STRATEGIC PLAN FOR RESTORATION AND ENHANCEMENT OF IMPORTANT HABITATS IN SCARBOROUGH MARSH AND ITS WATERSHED

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Prepared for
FRIENDS OF SCARBOROUGH MARSH
PO Box 7049
Scarborough, ME 04070

Prepared by
NORMANDEAU ASSOCIATES, INC.
25 Nashua Road
Bedford, NH 03110

and

Terence J. Dewan & Associates
121 West Main Street
Yarmouth, ME 04096

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1.0 INTRODUCTION

The goal of this report is to provide the Friends of Scarborough Marsh (FSM) with an inventory of key areas for restoration, enhancement and acquisition within the Scarborough Marsh and its watershed. These key areas include salt marsh sites suitable for restoration or at risk of degradation, important wildlife habitats, open space around the marsh, enlargement of existing conservation areas, and potential public access and education sites. An important second piece of the project was to develop priorities for ranking the key areas within several categories, including salt marsh restoration and enhancement, wildlife habitat enhancement, and land acquisition. At each stage of the project, extensive input from FSM was incorporated into the final product. Many meetings and assistance in data collection and verification by FSM members greatly contributed to the accuracy of this report and its associated maps.

The final products to FSM consist of this document, which includes the background, analysis, and data from the inventory and prioritization work; and an ESRI-based GIS package, which provides electronic maps of the various data layers for use in ArcExplorer and ArcInfo, and sites proposed for restoration, enhancement and acquisition. This database will permit FSM to manipulate the information collected during this project and assess different and new aspects of the study area. Each layer is annotated with the essential information regarding its contents (date, author, original source, etc) and should be utilized only within the constraints of its accuracy.

2.0 SITE DESCRIPTION

The Scarborough Marsh consists of approximately 3070 acres, including subtidal river, and intertidal mud flats and salt marsh vegetation. This does not include several areas of brackish marsh that were probably salt marsh prior to human-induced changes in tidal exchange and salinity. Almost all of the salt marsh acreage of Scarborough Marsh is owned by the Maine Department of Inland Fish and Wildlife (IFW), as well as some adjoining upland parcels. The Marsh is the largest contiguous salt marsh in the state and has been identified as a high quality estuary and salt marsh by numerous State and Federal agencies (IFW, US Fish and Wildlife Services, National Marine Fisheries Service). It is also under intense development pressure because it is located only 7 miles south of Portland in one of the most rapidly developing sections of the state.

The Scarborough Marsh watershed is approximately 38,000 acres (60 square miles) and includes a major drainage (Nonesuch River) as well as several significant tributaries (Figure 1). The watershed is dominated by mixed upland coniferous and deciduous forest, however the percentage of developed lands is steadily increasing, as new homes and roads appear throughout. Development is heaviest along the seacoast, along Route 1 and on the eastern side of the watershed. Three major transportation corridors cross the watershed, running from approximately southwest to northeast. From north to south, these include the Maine Turnpike (I-95), Route 1 and the Guilford Railroad line. These three form significant barriers to various aspects of the ecology of the marsh and its watershed. Simplistically, the roads clearly impede terrestrial wildlife passage and impact water quality, while the railroad runs on an earthen berm two miles long across the lower third of Scarborough Marsh, restricting tidal flows and salinity north of the railroad. An additional former rail line now used as a utility crossing and recreational trail forms another tidal barrier at the mid-marsh.

Figure 1. Scarborough Marsh and its Watershed

3.0 SALT MARSH RESTORATION STRATEGY

3.1 INTRODUCTION

The Scarborough Marsh itself is the primary focus of FSM. It is an exemplary resource due to its large size, habitat diversity, and contribution to estuarine systems. The US Fish and Wildlife Service analysis of coastal habitat indicates that the marsh supports some of the highest value habitat for rare- and declining migratory birds and fish in southern Maine (Banner 1998). Surveys by the Maine Department of Inland Fisheries and Wildlife found the highest number of water-dependent birds in the state (DeMaynadier and Hodgman 1999). It is known to support many species of wildlife, including migratory shorebirds, waterfowl, wading birds, salt marsh sparrows, migratory song birds, and a variety of resident and migratory fish. At least seven state and federally listed bird species breed within the marsh system, and many others rely on it for breeding, feeding and resting. Additional functions provided by the marsh include shoreline protection against flooding and erosion; fish habitat, particularly as a nursery for estuarine species; shellfish habitat in the huge mudflats of the major channels at low tide; trophic support to Casco Bay in the export of organisms, nutrients, and detritus; water quality enhancement through treatment of freshwater from the heavily developed surrounding upland; and human recreational, educational and aesthetic values (Daiber 1982, Neckles and Dionne 1999, Teal and Howes 2000)

The marsh has also experienced a wide variety of human manipulations of hydrology, vegetation and soils. Pre-colonial Native Americans gathered at several locations around the marsh to take advantage of the abundant birds, fish and shellfish. Many post-colonial impacts have been dramatic, such as construction of the railroad across the center of the marsh (now the Eastern Road) in the 1840's, followed in 1873 by the Boston and Maine (Guilford) railroad line. Tide gates were installed on the Eastern Road in 1876 to convert the marsh to freshwater for haying. Storms in the 1950's breached the Eastern Road berm reintroducing tidal flows, and after a brief attempt to restore the tide gates, a channel was permanently constructed through the berm in 1963. The marsh has since reverted to the salt marsh community seen today. US Route 1 forms a third major restriction on the marsh. Located north of the Eastern Road, Route 1 and its associated single crossing on Dunstan River have been in place for over 125 years.

Less dramatic but also significant are the impact of several centuries of haying on the plant community, and construction of hay roads and the ubiquitous ditches that have altered drainage for decades across almost all sections of the marsh. In recent years, increased development pressure, primarily in the form of new residential housing and roads, has altered freshwater inputs and nutrient loads. Additionally, invasive plant species, such as Phragmites (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*), have colonized portions of the marsh, partly due to range expansion of these species, and partly due to ideal conditions created by disturbance to the marsh.

One of the primary efforts in the strategic plan was to perform a marsh-wide review to assess areas for potential restoration and enhancement, and to prioritize those areas for action. The entire marsh was investigated by Normandeau Associates, Inc. (NAI) and members of FSM, and a list of sites that were candidates for restoration or enhancement was drawn up. Sites were designated as either marsh surface projects or tidal restriction projects. The team then reviewed the two lists within the framework of a matrix of site attributes. The matrix allowed each site to be scored for the various attributes, from which total site scores were calculated. The site scores, in combination with input from

team members familiar with the individual sites, were used to categorize the sites into three priority rankings. The process is described in more detail below. The site descriptions, matrices, and ranking priorities are provided in Tables 3-1 to 3-3.

3.2 SITE IDENTIFICATION

The marsh was surveyed for potential areas for restoration and enhancement using a variety of techniques. The initial survey tool was the review of true-color stereo aerial photographs, flown in May,1995 at an approximate scale of 1:12,000. Many pertinent marsh features, such as vegetation zonation, hydrologic patterns, and adjacent land use were clearly visible on the photos. Specifically, indicators of disturbance were sought: channel crossings with eroded creek banks, heavily ditched or excavated areas, waterlogged sites, barren pannes, monotypic areas of marsh (lacking habitat diversity), stands of Phragmites, hay roads, and any other atypical sections of the marsh were noted. Most were visited in the field by NAI staff. Additional sites were identified by members of FSM, and reviewed by NAI. A total of 38 projects were ultimately taken to the evaluation stage. Table 3-1 provides a list of the location, type of degradation, and potential solution for each project. Figure 2 shows the location of the proposed projects.

Once identified, the sites were categorized as tidally restricted or marsh surface projects, depending which impact was perceived to dominate the site. "Tidally restricted" projects were typically degraded due to a decrease in tidal exchange from a man-made structure or alteration of the marsh. Many sites upstream of culverts under road and railroad crossings fell into this category. "Marsh surface" projects were typically most directly degraded due to ditching, hay roads and fill from the upland. These sites were frequently located well away from large tidal channels, therefore were often complicated by low salinities from groundwater and upland runoff. A third category of "Future" was included to describe projects that were observed, but not considered immediately urgent, or would be best evaluated after the completion of other projects. Ultimately, 18 projects were classified as marsh surface, 11 as tidally restricted, and 9 as future.

Many sites had characteristics of both tidally restricted and marsh surface projects, in which case the decision as to the dominant influence became somewhat subjective. Also, the use of these two categories is arbitrary in that the cumulative impacts of downstream degradation are not considered. For example, all projects above a major tidal restriction are obviously influenced by that restriction, yet because of the local nature of a restoration project, some of the upstream projects might be classified as marsh surface. Important to remember in this categorization of projects is that the decisions were based on very preliminary information about the sites. More detailed assessment will be required on all projects, which may result in reassigning the status of individual projects, or modifying the proposed solution. This list is intended to be a starting point from which to guide FSM restoration and enhancement efforts, and changes to the list are inevitable as more information becomes available.

Within the 29 identified projects that were either marsh surface or tidally restricted, those that had already received some level of agency review for restoration or enhancement were further subdivided as "Active"; the remainder were considered "Potential". Four projects currently fall into the Active category:

- Dunstan Marsh Restoration Project,
- Libby River Project,
- Seavey Landing Ditch Plugging Project, and

Figure 2. Potential Salt Marsh Restoration/Enhancement Map for Scarborough Marsh.

Table 3-1. Summary of project sites, type of degradation and anticipated enhancement action. Projects are listed in order of approximate location from north to south on map.

Map Numbers	Project Type	Project Name	Problem	Enhancement Action
1	Future	Enhance flows under Payne Rd.	Tidal flows to brackish marsh area restricted.	Evaluate culvert sizing and invert.
2	Marsh Surface	Plug ditches on Nonesuch above road	Ditches drain marsh excessively.	Selectively plug ditches and add pools.
3	Marsh Surface	Remove roads and plug ditches on Nonesuch	Sheet flow at high tide is impeded.	Selectively breach hay roads and plug ditches.
4	Future	Remove weir on Nonesuch	Remnants of low bridge/weir impede flow at low tide.	Evaluate benefits of removal.
5	Active	Dunstan Marsh Restoration Project	Large Phragmites invasion.	Site is currently being studied for restoration. Will probably include culvert enhancement, new pannes and perimeter ditching.
6	Marsh Surface	Plug ditches and remove Phragmites SW of Rt 1	Marsh appears waterlogged and brackish; invasives expanding.	Enhance ditching and pools.
7	Tidal Restriction	Enhance flows at Phillips Brook	Tidal flows under Rt 1 maybe restricted.	Evaluate need to enlarge culvert.
8	Marsh Surface	Plug ditches on Nonesuch below road	Ditches drain marsh excessively.	Selectively plug ditches and add pools.
9	Marsh Surface	Deepen large pools by Route 1	Shallow pools by Route 1 go dry and are at risk for invasive plant colonization.	Deepen some pools to enhance habitat diversity.
10	Marsh Surface	Plug ditches west of industrial park	Marsh appears waterlogged and brackish; invasives expanding.	Enhance ditching and pools; remove hay road.
11	Future	Assess restoring tides to 2 impoundments	Impoundments are currently freshwater with no tidal exchange.	Evaluate habitat benefits of restoring tidal flows.
12	Marsh Surface	Plug ditches and restore large pool below impoundments	“T” ditch drains marsh excessively.	Plug ditch and add pool.

Table 3-2. (Continued)

Map Numbers	Project Type	Project Name	Problem	Enhancement Action
13	Marsh Surface	Breach hay road and plug ditches near Mill Creek	"C" shaped hay road impedes sheetflow.	Breach road in several locations.
14	Future	Enhance drainage southeast of Rt 1	Marsh appears waterlogged and brackish; ripe for invasives.	Enhance ditching and pools.
15	Tidal Restriction	RR bridge over Nonesuch River	May restrict tidal flows on river.	Evaluate and determine adequacy of bridge (project assumes widening it).
16	Tidal Restriction	Restore connection to Cascade Brook at Route 9	Historic channel is blocked by Route 9, limiting flows behind .	Add culvert under Route 9, and possibly deepen old channel.
17	Marsh Surface	Breach road and plug ditches below Willowdale	Sheet flow at high tide impeded by hay roads; ditches failed.	Selectively breach hay roads and plug ditches to enhance tidal exchange.
18	Marsh Surface	Plug ditches along Mill Creek	Ditches drain marsh excessively.	Selectively plug ditches and add pools.
19	Marsh Surface	Enhance flows behind railroad on Nonesuch River	Marsh behind railroad is waterlogged and brackish; ripe for invasives.	Improve tidal exchange, probably by ditch north of railroad.
20	Tidal Restriction	Enhance flows at Dunstan Landing Rd.	Area east of road has limited tidal exchange.	Widen existing ford in old road and add others to enhance sheet flow; evaluate deepening primary ditch connection.
21	Tidal Restriction	Remove dam on Cascade Brook	Tidal amplitude and salinities low because of impoundment.	Lower coffer dam or remove some dam panels.
22	Tidal Restriction	Enhance Eastern Rd. connection through box culvert.	Tidal restriction caused by Eastern Rd.	Enlarge box culvert and lower invert.
22	Tidal Restriction	Enhance Eastern Rd. connection through main channel	Tidal restriction caused by Eastern Road; dangerous currents, scouring.	Widen channel and stabilize banks.
23	Future	Enhance pools and pannes below Eastern Rd	Area has no pools and pannes and is very uniform high marsh.	Enhance site diversity by adding pools.

