Maquoit Bay, Maine

Climate Change Adaptation Plan

Manomet Center for Conservation Sciences

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May 2013

Cover photograph courtesy Steve Walker

Contents

Maps

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This report is available for download at: http://www.manomet.org/climate_solutions/Maquoit_Bay.pdf


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Site Description and History

Maine's Maquoit Bay is part of an ecologically diverse estuarine complex located in northern Casco Bay and adjacent to two of Maine's most developed towns, Brunswick (pop. 20,000) and Freeport (pop. 8,000) (Map 1). Because of its unique coastal bays and estuaries, the area has high ecological value making it one of the State's Focus Areas of Statewide Ecological Significance.[1] The Bay is known for some of the region's most productive intertidal mud flats and large expanses of eelgrass meadows and saltmarsh (Maps 2 and 3). These systems contain state significant wildlife habitat areas for migratory birds and waterfowl, fish, invertebrates and other wildlife, including commercially important fish and shellfish.[2]

Historically, land use here was once dominated by large lot upland farms to the west, salt hay farming to the north, and seasonal camps on small lots extending down the east side of the Bay to Merepoint Peninsula. Recent years have seen growing development pressure with residential home development and redevelopment of the seasonal camps to year-round homes, particularly to the northeast and down the Peninsula. Efforts by several conservation organizations have protected hundreds of undeveloped acres abutting the Bay through land purchase or protective easement, primarily on the Bay's western side (Map 4).

Public interest organizations taking an active role in Maquoit Bay include State and Federal agencies (US Fish and Wildlife Gulf of Maine Coastal Program, Maine's Department of Inland Fisheries and Wildlife, Maine Department of Marine Resources), municipalities (the Town of Brunswick, Brunswick Marine Resources Committee), non-profit organizations (Manomet Center for Conservation Sciences, Maine Audubon), and land trusts and other conservation organizations (e.g., Brunswick Topsham Land Trust, Maine Coast Heritage Trust, Casco Bay Estuary Partnership). The ability of these entities to collaborate on climate change adaptation will impact the future health and productivity of Maquoit Bay. Like many natural resources, the Bay is owned by no one entity, and no one actor alone can protect it.

Maquoit Bay includes a town-owned public access boat launch, from which most local harvesters access the mudflats. Over the past two decades, local shellfish wardens have succeeded in opening more of the Bay's highly productive clam flats to harvest by addressing substandard wastewater disposal systems of abutting residences, and by instituting a harvester service requirement that provides consistent clean up and stewardship. However, water quality is still a concern for some local officials. The Town of Brunswick enacted a 1999 referendum requiring pumpout of coastal property septic tanks every three years.[3]

Numerous streams drain to the Bay, but many of these are impacted by both man-made flow restrictions and diminished water quality, including excessive nutrient loading (Map 5). The Bay's limited flushing capacity and high nutrient loading is thought to predispose it to increased risk of damaging algal bloom and severe hypoxic events.[4]

Local residents are beginning to see evidence of a changing climate. The Town of Brunswick's Marine Warden stated that coastal water temperatures are the highest since the 1950's, and notes species shifts possibly related to the warmer water. There is a higher prevalence of quahogs and invasive green crab, while native soft shell clams seem to be struggling. Although the reason is unclear, eelgrass beds have diminished within Maquoit Bay, moving further out from the mudflat area from their highest point in the 1990's. These signs concern the Warden and others working on the coastal waters in this part of Casco Bay. Long recognized by conservation organizations and resource harvesters as worthy of protection, climate change will demand that existing and future conservation efforts factor in sea level rise, increased development pressure, and ocean acidification while ensuring that the Bay retains its high ecological value.

Management Goals

While no single set of management goals exists for the Maquoit Bay watershed, the recommended priorities identified by the steering committee of the Sagadahoc Region Rural Resource Initiative (SRRRI) mesh well with the protection of ecosystem service delivery under climate change.[5] The SRRRI recommended priorities for local action are:

1. Protect water resources and riparian areas
2. Maintain large unfragmented blocks
3. Maintain connections between core habitat areas
4. Protect habitat for rare species and rare and exemplary natural communities
5. Protect farmland and support farmers
6. Protect, develop and maintain trails

While the SRRRI blueprint for the region does not explicitly address climate change it does provide important background information for thinking about resiliency to climate change and appropriate adaptation actions. In particular, the recommendations to protect water resources and riparian areas through enhanced buffering and maintaining riparian forest will have multiple benefits. The recommendations to maintain blocks of undeveloped land and connections between habitat areas will support the reorganization of species and habitats that climate change will drive.

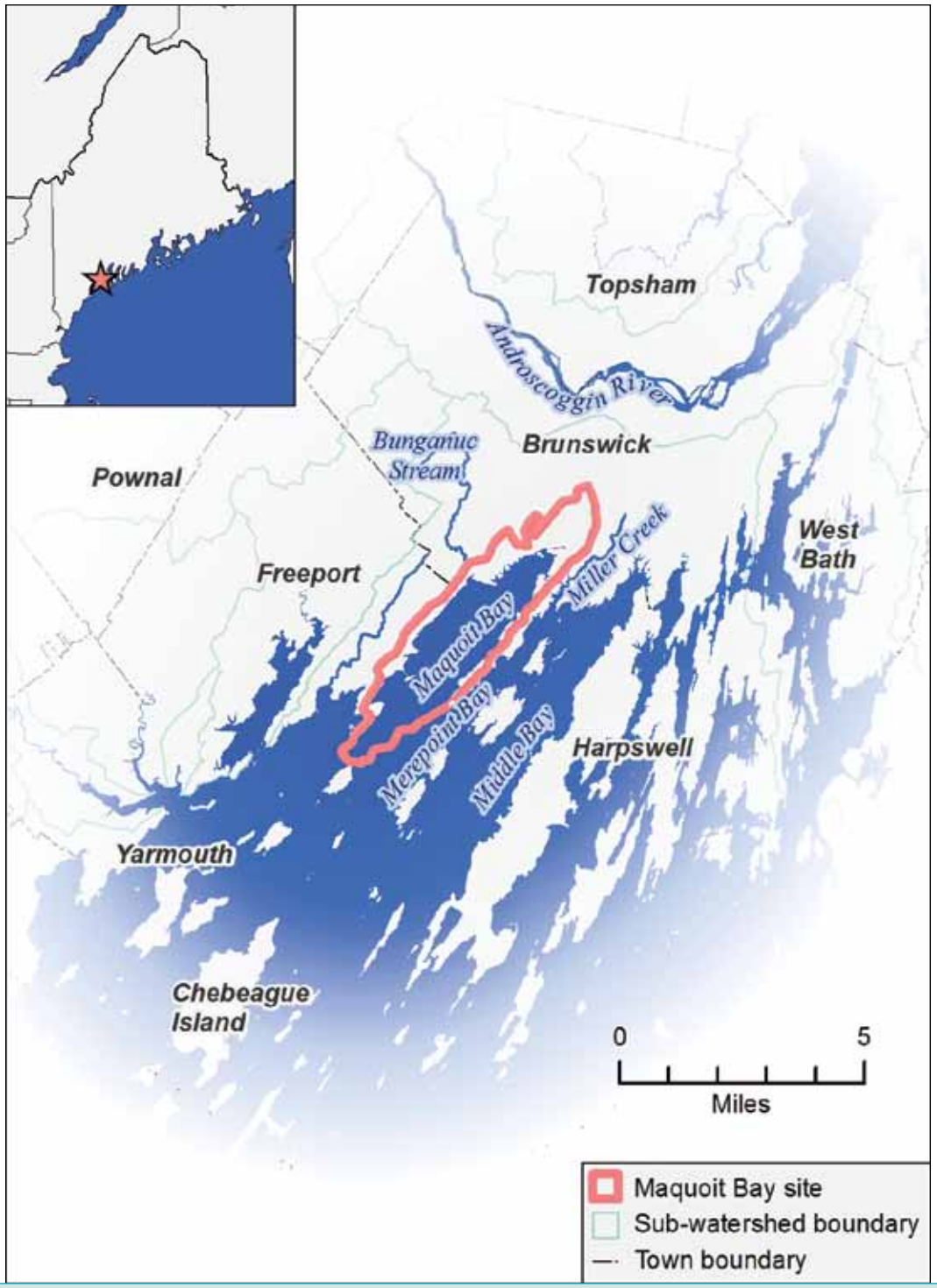
A Manomet stakeholder workshop held in Brunswick, ME identified the impacts of future development, increased precipitation, and sea level rise as priority areas for adaptation planning. These topics were included as major themes in the subsequent analysis of climate change impacts and formulation of adaptation recommendations.

