Sea Level Rise and Casco Bay's Wetlands:

A Look at Potential Impacts

FALMOUTH EDITION

Casco Bay Estuary PARTNERSHIP

Muskie School of Public Service · University of Southern Maine · www.cascobayestuary.org
PO Box 9300 · Portland, ME 04104-9300 · 207.780.4820 (phone) · 207.228.8460 (fax)

Sea Level Rise and Casco Bay's Wetlands:

A Look at Potential Impacts

• Curtis Bohlen • Marla Stelk • Matthew Craig • Caitlin Gerber

This report is one of a series of ten reports focusing on the following Casco Bay municipalities:

Brunswick	Phippsburg
Cape Elizabeth	Portland
Falmouth	South Portland
Freeport	West Bath
Harpswell	Yarmouth

Assistance with field work and other data collection provided by Melissa Anson and Melissa Smith.
GIS analysis provided by Lauren Redmond and Caitlin Gerber.

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Casco Bay Estuary Partnership 2013

Overview

The Intergovernmental Panel on Climate Change (IPCC) released a report in 2007 documenting a rise in average global temperatures, ocean temperatures and sea level rise. The sea level off Maine's 3,478 miles of coastline, as measured by the Portland, Maine tide gauge, has been rising at a rate of 1.8 ± 0.1mm/yr since 1912. This is markedly similar to the global average sea level rise determined by the IPCC. The most likely impacts of sea level rise in Maine will be inland migration of beaches, dunes and salt marshes over the next century.

Coastal wetlands are economically, environmentally and socially significant resources. They provide flood storage, flood protection, storm surge buffers, erosion control, water quality improvements, and wildlife habitat. Commercial fishing, shellfishing and outdoor recreation also contribute millions of dollars to Maine's economy and are dependent on healthy wetlands. Coastal communities and those along critical watershed areas will have to plan a comprehensive response to the changes in topography suggested by the projected impacts of sea level rise.

The unique geological make-up of Maine's coastline is characterized by very different coastal estuarine environments which are a direct result of prehistoric glacial activity. This led geologists such as Joseph T. Kelley, to subdivide Maine's coastline into four distinct sub-regions approximately corresponding to Casco Bay, Saco Bay, Penobscot Bay, and the northeast region around Cobscook Bay. Consequently, Maine's tidal wetlands are diverse, and the impacts to, and responses of, those wetlands to sea level rise are likely to be markedly different in each of those four regions.

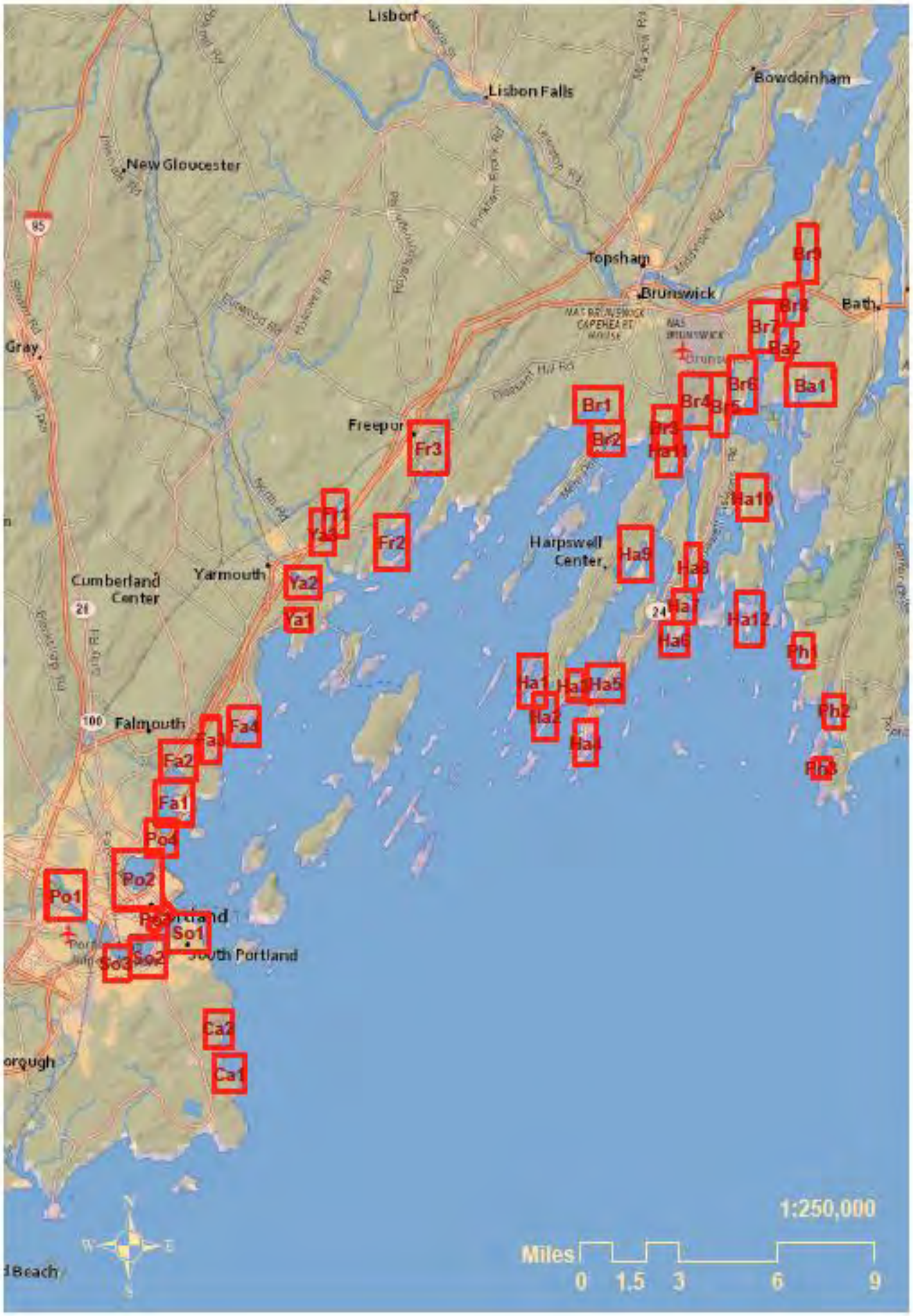
The Casco Bay Watershed comprises 986 square miles of land and stretches from the mountains near Bethel to the coastal waters between Small Point in Phippsburg and Dyer Point in Cape Elizabeth. Home to nearly 20 percent of Maine's population, the watershed contains 44 municipalities, including some of the state's largest and fastest growing towns. The Casco Bay Estuary Partnership (CBEP), one of 28 National Estuary Programs nationwide, is a collaborative effort of people and organizations interested in protecting and restoring the Bay. Our partnership includes local, state and federal government organizations, non-profits, local businesses, citizens, universities and more.

