Marsh	139	136	135	123	114	103
	Regularly-Flooded Marsh	118	311	515	1,258	3,596	3,821
	Trans. Salt Marsh	88	595	464	697	729	807
	Tidal Flat	10	12	71	89	163	426
	Rocky Intertidal	9	9	9	8	7	7
	Flooded Developed Dry Land	0	71	86	190	425	619
	Total (incl. water)	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**

Table 74. New London County, RIM Min (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	55,657	55,694	55,860	56,010	56,333	57,541
	Undeveloped Dry Land	32,773	32,276	32,194	31,722	30,829	30,300
	Developed Dry Land	11,108	11,037	11,022	10,890	10,447	10,114
	Irreg.-Flooded Marsh	2,970	2,789	2,755	1,800	180	99
	Swamp	1,266	1,254	1,244	1,202	1,124	1,076
	Tidal Swamp	377	361	353	277	138	103
	Tidal-Fresh Marsh	330	326	326	301	204	104
	Inland Open Water	305	304	302	297	278	258
	Riverine Tidal	251	236	80	58	45	38
	Estuarine Beach	217	209	207	197	166	144
	Inland-Fresh Marsh	139	136	135	121	102	96
	Regularly-Flooded Marsh	118	311	513	1,702	3,051	1,976
	Trans. Salt Marsh	88	595	463	714	775	813
	Tidal Flat	10	12	71	101	1,281	1,958
	Rocky Intertidal	9	9	9	8	6	6
	Flooded Developed Dry Land	0	71	86	218	661	995
	Total (incl. water)	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**

Table 75 New London County; RIM Max (Acres)

		Initial	2010	2025	2055	2085	2100
	Estuarine Open Water	55,657	55,694	55,864	56,124	57,786	59,861
	Undeveloped Dry Land	32,773	32,276	32,103	31,416	30,251	29,750
	Developed Dry Land	11,108	11,037	11,005	10,765	10,077	9,735
	Irreg.-Flooded Marsh	2,970	2,789	2,686	523	95	61
	Swamp	1,266	1,254	1,235	1,182	1,058	1,026
	Tidal Swamp	377	361	342	200	99	74
	Tidal-Fresh Marsh	330	326	320	251	64	30
	Inland Open Water	305	304	302	288	258	254
	Riverine Tidal	251	236	79	53	38	32
	Estuarine Beach	217	209	206	186	141	114
	Inland-Fresh Marsh	139	136	134	115	96	94
	Regularly-Flooded Marsh	118	311	643	3,301	1,726	1,584
	Trans. Salt Marsh	88	595	500	674	835	707
	Tidal Flat	10	12	90	190	2,058	919
	Rocky Intertidal	9	9	9	8	6	5
	Flooded Developed Dry Land	0	71	103	344	1,031	1,373
	Total (incl. water)	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**	**105,619**