Projected Climate Change Impacts

Climate change will impact many of the highly valued natural systems that characterize the Maquoit Bay. Sea level rise will alter ocean and bay shorelines and move tidal wetlands inland. Warming ocean temperatures and ocean acidification will change the species mix in the ocean, bays and rivers and will threaten the viability of the shellfish in the region. Increasing total precipitation and increasing heavy precipitation events will increase the threat of freshwater flooding and nonpoint source pollution. (See the Manomet adaptation plan for the Sagadahoc region of Maine for an expanded discussion of recent and projected climate change impacts.)

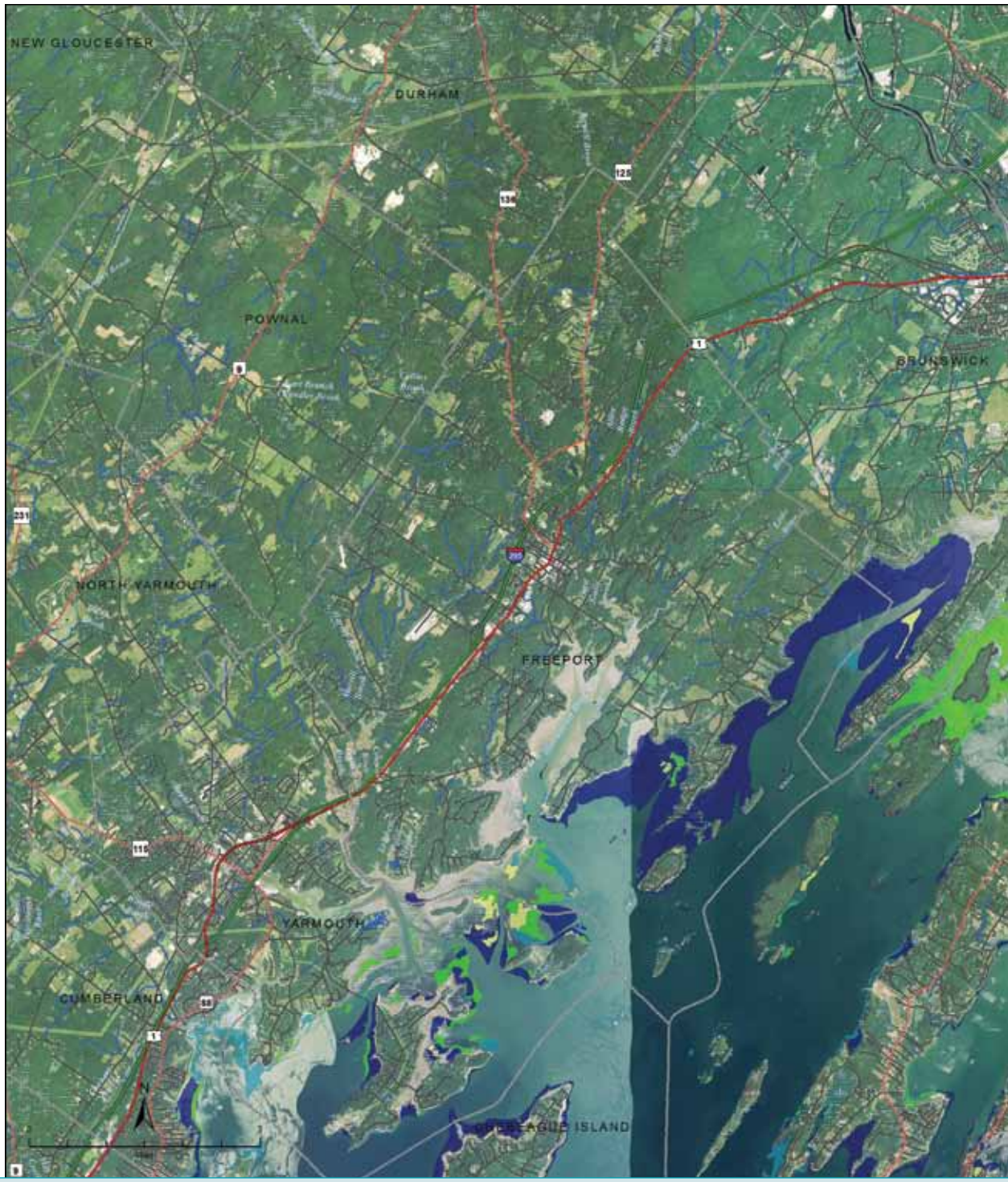
These changes will also impact the infrastructure of the region. Low lying coastal areas will suffer increased storm surge flooding and over time upgrades will be required to maintain the viability of the transportation network, utilities, homes and businesses located in vulnerable areas.

