Scarborough Marsh:
Historical Impacts, Current Conditions, and Restoration Potential

MAINE AUDUBON SOCIETY

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Executive Summary

Introduction

Scarborough Marsh, approximately 3,000 acres in size, is Maine's largest and best known salt marsh. It is owned and managed by the Maine Department of Inland Fisheries and Wildlife. This report summarizes the results of a study of the Scarborough Marsh ecosystem conducted in 1998 and managed by the Maine Audubon Society. The goals of the study were to raise citizen awareness of threats facing tidal marshes and increase local grassroots support for tidal marsh conservation and restoration; collect baseline data on tidal restrictions and invasive plants in Scarborough Marsh for use by cooperating agencies and organizations; and prioritize restoration opportunities within the Scarborough Marsh estuary. Maine Audubon trained a group of volunteers to gather field data on tidal restrictions, tidal elevations, salinity, and invasive plants, provided the technical expertise and logistical support for the project, and prepared this final report.

Ecology of Scarborough Marsh

Scarborough Marsh is a back-barrier salt marsh, formed behind the protective barrier beach at Pine Point and the more stable Prouts Neck. These barriers provide the sheltered conditions necessary for fine sediments to be deposited and salt marsh plants to become established in the intertidal zone. The salinity ranges from that of seawater in sections of the marsh near the mouth of the Scarborough River to brackish and fresh water at the most inland reaches of the marsh. Salt Marsh Hay and other typical salt marsh plants are found throughout most of the marsh, with species that are more adapted to the brackish conditions such as Narrow-leaf Cattail found well away from the river mouth where freshwater influence is stronger. As salt marshes develop over time, they build up a thick layer of peat (15 feet is not uncommon) as dead marsh vegetation and sediments brought in by the tides are deposited in a process known as accretion. In this fashion, tidal marshes have been able to keep pace with the gradual rise in sea level over the last 5,000 years. Scarborough Marsh provides unique wildlife habitat for a great variety of plants and animals, offers important opportunities for hunting, fishing, boating and nature study, and surrounds tidal flats with commercially-important shellfish beds.

Human activities have significantly altered Scarborough Marsh and other tidal marshes in the Gulf of Maine. The most significant threat continues to be roads and railroads that cross the marsh and form barriers to the free flow of tidal water. These barriers limit the amount of water reaching the inner marsh, and hence the salinity and amount of sediment available for marsh accretion. The worst type of tidal restriction is the tide gate, which is designed to prevent salt water from reaching sections of the marsh. This type of restriction will cause the marsh to decompose as it becomes less saline, resulting in a lower surface elevation on the inland side of the restriction. If the marsh surface subsides more than a few inches it becomes impossible to fully restore the native plant community that existed prior to the restriction. The spread of invasive plants such as Common Reed (*Phragmites australis)*, often abetted by tidal restrictions, also is a threat to the ecological integrity of the marsh. Past ditching for agriculture or mosquito control and direct fill of the marsh also add to the cumulative impacts to the marsh, while ongoing development in the surrounding uplands affects water quality and wildlife habitat. All these factors have adversely affected Scarborough Marsh.

Study Results

Fourteen tidal restrictions were evaluated during the study (Figure 3 and Table 1). An initial assessment and additional field studies found that five restrictions currently have or have had a significant impact on sections of the marsh system. These include Pine Point Road where it crosses Jones Creek, the Eastern Road, a low steel dam where Blue Point Road crosses Cascade Brook, Route 1, and the Black Point Road where it crosses the Libby River.

Jones Creek. Most of the drainage from the east-coastal section of Old Orchard Beach has been diverted into Jones Creek and hence into the Scarborough River. A tide gate located on Jones Creek was removed approximately 10-15 years ago, but a significant restriction still exists at this point. Some of the Jones Creek marsh has since reverted to salt-tolerant vegetation, but tidal flushing is poor and freshwater plants continue to occupy a significant portion of the marsh. Two large *Phragmites* stands totaling approximately 8 acres are found in this marsh.

Eastern Road. A tidal restriction has existed here since a railroad was built in the 1840's. A tide gate existed here for about 60 years until the 1940's or 1950's. Our study found that the tidal marsh peat subsided approximately 6 inches during the period the tide gate was in place. As a result, the vegetation, while consisting of native salt marsh plants, is significantly different from the natural high marsh community immediately seaward of the road. While our measurements indicate that the Eastern Road is a minor impediment to tidal flow, the tide gate made a permanent change in the marsh above this point.

Cascade Brook, Blue Point Road. A low steel dam installed by the Maine Department of Inland Fisheries and Wildlife to provide more freshwater habitat has significantly altered several acres of salt marsh. Salt-tolerant vegetation is limited to a small length of stream channel above this point. Several stands of *Phragmites* are located just seaward of this restriction.

Dunstan River, Route 1. Almost half the *Phragmites* in the marsh system is located in this area. Earlier studies have shown that its growth has been very rapid, with the result that open marsh habitat favored by waterfowl and wading birds is being lost. *Phragmites* is now spreading on the seaward side of Route 1. Our study found a significant difference in marsh elevation, salinity, and plant communities on opposite sides of the highway as one moves away from the immediate vicinity of the Dunstan River and toward the edge of the marsh. While the culverts under Route 1 allow fair tidal exchange, strong freshwater influence and possibly runoff from developed areas may also encourage the rapid spread of *Phragmites*.

Libby River, Black Point Road. The culvert width where the Libby River crosses under Black Point Road is only 18% of the river width, the lowest percentage of any restriction in the Scarborough Marsh system. An earlier study found significant differences in salinity, vegetation, and marsh elevation between the inland and seaward side of the restriction. One stand of *Phragmites* is located just upstream of the restriction.

Recommendations

Maine Audubon makes the following recommendations for restoration and further monitoring of Scarborough Marsh.

1. **Control *Phragmites* in the vicinity of Route 1**. Our study confirms that this is the highest restoration priority within the marsh system. The study results suggest that a restoration plan encompassing multiple elements, including additional culverts, ditches to improve tidal flushing, and if necessary, control in nitrates entering the watershed may be necessary. The Maine Department of Inland Fisheries and the National Atmospheric and Oceanic Administration have begun to investigate the feasibility of restoring this site.

2. **Restore Jones Creek Marsh.** Tidal flows to this marsh might be significantly improved by cutting a new channel that would cross Pine Point Road about 0.3 miles south of the current culvert. This could result in restoration of about 75 acres of tidal marsh south and east of the Boston and Maine Railroad, including over 30 acres of former salt marsh that is now freshwater wetland and enhancement of approximately 40 acres of existing salt marsh with improved tidal flushing. Additional restoration may be possible beyond the railroad. The Maine Department of Fisheries and Wildlife could partner with the US Fish and Wildlife Service, the Maine Department of Transportation, and other potential cooperators on a restoration effort at this site.

3. **Improve tidal flow under Black Point Road at the Libby River.** Placing additional culverts in the river channel at this point would restore tidal flows, possibly reducing or eliminating *Phragmites* just inland of the road and allowing salt marsh vegetation to replace brackish-marsh vegetation further inland. The Maine Department of Inland Fisheries and Wildlife, US Fish and Wildlife Service, and the Maine Department of Transportation could coordinate this restoration project.

4. **Continue to monitor *Phragmites* growth.** Evidence suggests that *Phragmites* was almost non-existent in the marsh 25 years ago but that it is now spreading rapidly. We recommend a volunteer-based monitoring project that would a) monitor the spread of selected *Phragmites* stands and b) repeat the marsh-wide *Phragmites* assessment summarized in Section IV after 5 years (in 2003) to see if new stands have appeared or existing stands have significantly increased in size. A local watershed group (see Recommendation 5) could coordinate the monitoring.

5. **Establish a Scarborough River Watershed Association.** Ultimately, maintaining and restoring the ecological integrity of the marsh will require a broad watershed-based constituency and an organization that can help build on and integrate the work of individuals, committees, and organizations with various interests in marsh conservation. While this study is the first to systematically evaluate the entire marsh system, it is still limited in scope and there is much follow-up work to be done. The future of the state's largest salt marsh will be best served by a watershed-based organization whose sole focus is conservation of Scarborough Marsh and its estuary system.

I - Introduction

Tidal marshes are highly productive ecosystems located at the interface between freshwater and marine environments. Maine has over 19,500 acres (79 km^2) of tidal marshes, far more than any other New England state, New York, or Canadian province in the Bay of Fundy/Gulf of Maine region. Tidal marshes provide habitat for a unique suite of organisms as well as playing an important role in the life cycle of a large number of migrating fish and birds with regional economic and recreational significance.

Despite strong state and federal wetland laws that have virtually eliminated most filling and draining of tidal marshes, many factors continue to threaten the long-term ecological integrity of these ecosystems. Typically located in areas of concentrated coastal development, tidal marshes are threatened by fragmentation of the upland fringe, polluted runoff, rising sea level, invasive plant species such as Common Reed (*Phragmites australis*), and legacies of past activities that include ditching, fragmentation by roads, and restriction of tidal flows. Tidal restrictions and their effects on tidal flow, salinity, available sediment, and plant communities are the greatest threat facing many Maine marshes. However, systematically collected data on the numbers of tidal restrictions and their effects are nearly non-existent for most Maine tidal marshes.

Maine Audubon Society recently developed the *Maine Citizens Guide to Evaluating, Restoring, and Managing Tidal Marshes* (Bryan et al. 1997), based on a similar manual used in New Hampshire. During 1997 Maine Audubon hosted a series of workshops on the use of the manual and trained over 50 potential volunteers on the use of the manual. During 1998 we began a volunteer-based tidal marsh monitoring project in the Town of Scarborough to provide baseline information to the scientific community, resource management agencies, and the citizens of Scarborough. The goal of the monitoring was to evaluate the impacts of past and current tidal restrictions and extent of *Phragmites* growth on Scarborough Marsh, Maine's largest salt marsh.

A web of roads and other human barriers restrict tidal flows in many portions of the Scarborough Marsh estuary. A network of ditches, past fill, and development along the marsh fringe all affect the ecological integrity of the marsh system. The rapid encroachment of *Phragmites* in parts of Scarborough Marsh may indicate restricted tidal flows and lower salinity levels. However, the effects of tidal restrictions and other alterations to the marsh have not been quantified on most of the marsh. State and federal agencies as well as local communities have expressed increasing interest in restoring Scarborough Marsh but good baseline data on potential restoration sites is not available.

Project Goals

- Raise citizen awareness of threats facing tidal marshes and increase local grassroots support for tidal marsh conservation and restoration
- Collect baseline data on tidal restrictions and invasive plants in Scarborough Marsh for use by cooperating agencies and organizations
- Prioritize restoration opportunities within the Scarborough Marsh estuary

This report summarizes the findings of the volunteer monitoring effort. The audience for this report includes local groups as well as state and federal conservation agencies. Local citizens and schools will also find the information of interest. Conservation organizations with a current interest in Scarborough Marsh include:

Scarborough Conservation Commission
Scarborough Coastal Pollution Committee
Scarborough Open Space Committee
Scarborough Planning Board
Scarborough Marsh Nature Center
Ducks Unlimited
Maine Audubon Society Conservation Department
Maine Department of Inland Fisheries and Wildlife
Maine State Planning Office Coastal Program
Maine Department of Environmental Protection
US Fish and Wildlife Service Gulf of Maine Project
Rachel Carson National Wildlife Refuge
Wells National Estuarine Research Reserve

Volunteer Monitoring

The Maine Audubon Society coordinated the project, provided technical expertise, lead field studies, and prepared the final report. Volunteer Tidal Marsh Stewards were used to the greatest extent possible, depending on their availability and the tasks to be performed. Several of the Tidal Marsh Stewards attended training workshops hosted by Maine Audubon and the Wells National Estuarine Research Reserve in 1997. In addition, volunteers received training for the specific monitoring protocol used in this project in 1998. Depending on the task, volunteers either worked independently or worked as field assistants with the Maine Audubon wetland ecologist. The purpose of using volunteer stewards was to increase the amount of data that could be collected within the available budget and to create local investment in and support of the study.

II - Ecology of Scarborough Marsh[1]

Scarborough Marsh is a prime example of a New England back-barrier salt marsh (Figure 1). Maine's largest tidal marsh, Scarborough Marsh is approximately 3,000 acres in size and accounts for 15% of the state's total salt marsh area. Virtually the entire marsh is owned by the Maine Department of Inland Fisheries and Wildlife, while almost all of the surrounding uplands are in private ownership.

Salt marshes are common features of sheltered estuaries. Estuaries are aquatic ecosystems that are partially enclosed by land where saltwater from the ocean mixes with freshwater from upland rivers and surface runoff. Salt marshes and mudflats are common estuarine wetlands. In the Gulf of Maine, salt marshes develop in a range of salinity from that of seawater, about 34 parts per thousand (ppt) of salt, to approximately 18 ppt. Brackish marshes are characterized by salinity ranging from 0.5 - 18 ppt. Freshwater tidal marshes are located where the salinity averages less than 0.5 ppt yet tides still affect the movement of water.