Table 3-2. (Continued)

Map Numbers	Project Type	Project Name	Problem	Enhancement Action
24	Future	Breach hay roads at Winnocks Neck	Hay road blocks sheet-flow, ripe for invasives.	Breach road in several locations.
25	Tidal Restriction	Add culvert under railroad at Winnocks Neck	Tidal exchange is limited by railroad	Enhance exchange with culvert under railroad.
26	Active	Cascade Brook Sediment and Phragmites Removal Project	Excess sediment from road washout enhanced Phragmites expansion.	Dredge sediment and Phragmites from marsh surface.
27	Future	Enhance flows behind Peterson Playfield	Tidal flows to brackish marsh are restricted.	Evaluate culvert sizing and invert.
28	Active	Seavey Landing Ditch Plugging Project	Ditches have failed and are water-logging marsh.	Enhance ditching and pools.
29	Tidal Restriction	Tidal restriction at railroad bridge over Scarboro River	May form primary restriction to upstream marsh.	Evaluate and determine adequate size (project assumes widening the bridge).
30	Marsh Surface	Clean up ballast along railroad	Marsh has been filled along both sides of railroad with ballast and rail debris.	Pull back ballast and remove debris.
31	Future	Dug harbor and channel off Black Point	Dug harbor provides little habitat value	Grade and replant edges; discourage maintenance dredging.
32	Marsh Surface	Breach road and plug ditches on Libby River	Ditches have failed and are water logging marsh; hay road blocks sheet flow.	Selectively plug and enhance ditches, add pools, breach road.
33	Active	Libby River Project	Degree of restriction under Black Point Road is being evaluated.	Enlarge culvert/change invert as needed.
34	Marsh Surface	Plug ditches on upper Libby River	Ditches drain marsh excessively.	Plug ditches and add pools.
35	Future	Manmade beach on Black Point	Beach appears maintained by adding sand.	Work with landowners to discourage beach nourishment.
36	Marsh Surface	Plug ditches by golf course	Ditches drain marsh excessively.	Plug ditches and add pools.

Table 3-2. (Continued)

Map Numbers	Project Type	Project Name	Problem	Enhancement Action
37a	Tidal Restriction	Enhance flows through culvert on Jones Creek	Tidal flows to brackish marsh are restricted.	Remove tide gate façade.
37b	Tidal Restriction	Add culvert under Route 9 at Jones Creek	Tidal flows to brackish marsh are restricted.	Evaluate second culvert under Route 9; add ditching.
38	Marsh Surface	Restore channels and pools in Jones Creek	Limited tidal exchange; Phragmites encroachment	Dredge out existing channels, deepen pools.

Table 3-2. Summary of potential restoration and enhancement projects on Scarboro Marsh. The first matrix presents Marsh Surface Projects, the second presents Tidal Restriction Projects. Refer to Map for locations of projects. See explanations of marsh characteristics and ranking criteria at the end of this table.

	MARSH SURFACE PROJECTS																	
	ACTIVE PROJECTS		POTENTIAL PROJECTS															
	28 Seavey Landing Ditch Plugging Project	26 Cascade Brook sediment and Phragmites removal project	9 Deepen large pools by Route 1	17 Breach roads & plug ditches below Willowdale	12 Plug Ditches and restore large pool below impoundment	13 Remove road and plug ditches near Mill Creek	18 Plug ditches along Mill Creek	6 Plug ditches and remove Phragmites southwest of Rt 1	30 Review RR ballast	19 Enhance flow behind RR on Nonesuch R.	8 Plug ditches on Nonesuch below Black Pt Rd	2 Plug ditches on Nonesuch above Black Pt Rd	3 Breach hay roads & plug ditches on upper Nonesuch	10 Plug ditches west of industrial park	36 Plug ditches by golf course	34 Remove fill & plug ditches on Libby R.	32 Breach hay roads & plug ditches on Libby R. above Black Pt Rd	38 Restore channels and pools on Jones Creek
SITE ASSESSMENT 1:																		
Size of area to benefit (1= <10 acres, 5=10-50, 10= >50)	2	3	1	3	2	2	2	2	1	2	2	1	3	3	1	2	3	2
DEGRADATION																		
Tidal Restriction (mild, moderate, severe)	1	3	1	1	1	1	1	1	1	2?	1	1	2	1	1	1	3	2
Invasive species (absent, encroaching, established)	2	3	2	2	1	3	1	3	2	1	2	2	3	2	2	2	3	3
Ditching (minor, moderate, severe)	3	1	2	3	3	3	3	3	1	2	3	3	3	3	3	2	3	2
Hay roads (barrier is occasional/absent, partial, complete)	1	1	2	3	1	3	1	1	1	1	1	1	3	2	1	2	1	1
Fill (minor/absent, moderate, extensive)	1	3	1	1	1	1	1	1	3	1	1	1	1	1	1	2	1	1
RESTORATION/ ENHANCEMENT POTENTIAL																		
Expense of solution (Total $$: high, medium, low)	3	2	3	2	3	3	3	3	3	2	3	3	2	3	3	2	2	2
Expense of solution ($$/acre: high, medium, low)	3	3	1	1	1	1	1	2	1	1	1	1	2	1	1	1	2	3
Flood risk to surrounding development (high, medium, low)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
PROJECT SCORE	**19**	**22**	**16**	**19**	**16**	**20**	**16**	**19**	**16**	**15**	**17**	**16**	**22**	**19**	**16**	**17**	**21**	**19**
SITE DESCRIPTION																		
Marsh Features																		
Rare species/habitat (distant, nearby, on-site)	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	2	1	1
Waterfowl/wading bird use (low, medium, high)	1	1	3	3	3	3	1	1	1	1	1	1	2	3?	1	1	1	3
High marsh sparrow use (low, medium, high)	1?	1	1	3	2?	3?	1	1?	1?	1	1?	1?	1?	1?	1	1?	2?	1
Adjacent Upland Features																		
Intensity of development in subwatershed (high, moderate, low/undeveloped)	3	3	3	3	3	3	3	2	3	3	3	3	1	3	2	2	1	1
Type of development in subwatershed (industrial, commercial/residential, undeveloped)	2	3	3	3	3	3	3	2	3	3	2	2	2	3	2	2	1	2
Proximity to large forested blocks (distant, near, adjacent)	1	2	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2
Proximity to riparian and freshwater wetland habitat (distant, nearby, adjacent)	1	3	1	3	2	2	1	1	1	1	1	2	2	1	1	1	2	3
Wildlife corridor (absent, broken, intact)	1	3	1	2	2	2	2	1	1	1	1	2	2	1	1	1	3	2

	MARSH SURFACE PROJECTS																	
	ACTIVE PROJECTS		POTENTIAL PROJECTS															
	28 Seavey Landing Ditch Plugging Project	26 Cascade Brook sediment and Phragmites removal project	9 Deepen large pools by Route 1	17 Breach roads & plug ditches below Willowdale	12 Plug Ditches and restore large pool below impoundment	13 Remove road and plug ditches near Mill Creek	18 Plug ditches along Mill Creek	6 Plug ditches and remove Phragmites southwest of Rt 1	30 Review RR ballast	19 Enhance flow behind RR on Nonesuch R.	8 Plug ditches on Nonesuch below Black Pt Rd	2 Plug ditches on Nonesuch above Black Pt Rd	3 Breach hay roads & plug ditches on upper Nonesuch	10 Plug ditches west of industrial park	36 Plug ditches by golf course	34 Remove fill & plug ditches on Libby R.	32 Breach hay roads & plug ditches on Libby R. above Black Pt Rd	38 Restore channels and pools on Jones Creek
RESTORATION/ENHANCEMENT POTENTIAL																		
Project Related Features																		
Existing information (absent/minimal, moderate, extensive)	3	3	1	1	1	1	1	1	2	1	1	1	1	1	1	2	2	1
Infrastructure obstacles (many, moderate, minimal/absent)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3
Access to work area (difficult, moderate, easy)	3	2	1	3?	2	2	1	3	3	3	3	2	1	3	3	2	2	1
Distance from major tidal channel (far, moderate, close)	3	2	1	1	3	2	3	3	3	1	2	1	2	2	2	2	2	1
Salinity potential (<5 ppt, 5-15 ppt, >15 ppt)	3	2	1	2	3?	3?	3	3	3	2	3	2?	2	3	3	3	2	2?
SITE SCORE	**45**	**51**	**37**	**49**	**46**	**49**	**40**	**42**	**42**	**37**	**40**	**39**	**44**	**45**	**38**	**40**	**43**	**42**

TABLE 3-2 (cont'd)

TIDAL RESTRICTION PROJECTS										
	ACTIVE PROJECTS		**POTENTIAL PROJECTS**							
	5 Dunstan Marsh Restoration Project	**33 LibbyR. Culvert Project**	**21 Adjust/Remove dam on Cascade Brook**	**22 Enhance flows under Eastern Rd**	**25 + 29 RR bridge over Scarboro River**	**15 RR bridge over Nonesuch River**	**37 Enhance flows on Jones Creek**	**16 Restore connection on Cascade Brook at Rt 9**	**20 Enhance flows at Dunstan Landing Rd**	**7 Enhance flows on Phillips Brook**
SITE ASSESSMENT										
Size of area to benefit (1= <10 acres, 5=10-50, 10= >50)	3	3	3	3	3	3	3	2	2	1
DEGRADATION										
Tidal Restriction (mild, moderate, severe)	3	3	3	3	3?	2?	3	3	3	2
Invasive species (absent, encroaching, established)	3	3	3	3	3	3	3	3	3	3
Ditching (minor, moderate, extensive)	3	2	1	2	3	3	3	1	1	1
Hay roads (barrier is occasional/absent, partial, complete)	1	1	1	1	1	1	1	1	1	1
Fill (minor/absent, moderate, extensive)	1	1	1	2	3	1	1	1	1	1
RESTORATION/ENHANCEMENT POTENTIAL										
Expense of solution (Total $$: high, medium, low)	1	2	3	1	1	1	3	2	3	1
Expense of solution ($$/acre: high, medium, low)	2	3	3	3	3	3	3	2	3	1
Flood risk to surrounding development (high, medium, low)	3	3	3	3	3	2?	2?	3	3	2
PROJECT SCORE	**20**	**21**	**21**	**21**	**23**	**19**	**22**	**18**	**20**	**13**
SITE DESCRIPTION										
Marsh Features										
Rare species/habitat (distant, nearby, on-site)	3	2	1	3	3	1	1	1	1	2
Waterfowl/wading bird use (low, medium, high)	2	2	3	3	3	3	3	3	3	1
High marsh sparrow use (low, medium, high)	1	2?	1?	2	3	3?	1	1?	1?	1
Adjacent Upland Features										
Intensity of development in subwatershed (high, moderate, low/undeveloped)	2	2	2	3	2	1	3	2	2	3
Type of development in subwatershed (industrial, commercial/residential, undeveloped)	2	2	2	2	2	2	2	2	2	2
Proximity to large forested blocks (distant, near, adjacent)	2	2	2	1	2	2	2	2	2	1
Proximity to riparian and freshwater wetland habitat (distant, nearby, adjacent)	3	3	3	1	1	1	3	3	3	1
Wildlife corridor (absent, broken, intact)	3	3	3	1	2	2	2	3	3	1
Project Related Features										
Existing information (absent/minimal, moderate, extensive)	3	2	2	3	2	1	1	2	2	1
Infrastructure obstacles (many, moderate, minimal/absent)	3	1	3	3	2	1	1	2	3	3
Access to work area (difficult, moderate, easy)	2	3	3	1	2	3	3	3	3	3
Distance from major tidal channel (far, moderate, close)	2	3	3	3	3	3	3	2	3	2
Salinity potential (<5 ppt, 5-15 ppt, >15 ppt)	2	3	2?	3	3	3	3	3	2?	2
SITE SCORE	**50**	**51**	**51**	**50**	**53**	**45**	**50**	**47**	**50**	**36**

TABLE 3-2. (cont'd)

Explanation of Assessment Criteria (the first value in each criterion receives a score of 1; the middle value, a score of 2; and the last value, a score of 3).

Size of area: estimate of tidal marsh acreage that would result from restoration or enhancement action; Small (<10 ac), Medium (10-50 ac), Large (>50)

Rare species/habitat: distant=outside of influence of restoration action; nearby=within influence of restoration action; on-site=within project limits

Shellfish beds: commercial and recreational shellfish beds are distant=outside of influence of restoration action; nearby=within influence of restoration action; on-site=within project limits

Anadromous fish run: distant=outside of influence of restoration action; nearby=within influence of restoration action; on-site=within project limits

Intensity of development in subwatershed: high=is dominant feature of direct drainage area to marsh; moderate=significant but not dominant; low/undeveloped= minor or absent

Type of development in subwatershed: dominant development in direct drainage area to marsh is industrial/intensive commercial; light commercial/residential; undeveloped

Proximity to large forested blocks: unfragmented forest blocks greater than 500 ac are distant (>1/4 mile), near (within ¼ mile but not adjacent); adjacent

Proximity to riparian and wetland habitat: restoration area abuts undeveloped riparian or freshwater wetland habitat at least 500' in width

Wildlife corridor: a 250' wildlife travel corridor connects the site to other habitats (absent= adjacent development has removed cover from corridor; broken= cover is partially interrupted by development; intact= corridor is uninterrupted by development

Tidal restriction from project (not including downstream restrictions): visual appearance of restriction and upstream habitat conditions suggest that the restriction is mild, moderate or severe

Invasive species: absent=none observed in marsh or adjacent upland; encroaching=limited number of plants but probably expanding, or stand expanding from adjacent upland; established=well developed stand(s) in marsh

Ditching effectiveness: based on both the density and functionality of man-made ditches in artificially altering drainage on marsh

Hay roads: elevated surface and modified substrates impede sheet flow over marsh on many tide cycles. Barrier to flow may be occasional=allowing flow over road in many areas, partial=most of flow is impeded; complete=flow is almost completely blocked by road

Fill: sediment deposits or debris from human activities are minor=confined in area or depth; moderate; extensive=large areas or deep fill in a small area

Water-borne nutrient load: terrestrial freshwater surface water or groundwater potentially carries a low, moderate or high nutrient load, depending on activities in surrounding watershed

Ownership: ownership of restoration area land is private with no deed protection covenant, public with no deed-protected conservation covenant; private or public with deed-protected conservation covenant

Degree of complexity: the restoration/enhancement action requires multiple solutions (relief of tidal restriction, dredging, ditch plugging, etc), several solutions or a single solution

Total cost of solution: total cost of project is high (>$150,000), moderate ($75,000–$150,000), low (<$75,000).

Cost/acre of solution: the cost per acre of marsh restored/enhanced is high (>$4000/acre), moderate ($2000 to $4000/acre); low (<$2000/acre)

Existing information: Technical information necessary to design and implement the project is absent, minimal (very basic or general), extensive (well-studied)

Flood risk to surrounding development: The presence of development close to the marsh and low in elevation may present a flood risk. High is heavily developed and/or low surrounding topography; moderate is little development or higher topography; low is no/little development and/or elevated surrounding topography

Infrastructure obstacles: including municipal services (sewer, water lines), gas lines, power, traffic control. More obstacles typically confine restoration options and increase costs.

Access to work area: the ability to get construction equipment onto the site is difficult= private access, distant from upland edge, or impeded by tidal creeks; moderate; easy

Distance from major tidal channel: in general, the proximity to strong tidal influence will improve the success of the restoration/enhancement action. Far= influenced by sheet flow on spring tides only; moderate; close=site is close to tidal channel

Salinity potential: in general, higher tidal salinities in the restored site will improve the success of the restoration/enhancement action

- Cascade Brook Sediment and Phragmites Removal Project.