Map 1. Location of Maquoit Bay



Map 1. Location of Maquoit Bay in southern Maine.

MAP 1



MAP 2

This map depicts eelgrass meadows and their proportion of cover using data provided by the Maine Department of Marine Resources through MaineGIS. Maine's eelgrass meadows form an important marine and estuarine coastal aquatic habitat for the state. Along with other plants, eelgrass forms the base of food production in the sea. Eelgrass provides shelter for juvenile fish, and invertebrates, is a site for primary settlement of the larvae of some bivalve mollusks, and in certain locations helps to stabilize unconsolidated sediments and shorelines.

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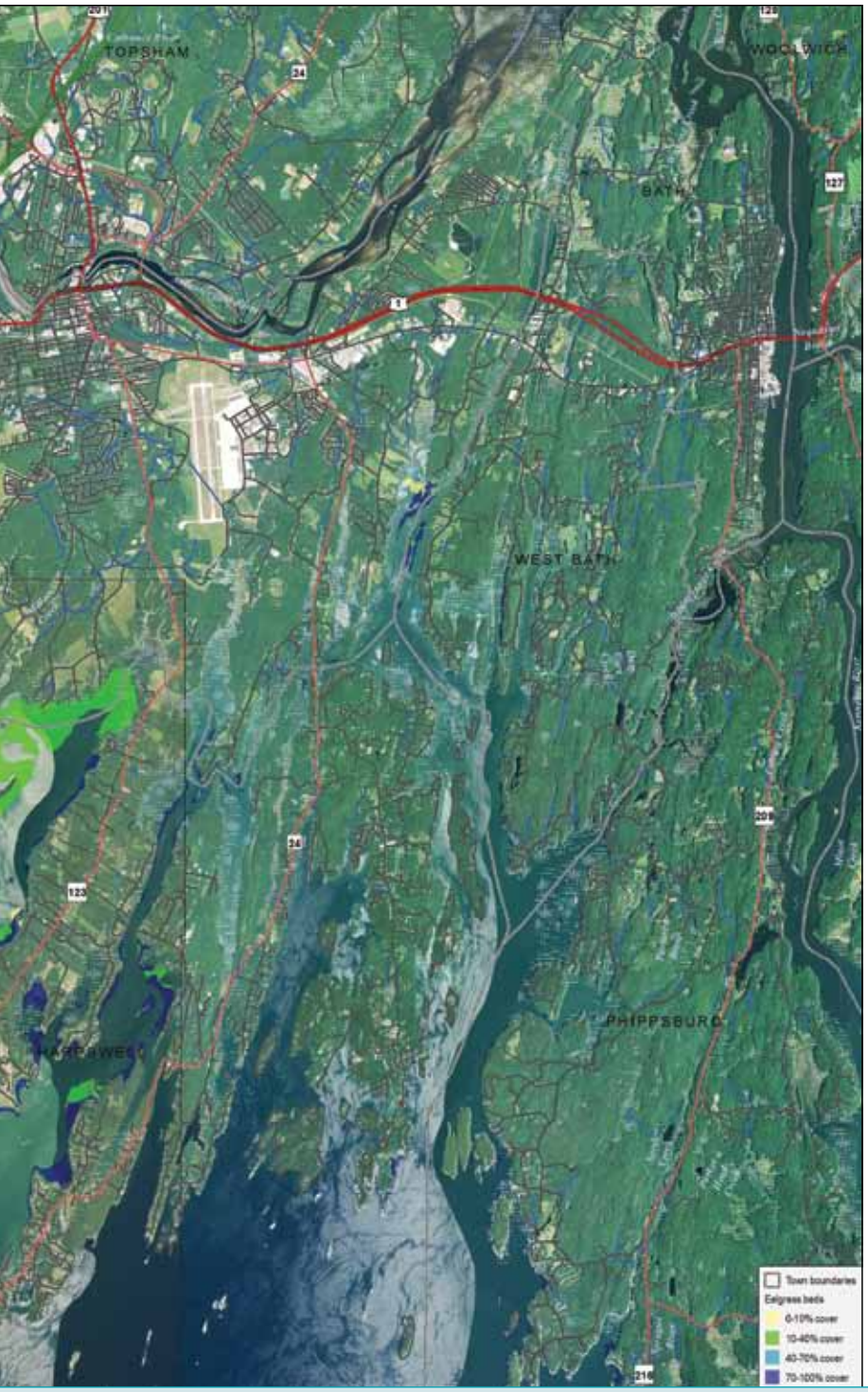
TOPSHAM
WOOLWICH
BATH
WEST BATH
PHIPPSBURG
Town boundaries
Eelgrass beds
0-10% cover
10-40% cover
40-70% cover
70-100% cover

MAP 3

This map depicts molluscan shellfish habitats using data from the Maine Department of Marine Resources and distributed by MaineGIS. These are polygon datasets that contain distribution information for the molluscan shellfish species; sea scallop (Placopectin magellanicus), american oysters (Crassostrea virginica), atlantic surf clams (Spisula solidissima), blue mussels (Mytilus edulis), european oysters (Ostrea edulis), hard clams (Mercenaria mercenaria), razor clam (Ensis directus) and softshell clams (Mya arenaria) for the coast of Maine, compiled between Feb. 2008 – Sept. 2010.