Tidal Marsh Formation

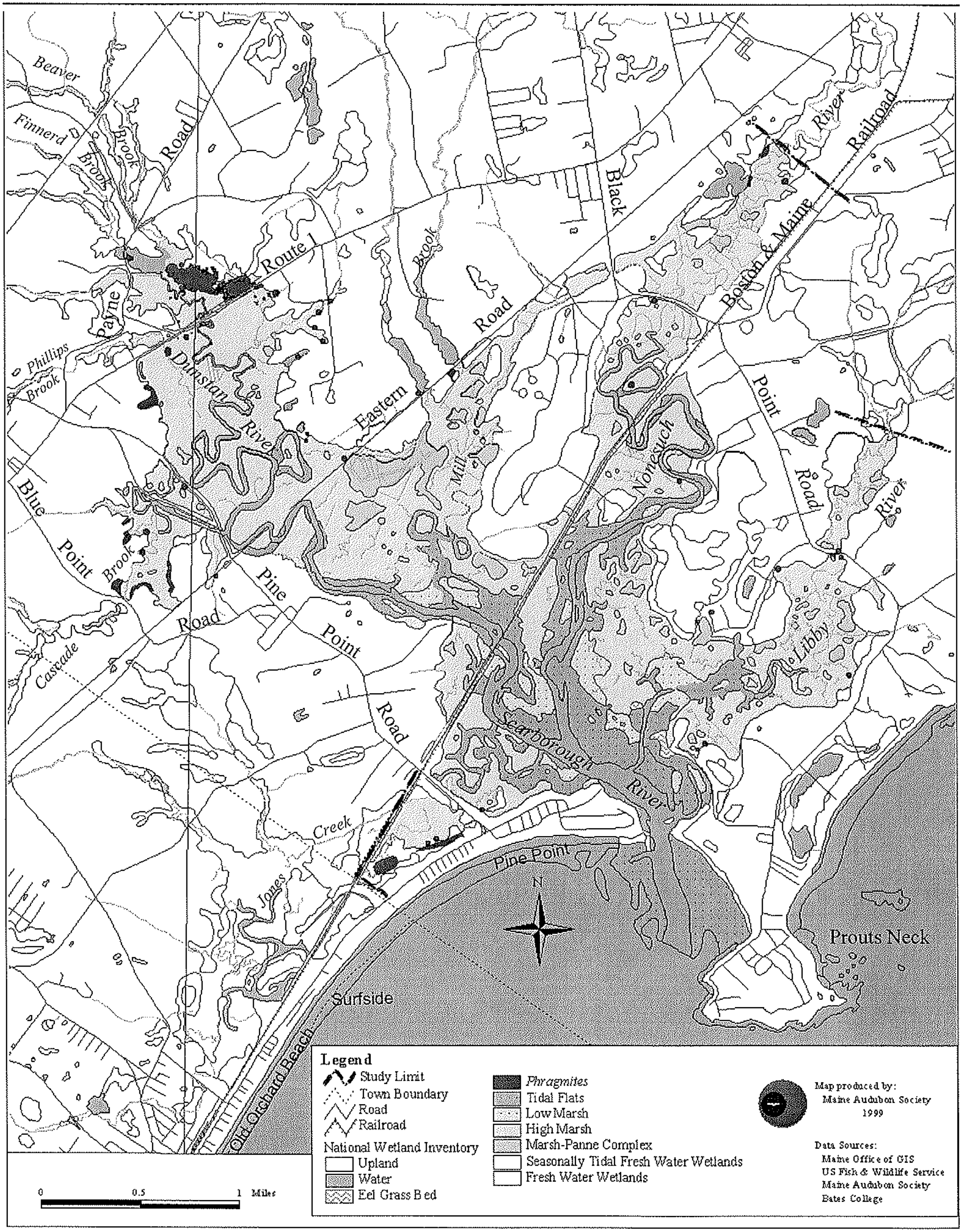
Tidal marshes form in low-lying coastal areas that are protected from excessive winds, waves, and currents. These "low energy" environments allow for the deposition of sediments suspended in tidal waters. Subsequently, marsh plant communities develop on this sediment base. Each of these two processes, the deposition of sediment material and the colonization by tidal marsh plants, reinforce one another. Once plants are established they trap additional sediments, and the increased deposition of sediments raises the marsh elevation, allowing expansion of the tidal marsh. Along the Maine coast, sea level has risen slowly over the past 4,000 to 5,000 years. Throughout this period salt marshes have maintained themselves at the tidal elevations necessary for plant growth through the accretion of sediments filtered from tidal waters and the formation of peat from plant fragments and sediments. Two common species are Smooth Cordgrass (*Spartina alterniflora*), which grows in areas flooded by daily tides, and Salt Meadow Grass (*Spartina patens*), which grows at a higher elevation in irregularly flooded areas.

Important Tidal Marsh Habitats

Scarborough Marsh contains a variety of habitats that support different plants and animals. Some of the more important habitat types are described below.

[1] Most of the material in this section was adapted from Bryan et. al. 1997.

Figure 1. Scarborough Marsh Ecosystem



Low marsh is flooded twice daily by tidal action. Smooth Cordgrass is the dominant plant in salt and brackish low marshes. Low marsh typically occurs as a sloping fringe between the high marsh and a tidal creek or mudflat.

High marsh is flooded irregularly by above-average tides. Salt Meadow Grass and Black Grass (*Juncus gerardii*) are the dominant plants in most high marshes. In brackish marshes with a strong freshwater influence, plants such as Narrow-leaf Cattail (*Typha angustifolia*) or bulrushes (*Scirpus sp.*) may dominate. High marsh is usually level and occurs between the low marsh and uplands. Healthy high marsh can be seen on the seaward of the Eastern Road, along the Nonesuch and Libby Rivers seaward of Black Point Road, and on the seaward side of Pine Point Road at Jones Creek.

Pannes are shallow "ponds" that form within high marsh. Flooded periodically by spring tides (the monthly above-average tides associated with full moon and new moon), pannes provide an abundance of food for waterfowl and migrating shorebirds. Good examples of pannes can be seen on the seaward side of Route 1 and along the Scarborough Marsh Nature Center trail on the west side of Pine Point Road.

Tidal creeks, **open water**, and **tidal flats** are also important components of the marsh ecosystem. Open water can be defined as a permanently flooded (i.e., below mean low water) water body greater than 100 meters (330 feet) wide. Tidal creeks are narrower, and may or may not have water at low tide. Tidal flats are nearly level to gently sloping unvegetated areas located within the intertidal zone.

Classification of Tidal Marsh Systems

Variation in topography, geology, tides, sediment supply, wave exposure, and rate of sea-level rise along the Maine coast lead to the development of different marsh types. The three basic types are coastal/back barrier marshes, finger marshes, and fringe marshes. The three marsh types can be determined visually from maps (see Figure 2) and are described below.

Scarborough Marsh is a back-barrier salt marsh, formed behind the protective sand beach at Pine Point and the more stable shoreline at Prouts Neck. Back barrier marshes are most common southwest of the Sheepscot River where most of Maine's sand beaches are found. Finger marshes are often found at the head of bays, while fringe marshes are found along protected shorelines in estuarine reaches of large rivers (coves, indentations, small tributaries, meanders) or at the toe of an eroding bluff. These types are more common in midcoast and Down East Maine.

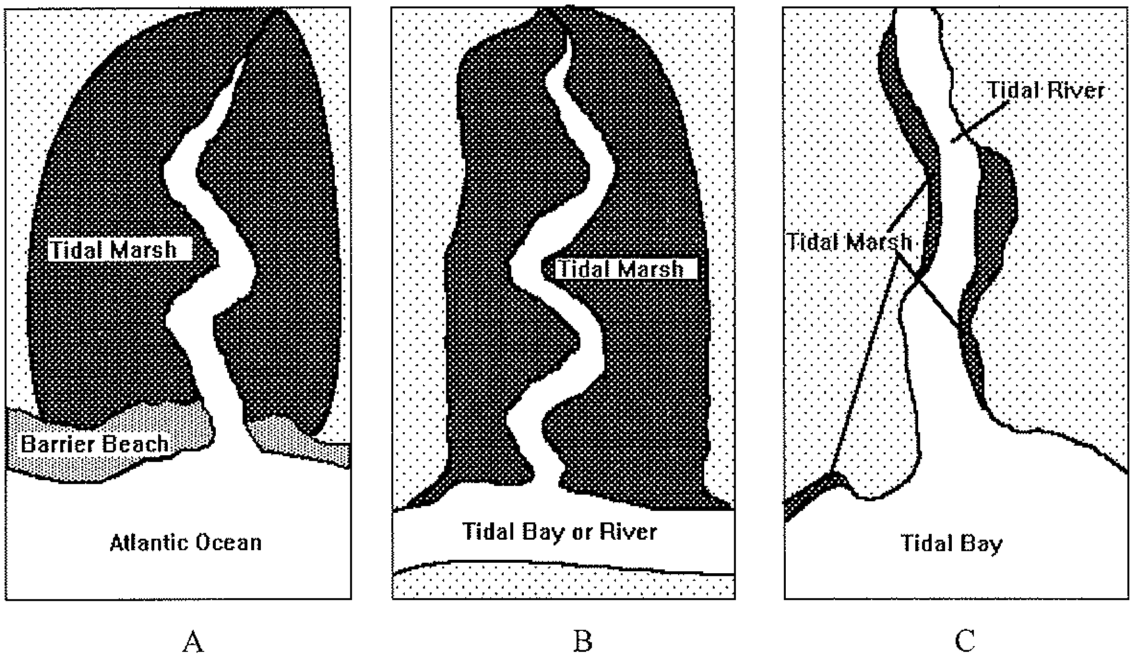


Figure 2. (A) Back-barrier Marsh; (B) Finger Marsh; and (C) Fringe Marsh

Ecological Functions of Tidal Marshes

Tidal marshes can be described in terms of the ecological functions they perform and the values they hold for society. Many ecological functions and societal values are closely related (e.g. wildlife habitat and recreation). Tidal marsh ecosystems are formed and persist through a combination of geological, hydrological and biological processes or functions. Several of these functions have been described in light of the tangible benefits they provide to the human community, directly or indirectly. Scientists recognize several important ecological functions of tidal marshes, including:

- **Shoreline anchoring** - The accretion of peat and sediment maintains marsh elevation as sea level rises and buffers the upland shoreline against the erosive action of the open water.
- **Storm Surge Protection** - The resistance to water flow presented by marsh vegetation slows the movement of water over the marsh, thereby helping to protect low-lying uplands and erodable shorelines during storms.
- **Water Quality Maintenance** - Pollutants often enter aquatic systems attached to sediment particles. Many of these particles are deposited on the marsh, limiting their transport to other ecosystems. Some pollutants may then bind with soil particles and become unavailable for uptake by plants or animals.
- **Wildlife, Finfish, and Shellfish Habitat** - The rapid growth rates of salt marsh grasses form the base of a highly productive food web. Salt marshes are used for food and shelter by a diverse animal community, including many species of birds, finfish, shellfish and

other invertebrates. The linkage between salt marsh productivity and the health of the Gulf of Maine remains to be studied, but it is likely that coastal marshes are important contributors to the productivity of the greater Gulf of Maine ecosystem.

These ecological functions have a tremendous financial value. Two-thirds of commercial shellfish and finfish landed in the U.S. depend on coastal wetlands for nursery and breeding habitat or on forage fish that breed in our coastal wetlands (Gosselink et al. 1974). The estimated total income for the harvest and processing of finfish and shellfish in Maine in 1993 was $462 million, resulting in twenty-two thousand jobs (Wilson 1993). Recreational fishing, hunting, wildlife watching, and boating in coastal wetlands also contribute significant economic value.

Societal Values of Tidal Marshes

Humans have depended on tidal marshes in Maine for millennia. Native Americans harvested birds, fish and shellfish from tidal marshes for thousands of years. In an area dominated by extensive forests, uplands adjacent to salt marshes became preferred sites for European settlement because the marsh grasses provided abundant fodder for their livestock.

Today, tidal marshes are valued by society for a variety of reasons. Scarborough Marsh offers some of Maine's best opportunities for bird watching, coastal canoeing and kayaking, sport fishing, and waterfowl hunting. Salt marshes are the major native grasslands of coastal New England, and their open, grassy expanses and coastal vistas are aesthetically attractive to many. As ecosystems that have maintained themselves for thousands of years, they provide excellent outdoor classrooms for the teaching of basic ecological concepts.

Threats to Tidal Marshes

Human activities have significantly altered Scarborough Marsh and other tidal marshes. The most significant threat continues to be roads and railroads that form barriers to the free flow of tidal water. These barriers limit the amount of water reaching the inner marsh, and hence the salinity and amount of sediment available for marsh accretion. The worst type of tidal restriction is the tide gate, which is designed to prevent salt water from reaching sections of the marsh. The marsh will then decompose as it becomes less saline, resulting in a lower marsh surface elevation on the inland side of the restriction. If the marsh surface subsides more than a few inches it becomes impossible to fully restore the native plant community that existed prior to the restriction. The spread of invasive plants such as Common Reed (*Phragmites australis*), often abetted by tidal restrictions, also threatens the ecological integrity of the marsh. Past ditching for agriculture or mosquito control and direct fill of the marsh also add to the cumulative impacts to the marsh, while ongoing development in the surrounding uplands affects water quality and wildlife habitat. All these factors have shaped the character of the Scarborough Marsh as we see it today.

