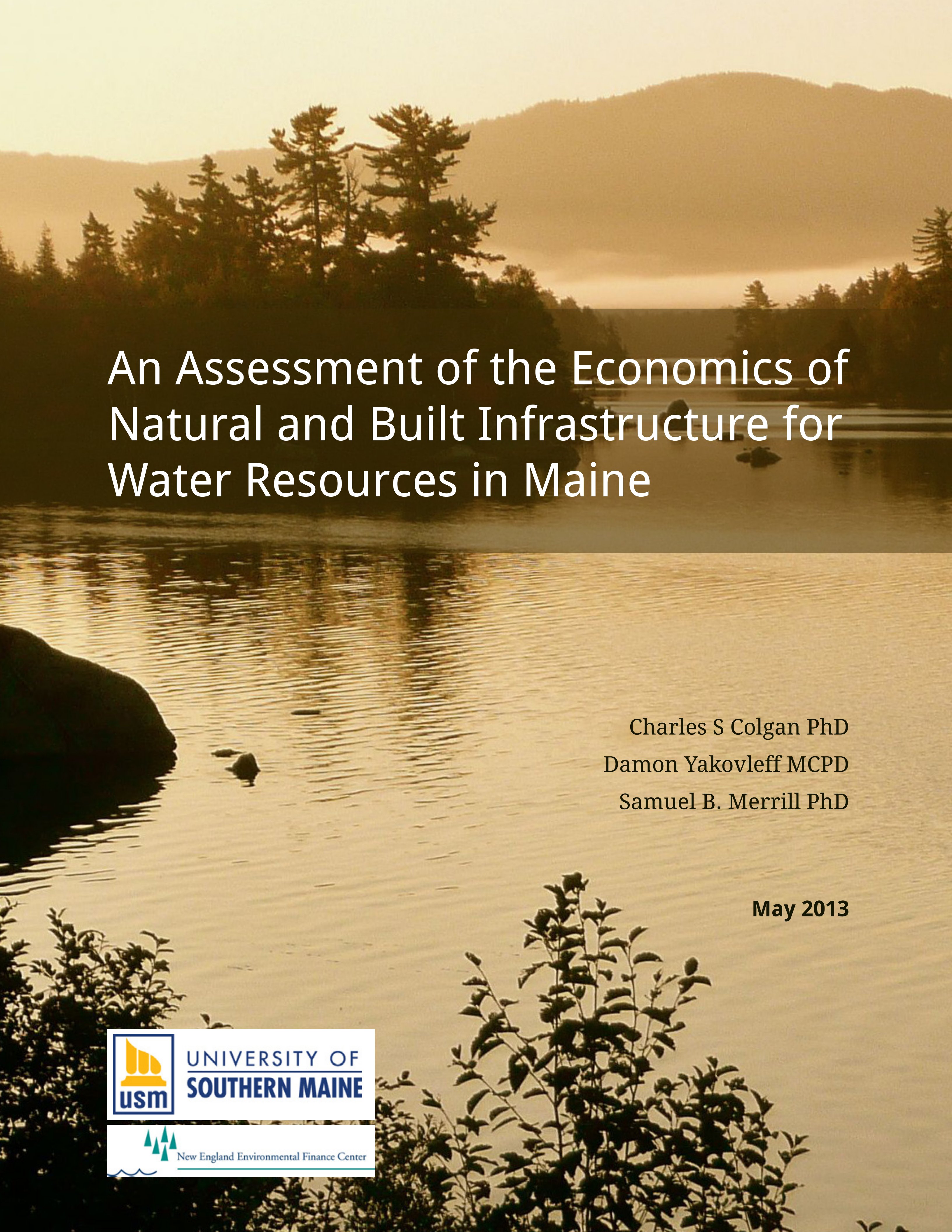

# An Assessment of the Economics of Natural and Built Infrastructure for Water Resources in Maine

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UNIVERSITY OF SOUTHERN MAINE
New England Environmental Finance Center

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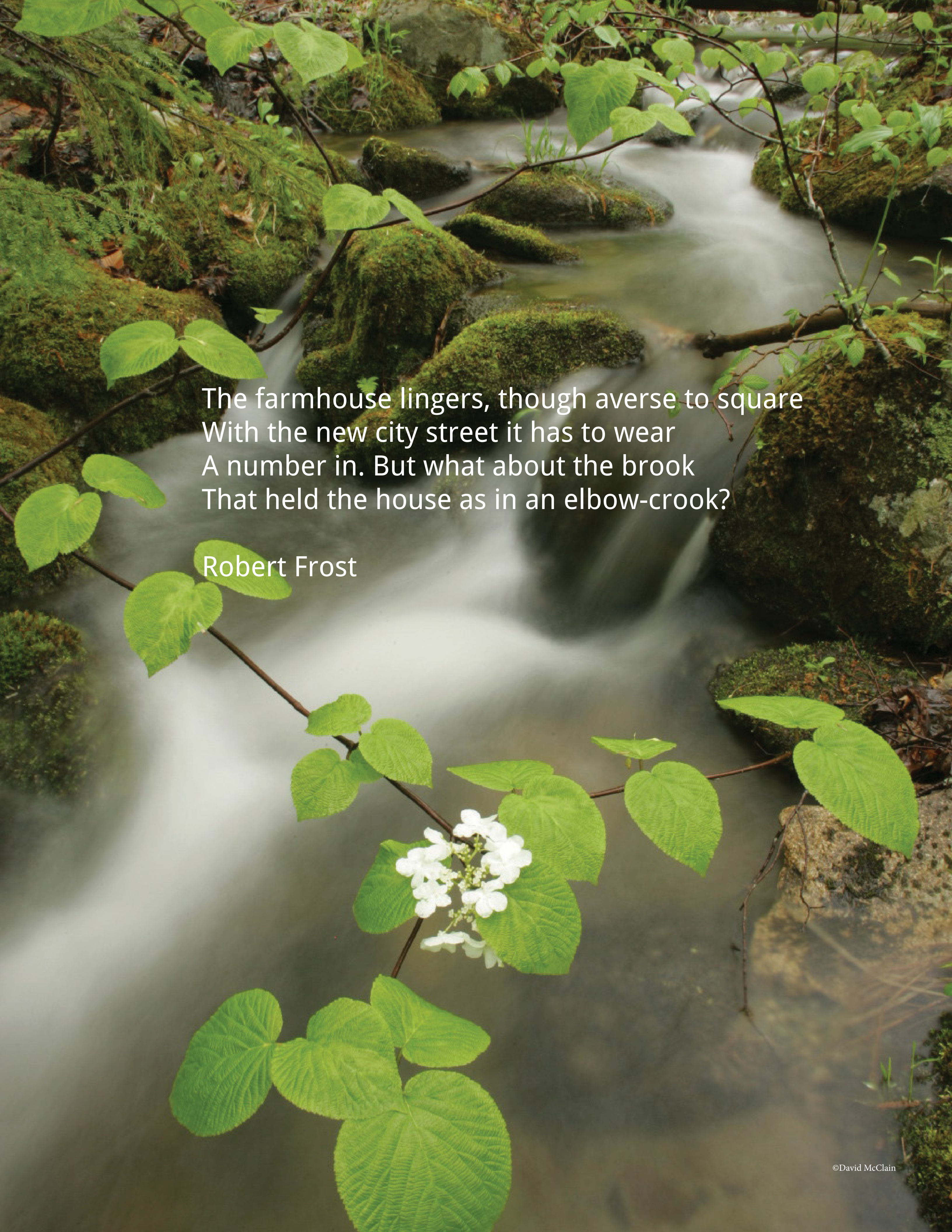
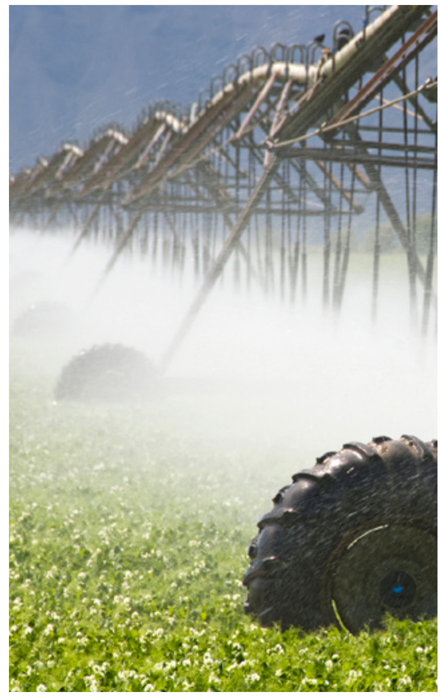


The farmhouse lingers, though averse to square
With the new city street it has to wear
A number in. But what about the brook
That held the house as in an elbow-crook?

Robert Frost

# Executive Summary

Clockwise: ©Bruce Kidman; ©Town of Sullivan; ISTOCKPHOTO.COM; ©Bridget Besaw

Water is Maine's most essential resource. Yet we only seem to notice it when there is too much or too little of it.

Water is critical to everything that lives in Maine. Most of the ways we use, or are affected by, water are greatly influenced by how we decide to manage the state's water resources. Traditionally, when population size justified the investment, we have focused on the construction of centralized water supply systems and strategies to remove wastes. But the demands on these centralized water systems are changing.

Dispersed population growth has spread the need for new systems across the landscape, creating stresses on both the quantity and quality of Maine's historically abundant groundwater and surface water supplies. Steps to address the inadequacies of these systems to manage stormwater flows are long overdue.

A changing climate is producing increasingly frequent and extreme precipitation. York County, for example, experienced 100 year and 500 year floods within a single year.

Historically, almost all water resource issues were addressed by building expensive new infrastructure. Today it has

# Water resources are most effectively and efficiently managed by both building, and not building, new infrastructure.

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become clear that water resources are most effectively and efficiently managed by both building, and not building, new infrastructure. Promoting the use of natural systems' abilities to keep water clean, to diffuse the effects of flooding, and to dispose of wastes (within limits) is now accepted as an effective and economically viable alternative to building large new structural solutions to water problems.

This report examines the opportunities to more cost effectively address water resource management needs in Maine through the combined use of natural systems ("natural infrastructure") and lower cost decentralized structures (part of the general category of "built infrastructure").

The report concludes that there are numerous opportunities for Maine to meet the demands for new, upgraded, and expanded water resources management and to do so at much lower costs than is often thought (or feared) possible.

Four aspects of water resources are examined in the report:

1. Maintaining drinking water quality
2. Mitigating flood hazards
3. Ensuring adequate culverts
4. Managing stormwater

## Maintaining drinking water quality

Maintaining drinking water that meets the strict standards of the federal Safe Drinking Water Act requires that water supply, transport, treatment, and distribution systems must be of high quality. But high quality can come at a high price; finding least-cost solutions to meeting federal requirements is a continuing challenge for public water systems. As populations grow, thresholds are reached where meeting federal standards can require expensive new treatment technologies. Avoiding such expense is an urgent need for many regions.

New York City confronted this problem a decade ago. After a cost/benefit analysis, the City decided it would be more cost effective to conserve land around their water sources and take other steps to preserve the cleanliness of the water coming to the City from the Catskill Mountains, 100 miles to the northwest. Over ten years, the City spent $1.4 billion to purchase land and protect supplies in the Catskills. But this substantial sum was considerably less than $3.0 to $6.0 billion in capital construction costs (plus $250 million in annual operating costs) that would have been required in the alternative. Where the option to preserve land was not available, in the Croton watershed, New York City had no choice but to spend $2.8 billion on a filtration plant.

While a water system serving nine million people may seem an out-of-scale comparison for Maine, the New York experience has very useful lessons for Maine. New York's approach, for example, requires that land conservation be on a strictly willing seller-willing buyer basis and the conserved lands are open for an array of recreational uses from hunting and fishing to hiking and cross-country skiing.

Closer to home, a recent study sought to apply the New York experience to the Portland Water District's service territory. Examining a complex mix of scenarios involving different options for investment timing and costs, the study found that combinations of riparian buffers, culvert upgrades, conservation easements, and sustainable management of forests are less expensive than building new filtration systems in most cases. In one case examined, $44 million in expenditures on these natural and diffused infrastructure options could save over $110 million in comparison with building a new filtration plant.

Portland's experience is likely to be shared to one degree or another with other Maine public water systems in places like Lewiston, Auburn, Damariscotta, Bangor, Mt. Desert Island, and Brewer. These are among nine Maine systems that currently hold waivers from the EPA relieving them of

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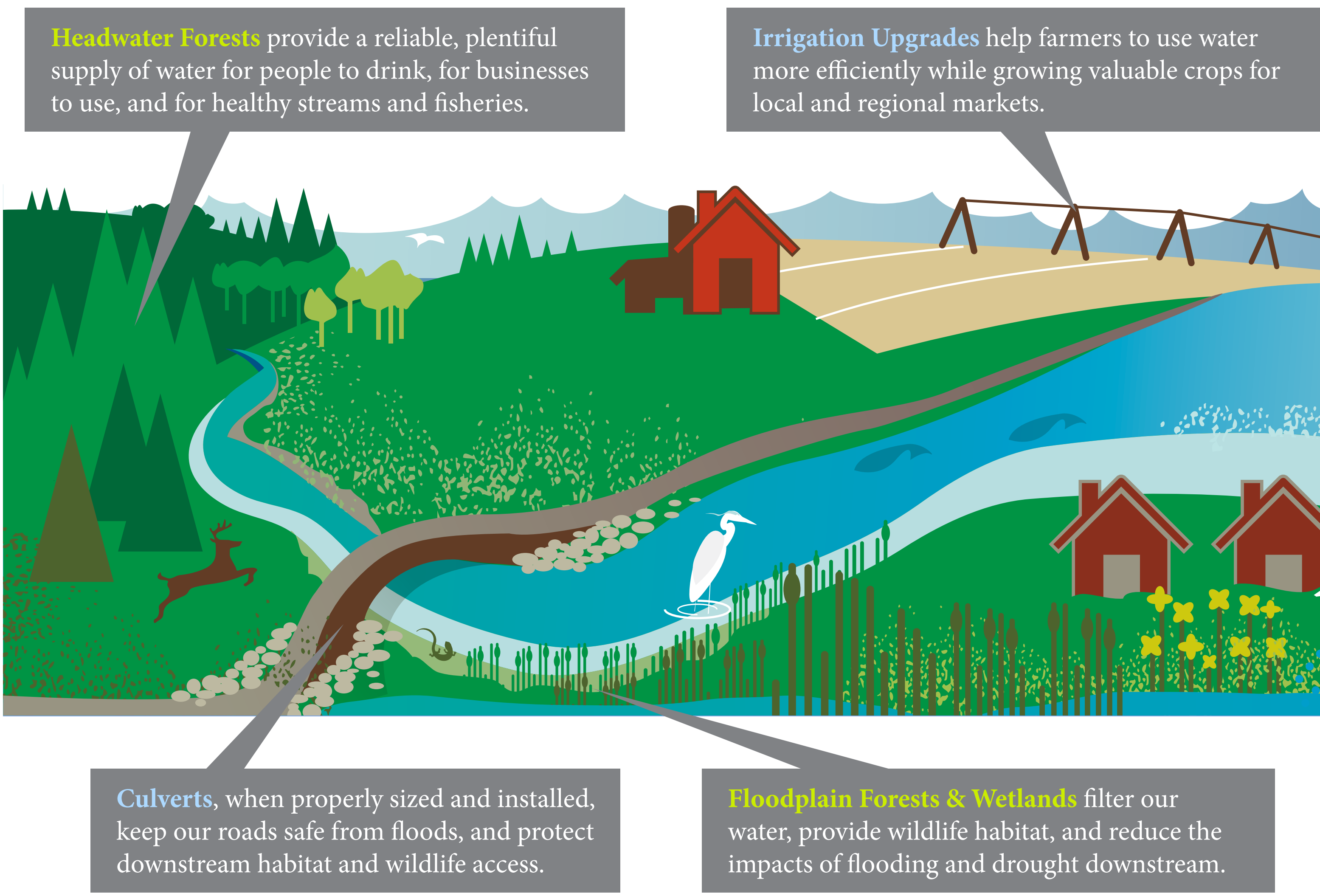
the requirement to build filtration systems. Maintenance of those waivers is a very high priority for each system.

Maine is fortunate in still having abundant land that can provide a variety of natural infrastructure services. A recent analysis described in this report estimates the amount of land in Maine whose conservation could help to maintain drinking water quality to range from 17,000 acres (including places where both drinking water and flood control



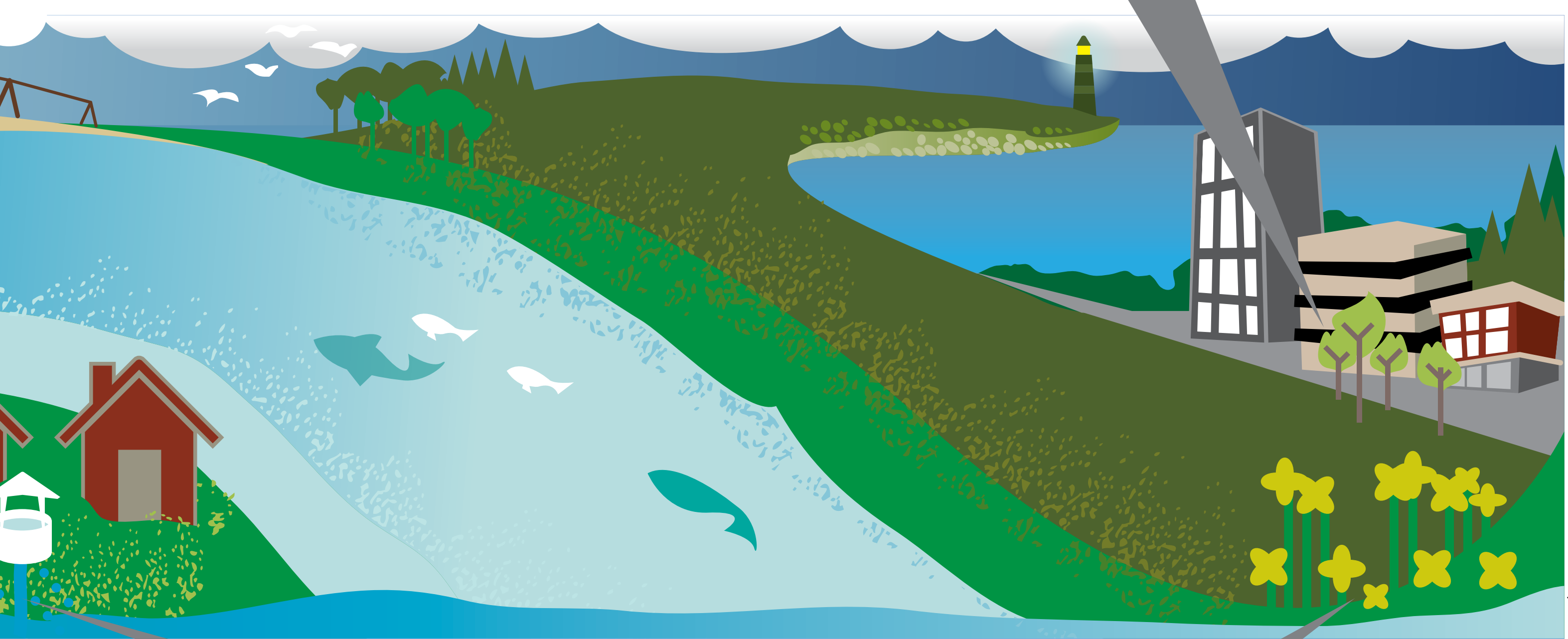
# Riparian buffers, culvert upgrades, conservation easements, and sustainable forestry are less expensive than building new filtration systems.

benefits would accrue) to 825,000 acres (where either one could be protected). (If places providing water-related wildlife habitat are included, the number goes up to 1.6 million acres.) Maine has a quarter century of experience in acquiring conservation easements and purchasing lands through state programs at prices ranging from $755 per acre in Piscataquis County to nearly $6,000 per acre in Cumberland County for an overall average price of $2,100 per acre. Taking the average price for conserving land, the 17,000 acres that provide both flood control and drinking water benefits would require around $28 million, which is about 10% of the value of current public water supply infrastructure exempt from property taxes under Maine law. Purchase of fee or conservation easements on all the land estimated to be valuable for drinking water protection or flood control would cost $1.36 billion at this average price, less than 1% of the total value of land in Maine, which is estimated to be $153 billion.

| Infrastructure Options | Quantity | Present Value Costs (millions) |
|---|---|---|
| Riparian buffers (acres) | 367 | $16.33 |
| Culvert upgrades and replacements (units) | 44 | $1.38 |
| Conservation certification (acres) | 4,699 | $0.14 |
| Afforestation/reforestation (acres) | 9,395 | $14.67 |
| Conservation easements - 80% forest cover (acres) | 13,215 | $11.85 |
| *Green infrastructure total* | | $44.37 |
| *Gray infrastructure (membrane filtration) total* | | $155.28 |
| **Avoided-cost benefits (gray minus green):** | | **$110.91** |

Source: Talbert et al., 2013

**Low Impact Development** techniques aid cities and towns in managing stormwater by mimicking the function of natural areas.



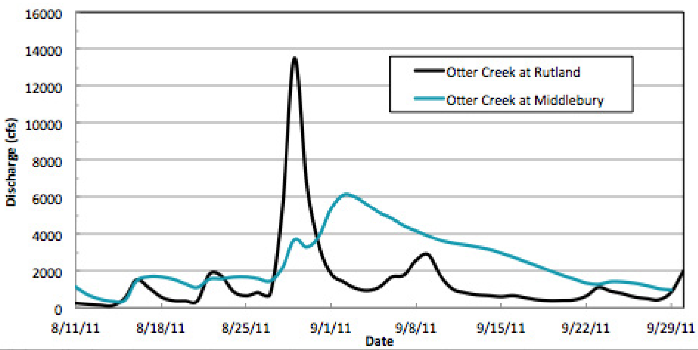
Source: The Nature Conservancy, 2013

**Groundwater Aquifers** provide an essential, long-term source of water for residential and commercial use.

**Coastal Wetlands & Estuaries** buffer our communities from coastal storms and saltwater flooding.

# Mitigating Flood Hazards

Numerous studies have shown the importance of maintaining open space, forestlands, and wetlands to mitigate flood damages. A particularly clear example arises from Vermont's recent experience with Tropical Storm Irene. The Otter Creek in mid-Vermont saw flows increase from a normal 1,000 cubic feet per second (cfs) to over 12,000 cfs at Rutland in the days immediately following the storm, causing significant damage to Rutland and the surrounding towns. Further downstream at Middlebury, VT., where flows should have been even higher, it was a dramatically different story. Peak flows were less than half the level at Rutland because a largely conserved wetland complex between Rutland and Middlebury was able to absorb much of the flood waters, releasing them slowly over time.




Source: McDavitt, 2012

To examine the potential for reducing flood damages in Maine through the use of such natural infrastructure, a simulation of the risks of flood damages in three York County watersheds was undertaken for this report. That analysis found that possible reductions in flood damages would yield over $275 million in present value benefits over a thirty-year period. These savings are compared against the cost of conserving land to mitigate flood damages, an estimated $15.0 million. In small watersheds, the costs may not exceed the benefits, but in large watersheds, the benefits of conserving land for flood control can be more than 100 times the costs.

Using natural infrastructure to mitigate coastal flooding damages is already embedded in Maine law in the Natural Resources Protection Act as applied to coastal sand dunes and other wetlands. Studies have shown the increasing economic vulnerabilities along Maine's shoreline from sea level rise. To date, no specific studies have been done in Maine to assess the costs in damages and repairs to public and private property that could be avoided by investments that protect and restore coastal wetlands. Still, such studies in

Maine DOT/Hallowell

other parts of the country clearly demonstrate the economic benefit and importance of preserving and restoring coastal wetlands.

# Ensuring Adequate Culverts

Culverts are perhaps the least visible elements of the infrastructure that we use every day, but roads collapse when culverts fail. The vast majority of culverts in Maine were designed to meet standards half a century out of date. When storm waters overwhelm these too narrow culverts, they undermine the substrate and leave travelers stranded. Road commissioners face pressures to replace the culvert and reopen the road as quickly as possible. Unfortunately, the default is to set in place a culvert no larger than the one that just failed. That is because smaller culverts cost less and require no new engineering plans and because federal policy for assistance to states and communities after major storms requires that replacements be of the same size as those damaged. These decisions simply set the stage for failure in future storms.

Studies cited in Maine, New Hampshire, and elsewhere show that a large number of culverts will not accommodate expected increases in extreme precipitation events. The choice is between upgrades to more appropriately sized structures now to prevent catastrophic failures or much higher costs in the future when they do fail. While both the costs and benefits of upgrades depend on the specific location, some estimates indicate that upgrades now are

## The vast majority of culverts in Maine were designed to meet standards half a century out of date.

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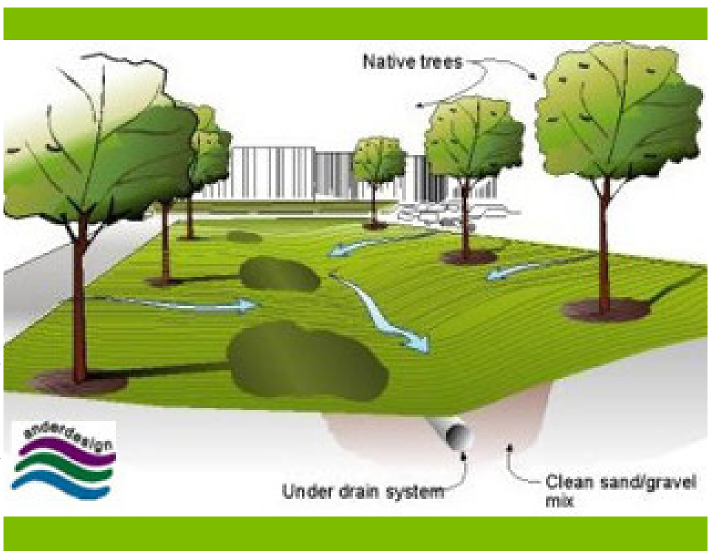


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likely to cost about half again the cost of simply replacing substandard culverts with similarly sized culverts. Rough projections suggest that a total investment of approximately $14-28 million would be required to cover the increased costs of upgrading Maine's highest priority culverts. While these upgrades are expected to result in significant future savings, estimates of these savings have not been modeled in Maine.

# Managing Stormwater

After years of delay, the Environmental Protection Agency has moved to enforce the requirements of the Clean Water Act directing municipalities to reduce pollution overflows into water bodies. When rain storms overwhelm the capacity of sanitary sewers to treat wastes, large quantities of untreated sewage are released in rivers and coastal waters. Retrofitting sewer systems to separate stormwater from waste water can be enormously expensive, so cities are looking for ways to reduce the flows of water resulting from rain storms that enter the waste water systems. The goal is either for current systems to handle the runoff or for separated stormwater systems to be reduced in size.