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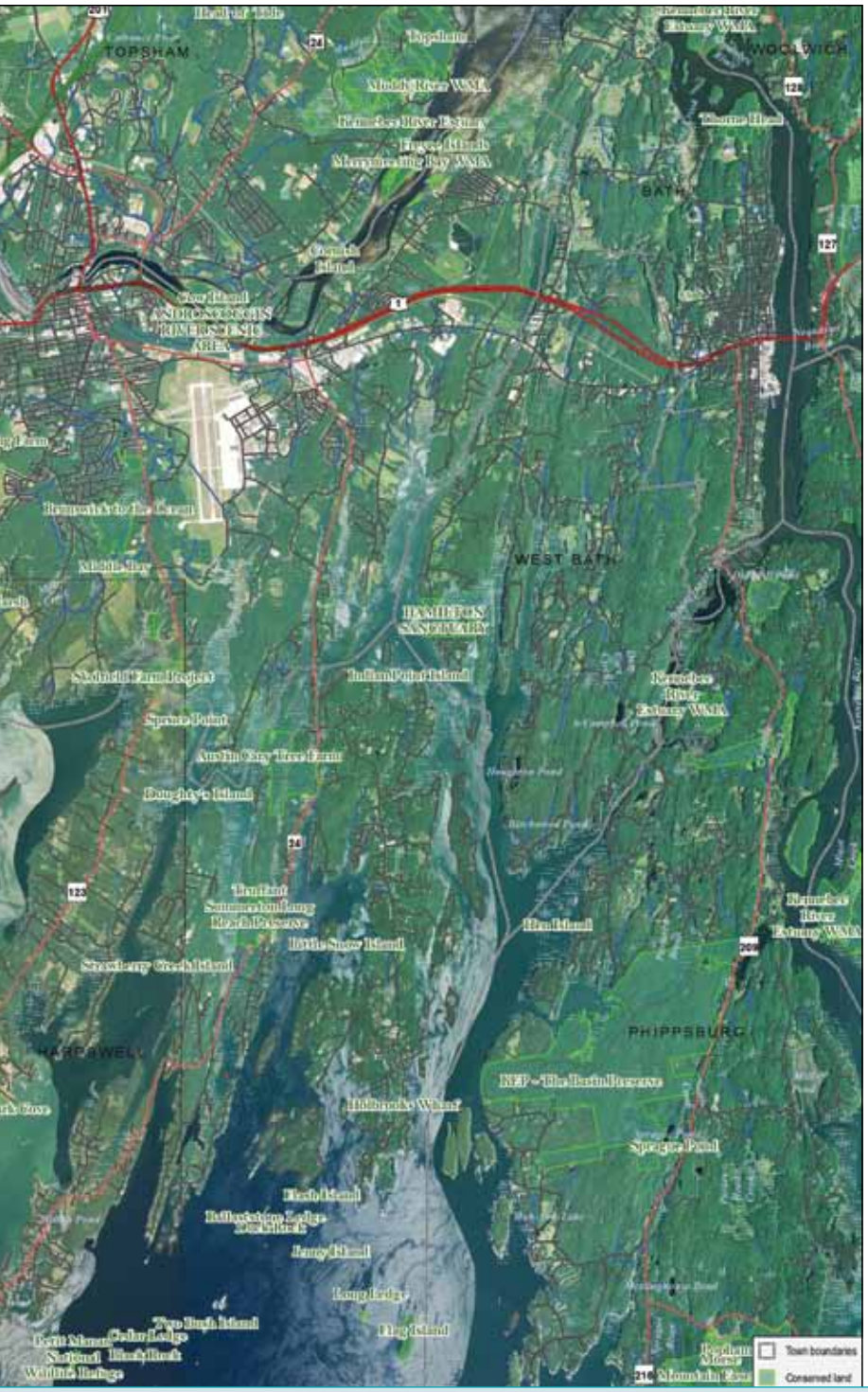
TOPSHAM
WOOLWICH
BATH
WEST BATH
PHIPPSBURG
HARPSWELL
24
1
127
123
209
216
Town boundaries
American oysters
Atlantic surf clams
Blue mussels
European oysters
Hard clams
Razor clams
Sea scallops
Softshell clams

MAP 4

This map depicts land that has been conserved and therefore has some kind of restriction on further development. Each site is labelled with the project or site name.


TOPSHAM
WOOLWICH
BATH
WEST BATH
PHIPPSBURG
HARPSWELL
Town boundaries
Conserved land

MAP 5

This map depicts structures potentially incompatible with aquatic stream habitat. Dam data was acquired from MaineGIS. Stream crossing data was acquired from the Gulf of Maine Coastal Program. Stream crossings were surveyed by program participants and classified as either severely impeding stream habitat connectivity or posing little impediement, all structures in-between were classified as potential barriers. Some sites were assumed to be severe barriers when a full site inspection could not be conducted. These crossings may or may not represent risks to infrastructure as well.

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TOPSHAM
BATH
Whiskeag Creek Dam
WEST BATH
Houghton Pond Dam
PHIPPSBURG
HARPSWELL
Town boundaries
MEGIS Dams
Potential
Severe

Ecosystem Service Vulnerabilities

Maquoit Bay and its adjacent uplands provide a number of "ecosystem services." Ecosystem services are those services such as food and water supply that intact, healthy ecosystems supply to humans. Climate change, in conjunction with other anthropogenic stressors, will impact ecosystem service delivery. The primary ecosystem functions and services of the coastal systems in Maquoit Bay include:

- Provisioning services: fish and shellfish harvest
- Supporting services: biodiversity maintenance
- Regulating services: water purification and flood control

Adaptation Recommendations by Ecosystem Service Category

Provisioning Services: Fish and shellfish

Ecosystems and Supporting Services: Biodiversity maintenance

CLIMATE CHANGE VULNERABILITIES

Sea level rise will affect coastal habitats, including mud flats, marshes, and eel grass beds that provide ecologically significant habitat for wildlife, including commercially valuable fish and shellfish. Rising atmospheric temperatures are warming ocean and bay waters, making Maquoit Bay vulnerable to algal blooms, including red tide. Clammers in the region report a decline in previously robust harvest that may be linked to ocean acidification. Previously productive mud flats have become "dead mud" with a lower than normal pH and no clams. More research is needed to determine the cause of the reduction in clam productivity.[6]

- **Sea level rise and marsh migration.** The shoreline of Maquoit Bay will be altered by sea level rise. Tidal wetlands will migrate inland and upslope in those areas where infrastructure and topography do not prevent it. Low lying areas of the Bay front are vulnerable to an increasing threat of storm surge flooding. Due to variations in the topography of the region's coastal zone sharp differences exist between areas that are vulnerable and those that are not. For those areas at low elevation, the road network, utilities, and septic systems are all at risk and will require periodic evaluation and upgrade to avoid failure. In Maquoit Bay, a one-foot sea level rise scenario is predicted to lead to loss of marsh, but a three-foot scenario may increase marsh areas if opportunities for upslope migration are preserved.[7]
- **Invasive species.** While invasive species are already present in Maine, rising water temperatures are likely to increase the presence of non-native and invasive species such as Asian shore crab, which are known to out-compete native species. Warmer waters are also more vulnerable to more frequent algal blooms, including red tide, which can devastate the shellfish harvest opportunities for an entire season.
- **Ocean acidification.** The world's oceans absorb approximately 25% of the carbon dioxide emitted from the burning of fossil fuels. This input is changing ocean chemistry and over time is reducing the pH of ocean water. The biological impacts of ocean acidification are complex and not yet fully understood. Experiments show that marine organisms react differently to acidification. Oysters, clams, some snails and urchins lose the ability to form shells in highly acid conditions while lobsters, crabs and prawns appear to increase shell building.[8] Ocean acidification will have direct adverse impacts on shellfish populations in the Sagadahoc region and may have indirect effects on the lobster fishery by impacting the marine environment and the food chain. A 2013 study found that Northeastern waters of the United States, including the Gulf of Maine, are more susceptible to acidification that some southern waters due to relatively low pH.[9] Acidification can also be magnified by nutrients in non-point source pollution (e.g., fertilizer runoff) causing algal blooms which can also lead to increased carbon dioxide in the water.[10]