The Study

CBEP looked at ten of the fourteen municipalities that line Casco Bay to identify potential areas of marsh migration and possible impacts to existing developed areas due to tidal inundation from sea level rise. Figure 1 shows focus areas across the study area.

FIGURE 1

Casco Bay Focus Areas



Falmouth, Maine

This report is designed to help municipal staff and decision makers understand risk levels and potential impacts associated with sea level rise, and to provide science-based projections to inform future policy-making responses. The U.S. Environmental Protection Agency (EPA) produced a publication titled *Synthesis of Adaptation Options for Coastal Areas* in January, 2009 which identifies several planning and management options for coastal communities.

The maps display places where roads, railroads, trails, dams, and other structures cross tidal wetlands. In most cases, these structures alter the way that water is passed from one side of the wetland to the other. When tidal exchange is restricted, even if it is restricted only during astronomical spring tides, long-term impacts to wetlands can develop that reduce ecosystem resiliency to respond to impacts such as sea level rise. Tidal restrictions also increase velocities in the creek channels, creating scour that may undermine structural integrity over time. Under the sea level rise scenarios illustrated in these maps, the impacts of roads and other crossings on wetland resiliency will only increase. At the same time, creek channel dimensions can be expected to grow significantly. As a result, one of the most effective adaptations steps that towns can take to protect existing infrastructure and allow for wetland migration is to increase the size of culverts beneath existing roads. Such sites are attractive opportunities to the habitat restoration funding community, and removal of existing tidal restrictions is a high priority for the Casco Bay Estuary Partnership. If your town is interested in exploring culvert replacement or removal projects and would like technical or grant writing assistance, contact CBEP staff for information on structural options, federal and state contacts, and funding opportunities.

In Falmouth, we have identified four primary areas as either being at risk of conflict between rising seas and existing developed areas, and/or areas where we see potential marsh migration (Figure 2).