Conservation of open space, forests, and wetlands to reduce flood damages also provides benefits in the management of stormwater. But rain that falls in the more developed urban areas often has the greatest impacts in terms of stormwater runoff, and this must be managed by employing a variety of strategies to reduce flows. Collectively known as Low Impact Development (LID), these include innovations in roof design, porous paving materials, and biological retention areas.

Such diffused infrastructure systems come at much lower cost than building complete separation systems. In a study of eleven municipal stormwater management programs, ten showed lower costs using Low Impact Development than building separation systems.

Finding alternatives to high cost separation systems is a matter of some urgency for Maine. The Maine Department of Environmental Protection estimates that communities have already spent $415 million to address stormwater issues and will invest an additional $142 million between 2012-17. Portland is currently building a $10 million detention system to reduce flows into Back Cove. At the same time, municipalities in the Bangor area as well as South

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Portland are actively promoting the use of LID techniques in current and new construction to reduce the need for expensive new systems in the future. The Bangor Area Stormwater Group claims a savings of over $400,000 to date by using LID approaches.

# Looking Ahead

There is strong evidence both within Maine and elsewhere of the economic benefits of new strategies for water resources infrastructure that maintains, restores, or mimics the functioning of natural systems. The system-level evidence in this report provides clear support for funding policies that enable the use of natural infrastructure and diffused built infrastructure to meet water resource management needs.

Not surprisingly, the evidence here indicates the necessity of case by case analysis of costs and benefits. Still it is important to note that the projections included here are significant underestimates of the benefits associated with natural infrastructure. This is because the economic benefits associated with preservation of wildlife habitat, open space, and recreation are not included in this analysis. This compelling, though incomplete, picture of the economic benefits suggests that financing programs should require or encourage the use of economic analysis in the evaluation of projects and that state agencies should develop the data and support systems to enable the most cost effective strategies to be chosen.

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# Introduction

Maine's abundant water resources are a significant but under-appreciated strength, particularly in a changing climate where extremes of flooding and droughts are becoming the norm. Surface and ground water supplies our homes, offices, stores and factories with high quality water that does not need the extensive treatment required in other regions. But what is a fundamental requirement one day can be a threat the next as increasingly frequent and powerful storms threaten lives and property through floods. Since ancient times we have managed both the promise and threats of our water systems through complex man-made structures designed to deliver water, remove wastes, and control the water flowing through the landscape.

But infrastructure we have built is aging, and is increasingly inadequate to meet the challenges of a changing climate and of population and economic growth. Today our water systems are under new pressures as development increases in Maine's headwaters regions—areas of the state that generally had limited and dispersed development in the past. Large undeveloped areas that once functioned as filters and distributors of water flows are now being replaced with cleared house lots and roads that shed water directly into our waterways. This runoff is often full of pollutants that harm water quality and wildlife habitat and exacerbate flooding downstream. The impact of these threats will be heightened by the warmer and wetter climate that will characterize Maine in the future. There is strong scientific consensus that New England will face both higher frequencies and intensities of precipitation, resulting in more frequent flood events, over the course of the 21st century (DeGaetano, 2009; Jacobson et al., 2009). However, it is not necessary to accept any specific projections of climate change to agree that making investments now to secure the state's natural and built infrastructure is reasonable insurance against an uncertain future, and significant and growing risks.

The need to rebuild, expand, and improve the systems that affect Maine's water comes at a time when the stress on public fiscal resources is at an unprecedented level. It is essential that great care be taken to choose management approaches that will deal with our need to both supply water for daily needs and minimize water's destructive capability. Recent experience in Maine and elsewhere has demonstrated that new approaches to water management offer the possibility of significant improvements in resource management at lower cost.

The key to this shift in perspective is the idea that it is sometimes better not to build in certain areas than to always impose structural solutions to water resource problems. This approach recognizes that nature often provides the best water systems management, especially when augmented by well-designed man-made structures. Conserving open space and restoring degraded wetlands can be more cost effective over time than structural solutions. For decision makers, the question is how best to balance investments in the different approaches to optimize the results for society.

The need to make the most cost effective choices about infrastructure for Maine's water resources is greatly increased by climate change. The rates of climate change are still uncertain, but the evidence that climate change is occurring is clear (Jacobson et al., 2009). For Maine, with its three different climate zones, changes will bring a net long term increase in both precipitation and mean temperatures but this long term change will not be steady. Rather, the long term trends will be shaped by periods of extremes in which in some years there will be much more precipitation and others there will be much less. Abundance of rain and snow will be accompanied by years with very little rain and snow with conditions in some areas approaching drought. Sea level rise will continue but may happen at slow rates in some years and rapidly in others. These different extremes must be planned for in thinking about infrastructure investments.

This report synthesizes and builds on the growing body of research exploring how an understanding of the economics of "natural" and "built" approaches to water resource management can inform the choices that Maine faces as the State seeks to address the expanding challenges to water resources. The term "green infrastructure" has emerged to denote a variety of both built and natural approaches to water management and has sometimes been more confusing than illuminating. In this report we use "natural infrastructure" to mean using existing natural landscape features to assure quality water supplies, reduce the threats to lives and property from floods and to ecosystems from nonpoint and point source pollution, and provide other associated benefits. "Built infrastructure" covers all man-made structural approaches to maintaining water supply and quality and reducing damages.

The economic assessment of the alternative approaches to water resource management falls within the general field of benefit-cost analysis. This type of analysis seeks to enable the comparison of gains from a particular approach with the resources that must be given up. For water resources, the gains fall into two general categories: "avoided costs," which are possible future losses or alternate expenditures to achieve the same outcome, and "non-market benefits," such as the value of wildlife habitat, scenic lands, or healthy ecosystems.

Extensive studies of both types of benefits have been done, but the measurement of non-market benefits requires more complex methodologies that have generally not been used in Maine. For this reason, we focus on avoided costs where the data in Maine and elsewhere are more available. As we will show, the differences between what must be spent now to manage water resources and the spending that can be avoided in the future are often so large that no additional measurement of benefits is needed.

The report is organized to first explore studies of the economics of natural infrastructure and types of built infrastructure that eliminate or significantly reduce the reliance on large scale structural approaches to water resource management, focusing on maintaining drinking water supplies, mitigating flood hazards, maintaining culverts to allow water flows through transportation networks, and the management of stormwater. We then examine Maine-specific data related to each of these water resource areas, followed by a concluding section. Two appendices elaborate on issues related to water infrastructure, one a case study of how considering connectivity within the water bodies of the Bangor region can yield benefits which have not yet been estimated in economic terms, and the other of the potential importance of natural infrastructure to agriculture in Aroostook County.

# Economics of Water Resource Management: Evidence from Outside Maine

The bulk of the evidence on the economics of natural and built infrastructure in water resource management comes from regions outside Maine, and so we start with some key studies to illustrate the basic principles in understanding the economics of new types of water resource infrastructure. These studies cover "natural infrastructure", which refers to the use of natural ecological systems to provide one or more water-related services or benefits for human communities. These can include: headwater forests, freshwater wetlands and aquifer recharge areas that capture and filter water for drinking water supply; riparian floodplains and wetlands that help to buffer—or attenuate—the intensity of flood events; coastal wetlands and estuaries that reduce the impacts of coastal flooding; and a range of natural areas that provide essential habitat for the state's commercial and recreational fisheries, wildlife, waterfowl and other important species.

There are also studies of those types of "built infrastructure" that perform a water resource management function by attempting to more closely mimic the function of natural systems. The focus in this report will be first on road-stream crossings that are adequately sized to allow a range of flow levels as well fish passage and then on Low Impact Development (LID) as a low-density structural alternative to the centralized management of stormwater management in more urban areas.

## Drinking Water Quality and Reliability

Natural areas play a vital role in safeguarding the quality and the reliability of drinking water supply systems. This is true of large municipal systems and small private residential wells, although the strategies for safeguarding each can differ. Most large municipal water systems in Maine rely on surface water, while smaller systems, even for cities such as Sanford, rely on the pumping of groundwater. In both cases, before water enters treatment facilities and public water mains, natural systems provide substantial and economically valuable filtration and storage functions. The Maine Drinking Water Program has identified priority areas for the state's surface and groundwater resources, which are described further in Appendix 1.

Surface water resources are supplied with runoff during precipitation events as well as from aquifers underlying surface waters. Wetlands store runoff and attenuate flows. These are supplemented by natural and artificial impoundment systems, such as dams and lakes. The loss of wetlands increases peak flows downstream during precipitation events. Surface drinking water supplies are filtered and purified as waters pass through wetlands systems en route to larger streams and rivers, which supply the reservoirs from which water typically enters municipal systems. The loss of water quality in surface waters is a major economic threat to ecosystems and to human health. The requirements to maintain water quality for human drinking water requires extensive, and expensive, infrastructure.

The Federal Safe Drinking Water Act contains a provision commonly referred to as the Surface Water Treatment Rule. This rule mandates "disinfection and filtration for all public water systems that use surface water or a source that is ground water under the direct influence of surface water" as the default requirement for public water systems (Maine CDC Drinking Water Program, 2013). Waivers for the filtration requirement are available for water systems that have exceptional water quality and can maintain stringent standards for source protection in supply watersheds and, as such, are relatively rare. According to the Assistant Director of the Maine CDC Drinking Water Program, Andrews Tolman, only nine water systems and eight sources in the State of Maine have filtration waivers, which is reduced from of twelve waivers in 1999 (Tolman, 2013). The largest system in Maine with a waiver is the Portland Water District, one of only ten systems serving greater than 100,000 customers in the United States that has such a waiver (Pires, 2004). Other systems in Maine with waivers are the Lewiston, Auburn, Great Salt Bay (Damariscotta), Bangor, Northeast Harbor, Seal Harbor, Bar Harbor, and Brewer systems.

Recent events in the nation's largest public water system illustrate how investments in natural infrastructure can yield significant benefits in the form of avoided costs of new built infrastructure. The New York City Water Supply System's use of natural filtration was approximately 2.5-4 times more cost effective than the construction of a filtration plant for the same level of purification (Grolleau & McCann, 2012). The New York City Water System realized these benefits by preserving traditional land uses such as agriculture public recreational access.

The New York City Water System has two major sources of supply: the Catskill Mountains, about 150 miles northwest of the City, and the Croton watershed in Westchester County to the northeast (the 19th century supply). In the Catskills, where abundant open space was still available, a strategy of land conservation allowed the City to avoid $3.0 to $6.0 billion in filtration plant capital costs plus $250 million annual operation costs. In the Croton watershed, where open space has been largely eliminated by the long term development of Westchester County, the City had no natural infrastructure options, and is building a $2.8 billion filtration plant that will be opened this year (see Table 1).

| System | % of Water Supply | Natural Infrastructure Costs | Conventional Infrastructure Costs |
|---|---|---|---|
| East Side: Croton | ~10% | Environment Degraded | $2.8 billion (2013) |
| West Side: Delaware / Catskills | ~90% | $1.4 billion (1997-2007) | $3-$6 billion + $250 - $300 million Annually (2007) |

Table 1: Comparison of New York Water Supply Watersheds.

The New York experience is similar in many ways to other large unfiltered system in the U.S. such as the Metropolitan District Commission in the Boston metro area or in Portland, Oregon, which have accomplished their water quality goals by sharply reducing all other land uses, including public access to surface water bodies in their watersheds (Hopper & Ernst, 2005). Economic analyses similar to that in New York have not been done for these other regional water systems but their policies reinforce the importance of using land conservation strategies to maintain drinking water quality.

## Riverine Flood Hazard Mitigation

One of the most economically valuable effects of preserving natural systems is the avoidance or reduction of flood hazard. Researchers such as Brody et al. (2011) have shown that floods in the United States have increased both in terms of number of events and magnitude of damage since the 1960s. New England, with its dense network of lakes and rivers, is particularly vulnerable to damaging flood events, as was demonstrated by the catastrophic flooding that occurred during Tropical Storm Irene in August, 2011. Other recent notable flood events in Maine include the 1987 "April Fools" flood, the October 1996 southwest Maine flood, the 2006 "Mother's Day" flood" and the 2007 "Patriot's Day" flood, among others. According to climate change research, such events in Maine are likely to become more frequent by the end of the 21st century (Jacobson et al., 2009). Compounding this is the increase in development that reduces the capacity of our natural systems to moderate such damaging storm events.

The traditional approach to flood hazard avoidance has often involved building large and expensive flood control structures like dams or levees, and the channelization of rivers and streams. These structures have many negative ecological and social consequences. Most dams in Maine were built in the late 19th to mid-20th centuries. Such structures are unlikely to be constructed to any extensive degree now because of both their financial and environmental costs; indeed, dams such as the Edwards Dam on the Kennebec and the Great Works dam on the Penobscot are now being removed from Maine's waterways to restore fish habitat. The combination of increasing risks from more frequent extreme weather events, increasing urbanized development even in rural areas, and decreasing opportunities to use built infrastructure to mitigate flood damages will require increasing attention to natural infrastructure as an option.

Natural systems in Maine moderate flood events in several ways. Maine is the most heavily forested state in the nation. Upland forests help moderate flooding by slowing down the rate at which water enters rivers and streams. The structure of trees themselves slows water down due to friction, especially during the warm season when leaf growth is full. As water reaches the forest floor, it then flows several different ways. Some percentage infiltrates into groundwater systems, some percentage evaporates or is transpired by vegetation, and some percentage runs off. In addition to forest lands, vegetated riparian floodplains and wetlands adjacent to waterways also significantly affects the ability of natural systems to moderate flood events. Wetlands help to buffer flows, provide critical wildlife habitat, and purify runoff of sediments and pollutants.

The experience in Tropical Storm Irene along the Otter Creek in southern Vermont provides a vivid example of the role of open space in flood attenuation. As was the case in many communities across Vermont, the town of Rut-

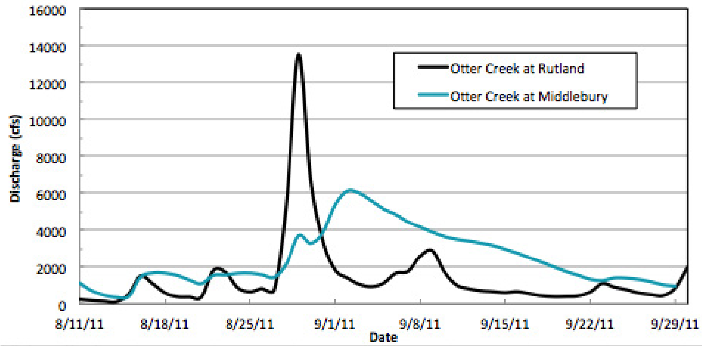


Figure 1: Mean daily flow for Otter Creek in Rutland and Middlebury (McDavitt, 2012).

land suffered severe flood damage when Otter Creek rose dramatically in the immediate aftermath of Irene—estimates are that flow through Rutland increased by nearly 20 times in less than a day. Yet thirty miles downstream in the town of Middlebury, where one might expect Otter Creek's floodwaters to have peaked at even higher levels, the effects of flooding were far less intense. This difference is largely explained by the 8,700-acre Otter Creek wetland complex, a mosaic of intact wetland and floodplain forest, that separates the two towns and that safely flooded to record levels after Irene. Figure 1 demonstrates the significantly lower peak flow, and the more gradual release of floodwaters, that occurred downstream of the Otter Creek wetland complex. Even small amounts of wetlands can be significant. Godschalk et al (1999) explain that a 5.7 acres wetland absorbed the runoff of a 410 acre watershed, and, through extrapolation, they argue that if only 3% of the area of the upper Mississippi had been preserved as wetlands the 1993 floods would have been avoided.

Other characteristics of streams are also significant. Channel types matter: natural streams contain large amounts of debris and meanders, which slow and buffer flood events. More natural streambeds also enhance biodiversity (Poulard et al., 2010). Streams naturally migrate laterally, a process that causes significant conflicts with development. Streams also have flood plains—flat zones that flood periodically. In order to avoid migration of streams into developed areas, many streams have been artificially straightened and lined with impervious surfaces that limit migration. These artificially straightened streams, unobstructed by debris and meanders, allow flood waters to drain more quickly, but to peak at a higher level. As development of a watershed increases, an increasing amount of its surface area tends to be paved or otherwise covered with surfaces that are impervious to infiltration. As infiltration decreases, more water runs off into stream and rivers. This is especially true when impervious surfaces are connected, as in a road network. Stream channels are often also directly impaired by road crossings, as is described further in the Built Infrastructure section of this report.

Numerous studies (Brody & Highfield, 2013; Kousky et al. 2011; Brody et al., 2007) have shown the relationship between the conservation of open space, especially adjacent to or containing wetlands, and the mitigation of downstream flooding. The Brody et al. (2007) study showed that wetland loss in Florida and Texas had statistically significant increased effects on the extent and impacts of flooding. Another recent national study (Brody & Highfield, 2013) showed a statistically significant correlation of $200,000 in annual avoided flood damage per municipality that attempted to mitigate flood damage through open space conservation. This study used historical data from FEMA's Community Rating System (CRS), which provides incentives for communities to mitigate flood damage through such methods as open space conservation, and based its valuation on the mean scores for open space conservation across all municipalities in the study. Another study (Kousky et al. 2011) used the FEMA HAZUS model—the application of which to Maine is discussed later in this report—to demonstrate that wetland conservation can reduce downstream flooding in a Wisconsin River.

| Geography | Results of Study | Method Used | Reference |
|---|---|---|---|
| Wisconsin River | Wetland conservation reduces downstream flooding | FEMA HAZUS modeling | Kousky et al. 2011 |
| Florida and Texas | Wetland loss significantly increases the impacts of flooding | Wetland Development Permit Analysis | Brody et al. 2007 |
| United States | $200,000 /year in avoided flood damage for municipalities that used open space conservation as a flood mitigation tool | Historical data from FEMA's Community Rating System (CRS) | Brody &Highfield, 2013 |

Table 2: Studies showing the relationship between open space conservation and the effects of downstream flooding.

The potential for Maine's natural systems to lose their ability to mitigate the effects of flooding is a serious concern, particularly as communities face a likely future with more frequent, extreme storm events. Because the cost of protecting all vegetated uplands and wetland areas in our watersheds would be prohibitively expensive and politically infeasible, it will be essential to develop ways to focus conservation efforts in the state on the areas expected to provide the greatest flood protection benefit for populated areas and critical built infrastructure. One attempt at this kind of analysis in Maine, and the associated economic implications, is discussed below.

## Coastal Flooding Protection

Maine faces the potential for significant losses due to ocean flood events over the course of the 21st century. Sea levels have already risen 0.6 ft. through the 20th century, which represents one of the fastest rates in the last five thousand years (Maine's Climate Future: Coastal Vulnerability to Sea Level Rise, 2009). The rate of sea level rise is likely to continue to increase. A conservative estimate, used by the State of Maine in setting its coastal sand dune rules, is to expect two feet of additional rise by the end of the 21st century. This estimate does not include the effects of additional rise due to recently detected melting in Greenland and Antarctica. Regardless of the rate of rise, the effects will be similar; the only question is when and to what extent they will occur. There will be an inland migration of dunes, beaches, and marshes. Where inland migration is not possible, because human development has created barriers, these systems will likely erode at much higher rates. As a result, coastal flood events will carry increasing destructive power.

Historically, much of Maine's development has occurred along its coastal margins. The degree of vulnerability of lives and property to coastal flooding depends on complex geological and hydrological factors which vary significantly along Maine's 3,500 mile coastline. Some developed areas are built high on rock ledges and are relatively well protected from storm flooding, even given sea level rise and increased storm frequency. These areas constitute the majority of Maine's coast. However, Maine also has a significant amount of coastal bluff lands, which constitute forty-six percent of the coastline. These bluffs are composed of soft, loose sediments, and are highly vulnerable to erosion especially in the context of sea level rise. Increased erosion, resulting from higher flood tides and more frequent storm events, can cause landslides in these bluffs that could destroy properties in whole neighborhoods. Beaches and dunes make up about two percent or about seventy miles, of Maine's coastline, and are by far the most vulnerable to increased storm related flood events (Maine's Climate Future: Coastal Vulnerability to Sea Level Rise, 2009).

The opportunities for natural infrastructure to protect vulnerable shorelines present perhaps the most complex issues in flood protection. Most of the vulnerable shorelines are already developed, so open space preservation opportunities are limited. Retreat from the shorelines will reduce property and life risks, but there is little social willingness to force retreat prior to storm damages. Built infrastructure interventions to reduce flooding risks in dynamic geological environments like beaches shift the risks from one area to another. Maintaining the functions of coastal marshes and estuarine wetlands may be the critical natural infrastructure opportunities in shoreline areas. Studies of the economic value of flood protection for coastal marshes and wetlands suggest that the values average around $500 per acre per year, with estimates going as high as $2,200 per acre per year (Woodward & Yu, 2001).

## Addressing Stream Crossing Vulnerabilities

As described in the previous section, the conservation of wetlands and other natural areas upstream of settled areas is vital for community protection during flood events. Even with such conservation measures, however, our surface transportation infrastructure is at significant risk at the points where it crosses waterways. A myriad of problems are associated with such crossings in Maine. These problems are compounded by the age of our infrastructure, the sheer number of crossings, and poor data about the location, condition, and even the ownership of much of our stream crossing infrastructure. As a water-rich state with many large rivers and roughly 33,000 miles of perennial streams, Maine's roads and rail lines must cross a vast number of waterways. Crossings of larger waterways generally occur by way of bridges, while culverts, which are typically large metal pipes, accommodate smaller waterways.

All stream crossings are at risk due to flood events, but culverts are of particular concern. Recent studies (NEEFC, 2011; MDOT, 2008) have indicated that a very large number of culverts in Maine are undersized and thus unable to accommodate peak water flows during flood events and more prone to failure. Poor data and uncertainties about climate change effects on extreme precipitation events makes estimating the number and cost to upgrade undersized culverts in the State extremely difficult, however a rough estimate is discussed below.

Regardless of the exact magnitude of the problem, its effects are well established. When undersized culverts fail, water overtops and washes away roadways, making roads impassable for days, weeks, or months. The number of such failures is expected to grow annually in our region as future weather conditions become wetter and more prone to extreme precipitation events (DeGaetano, 2009). These risks are increased further by land use changes that reduce the natural environment's ability to mediate peak flows. Recent storms, like Tropical Storm Irene highlighted dramatically the risk that transportation infrastructure faces at stream crossings. In Vermont, where Irene was particularly destructive, estimates of damages for state highways alone were $175-$250 million, with an added $21.5 million in damages to state-owned railroads (Vermont Agency of Natural Resources, 2012). Two hundred bridges on state highways were damaged, and municipalities reported 960 culvert failures. Total damage to roads and bridges in Vermont was estimated to exceed $700 million (Kinzel, 2011).

The particular issues of stream crossings are illustrated in the experience in Vermont's Green Mountain National

Forest. Prior to Tropical Storm Irene, the U.S. Forest Service upgraded a number of culverts in the Green Mountain National Forest with wider, natural-bottomed crossings designed to accommodate 100-year flood events. Many of the National Forest's conventionally-sized culverts blew out during Irene, with considerable accompanying damage to the adjacent roadways. In contrast, none of the new, wider crossings failed during the storm. While Forest Service staff estimate the wider structures to cost on average 20-40% more to construct, they project significant savings over time due to increased service life of the structures, and the reduced maintenance costs (compared to narrow, pipe culverts which require regular attention to keep clear of debris).

A recent study, commissioned by the Piscataqua Regional Estuaries Partnership (PREP), discussed the benefits of constructing and maintaining culverts capable of handling much larger flows for the Oyster River watershed in southern New Hampshire. The PREP study (Stack, 2010) assessed the current status and future needs for culvert infrastructure in the Oyster River watershed by modeling different climate change and land use change scenarios, and integrating the potential effects of Low Impact Development (LID) stormwater management practices. The study estimated that, conservatively, at least 5% of the culverts in the watershed are currently undersized to handle water flow. Given the predicted level of development in the watershed by the mid-21st century, and the most likely climate change effects on 25-year storm events, the study projected that the number of undersized culverts would increase to 23%, significantly increasing the magnitude of the maintenance and public safety challenges for communities. Figure 2 (below) demonstrates the projected relationship between an increase in expected precipitation and the number of culverts that would become too small to handle the resulting flood flows.

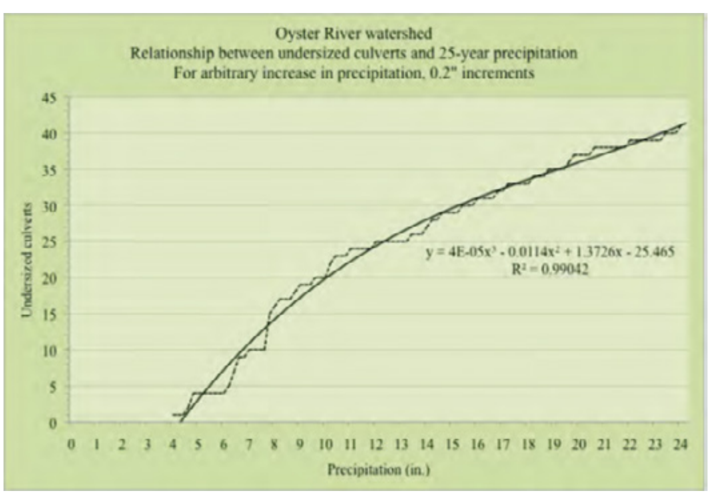


Figure 2: Relationship between increases in storm intensity and number of undersized culverts (Stack et al., 2010).

The PREP study found that incorporating LID practices in the watershed had a significant effect in lowering the projected culvert failure rate (though it should be noted that incorporating LID did not address any of the other issues associated with undersized culverts, like reduced wildlife passage). Using the most conservative of their projected climate change and development scenarios, the use of LID practices reduced the number of undersized culverts by 5%-8%. Under the most likely climate change scenario, LID practices decreased the number of undersized culverts by 25%-100%. The PREP study also estimated the incremental upgrade costs to replace culverts that are undersized. This incremental cost represents the difference between the cost of replacing an undersized culvert with one of the same size, and the cost of replacing it with a culvert designed for higher anticipated flows. The study estimated the additional cost to upgrade undersized culverts to be 49% per undersized culvert. Expected build-out under current regulations would increase the upgrade cost by 22%, however the study projected that enacting LID regulations would reduce the marginal upgrade cost to 14%. A similar approach to the one used in the PREP study can be applied to estimate the cost of upgrading undersized on a regional or statewide scale, as is discussed for Maine later in this report.