RECOMMENDED ADAPTATION ACTIONS:

- **Preserve opportunities for shoreline movement and marsh migration:** A recent analysis of the impacts of sea level rise on tidal wetlands in Casco Bay indicates that while that marsh will shift upslope, the total area may not diminish if opportunities for upslope migration remain viable. Map 6 shows the impact of three feet of sea level rise on the wetlands at the head of Maquoit Bay. Wetlands that will be inundated are shown in green, new wetlands that will result from upslope migration are shown in brown and areas where upslope migration conflicts with barriers such as roads, dams and shoreline hardening are shown in pink.[8] While many factors such as sea level rise rate and sediment supply will impact the future viability of wetlands, decisions on the location of new development and infrastructure will play a pivotal role. Protecting the areas identified as being important for upslope migration from shoreline hardening will be among the most important decisions impacting this valuable local resource. Specific recommendations include the following:
  - Ordinance changes to limit new structures and infrastructure within the at-risk areas (areas subject to future flooding and areas proximate to future bluff erosion);
  - Limitations on hard (riprap, sea walls) approaches to addressing bank erosion, emphasizing soft alternatives (planting, geotextiles, reconturing, living shorelines);
  - Identification and purchase of easements to help landowners realize some financial gain for avoiding the increased risk areas.
- **Maximize stream connectivity:** Map 5 shows the results of an analysis of barriers to stream connectivity in the Maquoit Bay region. The red triangles indicate culverts or other structures that severely impede stream habitat connectivity. Upgrading these structures to both improve stream connectivity and reduce the potential for flooding and infrastructure damage due to increasingly heavy precipitation events will contribute to ecosystem health in the Bay.
- **Monitor evolution of adaptation measures for ocean acidification:** Research is underway on the possibility of applying crushed clam shells to the mudflats of Casco Bay to lessen the adverse impacts of ocean acidification. Exploring the viability and potential benefits of returning natural calcium sources, such as clamshells, to Maquoit Bay to help buffer the localized effects of ocean acidification is recommended.[12]

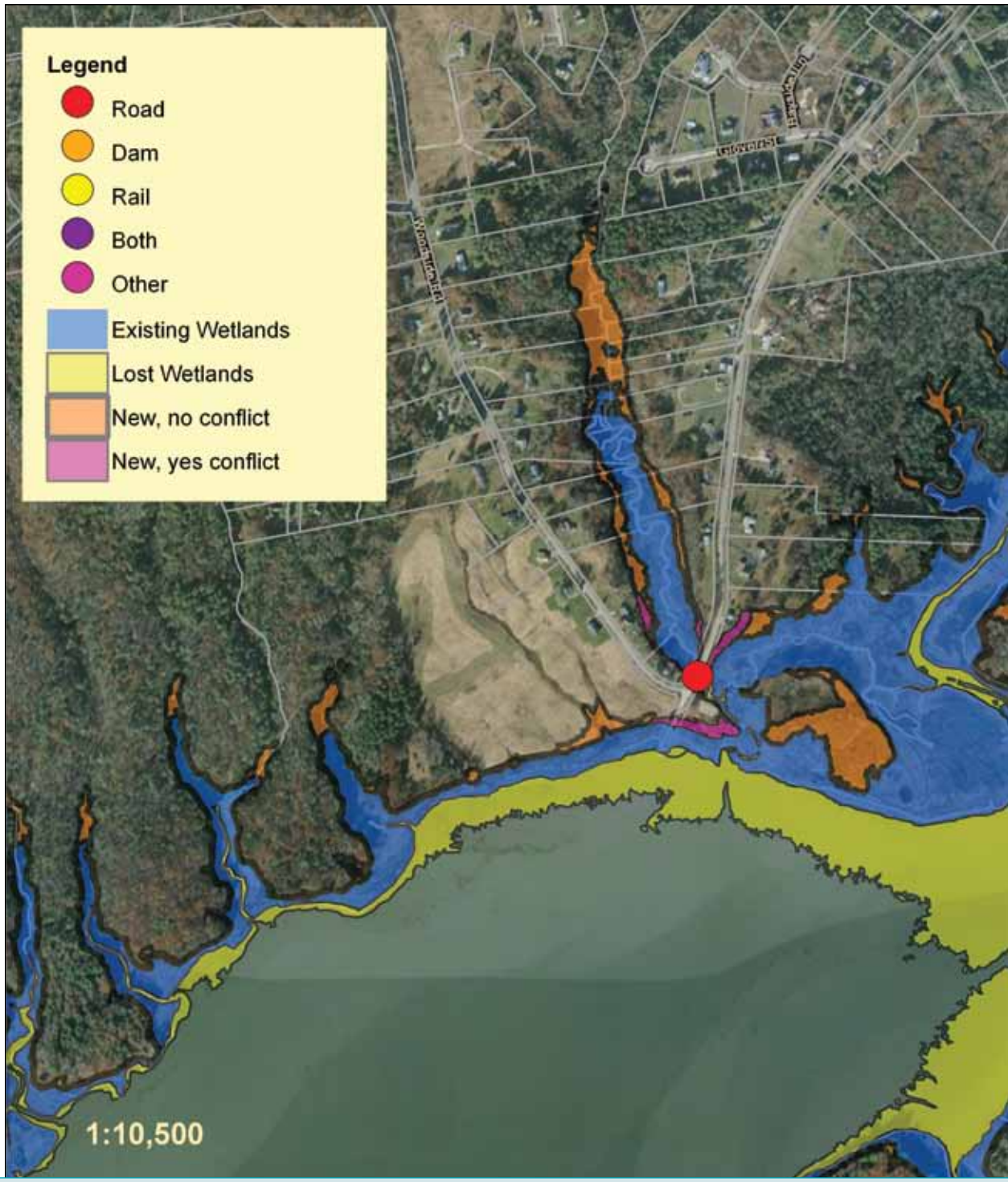
Regulating Services: Water Purification and Flood Regulation

CLIMATE CHANGE VULNERABILITIES

The projected increase in total annual precipitation, coupled with the projected continued increase in the prevalence and severity of heavy precipitation events will change design standards for storm water infrastructure in New England. Combined with continued urbanization of the Maquoit Bay watershed and the associated increase in impervious surface cover, climate change will increase the frequency and severity of fresh water flooding in the absence of best management practices. Changing precipitation patterns may also result in greater nutrient loading to the Bay from increased run-off. Nutrient loading is associated with an increased risk of harmful algal blooms, particularly when exacerbated by higher water temperatures. Increased storm water runoff can also decrease water clarity and limit light penetration to submerged aquatic vegetation.