III – Inventory and Assessment of Tidal Restrictions

The first phase of the assessment was an inventory of tidal restrictions within the Scarborough Marsh estuary. Because tidal restrictions caused by roads, railroads, bridges, culverts, and tide gates may significantly affect water levels, salinity, and sediment transport, the number and severity of tidal restrictions is a key indicator of the ecological integrity of a tidal marsh system.

Methods

The tidal restrictions inventory and assessment was based on the Phase 1 tidal crossing assessment developed by the Parker River Watershed Association (Purinton and Mountain 1997). National Wetland Inventory (NWI) data on Maine Audubon's geographic information system were used to identify tidal wetlands within the study area. A second data layer showing road and railroad crossings of the marsh was used to identify potential tidal restrictions. The potential restrictions were then marked on a base map for use in the field (Figure 3).

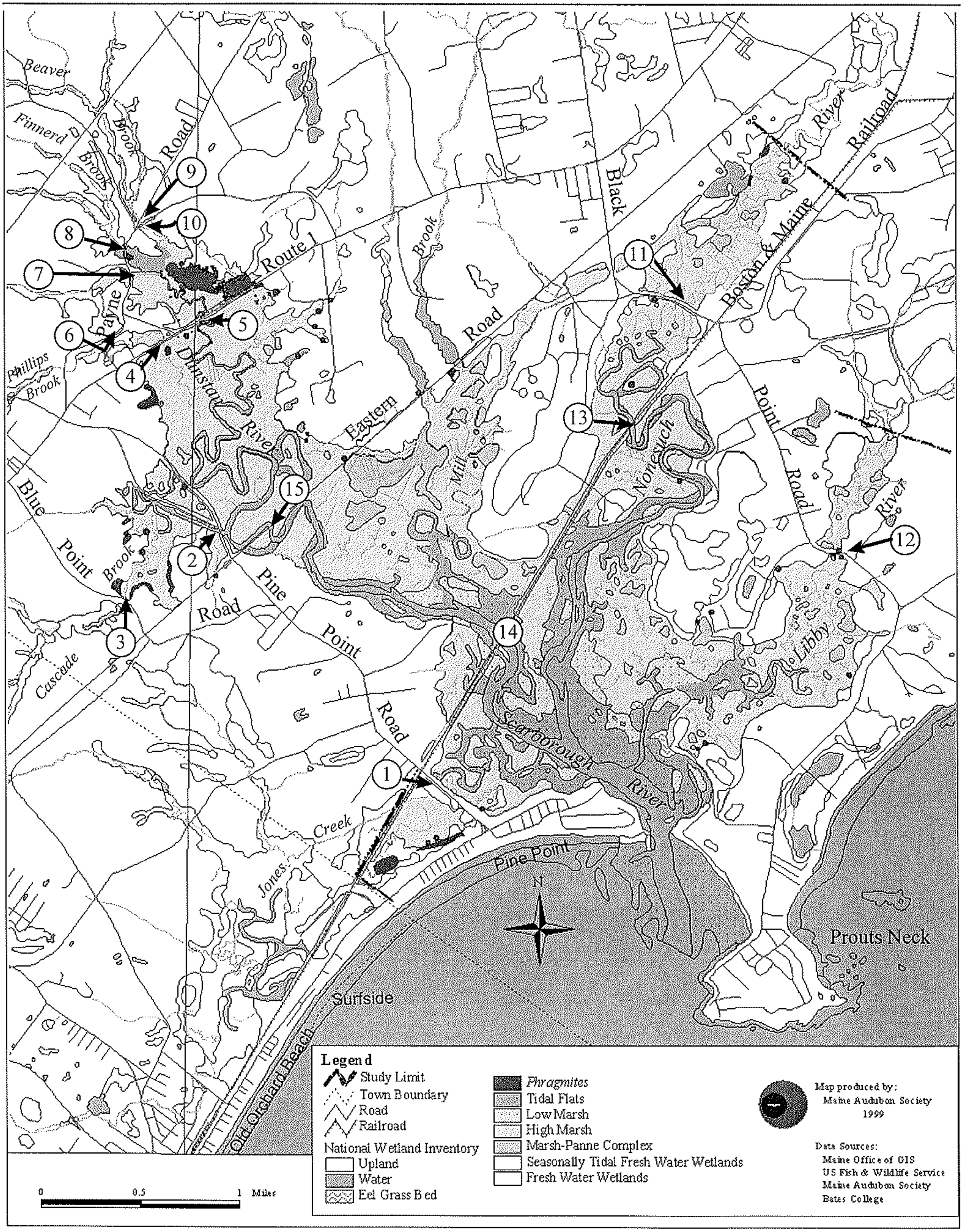
Volunteer Tidal Marsh Stewards gathered data on the type (bridge, culvert, etc.), height and width of the restriction. Because restrictions usually have higher current velocities than natural tidal creeks, water passing through a restriction often erodes the creek bank at either end of the culvert or bridge. Restrictions may also result in changes in the plant community. Evidence of the severity of the restriction, as indicated by scour pools and differences in vegetation above and below the restriction were also noted. The field protocol and a sample data form are included in Appendix A.

The restrictions were then rated according to the restriction classification scheme on the Parker River Watershed Association Phase 1 Data Sheet (Appendix A). Each restriction was given a score of 1 (best) to 5 (worst) in each of three areas: a) evidence of flow restriction, as indicated by the amount of erosion and pooling; b) ratio of culvert or bridge width to river width; and c) comparison of vegetation above and below the restriction. The score for each of the three areas was then summed to provide an overall rating for the restriction. Thus, the best possible overall rating based on the three scores would be a total of 3; the worst overall rating possible would be a score of 15.

Results and Discussion

The results of the tidal restriction inventory and assessment are summarized in Table 1. Of the seventeen restrictions identified in Figure 3, three (# 6, 9, and 10) were not rated because further field checks indicated that they were located at the natural transition point from tidal to

Figure 3. Location of Tidal Restrictions



freshwater wetland. The overall rating ranged from a score of 5 (best) to 12 (worst). Six received relatively low scores (overall score of 6.5 or less), six received medium scores (7 to 10), and two received relatively high scores (greater than 10). A discussion of the most severe restrictions is included below.

Table 1. Results of Tidal Restriction Inventory and Assessment, Scarborough Marsh, 1998.

		Field Measurements			Phase 1 Classification[1]			
Restriction #	Location	Restriction Width (ft)	Stream/ River Width(ft.)	Restriction Width as % of Total	Evidence of Restriction/ Erosion	Culvert/ Channel Ratio	Vegetation Difference Up-Down	Overall Rating
1	Jones Creek, Pine Point Road	7	34	21	4	4	4	12
2	Dunstan Canal, Pine Point Road	3	13	23	1	4	2	7
3	Cascade Brook, Blue Point Road[2]	20	22	91	3	5	4	12
4	Phillips Brook, Route 1	10	10	100	3	2	1	6
5	Dunstan River, Route 1	28	53	53	2	3	3	8
7	Dunstan River Tributary, Payne Road	3	5	60	1	3	2	6
8	Finnerd Brook, Payne Road	8	10	80	1	3	3	7
11	Nonesuch River, Black Point Road	30	50	60	3.5	2	1	6.5
12	Libby River, Black Point Road	5.5	30	18	3.5	5	1	9.5
13	Nonesuch River, Railroad tracks	130	150	87	1	3	1	5
14	Boston and Maine Railroad	500	750	67	1	3	1	5
15	Eastern Road	100	125	80	3	3	4	10
16	Dunstan Landing East	7	17	41	1	4	1	6
17	Dunstan Canal Tributary	3	2.5	100+	3	1	3	7

1. Classification based on Purinton and Mountain, 1997. 1 = Best Condition (nearest to natural); 5 = Worst Condition. See Appendix B for details.
2. Classification for culvert/channel ratio based on low steel dam located just upstream of Blue Point Road.

Restriction # 1 – Jones Creek, Pine Point Road. The Jones Creek restriction at Pine Point was rated one of the most severe. At this point a narrow (7 ft.) concrete box culvert constricts a creek that has a natural channel width of about 34 ft. Significant pooling was observed, and the vegetation is much different on either side of the restriction. Undisturbed low and high salt marsh dominated by Smooth Cordgrass and Salt Meadow Hay is located seaward of the restriction. Inland of the restriction the marsh is poorly drained and dominated by a short form of Smooth Cordgrass. For many years tidal flow to this section of the marsh was blocked by a tide gate. The tide gate was removed approximately 10 to 15 years ago to allow alewives access to spawning areas. After the gate was removed, salt water killed some of the freshwater vegetation that had invaded the marsh west of Pine Point Road during the time the tide gate was in place.

While the short form of Smooth Cordgrass occurs naturally in poorly drained areas of high marsh, its dominance in the Jones Creek marsh indicates that years of freshwater influence likely caused the original salt marsh peat to decay. Although salt water has returned, Salt Meadow Hay, the typical high marsh grass, has been unable to re-occupy the site.

It is likely that all of the large seasonally-tidal freshwater wetland south of the Scarborough town line in Old Orchard Beach was salt marsh at one time with a tidal inlet through the beach somewhere near Surfside. This inlet has been blocked and all freshwater draining the northern half of Old Orchard Beach now runs through a ditch connecting the Old Orchard marsh complex to Jones Creek and hence into the Scarborough River. The additional freshwater input to this area likely reduces the salinity of the Jones Creek marsh below the level that might be expected due to this relatively severe restriction. In 1988 a dam was installed on Jones Creek by the Maine Department of Inland Fisheries and Wildlife approximately ½ mile south of Pine Point Road to create a freshwater impoundment. This area is now dominated by uniform growth of Broad-leaf Cattail *(Typha latifolia).*

Restriction # 15 - Dunstan River, Eastern Road. The Eastern Road crosses the marsh about one mile seaward of Route 1. Where the river cuts through the Eastern Road is spanned by a steel footbridge approximately 100 ft. in length. There is some evidence of scouring above and below the bridge. The river channel is about 125 ft. wide at this point. The section of the marsh inland of the Eastern Road is dominated by the short form of Smooth Cordgrass, whereas typical high marsh plants such as Salt Meadow Hay and Black Grass (*Juncus gerardii*) dominate below the restriction. The differences in vegetation seem surprising given the small amount of apparent restriction created by the bridge. Other clues, including dead birch trees located within what is now salt marsh on the inland side of the Eastern Road, indicate that a more severe restriction was historically located at this point.

The Eastern Road was the site of the Portland, Saco and Portsmouth Line, a railroad built across the marsh in the early 1840's[2]. Tidal flows to the section of the marsh lying inland of the railroad were cut off in the 1870's or early 1880's. The tide gates and an extensive network of ditches were used to drain the marsh and encourage the growth of salt hay. The tide gates and ditches were so effective that the 1916 edition of the USGS topographic map of the area shows no marsh inland of the Eastern Road, except for a small area along Cascade Brook. The tide gates were maintained until the 1940's or early 1950's. After the marsh was purchased by the Maine Department of Inland Fisheries and Wildlife (MDIFW) in the 1950's the tide gates were used to flood the area with fresh water to encourage the growth of wild rice, a freshwater marsh plant favored by waterfowl. The gates were eventually removed by MDIFW. During a large storm in the 1950's (sometime after June, 1953 as indicated by aerial photography) the river cut a new channel and broke through the road at the site of the steel bridge that exists today. The old stream channel is now filling in with silt.

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[2] Becky Delaware, Past President of the Scarborough Historical Society, provided much of the historical information in this report.

Tidal flow to the marsh inland of the Eastern Road has been greatly improved by the elimination of the tide gate and the storm that created the new, wider opening through the Eastern Road. In order to further evaluate the magnitude of the present restriction and the historical impact of the tide gate, a detailed study of marsh and tide elevations was undertaken along the Eastern Road (see Section V).

Restriction #3 – Cascade Brook, Blue Point Road. This restriction is located near the upper limit of tidal range. While the bridge spans 91% of the tidal creek width, a low steel dam located just upstream of the bridge blocks tidal flow on all but the highest tide. This bridge was installed by the Maine Department of Inland Fisheries and Wildlife to create freshwater habitat for waterfowl and other waterbirds while allowing fish passage. Downstream the vegetation is a mix of typical salt marsh plants with stands of *Phragmites* located along the upland edge. Upstream of the dam salt marsh plants (primarily Smooth Cordgrass) are limited to the fringe of the tidal creek. Narrow-leaf cattail and wild rice are found in the remainder of the marsh.

Restriction #12 – Libby River, Black Point Road. The Libby River, which is 30 ft. wide in this area, passes through a 5.5 ft. diameter culvert. This culvert was installed in 1993 when Black Point Road was rebuilt. Prior to that date a 5 ft. diameter culvert was located at this point (Linnell 1994). Distinct erosion pools are located above and below the restriction. Linnell's study also indicated that the marsh inland of the road was drier, less saline, and that *Phragmites* was located inland but not seaward of the road. His study also indicated that the marsh on the inland side of the road averaged 6.6 inches lower in elevation than the marsh on the seaward side. This indicates that the peat probably has decayed and subsided due to the restriction of tidal flows. The Black Point Road was re-built in 1996. Unfortunately, a larger culvert that would allow free tidal flow was not installed at the time the road was rebuilt.