## Stormwater Management

Water quality in Maine's rivers and coastal waters has improved significantly since the middle of the 20th century, largely because of restrictions imposed on high-impact polluters in the Clean Water Act in 1972. The Clean Water Act mandated pollution controls on point source industrial and municipal polluters in Maine such as the textile and paper industries. Municipalities were also affected as they were required to construct or improve their sewage treatment systems to comply with the new requirements. The Clean Water Act also applies to "non-point" water pollution, runoff from the land and increased water flows into water bodies that occur during high precipitation events.

Such "stormwater" is regulated under the Clean Water Act, but it has taken much longer for the Federal Government to institute programs to address it, and to publish requirements for cities to upgrade their wastewater handling systems to address storm-level flows. Many older cities, such as Lewiston-Auburn, Augusta, Bangor and Portland have outdated sewer system designs which combine sanitary sewers with storm water drainage (Maine DEP, 2011). During high precipitation events, these systems allow stormwater runoff to mix with untreated sewage to discharge directly into waterways, and during rainy periods, water pollution levels exceed safety standards. In addition to the potential public health implications, there are also many negative economic consequences that result, such as the closures of shellfish flats and beaches. The EPA has begun to fine municipalities for such discharges, and gaps in conventional approaches to stormwater management are made worse by the increase in impervious surface coverage in suburbanizing areas.

In order to reduce pollution, the EPA requires municipalities to obtain a permit to discharge stormwater as part of the National Pollutant Discharge Elimination System (NPDES) Stormwater Program. This permit allows municipalities to operate a separated stormwater system, with limits on the total maximum daily load (TMDL) of pollutants. The NPDES permitting system does not allow the continued discharge of untreated stormwater from combined systems without a mitigation plan. The new rules were put into place in a two-stage process to allow municipalities to plan for and implement changes to their stormwater systems. Phase I, which covers larger cities, was issued in 1990. Phase II, issued in 1999, covers smaller urban areas and applies to many of Maine's municipalities. Permit holders are required to implement a stormwater management program that reduces stormwater runoff contamination and stops illegal discharges of pollutants.

For municipalities like Augusta, Bangor, Portland and thousands of other across the United States, solving the municipal stormwater discharge problem is the biggest infrastructure challenge they face, requiring the investment of significant sums in mitigating stormwater runoff to avoid costly penalties from the EPA. Typically, these communities respond by making investments in traditional treatment facilities located at the "end of the pipe," that is, just before wastewater is discharged into local waterways. Many municipalities in Maine do, in fact, have numerous pipes leading directly into local waterways, which greatly complicates solving the stormwater discharge problem.

One approach to upgrading stormwater systems is to separate the sewer and stormwater systems; however this can still result in untreated stormwater discharge that violates permitted pollutant levels. An alternate approach is for municipalities to construct stormwater detention basins, mostly underground, to collect stormwater during high precipitation events. Perhaps the best example of such a system is found in Chicago, which has over one hundred miles of stormwater storage tunnels (EPA, 2010) and will, by 2029, have spent $4 billion on their stormwater system. Multi-billion dollar deep tunnel projects are also underway in Washington, D.C, Portland, Oregon, and Milwaukee, Wisconsin (Garrison & Hobbs, 2011). Although the volume of stormwater during extreme storm events would overload municipal water treatment plants, when released from the storage basins or tunnels over time, the treatment facilities are able to treat at least enough of the stormwater to comply with the EPA mandates. These large conventional stormwater infrastructure projects are being installed across the country in order to treat stormwater discharge, as a better alternative to sewer and stormwater separation alone.

Other states have also provided support for reducing municipal stormwater pollution. Maryland has developed a comprehensive set of guidelines (Maryland Department of the Environment, 2011) that show different strategies for stormwater treatment based on facility age and type. For example, the guidelines break down estimated pollutant discharge based on standards in place over time. They also include a kind of "cap and trade system", where upgrades to stormwater systems in one part of a watershed can cancel deficiencies elsewhere. An important feature of the Maryland approach is that municipalities may choose combinations of built and natural infrastructure approaches to managing stormwater with explicit tradeoffs among different approaches specified based on their effectiveness in stormwater management. The Maryland program does not assign costs to the different approaches, but implicitly allows municipalities to calculate the appropriate avoided cost strategy for local hydrologic, geologic, and landscape conditions. Other states with substantial stormwater support programs include Washington, Oregon, Florida, and New York (Garrison & Hobbs, 2011).

New approaches to building stormwater management systems are designed to allow stormwater to be treated in a more cost-effective way before it even enters drainage systems through the use of decentralized built systems that attempt to mimic the function of natural systems. The term most often employed for this new approach to managing stormwater runoff is Low Impact Development (LID). Water district efforts to meet EPA mandates using LID approaches can significantly reduce stormwater discharge, and in fact are now a significant part of EPA stormwater regulations (EPA, 2013).

| Project | Conventional Development Cost | LID Cost | Cost Difference | Percent Difference |
|---|---|---|---|---|
| 2nd Avenue SEA Street | $868,803 | $651,548 | $217,255 | 75% |
| Auburn Hills | $2,360,385 | $1,598,989 | $761,396 | 68% |
| Bellingham City Hall | $27,600 | $5,600 | $22,000 | 20% |
| Bellingham Bloedel Donovan Park | $52,800 | $12,800 | $40,000 | 24% |
| Gap Creek | $4,620,600 | $3,942,100 | $678,500 | 85% |
| Garden Valley | $324,400 | $260,700 | $63,700 | 80% |
| Kensington Estates | $765,700 | $1,502,900 | -$737,200 | -96% |
| Laurel Springs | $1,654,021 | $1,149,552 | $504,469 | 70% |
| Mill Creek | $12,510 | $9,099 | $3,411 | 73% |
| Prairie Glen | $1,004,848 | $599,536 | $405,312 | 60% |
| Somerset | $2,456,843 | $1,671,461 | $785,382 | 68% |
| Tellabs Corporate Campus | $3,162,160 | $2,700,650 | $461,510 | 85% |

Table 3: LID and conventional infrastructure cost comparison in millions (EPA, 2007).

Low Impact Development infrastructure investments include a number of strategies, incorporating a large number of small systems of various types that, in aggregate, achieve stormwater treatment performance comparable or better than the conventional built approaches. They have been shown to provide a cost-effective solution in both private and public projects (Roseen, 2011; Garrison & Hobbs, 2011; Odefey et al. 2012). The approach has also been demonstrated to be more cost-effective in new construction than traditional stormwater strategies. Furthermore, retrofitting stormwater systems into older developments by municipalities has been tested and found effective. Table 3 above shows the results of a cost comparison conducted by EPA in twelve municipalities across the country, in which LID approaches were shown to be more cost-effective than conventional infrastructure in all cases but one.

Low Impact Development will usually not replace the need for centralized treatment and disposal of stormwater, but by reducing the amount of water moving through the system, LID reduces the capital and operating costs of the centralized stormwater infrastructure. This approach maximizes the benefits of the comparative advantage of both system types, and has been found to be the best option in several municipalities (Odefey, 2012, Garrison & Hobbs, 2011). The implications of this for Maine are discussed later in this report.

As with the natural infrastructure described above, an LID built infrastructure approach to stormwater management has ancillary benefits for which we do not have dollar estimates. These additional benefits include providing small-scale urban wildlife refuges and aesthetically pleasing landscaping within more developed areas. Street trees and vegetated buffer strips provide stormwater benefits by allowing water to infiltrate into soils as well as through absorption and transpiration of moisture over time. They also cool the air in summertime and reduce air pollution. Rain gardens, which are designed to collect runoff and detain it, function like vegetated buffers in natural streams, incorporating highly water-tolerant native plant species. Much of the water that collects in rain gardens will infiltrate, with excess running off only in the higher precipitation events. In places like Maine, where springtime snowmelt is a concern, rain gardens can function to retain melted water, even though their plants may be dormant. This process emulates the way that vernal pool systems function in natural areas. Artificial wetlands are essentially larger-scale rain gardens, and may be appropriate for larger planned residential or retail developments. The University of New Hampshire Stormwater Center has documented many of the ways that LID systems can provide better stormwater management results, as shown in Figure 3 below.

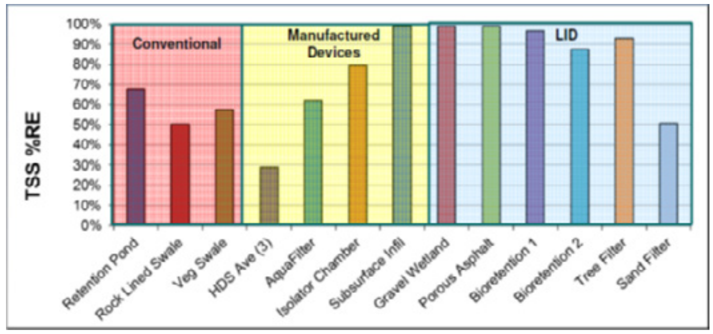



Figure 3: Percent removal of solids from stormwater by different system type, contrasting conventional with LID (Roseen et al., 2011).

Much of the technology for LID stormwater management involves potentially inexpensive redesign of traditional built infrastructure; useful changes include green or blue roofs, rain barrels, permeable pavements, and similar systems. In urban areas rooftops make up a large percentage of the impervious surface coverage. All of the water that falls onto a typical roof then runs off into the stormwater collection system, and the downspouts that channel water away from rooftops are in many cases directly connected to municipal sewer systems. Disconnecting downspouts and allowing them to run off to the surface can reduce peak stormwater volumes; downspouts can also be connected to rain barrels, to collect water for irrigation. Rain barrels can also be used as buffers by leaving their drainage valves partly open. Along similar lines, rooftops can also be connected to a cistern system, usually for non-potable water use like toilet flushing or landscaping irrigation.

One LID stormwater roof design that works much like a cistern and is called a "blue roof." It functions like a normal roof except that it allows water to collect during rain events and releases it slowly, greatly reducing peak runoff volume. A similar, though more sophisticated, system is called a green roof and involves placing vegetation and some kind of absorbent membrane on rooftops. New York City's stormwater plan provides extensive details about the use and effectiveness of LID approaches, including the ability of green and blue roof systems to reduce stormwater runoff volumes, as shown in Figure 4. This graph shows how the runoff from a significant precipitation event is concentrated with the first two hours after precipitation ends, but the release is stretched out over several hours with the blue and green roofs, reducing the amount of water entering the sewage system. The green roof is clearly the most effective at reducing peak volumes of runoff.

Permeable pavements represent another LID strategy for stormwater management. They function much like traditional pavement systems for constructing roads, sidewalks, parking lots, or other hard surfaces typical of our built

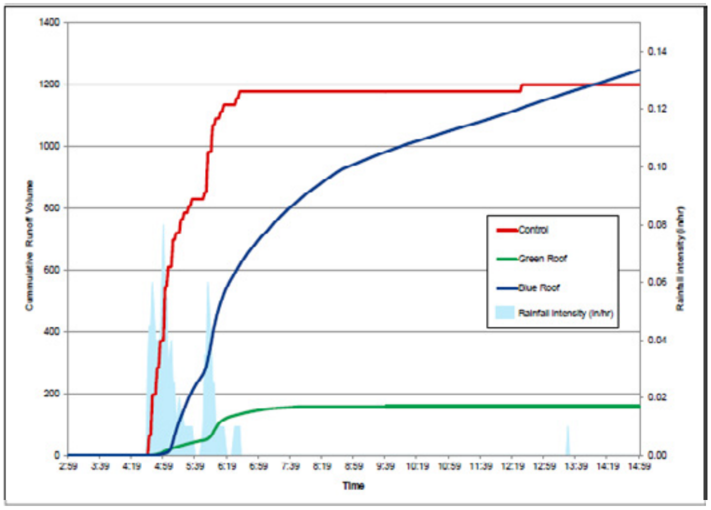


Figure 4: Comparative performance of conventional and LID systems in managing water runoff during a storm event in New York City (NYC DEP, 2011).

environments -- with an important difference. They allow stormwater to permeate their surface and infiltrate into-groundwater systems, greatly reducing peak runoff volumes. They also reduce the formation of ice in cold climates like Maine. Permeable pavements do require special care, however, as the permeable membrane can become clogged with sand or other debris. As long as they are periodically maintained, however, permeable pavements have been shown to be as durable as traditional pavements while retaining their stormwater treatment functionality.

Recent research by Roseen et al., (2011) at the University of New Hampshire Stormwater Center has shown how LID can be a more cost-effective site design technique than conventional approaches. In one example, permeable pavements and other LID infrastructure were installed in a big-box retail development and the LID design reduced overall stormwater costs by 26%. The permeable pavements of the design have many cost savings advantages over time when compared to conventional systems, although they are somewhat more expensive in initial capital costs. The new big-box development actually incorporated both permeable and conventional pavements, to capitalize on the comparative advantages of both approaches. The conventional pavement was located in higher traffic areas closer to the store's entrance. The system was designed so that runoff from the conventional pavement would infiltrate through the adjacent permeable system, and over a two-year period was found to function successfully. LID was similarly successful in residential development of detached single-family homes: in a new development in suburban New Hampshire, overall construction costs for stormwater systems were reduced by 6% with the LID design and achieved a $7,000 reduction in costs per unit construction cost. In addition, the homes sold an estimated 50% faster and were found to retain a higher value, 12% to 16%, over homes using conventional stormwater techniques.

Many large urban areas have successfully integrated LID approaches into their stormwater management plans. Here again, New York City is an innovator. (NYCDEP, 2011), New York incorporated both conventional and LID stormwater projects in a way that provided significant cost savings: the overall cost of the New York's integrated plan was $1.5 billion less than the all-conventional alternative, which consisted of constructing larger underground detention basins and more extensive upgrades to treatment facilities. The integrated plan has the additional benefit of reducing peak stormwater discharge by an estimated 2 billion gallons annually over the all-conventional plan, representing a significant improvement in water quality.

Other cities have found similar benefits from an integration of conventional and LID approaches to stormwater management. Portland, Oregon, was estimated to have saved an $61 million through choosing an integrated approach over an all-conventional approach (Garrison & Hobbs, 2011) and Kansas City, Missouri replaced a $54 million all-conventional approach with a $35 million integrated conventional and LID system for the same stormwater management capacity (Odefey, 2012). Philadelphia is also widely recognized for its LID stormwater management program, the forty-year benefit for which is estimated to range from $1,935 million to $4,466 million over an all-conventional approach (Stratus Consulting, 2009). In both New York City and Philadelphia the stormwater management programs have included a combination of LID investment requirements of both the municipality and private developers. Private investment in blue or green roofs, permeable pavements, and other LID stormwater technologies has been encouraged by significant property tax incentives.

| Municipality | Cost Savings of Integrating LID & Conventional | Reference |
|---|---|---|
| Kansas City, MO | $19 million | Odefey, 2012 |
| Portland, OR | $61 million | Garrison & Hobbs, 2011 |
| Philadelphia, PA | $1.9-4.5 million annual benefit over 40 years | Stratus Consulting, 2009 |
| New York, NY | $1.5 billion | NYC DEP, 2011 |

Table 4: Comparison of cost savings realized by a range of municipalities from integrating LID and conventional approaches to stormwater management.

A smaller city that has turned from traditional stormwater treatment to an LID approach is Syracuse, New York, which has much in common with municipalities in Maine. The area has older infrastructure as well as an industrial history, and it places a great deal of value on outdoor recreation.

The turn to an LID approach was triggered when, to comply with the EPA stormwater mandate, the city installed a "regional treatment facility" (RTF) in a low income neighborhood. This facility separates sewerage from stormwater before it enters the city's Lake Onondaga, which has been declared a superfund site since 1994. However, the treatment plant produced noxious odors and noise, and damaged the economic vitality of an already disadvantaged neighborhood. Three more similar treatment facilities were planned but neighborhood opposition blocked their construction. In 2009, a federal court required Syracuse to use LID approaches to reduce sewer overflows into Onondaga Lake and its tributaries, making it the first community in the United States to be legally required to use LID to meet Combined Sewer Overflows targets (Garrison & Hobbs, 2011).

Syracuse also engaged the public through education campaigns that increased awareness of the issue and offered specific steps private citizens can take to reduce stormwater volumes. The campaign distributed grant-funded rain barrels to city residents and the city invested extensively in the use of vegetated buffer strips and trees in the street medians. One project paved a city-owned lot with porous pavements and installed a rain garden. The city developed metrics to gauge the success of each individual project, measuring ancillary benefits as well as the reduction of pollutant discharge into area waterways.

# Economics of Water Resource Infrastructure: Evidence from Maine

Evidence from elsewhere in the U.S. described in the previous section makes clear that there are real and substantial economic benefits from choosing lower cost approaches that use locally appropriate mixes of natural infrastructure and environmentally-sensitive built infrastructure. This review of other experiences is needed because there is very little Maine-specific information about these benefits. But some studies have been done which can be summarized and we undertake preliminary analysis of some key opportunities to confirm that the growing experience elsewhere confirms the opportunities for Maine. In this section we cover:

- An estimate of land acquisition opportunities and costs based on data from The Nature Conservancy, the Land For Maine's Future Program, and Maine's Natural Resources Conservation Program
- An estimation of the costs of flood damages that could be avoided if natural infrastructure investments are made using a simulation model analysis of three watersheds in York County.
- Data on the economic values of coastal areas vulnerable to flooding as sea level rises.
- A summary of current information on culvert replacement needs.
- A summary of recent study for the Portland Water District that demonstrates the economic advantages of Low Impact Development for stormwater management.

## Natural Infrastructure Conservation Need Analysis for Maine

In order to quantify the potential investments needed to ensure that Maine's natural infrastructure can continue to provide critical benefits to society, it is necessary to first identify the places in the state where natural areas are currently providing these benefits. Conservation planners at The Nature Conservancy recently worked with a range of partners to complete just such an analysis. This work highlights places in Maine where natural habitat that is not currently in some level of conservation status can be credibly expected to provide one or more of the following water-related benefits to society: drinking water supply, flood attenuation, and wildlife habitat. The analysis identified the places projected to provide each of these individual benefits, as well as those places likely to provide multiple benefits. Figure 5 shows a zoomed map of The Nature Conservancy's statewide data focusing on three watersheds in York County. (A full map of Maine may be found in Appendix 1 below.) Table 5 summarizes the data set by county.

The Conservancy's analysis of conservation opportunities provides the basis for estimating the potential costs of conserving land for natural infrastructure purposes. The Conservancy provided possible acreage figures while data from two statewide programs that fund the conservation of natural areas can be used for price data. This data comes from the Land for Maine's Future program (LMF), which has used voter-approved bond revenue to conserve land statewide since 1987, and the Maine Natural Resources Conservation Program (MNRCP), which has used in-lieu fee payments to fund compensatory mitigation projects statewide since 2009. The two data sources include both conservation easement and fee simple acquisitions, and were used to create average land conservation cost estimates on a per acre basis by county. After low and high outliers (above two standard deviations) were removed from the data, the total sample size was 236 projects.

Table 6 shows the resulting cost estimates by county. The column "Overall Cost Per Acre" shows the cost to all parties for conserving land. Since both the Land for Maine's Future

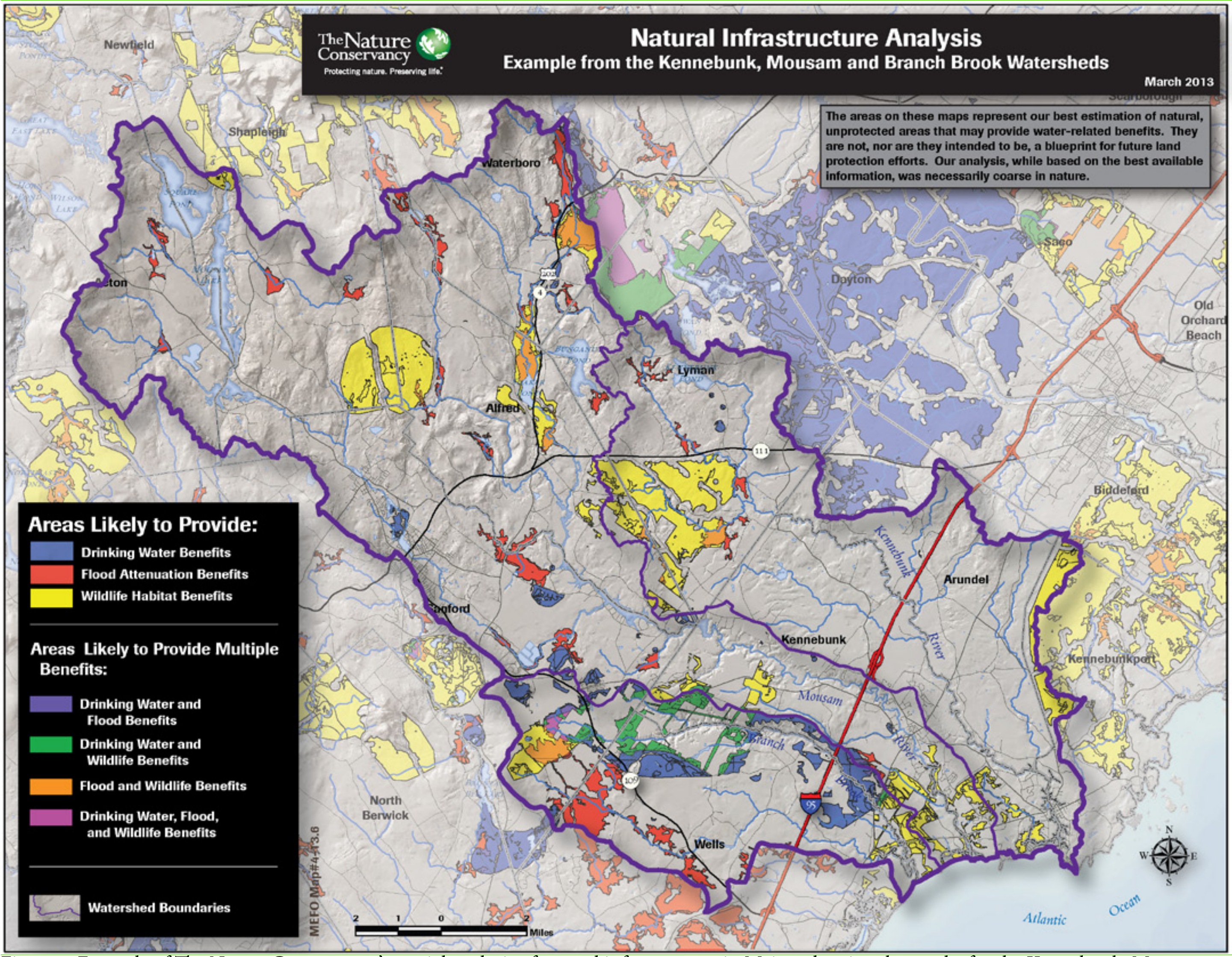



Figure 5: Example of The Nature Conservancy's spatial analysis of natural infrastructure in Maine, showing the results for the Kennebunk, Mousam and Branch Brook / Merriland River watersheds.

| County | Flood Control Benefit | Drinking Water Benefit | Flood Control AND Drinking Water Benefits | Flood Control OR Drinking Water Benefits | All Benefits (incl. Wildlife Habitat) |
|---|---|---|---|---|---|
| Androscoggin | 7,633 | 11,634 | 147 | 19,119 | 21,968 |
| Aroostook | 120,375 | 167,696 | 9,049 | 279,023 | 369,673 |
| Cumberland | 5,757 | 38,052 | 1,586 | 42,224 | 56,631 |
| Franklin | 10,640 | 13,306 | 133 | 23,813 | 104,689 |
| Hancock | 14,454 | 14,644 | 129 | 28,969 | 100,734 |
| Kennebec | 16,472 | 14,472 | 1,348 | 29,596 | 62,098 |
| Knox | 4,898 | 2,205 | 0 | 7,103 | 22,532 |
| Lincoln | 7,670 | 3,039 | 147 | 10,562 | 23,105 |
| Oxford | 15,035 | 46,443 | 985 | 60,493 | 118,008 |
| Penobscot | 76,576 | 4,360 | 218 | 80,717 | 152,966 |
| Piscataquis | 21,553 | 14,144 | 314 | 35,383 | 100,739 |
| Sagadahoc | 1,674 | 5,991 | 80 | 7,585 | 28,779 |
| Somerset | 28,738 | 47,625 | 894 | 75,470 | 127,098 |
| Waldo | 14,002 | 874 | 4 | 14,873 | 30,441 |
| Washington | 48,401 | 12,343 | 387 | 60,357 | 183,288 |
| York | 20,912 | 30,361 | 1,594 | 49,679 | 112,121 |
| **Total** | **414,790** | **427,189** | **17,015** | **824,966** | **1,614,870** |

Table 5: Acres of potential natural infrastructure from spatial analysis conducted by The Nature Conservancy.

| County | Total Acres | Overall Cost / Acre | Standard Deviation | Project Count |
|---|---|---|---|---|
| Androscoggin | 38,533 | $1,028 | $849 | 5 |
| Aroostook | 6,244 | $831 | $865 | 8 |
| Cumberland | 8,813 | $5,947 | $8,345 | 51 |
| Franklin | 28,143 | $818 | $646 | 10 |
| Hancock | 46,582 | $976 | $1,052 | 11 |
| Kennebec | 6,864 | $1,388 | $737 | 6 |
| Knox | 912 | $3,710 | $1,653 | 8 |
| Lincoln | 1,326 | $2,456 | $1,595 | 9 |
| Oxford | 9,651 | $1,255 | $761 | 10 |
| Penobscot | 6,156 | $1,619 | $1,440 | 12 |
| Piscataquis | 243,548 | $755 | $578 | 8 |
| Sagadahoc | 2,991 | $3,142 | $2,275 | 19 |
| Somerset | 64,396 | $1,742 | $1,870 | 7 |
| Waldo | 2,313 | $2,394 | $2,716 | 10 |
| Washington | 83,499 | $2,128 | $2,171 | 37 |
| York | 15,381 | $3,027 | $2,367 | 25 |
| **Total** | **565,351** | **$2,076** | **$1,870** | **236** |

Table 6: Per acre cost estimates for land conservation in Maine, based on Land for Maine's Future and Maine Natural Resource Conservation Program acquisition data. The Overall Cost/Acre column, presented in bold, is used for the overall acquisition cost estimate below.

program and the Maine Natural Resource Conservation Program share funding for most projects with different partners, this is the best representation of what an acre of conserved land has cost in each county. Standard deviation values are included to help emphasize that this is a rough estimate for planning purposes, and that actual conservation costs will vary significantly.