RECOMMENDED ADAPTATION ACTIONS

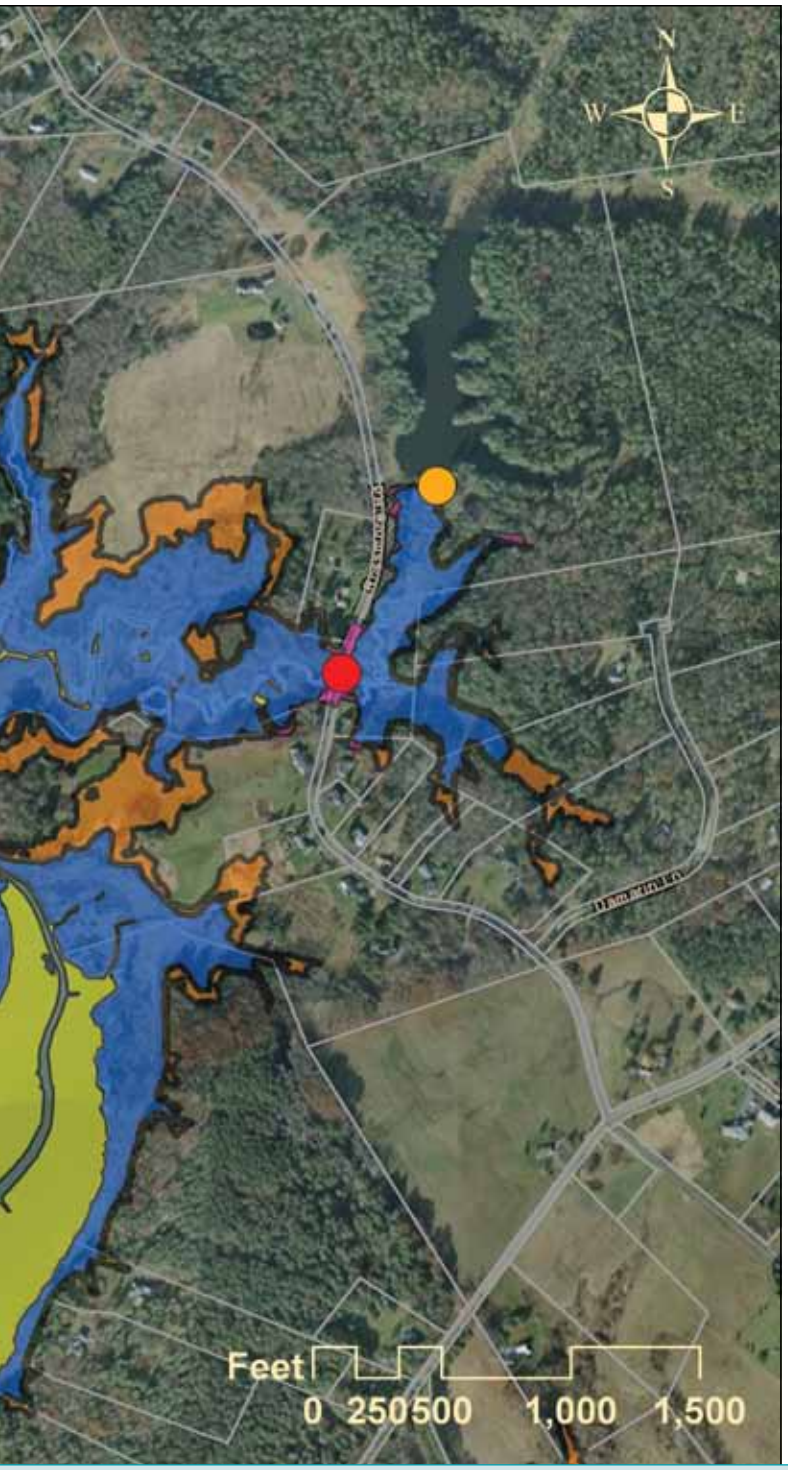
Low impact development approaches that minimize new impervious surface area and maximize on-site infiltration of runoff will help to maintain the health of the Bay. Protecting a regional network of open space will also contribute to the long-term vitality of the Bay. The green infrastructure network identified for the Sagadahoc region provides a template for climate smart land use planning.



MAP 6

Map 6 shows the impact of three feet of sea level rise on the wetlands at the head of Maquoit Bay. Wetlands that will be inundated are shown in green, new wetlands that will result from upslope migration are shown in brown and areas where upslope migration conflicts with barriers such as roads, dams and shoreline hardening are shown in pink.

Map 6 used with permission from the Casco Bay Estuary Partnership.


N
W
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S
Feet
0 250500 1,000 1,500

- **Regional Green Infrastructure.** At the regional scale, a shared vision of a resilient landscape will be essential to informing local planning and development decisions. As part of a related analysis of the Sagadahoc region, Manomet identified a green infrastructure network to support climate change adaptation efforts. Maps 7 shows the portion of the regional network that surrounds Maquoit Bay. The green infrastructure network blends protection of riparian corridors and wetlands, important habitat areas and agricultural lands.

  The network is intended as input to continued regional and local planning efforts to better prepare for both future development pressure and the effects of climate change. Refinement of the network will be required to accommodate evolving local comprehensive plans and detailed analysis of changing flood threat under climate change. In particular, modeling of storm surge inundation under different increments of sea level rise is needed to delineate areas where new development should be minimized. Detailed storm surge modeling was not available as an input to the green infrastructure analysis.

  Refining development controls to protect the green infrastructure network will support resiliency to freshwater flooding and nonpoint source pollution, minimize exposure of new development to sea level rise, enhance biodiversity and support food security for the region. The Sagadahoc region has a significant opportunity for climate smart planning in that the relatively intact natural landscape provides valuable adaptation services at little or no cost. Health and safety benefits and minimization of tax burden are available to the communities of the region if they work together to protect a functional green infrastructure network as population growth and new development takes place.[12]

- **Low Impact Development.** Low impact development standards are typically focused on minimizing the adverse storm water and nonpoint source pollution impacts associated with new development. Site design elements include minimizing new impervious surface area, infiltrating storm water on site and utilizing small-scale green infrastructure features such as rain gardens and grassed swales to minimize the direct linkage between impervious surfaces and receiving waters. In conjunction with a regional green infrastructure approach, LID standards provide significant cost savings as compared to traditional engineered storm water management systems.[13] Map 8 shows the impervious surface cover in the region in 2007. Using LID approaches to minimizing direct connection between new impervious surfaces and receiving waters will be a significant factor in the expense and effectiveness of storm water management efforts. A Manomet survey of local governments in the Sagadahoc region found that none of the localities currently require low impact development measures, indicating a significant opportunity for improved effectiveness.