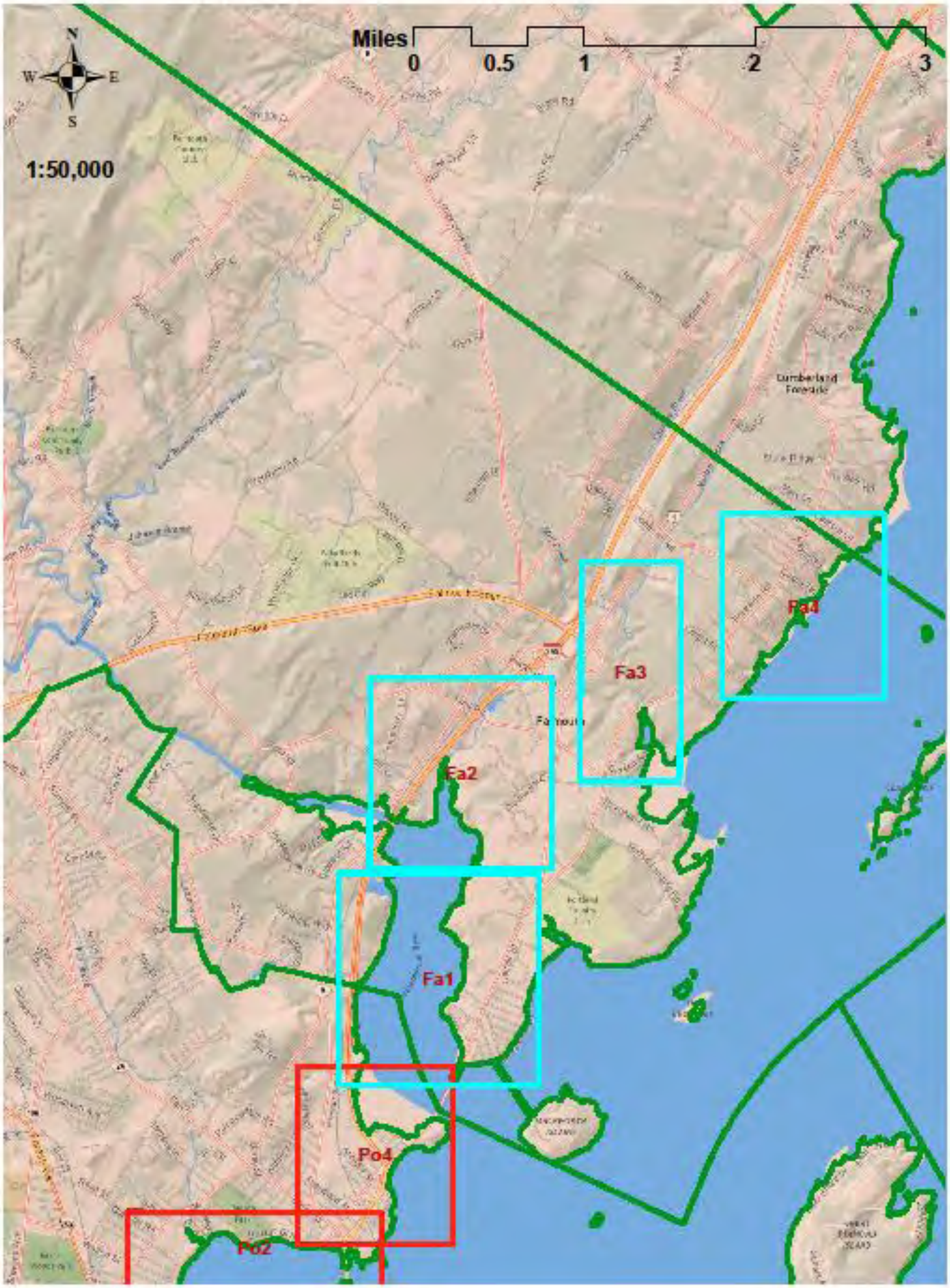
These areas are identified as:

Lower Presumpscot Estuary
Upper Presumpscot Estuary
Mussel Cove
Falmouth Foreside

Two maps were produced for each of the areas above. The maps show existing infrastructure such as roads and dams, as well as existing wetlands (blue), then show how these resources are likely to be impacted by a 1’ and then a 3’ rise in sea level. Projected impacts are displayed as lost wetlands (yellow), and conflicts between existing infrastructure and sea level rise are shown in pink. Projected new wetlands are shown in orange.

FIGURE 2

Falmouth Focus Areas



As mentioned previously, caution must be taken when interpreting these maps because some of the areas may or may not pose any serious future risk for tidal inundation. Local knowledge of these areas will be necessary to more accurately gauge whether or not they are areas of concern for Falmouth according to current or future development plans, comprehensive plans, or conservation plans. Some areas may pose concern with regard to existing or future infrastructure, and other areas may see more significant changes with regard to wetland type and, subsequently, habitat.

Fa1: Lower Presumpscot Estuary

Figures 3 and 4 show projected sea level rise impacts on tidal wetlands and developed areas in the lower Presumpscot Estuary and along the shores of Mackworth Point. Figure 4 shows minor amounts of potential marsh migration and loss occurring at the one-foot sea level rise projection. However, Figure 4 shows a more significant degree of marsh migration. Under a 3' increase in sea level, the analysis projects conflict with existing development around Foreside Commons, Kelley Road and Greenway Drive as well as between Hammond Road and Winslow Road, and between Brown Street and Carroll Street. A dam at the site of the Portland Country Club will limit migration of tidal wetlands into the golf course, but this structure could be impacted by rising seas, in part due to the loss of existing wetlands along the immediate shoreline due to inundation.