As this analysis shows, an investment of $28.8 million could conserve all of the places projected to provide both drinking water supply and flood control benefits for communities across Maine. Purchase of all the land that the Conservancy estimates is valuable for either flood control or drinking water protection would cost $1.36 billion at this average price, less than 1% of the total value of land in Maine estimated to be $153 billion. To gauge the magnitude of this theoretical expenditure, it can be compared with the value of public water supply property exempt under Maine law. Table 8 shows the 2011 value of this property for each county. The total value of exempt property is approximately $275 million, and this is certainly an understatement as the values for some systems, such as in Lewiston-Auburn are not included in this data. In other words, the value of current infrastructure to manage public water supply is more than 10 times higher than what it would cost to conserve all of the land that provides both water quality and flood control benefits. Even the theoretical maximum of over $700 million to acquire land for drinking water quality is not out of line with the current value of what we have already spent for water supply infrastructure. This does not mean that additional investments to upgrade, repair, and maintain built water supply infrastructure will not be necessary, but the costs may be significantly reduced if natural infrastructure is included in the long term investment mix.

| County | Flood Control Benefit | Drinking Water Benefit | Flood Control AND Drinking Water Benefits | Flood Control OR Drinking Water Benefits | All Benefits (incl. Wildlife Habitat) |
|---|---|---|---|---|---|
| Androscoggin | $7,846,621 | $11,959,793 | $151,621 | $19,654,793 | $22,583,555 |
| Aroostook | $100,031,716 | $139,355,615 | $7,519,580 | $231,867,752 | $307,198,325 |
| Cumberland | $34,237,310 | $226,297,002 | $9,429,738 | $251,104,574 | $336,785,692 |
| Franklin | $8,703,489 | $10,884,491 | $108,548 | $19,479,432 | $85,635,796 |
| Hancock | $14,106,759 | $14,293,008 | $125,901 | $28,273,866 | $98,316,298 |
| Kennebec | $22,863,828 | $20,086,986 | $1,871,444 | $41,079,370 | $86,191,368 |
| Knox | $18,169,934 | $8,180,655 | $282 | $26,350,308 | $83,595,010 |
| Lincoln | $18,838,137 | $7,462,713 | $360,181 | $25,940,669 | $56,746,864 |
| Oxford | $18,868,762 | $58,285,916 | $1,236,156 | $75,918,521 | $148,100,576 |
| Penobscot | $123,976,247 | $7,058,235 | $353,179 | $130,681,303 | $247,651,381 |
| Piscataquis | $16,272,206 | $10,678,921 | $236,946 | $26,714,181 | $76,057,664 |
| Sagadahoc | $5,259,375 | $18,824,498 | $250,622 | $23,833,250 | $90,422,770 |
| Somerset | $50,062,305 | $82,963,124 | $1,556,712 | $131,468,717 | $221,405,287 |
| Waldo | $33,521,490 | $2,092,475 | $9,091 | $35,604,874 | $72,876,141 |
| Washington | $102,997,569 | $26,265,216 | $823,790 | $128,438,995 | $390,037,813 |
| York | $63,300,199 | $91,901,664 | $4,825,043 | $150,376,820 | $339,389,227 |
| **Total** | **$639,055,948** | **$736,590,311** | **$28,858,835** | **$1,346,787,425** | **$2,662,993,768** |

Table 7: Estimates of total investments needed to conserve areas of projected natural infrastructure, listed by county and by different benefits.

| County | Public Water Supply Exempt Property |
|---|---|
| Androscoggin | $0 |
| Aroostook | $4,780,720 |
| Cumberland | $163,164,373 |
| Franklin | $17,467,071 |
| Hancock | $202,800 |
| Kennebec | $18,799,300 |
| Knox | $1,262,400 |
| Lincoln | $924,100 |
| Oxford | $3,209,270 |
| Penobscot | $37,456,500 |
| Piscataquis | $1,650 |
| Sagadahoc | $3,508,560 |
| Somerset | $7,094,166 |
| Waldo | $134,080 |
| Washington | $3,579,365 |
| York | $13,370,200 |
| **TOTAL** | **$274,954,555** |

Table 8: Value of Public Water Supply Exempt Property (Maine Revenue Services, 2011).

Potential investments in conserving land for other natural infrastructure benefits represents a theoretical maximum whose benefit-cost ratio will vary from that of the water supply/flood control categories, and there is no implication here that all such investments will be economically worthwhile. However this analysis indicates that the benefit-cost ratios are likely to exceed 1 in many cases, which means that state, regional, and municipal investment strategies for water resources should become more familiar with the economic benefits in order to make the best decisions.

This will require careful development of criteria to optimize the potential value to society of these types of investment in water resource infrastructure. For example, investments in drinking water supply could be focused on high value aquifers or on surface water systems with filtration avoidance waivers. A great deal of literature exists detailing the costs and the benefits of this type of drinking water supply conservation and an example of a detailed analysis of the costs and benefits of conservation investments for drinking water quality protection is found is presented later in this report. The same principle applies to investments for flood control, for which an example is also offered in the next section.

## Avoided Costs of Riverine Flooding in York County (Natural Infrastructure)

The estimation of flood control benefits from investments in natural infrastructure requires detailed investigation of the hydrography, geology, population, and land uses in specific watersheds. This process can be illustrated for several watersheds in Maine using a simulation model of flood damages developed for the U.S. Federal Emergency Management Agency (FEMA) known as HAZUS. We used this simulation model to estimate the avoided costs due to increased flooding as a result of wetland loss in three watersheds in York County. The three selected watersheds—Branch Brook / Merriland River watershed (also known as Little River), Kennebunk River, and Mousam River—provide a good example for other small to medium sized watersheds in Maine because they contain a mixture of developed and rural land uses. The largest city in the watersheds, Sanford, is the seventh largest municipality in the state.

The Branch Brook / Merriland River watershed drains 31 square miles and had an estimated population of 3,650 (U.S. Census Bureau, 2010). One of its tributaries, Branch Brook, provides drinking water for the Kennebunk, Kennebunkport, and Wells Water District. The upper reaches of the watershed contain the Wells Barrens / Kennebunk Plains, an area identified by conservation groups as providing critical wildlife habitat (Beginning with Habitat, 2007). Much of the Branch Brook / Merriland River watershed is conserved, with 34% of the area in some conserved or regulated status (SWIM, 2013). However, an additional 41% is open space that might be vulnerable to development.

The Kennebunk River watershed is slightly larger than the Branch Brook / Merriland River watershed, draining 38 square miles with a 2010 population of 10,919 (U.S. Census Bureau, 2010). Towns in the drainage area include Arundel, Lyman, Kennebunk, and Kennebunkport. While the watershed does not provide a municipal drinking water supply, this river does provide critical wildlife habit including rare Atlantic White Cedar communities (SWIM, 2013). Several conservation areas exist in the watershed; however, it still faces extensive development pressure. Single family homes are replacing agricultural land uses in the watershed. In addition, large-scale retail development has been increasing, especially in the southern reaches of the watershed along U.S. Route 1 (SWIM, 2013). The development changes may be increasing the frequency of severe flooding, as happened in 2006 and 2007, although more information is necessary to establish that this increase is statistically significant.

The Mousam River watershed is located between the Kennebunk and Branch Brook / Merriland River watersheds. In addition to the City of Sanford, portions of the towns of Acton, Shapleigh, Alfred, Waterboro Lyman, and Kennebunk are in the Mousam River watershed. The Mousam River Watershed drains 122 square miles and had a total population of 27,078 in the 2010 census. The Mousam River watershed is another useful example due to its recent history of flooding.  The section of the river in Kennebunk had significant flooding in May 2006 during the Mother's Day storm and in 2007 during the Patriot's Day storm. During these events several homes in Kennebunk's Intervale neighborhood were damaged or destroyed (Gleason, 2010).  According to a report issued by the US Geological Survey (2008) the 2006 flood event represented a 500-year flood based on current estimates of high-precipitation event frequency.

In order to generate estimated flood damages for the three rivers, FEMA's HAZUS model was used to generate an estimate for flood losses in an area under given flood scenarios. The key variable explored in this analysis is the effect that wetland function loss might have on flood damages taking into account the probability of flooding.  Flood probabilities are often expressed using terms like "10-year" or "100-year" flood.  This description is usually taken to mean that a 10-year flood is one that will occur every 10 years, or a 100-year flood as one that will occur every 100 years.  However this is not quite accurate.  The term "10-year" flood actually means that there is 10% (0.10) chance of a flood that size occurring every year.  On average over ten years, the flood has a chance of occurring once, but there is actually a chance that it will occur each year.  The 10-year flood is much more likely than a 500 year flood (10% every year, v. 0.2% every year.)   This is why very large, very low probability floods occurred within one twelve month period, in 2006 and 2007 in York County. The probability of this sequence happening naturally is roughly 1/250,000 but the fact that it has already happened in York County underscores the importance of planning and investing even for seemingly remote possibilities.

HAZUS allows analysis of wetland functionality through a feature allowing the modeling of "flood control structures"[1]. This estimates flood damages in both the Branch Brook/ Merriland River and Kennebunk River systems, using the 10, 25, 50, 100, and 500-year floods to model damages. The Mousam River damage estimates were extrapolated from the Kennebunk and Branch Brook / Merriland River systems—HAZUS did not model open space flood management in the Mousam River watershed well because it contains a number of conventional flood control systems.  The total values for non-conserved wetlands in the respective watersheds was 1,625 acres for the Branch Brook / Merriland River, 2,864 acres in the Mousam River, and 492 in the Kennebunk River.

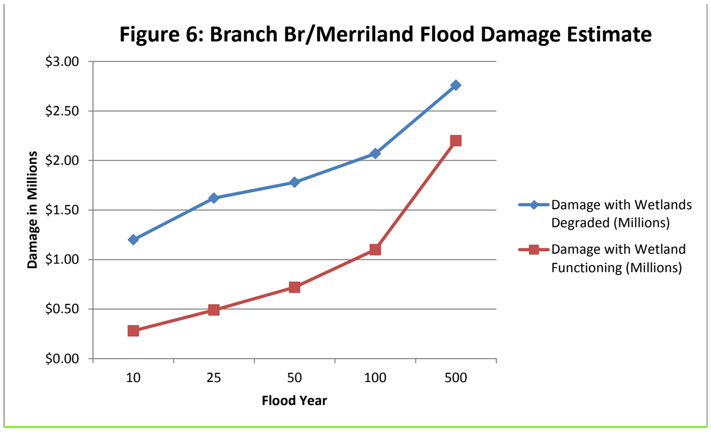
The following tables and figures are organized to present the results of this analysis for several different variables.  As outlined in the tables, these are:

- Flood Year: Expected return period magnitude intervals of flood events
- Damage With Wetlands Functioning: This is the damage estimate for the watershed with intact wetland systems.
- Damage With Wetlands Lost: This is the damage estimate for significant loss of wetland functionality
- Percent Change in Damages: This is the percent difference between each damage condition, for each flood year interval
- Annual Probability of Flood Event: This is the flood interval expressed as a probability
- Risk Adjusted Annual Damages With / without Wetlands: This shows, for each flood magnitude category, the risk in a given year. It is calculated by multiplying the probability of occurrence by the damage estimate. It is shown in two columns, with and without intact wetland functionality
- The final values, under each Risk Adjusted Annual Damage column, show the total estimated flood damages based on the summed values for each magnitude interval. This is shown both as an annual value, and as a 30 year total based on a 3% discount rate.

[1]Traditionally this would mean dams or similar impoundments, but since HAZUS does not include native support for modeling of wetland functionality loss or impairment, it was modeled using this parameter. Flood policy experts have supported policies of "treating natural wetlands as flood control devices" (Brody et al., 2011). It must be noted that this assumes total wetland loss in the event wetlands are not protected, which is possibly unrealistic, however it would be difficult to capture a situation where wetlands are only partly degraded using this method as it is very time consuming. However, for planning and conceptual illustration purposes, this method is quite useful.

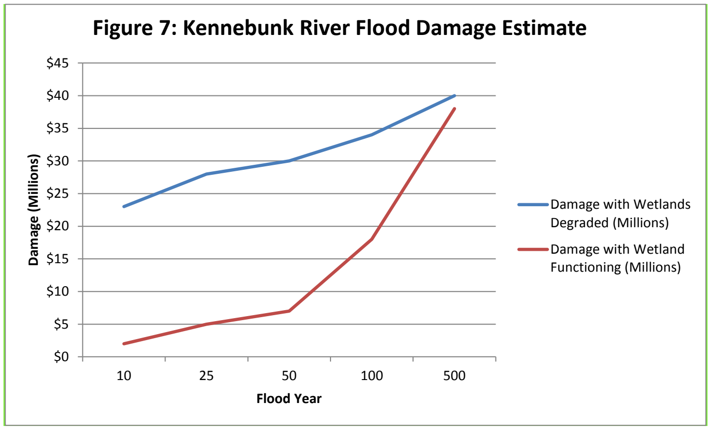
| Flood Year | Damage w/Wetlands Functioning (Millions) | Damage w/Wetlands Lost (Millions) | Percent Change in Damages | Annual Probability of Flood Event | Risk Adjusted Annual Damages w/ Wetlands (Millions) | Risk Adjusted Annual Damages w/o Wetlands (Millions) |
|---|---|---|---|---|---|---|
| 10 | $0.28 | $1.20 | 329% | 0.1 | $0.028 | $0.120 |
| 25 | $0.49 | $1.62 | 231% | 0.04 | $0.020 | $0.065 |
| 50 | $0.72 | $1.78 | 147% | 0.02 | $0.014 | $0.036 |
| 100 | $1.10 | $2.07 | 88% | 0.01 | $0.011 | $0.021 |
| 500 | $2.20 | $2.76 | 25% | 0.002 | $0.004 | $0.006 |
| | | | | **Annual Total** | **$0.077** | **$0.247** |
| | | | **Expected Present Value over 30 years** | | **$1.51** | **$4.84** |

Table 9: Flood damage estimates for the Branch Brook/Merriland River watershed, discounted at 3%.



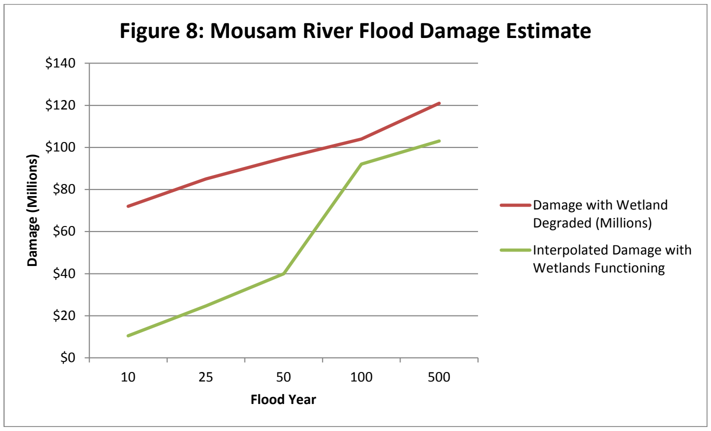

| Flood Year | Damage w/Wetlands Functioning (Millions) | Damage w/Wetlands Lost (Millions) | Percent Change in Damages | Annual Probability of Flood Event | Risk Adjusted Annual Damages w/ Wetlands (Millions) | Risk Adjusted Annual Damages w/o Wetlands (Millions) |
|---|---|---|---|---|---|---|
| 10 | $2 | $23 | 1050% | 0.1 | $0.20 | $2.30 |
| 25 | $5 | $28 | 460% | 0.04 | $0.20 | $1.12 |
| 50 | $7 | $30 | 329% | 0.02 | $0.14 | $0.60 |
| 100 | $18 | $34 | 89% | 0.01 | $0.18 | $0.34 |
| 500 | $38 | $40 | 5% | 0.002 | $0.08 | $0.08 |
| | | | | **Annual Total** | **$0.80** | **$4.44** |
| | | | **Expected Present Value over 30 years** | | **$15.70** | **$87.15** |

Table 10: Flood damage estimates for the Kennebunk River watershed, discounted at 3%.




| Return Period | Damage w/ Wetland Lost (Millions) | Mean % Damage Increase from Wetland Loss | Interpolated Damage with Wetlands Functioning (Millions) | Annual Probability of Flood Event | Risk Adjusted Annual Damages w/ Wetlands (Millions) | Risk Adjusted Annual Damages w/o Wetlands (Millions) |
|---|---|---|---|---|---|---|
| 10 | $72 | 689% | $10 | 0.1 | $1.04 | $7.20 |
| 25 | $85 | 345% | $25 | 0.04 | $0.98 | $3.40 |
| 50 | $95 | 238% | $40 | 0.02 | $0.80 | $1.90 |
| 100 | $104 | 89% | $92 | 0.01 | $0.92 | $1.04 |
| 500 | $121 | 15% | $103 | 0.002 | $0.21 | $0.24 |
| | | | | **Annual Total** | **$3.95** | **$13.78** |
| | | | **Expected Present Value over 30 years** | | **$77.53** | **$270.50** |

Table 11: Interpolation of flood damage estimates for the Mousam River[1].




[1]HAZUS was used to calculate baseline flood damage estimates for each flood year in the Mousam River. However, the effects of wetland functionality in the Mousam was not modeled using HAZUS. Instead, the percent change was interpolated from modeling on the neighboring rivers where a HAZUS analysis was run. Running wetland analysis for the Mousam River greatly exceeded available staff time.

| Watershed | Expected Present Value Flood Losses without wetlands | Expected Present Value Flood Losses with wetlands | Expected Present Value of Avoided Flood Damages | Acquisition Costs at State Conserv. Lands Average | Net Benefits | Benefit-Cost Ratio |
|---|---|---|---|---|---|---|
| Branch Brook | $4.84 | $1.51 | $3.33 | $4.92 | ($1.59) | 0.68 |
| Mousam River | $87.15 | $15.70 | $71.45 | $8.67 | $62.78 | 8.24 |
| Kennebunk | $279.50 | $77.53 | $201.97 | $1.49 | $200.48 | 135.55 |
| **Total** | **$371.49** | **$94.74** | **$276.75** | **$15.08** | **$261.67** | **18.35** |

Table 12: Summary of HAZUS Analysis by Watershed and Comparison with Costs.

The results of the HAZUS analysis for each of the watersheds are shown in Table 12. This table shows the expected present value of the HAZUS-estimated flood damages if key unprotected wetlands are unavailable to attenuate floods and mitigate flood damages and the expected values if those wetlands are available to provide flood control services. The differences between these two estimates are the avoided flood damages and the benefits of conserving the wetlands. These net benefits are estimated to total over $275 million on an expected present value basis.

Using the earlier analysis combining the acres of land to be conserved for flood control benefits with the average prices from past State conservation lands purchases it is possible to approximate the benefits and costs of using natural infrastructure investments to mitigate flood damages in these York County watersheds (also shown in Table 12). Subtracting costs from benefits yields positive net benefits in two of the three watersheds and in the three watersheds combined. Using the assumptions in the analysis, the net benefits in the smallest of the watersheds, Branch Brook, are negative. This is not surprising as the flood mitigation benefits from conserved lands are likely to require relatively large landscapes to have their greatest effectiveness. The net benefits in the other, larger, watersheds are significant, however, exceeding the estimated costs by more than $260 million, with an overall benefit/cost ratio of more than 18 to 1.

Care should be taken in interpreting these results as they were estimated using relatively gross approximations. There is no implication here that the benefits will exceed the costs for any particular project in these watersheds. But the analysis does show that, particularly for the larger watersheds, flood control benefits in the form of reduced damages could be quite large compared with the costs of purchasing the land to realize those benefits. It should also be noted that other benefits resulting from protecting drinking water are available on over 200 acres used for flood control based on the Conservancy's analysis. Non-market wildlife habitat protection benefits would be available on nearly 1,300 acres.

For project-level economic evaluation more detailed data on land use, vulnerabilities, and possible flood behaviors are needed beyond the average values used here. This is possible by combining HAZUS estimates of flood events with the US Army Corps of Engineers Hydrological Engineering Center River Analysis System (HEC-RAS).

## Coastal Flood Protection Investments (Natural Infrastructure)

Both natural and built infrastructure can contribute to the process of adapting to higher and more frequent coastal flood events in ways that are economically cost effective and ecologically friendly, but the data and analytic tools to estimate overall or specific benefits and costs are not currently available for Maine. Estimates of the size of values at risk from increased coastal flooding to sea level rise are available to give an idea of importance of addressing appropriate natural and built infrastructure strategies for coastal flooding. The general size of economic values are suggested in a study by Pendleton (2006) and shown in Table 13 which presents estimates of economic values associated with functioning estuaries in Maine that are vulnerable to damage and degradation as sea level rise continues.

One study (Colgan & Merrill, 2008) estimated that lost wages alone in the coastal regions of York County from a large storm event at $41.5 million. This study made the case for how climate change will only worsen the economic outcome for developed coastal areas during storm events. While this study focused on southern coastal Maine, given the analysis of marsh transgression (the movement of marsh inland as water rises) discussed by Mansfield (2012) such methods for adapting policy to climate change apply to all of coastal Maine.

| Valuation | Amount | Other Value | Study Details |
|---|---|---|---|
| Maine Commercial Fisheries | $306.7M from estuaries | 83.6% of Total Value | 2004 Landings: Value of Top Estuarine Dependent Species |
| Tourism, Maine | 16.159 Million Annual Beach Visitation Days, 13.513 Million Annual Days Swimming | 4.3 Million Annual Visitation Days Waterside | Based on 2001 Study |
| Recreational Fishing, Maine | $45M Low - $297M High | 2.967M Annual Visitation Days | 2005 Estimate |
| Coastal Wildlife Viewing, Maine | $200M Low - $1,998M High | 19,982 Annual Visitation Days | 2005 Study |

Table 13: Studies demonstrating the economic value of coastal estuaries in Maine (Pendelton, 2006).

Maine has policies to protect the key coastal wetlands of beaches. The Coastal Sand Dune Rules issued by the state (MDEP, 2006) issued under the Maine Natural Resources

Protection Act (38 M.R.S.A. §480-A), limit the construction or reconstruction of buildings greater than 35 feet in height or 2,500 square feet in size unless the applicant demonstrates the site will remain stable after allowing for a two foot rise in sea level over 100 years, and the increased height will not have an unreasonable adverse effect on existing uses including native dune vegetation and recreational beach use.

Protection of Maine's tidal marshes is also critical part of mitigating coastal flooding. According to the latest data provided by the Maine Natural Areas Program, there are approximately 21,890 acres of tidal marches in Maine (2013). The total area of tidal features, including mudflats and the latest tally of marshlands, was 27,289 acres. However, this figure represents a system in constant flux. A recent analysis of tidal marsh transgression (Mansfield, 2012) in the eastern coastal regions of Maine estimated that marsh transgression over the last fifty years has varied significantly depending on local conditions. In areas exposed more directly to open water, salt marshes were eroding quickly, at a rate of up to one meter per year. However, marshes not exposed to open water were found to give significant protection to abutting freshwater marshes at current rates of sea level rise. The study also found that sediment accumulation rates were slightly behind rates of sea level rise in most marshes. As a result, future saltwater marsh transgression rates could be much higher. In Downeast Maine, this could threaten cranberry bogs, human settlements, as well as other areas adjacent to saltwater marshlands.

In Maine's coastal urban areas, many of the tidal wetlands and marshlands have been filled in and developed. This is particularly true in Portland, where whole neighborhoods have been built on filled wetlands and are vulnerable to flooding due to sea level rise. Expensive hard barriers, such as sea walls may be the only feasible ways to address coastal flooding issues in urban areas. One recent simulation scenario modeled the economic cost / benefits of building a hurricane barrier in Portland, which could be erected across its Back Cove in the event of a high storm surge forecast (Merrill et al., 2012). While such a barrier was found to be cost effective, hard barriers can redirect wave energy elsewhere, intensifying flood damage outside of protected areas (Maine's Climate Future: Coastal Vulnerability to Sea Level Rise, 2009). In this case, where barriers are constructed, it may be worthwhile to consider investing in enhanced protections of surrounding natural flood protection infrastructure beyond current guidelines.

Investments in infrastructure of various types can protect development along Maine's vulnerable bluff lands and its beaches. However, in some areas the costs to protect such real estate may far exceed its value. Policies to encourage the retreat of buildings from the shore have long been discussed, but recent changes in the Federal Flood Insurance will have the most immediate effect. These changes will phase out the subsidies that building owners in vulnerable areas have received in which rates did not reflect actual risks. After storms, owners of damaged properties will be faced with either elevating the buildings above likely flood levels or paying stratospheric insurance premiums (New York Times, 2013). The net effect will be to restore some of the natural infrastructure functioning of shore lands. In areas where this occurs, decisions about publicly provided infrastructure will have profound effects on the future of post-storm damaged communities, as New York and New Jersey are currently finding in the wake of Hurricane Sandy.

## Upgrading Culverts in Maine (Built Infrastructure)

The Maine Department of Transportation, municipalities, federal agencies, as well as non-profit organizations like Maine Audubon and The Nature Conservancy are currently working to develop a full inventory of the number of undersized culverts in Maine and an estimate for the incremental cost increase of upgrading them to a size that is suitable for maintaining aquatic systems connectivity and ensuring public safety in the face of increasing water flows. In addition, a number of organizations are developing approaches to prioritize replacement of the culverts which are most likely to fail, and which would provide the largest benefits to wildlife and to promoting the resiliency of our transportation networks. Researchers with the Maine Sustainability Solutions Initiative at the University of Maine are currently working on a decision-support tool to map culvert locations, analyze replacement needs and costs, and identify potential funding sources for their replacement (University of Maine Research Highlights, 2013). Such a tool would provide great value for the statewide prioritization process.

In the interim, organizations are collaborating to develop prioritization methods at the watershed and municipal scale. One such approach—described in more detail in Appendix 2—prioritizes aquatic connectivity improvements for four municipalities: Bangor, Belfast, Houlton and Lyman. The results are summarized in Table 13 below, and suggest that fewer than 20% of road-stream crossings in municipalities are priorities to upgrade for ecological purposes.

Initial attempts have been made to approximate the total number of road-stream crossings in Maine, though the number is challenging to calculate because there are so many small culverts in the state. A recent study by the New

| Munici-pality | Total # of road-stream crossings | # of cross-ings that are barriers | # of barri-ers on town or private roads | # of priority barriers for restoration | % of total crossings that are priorities |
|---|---|---|---|---|---|
| Bangor | 30 | 15 | 4 | 3 | 10% |
| Belfast | 36 | 17 | 7 | 6 | 17% |
| Houlton | 70 | 34 | 24 | 15 | 21% |
| Lyman | 45 | 32 | 22 | 8 | 18% |
| **Total** | **181** | **98** | **57** | **32** | **18%** |

Table 14: Summary of aquatic connectivity improvement case study for four municipalities in Maine (TNC, 2013).

England Environmental Finance Center (NEEFC, 2011) underscored this point, noting that current estimates do not include thousands of crossings on intermittent and seasonal streams. The report was commissioned to provide a cost estimate for a 2010 bill then under consideration by Maine's legislature that would have required all culvert replacements in the state to be 1.2 times bank-full width, which is considered a national standard to allow improved wildlife passage and flood resiliency. The NEEFC study estimated the number of road-stream crossings in Maine conservatively at 35,000, including crossings in northern forest lands and elsewhere which would have been exempt from the new standard. The NEEFC study estimated that the total number of non-exempt statewide culverts was approximately 30,000. In addition, the NEEFC report estimated the cost to upgrade all of the state's culverts to the new 1.2 bank-full width standard at $230-$474 million, though it's important to note that only a small portion of the culverts in the state are typically replaced each year.