IV – Invasive Plants

Invasive plants are often symptoms of ecosystem change or stress. At low densities, invasive plants may not pose a significant threat to the ecosystem. However, when they crowd out native plants and cause a significant change in the plant community, wildlife habitat is lost and the basic nature of the ecosystem is changed.

Invasive plants become established in two basic ways. First, exotic (non-native) plants sometimes are able to outcompete native plants due to faster growth and/or an ability to tolerate a wide range of site conditions. Purple Loosestrife (*Lythrum salicaria*), a native of Europe, has invaded many freshwater and slightly brackish marshes in southern and central New England. It is spreading northward, and in midsummer its striking spikes of purple flowers now decorate many wetlands in southern Maine. Purple Loosestrife is very aggressive, and will invade open water habitat and choke out native sedges and grasses, displacing waterfowl and other open-wetland animals. Native plants may also become invasive when human alterations of an ecosystem create conditions favorable for a species to invade new habitat. When tidal restrictions limit the amount of salt water entering a tidal marsh, native species such as Narrow-leaf Cattail that are typically limited to the upper reaches of the marsh where salinity levels are low often spread seaward and eliminate typical salt mash plants and the animals that depend on them.

Phragmites is spreading rapidly in parts of Scarborough Marsh

Common Reed (*Phragmites australis*).[3] *Phragmites australis*, or Common Reed, is an invasive plant that is a native of the Americas and Eurasia. However, in recent decades it has become a widespread invasive species on this continent. Observers of Scarborough Marsh have witnessed the rapid spread of *Phragmites* over the last 20 years along Route 1 where it crosses the marsh. *Phragmites* is easily recognized by its height (5-15 feet), plume-like inflorescence, and habit of growing in dense, single-species stands.

[3] The information on *Phragmites* in this section is primarily based on reports by The Nature Conservancy (1995) and Niedowsky (1999).

Although native to North America, scientists now believe that the invasive form of *Phragmites* now overtaking wetlands throughout the US was introduced from Europe. *Phragmites* is especially common in brackish wetlands, where it is able to outcompete native tidal marsh species, and on disturbed sites. Tidal restrictions caused by roads, railroads, and other forms of development have encouraged the spread of *Phragmites* in tidal marshes throughout the East Coast. High nitrate concentrations from farms and urban areas may also stimulate the growth of *Phragmites* in wetlands, while highway construction and other development create exposed soils that facilitate colonization of new areas. *Phragmites* may become established by wind-blown or bird-deposited seeds, or by movement of rhizomes (underground stems). Construction equipment is probably responsible for moving rhizomes to many new sites, especially excavators that are responsible for the maintenance of highway ditches where *Phragmites* frequently grows. Tidal ice may also move rhizomes within a marsh system. Once it becomes established, *Phragmites* typically spreads through growth of rhizomes. Lateral expansion of colonies is typically about 1 meter per year, but new colonies may spread up to 10 meters per year in nutrient-rich areas.

An undergraduate research project at the University of Southern Maine found that the area of *Phragmites* in the vicinity of Route 1 increased by approximately 50% in the nine-year period from 1986 to 1995 (Moore 1996). This is confirmed by long-time observers of the marsh who report that *Phragmites* was virtually non-existent in the Route 1 area 25 years ago.

Methods

The invasive plant search primarily focused on locating and mapping *Phragmites* stands within Scarborough Marsh. Although observations show that Narrow-leaf Cattail appears to be expanding on the inland side of Route 1, the search concentrated on *Phragmites* because it is more aggressive than Narrow-leaf Cattail. *Phragmites* is able to grow in more saline areas than Narrow-leaf Cattail, spreads more rapidly, and usually eliminates all other native marsh plants once established.

Two data sources were used. The first was from an unpublished study conducted by Bates College (Bohlen et al. 1998). Bates students under the direction of Dr. Curtis Bohlen mapped the perimeter of *Phragmites* stands and other plant communities by locating the stand boundaries in the field with an accurate (< 2 meters) Global Positioning System (GPS) unit. The Bates study was limited to the marsh area between Route 1 and Payne Road and that area of the marsh located with 200 meters of the seaward side of Route 1.

Volunteer Tidal Marsh Stewards identified invasive plants on the remainder (>95%) of the 3,000-acre marsh system. The volunteers were asked to survey the marsh from vantage points (bridges, roadsides and other points offering good views of the marsh) and to sketch the location and extent of stands of *Phragmites* and other potentially invasive species on a base map. They were then asked to estimate the size of the stand (as defined by three broad size classes), identify the dominant species, and estimate the relative dominance of each species if possible. The invasive plant survey protocol is included in Appendix C.

Once the data were collected they were compiled on Maine Audubon's Geographic Information System (GIS). National Wetland Inventory (NWI) maps were used as the base layer for the GIS mapping. The Bates GPS *Phragmites* data and the estimated locations identified by volunteers were added to the base map.

Results and Discussion

The combined extent of *Phragmites* mapped by Bates and Maine Audubon is shown in Figure 1. Approximately 55 acres of *Phragmites* were found in the Scarborough Marsh estuary (Table 2). Of this, 25 acres (over 40%) was found on the inland side of Route 1. After the Route 1 area, the largest concentrations of *Phragmites* are found between Blue Point Road and Pine Point Road and in the Jones Creek area near Pine Point. Scattered small stands are found throughout the remainder of the estuary. Most stands are located in the transition zone at the marsh edge, although a few stands are surrounded by comparatively healthy high marsh.

Table 2. Approximate area of *Phragmites australis* in the Scarborough Marsh estuary, 1998.

Source	Sq. Meters	Acres
Bates[1]		
Inland of Rt. 1	99,397	24.6
Seaward of Rt. 1	7,532	1.9
Bates Total	106,929	26.4
Maine Audubon[2]	117,519	29.0
Marsh Total	224,448	55.5

1. Source: Bohlen et. al 1998. Stand boundaries field-located with accurate GPS.
2. Source: Volunteer surveys. Estimate based on hand sketch maps. Total area may be +/- 5-10 acres.

Several possible factors may explain the abundance of *Phragmites* in the vicinity of Route 1 and Dunstan Landing. First, these areas are quite far from the ocean and have several small streams draining into them that result in lower salinity. Second, there are three tidal restrictions between each of these areas and unrestricted tidal waters. The most seaward of these is the Boston and Maine Railroad (Restriction #14, Figure 3), which forms a barrier approximately 2 miles in length across the marsh. Although an opening 400 ft. wide exists over the main channel, the remainder of the railroad bed forms a dam that prevents water from flowing over the high marsh during the "spring" tides that occur near the times of full moon and new moon. Thus, only the water that can pass under the railroad bridge is available to reach the inner marsh.

The second major tidal restriction affecting the Route 1/Dunstan Landing area is the Eastern Road, located about one mile seaward of Route 1 (Restriction 15, Figure 3). The Eastern Road forms a nearly continuous barrier over 0.8 miles of marsh. There is a 100-ft. bridge over the main channel. However, because the channel averages approximately 125 ft. in width in this vicinity, this opening constricts tidal flow during normal tides. More significant may be the roadbed itself, which prevents flow across the marsh during the peak tides that occur several days each month. Approximately 7 acres of *Phragmites* are located between the Eastern Road and Route 1. Two notable stands of *Phragmites* are located just seaward of Route 1 opposite Anjon's Restaurant near the Maine Inland Fisheries and Wildlife pullout. Unlike many stands that are located at the upland edge of the marsh where fresh water influence is strong, these stands are surrounded by comparatively healthy salt marsh. While smaller in size than stands on the inland size of Route 1, these stands are robust and are spreading.

Route 1. Approximately 25 acres of *Phragmites* are located between Route 1 and Payne Road on the inland side of Route 1. Two relatively large (14 ft. diameter) culverts located under Route 1 constitute the third restriction between the inland side of Route 1 and unrestricted tidal flow (Restriction #4, Figure 3). These culverts account for 53% of the stream channel width and thus may be a moderate, but not severe, restriction to tidal flow. Other factors may also affect the amount of *Phragmites* inland of Route 1. In particular, most of the *Phragmites* is located adjacent to a large freshwater wetland on the northwest side of the marsh. It is likely that this wetland reduces the salinity on the side of the marsh where most of the *Phragmites* is found. In contrast, ditches on the south side of the marsh may result in better drainage of fresh water and allow more tidal flooding. In addition, upstream land uses may be contributing to high nitrate levels which could stimulate more robust *Phragmites* growth. Residential and commercial development in the area, as well as a farm located on a marsh tributary on Payne Road, are potential sources of nitrogen.

Dunstan Landing Marsh. A full-channel bridge on Pine Point Road crosses the Dunstan canal (Restriction #2), which may explain in part why there is less *Phragmites* here than near Route 1. This area is also located closer to unrestricted tidal flows than Route 1, and has fewer freshwater sources. However, there are eight stands of *Phragmites* totaling about 7 acres in this area.

Jones Creek Marsh. Two large stands of *Phragmites* totaling about 8 acres in area are located just inland of Pine Point and west of Pine Point Road. As discussed in Section III, a tide gate was located in the Pine Point Road culvert (Figure 3, Restriction #1) for many years. Salt marsh vegetation has since returned to part of the marsh, but two large stands of *Phragmites* remain in areas where freshwater vegetation is still dominant. It is not known whether these stands are spreading.

In order to evaluate the potential impact of tidal restrictions on invasive species and other aspects of marsh ecology, more detailed studies were undertaken in the vicinity of the Eastern Road and Route 1 (see Section V).

V – Impact of Selected Tidal Restrictions

The inventory and assessment of tidal restrictions and the *Phragmites* mapping indicate that several hot spots of ecological concern are found in the marsh. Two tidal restrictions, the Eastern Road (Restriction # 15, Figure 3) and Route 1 (Restriction #4, Figure 3) were selected for further analysis. The Eastern Road was selected because the tide gate that was located there for approximately 60 years seems to have affected the plant community now found on a significant portion of the marsh inland of the road. Marsh peat frequently decays due to lower salinity levels caused by a tidal restriction, resulting in a lower marsh surface elevation inland of a restriction. This in turn often results in a different plant community than found seaward of the restriction. We suspected the marsh surface may have subsided inland of the Eastern Road. The second location was Route 1, which was selected because almost half of the *Phragmites* found in the Scarborough Marsh is located in this area.

The objectives of this portion of the study were to:

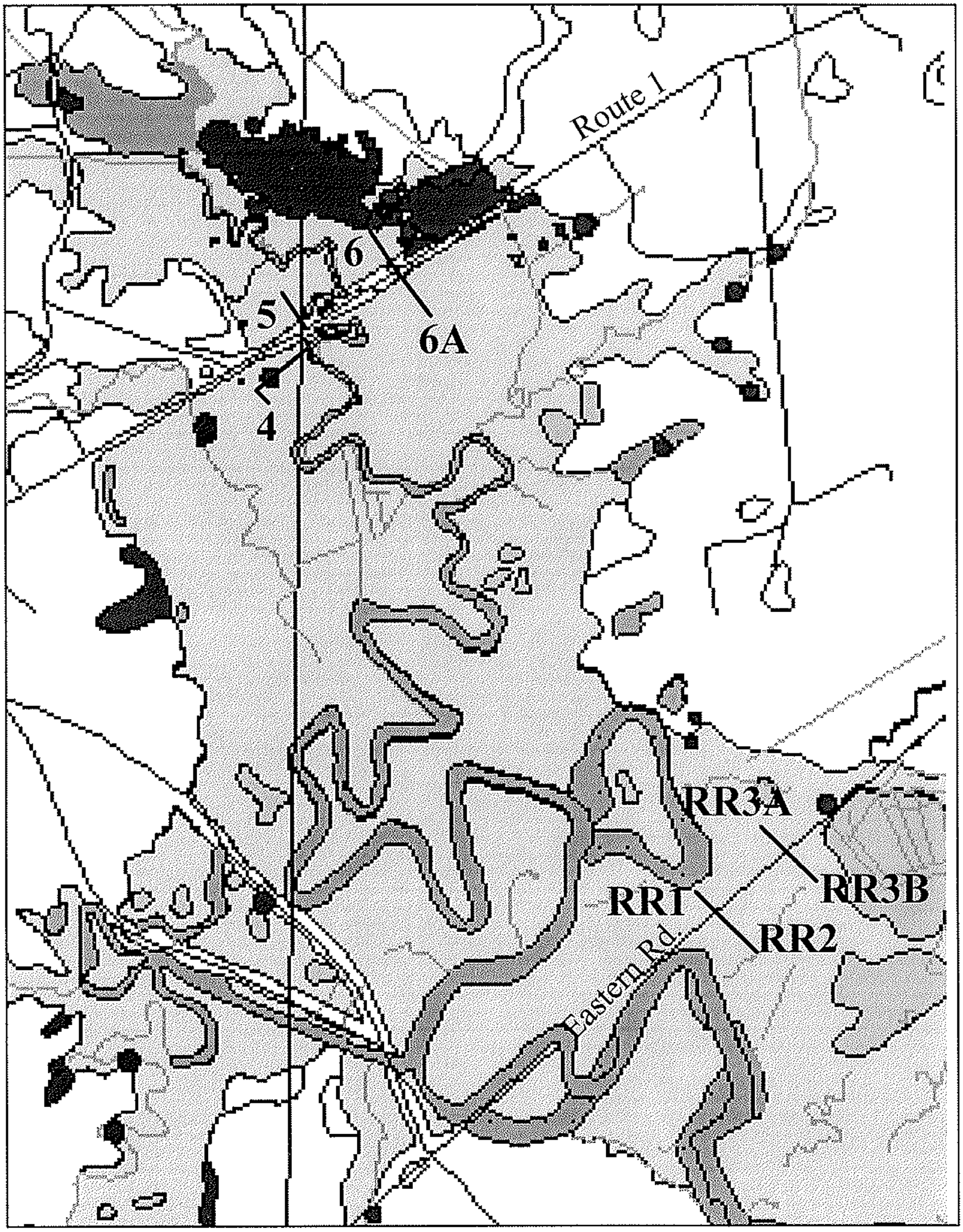
a) estimate the impact that these tidal restrictions have on tidal elevations (depth of flooding over the marsh), and
b) determine if tidal restrictions had caused the marsh surface to subside, and
c) look for differences in plant communities on either side of restrictions.