Fa2: Upper Presumpscot Estuary

Figures 5 and 6 show projected sea level rise impacts on tidal wetlands and developed areas in the upper Presumpscot Estuary. Exposed fringing wetlands adjacent to the estuary may begin to disappear under the surface of rising sea levels at 1', and even more so at 3'. If seas rise by 3', the projection shows that elevations are suitable in several areas for the formation of new wetlands as marsh migrates inland. The result may be a zero net gain or loss of wetlands as they migrate inward. Due to the significant amount of existing development around the estuary, several low lying areas shown in Figure 6 are at risk from tidal inundation with a 3-foot rise in sea level, including the wastewater treatment plant outfall. In particular, the area between Foreside Estates, Providence Avenue and Route 88 as well as the area around Farm Gate Road and Heron Point Road are at risk from tidal inundation. The presence of several restrictions to tidal exchange, particularly where Lunt Road crosses a tidal creek (43.723718,-70.24131), and along the old ice ponds, could inhibit new wetland formation in response to sea level rise.

Fa3: Mussel Cove

Figures 7 and 8 show projected sea level rise impacts on tidal wetlands and developed areas in the vicinity of Mussel Cove. The impacts of sea level rise in this area are likely to be complicated by the presence of road crossings that may currently restrict tidal exchange between Foreside Road and to a lesser degree, if at all, US Route 1. Most of this wetland system is surrounded by the Falmouth Forest Preserve and does not appear to pose any conflicts with existing infrastructure and development if sea level rises by 1'. However, a 1' increase in sea level could result in almost total loss of the existing tidal wetlands downstream of Foreside Road, at the head of Mussel Cove. Elevations adjacent to the existing creek near Route 1 are suitable for patches of new wetland to form as marshes migrate inland. If sea level rises by 3', elevations are suitable for substantial new pockets of wetland to form in the vicinity of US Route 1 and Interstate 295. Low-lying areas adjacent to Route 1 could be impacted by a 3' increase in sea level. Again, ultimately, the effects of sea level rise will depend in part on the degree to which Foreside Road, and to a lesser degree Route 1, restrict tidal exchange.

Fa4: Falmouth Foreside

Figures 9 and 10 show projected sea level rise impacts on tidal wetlands and developed areas along Falmouth Foreside. The steep shoreline in this area will likely limit both the impacts from sea level rise, although erosion is likely to be a problem along the immediate shoreline. Elevations are generally not suitable for marsh migration. The maps highlight that two low-lying areas are vulnerable to impacts from sea level rise, particularly if sea level rises by 3': the wharf and buildings adjacent to the Falmouth Sea Grill, and the Falmouth Town Landing. Although some impacts are projected at 1', under a 3' increase, impacts are projected to expand toward waterfront homes on Burgess Street, Mason Street and Studley Street.