The first two are tidal restriction projects, the latter two, marsh surface projects.

3.3 SITE ASSESSMENT

The 29 active and potential sites were then evaluated for 22 attributes pertinent to restoration or enhancement (Table 3-2). Some of the attributes described aspects of their existing condition, such assize of the area that would benefit from restoration or enhancement, use by rare species, waterfowl and wading birds, and high marsh sparrow species. Also evaluated were adjacent upland features that were likely to affect the design and outcome of the project, including the level and type of development in the immediate vicinity of the site, its proximity to large, undisturbed upland and freshwater habitats, and its potential to connect to wildlife travel corridors. The type(s) of degradation exhibited by the site were assessed: tidal restriction, invasive plant species, ditching, hay roads, and fill. And certain key aspects of the restoration or enhancement project itself were assessed, including the total cost of the solution, the cost/acre of the solution, and the potential flood risk to surrounding development. Finally, project specific attributes, such as available site information, known infrastructure obstacles, access to the work area, proximity to a major tidal channel and salinity potential, were considered.

For each site, scores were estimated for all of the 22 attributes (Table 3-2). Individual scores ranged from 1 to 3, with 1 indicating the least desirable condition for restoration or enhancement, and 3 the highest. Note that some values may be intuitively reversed, e.g., a high total cost of a project is given a score of 1 because an expensive project is more difficult to implement than a less costly one. Criteria for each attribute are provided in the explanation at the end of Table 3-2.

Scoring for each project was summed in two ways. Project Scores were tallied from those attributes that would most influence the feasiblity and urgency of a project, including site size, the type and level of degradation, and the restoration and enhancement potential (Table 3-2). A total Site Score was also tallied using the sum of all attributes assessed. Higher Project and Site Scores were assumed to be indicative of relative greater priority for restoration and enhancement, however, the narrow overall range of scores within the two categories of marsh surface and tidal restriction projects prevented using simply the scores for prioritization.

3.4 SITE PRIORITIZATION

A subcommittee of FSM members and NAI met to review the 38 active, potential and future projects. The matrix data and the Project and Site Scores for the 29 active and potential projects were reviewed and refined based on site-specific information provided by various members of the subcommittee. Additionally, aspects of each project were discussed which may not have been captured accurately by the Project and Site Scores. One such aspect was the knowledge of individual sites by FSM members and their sense of relative importance or feasibility of the project. Also considered was the connectivity or linkage of the site to other proposed projects, e.g., would restoration of one site effect the condition of, or the opportunity to restore a nearby or upstream site? Another consideration was the likelihood of financing a project, based on a combination of the cost, owner cooperation, known available funding, and type of restoration. These factors, in tandem with the Project and Site Scores, led to prioritizing the projects into three categories of action: highest priority, high priority, and priority (Table 3-3). The use of these terms is meant to reinforce that all of the projects are important, but given the constraints of funding and manpower, certain ones will be pursued first.

Table 3-3. FSM marsh restoration/enhancement priorities for identified projects. Sites are listed in numerical order of the map numbers, and do not indicate ranking within the priority categories.

Priority Category	Map Numbers	Project Type	Project Name
Highest Priority			
	3	Marsh Surface	Remove roads and plug ditches on Nonesuch
	5	Active	Dunstan Marsh Restoration Project.
	10	Marsh Surface	Plug ditches west of industrial park
	12	Marsh Surface	Plug ditches and restore large pool below impoundments
	13	Marsh Surface	Breach hay road and plug ditches near Mill Creek
	17	Marsh Surface	Breach road and plug ditches below Willowdale
	21	Tidal Restriction	Remove dam on Cascade Brook
	22	Tidal Restriction	Enhance Eastern Rd. connections
	25	Tidal Restriction	Add culvert under railroad at Winnocks Neck
	26	Active	Cascade Brook Sediment and Phragmites Removal Project
	28	Active	Seavey Landing Ditch Plugging Project
	29	Tidal Restriction	Tidal restriction at railroad bridge over Scarboro River
	33	Active	Libby River Tidal Restriction Project
High Priority			
	6	Marsh Surface	Plug ditches and remove Phragmites SW of Rt 1
	8	Marsh Surface	Plug ditches on Nonesuch below road
	18	Marsh Surface	Plug ditches along Mill Creek
	30	Marsh Surface	Clean up ballast along railroad
	32	Marsh Surface	Breach hay road and plug ditches on upper Libby River
	34	Marsh Surface	Remove fill and plug ditches on Libby River
	37a,b	Tidal Restriction	Enhance flows through culvert on Jones Creek
	38	Marsh Surface	Restore channels and pools in Jones Creek
Priority			
	2	Marsh Surface	Plug ditches on Nonesuch above road
	7	Tidal Restriction	Enhance flows at Phillips Brook
	9	Marsh Surface	Deepen large pools by Route 1
	15	Tidal Restriction	RR bridge over Nonesuch River
	16	Tidal Restriction	Restore connection to Cascade Brook at Route 9
	19	Marsh Surface	Enhance flows behind railroad on Nonesuch River
	20	Tidal Restriction	Enhance flows at Dunstan Landing Rd.
	36	Marsh Surface	Plug ditches by golf course
Future			
	1		Enhance flows under Payne Rd.
	4		Remove weir on Nonesuch
	11		Assess restoring tides to 2 impoundments
	14		Enhance drainage southeast of Rt 1
	23		Enhance pools and pannes below Eastern Rd
	24		Breach hay roads at Winnocks Neck
	27		Enhance flows behind Peterson Playfield
	31		Dug harbor and channel off Black Point
	35		Manmade beach on Black Point

Thirteen sites were included as highest priority, including the 4 active projects ongoing on the marsh, 5 marsh surface projects and 4 tidal restriction projects. Eight projects were considered high priority, with 7 marsh surface sites and 1 tidal restriction site. Another 8 were considered priority projects, including 4 marsh surface and 4 tidal restriction sites. Finally, the 9 projects identified for future work were included in Table 3-3 to ensure they are carried forward in all discussions of marsh work.

3.5 OTHER SALT MARSH IMPROVEMENT EFFORTS

The list of restoration and enhancement projects provides an excellent base from which FSM can move forward with fund-raising and project planning; however, the list considers the marsh as observed in 2001. A second very important role available to FSM will be to monitor marsh conditions over time and to track changes observed.

3.5.1 Invasive Plant Species Watch

Invasive plant species are of growing concern on salt marshes in southern Maine. An example is Phragmites (*Phragmites australis*), which has been present on Scarborough Marsh for at least 25 years, but is rapidly expanding in several sections. Scientists are still debating the conditions necessary for Phragmites to colonize and expand on a site, and eradication can prove very difficult in areas of moderate to low salinities. The early detection and monitoring of a Phragmites stand is very useful in assessing the urgency and type of treatment, if any, is needed. This tall plumed grass is usually very prominent on a marsh landscape, and therefore is easily spotted. A routine, marsh-wide Phragmites survey and mapping effort would provide FSM with a means of identifying those Phragmites stands that are expanding rapidly, and those that are of less concern. A layer showing locations of all known Phragmites stands as of summer 2001 is included in the ArcExplorer Data Base provided with this project. This layer indicates simply the location, not the extent, of individual Phragmites stands. Areas where extensive stands occur are depicted with multiple symbols, and are by no means quantitative.

A Phragmites Watch of FSM volunteers would be extremely beneficial in tracking the progress of this species. At a minimum, FSM could continue to supplement the 2001 map by noting any new, unrecorded stands of Phragmites within the marsh. A more effective refinement would be to develop a semi-quantitative approach for describing the quality of the stand over time. Stands should be revisited every 2-5 years to track the rate of expansion. Some parameters to consider evaluating include

- the approximate area of the stand (this could be measured from current aerial photographs, GPS, direct measurements of several dimensions of the stand, or estimated from visual observation),
- average density and height of the plants,
- other vegetation occurring within and around the stand,
- high water stains on the stems,
- any associated disturbance in the upland, and
- a permanent photographic station to record the stand at each site visit.

Use of a volunteer base has the additional benefit of increasing awareness in the community of the general state of the marsh, and in particular, the encroachment of Phragmites in obscure corners of the marsh.

A similar approach could be used for tracking purple loosestrife (*Lythrum salicaria*). This species has a lower salinity tolerance than Phragmites, but is making inroads into the tributaries of the marsh, and may soon be found on the intertidal marsh proper. While not as prominent as Phragmites during most of the year, purple loosestrife is very visible during July and early August, when its showy purple flower spikes are easy to spot. This species can not be reliably detected in aerial photographs, so a ground effort is the only mechanism for finding and mapping this species. All of the same parameters described above for Phragmites are suitable for purple loosestrife.

3.5.2 Citizen Awareness

Another outreach effort that could further protect Scarborough Marsh is development of a Citizen's Guide to the Protection of Scarborough Marsh. This pamphlet could summarize, in lay language, the protections afforded the marsh, and its immediate buffer. Best management practices for lawns and landscaping, maintenance of a vegetated upland buffer, and avoidance of dumping or filling in the marsh could be explained, and the benefits to the marsh and the landowner expounded. A direct mailing to all marsh abutters could be a relatively inexpensive way to reach a large number of people who directly impact the marsh, and may expand the reach of FSM.

Recently, homeowners, landowners and town officials have been engaged in a study of land use and water quality in the Libby River Watershed. The Maine DEP booklet "A Citizens' Guide to Coastal Watershed Surveys" (1996) was used by trained volunteers to locate and identify potential sources of water pollution in the watershed. Following the survey, volunteers worked with neighborhood organizations and town officials to participate in remediation projects. These citizen-initiated projects, ranging from the planting of vegetated buffers to an inventory of storm water detention ponds, will help decrease polluted runoff and improve water quality in the Libby River, and ultimately Scarborough Marsh and Casco Bay. FSM hopes to expand this type of grassroots effort to the other watersheds within Scarborough Marsh.

4.0 WATERSHED PROTECTION PRIORITIES

4.1 INTRODUCTION

The Scarborough Marsh watershed is approximately 38,000 acres (60 square miles) and includes a major drainage (Nonesuch River) as well as several significant tributaries. The Maine Office of Geographic Information Services (OGIS) identified six subwatersheds draining into the marsh (Figure 1, Map 1). NAI reviewed the watershed data to assist FSM in prioritizing those areas of the watershed that are at risk through development, those that are significant for wildlife and vegetation conservation, and those that provide educational and recreational opportunities. The impacts of each activity on the health and aesthetics of Scarborough Marsh were of prime importance in the analysis.

The watershed analysis consisted of three separate steps. The first involved the physical analysis of identifying subwatersheds for the various tributaries within the entire watershed, followed by calculating the percentages of various land uses within each subwatershed. With those data, an approximation of the amount of impervious surface, runoff and nutrient loading to the major streams was performed. This first step provided the contributions of each subwatershed to the Scarborough Marsh, and allowed us to identify those subwatersheds which are most degraded and which are providing the highest nutrient and other contaminant loads to the marsh.

The second step included reviewing the vegetation cover types within the watershed and identifying corridors or potential corridors that would enable wildlife and vegetation to migrate among major blocks of unfragmented habitat, such as Scarborough Marsh, Saco Heath and Ash Swamp. Brooks and rivers typically form natural wildlife travel corridors, so those were the primary targets for review. Known locations of rare wildlife and vegetation species were included, as was the amount of existing conservation lands within each corridor. The combination of relatively low fragmentation and high percentages of conservation lands established the highest priority corridors.

The third step involved combining the first two steps into a cohesive package, which provides FSM with key areas to consider for land conservation around the marsh and across the watershed. These areas incorporate important wildlife habitats and corridors, as well as considering subwatersheds which are most heavily developed and are contributing the highest nutrient loads to the marsh. The wildlife habitats and developed areas may seem in some respects mutually exclusive, but in a rapidly developing landscape, maintaining/establishing wildlife corridors benefits both wildlife and quality of human life. Many studies have identified the importance of vegetated buffer zones along water courses for wildlife, water quality and aesthetics. Clearly, progressive planning in the Scarborough Marsh watershed will be to the benefit of wildlife and people alike.

These analyses included the use of the following GIS layers:

- Base map (GIS, 2000, and Greater Portland Council of Governments)
- Land use (Maine GAP, 1998)
- Watersheds (OGIS, 2000)
- Vegetation cover (USFWS Gulf of Maine, Habitat Mapping Project, 2000)
- Conservation lands

    - Digital (Coastal Mosaic Program, Wells National Estuarine Research Reserve, 2000)
    - NAI mapped (Data provided by Buxton Gorham, Saco, S. Portland, 2001)
- Unfragmented lands of 500 acres or more (Maine Natural Areas Program, 2001, based on 1993 Maine GAP imagery)
- Rare species
    - Maine Department of Inland Fisheries and Wildlife, 2000, Maine Natural Areas Program, 2000)
- Scarborough tax parcel map (Coastal Mosaic Program, Wells National Estuarine Research Reserve, 2000)

The following sections describe the watershed analysis in greater detail.

4.2 PHYSICAL STUDIES

4.2.1 Methodology

An impervious surface and a nutrient export analysis was conducted for the Scarborough Marsh watershed. The purpose of this analysis is to highlight the areas of the watershed that contribute large amounts of nutrients (and other waterborne pollutants) and contain large percentages of impervious surfaces. General areas of potential water quality problems are identified and discussed. The analysis was based on the Maine GAP land cover data (1994) imagery, and therefore does not include the additional development in the watershed over the last 7 years. It is also lacking the resolution to distinguish below a 30 m pixel size (approximately ¼ acre), so is limited in its ability to detect small mixed use lots (e.g., a wooded residential lot may be inappropriately classified as forest)..

4.2.2 Impervious Surfaces

Impervious surfaces include land covers that prevent water from infiltrating into the soil such as roads, rooftops, and sidewalks. In a natural environment, little rainfall is converted to runoff. Approximately half of all runoff seeps into the soil, filters through and becomes part of the underlying groundwater aquifer. The shift away from infiltration that often accompanies watershed development reduces groundwater recharge, lowering water tables. This threatens groundwater supplies and reduces groundwater contributions during periods of dry weather stream flows (Duane and Leopold 1978, Harbor 1994).