Methods

Four pairs of transects were established on either side of the Eastern Road and Route 1. Each member of a transect pair was located on opposite sides of the restriction and in similar topographic positions (generally on high marsh). Transects RR 1-2 and RR 3A-3B are located on the Eastern Road; Transects 4 and 5 are located on opposite sides of Route 1 just west of the Dunstan River; and Transects 6 and 6A are located about 1,000 feet east of the Dunstan River on opposite sides of Route 1 (Figure 4).

A surveyor's transit was used as a level to measure elevations at representative points along each transect. The percent coverage of plant species was estimated on a 10-ft. diameter plot surrounding each elevation data point. One tidal monitoring gauge was located on each transect to record maximum tidal elevation at spring tides. Salinity was recorded with a refractometer from water samples taken from the high marsh surface at low tide. The measurements reflect the salinity of the top 1-2 cm of the marsh peat. Tidal elevations and salinity were measured on two to three spring tides per transect from September to December 1998.

Figure 4. Transect Locations



Results and Discussion

Route 1

The impact of the Route 1 tidal restriction is shown in Table 3. During spring tides the high tide level averaged 2.8 inches lower on the inland side of Route 1. Flooding depth ranged from 10 inches to 15 inches over the marsh surface, which is similar to depths found seaward of the Eastern Road where there are fewer tidal restrictions. On Transect pair 6-6A flooding depths were greater on the inland side of the highway, which apparently is due to the marsh surface having subsided over 5 inches on the inland side. The data indicate possible subsidence of the inland side of Transect pair 4-5, but the estimate is less reliable due to the more variable terrain in this area. Salinity measurements (parts per thousand) indicate that there is little difference on either side of the highway near the Dunstan River (Transects 4 and 5). However, salinity appeared to be lower on the inland side of the highway at transect pair 6-6A where a large freshwater wetland combined with the dam effect created by Route 1 is apparently affecting the salinity of this part of the marsh. More salinity measurements should be taken to confirm this apparent trend.

Table 3. Impact of Route 1 Tidal Restriction

	TRANSECT			
	4-5		6-6A	
	Seaward	Inland	Seaward	Inland
Relative high tide level (inches)	0.00	-2.8	0.00	-2.3
Average spring tide flooding depth over high marsh (inches)	15.2	14.0	10.0	13.7
Subsidence of marsh surface relative to seaward side (inches)	0.00	-2.3	0.00	-5.2
Average Salinity (ppt)	21.00	23.00	18.50	13.50

The differences in tidal depth, marsh surface subsidence, and salinity are reflected in the plant communities observed along the transects. The plants observed along Transects 4-5 were generally similar on either side of the highway. The predominant plants, in order of relative abundance, are listed in Table 4. The mix of species is typical of the inland reaches of a tidal marsh where freshwater is beginning to influence the plant community. The Transect passes through a small stand of *Phragmites*, on the seaward side of Route 1. *Phragmites* generally is found on the inland side of tidal restrictions or on the marsh fringe. This stand is surrounded by apparently healthy high marsh with patches of salt meadow hay and bulrush, and there are no significant physical features (marsh elevation, disturbance, or ditches) that might explain its presence. It is clear from this stand that *Phragmites* is capable of spreading seaward of Route 1 in areas of healthy high marsh.

Table 4. Route 1, Transects 4-5; Predominant Plants in Order of Relative Abundance.

Seaward	**Inland**
Salt Meadow Grass	Salt Meadow Grass
Smooth Cordgrass	Smooth Cordgrass
Phragmites	Salt Marsh Bulrush[1]
Salt Marsh Bulrush[1]	

1. Includes *Scirpus robustus* and *Scirpus maritimus*

The differences in the plant communities at Transects 6-6A are more typical of a restricted marsh and reflect the differences in salinity and marsh surface elevation. Typical high marsh vegetation is found seaward of Route 1, whereas a mixture of salt marsh, brackish marsh, and invasive species is found immediately across the highway on the inland side (Table 5).

Table 5. Route 1, Transect 6-6A; Predominant Plants in Order of Relative Abundance

Seaward	**Inland**
Salt Meadow Grass	Salt Meadow Grass
Smooth Cordgrass	Smooth Cordgrass
(short form)	Narrow-leaf Cattail
	Phragmites

Overall, it appears that the Route 1 tidal restriction is a relatively minor influence on tide heights. However, observed subsidence of the marsh surface and prevalence of *Phragmites* on the inland side away from the influence of the Dunstan River indicates that the impact of Route 1 as a restriction is significant where freshwater influence is strongest. This suggests that attempts to slow the spread of *Phragmites* should focus first on reducing freshwater influence near the marsh perimeter, possibly through a system of ditches. This potential mitigating measure is supported by observations of plant communities on either side of the Dunstan River inland of Route 1. *Phragmites* is almost absent and typical salt marsh vegetation is more dominant west of the river where there are ditches extending from the river toward the upland. On the opposite side of the river there are very few ditches and *Phragmites* is much more aggressive.

Eastern Road

The impact of the Eastern Road tidal restriction is shown in Table 6. The high tide level was 4.2 to 7.1 inches lower (average of 5 inches lower for 8 observations) on the inland side of the road during spring tides. Flooding depth ranged from 14.2 inches over the marsh surface on the seaward side of the road to 15.1 inches on the inland side. (Because Transect pair RR 1-2 consisted of high marsh on the seaward side and mostly low marsh on the inland side, depth of flooding and subsidence could not be compared at that location.) The survey found that the high marsh surface was 6 inches lower on the inland side of the road at Transect pair RR 3A-3B, where the marsh surface was otherwise similar on both sides of the road. The subsidence of the marsh surface accounts for the greater depth of water over the marsh surface on the inland side of RR 3A-3B, despite a slightly lower water level on that side of the road. Measurements indicate that there is little difference in salinity on either side of the Eastern Road. Salinity was slightly higher on the seaward side on two occasions. More salinity measurements should be taken to confirm this apparent trend.

Table 6. Impact of Eastern Road Tidal Restriction

	TRANSECT			
	RR 1-2		**RR 3A-3B**	
	Seaward	**Inland**	**Seaward**	**Inland**
Relative high tide level (inches)	0.00	-4.2	0.00	-7.1
Average spring tide flooding, depth over high marsh (inches)	n/a	n/a	14.2	15.1
Subsidence of marsh surface relative to seaward side (inches)	n/a	n/a	0.00	-6.0
Average Salinity (ppt)	28.5	26.5	27.0	27.0

Transect RR 3A-3B provided the best comparison of plant communities on either side of the Eastern Road. The mix of plants on the seaward side of the road is typical of a healthy high marsh, with Black Grass and Salt Meadow Grass predominating (Table 7). The vegetation is noticeably different on the inland side of the road, where Black Grass is entirely absent and the short form of Smooth Cordgrass is the most abundant plant. The short form of Smooth Cordgrass, commonly found where high marsh has decayed or become less well drained, is characteristic of the lower marsh elevation on the inland side. The differences in the plant communities on opposite sides of the Eastern Road are quite apparent even to a casual observer standing on the road.

Table 7. Eastern Road, Transect RR 3A-3B;
Predominant plants in order of relative abundance.

Seaward	**Inland**
Black Grass	Smooth Cordgrass (short form)
Spike Grass	Salt Meadow Grass
Salt Meadow Grass	Spike Grass
Smooth Cordgrass	
Seaside Milkwort	

The marsh surface subsidence and subsequent change in plant community are the result of the tide gate that was located in the Eastern Road for approximately 60 years (see Section III for a history of tidal restrictions on the Eastern Road). Dead birch trees at the end of Transect 3A, located approximately 500 feet seaward of the current edge of the marsh, attest to the severity of the restriction. Because birch trees cannot survive in salt-saturated soils, the dead trees verify that there was no salt water influence inland of the Eastern Road for a significant time. Although tidal flows are much improved due to the removal of the tide gate and the new channel that cut through the road during the 1950's, the legacy of past tidal restrictions remains today.

VI – Overall Marsh Assessment

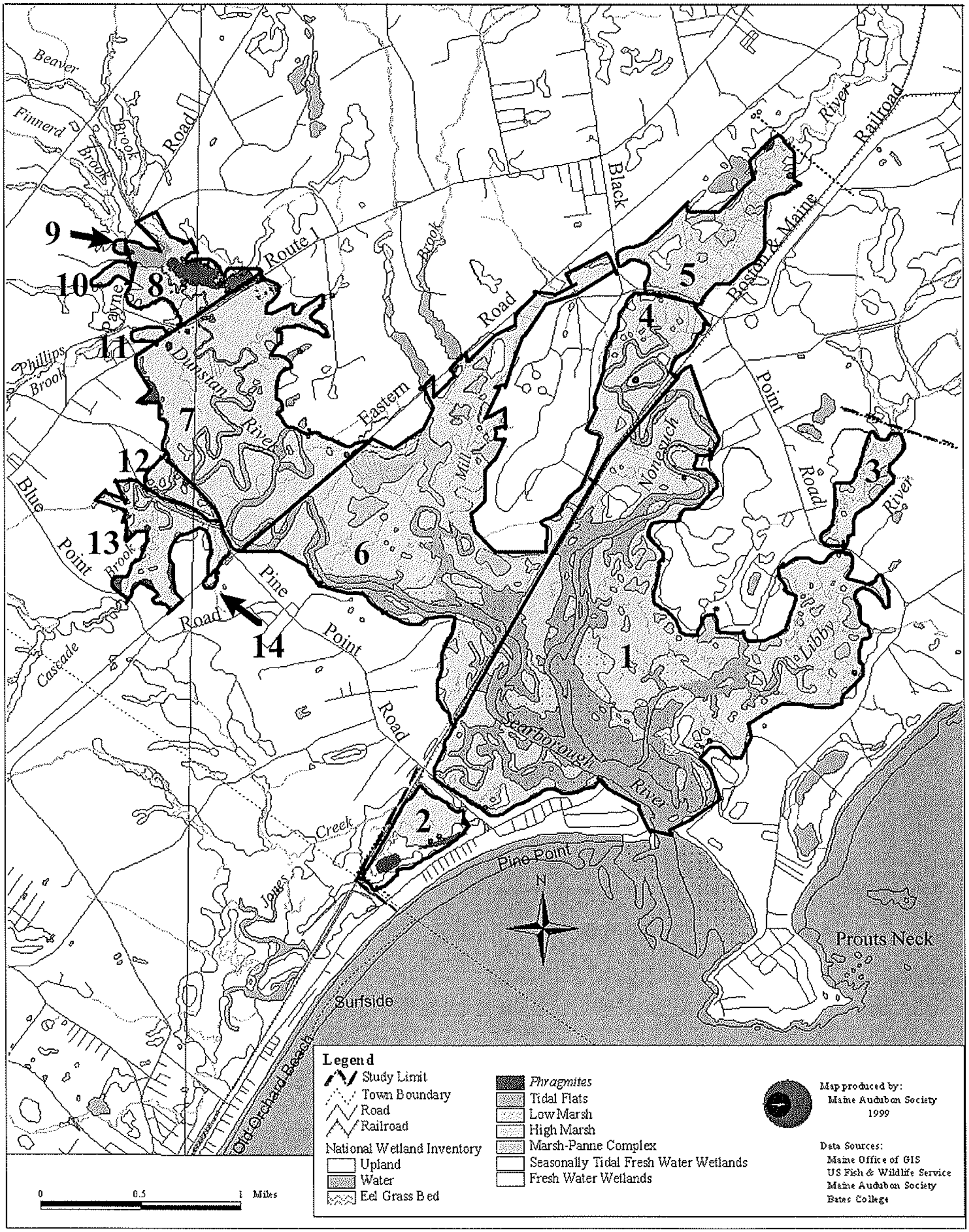
The final phase of the project was to conduct an overall assessment of the Scarborough Marsh system using methods described in the *Maine Citizens Guide to Evaluating, Restoring, and Managing Tidal Marshes* (Bryan et. al. 1997). The *Maine Citizens Tidal Marsh Guide* includes seven assessments that can be undertaken by local citizen groups with an interest in marsh conservation and restoration. Two assessments that focus on threats to the marsh and potential for restoration were used in this project: Ecological Integrity of the Marsh System (Assessment 1) and Ecological Integrity of the Zone of Influence (Assessment 2). Ecological Integrity is a measure of the state of an ecosystem as compared to an undisturbed ecosystem of the same type and in the same region. In evaluating the Ecological Integrity of the Marsh System we looked at conditions within the marsh that affect the health of the ecosystem; when evaluating the Ecological Integrity of the Zone of Influence we looked at surrounding land uses that impact the marsh.