FIGURE 3: Fa1 **Foreside Road & Route 1 Area: 1 ft Sea Level Rise**

FIGURE 4: Fa1 **Foreside Road & Route 1 Area: 3 ft Sea Level Rise**

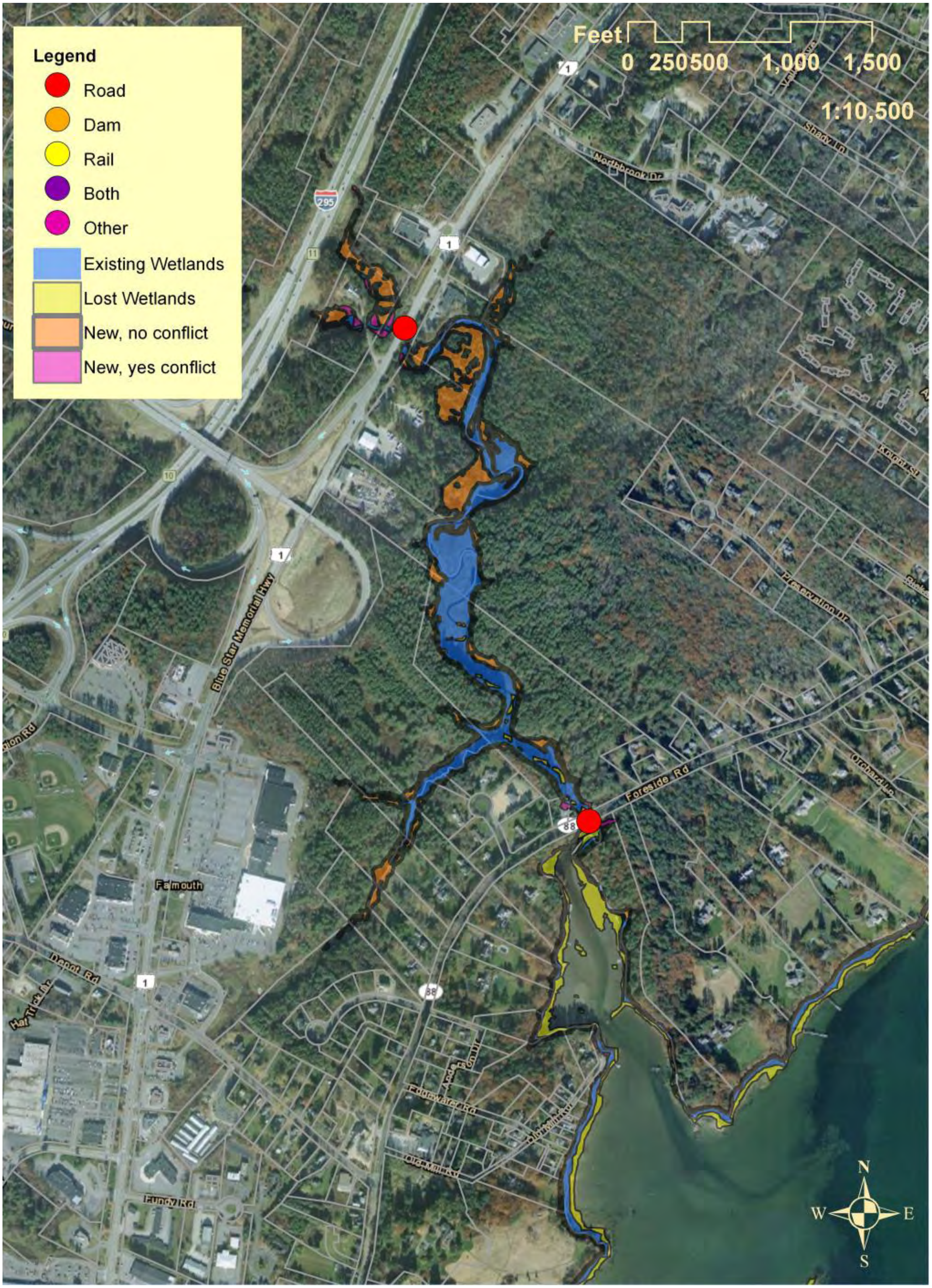


FIGURE 5: Fa2 **Upper Presumpscot River Area: 1 ft Sea Level Rise**

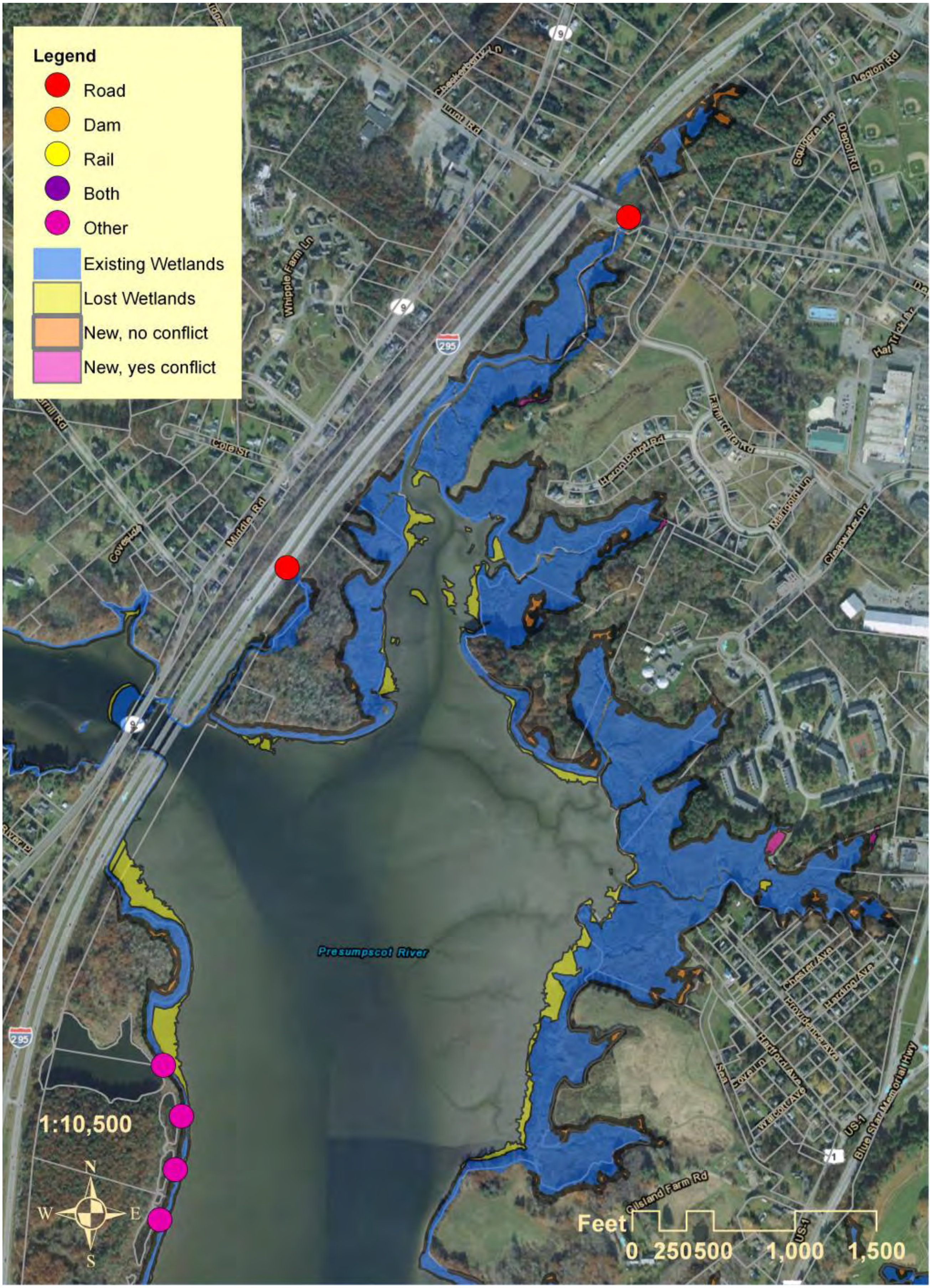


FIGURE 6: Fa2 **Upper Presumpscot River Area: 3 ft Sea Level Rise**