Impervious surfaces also change the hydrology of streams by increasing peak discharge volumes. When peak discharge increases the streams respond by increasing their cross-sectional area to accommodate the higher flows. The increase is frequently accomplished by widening or down cutting of streambed and streambanks and results in habitat degradation (Schueler 1994). Impervious surfaces also increase the velocity and time of concentration of runoff (Schueler 1994). Impervious surfaces collect and accumulate hydrocarbons, heavy metals, sediments, bacteria and nutrients and are quickly carried to the receiving water body with no opportunity for infiltration

An impervious surfaces analysis was conducted with methods outlined in the *NEMO Technical Paper 4 and the Rapid Watershed Planning Handbook* (1998). Land use/cover data was obtained from the

Maine Gap Analysis (1998). The land use cover data was summarized for the watershed, as well as each sub-basin, and a appropriate coefficient was applied to derive an estimate of impervious surfaces. The following impervious cover thresholds were taken from Schueler's Watershed Protection Techniques.

- If less than 10% of a local sub-basin is covered with impervious surfaces, streams are generally considered protected, although sensitive streams may begin to be stressed. The emphasis here should be on a protective planning techniques

- If 11% to 25% of a local sub-basin is covered with impervious surfaces, streams considered impacted and show clear signs of impacts. Streams in this category are in the fair to good category during storms and dry weather. Stream biodiversity declines to fair levels and the most sensitive species disappear from the stream. Mitigation may still be achieved with effective best management practices.

- Where over 25% of a sub-basin is covered with impervious surfaces, streams are considered non-supporting. Stream banks become highly unstable, water quality is consistently rated as fair to poor, recreation may not be possible, downstream receiving waters will be impacted due to increased nutrient load and the streams are usually dominated by pollutant tolerant species.

Nutrient Export Analysis

Human activities within a watershed can significantly increase the amount of nutrients to the receiving waterbody compared to natural background levels. Land use is highly correlated with nutrient export from the land surface and the resulting water quality (Omernick 1977). Urbanized areas generally export large amounts of phosphorus and nitrogen because of minimal vegetation and a reduction of infiltration. Urban regions also have a higher risk of contaminating surface and groundwater because they generally have more pollution sources including bacteria, pesticides and trace metals. Agricultural areas are also known to contribute sediment, nutrients, insecticides and herbicides into the water.

An analysis was conducted to determine the estimated nutrient loads being delivered to the Scarborough Marsh (nitrogen and phosphorus). The watershed was delineated into six sub-basins. The six sub-basins drain either to a specific stream or directly into the marsh (Figure 4-1). Estimating nutrient loads involved applying a nutrient loading coefficient to the land uses/covers mapped for the ME_GAP program. An appropriate nutrient loading coefficient was applied according to Omernik (1977), Reckow et al (1980) and Athayde (1983). Annual water yield from each sub-basin was then calculated by assuming 22 inches of runoff per year (42 inches annual rainfall minus 20 inches evaporation and transpiration). The annual loads of phosphorus and nitrogen were then divided into the annual water yield to give a projected concentration of water reaching the Scarborough Marsh.

Nitrogen is typically the primary limiting nutrient in the seaward portions of most estuarine systems (Paer, 1993) while phosphorus is typically the limiting nutrient in freshwater aquatic systems. The recommended level of nitrogen in estuaries to avoid algal blooms is 0.1 to 1.0 mg/l, while phosphorus concentrations of .01 to .1 mg/l. Higher concentration of both will support less diversity (NOAA/EPA 1988). The analysis presented here was completed for both phosphorus and nitrogen because although the ultimate receiving waters are estuarine, there are freshwater rivers, streams, ponds and wetlands in the watershed.

The goal of the nutrient analysis is to show which sub-basins are potentially contributing excessive amounts of nutrients. In order to compare nutrient export from the sub-basins it was assumed that nutrient export from each sub-basin should be proportional to the land area the sub-basin occupies within the entire Scarborough Marsh watershed. For example if the Libby River sub-basin contains 6% of the land within the Scarborough marsh watershed, nutrient export should remain at or below 6%. Table 4-1 lists the nutrient export and percentages for each sub-basin for the entire watershed. Sub-basins contributing excessive amounts of nutrients can then be targeted for specific nutrient reduction/stormwater management strategies.

4.2.3 Results

The Scarborough Marsh watershed has a total area of approximately 38,000 acres (approximately 60 sq. miles) and ranges in elevation from 20 to 220 feet. The watershed is made up of lands in the towns of Scarborough, Saco, Old Orchard Beach, Gorham, Buxton, and South Portland (Figure 1, Map 1). The watershed was classified into different land use/cover categories based on data from the ME-GAP Analysis program (Table 4-2) The watershed is primarily forested (20,569 acres or 54%). The next largest land use/cover category is pasture or grassland (8,897 acres or 24%). Table 4-2 shows all other land use/cover categories within the sub-watersheds of Scarborough Marsh. A description of land use/covers and the results of the impervious and nutrient analysis, by sub-basin are presented below.

Libby River Sub-basin

The Libby River sub-basin is approximately 2,463 acres (6% of the watershed). The sub-basin is dominated by forest (1,042 acres or 42%) and located entirely within the town of Scarborough. Table 4-2 shows all other land use/cover within the sub-basin. The sub-basin contains approximately 160 acres of impervious surfaces, or 7% of the sub-basin, which places it into the protected category. The Libby River sub-basin ranked 4th in nutrient export. Although the sub-basin contains only 6% of the land area in the Scarborough Marsh watershed it exported 18% of the nitrogen and 20% of the phosphorus to Scarborough Marsh.

Scarborough Marsh Sub-basin

The Scarborough Marsh sub-basin is approximately 7,209 acres in size (19% of the entire watershed) and is the second largest sub-basin delineated for this study. The sub-basin is located within the town of Scarborough, Saco and Old Orchard Beach. Table 4-2 shows all land use/covers within the sub-basin. The impervious surface analysis shows that approximately 3% of the sub-basin is covered with impervious surfaces, placing the sub-basin into the protected category (Table 4-1). The Scarborough Marsh sub-basin exports approximately 14% and 15% of the nitrogen and phosphorus, respectively, to the Scarborough Marsh (Table 4-1).

Nonesuch River Sub-basin

The Nonesuch River sub-basin is approximately 16,240 acres in size (43% of the entire watershed) and is the largest sub-basin delineated for this study. The sub-basin is in five separate communities including: Saco, Gorham, Buxton, South Portland and Scarborough. The three major land use/covers within this sub-basin are forest (9,520 acres or 59%), pasture (3,777 acres or 23%) and residential (964 acres or 6%). The Nonesuch River sub-basin contains 892 acres of impervious surfaces or 6% of the sub-basin, placing it into the protected category (Table 4-1). The Nonesuch River sub-basin

Table 4-1. Nutrient Export by Subwatershed for Scarborough.

Subwatershed	Total Acreage	% of Watershed	Nitrogen mg/l per year	Nitrogen % of Export	Phosphorus mg/l per year	Phosphorus % of Export	% Impervious Surfaces
Libby River	2,463	6%	0.74	18%	0.07	20%	7%
Mill Brook 2	2,921	8%	0.78	19%	0.08	23%	11%
Mill Brook 1	4,212	11%	0.77	19%	0.06	18%	6%
Cascade Brook	4,885	13%	0.52	13%	0.03	9%	1%
Scarborough Marsh	7,209	19%	0.56	14%	0.05	15%	3%
Nonesuch River	16,240	43%	0.65	16%	0.05	15%	6%
Total	37,930	100%	4.02	100%	0.34	100%	

Table 4-2. Land Use/Cover (acres) Within the Subwatershed of Scarborough Marsh.

	Libby River	Scarborough Marsh	Mill Brook 1	Nonesuch River	Mill Brook 2	Cascade Brook	Total	% of Watershed
Forest	1,042	3,052	2153	9,520	1,392	3,410	20,569	54%
Pasture	513	1,709	1228	3,777	669	1,001	8,897	23%
Salt Emergent	425	953	90	586	240	4	2,298	6%
Residential	212	409	318	964	324	44	2,271	6%
Idle	91	416	111	588	69	217	1,492	4%
Mudflat	70	257	19	128	95		569	2%
Fresh Emergent	22	90	171	206	15	57	561	1%
Business	7	193	39	85	30	16	370	1%
Agriculture	24	51	14	141	21	31	282	1%
Water	42	32	64	141			279	1%
Wet Meadow				17		26	43	<1%
Shallow Water					50	5	55	<1%
Sand Shore		22					22	<1%
Salt Aquatic Bed	3	2					5	<1%
Peatland	12			25		74	111	<1%
Exposed Rock/Talus		23	5	62	16		106	<1%
Total	2,463	7,209	4,212	16,240	2,921	4,885	37,930	100%

exports 16% of the nitrogen and 15% of the phosphorus into Scarborough Marsh, well below the 43% threshold (Table 4-1).

Mill Brook 1 Sub-basin

The Mill Brook sub-basin is approximately 4,212 acres in size (11% of the entire watershed) and located within the town of Saco and Old Orchard Beach. Land cover within this sub-basin is forest (2153 acres or 51%). Pasture (1228 acres or 29%) followed by residential (318 acres or 8%) (Table 4-2). The Mill Brook sub-basin contains 240 acres of impervious surfaces or 6% of the sub-basin, placing it into the protected category (Table 4-1). The Mill Brook sub-basin exports 19% of the nitrogen and 18% of the phosphorus into Scarborough Marsh, primarily from the residential and pasture land uses in the sub-basin. Portions of this sub-basin are sewered.

Mill Brook 2 Sub-basin

The Mill Brook 2 sub-basin is approximately 2,912 acres (8% of the watershed) and located within the town of Scarborough (Map 1). Land use in this sub-basin is also dominated by forest (1392 acres or 48%) of the sub-basin (Table 4-2). The sub-basin contains approximately 324 acres of impervious surfaces or 11%. Streams within this sub-basin are considered impacted. The Mill Brook 2 sub-basin also is the largest exporter of nutrients contributing 19% and 23% of the nitrogen and phosphorus, respectively despite the fact that that it occupies only 8% of the land mass of the entire watershed.

Cascade Brook sub-basin

The Cascade brook sub-basin is approximately 4,885 acres (13% of the watershed) and contains 3410 acres of forest (71%) and is located almost entirely within the town of Saco (Map 1). The sub-basin has approximately 1% impervious coverage (Table 4-1). The sub-basin exports approximately 13% of the nitrogen and 9% of the phosphorus into the marsh. The majority of this sub-basin is unsewered.

4.2.4 Discussion

Land preservation, nutrient control and mitigation should be a high priority in the sub-basins already exhibiting high levels of nutrient export, which include the Libby River, Mill Brook 2 and Mill Brook 1 sub-basins. In the analysis, these sub-basins contributed nutrients above their respective portion of the acreage they occupy within the Scarborough Marsh watershed (Table 4-1). The Mill Brook 2 sub-basin also contained 11% impervious surfaces in 1994, placing it into the impacted category. These three relatively small sub-basins are located in areas of the watershed that are developing rapidly and should be reviewed for protective and mitigative measures to prevent further increases in nutrient export. The Cascade Brook sub-basin exported 13% of the nitrogen into the marsh while it also occupied 13% of the landmass. To prevent nutrient exports from becoming disproportionately high, it should be targeted for immediate protection measures. The Nonesuch and Scarborough sub-basins both contained relatively low amounts of impervious surfaces and exported less nutrients than their areal proportion of the watershed (Tables 4-1 and 4-2). Preserving raw undeveloped land within these sub-basins, especially where land is to be developed, make minimization of nutrient export and impervious surfaces a priority.

All of these watersheds have experienced considerable growth since the 1994 date of the land cover photography used in this analysis. New residential housing is currently capped at 140 units per year (in 2001 this represented an approximate growth rate of 2.2%(J. Zipnewski, Scarborough Town Planner, pers. comm.), which is rapidly filled each year, indicating the potential for additional growth.

Given these factors, the need for informed, watershed-wide management will be imperative for controlling the impacts of growth to Scarborough Marsh.

Reduction in nutrient export and reducing impervious surfaces from the sub-basins that contribute excessive amounts of nutrients can be accomplished by incorporating best management practices in the design of new development wherever possible and designing mitigation measures where increases in nutrient export are unavoidable. Examples of nutrient control include land acquisition and preservation, and best management practices on developed sites, including grassed swales for stormwater treatment, control of construction site erosion, maintenance of naturally-vegetated buffer strips, maintenance of septic systems, limiting lawn cover, reduced fertilizer, maintenance of catch basins, avoidance of steep slopes, encouraging infiltration, control of pet waste, and minimization of impervious areas. Examples of other mitigation measures include but are not limited to installation of wet detention basins/ponds, use of constructed wetlands for treatment of runoff and repair or replacement of malfunctioning septic systems. Best management practices and mitigation should be tailored to specific development proposals. Provisions should be made for the maintenance of constructed structures.

4.3 WILDLIFE HABITATS AND TRAVEL CORRIDORS

Seventeen species of plants, animals, or vegetation communities are listed on the state and federal databases as presently occurring or historically occurring in the Scarborough Marsh watershed. These include as seven animal species, four plant species, three vegetation communities and three significant wildlife habitats. Nine are associated with the salt marsh itself, the remaining are in the surrounding terrestrial watershed.

Unfragmented lands were defined by Maine Natural Areas Program as blocks greater than 500 acres that lacked public roads or development as of 1993. Blocks greater than 1000 acres were distinguished from those of 500-1000 acres. As would be expected, the distribution of these parcels follows the inverse of the development pattern, and are most prevalent north of I-95 and on the western side of the watershed. Five unfragmented parcels of 1000 acres or more occur within the watershed: the Scarborough Marsh, Saco Heath, and three parcels associated with the Upper Nonesuch. Six parcels between 500 and 1000 acres occur, five of them north of I-95, and one parcel associated with Cascade Brook.

It is important to remember that this analysis only addresses unfragmented lands greater than 500 acres in size. There are a number of tracts between 100 and 500 acres that may be quite important when considering the rapidly developing landscape along the coast, and in South Portland and Scarborough. These smaller unfragmented lands may be valuable for open space and for providing linkages between other larger tracts. They are provided in the GIS unfragmented lands layer, although the accuracy of this layer must be closely monitored over time as new roads and subdivisions break up unfragmented areas.