The NEEFC study attempted to prioritize which of the state's 35,000 road-stream crossings would make most sense to upgrade first. While it is a broad generalization to apply the above analysis of four municipalities to the entire state, if 18% of the state's culverts were likewise found to be top priorities for replacement, then one could extrapolate that the total cost of replacing the highest priority crossings would be approximately $41-85 million. Applying the previously described outcome of the New Hampshire culvert study (Stack, 2010)—that the additional cost to upgrade undersized culverts is approximately half-again the cost per culvert—it is possible to further extrapolate that a total investment of approximately $14-28 million would be required to cover the marginal increased costs of upgrading Maine's highest priority crossings. This is a conservative estimate because, for standardization purposes, the 2011 NEEFC study considered only the costs of replacing culvert pipe, whereas in practice a diversity of other costs are also incurred in culvert replacements, and vary widely between projects (e.g., with ledge that may need to be blasted, roads nearby that may need closure and transportation staff to monitor, etc.).

While these and other studies in New Hampshire and Vermont referred to earlier have attempted to estimate the size of the culvert replacement problem in both the magnitude of potential culvert replacements and the costs of making the replacement, no estimates of the benefits of replacement have been found. The avoided-cost benefits will consist of a reduction in the number of times a culvert has to be replaced over a future period plus the increased expenditures needed to replace washed out roads, which are usually much more severely damaged with undersized culverts. Maine DOT has not kept records on its expenditures related to culvert failures, so it is not possible to estimate the benefits from future replacements.

## Low Impact Development for Stormwater Management (Built Infrastructure)

Maine is making a great deal of progress in dealing with the stormwater (or Combined Sewer Overflows, CSOs) issue. State-level program support for municipal stormwater compliance comes from the Maine Department of Environmental Protection (Maine DEP). According to the Maine DEP 2011 CSO Report, Maine currently has thirty-two municipalities with CSOs, down from a high of sixty in 1989. Statewide, the volume of untreated sewerage released has also fallen by approximately 80%. However, much work remains in order to reach full statewide compliance with the EPA mandate. There are currently 163 CSO outfalls (or discharge pipes) distributed throughout the state. According to the report, communities have invested $415.1 million in CSO abatement since the process began. It estimates an additional $142.7 million must be spent on this process in the next five years, with an at least an additional $200 million to follow.

Recently, Portland began work on a 2 million gallon stormwater detention system under Baxter Boulevard, which will intercept combined sewer and stormwater that currently flows into the Back Cove during storm events. This system is expected to cost $10 million and take eight months to complete. The City has also decided to invest $170 million to reduce the overflow discharge from 400 million gallons per year to 87 million gallons per year (Billings, 2013). While this type of built infrastructure is necessary to meet EPA mandates, it has some negative economic effects in terms of associated construction disruptions and strain on public budgets, particularly when compared to what are often less expensive and more effective LID alternatives that have been implemented in many municipalities across the country.

While Maine has not employed LID for stormwater management to any large extent, there have been several recent developments that indicate its use will become more widespread. An example is the Bangor Area Stormwater Group, which promotes LID approaches to stormwater management. According to its website (2013) the group's activities have saved taxpayers in its operating area over $400,000 dollars. The City of South Portland has also made efforts to support LID by issuing a guide to LID construction practices on its website (2013). Many other groups are working on reducing stormwater pollution in Maine, including the Casco Bay Estuary Partnership, the Cumberland County Soil and Water Conservation District, the Maine Sea Grant program, Think Blue Maine, the Friends of Casco Bay, and many other dedicated organizations.

Encouraging LID techniques on private property is essential to meeting municipal water quality goals in Maine, since 95% of all land is privately owned. While regulatory measures can encourage a move toward lower stormwater impacts in future developments, measures must be taken to retrofit existing buildings and infrastructure. Maine's residential housing stock is one of the oldest in the nation and as such lags significantly in terms of stormwater attenuation in most of its built environment. Older buildings may have larger parking lots than necessary or downspout connections directly to the sanitary sewer. Applying regulations retroactively is very costly and politically problematic, however and so publically financed alternatives at the municipal level are more feasible. Low Impact Development approaches can be used to treat stormwater as it runs off private property and onto public property through decentralized methods such as street trees, rain gardens, and other techniques available to municipalities. However, if public financing is to support meeting water quality goals through actions on private lands, much more information on the economic costs and benefits will be needed to inform decisions on what types of private actions should be supported as the most cost effective use of public funds.

While LID approaches have significant potential to enhance water resource management for the urbanized parts of Maine, there are also opportunities for diffused built infrastructure to benefit the state's more rural areas. As an example, in 2010 the Maine Potato Board sponsored a survey of farm operations that spanned the state from Fryeburg to Fort Kent (see Appendix 3). Of particular interest was the number of water withdrawal sites on potato farms that were out of compliance with Maine's Chapter 587 Low Flow Rules. Maine adopted flow and water level regulations in 2007 as a means of providing opportunity for activities such as agricultural irrigation while still protecting valuable natural resources. Improved water management and conservation techniques assure protection of water resources by storing and managing surplus flows for use during seasonal or annual drought events. The Maine Potato Board survey indicated a significant need to upgrade irrigation system infrastructure: out of 128 active withdrawal sites, only 35 were found to be in compliance with the Low Flow Rule. Those with older infrastructure were determined to need new irrigation ponds and center pivot irrigation systems, resulting in cost estimates from $25-29 million to bring all sites into compliance. While funding programs are available to farmers through the USDA Natural Resources Conservation Service, matching funds are required to achieve the potential water resource benefits of these infrastructure upgrades.

## Value of Filtration Avoidance Waivers in Maine (Natural, Built Infrastructure)

The New York City Water Supply System example, described in the section on drinking water above, provides a valuable example for Maine's water systems, particularly those with filtration avoidance waivers. As described in that section, waivers from the Federal Safe Drinking Water Act's Surface Water Treatment Rule are relatively rare, and require a water system to maintain stringent standards for source protection in their supply watersheds. In Maine, the water systems with these filtration avoidance waivers include the Portland, Lewiston-Auburn, Great Salt Bay (Damariscotta), Bangor, Northeast Harbor, Seal Harbor, Bar Harbor, and Brewer systems. Of these systems, the one at most immediate risk of potentially losing its filtration waiver is Lewiston-Auburn. In 2012, Lake Auburn experienced an algae bloom and fish kill that have raised questions about its waiver. While there is no definitive answer for the recent and precipitous decline in what was previously excellent water quality, factors related to climate change (e.g., changing hydrology, storm events, and stratification) have been suggested.

The World Resources Institute recently completed an analysis of the Portland Water District and its water supply to estimate the economic benefits of avoiding water filtration investments in Maine. The Portland Water District's supply, Sebago Lake, has some of the cleanest water in the United States, but it is threatened by development pressure, which, if unchecked, could foul the supply. Should the quality of the water supply fall below the Federally-mandated thresholds, the Portland Water District could lose its filtration avoidance waiver and would have to build a filtration plant—an extremely expensive proposition. Alternately, Portland Water District could follow a similar path to New York City, and argue to maintain its filtration waiver through investment in the permanent conservation of the Sebago Lake watershed.

The study of the Portland Water District, conducted by Talberth et al. (2013), compared a conventional approach to maintaining Portland Water District's filtration waiver with an approach that integrated investments in the kinds of natural and built infrastructure described in this report. The bulk of the costs associated with the conventional approach involved the construction of a membrane filtration facility. The alternate approach integrated investments in riparian buffers, culvert upgrades and replacements, reforestation, sustainable certification of future timber harvests, and conservation easements. The study used six different scenarios to examine alternatives under different cost and financing assumptions. While the results varied among the scenarios depending on assumptions about the timing, nature, costs and effectiveness of different strategies, the majority of the scenarios showed the approach integrating investments in natural and built infrastructure to be the most cost effective. Table 15 (below) shows the results for the most optimistic of these scenarios.

| Infrastructure Options | Quantity | Present Value Costs (millions) |
|---|---|---|
| Riparian buffers (acres) | 367 | $16.33 |
| Culvert upgrades and replacements (units) | 44 | $1.38 |
| Conservation certification (acres) | 4,699 | $0.14 |
| Afforestation/reforestation (acres) | 9,395 | $14.67 |
| Conservation easements - 80% forest cover (acres) | 13,215 | $11.85 |
| *Green infrastructure total* | | |
| *Gray infrastructure (membrane filtration) total* | | |
| **Avoided-cost benefits (gray minus green):** | | |

Table 15: Best case scenario comparing estimates of cost effectiveness for Portland Water District between conventional infrastructure and integrated investments in both natural and built infrastructure (Talberth et al., 2013).

The Portland Water District study notes that natural and built infrastructure solutions to drinking water management are not mutually exclusive, but may be combined in various cost-effective approaches. The study also notes that there are important "ancillary benefits" such as carbon sequestration or Atlantic salmon habitat associated with the choice to use natural infrastructure options. The report estimated the economic value of these "nonmarket benefits" to be between $72 and $125 million and noted that including them would make an even stronger case for the integrated approach. Over a twenty-year time period, the report found that the inclusion of ancillary benefits make integrated investments in natural and built infrastructure the most cost effective choice in every scenario.

It should be noted that, while much of the concern about adequate water resources infrastructure is centered on the challenges likely to result from a much wetter climate in the future, climate change is also likely to result in periods of drought in some or all of Maine at irregular intervals (Gupta et al, 2008). While drought may reduce the need for flood hazard protections, it will increase pressure on the maintenance of adequate safe drinking water supplies. The types of benefits that PWD estimates in this study are likely to be significantly larger if natural infrastructure can be used to maintain drinking water quality even in periods of low water replenishment and flows.

# Conclusion

If investments are made in the natural and built water infrastructure discussed in this report, a significant economic return can be expected for the state of Maine. In this study we have examined a range of evidence considering the economic costs and benefits of water resource infrastructure investments addressing issues of maintaining drinking water quality, mitigating flood damages in both river and coastal environments, assuring the effectiveness of culverts, and addressing the critical problems of stormwater management. The evidence examined includes studies completed in other states and in Maine, as well as analyses specifically conducted for this report.

Evidence from Maine and elsewhere clearly supports serious and detailed consideration of using natural infrastructure approaches to mitigate flood risks in river watersheds and to avoid having to invest in expensive filtration plants to protect drinking water. There is also strong economic support for finding ways to use lower cost built infrastructure approaches like Low Impact Development for managing storm water runoff. Studies in Maine and elsewhere indicate that natural and low cost built infrastructure may be cost effective in coastal flood damage mitigation and in upgrading culverts to reduce damage to transportation systems and ecosystems, but the state of economic research does not yet support broad estimates of benefits.

The focus of this study has been on what are termed "avoided-cost" benefits—savings in public and private expenditures or in damages to public and private property that can be avoided by choosing one infrastructure strategy over another. In cases involving Maine-specific estimates of protecting drinking water and avoiding flood damages, aggregate estimates of benefits were found to be several multiples of costs (though this is not necessarily the case for individual projects). It is also noted in many of the studies examined that avoided-cost benefits are only one part of the potential benefits to society from a careful selection of natural and built infrastructure investments. Additional benefits in the form of wildlife habitat protection and provision of recreation and open space add to the avoided-cost benefits of many infrastructure investments, increasing the yield of net positive benefits.

The challenge for Maine now is to find the resources to make the needed investments. A number of federal and state funding programs, including those mentioned in this report, already exist that can enable the state, municipalities and non-profit organizations to invest in natural and built infrastructure. Unfortunately, significant reductions in federal funding for land and water conservation, combined with a gradual reduction in state funding levels, yield far too few resources to meet the substantial investment need described in this report. There is a genuine need for new sources of funding focused on securing the natural and built infrastructure that sustains Maine's water resources. Such new funding sources, if carefully designed and strategically implemented, could avoid considerable future costs for the state, secure valuable benefits and services now, and catalyze investment by municipal, federal and private sources.

The incomplete, though compelling, picture of economic benefits presented in this report suggests that financing programs should require or encourage the use of economic analysis in the evaluation of projects and that state agencies should develop the data and support systems to enable the most cost effective strategies to be chosen. In compiling this report we were struck by the amount of potentially valuable economic information that would help make decisions about infrastructure strategies that is lost in the focus on day-to-day administration in state agencies. Careful choices about water infrastructure will require careful maintenance of data.

The image of Maine as a naturally beautiful state depends on safeguarding its water resources. Water resources are vital to keeping and attracting vibrant businesses and residents, as well as to keeping tourists returning year after year. Water is so fundamental to the image of the state of Maine that one of its most successful business, which bottles and exports huge volumes of it, brands it as "what it means to be from Maine." For many and sound reasons, investing in water resources makes sense for Maine and emerging evidence suggests that those investments can be made at lower costs and with greater benefits than was previously thought possible.

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# Appendix 1:
# Natural Infrastructure Spatial Analysis

*Dan Coker and Josh Royte, The Nature Conservancy in Maine, April 2013*

**Background**

While extensive information is available in Maine describing the different types and potential locations for built infrastructure investments, far less has been done to describe explicitly the state's natural infrastructure. Towards this end, The Nature Conservancy worked with partners to conduct the following natural infrastructure spatial analysis, with the specific objective to *identify places in Maine where natural **habitat** provides water-related **benefits** for the state*.

**Assumptions for Spatial Analysis**

- Use statewide, broadly-accepted datasets and prioritization systems wherever possible to benefit from public, consensus processes that have already been completed.
- Identify places that are currently not developed nor in some level of conservation status (Gap 1, 2 or 3); this allows a focus on natural lands that could be converted to other land uses.
- Understand that statewide data are only available for some of the potential water-related benefits provided by the state's natural infrastructure, so the results of this analysis are likely to be a conservative estimate of the potentially important places.
- Be clear that the intent is for this analysis to be a credible, first iteration not a definitive, final product. It is the hope that a more comprehensive process can be developed to expand on this initial snapshot of the natural infrastructure of Maine.

**Process**

After considering the full range of potential ecosystem services provided by natural habitat in Maine, the Conservancy narrowed to a short list those that could be most easily described spatially and provide the most meaningful examples of "nature's benefits" to the general public. The **benefits** included in this analysis are:

1) Drinking Water Supply. Forests, wetlands, floodplains, and other natural habitats play critical roles in ensuring the abundance and quality of our drinking water supply. The State of Maine Drinking Water Program, working with the Maine Geological Survey (MGS), developed several datasets to identify the most important areas for the state's drinking water supply, a sample of which is shown below in the map of "Drinking Water Supply Priority Areas." The datasets used in this analysis are:
    a. *High Yield Aquifers (http://www.maine.gov/megis/catalog-Aquifer Polygons),* which are a subset of the state's mapped aquifers that have been documented to yield more than 50 gallons per minute. While all of the state's aquifers have not been tested, those included in the dataset are generally those already providing an active water supply or located in particularly vulnerable substrate.

b. *Source Water Protection Areas (http://www.maine.gov/megis/catalog-WELLMODELS and WELLSBUF),* which identify the most important areas to protect around groundwater wells to maintain water quality. For the highest priority sources, the Drinking Water Program did detailed modeling to determine the well-head protection areas; for all others, a fixed-radius buffer was used with the size determined by the number of water users.

c. *Surface Water Supply Watersheds (http://www.maine.gov/megis/catalog-DIRSHED),* which identify the portions of watersheds determined to have the greatest influence on the quality of the state's surface water supplies. The majority of these watersheds were modeled by the Drinking Water Program; for the handful of surface water supplies not yet modeled because of resource constraints, staff from the Conservancy completed the analysis using the method described below for "Determining Surface Water Supply Watersheds."

2) Flood Attenuation. During flood events, wetland and riparian habitat absorb excess water and slow runoff, reducing peak flows and lessening the impacts of downstream flooding. With no known datasets or models for this benefit in Maine, staff from the Conservancy analyzed National Wetland Inventory (NWI - *http://www.fws.gov/wetlands/*) wetlands of at least 50 Acres in size, the National Hydrography Dataset (NHD) 1/100K flow network (*http://nhd.usgs.gov/data.html*), a modified version of Maine's impoundments dataset (*http://www.fws.gov/wetlands/Data/metadata/conus_wet_poly_metadata.htm)*, and a modified version of the 2004 Maine Land Cover Dataset (MELCD2004 at *http://www.maine.gov/megis/catalog*) to identify wetlands likely to buffer one or more developed areas. See below for the map "Wetlands Likely to Provide Flood Attenuation Benefits" for a sample of the results and see **"**Details of Flood Attenuation Analysis**"** for a more detailed description of the analysis.

3) Wildlife Habitat. Natural areas provide essential habitat for the state's commercial and recreational fisheries, waterfowl, and other fish, wildlife and aquatic species. Priority areas for this habitat have been identified by Maine's Beginning with Habitat (BwH) program, managed by the Maine Department of Inland Fisheries and Wildlife (MDIFW), and by the U.S. Fish and Wildlife Service (USFWS). The specific datasets used in this analysis are described below, and an example of the priority areas is shown below in the map "Wildlife Habitat Priority Areas":

a. *BwH Focus Areas* (*http://www.beginningwithhabitat.org/about_bwh/focusareas.html*) including all areas with freshwater or estuarine element occurrences and excluding all island focus areas.

b. *Salmon Habitat* (*http://www.fws.gov/GOMCP/maps_salmon.html*), including 100 meter buffers on all streams in USFWS Priority-1 salmon watersheds and the top 25% parr production reaches.

c. *Beginning with Habitat Rare (T&E) Aquatic/Wetland species & natural communities* (*http://www.maine.gov/doc/nrimc/mnap/*), known to be in good condition and not included in the Focus Areas referenced above.

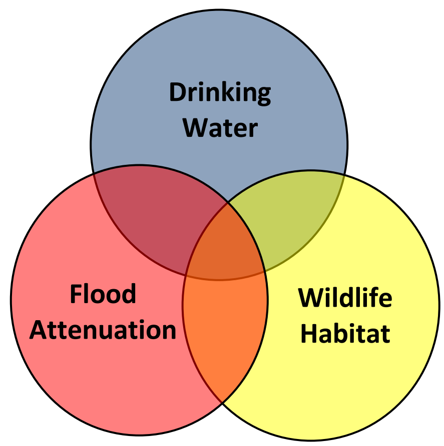
Staff from the Conservancy then identified the statewide data layers that most credibly capture the majority of habitat types projected to provide the short list benefits described above. The **habitat types** included in this analysis are:

1) NWI Wetlands, excluding open water and tidal areas, dissolving all polygons by type (including forest floodplains), and then including those greater than 10 acres in size.
2) BwH Undeveloped Blocks (*http://www.beginningwithhabitat.org/the_maps/map3-undev_habitat.html*), including those 500 acres in size or larger.
3) DHHS/MGS Aquifers, including all aquifer polygons in the DHHS Drinking Water Program/MGS dataset.

These datasets were combined and the lands currently in some conservation land status (Gap 1, 2 or 3 in the Conservancy's statewide conservation lands dataset) and developed areas (from a modified version of MELCD2004) were removed leaving only the unprotected, undeveloped lands in at least one of the habitat types. For an example of the results of this combination, see the map below "Important Habitat Types and Existing Conservation Lands."

**Results**

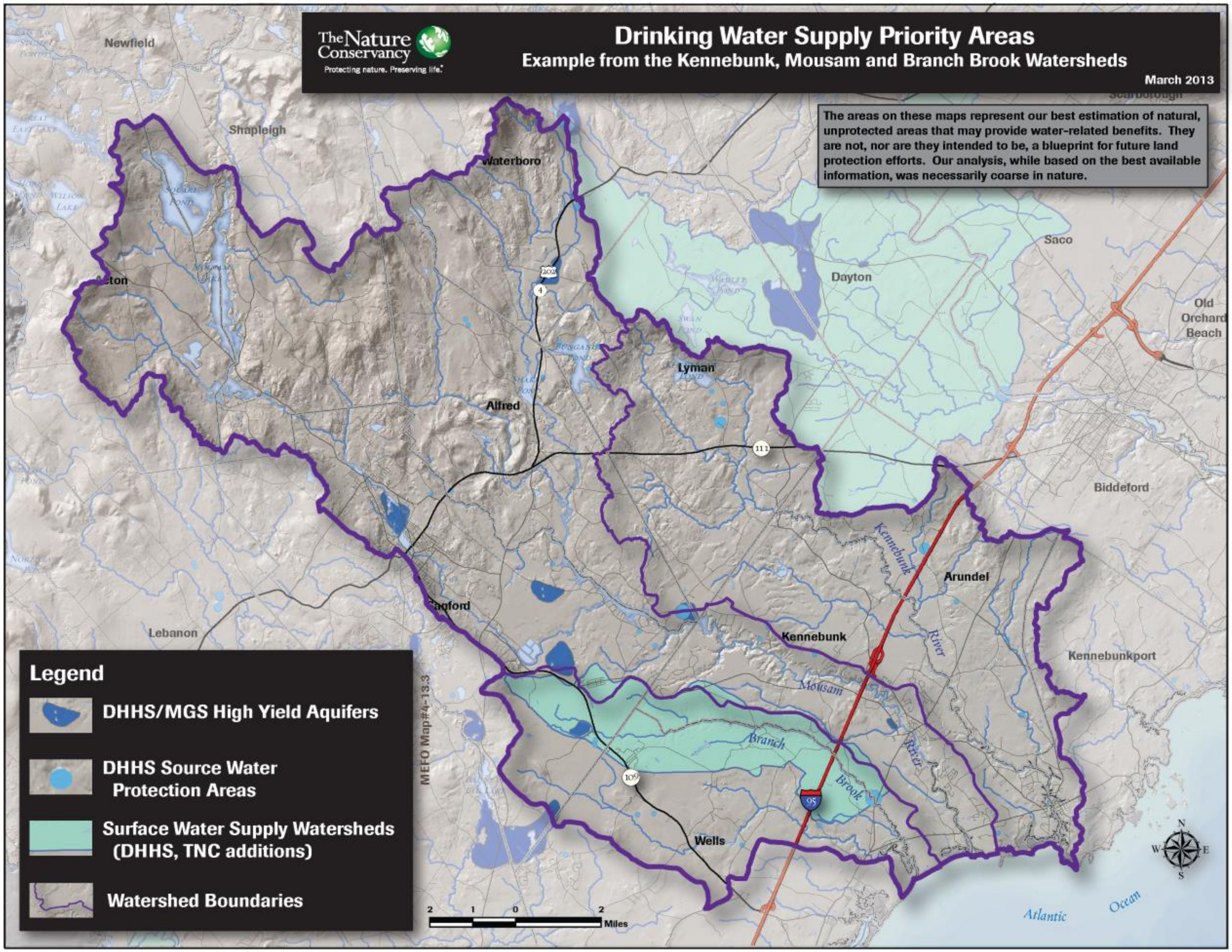
The selected habitat and benefit layers were then combined to provide an initial projection of the places where unprotected, undeveloped habitat is likely to provide one or more important water-related benefits. The statewide results can be seen below in the map titled "Natural Infrastructure in Maine," and a specific example is provided below in the map titled "Natural Infrastructure Analysis: Example from the Kennebunk, Mousam and Branch Brook Watersheds." Polygons were color coded in these maps to roughly follow the Venn diagram at right, highlighting the areas likely to provide individual and overlapping benefits. The table below shows a summary of the total acreage in area[1].




| Areas Likely to Provide: | Area |
|---|---|
| Drinking Water Benefits | 496,386 acres |
| Flood Attenuation Benefits | 416,584 acres |
| Wildlife Habitat Benefits | 982,114 acres |
| | |

[1] The acreage totals included in this table and used in the subsequent maps have been updated to reflect revised Surface Water Supply Watershed data for drinking water benefits, and corrected Beginning with Habitat Focus area data. These updates were made after the calculations were completed for the body of this report, but they do not significantly change the key takeaways of that analysis.

| **Areas Likely to Provide Multiple Benefits:** | |
|---|---|
| Drinking Water and Flood Benefits | 18,807 acres |
| Drinking Water and Wildlife Benefits | 38,898 acres |
| Flood and Wildlife Benefits | 114,234 acres |
| Drinking Water, Flood, and Wildlife Benefits | 4,443 acres |


The Nature Conservancy
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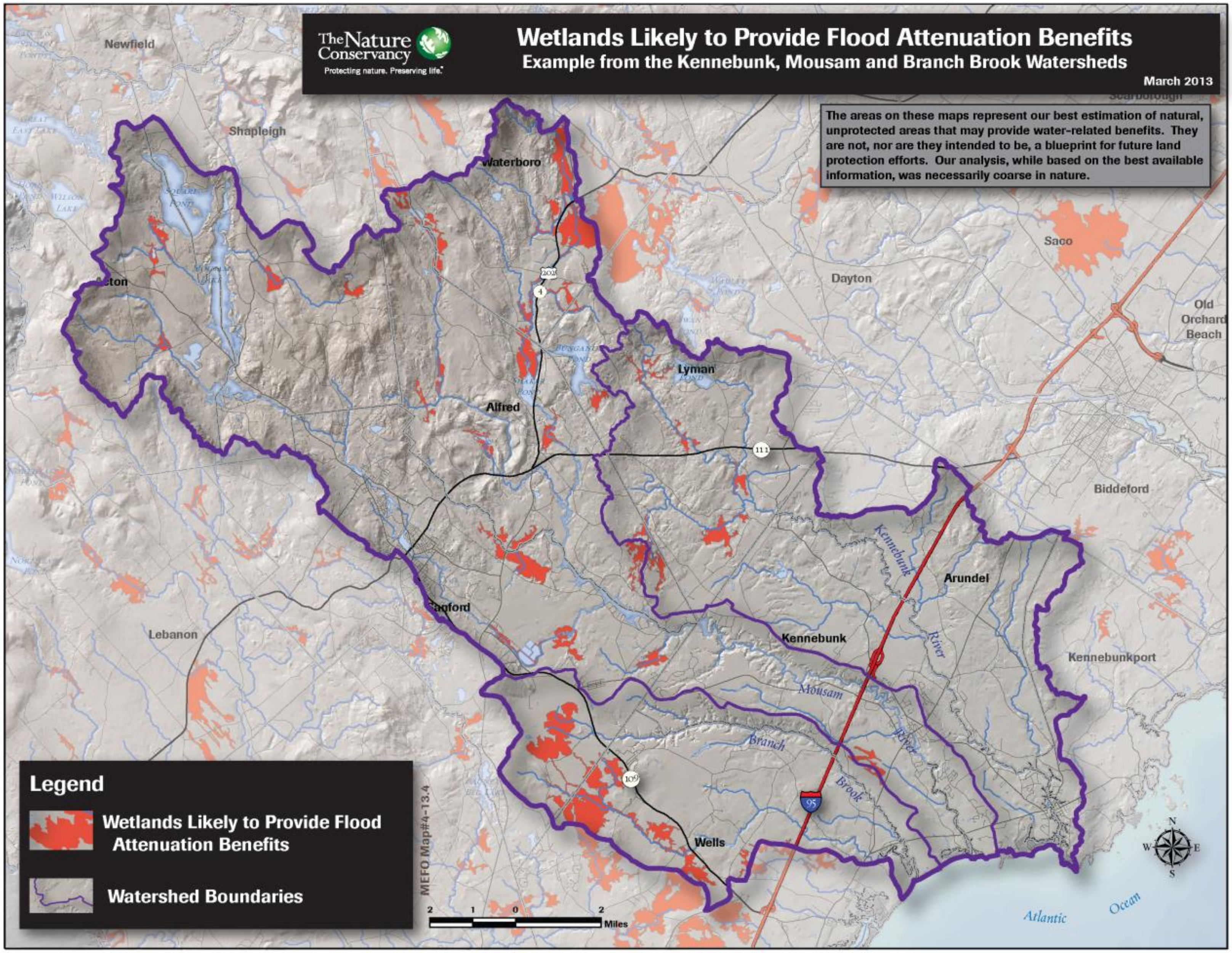
Drinking Water Supply Priority Areas
Example from the Kennebunk, Mousam and Branch Brook Watersheds
March 2013
The areas on these maps represent our best estimation of natural, unprotected areas that may provide water-related benefits. They are not, nor are they intended to be, a blueprint for future land protection efforts. Our analysis, while based on the best available information, was necessarily coarse in nature.
Newfield
Shapleigh
Waterboro
Saco
Dayton
Old Orchard Beach
Lyman
Alfred
Biddeford
Arundel
Kennebunk
Kennebunkport
Lebanon
Wells
Kennebunk River
Mousam
Branch Brook
Atlantic Ocean
Legend
DHHS/MGS High Yield Aquifers
DHHS Source Water Protection Areas
Surface Water Supply Watersheds (DHHS, TNC additions)
Watershed Boundaries
MEFO Map#4-13.3
2 1 0 2 Miles