Methods

To identify local differences within the marsh system, the marsh is broken down into a series of **Evaluation Units (EUs)** based on tidal restrictions. The evaluation units used in this analysis are shown in Figure 5. The *Maine Citizens Tidal Marsh Guide* then asks the user to answer a series of predictor questions about the marsh. For example, in evaluating the Ecological Integrity of the Marsh System, the user must identify the number and severity of tidal restrictions affecting the evaluation unit, the area of fill, the area affected by ditching, and the area dominated by invasive plants. In evaluating the Ecological Integrity of the Zone of Influence, the user records the dominant land use surrounding the marsh, the number of buildings within the 250 foot shoreland zone around the marsh perimeter, and the percentage of natural vegetation buffer surrounding the marsh perimeter. A complete list of the questions used in the analysis is included in Appendix D.

For each question, the evaluation unit is assigned a **Functional Index** score ranging from 1.0 (most natural) to 0.1 (least natural). For example, an evaluation unit with less than 5% of its area dominated by *Phragmites* would receive a score of 1.0, whereas one with more than 20% dominance by invasive species would receive a score of 0.1. An **Average Functional Index (AFI)** is then calculated for the evaluation unit. Average Functional Index is a relative indicator of the ecological health of the system. After the individual evaluation unit scores have been calculated, an overall AFI score can then be calculated for the entire marsh system. The size of each evaluation unit is considered when calculating the overall AFI score for the entire marsh.

Figure 5. Scarborough Marsh Ecological Evaluation Units



Results and Discussion

Ecological Integrity of the Marsh System

The results of the analysis are summarized in Table 8 and 9. The Average Functional Index (AFI) scores ranged from 0.27 for EU 8 to 0.90 for EU 1. The low score for EU 8 (the area on the inland side of Route 1) is primarily due to the number of tidal restrictions affecting this unit, the amount of ditching, and the large amount of *Phragmites* growing in the unit. EU 10, a small branch of the Route 1 marsh cut off by Payne Road, also received a low AFI score due to the number of restrictions, amount of ditching, and fill placed for the roadbed. (Because the fill for a road is assigned to the EU on the inland side of the road, small marsh fingers cut off by roads tend to have a low Functional Index for fill.). EU 2, the Jones Creek Marsh west of Pine Point Road and EU 14, small finger of marsh cut off by the Eastern Road, also had relatively low AFI scores. EU 1, the most seaward of the evaluation units, had a very high AFI due to the lack of tidal restrictions, evidence of only small isolated patches of *Phragmites*, and little fill or ditching. Because this evaluation unit comprises about one third of the total marsh system area, it makes a significant contribution to the ecological health of the entire marsh system as measured by the Overall Average Functional Integrity.

Table 8. Summary Data, Ecological Integrity of the Marsh System

			QUESTION					
			1.1	1.2	1.3	1.4	1.5	
EU #	**Total area (acres)**	**Location**	**No .of Restrict-ions**	**Restriction Width as % of Total**	**Total Fill (acres)**	**Ditching (acres)**	***Phrag-mites* (acres)**	**AFI**
1	1023	Lower Scarborough River	0	n/a	0	11	<1	0.90
2	77	Jones Creek, inland of Pine Point Road	1	21	21	2	8.0	0.36
3	58	Libby River, inland of Black Point Road	1	18	1	2	<1	0.74
4	151	Nonesuch River, B&M Railroad to Black Point Road	1	87	6	6	<1	0.77
5	207	Nonesuch River, inland of Black Point Road	2	60	12	13	2	0.44
6	700	Boston and Maine Railroad to Eastern Road	1	67	4	57	<1	0.63
7	464	Eastern Road to Route 1	2	67	7	105	7	0.47
8	66	Dunstan River, Route 1 to Payne Road	3	53	6	57	25	0.27
9	22	Finnerd Brook, inland of Payne Road	4	53	1	0	0	0.63
10	6	Dunstan River, inland of Payne Road	4	53	1	3	0	0.35
11	6	Phillips Brook, inland of Route 1	3	53	1	0	0	0.53
12	22	East of Dunstan Landing Road & Canal	3	23	4	0	<1	0.57
13	92	Dunstan Canal to Blue Point Road	3	23	8	0	7	0.47
14	4	Dunstan Canal Tributary	4	23	1	0	0	0.39
Total:	2898		n/a	n/a	72	256	55	0.68

1. Based on most severe restriction between EU and unrestricted tidal flow.

Restoration Potential. The AFI scores can be used as a preliminary indicator of restoration potential; evaluation units with the lowest scores may be more likely to need restoration. Based on this approach, the evaluation units with the greatest restoration potential, ranked from lowest to highest AFI scores, are EUs 8, 10, 2 and 14. However, in evaluating restoration potential, the results of these evaluations must be balanced with the analysis of tidal restrictions and extent of *Phragmites* or other invasive species, as well as the area that could be restored in an evaluation unit. Restoring tidal flows and controlling invasive species can be expensive, so it is important to focus restoration efforts on evaluation units where restoration will affect the greatest number of acres per dollar spent. In considering the results of Assessment 1 plus the evaluations of tidal restrictions and *Phragmites* in Sections III, IV, and V, EUs 8 and 2 appear to have high potential for marsh restoration. Although EUs 10 and 14 had low AFI scores, they are located well inland in the transition zone where freshwater influence is strong, so restoration efforts, such as installing larger culverts, might have little effect. Moreover both EUs 10 and 14 are small, so restoration efforts based on actions such as culvert replacement would not be cost effective. EU 5 had a low AFI score, but the major contributing factors are the road itself and the restriction caused by the bridge. Both have been upgraded in the recent past, so any changes at this location in the near future are unlikely. Furthermore, the restriction caused by the bridge is less than that of a culvert of similar width, a fact not integrated into the relatively simple quantitative assessment method used. EU 7 also had a low AFI score, but that is mostly due to the lasting impact of the tide gates described in Section V. Hydrologic modeling would be necessary to determine if placing culverts at intervals under the Eastern Road to improve tidal flow during spring tides would be cost effective. EU 13 might warrant further study. This area has low tidal dam at Black Point Road and comparatively high concentration of *Phragmites*. Detailed hydrologic studies would be needed to determine the impact of the dam on salinity and *Phragmites* growth in this evaluation unit.

Despite a relatively high AFI score, EU 3 on the Libby River appears to have restoration potential. This area has the most severe tidal restriction on the marsh and stands of *Phragmites* are located just upstream of the restriction. Additional culverts under Black Point Road could benefit almost 60 acres of salt marsh.

Ditching affects many of the evaluation units, especially EUs 7, 8 and 10. While plugging ditches can create valuable waterfowl and wading bird habitat, pannes and other shallow water habitats appear to be abundant in the marsh. No studies have been done to show that shallow water habitats are limiting wildlife. In addition, plugging ditches could reduce tidal exchange and might promote the growth of *Phragmites* in areas of freshwater influence. In some cases (especially EU 8) areas with ditching have natural salt marsh vegetation and less *Phragmites* than nearby areas. Therefore, top restoration priority should be given to restoring tidal flows and controlling the spread of *Phragmites*.

Ecological Integrity of the Zone of Influence

The results of this assessment are included in Table 9. The evaluation units with the lowest scores, EUs 10, 11, 12, and 14, are also the smallest units in the marsh system. This is because the Zone of Influence is proportionately larger around a small evaluation unit, so the AFI score is more sensitive to development adjacent small units.

Table 9. Results of Zone of Influence Ecological Integrity Assessment

EU	Location	Acres	AFI
1	Lower Scarborough River	1023	0.53
2	Jones Creek, Pine Point Road	46	0.37
3	Libby River, inland of Black Point Road	58	0.40
4	Nonesuch River, B&M Railroad to Black Point Road	151	0.37
5	Nonesuch River, inland of Black Point Road	207	0.70
6	Boston and Maine Railroad to Eastern Road	700	0.53
7	Eastern Road to Route 1	464	0.53
8	Dunstan River, Route 1 to Payne Road	66	0.67
9	Finnerd Brook, inland of Payne Road	22	0.67
10	Dunstan River, inland of Payne Road	6	0.23
11	West of Anjon's restaurant	6	0.23
12	East of Dunstan Landing Road & Canal	22	0.23
13	Dunstan Canal to Blue Point Road	92	0.83
14	Dunstan Canal Tributary	4	0.10
Total Acres/ Overall Average Functional Integrity:		2867	0.54

The Overall Average Functional Integrity of the Zone of Influence represents the general condition of the surrounding uplands and freshwater wetlands within ½ mile of the entire marsh system. The medium Overall AFI score (0.54) indicates that development pressures around the marsh are significant, but that despite these pressures the marsh is somewhat buffered by its large size. As development pressures continue, however, threats to water quality will increase due to surface runoff, and disturbance of wildlife in the marsh will increase. In addition, the development results in loss and fragmentation of wildlife habitat needed by species that use both the marsh and surrounding uplands, such as red fox or white-tailed deer. Species that utilize upland grasslands, a habitat type that is disappearing from our region but found in the zone of influence, will also benefit from habitat conservation. Upland species such as wood thrush or broad-winged hawk, which require relatively large blocks of forest, will also decline as more land is developed around the marsh.

VII – Recommendations

This assessment of Scarborough Marsh found that despite a long history of intensive human use including tide gates that cut off tidal flows, farming, ditching, and development of the surrounding uplands, although far from a pristine condition, in many ways the ecological integrity of the marsh is better than it has been for almost 100 years. This is primarily due to the removal of tide gates and the opening of a new channel in the Eastern Road in the 1950's and the removal of a tide gate at Jones Creek near Pine Point. However, significant differences in the vegetation on either side of Pine Point Road and either side of the Eastern Road suggest that the tide gates created permanent changes in the marsh. The primary physical change identified by this study is the lower marsh surface elevation on the inland side of the marsh due to decay of marsh peat during the time that the tide gates were functioning. Similar effects were found by Linnel (1994) where Black Point Road crosses the Libby River. The rapid growth of Common Reed (*Phragmites australis*) in the vicinity of Route 1 and in other parts of the marsh (especially Cascade Brook just seaward of Blue Point Road and in the Jones Creek marsh) is resulting in a loss of open marsh habitat for ducks, geese, egrets, herons, and other wading birds. Although there are only 50-60 acres of *Phragmites* in the entire 3,000-acre marsh system at this time, the area of *Phragmites* in the vicinity of Route 1 increased by approximately 50% in 10 years. Because of its aggressive nature, this plant should not be ignored.

Extensive ditches affect parts of the marsh (see section VI), but in many cases they promote tidal exchange and probably help to control the spread of *Phragmites*. While plugging ditches can enhance habitat for some wildlife species, restoration of adequate tidal flows to restricted sections of the marsh and control of *Phragmites* should take precedent over ditch plugging and associated habitat enhancement.

Specific recommendations, based on the findings of this study, for monitoring and restoring Scarborough Marsh are discussed below.

1. Control of *Phragmites* in the vicinity of Route 1

The *Phragmites* stands in the vicinity of Route 1 have been identified as a concern by the Maine Department of Inland Fisheries and Wildlife, the National Oceanographic and Atmospheric Administration, and the US Fish and Wildlife Service. These agencies have considered restoration of natural marsh conditions by eliminating or reducing the amount of *Phragmites* on the inland side of Route 1. Our study confirms that this is the highest restoration priority within the marsh system. Our analysis of *Phragmites* (Section IV) as well as tide and marsh elevations (Section V) suggests that a restoration plan encompassing multiple elements will be necessary. *Phragmites* control in this area should consider:

a) additional culverts to increase tidal flow under Route 1;

b) a system of ditches to improve tidal flushing where *Phragmites* is most aggressive, thereby minimizing freshwater influence; and
c) the level of nitrates in the watershed and, if necessary, steps to control its influence.

While our study found problems and suggests possible solutions, the recommendations should be considered preliminary in nature. Additional research will be needed to create the best management plan for this area. The Maine Audubon Society strongly recommends that state and federal agencies listed above continue to work toward a solution to this problem.