The distribution and type of conservation lands within the watershed also figured heavily in the analysis. Conservation lands within Scarborough, South Portland and Old Orchard Beach were provided electronically by the Coastal Mosaic Program at the Wells National Estuarine Research Reserve. These data were developed in 2000, and differentiated between types of owners: federal, state, town, and private. The level of protection is difficult to ascertain from some of the sites. For example, some town-owned lands are used for purposes other than conservation, and offer little in the way

of long-term habitat protection. Additionally, tax shelters such as farmland, open space and tree growthare temporary, with no long-term binder for protection from development.

For this study, the conservation lands were combined into two categories of protection: permanent and temporary (Map 3). Permanently protected lands included all those in public (federal, state, town) and private ownership, recognizing the limitations of the definition as described above. Temporarily protected lands included the tax shelters: farm land, open space and tree growth.

4.3.1 Identification of Wildlife Corridors

Using the combined data from the land cover type mapping, unfragmented land parcels and conservation lands, the identification of wildlife corridors was undertaken. Large parcels of undeveloped lands were selected as the refugia for many plant and wildlife species in the watershed. Four sites were selected: Scarborough Marsh, Saco Heath, the Ash Swamp and the northern part of the Nonesuch River watershed plus Scottow Bog (Map 3). All sites contained large unfragmented acreages (>500 acres), several contained rare species or habitats (Scarborough Marsh, Saco Heath and the Nonesuch), each parcel had at least some existing conservation lands, and the set encompassed the geographic breadth of the Scarborough Marsh Watershed.

The next step was to connect the four parcels in one or more ways to each other. Wildlife corridors were developed along stream courses on the premise that many animal species use streams and floodplains as travel corridors (Map 3). Six streams were selected that provided linkages among the large parcels, based on the abundance of protected land, a minimum of roads and development, and the presence of natural vegetation. In some areas a small overland connection at the top of the stream (Mill Brook, Bond Brook and Libby River) was necessary to complete the connection. A summary of the rationale for the individual wildlife corridors is provided in Table 4-3.

The corridor width shown on Map 3 is approximately 1200 feet. This is very wide, twice the typical corridor widths of 250-600 feet recommended for birds, amphibians and mammals, however it is likely that the full corridor width will not be available in many areas. In such cases the corridor can be narrowed to less than the 1200 feet. In extreme cases one side of the stream may have no protection at all, so that the corridor may need to be configured so it protects only one side of the stream. On the smaller streams, this should not present an impediment to most animal species, and even the Nonesuch can be easily crossed in low water, but protection of both sides of the watercourses should be the goal.

4.3.2 Protection Of Wildlife Corridors

The level of existing protected lands within the various travel corridors ranges from 2% to 91%, with an average of 30% (Table 4-4). This protection varies in its strength, as the 91% on Mill Brook attests. Almost all of the Mill Brook conservation land is in tree growth, which is a temporary timber management tax shelter, and can be reversed on the owner's request. Finnerd Brook is an example of lands in a mixture of state, town and private conservation, with the level of protection ranging from IFW State Wildlife Management Area to tree growth. Efforts to increase the level of protection within the temporary conservation lands should be considered equally important to adding new parcels by acquisition or conservation easements.

Table 4-3. Rationale for Wildlife Corridors as depicted on Wildlife Corridor Map.

Nonesuch River Corridor
- Largest corridor in watershed
- Many road crossings, including I-95 and Rt. 1
- Includes/adjacent to 3 mapped Deer Wintering Areas
- Includes three parcels of unfragmented land greater than 1000 acres
- Includes a spur to Scottow Bog
- Above I-95 includes many stretches of undeveloped land
  Some tree growth and minor State conservation land
- Below I-95, development pressure along roads is high, especially along Route 1

Libby River Corridor
- Connects marsh to Nonesuch Corridor
- Mostly forested wetland
- Crosses 2 roads and Guilford railroad
- Minor conservation lands and rapidly developing around edges

Mill Brook Corridor on Jones Creek
- Connects overland to Cascade Brook Corridor
- Mostly in tree growth already, consider permanent easements
- Crosses Portland Ave and Eastern Road

Cascade Brook Corridor
- Connects Scarboro Marsh to Saco Heath
- Little currently in conservation land
- Has 4 road crossings, including I-95 and Route 1
- Leary Farm forms top of corridor

Finnerd Brook
- Includes largest mapped Deer Winter Area
- Approximately 50% of corridor in Open Space, Tree Growth, and small amount Town land
- Connects to IFW waterfowl impoundment

Ash Swamp
- Forms central hub, along with Saco Heath, for connecting other corridors
- Bisected by Ash Swamp Rd, with relatively little current development
- Includes mapped Deer Wintering Area, some Tree Growth, open space lands
- West side connects to Leary Farm

Ricker Brook
- Connects Saco Heath to Nonesuch
- Little conservation land within corridor
- Three secondary road crossings, with single family homes

Bond Brook
- Connects Ash Swamp to Nonesuch Corridor
- Small middle section in tree farm, the rest is unprotected
- One secondary road crossing

Table 4-4. Acreage of wildlife corridors in temporary and permanent conservation land. The number is also expressed as a percent of the total acreage in the corridor.

Wildlife Corridor	Total Conservation Acres	Percent of Total Corridor
Bond Brook	20	16%
Cascade Brook	7	2
Finnerd Brook	180	45
Libby River	30	12
Mill Brook	158	91
Nonesuch River	528	25
Ricker Brook	18	10

Impediments to the success of the wildlife corridors remain the road crossings. Many quiet secondary roads do not present a substantial barrier to most species, with the notable exception of amphibian passage during migration. Busy secondary roads (Holmes Road, Portland Ave) can cause substantial mortality in slower moving species (salamanders, turtles, small mammals), and can deter crossings due to disturbance and noise. Wide, heavily traveled roads such as Route 1 and I-95 present a serious barrier to all wildlife attempting to cross, and can effectively isolate populations on either side.

FSM should consider pursuing improved passage for wildlife across roads within the watershed that bisect the wildlife corridors. Enhanced culverts at key crossings, designed with adequate size, light and moisture, should be promoted to encourage wildlife passage (see Section 5.1.6). Road crossing impediments, such as jersey barriers and deep center ditches, should be discouraged, as should roadside plantings of wildlife food value, which will unnecessarily attract animals to the road.

Coordination with the Department of Transportation and Maine Turnpike Authority will be vital to ensure that wildlife crossing improvements are considered as part of each road project.

As a note of urgency, NAI observed many new single lots and subdivision under construction during fieldwork for this project. The new development borders many of the existing roads throughout the watershed, and new roads are under creation, affecting both the unfragmented lands analysis and the location of wildlife corridors. At a minimum, this means that the opportunities for protecting existing open space and connector corridors are declining, and that the road crossing locations of the corridors shown on Map 3 should be reviewed relative to new development, and relocated if ecologically practicable. If this aspect of the work is a priority to FSM, it should be pursued immediately, since the potential is declining and the costs are rising with time.

4.4 LAND ACQUISITION PRIORITIZATION AROUND SCARBOROUGH MARSH

This section presents essentially an extension of Section 4.3 in an effort to protect a buffer of land around Scarborough Marsh. In order to maintain the quality of habitat in the Marsh, the level and type of development in its immediate surrounds must be controlled. In general, land clearing for lot development increases overland runoff to the marsh, which may carry an increased nutrient and pollutant load. The additional freshwater alone may enhance the spread of invasive species such as Phragmites and purple loosestrife. The increased nutrient load in the runoff exacerbates the condition. Land clearing also eliminates, or reduces the quality of, cover and forage for species that utilize both the marsh and adjacent upland. As development intensifies to dense residential, commercial and industrial, the impacts are compounded with increased runoff, noise and light disturbance, and re-

stricted travel between marsh and upland. Some wildlife species are capable of acclimating to disturbance, but the combination of altered habitat quality in the marsh and a decline in the amount of suitable upland habitat adjacent to the marsh will inevitably lead to a reduction in species abundance and richness (the number of species) on the marsh.

All of the intertidal portion of Scarborough Marsh lies within the Town of Scarborough. Scarborough is under intense development pressure, with an increase of approximately 2.2% in residential housing in 2001 (J. Zipnewski, Scarborough Town Planner). This rate of growth is currently controlled by a cap on the number of new homes (140) permitted per year, which is quickly filled annually and indicates that the potential rate of growth is even higher. Many of the dense residential areas lie in the vicinity of the Marsh and directly affect the water quality and habitat quality of the upland adjacent to the marsh. FSM is interested in working with willing landowners to preserve the biological integrity of Scarborough Marsh. This should be a high priority issue for the Town of Scarborough and the State of Maine.

5.0 WILDLIFE ENHANCEMENT OPPORTUNITIES

In addition to the goals of establishing of wildlife corridors within the watershed, and protection of critical lands adjoining Scarborough Marsh, other wildlife habitat enhancement opportunities occur within the watershed. Some have already been discussed in the context of habitat restoration or enhancement, but will be presented here to highlight habitat improvements that will benefit certain suites of species. FSM is focused on restoring the marsh to benefit the fish and wildlife species that utilize it. Additional species of interest that use the marsh and nearby upland include deer, otter, raccoon, and muskrat.

5.1 POOLS AND PANNES IN MARSH

A number of sites identified for salt marsh restoration and enhancement in Section 3.0 included creation/restoration or enhancement of pools and pannes on the high marsh. In some areas, existing pools have been drained by ditches and no longer hold sufficient water at low tide. In other areas, a uniform ditched high marsh with no standing water is indicative of pools that were drained and filled in during the ditching process. Although unditched marshes are rare in New England, the current consensus among ecologists is that pools and pannes were once prevalent on, and an important part of, the high marsh (Miller and Egler 1950, Redfield 1972). Their absence eliminates habitat that is valuable to species from the bottom to the top of the food web. Dabbling waterfowl feed on algae, invertebrates, and plant material in pools, loaf on the surface and around the edges, and certain species breed and nest in the upper reaches of salt marshes. Diving waterfowl hunt fish and invertebrates in the deeper pools. Wading birds and shorebirds of all sizes use pools and pannes as important stopover areas during migration for feeding and resting, and resident species (a number of herons, egrets, sandpipers) depend on these areas throughout the season. In areas of sufficient vegetative cover, rails feed along the edges of pools in the water and exposed mud at low tide.

When considering pool and panne restoration on Scarborough Marsh, FSM needs to consider both the specific condition of an individual site, and a more landscape-wide perspective of the type and distribution of pools. Deep pools that support a variety of adult and juvenile fish, invertebrates and aquatic vegetation such as widgeon grass (*Ruppia maritima*) are highly valuable for most waterfowl and wading birds. These pools should retain a minimum water depth of 1 foot, and should be flooded at mean high water to ensure adequate hydrology and exchange. Ideally the pools will have an irregular edge to provide adequate cover, and a range of depths so that the edges draw down at low tide to expose sediment and shallow water for smaller bird species to loaf and feed.

Shallow pools which are flooded during average and above average tides provide important refugia for juvenile and young-of-the-year fish, and many invertebrates. These pools can be small depressions less than one foot deep, and should have gradually sloping grades to provide a deep pool for refuge during portions of the month when tides are below average, and to provide a habitat gradient for predators such as shorebirds and waders. Because hypersaline conditions are deleterious to many fish and invertebrates, this type of pool should not be constructed too high in elevation in the marsh.

A third panne type is a very shallow depression, on the order of a few inches deep, that is inundated only periodically by tides. These pannes will develop soils that are hypersaline during dry periods and provide a unique habitat dominated by mats of cyanobacteria, stunted vascular plants such as

spike grass, glassworts, and forbs, and invertebrates. These shallow pannes are used by a range of bird species when flooded, and many small sandpipers when drawn down.

Ideally, Scarborough Marsh will ultimately support a diversity of these pools and pannes, and thus provide habitat for the widest range of plant and animal species possible. The distribution of the three major pool/panne types will be dependent on the local elevations and flooding frequency of the marsh to determine which type(s) are appropriate. In general, deep and shallow pools will predominate and very shallow pannes will occur only in the upper reaches of the more saline portions of the marsh, where high salinities and monthly flooding are ensured.

Mosquito control must also be considered during assessment of pool and panne projects. Although a valuable wildlife food source during the larval stage, mosquitos are considered a nuisance species to humans and now are potentially disease-bearing. Adequate flooding to allow a fish population to persist, and high salinities are the most effective approaches in reducing the number of mosquito species and abundance.

5.2 POTHOLES IN JONES CREEK

Another area to consider creation of pools is in the non-tidal portion of Jones Creek (Map 3). In this area, the IFW has created an impoundment behind the railroad bed. The marsh has become increasingly vegetated over the years, to where many open water areas are filled with cattail, and shrubs are expanding on the drier areas of the site. To enhance the site for waterfowl, muskrat and associated species, pools could be dredged in the cattail and shrubby areas to create more open water. A diversity of pool sizes and depths would be most beneficial, with the concept of maximizing the interspersion of open water and vegetation. The dredge material could be removed from the site, or piled in one or several locations to provide islands that may support nesting black ducks or mallards. Because the site is too wet in many areas for standard low pressure equipment, and there is not enough open water in other areas for a barge, either a semi-aquatic excavator or dragline may be necessary to perform the work. Performing the work during winter (frozen conditions) will further improve access to the site, and minimize habitat damage within the work area.

5.3 ENHANCE DUG PONDS IN SUBDIVISIONS

On the east side of the marsh, a number of recent residential subdivisions containing large ponds have been constructed in areas of glacial outwash. Most were mined for sand and gravel prior to the subdivision. The ponds were created as a central point around which the houses were constructed. Examples of this occur off Black Point Road in subdivisions lining the north side of Libby River on Old Neck Road and Clearwater Drive (Map 3). For the most part, these ponds are steep sides, with no topsoil and limited vegetation in or around the pond edges. They currently offer little habitat value, but present an opportunity to create a valuable and increasing rare waterfowl habitat: open fresh water in close proximity to salt water/marsh. FSM could work with the subdivision associations to enhance the quality of the ponds in several ways.

- Increase the pond/shore edge by resculpting the perimeter. Eliminate the bowl effect and replace with shallow water shelves and an irregular shoreline.
- Add topsoil to the pond edge to provide a growth medium for aquatic and wetland vegetation.