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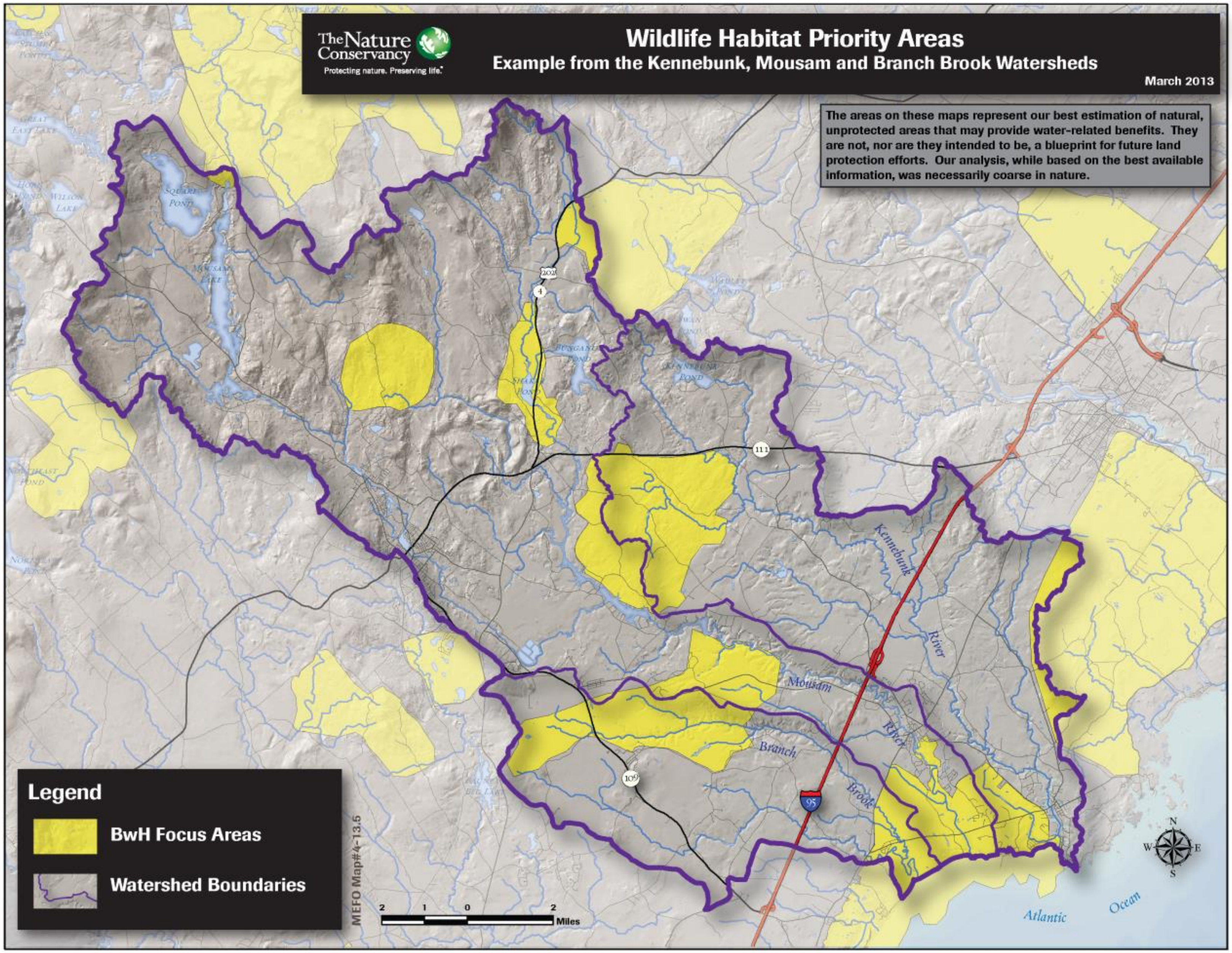
Wetlands Likely to Provide Flood Attenuation Benefits
Example from the Kennebunk, Mousam and Branch Brook Watersheds
March 2013
The areas on these maps represent our best estimation of natural, unprotected areas that may provide water-related benefits. They are not, nor are they intended to be, a blueprint for future land protection efforts. Our analysis, while based on the best available information, was necessarily coarse in nature.
Newfield
Shapleigh
Waterboro
Alfred
Lyman
Dayton
Saco
Old Orchard Beach
Biddeford
Arundel
Kennebunk
Kennebunkport
Lebanon
Wells
Kennebunk River
Mousam River
Branch Brook
Atlantic Ocean
Legend
Wetlands Likely to Provide Flood Attenuation Benefits
Watershed Boundaries
MEFO Map#4-13.4
Miles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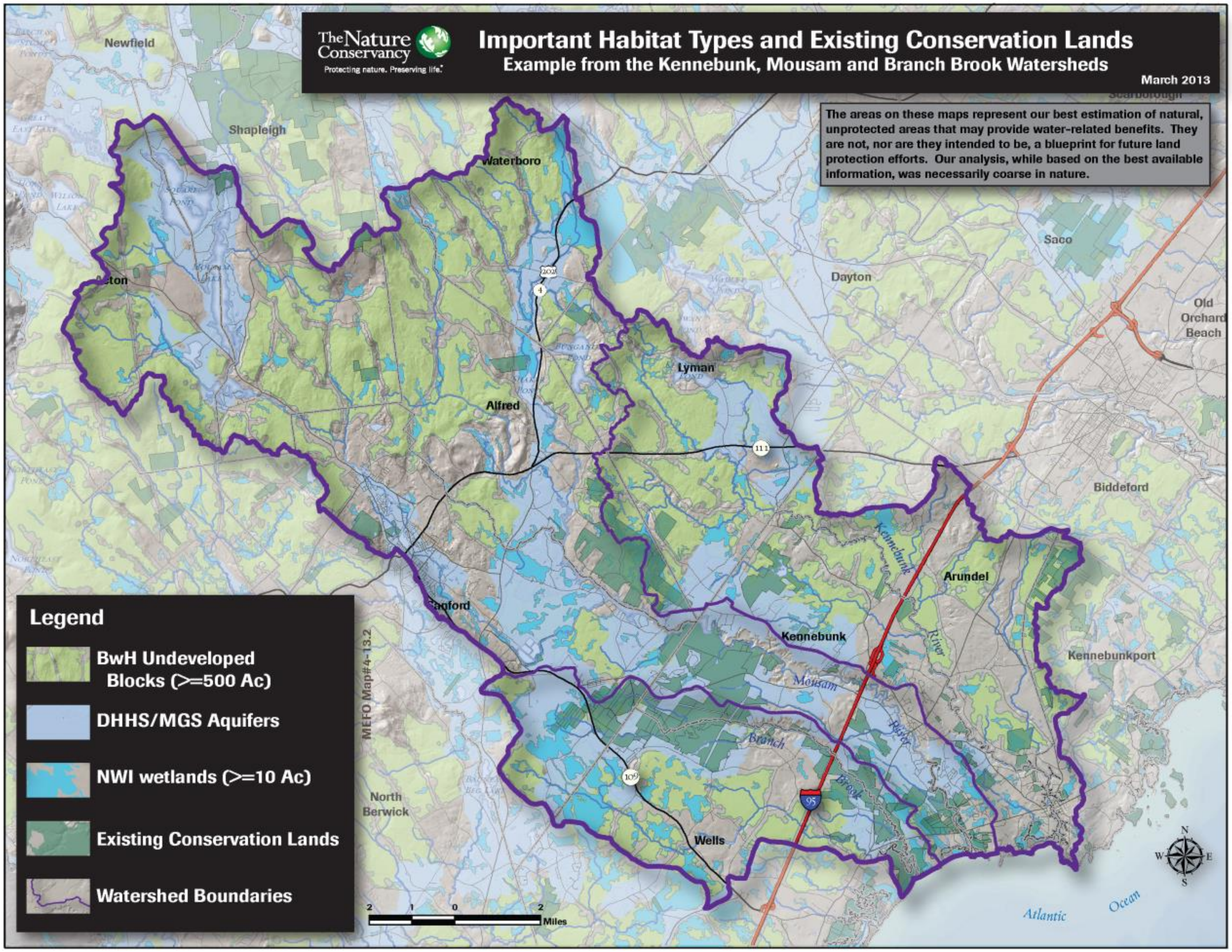
Wildlife Habitat Priority Areas
Example from the Kennebunk, Mousam and Branch Brook Watersheds
March 2013
The areas on these maps represent our best estimation of natural, unprotected areas that may provide water-related benefits. They are not, nor are they intended to be, a blueprint for future land protection efforts. Our analysis, while based on the best available information, was necessarily coarse in nature.
Legend
BwH Focus Areas
Watershed Boundaries
MEFO Map#4-13.5
Miles
Kennebunk River
Mousam River
Branch Brook
Atlantic Ocean
Square Pond
Mousam Lake
Kennebunk Pond
202
4
111
109
95
N
S
E
W



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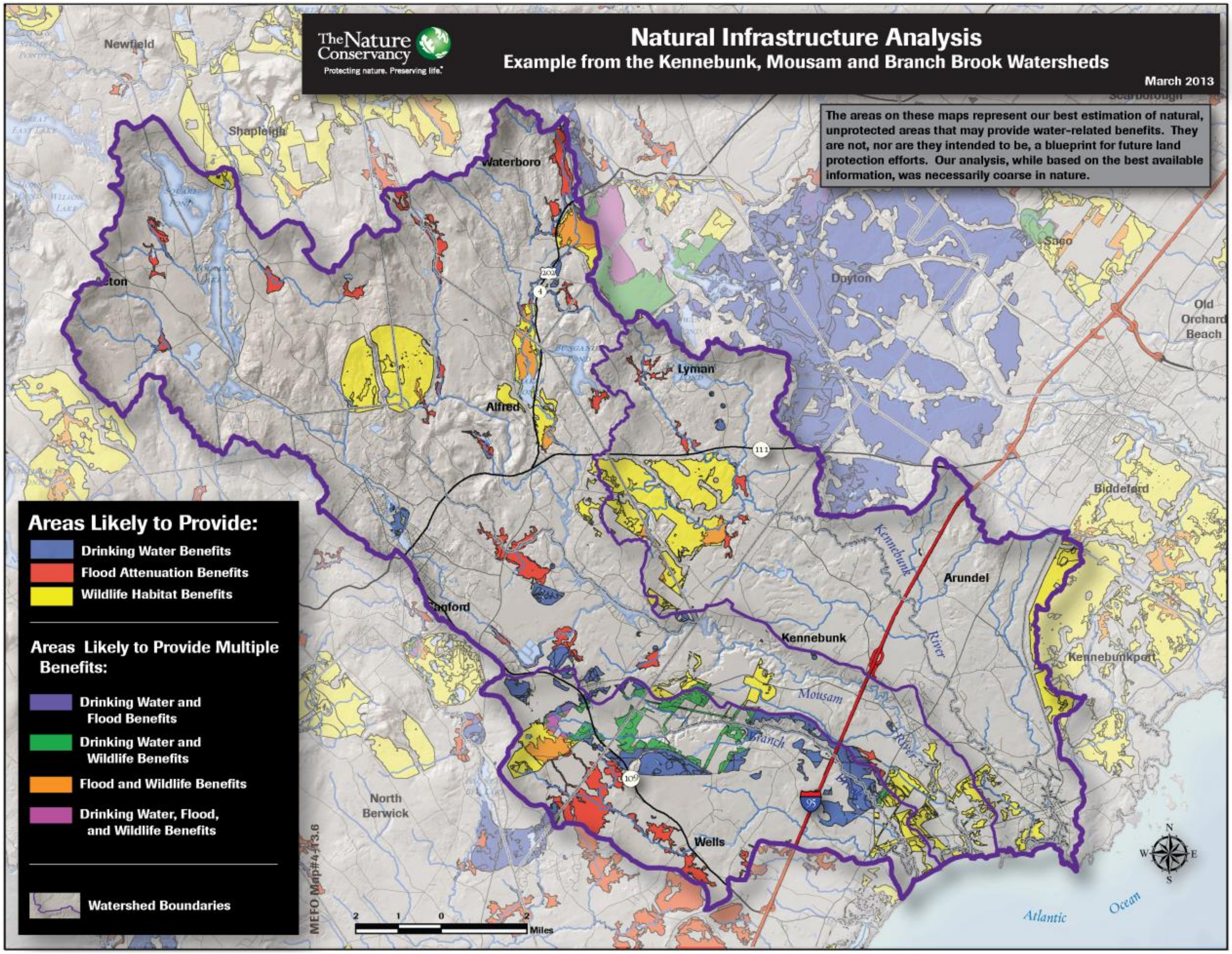
Important Habitat Types and Existing Conservation Lands
Example from the Kennebunk, Mousam and Branch Brook Watersheds
March 2013
The areas on these maps represent our best estimation of natural, unprotected areas that may provide water-related benefits. They are not, nor are they intended to be, a blueprint for future land protection efforts. Our analysis, while based on the best available information, was necessarily coarse in nature.
Legend
BwH Undeveloped Blocks (>=500 Ac)
DHHS/MGS Aquifers
NWI wetlands (>=10 Ac)
Existing Conservation Lands
Watershed Boundaries
MEFO Map#4-13.2
Miles
Newfield
Shapleigh
Waterboro
Alfred
Lyman
Dayton
Saco
Old Orchard Beach
Biddeford
Arundel
Kennebunk
Kennebunkport
Wells
North Berwick
Kennebunk River
Mousam River
Branch Brook
Atlantic Ocean



The Nature Conservancy
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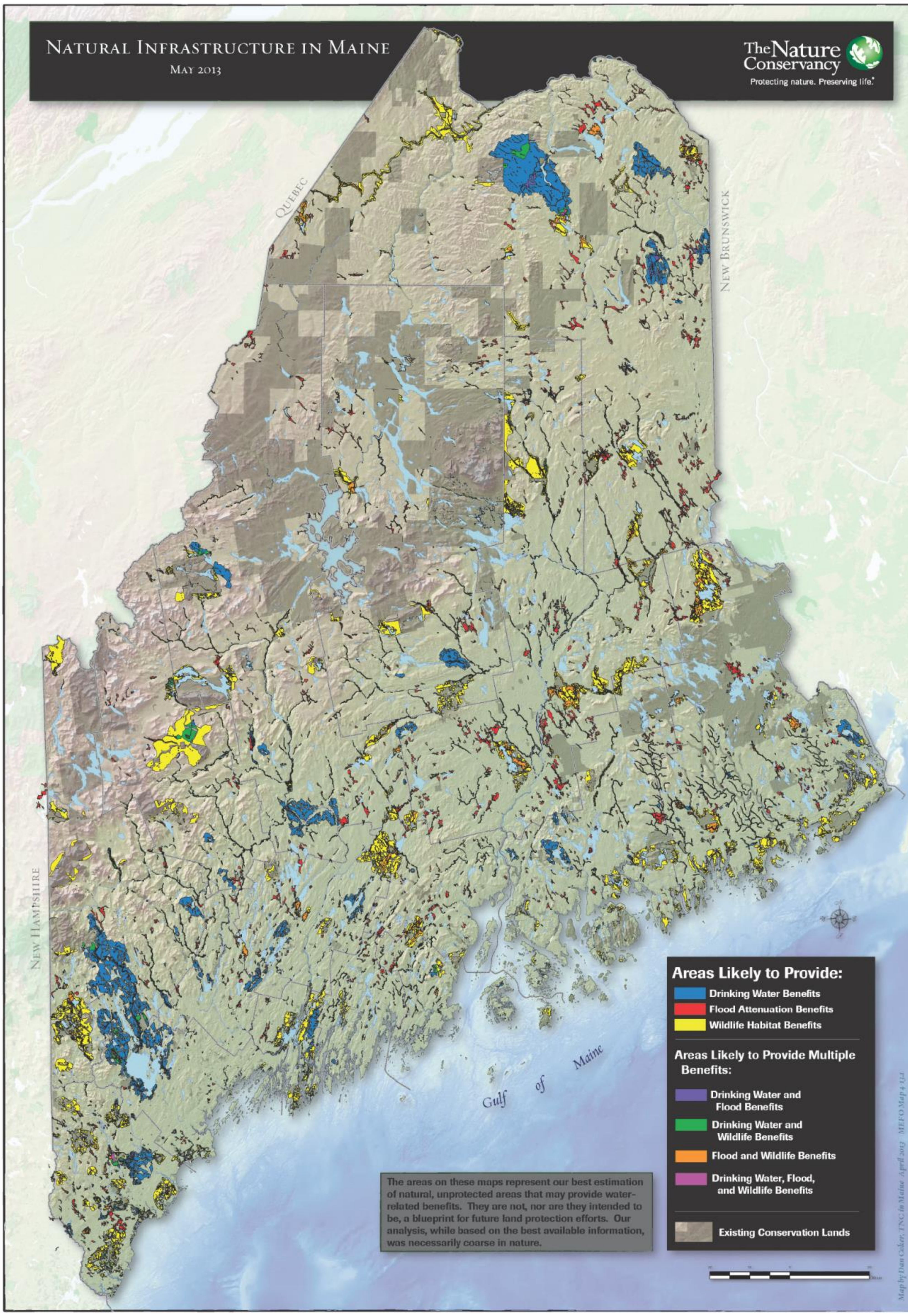
Natural Infrastructure Analysis
Example from the Kennebunk, Mousam and Branch Brook Watersheds
March 2013
The areas on these maps represent our best estimation of natural, unprotected areas that may provide water-related benefits. They are not, nor are they intended to be, a blueprint for future land protection efforts. Our analysis, while based on the best available information, was necessarily coarse in nature.
Areas Likely to Provide:
Drinking Water Benefits
Flood Attenuation Benefits
Wildlife Habitat Benefits
Areas Likely to Provide Multiple Benefits:
Drinking Water and Flood Benefits
Drinking Water and Wildlife Benefits
Flood and Wildlife Benefits
Drinking Water, Flood, and Wildlife Benefits
Watershed Boundaries
Newfield
Shapleigh
Waterboro
Alfred
Lyman
Dayton
Saco
Old Orchard Beach
Biddeford
Arundel
Kennebunk
Kennebunkport
Wells
North Berwick
Kennebunk River
Mousam River
Branch
Atlantic Ocean
2 1 0 2 Miles
N S E W


Natural Infrastructure in Maine
May 2013
The Nature Conservancy
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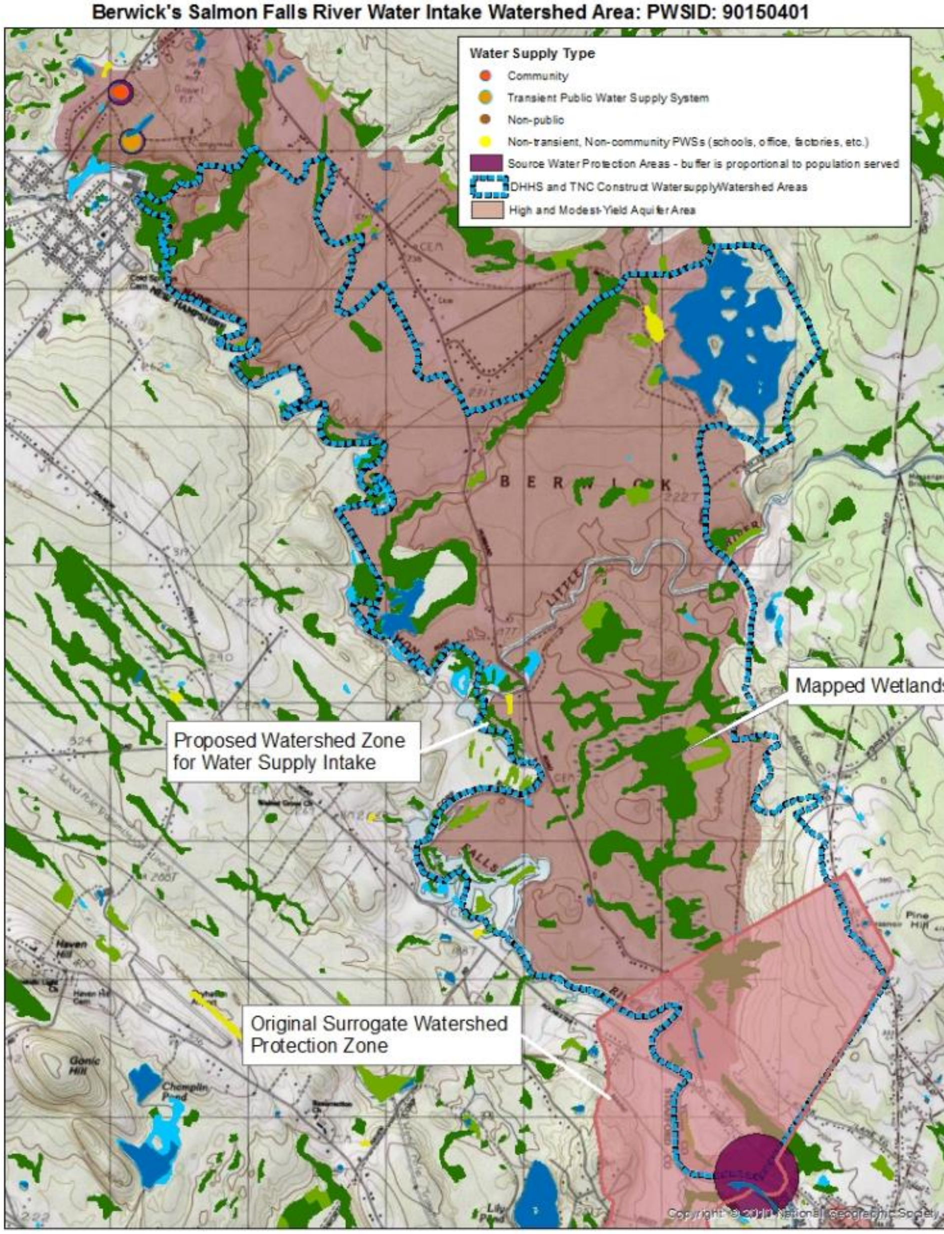
Quebec
New Brunswick
New Hampshire
Gulf of Maine
Areas Likely to Provide:
Drinking Water Benefits
Flood Attenuation Benefits
Wildlife Habitat Benefits
Areas Likely to Provide Multiple Benefits:
Drinking Water and Flood Benefits
Drinking Water and Wildlife Benefits
Flood and Wildlife Benefits
Drinking Water, Flood, and Wildlife Benefits
Existing Conservation Lands
The areas on these maps represent our best estimation of natural, unprotected areas that may provide water-related benefits. They are not, nor are they intended to be, a blueprint for future land protection efforts. Our analysis, while based on the best available information, was necessarily coarse in nature.
Map by Dan Coker, TNC in Maine April 2013 MEFO Map 4 13.1

## Determining Surface Water Supply Watersheds

For the handful of surface water supply watersheds not yet modeled by the Maine Drinking Water Program, staff from the Conservancy completed the followed assessments to determine an area suitable to conserve each surface source:

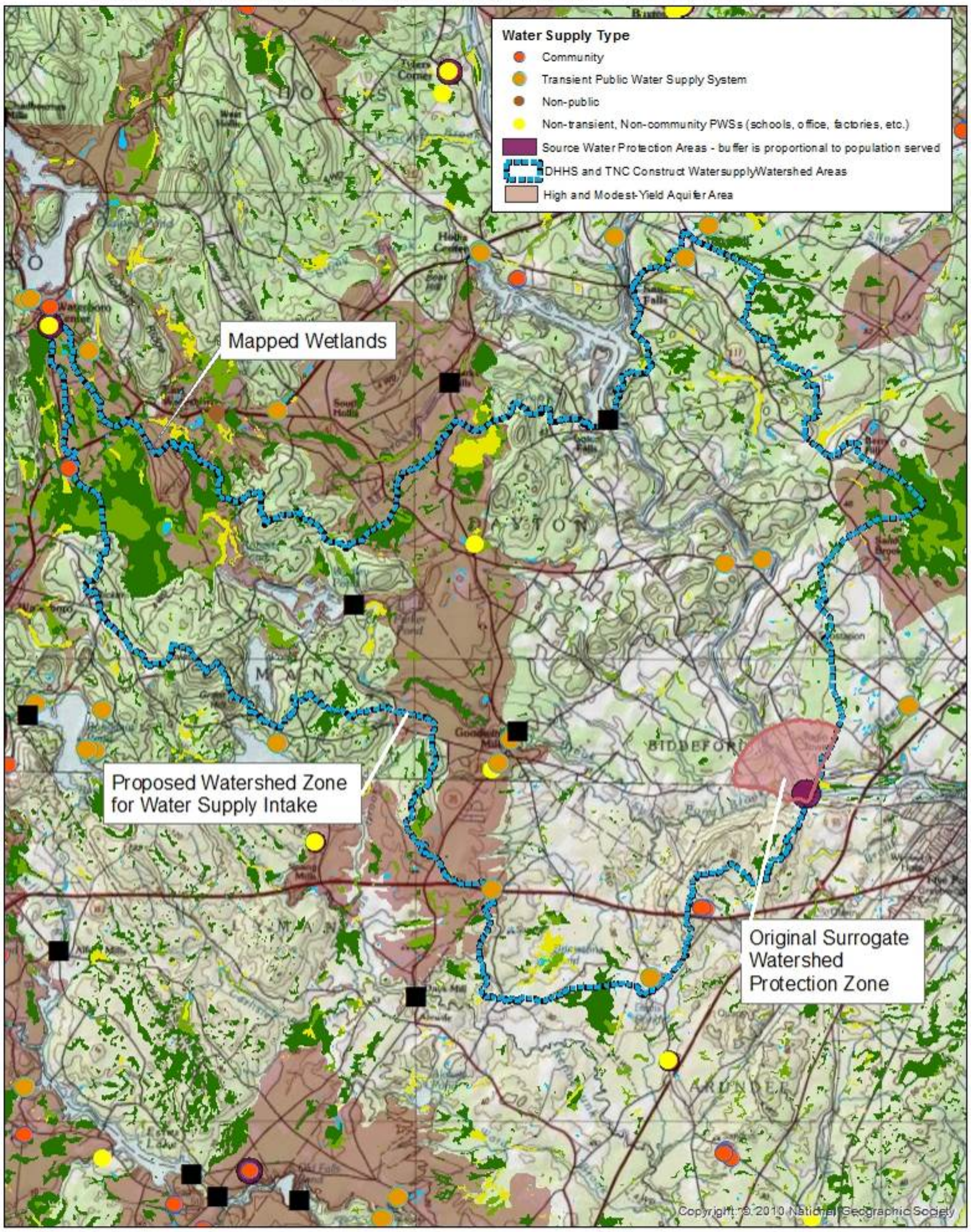
- **Berwick's Salmon Falls River Intake (PWSID: 90150401)**: Supplying water to a densely populated area of southern Maine this 4,000-acre watershed area includes largely forested hillsides sloping down to the Salmon Falls River. The boundary includes broad flat wetlands which lay over and likely recharge a sand and gravel aquifer. It also includes the lower reaches of the Little River and several other tributary streams that cut down through the coastal plain aquifer. The boundary extends along the aquifer and boundary of road from development, to the East Rochester, NH dam NH/South Lebanon. This area includes a focus area identified by the Piscataquis-Salmon Falls Watershed Collaboration Action Plan.