2. Restoration of Jones Creek marsh

Our studies found that the Jones Creek marsh has a severe tidal restriction, large *Phragmites* stands, and a significant area that has reverted to freshwater marsh. The existing Pine Point Road culvert and ditch that flows through the former Snow's Chowder factory is a significant barrier to tidal flow. Tidal flows to this marsh might be significantly improved by cutting a new channel that would cross Pine Point Road about 0.3 miles south of the current culvert. This could result in restoration of about 75 acres of tidal marsh south and east of the Boston and Maine Railroad, including aver 30 acres of former salt marsh that is now freshwater wetland and enhancement of approximately 40 acres of existing salt marsh with improved tidal flushing. Additional restoration may be possible beyond the railroad. Additional studies are recommended at this site to further evaluate the potential for restoration. The Maine Department of Inland Fisheries and Wildlife, the US Fish and Wildlife Service, and other parties(e.g., Ducks Unlimited, Maine Department of Transportation) could cooperate on this project.

3. Additional culverts under Black Point Road at the Libby River

The culvert width where the Libby River crosses under Black Point Road is only 18% of the river width, the lowest percentage of any restriction in the Scarborough Marsh system. A previous study by Linnell (1994) found that the marsh was drier, its elevation and salinity lower, and the plant community different on the inland side of the restriction. Placing additional culverts in the river channel at this point would enhance tidal flows to almost 60 acres of salt marsh, possibly reducing or eliminating *Phragmites* just inland of the road and allowing salt marsh vegetation to replace brackish-marsh vegetation (Narrow-leaf Cattail and Bulrushes) further inland. The Maine Department of Inland Fisheries and Wildlife, US Fish and Wildlife Service, and the Maine Department of Transportation could cooperate on this restoration project.

4. Continued monitoring of *Phragmites* growth

Anecdotal evidence suggests that *Phragmites* was almost non-existent in the marsh 25 years ago but that it is now spreading rapidly. A study conducted by a student at the University of

Southern Maine documented rapid growth in the vicinity of Route One. We recommend a monitoring project that would:

a) monitor the spread of selected *Phragmites* stands covering a representative range of marsh conditions to provide better estimates of growth rates (as measured by stand area), and
b) repeat the *Phragmites* assessment summarized in Section IV after 5 years (in 2003) to see if new stands have appeared or existing stands have significantly increased in size.

The monitoring could be undertaken as part of a scientific research project and/or with the help of volunteer monitors.

5. Formation of a Scarborough River Watershed Association

There are many diverse groups and individuals with a keen interest in the ecological well being of the Scarborough River estuary. Duck hunters, fishers, clam diggers, boaters, birdwatchers, and others use the estuary on a regular basis; for some it is their major source of income. In addition, there are many conservation organizations involved in one way or another with the marsh, including several town boards, state agencies (including the Department of Inland Fisheries and Wildlife, the owner of most of the marsh), federal agencies, and private non-profit groups such as Maine Audubon. However, these groups typically focus on one aspect of the marsh (e.g. water quality sampling or wildlife management), while none typically looks on the entire marsh system and the watershed that feeds it. Ultimately, maintaining and restoring the ecological integrity of the marsh will require a broad watershed-based constituency and an organization that can help build on and integrate the work of the various groups with an interest in marsh conservation. While this study is the first to systematically evaluate the entire marsh system, it is still limited in scope and there is much follow-up work to be done. Maine Audubon initiated this study because of the statewide significance of the marsh and its long-term interest in the marsh through the Scarborough Marsh Nature Center. However, the interests of Maine's largest salt marsh will be best served by a watershed-based organization whose sole focus is conservation of Scarborough Marsh and its estuary system.

Glossary

This glossary provides non-technical definitions of technical terms, some of which are used in this manual. This is by no means an exhaustive list of all the terminology pertaining to tidal marshes. For more detailed reference to tidal marsh terminology, see the references listed in Section 9 of this manual.

accretion	the gradual build up of surface elevations due to the deposition of suspended sediments on the marsh surface
aquatic	in or near water in such habitats as ponds, lakes, rivers and oceans
back-barrier marsh	a marsh that forms in the low-lying area behind a barrier beach formation
barrier beach	an elongated landform created by the deposition of sedimentary materials by wind and wave currents, usually parallel to the shoreline, with water on at least two sides, and composed of sand, gravel, or cobblestones
brackish marsh	tidal marshes where the average water salinity is less than 18 parts per thousand (ppt) but greater than 0.5 ppt, which is the upper limit of salinity in a freshwater tidal wetland
buffer zone	an undeveloped area bordering on a wetland that serves to lessen the impact of disturbance (e.g., urban development)
deepwater habitats	permanently flooded areas deeper than 6.6 feet (e.g., lakes)
degraded	characterized by loss of natural ecological structure or function
dominant plant community	a single species or association of plants that are indicative of the ecology of an area, e.g. in a cattail marsh the dominant plant community is cattails
drainage pattern	the paths followed by surface runoff from precipitation within a watershed
ecology	the study of interactions between living things and their environment
ecological integrity	the natural (undisturbed) quality of an ecosystem
ecosystem	a community of plants and animals and the physical environment they inhabit (such as estuaries and tidal wetlands) which results from the interactions among soil, climate, vegetation, and animal life
emergent plant	erect, rooted, herbaceous plants that can tolerate flooded soil conditions, but not prolonged periods of being completely submerged, these include grasses, sedges, rushes, and rooted aquatic plants; there are two types of emergent plants:

estuary	areas where saltwater from the ocean mixes with freshwater from inland rivers and surface runoff
evaluation unit (EU)	subsection of a tidal marsh delineated by tidal restrictions used as the basic unit for evaluation of the marsh system
fill	material, usually associated with the dredging of a harbor or inlet, placed on the surface of the marsh; the change in elevation caused by the disposal of this material in the marsh can lead to the loss of the area as a functioning tidal marsh
freshwater source	the point of origin of nontidal waters including rivers, streams and surface runoff
freshwater tidal marshes	marshes that are tidally influenced, but where the average water salinity is less than 0.5 parts per thousand
geomorphology	the study of the natural processes involved in the creation of landforms such as tidal marshes and barrier beaches
habitat	the environment in which the requirements of a specific plant or animal are met
herbaceous plant	a non-woody plant with a soft stem (e.g., bulrushes and cattails)
high marsh	areas of tidal marshes that are irregularly flooded (frequently beyond the reach of daily flooding) and are typically dominated by salt hay grass (*Spartina patens*)
hydrology	the scientific study of the properties, circulation, and distribution of water as it occurs in the atmosphere and at the earth's surface as streamflow, precipitation, soil moisture, and ground water
hydrologic regime	the frequency and duration of flooding and/or saturation
hydroperiod	the duration of typical flooding/saturation events; in tidal marshes, the hydroperiod can range from daily flooding to irregular flooding (e.g., every few days, weeks, or months); depends on the marsh elevation
intertidal emergent	an erect rooted herbaceous plant growing in the intertidal zone
intertidal zone	areas that are alternately exposed and flooded by tides
invasive species	plant species that, when introduced to an ecosystem, can disturb the natural balance and habitat diversity by invading and dominating the natural tidal marsh plant community, frequently establishing dense monotypic (single species) stands of vegetation
low marsh	areas of marsh that are flooded twice a day and are dominated by saltwater cordgrass (*Spartina alterniflora*)
marine	relating to ocean environments

marsh hydrology this term describes (1) the hydrologic pathways such as precipitation, surface runoff, ground water, tidal fluctuations and flooding rivers which transport nutrients to and from wetlands; (2) the water depth; (3) frequency and duration of flooding in tidal marshes

marsh peat the organic soil formed by the accumulation of dead marsh plant material and trapped sediments from tidal waters

marsh restoration improvement of existing marsh condition by reversing some of the adverse impacts caused by coastal development

marsh system an area of marsh associated with a single opening to the ocean, a single freshwater input, or adjacent to and contiguously along the shore of a tidal river or bay

mitigation activities taken to minimize or offset wetland impacts due to development or construction. Restoration and enhancement of existing wetlands or creation of new wetlands are forms of impact mitigation

non point source a pollution source that does not come from a single point. Typical non-point sources include parking lots, roads, and agricultural fields

open water areas within or adjacent to a marsh that are below mean low water and greater than 100 meters wide (330 feet); this manual uses an arbitrary division of 100 meters to distinguish between open water and tidal creeks

organic matter a combination of decayed and decaying plant and animal residue

overland flow a term to describe the sheet-like flow of water over a land surface, not concentrated in individual channels; usually associated with areas of low infiltration such as paved surfaces or surfaces lacking vegetation (see also surface runoff)

pannes shallow ponds that form on the surface of the marsh and hold salt water between tides

point source a pollution source that comes from an identifiable point, such as a factory discharge pipe or septic system outlet

primary consumer animals that eat plant material as their main source of energy

sea level the level of the surface of the ocean at its mean (average) position between high and low tide

sheet flow unchannelized flow of water across the surface of a marsh or upland

subsidence a sinking of the marsh surface, through compaction and degradation of marsh peat; often occurs when *Spartina patens* is deprived of tidal flow

spit a small point of land, especially sand or gravel, formed by the deposition of material by wind and water currents that runs into a body of water

spring high tide	tides associated with the full and new moon that are higher and lower than the average tide
staddle	a structure consisting of numerous pilings driven into the marsh on which to stack salt hay to keep it above the tidewaters until it could be hauled off
substrate	the type of bottom sediments such as sand, gravel, peat
surface runoff	the movement of water over the land surface (usually in defined channels), resulting from rainfall or snowmelt; percentage of precipitation that becomes runoff varies depending on the slope of the area, the degree of soil saturation, amount of vegetated coverage, or type of surface e.g. paved areas
tidal amplitude	the variations in the height of tides caused by the lunar cycle, elevation above sea level, the barometric pressure, tidal restrictions and the seasons
tidal creeks	streams in the tidal marsh that are less than 100 meters wide at mean low water and whose main source of water is dominated by tidal action
tidal flats	areas that are irregularly exposed and are devoid of emergent vegetation, also called mud flats or unconsolidated bottom
transition zone	area surrounding a wetland where conditions gradually change from wetland biota to upland biota
turbidity	the clarity of the water column as determined by the presence of suspended particles making the water cloudy
upland islands	areas of upland soils and vegetation located within a tidal marsh
vegetated tidal marsh	marshes dominated by emergent vegetation and influenced by the tides
watershed wetlands	the area from which all water including precipitation, streams and rivers drain to a single point those areas that are inundated or saturated by surface or ground water, support a prevalence of vegetation adapted to life in saturated conditions (i.e., hydrophytes), and are characterized by hydric soils; these include bogs, marshes, swamps, wet meadows, and similar areas
Zone of Influence	area surrounding a wetland in which the activities that take place have an impact on the wetland; the *Maine Citizens Tidal Marsh Guide* considers a 1/2 mile Zone of Influence, with particular focus on activities within the 250 foot shoreland Zone

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Appendix A. Common and Scientific Names of Plants Mentioned in this Report

Common Name	Scientific Name	Habitat
Smooth Cordgrass	*Spartina alterniflora*	Low Marsh
Smooth Cordgrass, short form	*Spartina alterniflora*	Poorly-drained High Marsh
Salt Meadow Grass	*Spartina patens*	High Marsh
Black Grass	*Juncus gerardii*	High Marsh
Common Reed	*Phragmites australis*	Brackish Marsh
Narrow-leaf Cattail	*Typha angustifolia*	Brackish Marsh
Salt marsh Bulrush	*Scirpus spp.*[1]	Brackish Marsh
Spike Grass	*Disticlis spicata*	High Marsh
Seaside Milkwort	*Glaux maritima*	High Marsh
Broad-leaf Cattail	*Typha latifolia*	Fresh/Brackish Marsh

[1] Includes *Scirpus robustus and Scirpus maritimus*

Appendix B. Protocol for Tidal Restriction Inventory and Assessment

Equipment: Base map, Phase One data sheets (minimum of one per crossing), sharp pencils, 200 ft. fiberglass tape with weighted end, rubber boots or mud sneakers, camera/film. Optional: clipboard, plastic bags for data sheets, aerial photos, staff gauge, orange safety vest.

Map Reference Number: Crossing number as marked on base map

Water Body/Stream Name: We do not have names for all streams. Ask locals for streams not named on topographic maps.

Landmark Location Description: For small unnamed streams or areas with multiple crossings, record distance and direction from a known landmark. Example: 0.6 miles East of US Route one on Blue Point Road.

Tidal Conditions: Circle approximate tidal elevation (Low, Mid, etc.) and direction (Incoming, Outgoing, Change).

Photographs: Standing on the creek bank, photograph the crossing from the landward ("upstream") and seaward ("downstream") sides. Mark and label the photos. Example: Crossing 1, Blue Point Road, taken from landward side.

Sketch: See handout from tidal crossing handbook.

Crossing Type:

a) Circle appropriate choice (Bridge/Culvert). Describe if "other".
b) Does the road approach the crossing on fill placed on the marsh surface, or does the crossing go from headland to headland (no fill on marsh)? Circle appropriate choice.

Dimensions of Opening: Record height and width of opening. Note number of culverts at each crossing (sometimes there are 2 or more in one creek crossing), diameter of each culvert (or height and width if oval). For multiple culverts, calculate effective diameter as follows:

Individual culvert cross sectional area = 3.14 x $(\text{Diameter} \div 2)^2$

Total cross sectional area = Sum of individual culvert cross sectional areas.