- Plant vegetation that will provide a food source for waterfowl, litter for aquatic invertebrates, and cover for all wildlife. Plant species to consider include:
  - Burreed (*Sparganium* spp)
  - Soft rush (*Juncus effusus*)
  - Rice cut grass (*Leersia oryzoides*)
  - Blue vervain (*Verbena hastata*)
  - Beggars tick (*Bidens* spp)
  - Blueflag (*Iris versicolor*)
  - White water lily (*Nymphaea odorata*)
  - Yellow pond lily (*Nuphar luteum*)
  - Pondweeds (*Potamogeton* spp)
- Add loafing and hiding places along the pond edge for waterfowl, turtles, frogs, etc by placing logs and boulders in the shallows of the pond
- Encourage landowners to not mow to the water's edge, and to plant additional cover for wildlife, including shrubs (willow (*Salix* spp), alder (*Alnus incana*), buttonbush (*Cephalanthus occidentalus*) and trees (red maple (*Acer rubrum*) and black willow (*Salix nigra*)).

A similar enhancement would increase the habitat value of the northeastern impoundment at Willowdale Golf Course. Unlike its western counterpart, the impoundment currently is steep-sided with very little vegetation to support waterfowl and other species. Creating shelves by adding fill directly, or constructing terraces of logs or sheet pile behind which fill is placed would create shallow water habitat on which aquatic plants could grow. These shelves could be placed at intervals around the impoundment to add diversity to the structure of the pond and increase its attractiveness for waterfowl.

5.4 REDUCE CUTTING OF VEGETATED BUFFER ALONG MARSH AND STREAMS

This will involve a community outreach effort to educate residents in the value, and in cases of the Shoreland Protection Act, the regulations concerning maintenance of buffers for wildlife along the edge of the marsh and streams. Examples of frequent overclearing by the marsh are by Anjon's on Milliken Lane, Flaherty's Farm, and some residences along Winnocks Neck Road (Map 3). Leaving some shrubs, and low herbaceous vegetation will not interfere with existing vistas, and will enhance the willingness of many mammalian and bird species to use and travel along the upland edge of the marsh. As discussed in Section 3.5.2, these buffers also provide the benefit of improved water quality of runoff onto the marsh. For marsh screening and water quality purposes, minimum buffer widths should be 25 feet. Buffers wider than 25 feet should always be encouraged for their value in additional wildlife habitat and travel, and further water quality improvement.

5.5 PROTECT/MAINTAIN OPEN FIELDS

Open fields adjacent to salt marshes are increasingly rare as farms give way to subdivisions. Several warblers and sparrows that migrate along coastal routes prefer open fields and shrubs adjacent to salt marsh. The resident rodent population in both high marsh and upland habitats is also important to hawks (harriers (*Circus cyaneus*) and red-tailed hawks (*Buteo jamaicensis*)) and owls (short-eared (*Asio flammeus*) and great horned (*Bubo virginianus*)).

FSM can attempt to conserve open fields by a combination of acquisition/easements, and management. Ideal wildlife management would be to mow the hay and fallow fields once per year in late summer after bird nesting is complete, and before migration begins. Establishment of a shrubby border at Seavey Landing and Winnocks Neck Road fields would enhance their use by all species, and provide additional hunting perches for the raptors.

5.6 WILDLIFE ROAD CROSSINGS

As described in Section 4.3.2, roads present a significant barrier to many wildlife species. While Route 1 and I-95 will continue to prove formidable for wildlife crossing, culverts designed specifically for wildlife use may be appropriate for enhancing wildlife passage under busy secondary roads. These culverts are still in the early stages of development and are continually being refined, but have proven effective for several target species, and other non-target species. Key component of the design include adequate size, lighting and moisture. Box culverts are typically used, with grates on the roadway to admit light and moisture into the interior of the culvert. Alternatively, box culverts for stream crossings have been modified to include an elevated sidewalk for wildlife passage adjacent to the stream. The crossings are usually used in conjunction with fencing and berms along the roadside to funnel wildlife to the culverts, and deter access onto the road.

Within the Scarborough Marsh watershed, several locations appear to be suitable for consideration for wildlife culvert crossings. At each location the road should be monitored, particularly for amphibian passage during spring migration, to determine if the road is within a current travel route, and whether a wildlife crossing culvert would be beneficial. The Maine Audubon Society has a program for surveying amphibians in spring, with which FSM could coordinate. Table 5-1 lists the road and the designated wildlife travel corridor within which the crossing should be considered.

Table 5-1. Potential locations for wildlife crossings (refer to Map 3 for locations).

Road	Wildlife Travel Corridor	Crossing
I-95 to Rt 1 connector	Nonesuch River	Culvert
Highland Ave	Libby River	Volunteer*
Milliken Mills Rd	Mill Brook	Culvert
Broad Turn Road	Finnerd	Volunteer*
Holmes Road	Bond Brook	Culvert
Mast Hill Road	Ricker Brook	Culvert
Flag Pond Road	Ricker Brook	Culvert
Ash Swamp Road	Ash Swamp	Culvert

*The road is too low to accommodate a box culvert. A volunteer program to assist migratory amphibians may be appropriate if springtime migratory routes are found.

The crossings should be constructed to accommodate slow-moving amphibians and reptiles (salamanders, frogs, turtles) and mammals such as muskrat, otter, and raccoon. Placement will require assessing the crossing area to determine the most appropriate location to capture terrestrial wildlife. Often terrestrial wildlife will follow the banks of a stream or moist swale, but be reluctant to enter a culvert with a stream in the middle of it.

6.0 INVENTORY OF RECREATION AND EDUCATION FACILITIES

In addition to Scarborough Marsh being a unique ecological jewel, it also provides an immense variety of public recreational opportunities to thousands upon thousands of individuals from near and far. From fishing for stripers in the river to canoeing and kayaking; from bird watching to duck hunting; hiking and bicycling opportunities, the marsh is a rich resource for varied reasons. These and other recreational uses occur throughout the Watershed. So, not only is the marsh for birds, fish and other wildlife, it is also a "people" marsh.

As part of an overall watershed strategy, FSM has initiated an effort to better define existing recreational facilities and to raise options to serve future recreational needs. Any such plan will likely include at least the following objectives designed to preserve the inherent characteristics of this special place:

- Improve and develop facilities that provide greater access to the marsh and the surrounding watershed without compromising basic wildlife management objectives.
- Provide recreational opportunities for people of all ages and abilities to enjoy the watershed throughout much of the year.
- Provide opportunities to observe wildlife in a manner that is both safe and non-intrusive.
- Offer the visitor a variety of opportunities to experience the marsh in an appropriate manner.
- Encourage the SEEC (Scarborough Estuarine Ecosystem Curriculum) project and assist in coordinating areas of mutual interest.
- Evaluate limits on access, parking, and recreational facilities to assure that the carrying capacity of the marsh is not exceeded.
- Develop architectural and site facilities that are models of sustainable design.
- Develop a coordinated interpretive plan for the watershed.
- Respect the privacy of adjacent property owners.

6.1 SCARBOROUGH MARSH/WILDLIFE MANAGEMENT AREA

The state-owned Scarborough Wildlife Management Area contains 3,100-acres of regularly and irregularly flooded salt marsh, salt creeks, coastal fresh marsh, tidal flats, and upland. The Maine Department of Inland Fisheries and Wildlife (MDIFW) currently manages the area and allows public access and recreational activities when they do not conflict with management objectives.

Management of the area by MDIFW is directed toward improving the area for resident and migratory waterfowl. The long-range objectives call for providing suitable habitat for optimum levels of all wildlife species and providing maximum utilization of the area by sportsmen and other individuals seeking outdoor recreation.

Public recreational activities consist of "consumptive" wildlife uses such as hunting, trapping and fishing, and numerous "non-consumptive" uses, such as bird watching, educational events, and canoeing. Overnight camping and campfires are not permitted in the area.

6.2 INITIAL STEPS

In assisting Friends to identify recreational facilities, needs and opportunities, Normandeau Associates, Inc. subcontracted with Terrence J. Dewan & Associates of Yarmouth, Maine, a firm who has

familiarity with Scarborough's recreational programs. Dewan developed a comprehensive inventory of existing public recreational sites (Map 4) and some preliminary concepts for Friends to consider. A separate document summarizing their findings (Recreational and Educational Opportunities on Scarborough Marsh, 2002) is available upon request to FSM.

6.2.1 Scarborough Marsh Nature Center

Discussions and evaluations during the development of the strategy clearly suggest that a process be initiated soon to replace the Scarborough Marsh Nature Center. The Center currently serves over 10,000 visitors per year and is the most highly visible point of public contact for recreation and educational activities. However, the facility is severely restricted by lack of space to meet the growing demands for operations, services, and programs.

The existing building was never meant to be permanent and suffers from a general aesthetic malaise. Environmental restrictions would prohibit any meaningful expansion to the building or the site.

The new Scarborough Marsh Nature Center should welcome the public and excite them about the dynamic nature of the Marsh. The Center should also be a first-class example of sustainable architecture, sited and constructed to show how to build in an attractive, environmentally friendly manner.

The plans to replace the Nature Center should be a high priority for the interested marsh parties. With the increasing demand for residential property in the watershed there is a diminished supply of suitable land. The cost of real estate continues to rise, especially on buildable land that has views and physical access to the Marsh, which would be necessary to attract visitors.

7.0 ESSENTIAL DATA NEEDS FOR SPECIFIC PROJECTS

To assist FSM in estimating the information needs and obstacles for the various projects identified in Sections 3 through 5, NAI and TJD&A selected five potential projects that provide examples from two categories of projects: marsh restoration and enhancement, and watershed habitat enhancement. All projects are considered important in their respective categories, in particular, the marsh restoration and enhancement projects were taken from the highest priority list. The other two were NAI's preliminary assumption of importance. The five projects are:

Marsh Restoration and Enhancement (Map 2)

1) Libby River ditch plugging and hay road removal (Project 32)
2) Assess extent of tidal restriction under Guilford rail line (Project 29)
3) Plug ditches west of industrial park (Project 10)

Watershed habitat enhancement (Map 3)

4) Pools in Jones Creek wetland
5) Pond enhancement

7.1 LIBBY RIVER DITCH PLUGGING AND HAY ROAD REMOVAL (PROJECT 32)

Existing Conditions: This marsh surface project is located on the Libby River beginning approximately 300 feet upstream of Black Point Road on the southeast side of the main river channel. The degradation to the high marsh comes from a long (600 ft) raised hay road that traverses the project area in a northeast-southwest direction. The road is fairly continuously elevated, averaging 1-2 inches above the surrounding marsh surface, up to a maximum of approximately 4 inches. It runs parallel to the main creek channel, until the road's northern end where it loops back to connect to the upland adjacent to Larrabee's hay field. The road bisects two large pools on the marsh, crosses the "seaward" tip of a third, and effectively forms a barrier to tidal flooding and drainage to approximately 4 acres of high marsh. Phragmites is well established on the upland edge of the project area and appears to be continuing expansion onto the marsh surface. Additionally, the site has been ditched, with several ditches running from the main channel to the upland, and at least one set of laterals paralleling the upland edge.

Restoration: The hay road needs to be breached in multiple locations to enhance sheet flow and drainage on the marsh surface. This will improve tidal flow (and associated higher salinities) into the high marsh behind the road, and lessen impoundment of freshwater from runoff and precipitation. Both aspects should restore more natural functioning to the marsh surface, and reduce the spread of Phragmites.

The breaches should occur in all three large pools that the road crosses and in at least two other locations on the vegetated marsh surface. To breach the road, it should be dredged down to the elevation of the surrounding marsh, which in the case of the pools could require removing up to a half-foot of material. The length of the breach should be a minimum of 10 feet, and longer if the material can be disposed of. The dredged material can be used to plug the lateral ditches, in the typical ditch plug-

ging method as used at Seavey Landing. This consists of fill in the ditch reinforced with a plywood "dam" to support the plug until it becomes vegetated. The ditches draining from the upland to the main channel may provide drainage for freshwater off the marsh. It may be desirable to enhance these ditches by removing the in-grown vegetation. The lateral ditches are better candidates for ditch plugging in at least two locations, one at the north, another at the south. Should additional disposal areas be needed, an extensively ditched section of high marsh occurs approximately 1000 feet north-east of the project area and would also benefit from ditch plugging.

Construction equipment can access the site through Larrabee's field and can get onto the marsh via the northern end of the hay road where it connects to the upland. An access road to the marsh may need to be cut through the narrow strip of woods bordering the marsh. Construction equipment necessary for the work will include a small excavator with a smooth bucket and several haulers (low pressure or track dumps or trailers). No surface protection will be necessary on the road, but pads may be needed when installing the ditch plugs.

Considerations: When evaluating the project, the primary questions will revolve around the anticipated conditions on the marsh after the culvert improvements under Black Point Road are completed. The elevations of mean and spring high tide, and the associated salinities will affect the location of the ditch plugs and may alter the number and location of breaches in the hay road. If tidal flooding and salinities are anticipated to increase significantly over the marsh surface, an alternative disposal method for breaching the hay roads could be to broadcast the dredge material in a thin (<1 inch thick) layer over the adjacent marsh. This will allow additional substrate for high marsh species without the risk of providing suitable sites for Phragmites colonization.

The existing Phragmites stands should be monitored for productivity and expansion. With adequate hydrology and salinity, the Phragmites should not expand and a decrease in vigor of the existing stands should decline. If continued expansion is observed, use of an herbicide may warrant consideration.

7.2 ASSESSING THE EXTENT OF TIDAL RESTRICTION AT THE GUILFORD RAIL LINE (PROJECT 29)

Existing Conditions: The Guilford Rail Line was initially constructed in the 1840's by the Boston & Maine Railroad Company, and was restored over the last few years to provide improved passenger rail service to southern Maine. It runs for approximately 2 miles across the marsh, with two bridges: one for the Scarborough River and one over the Nonesuch (Map 2). The remainder of the railroad runs on a raised earth and ballast berm across the marsh surface. The Scarborough River Bridge is over 400 feet wide, and the Nonesuch bridge appears to span most of the river channel. These two points are the only points of entry for tidal flows to reach the 1500-2000 acres of marsh upstream of the railroad. It is very likely that the rail line presents a tidal restriction on most tides, and is most pronounced on above-average tides when sheet flow across the marsh is blocked by the berm. Storm-driven extreme high tides, which are infrequent, but important events on salt marshes, would be even more restricted by the rail line, again due to the inability of tides to surge upstream over the marsh surface. These extreme high tides are thought to be significant in maintaining salt marsh conditions at the upper reaches of the marsh.

Assessment: The presence and magnitude of the tidal restriction at the railroad need to be assessed. A hydrologic study performed during IFW's assessment of the Dunstan Marsh (FSM Project # 5) in-

cluded placing long-term water level recorders above and below the Guilford RR bridge on the Scarborough River, and surveying associated marsh surface elevations. These data will provide a preliminary assessment of the restriction. They will be available in the 2002 final report to the Julie-N Oil Spill Trustees.