Berwick's Salmon Falls River Water Intake Watershed Area: PWSID: 90150401



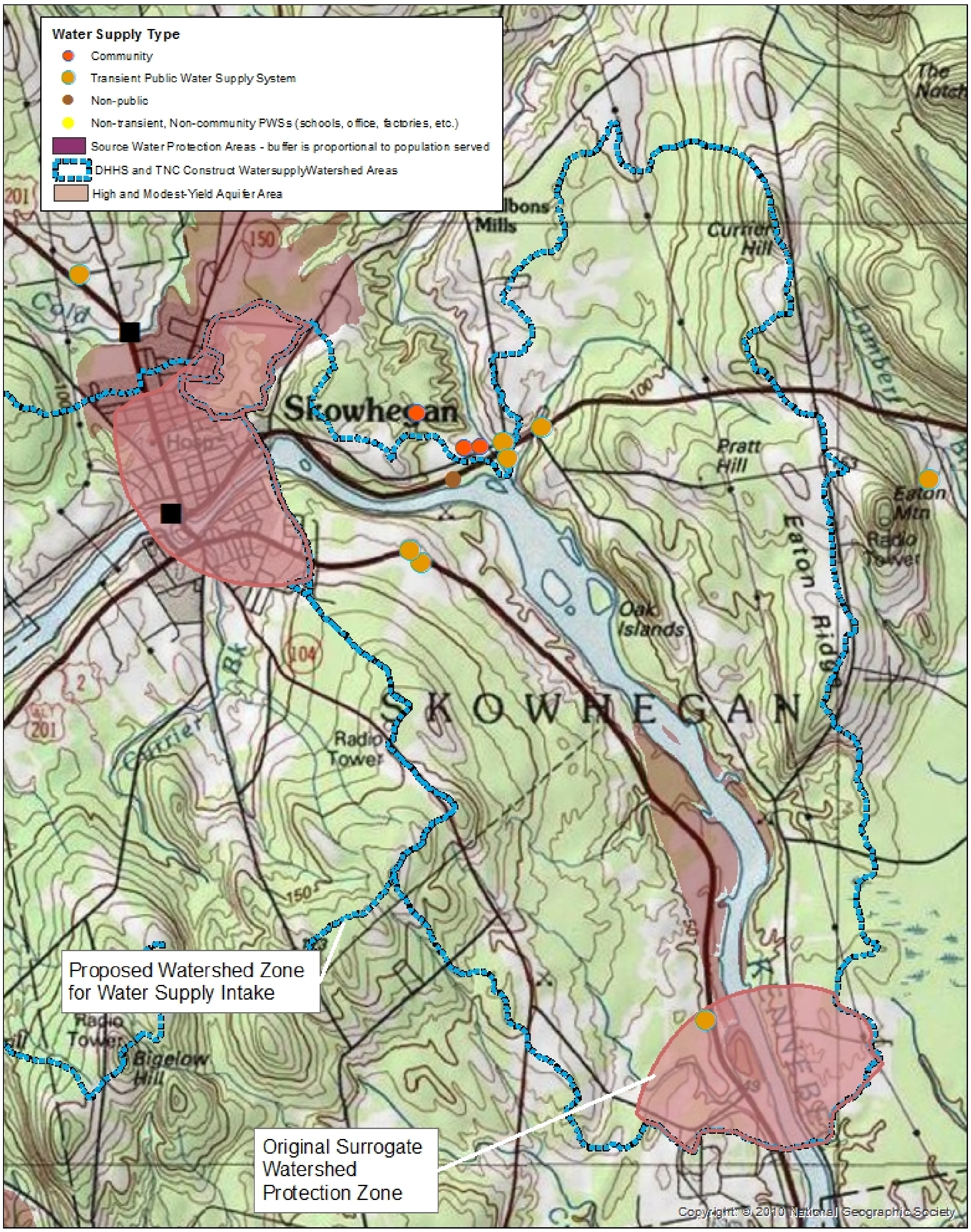
**Biddeford's Saco River Intake (PWSID: 90170401)**: With a watershed that extends into New Hampshire over hundreds of thousands of acres, we focused on areas with the most significance area for the water intake; the small watersheds that drain directly to the Saco downstream from the Union Falls Dam, and larger tributary watershed of Swan Pond Brook draining a large aquifer area that extends from Dayton into Waterboro. This covers just over 34,000 acres. There are broad wetland areas in the upper headwaters of this sub-watershed that are particular important for maintaining water quality downstream to the mouth of Swan Pond Brook a half mile upstream of the intake structure. These watersheds are drawn largely from the state Drainage scale watersheds GIS layer.

Biddeford's Saco River Water Intake Watershed Area: PWSID: 90170401



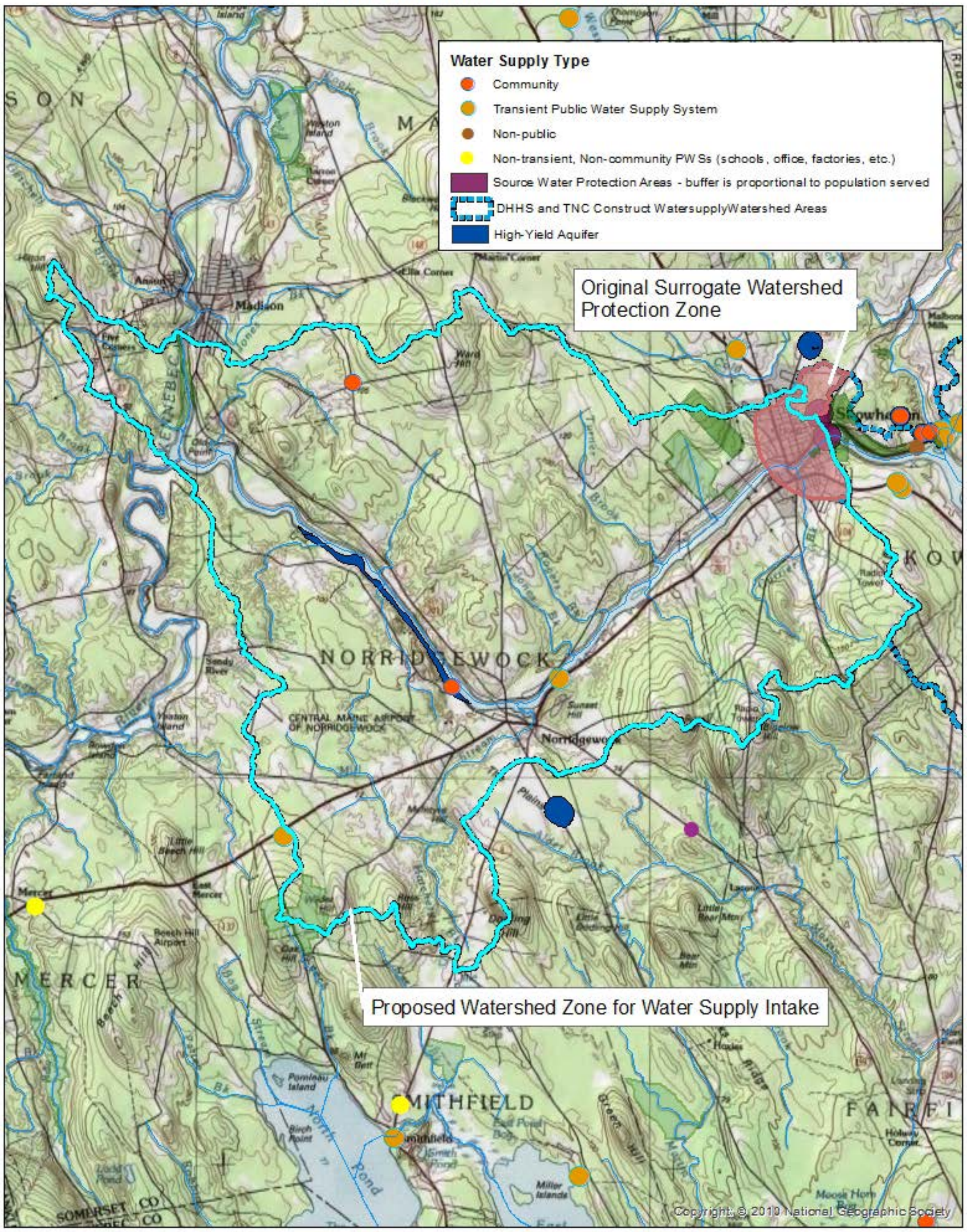
**Somerset Mill's Kennebec River Intake (PWSID: 93867401)**: This polygon includes all the lands that drain directly to the Kennebec between the water intake and the upstream dam – and next water intake – in Skowhegan. This covers 10,000+ acres. This drainage area includes roads, farm fields and rural development and arguably this direct drainage has little impact on the mainstem Kennebec River except to provide in-stream chemical and biological treatment from upstream pollutants and sediment.

Sommerset Mill's Kennebec River Water Intake Watershed Area: PWSID: 93867401



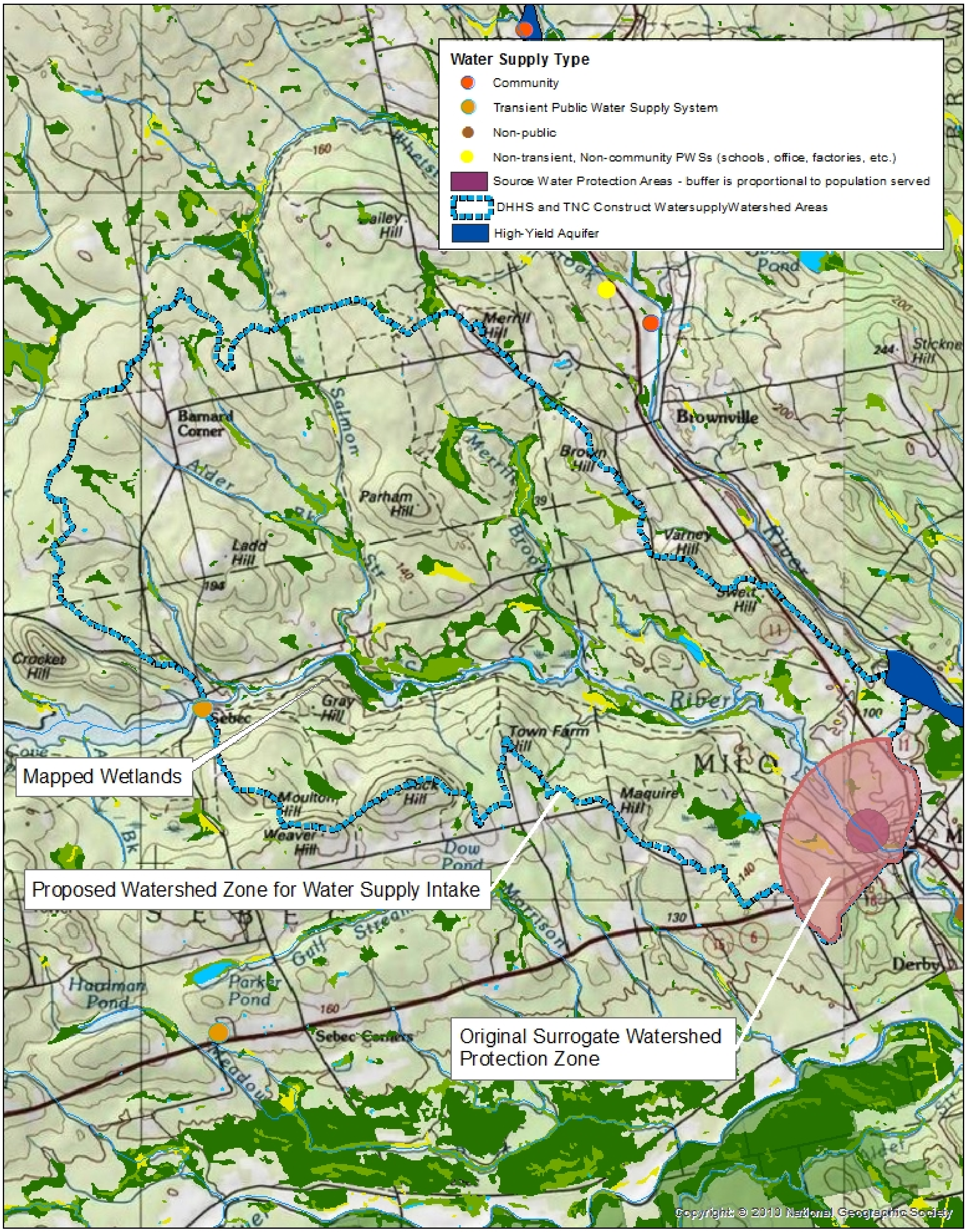
**Skowhegan's Kennebec River Intake (PWSID:91450401)**: This polygon developed instead of a standardized buffer upstream of the water intake. The proposed watershed area includes 35,000 acres upstream of the water intake to include several tributary stream subwatersheds that confluence the Kennebec. It continues upstream until the Dam in Madison and confluence with Lemon which is a much larger watershed. The rationale includes the contribution of tributaries upstream of a water intake, watersheds for several supply wells and the reach of stream downstream of a dam and two urban areas which provides in-stream biological treatment and dispersal of upstream pollutants.

Skowhegan's Kennebec River Water Intake Watershed Area: PWSID:91450401



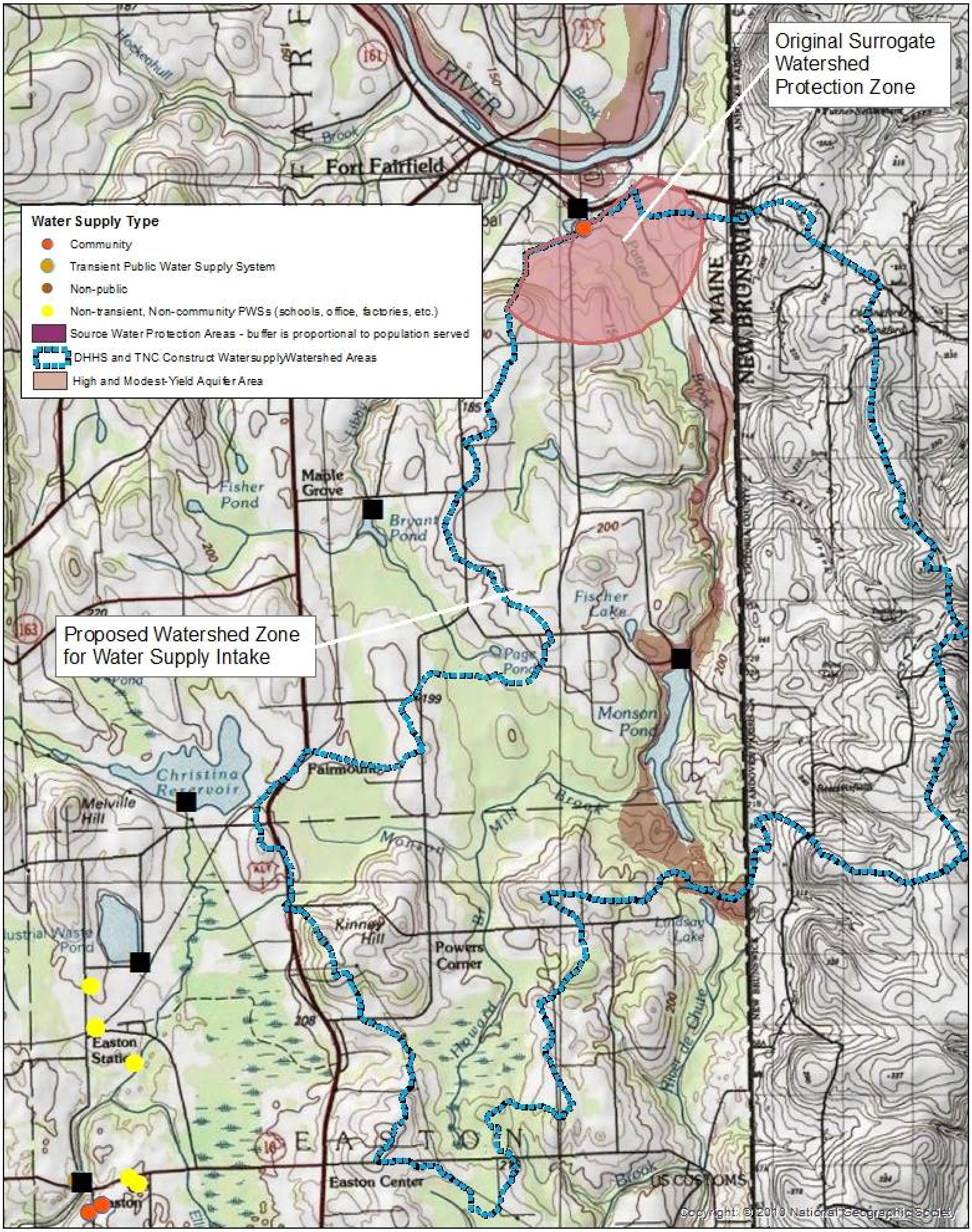
**Milo's Sebec River Water Intake (PWSID: 91000401):** At 15,200 acres this watershed includes the watershed draining towards the Milo water intake up to the Sebec Lake Dam outlet. This includes at least a half dozen tributary streams and several floodplain and tributary wetland complexes that help filter out chemical and particulate matter

**Milo's Sebec River Water Intake Watershed Area: PWSID:91000401**



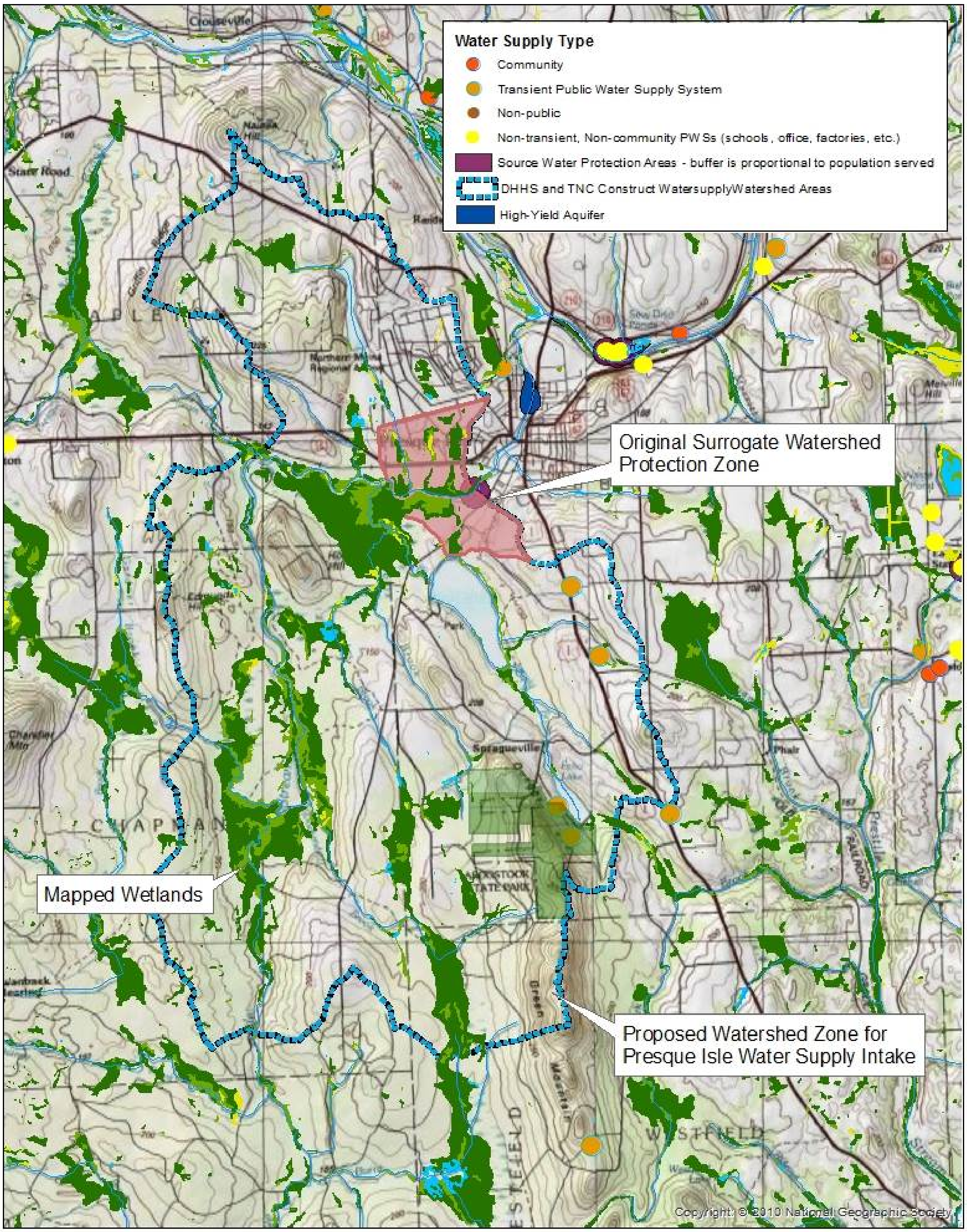
**Houlton's Pattee Brook Water Intake (PWSID: 90550401):** The Houlton water intake is near the mouth of Pattee Brook watershed before its confluence with the Meduxnekeag. This watershed is well defined by local topography although a new watershed boundary was defined from the exiting state Drainage layer to carve off the more westerly watersheds that drain directly to the Meduxnekeag downstream of where the water intake is.

Fort Fairfield's Pattee Brook Water Intake Watershed Area: PWSID: 90550401



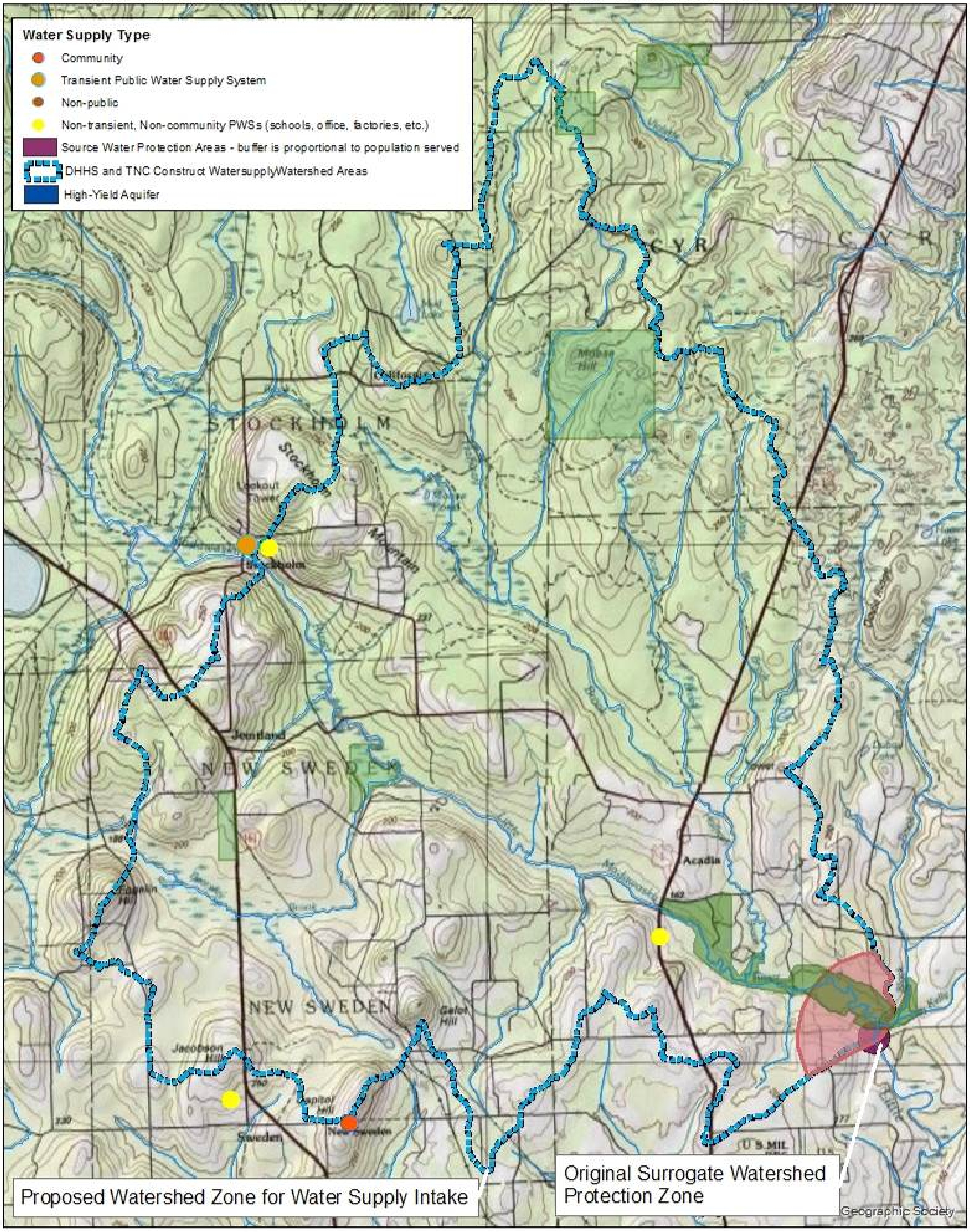
**Presque Isle's P.I. Stream (PWSID: 91310401):** This watershed area (29,300 acres) includes the watersheds extending north and south of the water intake which includes several large forested and shrub wetland complexes in a confined valley bottom. The larger N. Branch Presque Isle watershed was not included upstream of its confluence with the Presque Isle Stream.