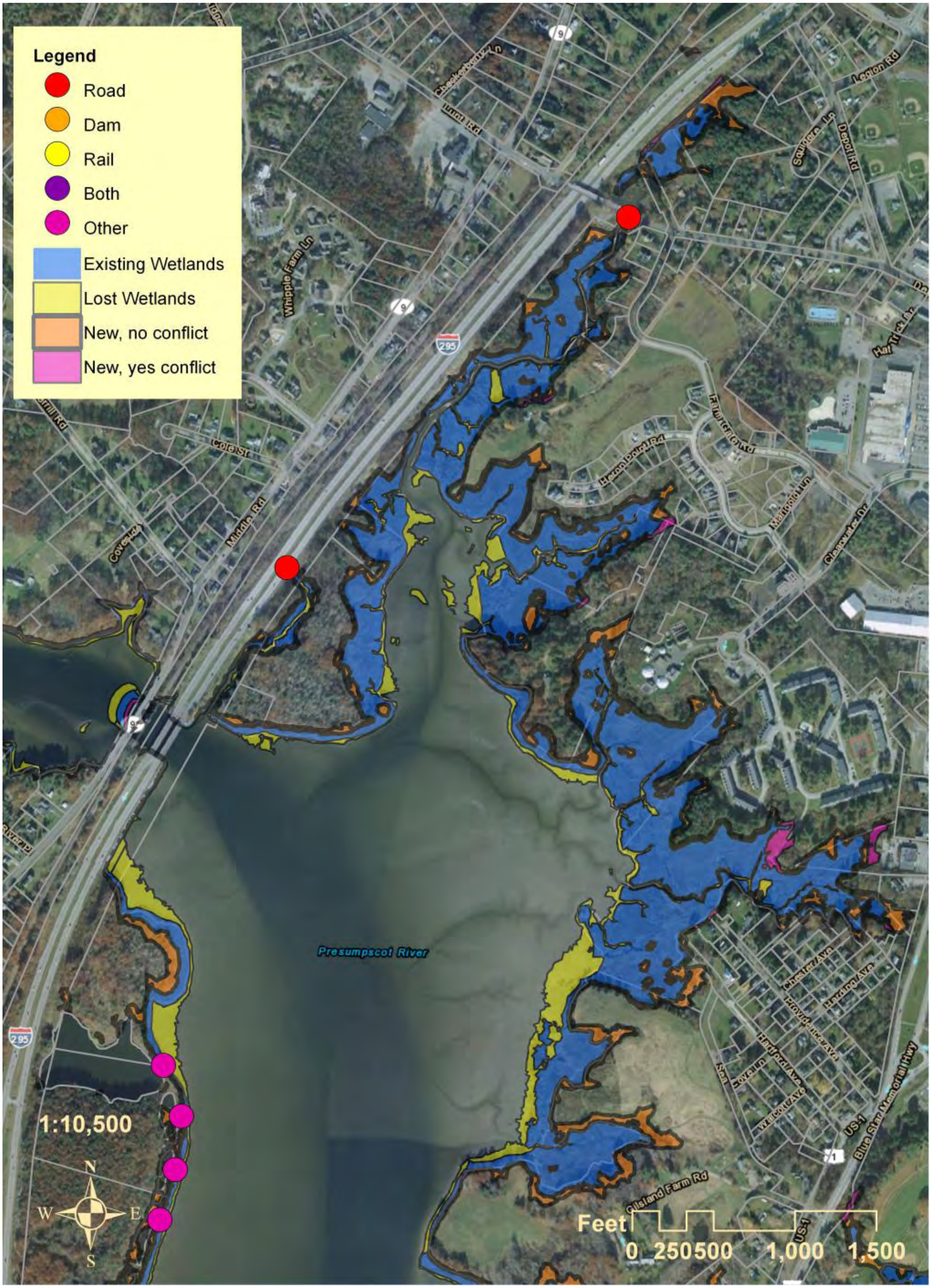


FIGURE 7: Fa3 Lower Presumpscot River Area: 1 ft Sea Level Rise

FIGURE 8: Fa3 Lower Presumpscot River Area: 3 ft Sea Level Rise

FIGURE 9: Fa4

The Boathouse Area: 1 ft Sea Level Rise

FIGURE 10: Fa4

The Boathouse Area: 3 ft Sea Level Rise

Suggested Uses of this Information:

The next logical questions after reviewing your town's report might be to ask "how do we use this information?" and "what can we do about the predicted effects of sea level rise on our coastal marshes?" As stand-alone information, your town's maps can provide the basis for starting community discussions on the potential impacts of sea level rise. These maps can be used in conjunction with current planning processes or documents in your town, such as municipal and Shoreland zoning, your comprehensive plan, open space plan, or capital improvement plan, and related ordinances such as your floodplain ordinance, to begin to develop adaptation strategies that would work best in your community in order to preserve and protect what is important to your community and reduce costs resulting from increasing levels and frequency of inundation. The following actions and questions can help your town begin to integrate this information into your community discussions and local decision-making:

- Review the maps to identify those areas where coastal marshes will try to migrate landward;

- Determine if there are obstacles to that happening. If not, who owns those lands? How might they be managed to allow marsh migration to occur in undeveloped areas? Are these areas part of the town's future investment and development strategies? If there is already development in those places, what stands in the way of marsh migration? Roads or other infrastructure? How vulnerable might that infrastructure be?

- If your town has zoning, how are those areas zoned now? Is that appropriate in light of the predicted effects of sea level rise?

The Maine Coastal Program, Maine Geological Survey and the Municipal Planning Assistance Program, all at the Maine Department of Agriculture, Conservation and Forestry, have been working with regional councils, communities and regions along the Maine coast to address these questions and develop local responses. Because the impacts are unique in each community, responses will be as well. To date, municipal responses that might be transferable to your community have included: changes to freeboard required in the flood plain ordinance; strategic conservation actions to ensure that marshes can migrate; adoption of Highest Annual Tide elevation from the LiDAR data into the Shoreland Zoning Ordinance; identification of tidal restrictions; and addition of sea level rise chapters into comprehensive plans. For more information on these or for help developing other adaptation strategies, contact your regional planning organization (Greater Portland Council of Governments or Midcoast Council of Governments) or the Municipal Planning Assistance Program at the Department of Agriculture, Conservation and Forestry.

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Appendix:

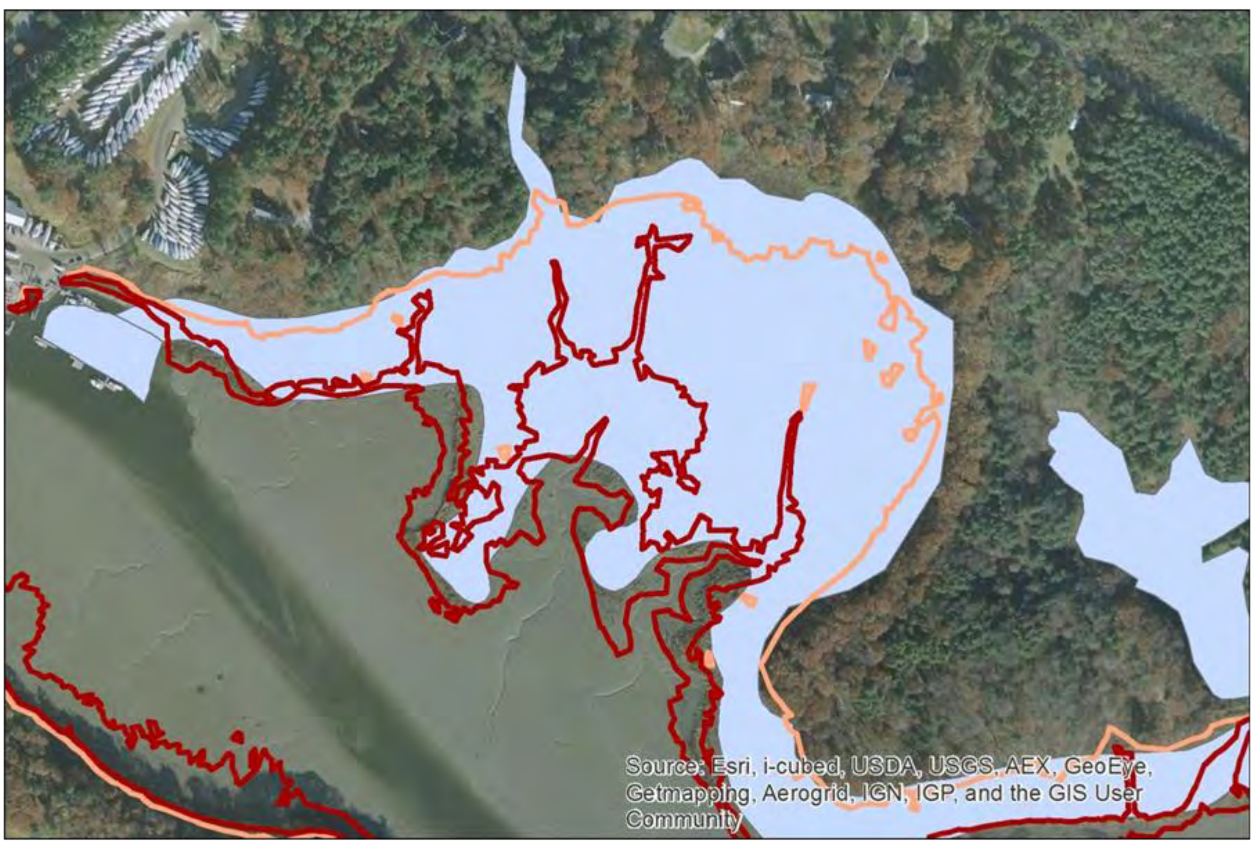
Methods:

The study is based on a detailed analysis of high resolution terrestrial elevations derived from "LIDAR" (Light Detection and Ranging) data. LIDAR is a technology similar to RADAR that uses light waves instead of radio waves to measure distance from a plane to the ground. Raw LIDAR data is post-processed to produce a "Digital Elevation Model" (DEM) that shows estimated ground elevations free of buildings, trees, and other obstructions. The resulting DEM can be highly accurate, with elevations estimated every few feet (horizontally), absolute vertical errors typically less than a foot, and relative vertical errors much smaller than that on a local scale.

Two sources of LIDAR data were used in this analysis: (1) FEMA South Coast LIDAR 2006, (2) LIDAR for the Northeast 2011. Both data sets were acquired as DEM tiles from the University of Southern Maine's Geographic Information Systems Laboratory in the spring of 2011. As received, the two data sets were based on different units of measure (feet vs. meters), so the LIDAR for the Northeast 2011 data set was scaled and resampled using bilinear interpolation before the two data sets were combined to produce a single composite LIDAR DEM for the study area.

LIDAR data was combined with information on tidal heights compiled by NOAA for the Portland tide gauge (station 8418150) in order to identify portions of the shoreline that lie within the upper intertidal zone (between the Mean Tide Level [MTL] and the Highest Annual Tide [HAT]). These elevations are roughly coincident with the lower (MTL) and upper (HAT) limit of tidal wetland development in Maine. Not every location between these elevations will develop tidal wetland. Tidal wetlands only occur where other environmental conditions are also suitable, such as having suitable soils, low slopes, and low to moderate wave exposure. Nevertheless, in areas with existing tidal wetland, the overlap between existing tidal wetland and areas identified solely on the basis of elevation is quite good. Figure 11 shows an overlay of CBEP's elevation polygons (outlined in red and orange as high and low marsh areas) compared to wetlands identified in the National Wetlands Inventory (light blue), for a Tidal wetland in Maine. The accuracy is sufficient for the purpose of this study.

FIGURE 11



It is important to note that the maps we have produced are not maps of flood risk, but maps of the projected upper intertidal zone. The areas highlighted in these maps are, in the absence of efforts to protect them from the ocean, expected to be flooded on a regular basis (ranging from daily to annually) due to the action of the tides. Significantly larger areas may be at risk of inundation or flooding due to storms. Because the maps we have produced to date are based solely on elevation, there may be areas in your community which show up as sitting at the proper elevation for tidal marsh development, but that do not now harbor salt marshes. Typically such areas are beaches, rocky shores, or the base of steep bluffs, so there is little chance for confusion, but the maps need to be read with this in mind.

To predict where the upper intertidal zone (and thus tidal wetlands) may exist in the future, we developed a pair of maps showing elevations suitable for tidal wetland development, one showing a 1' rise in sea level, and one a 3' rise in sea level. While these scenarios are hypothetical, they are consistent with climate change and sea level rise modeling efforts. A recent analysis of climate change for the Casco Bay region commissioned by CBEP suggests that an increase in sea level on the order of 1' is likely by the middle of this century, while increases of 2' to well over 3' are possible by 2100 (Table 1).

In general, Casco Bay's shoreline is characterized by steep rocky slopes, so we are more fortunate than our southern neighbors in that our coastline may not be as affected by tidal inundation. However, where we have mapped upper intertidal zone areas, we do see places where existing development (as determined by 2007 data on impervious surfaces) may be vulnerable to inundation in the future, or may be in conflict with landward migration of tidal wetlands as sea level increases.

TABLE 1:

Estimates of future stillwater elevations at the Portland tide gauge under lower and higher greenhouse gas emissions scenarios (all estimates in feet relative to NAVD 1988; based on CBEP 2010 report).

Scenario	Lower Emissions		Higher Emissions	
Year	2050	2100	2050	2100
Subsidence	0.024	0.043	0.024	0.043
Dynamic	NE	0.52	NE	0.79
Eustatic	0.66	1.6	1.4	4.6
Total Predicted Stillwater Elevation (ft)	9.5	11.1	10.3	14.3
Net Change in Sea Level	**0.6**	**2.2**	**1.4**	**5.4**