Additional assessment needs to focus specifically on the full length of the rail line. Hydrologic data and modeling should occur at the Nonesuch River bridge to capture the dynamics of tidal and fresh flows in that section of the marsh, and need to be tied into the work already performed at the Scarborough River bridge. Associated marsh surface elevations should be expanded to include transects above and below the length of the railroad to assess the degree, if any, of upstream marsh subsidence that has occurred over the last 150 years. Finally, marsh-wide modeling will be necessary to estimate the current conditions and the impact of the railroad on tidal flows. This is a very large, complicated system, with multiple freshwater inputs, and several potentially significant barriers to tidal flow in addition to the Guilford line (Eastern Road, Route 1, Route 9 at Cascade Brook and Jones Creek, Black Point Road at Libby River). A sophisticated modeling effort will be required to account for the numerous elements influencing tidal flows, and to understand the repercussions of relieving restrictions at various locations. Much of the modeling on the Scarborough River has already been performed by Wood Hole Group, E. Falmouth, MA. Any new data collection and modeling should make use of their work to date.

Assuming a restriction is occurring at the Guilford railroad, recommendations for alleviating it should follow. These may include

- expanding the bridge over one or both rivers,
- improving the flow efficiency under existing bridges by deepening the channel or structural changes to the pilings,
- installing a series of culverts on the marsh surface to allow sheet flow on high tides, and/or
- reestablishing flows in old channels via culverts under the railroad.

Considerations: When evaluating the impacts of the railroad, additional factors will shape the decisions made for restoration. Flooding concerns to residences in various areas of the marsh may prevent full restoration of tidal flows. Associated concerns of impacts to drinking water or irrigation wells, and septic systems may also be raised. In confined areas, use of self-regulating tide gates may be appropriate.

Ecological issues due to a change in tidal regime on the upstream marsh will also need to be considered. Generally, increased tidal amplitude and salinity benefit the marsh community, but some areas of the marsh may be more valuable under existing conditions. If a section of marsh has subsided substantially (on the order of several inches or more), increased frequency of flooding can convert high marsh areas low marsh to the detriment of marsh habitat diversity. Several salt marsh sparrows breed in the higher areas of the marsh, and their habitat may be reduced or eliminated by increased flooding. Brackish vegetation and invasive species will be pushed back with greater tidal flow, but the associated loss of habitat for species which utilize the brackish community will have to be considered. As with all restorations, one habitat is replaced with another, and it is up to the restorationists to determine the desired goals of the project.

An additional consideration is the cumulative effect of this restriction on other projects throughout the marsh. If there is a substantial restriction at the Guilford Railroad, then all other restoration and enhancement projects upstream should be evaluated in light of this primary restriction. Even if upstream projects proceed before any action is taken at the Guilford Railroad, the potential effects of additional tidal flow and increased salinity should be considered in the project's design. If anything, this adds to the urgency of performing the assessment of the Guilford railroad to either eliminate it as an issue, if no substantial restriction is found, or incorporate it into all future project planning.

A final long-term consideration is the effect of rising sea level on the future of Scarborough Marsh. While the magnitude and rate of sea level rise is still being debated, the fact that it is occurring is generally accepted. Given the potential massive impact of changing the tidal regime on Scarborough Marsh, the effect of sea level rise should be considered carefully when determining the extent of the restoration.

7.3 PLUG DITCHES WEST OF INDUSTRIAL PARK (PROJECT 10)

Existing Conditions: This site is approximately 15 acres in size located at the edge of the high marsh, north of Eastern Rd berm and west of the Scarborough Industrial Park (Map 2). The immediate upland is a mixture of hay fields, upland forest and a narrow fringe of freshwater wetland. Several freshwater drainages flow into the marsh via small ponds/impoundments.

The marsh is dominated by a mixture of high marsh species (primarily salt hay with some spike grass), and brackish species (salt marsh bulrush (*Scirpus maritimus*, baltic rush (*Juncus balticus*), and cattail (*Typha angustifolia*). A small stand of Phragmites occurs at the southern end of the site. The area has been extensively ditched, with a network running from the main channel connecting to both ponds, presumably in an attempt to drain off the considerable fresh water that flows onto the marsh at this point. Many of the ditches have slumped and are ingrown with vegetation, principally salt marsh bulrush. That salt marsh bulrush replaces cordgrass (*Spartina alterniflora*) in the ditches is indicative of very brackish conditions. Few pools exist in the area, but the marsh surface is soft and saturated or ponded in many areas, particularly in the stands of salt marsh bulrush.

Restoration: The primary goal of enhancement in this area is to improve freshwater drainage off the marsh surface, and tidal flow from the Dunstan River onto the marsh. This can most likely be accomplished by a combination of plugging some ditches in the higher reaches of the marsh, and cleaning out several of the primary ditches to allow fresh water to drain at low tide. A likely scenario would be to improve the main ditches leading from Dunstan River, and perhaps a perimeter ditch along the edge of the forested wetland. The remaining secondary ditches should be plugged. A complimentary goal of enhancement would be to increase the number of pools in areas of high marsh and salt marsh bulrush, presumably where ditch plugging occurs. Given the slumping observed around the old ditches, simply plugging the ditches may be sufficient create adequate pools. Additional excavation may be required to place pools in apparently unditched high marsh.

Evaluation of existing conditions will need to assess the locations of maximum groundwater flow, as well as the frequency of surface flooding from tides. These two elements of the study will require installation of groundwater wells and a topographic survey of the marsh surface to relate to the recent hydrologic study of Dunstan Marsh by Woods Hole Group. Based on these results, the drainage ditches can be most effectively located to draw off freshwater at low tide and introduce high salinity

seawater during high tide. Review of aerial photographs combined with topographic survey will indicate appropriate places for additional pools in the high marsh.

A final goal of this project should be to assess the small stand of Phragmites, in particular, its rate of expansion. It is visible in the 1995 photographs, so is probably not expanding rapidly, however the brackish conditions of the project area are ideal for expansion and elimination of the Phragmites may be the wisest course. Due to the location of the stand, the improvements in tidal exchange are not likely to dramatically impact the status of the Phragmites. Several applications of herbicide may be necessary to eliminate it.

Considerations: At present, this area offers a brackish marsh habitat adjacent to salt marsh. This was probably a common transition-zone community throughout Scarborough Marsh in pre-development times, but has been eliminated in many of the upper reaches of the marsh. The large stand of salt marsh bulrush probably provides habitat for a number of secretive marsh birds, including bitterns and several species of rails. The only recent breeding by least bitterns (*Ixobrychus exilis*) on Scarborough Marsh was in this area. FSM will need to assess the beneficial aspects of the current habitat versus those of the proposed enhancement, which is likely to result in a reduction in salt marsh bulrush.

7.4 EXCAVATION OF POOLS IN JONES CREEK WETLAND

Existing Conditions: This project will occur in the freshwater portion of Jones Creek, described in Section 5.1.2. The area is currently non-tidal, though it was originally salt marsh fed by a tidal creek through the Old Orchard barrier beach. The tidal creek has been lost to development along the barrier beach, and the swamp is further isolated from tidal exchange by Route 9 and the Guilford Railroad. The swamp is now supported by fresh water impounded by a fish weir constructed by the IFW to promote waterfowl habitat. Much of the old tidal channel remains open water, but the more shallow marsh areas are ingrown with cattail and shrubs. According to local birders, waterfowl use has declined substantially in the last decade; primary breeding bird usage appears to be red-winged blackbirds (*Agelaius phoeniceus*) and swamp sparrows (*Melospiza georgiana*). The decline in waterfowl numbers is probably due to the decrease in open water as the cattail and shrubs continue to expand.

Recommendations: The goal of this project is to create additional open water and to increase the vegetation/water interspersion in the swamp to enhance the site for waterfowl, in particular, black ducks (*Anas rubripes*) and other dabblers such as wood ducks (*Aix sponsa*). To accomplish this, multiple pools can be dredged in the shrub and cattail areas. Pools should be one-quarter to one-half of an acre in size and between one and two feet in depth. The size and number of pools will depend in part on the ability to dispose of the dredge material. One option will be to find an offsite dump or compost area. A cheaper, and potentially desirable, solution is to dispose of some or all of the material on-site in the uplands, or in the wetland to create one or more small islands. These islands will provide additional habitat diversity, and may create limited nesting habitat for certain waterfowl.

Placement of the pools should concentrate at the northeastern end of the site. Locations of former pools are visible in aerial photographs and some old channels may still exist. This area is also relatively easily accessible from the abandoned remnant of Little River Road across the railroad tracks. Use of specialized low-pressure, semi-aquatic equipment for dredging and hauling will minimize damage to the surrounding habitat. Performing the work during the dormant season, preferably under frozen conditions, will further minimize damage.

Considerations: Disposal of the dredge material will present the greatest obstacle from a regulatory perspective. On-site disposal will eliminate expensive hauling and disposal costs, but if placed in the wetland, will be considered a wetland fill. FSM should explore the possibility of disposing of the material on upland associated with the abandoned road.

Invasive species may also be a concern at the edge of the pools. Several small stands of Phragmites are already established in the area, and any exposed disturbed substrate will present an ideal location for additional expansion. Purple loosestrife was observed in the wetland adjacent to the railroad tracks, and is probably elsewhere in the cattail stand. FSM should be vigorous in its monitoring of the area to identify and eliminate, if possible, establishing stands of either species.

7.5 ENHANCEMENT OF DUG POND ON OLD NECK ROAD

Existing Conditions: As described in Section 5.1.3, this pond is one of several in the area that were excavated as part of a sand and gravel mining operation, and later as a subdivision. It is approximately 3 acres in size, oval in shape, with no apparent inlet or outlet. This suggests it is primarily groundwater fed, and with no outlet, must be quite flashy during periods of precipitation. The water level in the pond appears to flucutate approximately 2 feet, and when at a low point, exposes a barren sandy substrate on the shoreline. No vegetation was observed in the pond, or on the pond edge. Seagulls periodically raft in the middle of the pond, but no other waterbirds were observed during several site visits. It is bordered on all sides by a relatively steep slope of mowed herbaceous vegetation around which residential housing occurs.

Recommendations: This site would benefit from the addition of fine mineral and organic substrates within the zone of water level fluctuation. Currently the coarse sandy material does not hold water sufficiently to support vegetation during the drawdown period. Because of the steepness of much of the pond's slopes, some bioengineering materials will likely be necessary to develop and maintain a vegetated wetland fringe. A design that will provide a substrate for vegetation and some diversity in the shape of the pond would be to construct several narrow shallow terraces that extend from the full pond limit to below the low water line. A minimum of four large and four small terraces would greatly add to the vegetation/water edge, and would allow vegetation to develop and possibly expand to the adjacent shores.

The terraces could be constructed with coir fiber rolls behind which topsoil is placed. Planted vegetation would include species that can tolerate fluctuating water levels, as well as shallow marsh emergents in the deeper sections. Species that would be appropriate for this pond includes:

- Shallow marsh: soft stem bulrush, arrowhead, and burreed
- Exposed shore: soft rush, woolgrass, beggars tick, and blue vervain

This pond would definitely benefit from the addition of some logs, large rocks that are emersed at high water, and organic matter in the form of old leaves and branches below the low water line.

Supplemental plantings along the shoreline above the full pond level might include deep-rooted or highly tolerant shrubs such as willows (*Salix* spp.) and alders (*Alnus incana*). Trees that would grow to overhang the bank, such as black willow, gray birch or white pine, would provide a long-term benefit to the pond edge. A vegetation management agreement with surrounding homeowners would

be beneficial in leaving some areas unmown or at least in shrub cover to provide more wildlife-friendly habitat.

Considerations: This project will require the close support and cooperation of the residents surrounding the pond. It will be important for FSM to emphasize to the homeowners that this project will result in a more attractive and interesting pond, due to the presence of flowering plants and associated wildlife, including waterfowl, herons, frogs and turtles. This will also give FSM the opportunity to educate them both in pond ecology and the larger unique landscape-level importance of the pond and nearby salt marsh. Informed, involved neighbors will be invaluable in protecting any improvements to the pond, and in long-term maintenance issues such as identifying and removing invasive species such as purple loosestrife or Phragmites.

The well-draining sandy substrates present a challenge both in establishing vegetation due to the sterile, droughty conditions during low water periods, and the potential for excess nutrients moving quickly with little natural treatment from the surrounding houses directly into the pond. To address the first issue, a diversity of highly tolerant species should be planted with the assumption that the most suitable species will survive. A deep layer of quality topsoil partially mixed with the sand will also enhance nutrient availability and moisture retention in the root zone. To address the second issue which is more water-quality related, homeowners should be encouraged to use appropriate (slow release, no herbicides) fertilizers on lawns and gardens, and maintain/establish a unmown vegetated buffer around the pond to treat runoff.

8.0 COST ESTIMATES FOR RECOMMENDED PROJECTS

Estimates for costs for the projects described in Section 7 are presented in this section. For restoration and enhancement projects, costs include preliminary work such as design and data collection, permitting, construction, and monitoring. Costs are provided based on estimates of work from private consultants and contractors. FSM, by working in partnership with regulatory agencies, may reduce the cash outlay if agencies can assist in certain tasks, such as baseline data collection and permitting. In the construction projects, the costs assume that FSM owns up to 3 water level recorders capable of long-term (minimum 2 weeks) data logging. Obviously, all costs are preliminary and are intended to provide comparisons among the various projects as to relative costs.

8.1 LIBBY RIVER DITCH PLUGGING AND HAY ROAD REMOVAL (PROJECT 32)

Baseline data collection assumes that the hydrologic work for the Black Point Road culvert replacement will be utilized, and supplemented by site-specific tide and salinity surveys on 2 dates. Permits assume 2 meetings with agencies, preparation of permit application, and response to comments. Construction assumes that the on-site ditch plugging sites are adequate storage for the volume of material removed from the hay road and ditch clean-outs. Post-construction monitoring includes site-specific tide and salinity monitoring on 2 dates in the first year, and assumes that additional post-construction monitoring results for the culvert replacement will be available. In all 4 years, vegetation monitoring and Phragmites status assessment will occur.