- **Enhance Wetland and Riparian Corridor Management.** Development of enhanced Town planning ordinance standards for riparian and wetland areas is recommended. Map 9 highlights riparian resources (shown in dark blue) that contribute to flood control and help to protect water quality. Protecting and restoring these wetlands and vegetated riparian buffers will limit nonpoint source pollution and help to keep receiving waters cool. Specific measures include:

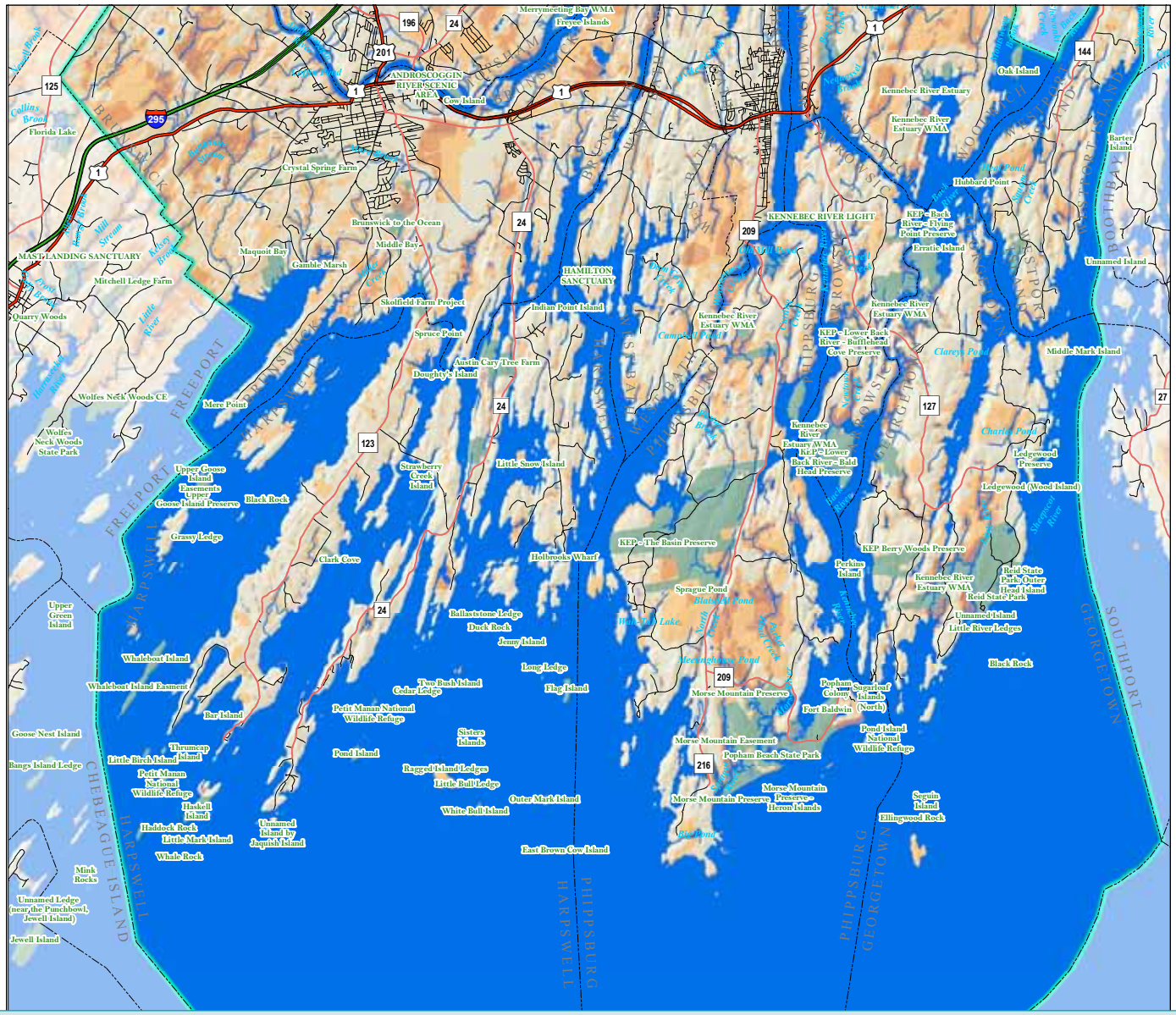
  - Ensure vegetative buffers along upland tributary streams, for example a 100 foot no-cut buffer on all first order streams in watershed.
  - Increase protection of freshwater wetlands throughout watershed.

  In addition, working with the land trusts in the watershed to encourage that their land purchases are informed by future climate change scenarios, changing flood threat, and the value of protecting riparian corridors and non-tidal wetlands will be of benefit to the resiliency of the region.

Conclusion

Climate change will present significant management challenges for Maquoit Bay. The good news is that many of the recommended adaptation options have the potential of providing multiple benefits. Maintaining and restoring vegetated riparian buffers and associated wetlands will support biodiversity, limit flood threat and help to keep receiving waters cool. Limiting new development in areas identified as important for upslope migration of wetlands will both contribute to the long-term ecological integrity of Maquoit Bay and avoid the public expense of maintaining infrastructure in flood hazard areas. As part of the larger Casco Bay, Maquoit receives attention from many conservation organizations, partnerships, and interest groups. Enhanced local efforts to leverage these resources into a comprehensive approach specific to Maquoit Bay could provide significant benefits. Climate smart planning efforts have the potential to both enhance the resiliency of the Bay and save the community money in the long term.