Effective diameter = 2 x Total cross sectional area ÷ 3.14

Upstream/Downstream Channel Width at Crossing:

- ***Distance from Crossing:*** Bridges and culverts often cause an increase in current velocity and subsequent bank erosion (see page 19 of the *Tidal Crossing Handbook*). Measure the channel width at a point beyond any erosion that may be due to increase in current velocity through the crossing. Except for very small creeks (less than 10 feet wide), fifty feet from the crossing should be considered the minimum distance at which to measure channel width. Greater distances (100 feet or more) may be required. Note the distances (upstream and downstream) from the crossing where the measurements were taken.
- ***Defining Channel Width:*** Many tidal creeks have gently sloping banks, making channel "width" difficult to define. For the purposes of this manual, measure channel width from the high marsh/low

marsh dividing line on one side of the creek to the same point on the opposite bank. This is typically the upper limit of *Spartina alterniflora*.. Note any difficulties in measuring width.

Height from Creek Bottom to Culvert Bottom: Culverts that are not flush with the creek bottom may cause tidal delays and pooling. Record the distance from the creek bottom the culvert bottom.

Length of Crossing over Marsh: Measure this distance from the base map or aerial photos.

Crossing Width: If it can be done safely, measure the entire width of roadway fill on the marsh surface adjacent to the crossing. Note: This measurement should be omitted or visually estimated for busy roads. Note on data sheet if estimated and not measured.

Culvert Length/Bridge Width: Omit or estimate for busy roads.

Road Surface Width: Omit or estimate for busy roads.

Evidence of Flow Restriction/Erosion: Classify the upstream and downstream sides of the crossing separately by circling "upstream" or "downstream" on the line(s) that best describes the amount of erosion. See discussion on page 19-21 of the *Tidal Crossing Handbook* under "Bank Erosion". Also look at aerial photos to estimate amount of erosion.

Channel vs. Culvert Opening: Divide the upstream channel width by the opening width to obtain the upstream channel to crossing width ratio. Repeat for the downstream side. Classify the upstream and downstream sides of the crossing separately by circling "upstream" or "downstream" on the appropriate line(s). See discussion on page 18-19 of the *Tidal Crossing Handbook*

Vegetation Comparison: See discussion on pages 21-22 of the *Tidal Crossing Handbook.* Make your best guess. This information is for preliminary assessment only and will not be used to calculate the overall rating.

Overall Rating: Sum the four classification numbers from the flow restriction/erosion and channel-to-culvert ratios. Do not add in the classification rating for Vegetation Comparison.

Tidal Marsh Assessment
Phase I
Tidal Crossing Data Sheet

Location	
Map Reference Number	
Water Body/Stream Name	
Town	
Street	
Landmark/Location Description	

Plan View Sketch

Date:
Time:
Tidal Conditions: Low Mid/Low Mid Mid/High High
Incoming Outgoing Change
Weather: Sunny Partly Cloudy Overcast Rain

A Photo #1 - Reference #:
B Photo #2- Reference #:
C Photo #3- Reference #:

1"=

North Approximate Scale (Feet)

Volunteer Name(s):
General Notes:

PHASE I DATA SHEET (continued)

Crossing Information	
Type a) Bridge Culvert Other b) Road on marsh Headland to headland	
Dimensions of Opening (Height, Width, Diameter Include Sketch if Applicable)	
Upstream Channel Width at Crossing	Distance from crossing:
Downstream Channel Width at Crossing	Distance from crossing:
Height from Creek Bottom to Culvert, Upstream	
Height from Creek Bottom to Culvert, Downstream	
Height from Creek Bottom to Road, Upstream	
Height from Creek Bottom to Road, Downstream	
Length of Crossing over Marsh (from map/photo)	
Crossing Width (over marsh)	Culvert length/bridge width:
Road Surface Width (In Middle)	
Road Surface Material	
Condition (1-5*) of Bridge	1 2 3 4 5
Condition (1-5*) of Road	1 2 3 4 5
Condition (1-5*) of Culvert	1 2 3 4 5

*1. Excellent 2. Good 3. Fair 4. Poor 5. Need of Immediate Repair

Circle The Most Appropriate Response

	Restriction Classification Scheme	
Classification	**Evidence of Flow Restriction/Erosion**	**Notes**
1 Upstream / Downstream	Unrestricted/ No Pooling	
2 Upstream / Downstream	Flow Detained/ Slight Erosion	
3 Upstream / Downstream	Minor Pooling/Erosion Present	
4 Upstream / Downstream	Significant Pooling/Significant Erosion Present	
5 Upstream / Downstream	Major Pooling/Major Erosion Present	
Classification	**Channel vs. Culvert /Opening**	
1 Upstream / Downstream	River Width < Opening Width	
2 Upstream / Downstream	River Width = Opening Width	
3 Upstream / Downstream	River Width 1.1 to 2.0x Opening Width	
4 Upstream / Downstream	River Width 2.1 to 5.0x Opening Width	
5 Upstream / Downstream	River Width 5.1x + Opening Width	
Classification	**Vegetation Comparison**	
1	Upstream = Downstream	
2	Upstream Slightly Different Than Downstream	
3	Upstream Different From Downstream	
4	Upstream Much Different Than Downstream	
5	Upstream Completely Different Than Downstream	
Overall Rating =		

General Notes:

Appendix C. Protocol for Invasive Plant Search

Scarborough Marsh Assessment

Preliminary Search for Invasive Plant Species

Draft Methods 6-24-97

OBJECTIVE:

Within a salt marsh, invasive plants often thrive in areas of reduced salinity or high nutrient levels. Thus, they are often the symptom of restricted tidal flows and/or other human influences on the marsh system, such as input of nutrients from runoff and septic systems (see pages 15-16 of the *Citizens Tidal Marsh Guide.*) The objective of this part of the assessment is to obtain a preliminary estimate of the extent and location of invasive plants in the tidal marsh system. Combining this information with an inventory and evaluation of tidal restrictions will help to prioritize sites for more detailed monitoring and possible restoration.

EQUIPMENT:

Aerial photos, base map, pencils, data forms. Optional: ziplock bags for data forms, clipboard, compass, binoculars or spotting scope, safety vest for working near roads.

METHODS:

The target species of the search will be common reed (*Phragmites australis)* and purple loosestrife *(Lythrum salicaria)*. Observers should also record the presence of narrow-leaf cattail (*Typha angustifolia)* and broad-leaf cattail (*Typha latifolia)*, as extensive growth of these species may indicate the effects a tidal restriction or nutrient source.

This phase of the survey will be done by crews of one or two volunteers. Divide the marsh into survey areas for each crew.

1. Identifying and Delineating Invasive Plant Stands: Crews will survey the marsh from vantage points and estimate the location and extent of plant communities dominated by the species listed above. Each contiguous group of plants with similar species composition is called a "stand". A stand could be a single species (e.g., pure *Phragmites*) or group of species (e.g., mixed *Phragmites and T. angustifolia*).

- Mark stands on the base map or aerial photo and <u>assign each stand a unique number</u>. Record the relevant information on the data sheet. If the species composition changes significantly, then identify that area as a new stand on the map and fill in a new line on the data sheet.
- If possible, try to draw the stand to approximate scale on the base map. On the 1: 12,000 base map (1" = 1,000'), small stands can be indicated by a dot or an "x". For example, a 1/8" diameter dot on the map represents 250 feet on the ground. The aerial photos supplied are also scale of 1" = 1,000'.

2. Estimate the Size Class of the Stand: Assign the stand to one of the three following size classes and record the size class on the data form:

Class 1: Tennis court size or smaller
Class 2: Larger than a tennis court but smaller than a football field
Class 3: larger than a football field

3. Check species present in stand: On the data form, check the species present in the stand. At minimum, identify the presence of *Phragmites* vs. other species. For stands that are easily accessible, more detailed information suggested below will be helpful, but is not necessary.

- If any species is clearly dominant or comprises only a minor part of the stand composition, estimate, if possible, the relative composition by % cover. Use broad cover classes (e.g. <25%, >75%, etc.).
- In some cases, *Phragmites* or other species are mixed with typical marsh vegetation, especially *Spartina patens*. This commonly occurs when a stand is invading a new area or where growth conditions for the invasive plant are not optimal. Record the estimated amount of *Phragmites* or other species in the appropriate column and note typical vegetation in the "Comments" column (e.g., "*Phragmites* invading marsh, *S. alterniflora* >50% cover").

COMPILATION OF DATA:

When you have completed your portion of the survey, check in with the coordinator to compare notes with other crews. Areas not accessible or visible from land may need to be surveyed from a canoe or boat at high tide. After all of the marsh has been surveyed, a preliminary map of invasive species will be prepared and the data will be compiled.

PREIMINARY INVASIVE PLANT SURVEY DATA FORM

Marsh System: ______________________________

Observers: ____

			Check Species Present				
Date	Stand Number	Estimated Size Class	Phrag-mites	P. loosestrife	Narrow L. Cattail	Broad L. Cattail	Comments

Stand Number: Mark stand number on data sheet and on map.

Size Class : 1 = Smaller than tennis court; 2 = > tennis court but < football field; 3 = > football field

Check Sp[ecies Present: Place a check mark or "x" in appropriate column or estimate % cover within stand.

Marsh System: ______________________ **Evaluation Unit** ______ **of** ______

Assessment 1 *(Page 1 of 3)*
Ecological Integrity of the Marsh System

FIELD VISIT:
Date:____________ Time:____________
Tide:____________
Weather:______________________
Observers:______________________

A Evaluation Questions	B Dates, Calculations, and Notes	C Evaluation Criteria	D Functional Index (FI)

Note: Results should be based on evaluation units and placed in the summary table on Page D-14.

Questions that may require field observation:

Evaluation Questions	Dates, Calculations, and Notes	Evaluation Criteria	Functional Index (FI)
1.1. Number of tidal restrictions.		a. no tidal restrictions	1.0
		b. one tidal restriction	0.5
		c. more than one tidal restriction	0.1
1.2. Type of tidal restriction.		a. headland to headland bridge or no restriction	1.0
		b. free flow over marsh surface obstructed by road but bridge or culverts not restricting flow through tidal creek	0.5
		c. tidal gate, culvert, road or bridge on the marsh surface that significantly restricts tidal flow including through creeks and channels	0.1
1.3. Fill on marsh surface (spoils, crossroads, etc.).		a. < 5% of EU filled	1.0
		b. 5% - 15% filled	0.5
		c. > 15% filled	0.1
1.4. Ditching on surface of the EU.		a. no ditching within EU	1.0
		b. ditches affect ≤20% of EU	0.5
		c. ditches affect > 20% of EU	0.1
1.5. Alteration of the natural marsh plant community: dominance of invasive species within EU		a. < 5% of EU dominated by invasive species	1.0
		b. 5% - 20%	0.5
		c. > 20%	0.1

AVERAGE FUNCTIONAL INDEX for Assessment 1 = Average of Column D = ________.

Marsh System ______________________________ **Evaluation Unit** _______ **of** ______

Assessment 1 *(Page 2 of 3)*

Ecological Integrity of the Marsh System

Narrative Description of Restoration Potential

1. Describe the exact locations and types of restrictions affecting the evaluation unit. Include a description of the extent of the flow that is restricted (e.g., culvert restricting flow at mid-tide).

2. Describe the area of the evaluation unit that was filled including current uses, approximate acreage, and plant community.

Marsh System: ______________________________ **Evaluation Unit** _______ **of** ______

Assessment 1 *(Page 3 of 3)*

Ecological Integrity of the Marsh System

Narrative Description of Restoration Potential *(Continued)*

3. Describe the exact location and arrangement of ditching relative to the tidal flow and apparent impact (area, affect on evaluation unit hydrology). Supplement with sketch map or photos.

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4. Describe the area of the evaluation unit with invasive plant species by estimating the size of the area, listing the species present and the relative proportion of each species.

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Marsh System: ______________________________

Assessment 2
Ecological Integrity of the Zone of Influence

FIELD VISIT:
Date:______________ Time:____________
Tide:______________
Weather:______________________________
Observers:____________________________

	A Evaluation Questions	B Dates, Calculations, and Notes	C Evaluation Criteria	D Functional Index (FI)
Questions that may require field observation:				
2.1.	Dominant land use in the ½ mile Zone of Influence surrounding the marsh system.		a. forests, fields, dune/beach, freshwater wetlands, open water or similar open space	1.0
			b. agricultural or rural residential (ave. lot size > 2 acres)	0.5
			c. commercial, industrial, high density residential or heavily used highways	0.1
2.2.	Ratio of the number of buildings within the marsh system **and/or** within the 250 foot Shoreland Zone to the total area of marsh system.		a. < 0.1 building/acre	0.1
			b. from 0.1 - 0.5 building/acre	0.5
			c. > 0.5 building/acre	0.1
2.3.	Percent of the marsh system/upland boundary that has a buffer of woodland or idle land at least 250 feet in width.		a. > 70%	1.0
			b. from 30% - 70%	0.5
			c. < 30%	0.1

AVERAGE FUNCTIONAL INDEX for Assessment 2 = Average of Column D = ________.