Aroostook River Presque Isle Watersupply Watershed Intake Area: PWSID:91310401



**Little Madawaska River (PWSID: 90915401):** At 44,000 acres this large watershed has dozens of feeder streams and tributaries branching in all directions that lead to the water intake in Caribou. While there is agriculture on many of the hilltops and hillsides, the valley bottoms are forested providing excellent infiltration and flow moderation for this water intake.

Little Madawaska River Water Intake Watershed Area: PWSID:90915401



**<u>Details of Flood Attenuation Analysis</u>**

**Objective of Analysis**: To identify wetlands upstream of developed areas (and/or small dams) that might be providing flood attenuation benefits to either the developed areas or the small dams.

**Datasets** Utilized and any pre-analysis sorting or subsetting:

- National Wetland Inventory (NWI) wetlands – dissolved by 'type' and only dissolved polygons of at least 50 acres included in the analysis
- 100K NHD Network for Maine – with flow direction
- Beginning with Habitat landcover data – an enhanced version of the MELCD 2004 land cover data prepared by TNC for BwH wildlife connectivity analysis
- Maine Dams dataset – dam dataset enhanced from MEGIS by TNC for hydrologic flow analyses (name corrections, QC, snapping to 100k NHD network)

**Creation of developed areas** to be used as places benefiting from flood attenuation effects of upstream wetlands: developed classes were extracted from BwH landcover, converted to 30m raster, focal sum run (5 mile radius) and extracted cells with at least 110 cells within focal radius (cutoff chosen primarily by visual inspection), were then used as basis to create polygons from these clusters of cells (1156 polygons). These polygons were then intersected with the 100k NHD network to create points to use in network tracing analysis. This created 718 multi-point features -> exploded to 1202 points. These points were then intersected with the 100k NHD network to create flags from which to trace upstream for network analysis.

**Preparation of wetland polygons** to be used in network analysis: 50 acre plus dissolved wetland polygons that were within 100m of the NHD network OR within 100m of lakes/ponds (1/24K) that were within 100m of the NHD network were selected for the analysis.

**Analysis**: All analyses were run in ArcGIS using a python script. For more information, or to obtain a copy of the python script, please contact the Conservancy. Selected wetland polygon complexes were coded for the number of developed areas and small dams for which they might be providing flood attenuation/protection. In the developed area network analysis, dams were treated as barriers to flood attenuation benefit, that is, if a dam was in-between a developed area and an upstream wetland complex, the dam was considered a barrier to any flood attenuation effects that the wetland complex might be providing. The same held true in the dam analysis. Small dams (dams on smaller streams) were only considered to be benefiting from a wetland's flood attenuation if they were directly downstream from the wetland complex. If there was an intervening dam between the subject dam and the wetland complex, the subject dam was considered to be receiving no flood attenuation benefit. A note on river size and developed areas: if a developed area was directly on a large size river (size 3 or 4), then only wetlands on upstream sections of size 3 or 4 rivers/streams were considered to be providing potential flood attenuation benefits.

**Enhancements to the original analysis**: After completing the initial analysis statewide and receiving feedback on the results from experts and stakeholders, we explored several possible enhancements to the analysis focused on a southern Maine pilot area. These enhancements were aimed at helping us better rank wetlands for their relative importance and likelihood to provide significant flood attenuation benefits. These enhancements were primarily aimed at coding wetlands with their size, their size relative to the size of the watershed of the developed areas they may be benefiting, the number of downstream developed areas they may be serving, and the total downstream human population they may be serving. We used the NHD 30m flow accumulation and 30m flow direction rasters to develop the watersheds for the pilot developed areas. In addition, we used the 2010 Census Block data (*http://www.maine.gov/megis/catalog/-BLOCKS10*), available from MEGIS for our downstream population estimates. Again, all analyses were run in ArcGIS/python. Final attributes added to wetlands flagged as providing possible flood attenuation benefits:

- *UrbanAreaCount* - # of developed areas the wetland may be serving
- *Acres_Protected* – Acres of the subject wetland already in some sort of protection status
- *MaxUrbanWatershedServed* – Acres of the largest developed area watershed the wetland may be serving
- *MinUrbanWatershedServed* – Acres of the smallest developed area watershed the wetland may be serving
- *SumUrbanWatershedServed* – Total acres of developed area watersheds served by the subject wetland
- *TotalPopulationServed* – Estimate of the total downstream population served by the potential attenuating effects of the wetland

# Appendix 2: Aquatic Connectivity Improvement A Municipal Case Study

*Josh Royte, The Nature Conservancy in Maine, April 2013*

**Context**

In Maine today, there is a great deal of interest in facilitating the upgrade of road-stream crossings (commonly called culverts) in a way that maximizes the resulting benefits for aquatic connectivity and public safety. Given that most culvert upgrades require additional resources to complete—potentially including larger pipes, arch culverts or bridges, extra fill, etc.—it is critical that any road manager has information to help target resource investments to the most efficient locations possible. The analysis described below provides an example of an approach to prioritizing culvert upgrades for private and town maintained roads in four Maine municipalities: Houlton, Belfast, Bangor and Lyman. This case study focuses on just the habitat component, and additional information is needed from the municipalities to develop a more comprehensive set of overall priorities or sequencing of projects. Municipalities would also provide important perspective on the age and condition of structures, road maintenance schedules, and might know if a structure has been a problem in the past for debris blockages, flooding, or erosion or undermining problems.

**Approach**

Road-stream crossing data were collected in these municipalities using the Maine Stream Crossing Survey methodology, a coordinated effort of public agencies, non-profit organizations and volunteers that has assessed over 10,000 stream road-crossings in Maine over the past 8 years. For each crossing, the data collected includes: width of the stream; length, width, and height of the bridge or culvert; any drop or perch from the culvert or bridge outlet to the stream; and any blockages among dozens of other measurements at each site. Surveyors also take pictures up and downstream, as well as inward and outward from each culvert, which helps show where problems might be for fish and other wildlife moving up and downstream.

The prioritization approach used here has been tested in sites around the state from the Lower Penobscot River, Kennebec Estuary, Casco Bay Estuary, and for several large landowners by a number of groups, including the U.S. Fish and Wildlife Service's Gulf of Maine Coastal Program, The Nature Conservancy, Casco Bay Estuary Partnership, and Kennebec Estuary Land Trust. Starting with the full set of crossing for a given watershed, landownership, or town, crossings are filtered out that are less important allowing focus on the areas of highest priority. Severe, potential or partial barriers generally make up 14-60% of the crossings in a given geography. For those barriers, some may block only short stretches of upstream habitat (e.g., less than a quarter mile of habitat) while the restoration of others could open up 2-4 times as much habitat for the cost/effort. Streams that provide documented habitat for wildlife known to require up and downstream movements (especially Eastern brook trout and sea-run fish like alewives, Atlantic salmon, or blueback herring), rank higher than a stream where there is either no data or negative data (i.e., we know from surveys there are no special habitat values there).

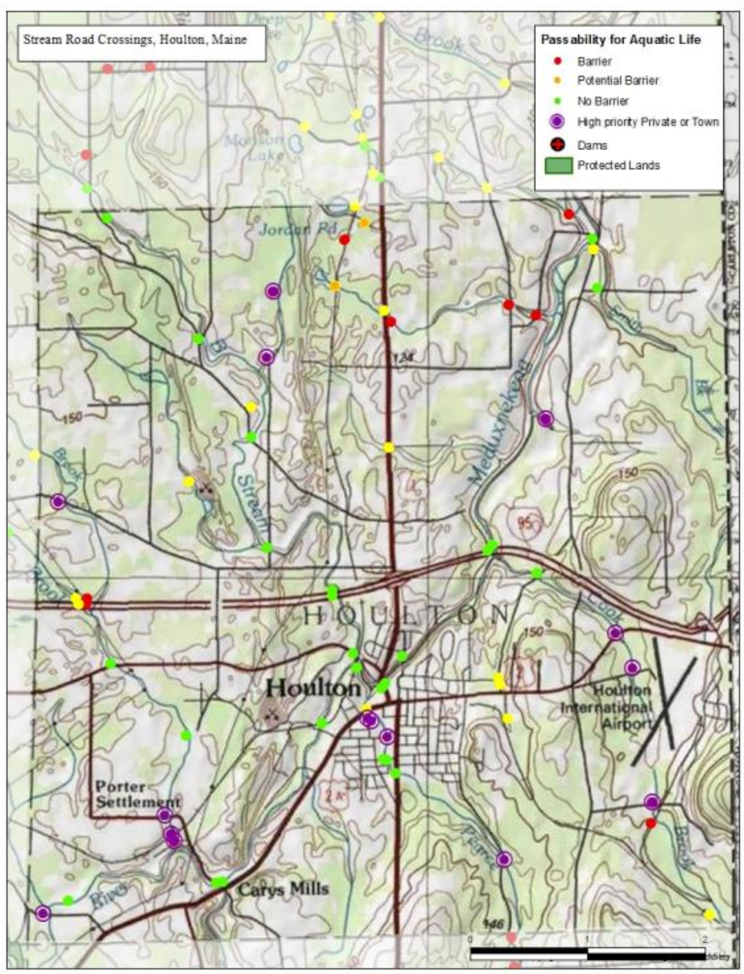
Streams with documented invasive fish species would be priorities NOT to connect to intact stream networks, particularly those harboring sensitive species such as juvenile salmon or any Eastern brook trout.

**Results**

**Houlton, Maine** (23,487 acres)

- Approximately 103-mile network of perennial stream habitat
- Atlantic salmon watershed, although not listed as Distinct Population Segment because of poor downstream access
- Brook trout in many of the Meduxnekeag River tributaries
- 70 Road Crossings
- 36 are not a barrier to fish movements (3 more were not accessible)
- 31 are severe or partial barriers with one or multiple culverts, some bridges, one ford
    - 1 is under a railroad (not a town problem; 4 are highway (I-95); 2 are state roads (Route 1 and Route 2)
    - 3 have <.25 miles of habitat upstream; 6 are in waters without mapped brook trout
    - That leaves 15 town and private roads as potential restoration sites
        - 11 are known priorities because of know brook trout habitat
        - 4 have not been surveyed for brook trout

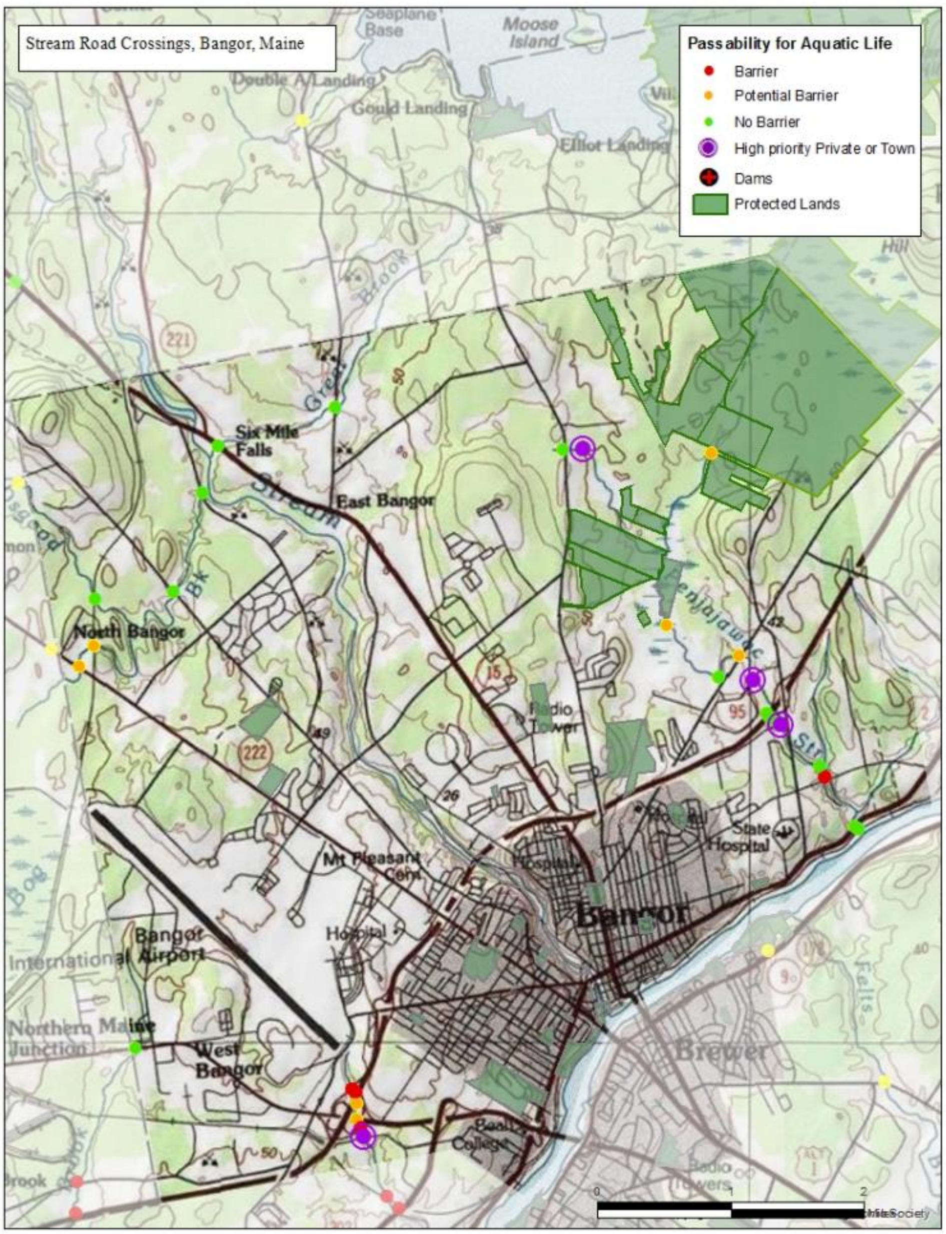
*Municipal Input*: Houlton identified the highest priority for a culvert upgrade as one identified here on Moose Brook, in the SW corner of town near "Porter Settlement" on the map below. This was at risk of failure in recent floods and it is on a dead-end access road to the town's largest business a starch mill. This culvert is also a priority for the Houlton Band of Maliseets as it blocks fish passage upstream.



**Bangor, Maine** (21,906 acres)

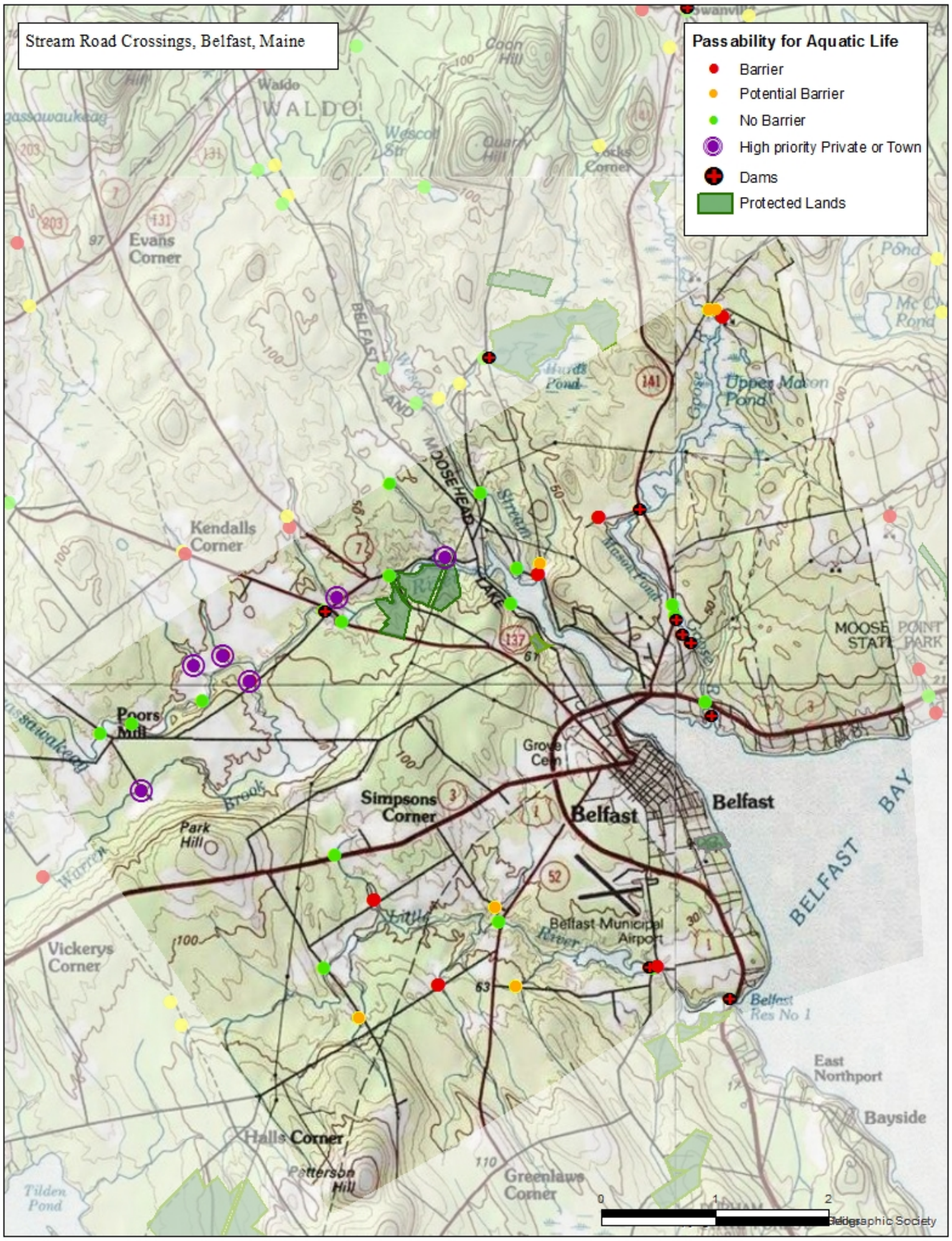
- Approximately 22 miles of perennial streams and 4 miles of Penobscot River shore
- 30 Road Crossings
- 15 are not barriers to fish movement
- 15 are severe or partial barriers
    - 11 are state roads or railroads
    - 4 are town or private roads
        - One has no modeled salmon units and no know brook trout habitat
        - Three are on Penjajawoc Stream with at least some modeled Atlantic salmon habitat and conservation lands up and/or downstream

| |
|---|
| *Municipal Input*: Bangor recognized one of the stream barriers surveyed on Penjajawoc Stream and was able to remove the culvert from an abandoned road leading to a low cost, permanent solution. |



**Belfast, Maine** (21,999 acres)

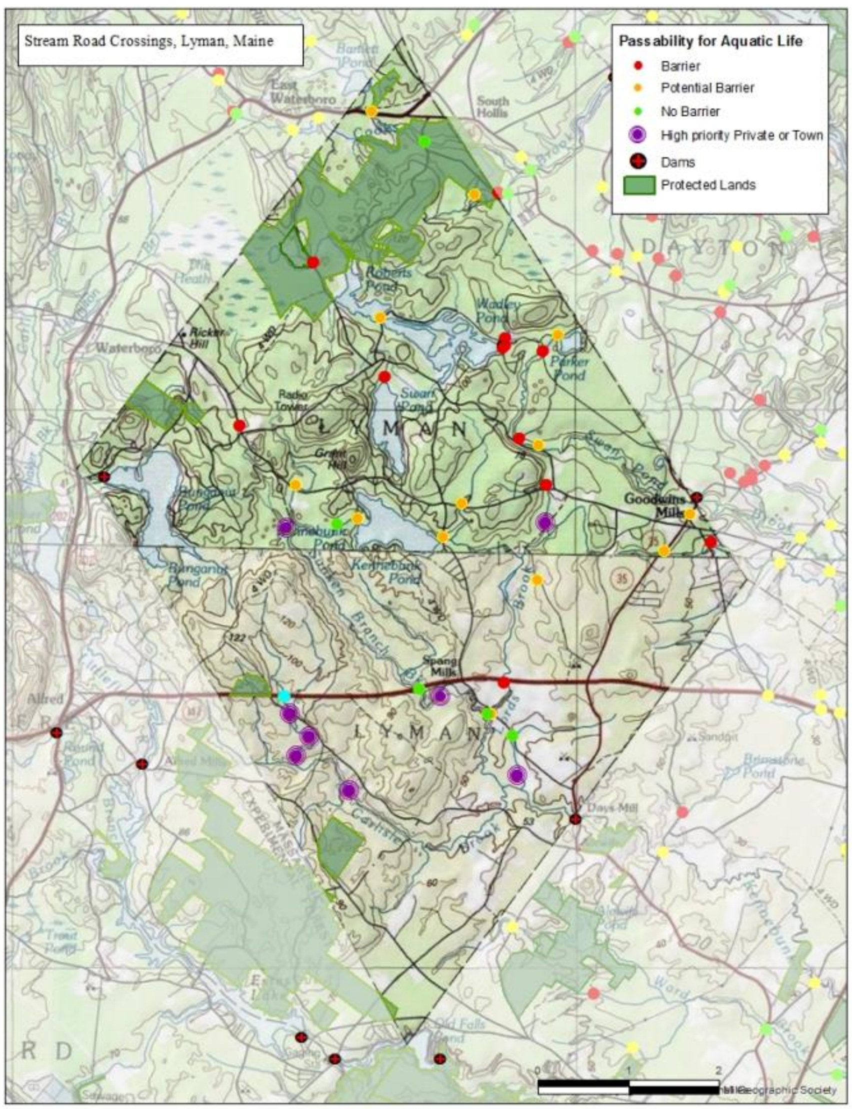
- Approximately 55 miles of perennial streams and about 5 miles of shore on Belfast Bay
- 36 Road stream crossings
- 19 are not barriers to fish movement
- 7 severe or partial barriers are on town or private roads
- 6 of these barriers, if removed would add over a mile of upstream habitat
- Highest priority are the 6 on the Passy River due to the large amount of habitat upstream and relative few dams downstream to the ocean.



**Lyman, Maine** (25,904 acres)

- Approximately 61 miles of perennial streams divided between the Saco River, Kennebunk River, and Mousam River watersheds.
- 45 Road stream crossings
- 12 are not barriers to fish movement
- 32 are severe or partial barriers to fish movement
    - 10 are State Roads
    - 22 are Private or Town Road crossings
        - 9 have lake habitat or < ¼ mile of stream habitat upstream
        - 13 have either known or potential Eastern brook trout habitat
        - 8 others are higher priorities because connect >1/2 a mile and drain to the Kennebunk River with only one dam downstream to the ocean
        - 5 of those 8 stand out further because of the amount of brook trout waters without nearby invasive fish and habitat for rare turtles and/or dragonflies

*Municipal Input*: Lyman identified one high priority culverts, an eight-foot arch on Lords Brook, has been a problem and help is needed to upgrade this to a structure that could stake the more common flood flows.



# Appendix 3:
# Maine Potato Board Irrigation Survey Report

*Maine Potato Board, 2010*

During the spring and summer of 2010 the Maine Potato Board met with 33 individual potato growing operations in Maine. The farms were located from Fort Kent to Fryeburg including the towns of: Fort Kent, St. Agatha, Limestone, Caribou, Woodland, Washburn, Mapleton, Fort Fairfield, Presque Isle, Easton, Mars Hill, Robinson, Monticello, Houlton, New Limerick, Island Falls, Sherman, Sangerville, Exeter, Dover Foxcroft, Corinna, Fryeburg, and Rumford. The purpose of this effort was to compile an inventory of the current irrigation capacity of potato growers in Maine, make some determination regarding the status of compliance with the chapter 587 flow-rule, and to get an idea what the future demand for irrigation capacity may be. We used the data that was compiled to develop costs estimates to replace existing non- compliant water sources with ones that will comply with chapter 587.

Early in the spring of 2010 a list of irrigating potato growers was created. The list was developed with input of equipment suppliers, regulators and others with knowledge of irrigation in the Maine potato industry. We believe the list to be comprehensive.

The following summary represents the current status of irrigation activity.

| | |
|---|---:|
| Current Irrigators | 33 |
| Current Acres Irrigated | 9,690 |
| Number of Withdrawal Sites | 128 |
| Number of Non-Compliant Ch 587 Withdrawal Sites | 93 |
| Number of Traveling Guns | 56 |
| Number of Center Pivots | 74 |
| Miles of Above Ground Pipe | 35 |
| Miles of Buried Pipe | 55 |

The following summary shows future irrigation needs.

| | |
|---|---:|
| Number of new irrigated acres | 8,125 |
| Number of new ponds | 56 |
| Number of new center pivots | 86 |
| Miles of new underground pipe | 40 |
| Number of water management plans | 89 |

Several pieces of information stood out as significant. Most notably, out of 128 current water withdrawal sites only 35 are in compliance with the State of Maine Chapter 587 Low Flow Rules. The remaining 93 sites will have to be replaced with sources that are compliant with Chapter 587 Low Flow Rules. This will require, in most instances that a pond be built to accommodate the withdrawal limits imposed by Chapter 587. A pond large enough to irrigate 100 acres is estimated to cost between

$150,000 and $200,000 to construct. The estimated cost of source construction for 93 new sources will be between $13.9 million and $18.6 million. The need for additional center pivot irrigation systems and the underground pipe to supply them will require an additional $11.1 million investment.

The Maine potato industry currently irrigates about 18% of the planted acreage. It is the desire of the industry to irrigate an additional 8,125 acres, bringing the total of irrigated acres to 32%of the planted acreage.

The number of growers who do not currently irrigate, but would like to is unknown. The numbers in this report reflect only those growers who currently irrigate.