- High priority for protection from development
- Moderate-high priority for protection from development
- Moderate priority for protection from development



MAP 7

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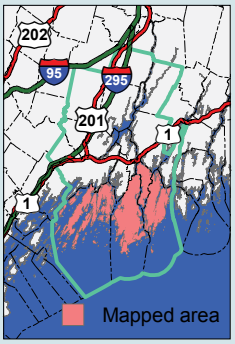
- Town boundary

Roads

- Interstate
- U.S. route
- State route
- Local road
- Sagadahoc area boundary
- Lakes/ponds/wetlands
- Streams
- Wetlands
- Conserved land



0 5
Miles

MAP 7

Components

	THEME/SUBTHEME WEIGHT
COMPONENT 1	
Riparian areas NWI Wetlands including all wetland types, not buffered, *(all equally weighted, combined using a Boolean OR with* NHDFlowlines, Area, and Waterbody including all types, not buffered, *(combined using a Boolean OR with)* TNC's Active River Area (ARA) consisting of non-source water cells	1
COMPONENT 2	
Unfragmented habitat & forest Undeveloped habitat blocks, unfragmented forest blocks *(all equally weighted, combined with simple linear sum)*	1
COMPONENT 3	
Significant wildlife habitats Inland wadingbird waterfowl habitats, tidal wadingbird waterfowl habitats, seabird nesting islands, deer wintering areas, significant vernal pools, shorebird roosting areas, shorebird feeding areas, brook trout habitat *(all equally weighted, combined with simple linear sum)*	1
Rare species Endangered animal occurences, threatened animal occurences, special concern animal occurences, endangered plant occurences, threatened plant occurences, special concern animal occurences *(all equally weighted, combined with simple linear sum)*	1
Rare/exemplary communities Critically imperiled natural community, imperiled natural community, rare natural community, A/B rank exemplary community *(all equally weighted, combined with simple linear sum)*	1
COMPONENT 4	
Prime farmland Includes NRCS-designated prime farmland and farmland of statewide importance *(all equally weighted)*	1

MAP 8

This map depicts impeiVious surfaces *circa* 2007 using source aerial photographs from the National Agricultural Imagery Program and provided by the Maine Department of Inland Fisheries and Wildlife. Areas shown in red on this map are considered to be an impervious surface.


TOPSHAM
BATH
WEST BATH
PHIPPSBURG
Town boundaries
Impervious surfaces

MAP 9

This map depicts surface water and riparian resources. Light blue areas are mapped as streams, rivers, lakes, ponds, or wetlands by either the National Hydrography Dataset or National Wetlands Inventory. Darker blue areas have been identified by The Nature Conservancy's Active River Area model as being important for the maintenance of riparian habitat and streamflow regime. Please note that the islands in and around Casco Bay are considered by the NRCS to be a separate HUC-12 sub-watershed from the physcial water; this distinction has been glossed over to avoid visual complexity in this map, however.

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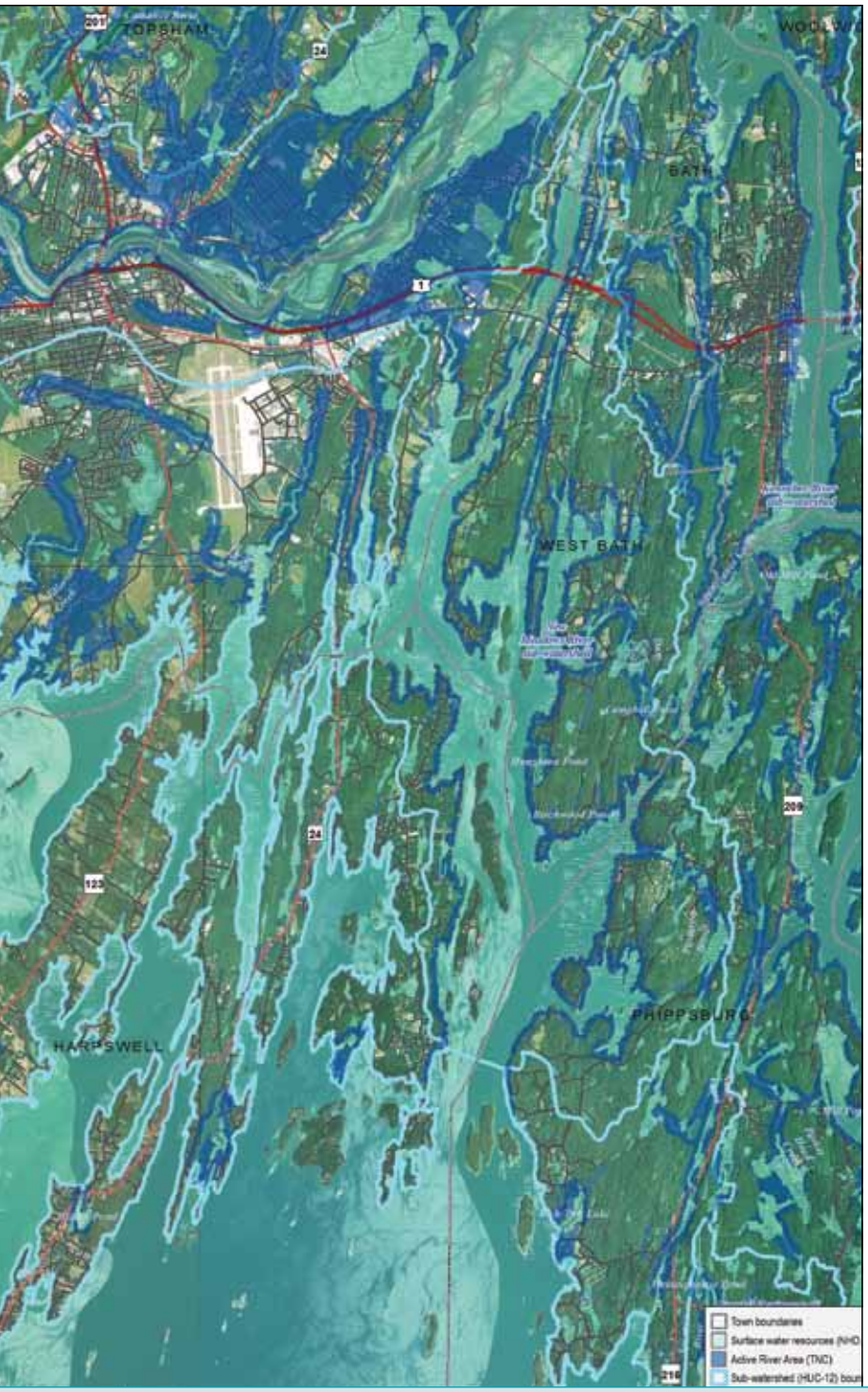
TOPSHAM
BATH
WEST BATH
HARPSWELL
PHIPPSBURG
Town boundaries
Surface water resources (NHD
Active River Area (TNC)
Sub-watershed (HUC-12) boun

Endnotes

1 Focus Areas of Statewide Ecological Significance: Maquoit and Middle Bay, http://www.maine.gov/doc/nrimc/mnap/focusarea/maquoit_middle_bay_focus_area.pdf, accessed 5.15.2012.

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12 Joe Grant and Danielle Gallet, *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits* (Center for Neighborhood Technology, 2010), http://www.cnt.org/repository/gi-values-guide.pdf.

13 Environmental Protection Agency United States., *Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices* (Washington, D.C.: U.S. Environmental Protection Agency, 2007).


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