Baseline Data Collection (includes site-specific topographic survey, local tide height survey, vegetation monitoring)	$8,000
Project Design	$5,000
Permitting	$9,000
Construction (breach road, 5 ditch plugs, enhance 2 ditches, Phragmites control)	$20,000
Post-construction Monitoring (4 years over 5-year period; assumes primary hydrologic monitoring provided by culvert project)	$20,000
Total	**$62,000**

8.2 ASSESSING THE EXTENT OF TIDAL RESTRICTION AT THE GUILFORD RAIL LINE (PROJECT 29)

The hydrologic study and alternatives analysis assumes that the Woods Hole Group hydrologic data and modeling effort is fully available to FSM. Ten topographic survey transects will be located above and below the Guilford RR and 2 above Eastern Road.

Hydrologic study (4 additional water level recorders, revise grid to include Nonesuch and Mill Creek, rerun model)	$55,000
Topographic Survey (12 long transects across marsh surface)	$5,000
Alternatives Analysis (to hypothetically eliminate restriction)	$20,000
Preliminary Engineering Design & Cost Estimate of Preferred Alternative	$6,000
Total	**$86,000**

8.3 PLUG DITCHES WEST OF INDUSTRIAL PARK (PROJECT 10)

Baseline data collection assumes that Woods Hole Group data is available for main channel hydrology; this project will measure local tide heights and salinities on 2 dates. Vegetation monitoring includes establishing up to 10 permanent transects. Topographic survey will cover the entire15-acre project area plus adjacent high marsh to the main channel. Permits assume 2 meetings with agencies, preparation of permit application, and response to comments. Construction assumes that the on-site ditch plugging sites are inadequate storage for the volume of material removed from the ditch clean-outs and perimeter ditching. The remaining material will be broadcast in a thin (<1 inch) layer within the Scirpus vegetation zone. Phragmites control will consist of dredging pool in location of small Phragmites stand and using material at bottom of ditch plugs. Post-construction monitoring includes site-specific tide and salinity monitoring on 2 dates in the first year only. In all 4 years, vegetation, soil salinity monitoring and Phragmites status assessment will occur.

Baseline Data Collection (includes local tide, surface water and pore water salinity and vegetation monitoring, topographic survey)	$12,000
Project Design	$5,000
Permitting	$9,000
Construction (enhance 2 primary ditches, dredge perimeter ditch, 8 ditch plugs, Phragmites control)	$40,000
Post-construction Monitoring (hydrology (first year), vegetation and soils for 4 years over 5-year period)	$25,000
Total	**$89,000**

8.4 EXCAVATION OF POOLS IN JONES CREEK WETLAND

Baseline Data Collection (includes hydrologic study (3 water level recorders, 2 tide stake surveys), minor sediment chemistry testing, vegetation survey, topographic survey)	$18,000
Project Design, including dredge disposal plan	$8,000
Permitting	$13,000
Construction (dredge 5 pools, dispose of dredge material in one island and on old Little River road, stabilize sites)	$50,000
Post-construction Monitoring (Monitor hydrology (first year) and vegetation in pools, stability of dredge disposal sites for 4 years over 5-year period)	$22,000
Total	**$111,000**

8.5 ENHANCEMENT OF DUG POND ON OLD NECK ROAD

Baseline Data Collection (includes hydrologic study (6-month water level recorder), minor vegetation monitoring, topographic/bathymetric survey)	$8,000
Project Design	$5,000
Permitting	$10,000
Construction, includes 4 large and 4 small shallow-water terraces using bioengineering technology, placement of backfill and topsoil in terraces and around pond edge, planting and seeding terraces and terrestrial pond edge, placement of rocks and logs in pond	$25,000
Post-construction Monitoring (Monitor stability of terraces and viability of vegetation for 4 years over 5-year period)	$16,000
Total	**$55,000**

9.0 FUNDING SOURCES

9.1 FEDERAL FUNDS

American Rivers/NOAA Community-Based Restoration Program

Projects Considered: restore anadromous fish habitat or natural riverine functions, improve freshwater habitats important to anadromous fish; preference on removal or retrofit of dams/culverts and restoration or creation of fish passages; will fund preliminary analysis, engineering, design, etc.; project should include public outreach and education

Due Date: December 1, 2001 and April 1, 2002

Funds Available: $5,000 - $25,000, no local match required but encouraged, can have multiple funding sources

Application: available at www.amrivers.org/feature/restorationgrants.htm

Contact: Peter Raabe, River Restoration Finance Associate, American Rivers, 1025 Vermont Ave, NW, Suite 720, Washington, DC 20005, (202) 347-7550 ext 3006, email rivergrants@amrivers.org

Notes: focused on local community-based partnerships, prefers application emailed, encourages contact and discussion prior to application submittal, must achieve goals within 18-month time frame

Trout Unlimited- NOAA Community-Based Restoration Program, Embrace-A-Stream Program

Projects Considered: funds available for TU chapters/councils with community volunteer support for coldwater fisheries conservation projects; goals to conserve, protect, and restore coldwater fisheries and watersheds; 3 types considered, resource, research and education

Due Date: December 21, 2001 and December 21, 2002

Funds Available: Maximum $10,000, 1-1 matching single year grant

Application: from www.nmfs.noaa.gov/habitat/restoration/TU.html.

Contact: Peter Kelly, TU, 1500 Wilson Boulevard, Suite 310, Arlington, VA, 22209-2404, or Region 1 TU coordinator Dayton Goudie (603) 838-6332

Notes: must come from TU, requires fund-raising; technical support and volunteer support; single-year but renewable;

The National Fish and Wildlife Foundation (NFWF): Maine Habitat Restoration Partnership Grant

Projects Considered: habitat restoration work (salt marsh restoration, river restoration, grassland restoration) in coastal wetlands along migratory fish rivers

Due Date: August and December

Funds Available: non-federal match requirements vary, ranges from $1,000 to $25,000

Application: see Contact below

Contact: Lois Winter/Stew Fefer, FWS, Gulf of Maine Program, 4R Fundy Road, Falmouth, ME, 04105, (207) 781-8364,

Notes: administered through FWS Gulf of Maine Program (see below)

NFWF General Challenge Grant

Projects Considered: to conserve and restore fish, wildlife and native plants; address priority actions promoting fish and wildlife conservation and their habitats; work proactively to involve other conservation and community interests, environmental education activities

Due Date: rolling, but decisions based on the due dates of June 1 and October 15

Funds Available: between $10,000-150,000, with Small Grants of less than $5,000 for open decision all year; funds are challenge, with match of at least 1:1 but often 2:1 from non-federal source required

Application: www.nfwf.org/programs/application.htm

Contact: National Fish and Wildlife Foundation, 1120 Connecticut Ave, NW, Suite 900, Washington, DC, 20036, 202-857-0166 or Northeast office, Eric Hammerling, 619-970-6393

Notes: requires a pre-approval letter, no general administration costs or overhead, single year, no basic research.

5-Star Restoration Challenge Grants (by EPA, NFWF and Wildlife Habitat Council)

Projects Considered: grants given to support community-based wetland, riparian and coastal habitat restoration projects with diverse partnerships that foster local natural resource stewardship via education, outreach and training

Due Date: March 1, 2002

Funds Available: $5,000 to 20,000 but average $10,000

Application: www.epa.gov/owow/wetlands/restore/5star/

Contact: Tom Kelsch, National Fish and Wildlife Foundation, 1120 Connecticut Ave, NW, Suite 900, Washington, DC, 20036, 202-857-0166, kelsch@nfwf.org

Notes: must be a “diverse partnership” of five organizations, must have restoration component, not just research, monitoring or planning, 1-year completion but can be part of larger project

Fish America Foundation

Projects Considered: those which encourage local efforts to accomplish meaningful on-the-ground restoration of marine, estuarine or riparian habitats and freshwater fish habitats for anadromous species

Due Date: closed this year, anticipate in future years, September

Funds Available: $5,000 to 30,000, no match required but encouraged

Application: at www.fishamerica.org

Contact: Fish America Foundation 225 Reinekers Lane, Suite 420, Alexandria, VA 22314 or fishamerica@asafishing.org

Notes: part of NOAA and American Sportfishing Association, must complete a set objective within 1 year but can be part of a larger project, community participation and volunteer efforts required

North American Wetlands Conservation Act Grants Program

Projects Considered: for land acquisition, restoration and/or enhancement via public or private partnerships; any type of wetland conservation projects

Due Date: Standard Grants, March and July, Small Grants, December

Funds Available: not listed, Standard larger than $50,000, Small less than that, 1:1 matching required

Application: www.northamerican.fws.gov/NAWCA/grants/htm

Contact: Davis Buie, david_buie@fws.gov, 301-497-5870

Notes:

US Fish and Wildlife Service (FWS) National Coastal Wetlands Conservation Grant Program

Projects Considered: Funding from the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) for state conservation agencies to acquire, restore or manage coastal wetlands for fish and wildlife values.

Due Date: June 8

Funds Available: ranged from $10,000 to $1,000,000, must have minimum matching of 35% non-federal funds

Application: www.fws.gov/cep/cwgcover.html

Contact: Lois Winter/Stew Fefer, FWS, Gulf of Maine Program, 4R Fundy Road, Falmouth, ME, 04105, (207) 781-8364, or Phil Bozenhard, Regional Biologist, Maine Department of Inland Fisheries and Wildlife (MDIFW), (207) 287-8000

Notes: this program is mainly for states, must have state backing

FWS Branch of Habitat Conservation: Gulf of Maine Coastal Program

Projects Considered: to protect and restore nationally important coastal fish and wildlife habitat through partnerships

Due Date: NA

Funds Available: technical and biological assistance, along with federal funding opportunities; requires matching funds from other government agencies, private organizations and/or private landowners

Application: www.fws.gov

Contact: Lois Winter/Stew Fefer, FWS, Gulf of Maine Program, 4R Fundy Road, Falmouth, ME, 04105, (207) 781-8364

Notes: may access federal funds to support habitat restoration initiatives statewide that benefit wetlands, streamside habitat for migratory fish, and coastal nesting islands

FWS Branch of Habitat Conservation: Partners for Fish and Wildlife Program

Projects Considered: restoration and protection of habitat on private lands

Due Date: NA

Funds Available: NA, dollar-for-dollar match

Application: www.partners.fws.gov

Contact: Ron Joseph, FWS, Maine Field Office, Old Town, ME, (207) 827-5938

Notes: for private landowners or anyone interested in restoring and protecting habitat on private land-land is donated for at least 10 years, money can be used for technical assistance or actual work done, also gives advice on restoration procedures

North American Waterfowl Management Plan Grants, North American Wetlands Conservation Act (NAWCA)

Projects Considered: to conserve wetlands and increase migratory bird populations; should provide clear benefits for waterbirds as well as federally endangered/threatened species and/or anadromous fish

Due Date: April and August, large grants, December, small grants

Funds Available: large matching grants, up to $1,000,000, to manage, restore and/or acquire habitat through purchase or easement; small grants, less than $50,000, is available to encourage new partnerships; all grants should provide more than 200% in non-federal matching funds

Application: see Contact below

Contact: Lois Winter/Stew Fefer, FWS, Gulf of Maine Program, 4R Fundy Road, Falmouth, ME, 04105, (207) 781-8364, or Phil Bozenhard, Regional Biologist, Maine Department of Inland Fisheries and Wildlife (MDIFW), (207) 287-8000

Notes: typically, habitat acquired through fee or easement with funding has been transferred to MDIFW for protection and management

U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP)

Projects Considered: conservation where there are significant natural resource concerns, for non-federal landowners engaged in livestock and/or agricultural production

Due Date: rolling

Funds Available: cost share up to 75%, incentive payments up to 100% for 3 yrs, max $10,000 per person per year

Application: www.nrcs.usda.gov

Contact: Sandra Lary, Bill Yamartino, Bangor, Maine 207-866-7241

Notes:

NRCS Wetlands Reserve Program (WRP)

Projects Considered: wetlands and salt marsh restoration

Due Date: NA

Funds Available: up to 75% of funds for on-the-ground implementation costs

Application: see Contact below

Contact: Sandra Lary, Bill Yamartino, Bangor, Maine 207-866-7241

Notes:

NRCS Wildlife Habitat Incentive Program (WHIP)

Projects Considered: to develop and improve habitat for fish and wildlife on private land, provides technical assistance and implementation of plans

Due Date: rolling

Funds Available: cost share, NRCS pays up to 75%, maximum of $10,000

Application: www.nrcs.usda.gov

Contact: Leslie Deavers 202-720-3534, leslie.deavers@usda.gov

Notes:

Land and Water Conservation Fund (LWCF)

Projects Considered: federal land management agencies and partners can request money from "federal-side LWCF funds" to acquire lands for federal protection; state agencies can request money from "state-side LWCF funds" to acquire land for state and local protection and/or to expand outdoor recreation opportunities

Due Date: NA

Funds Available: no match required, unclear if state-side LWCF funds available, federal-side funds averaging $4-5 million have been used in the past

Application: see Contact below

Contact: Lois Winter/Stew Fefer, FWS, Gulf of Maine Program, 4R Fundy Road, Falmouth, ME, 04105, (207) 781-8364

Notes: Congressional approval is needed to access and appropriate all LWCF funds

See also the Catalog of Federal Funding Sources for Watershed Protection, www.epa.gov/owow/watershed/wacademy/fund.html

TEA-21 Enhancement Grants

TEA-21 Enhancement grants are available for alternative transportation activities. These funds can be used for the following:

- Pedestrian and bicycle facilities
- Pedestrian and bicycle safety and education activities
- Acquisition of scenic easements and historic easements and sites
- Scenic or historic highway programs including tourist and welcome centers
- Landscaping and scenic beautification
- Historic preservation
- Rehabilitation and operation of historic transportation buildings, structures or facilities
- Preservation of abandoned railway corridors
- Control and removal of outdoor advertising
- Archaeological planning and research
- Mitigation of highway runoff and provision of wildlife undercrossings
- Establishment of transportation museums.

Contact the National Transportation Enhancements Clearinghouse to learn more about TEA-21. This site contains case studies of how other communities have raised matching funds.

A second source of funding authorized by TEA-21 for trail projects is the Recreational Trails Program which funds acquisition, construction, and management of recreational trail facilities. To learn more about the program, contact John Balicki, Maine Department of Transportation's bicycle and pedestrian coordinator.

Rivers Trails and Conservation Assistance Program

RTCA is a program of the National Park Service. The program provides valuable on-the-ground technical assistance, from strategic consultation and partnership development to serving as liaison with other government agencies. Communities must apply for assistance.

www.ncrc.nps.gov/rtca/.

Urban Park and Recreation Recovery Program

$28.9 million is available for funding rehabilitation projects under the UPARR program. Rehabilitation grants awarded focus on neighborhood park and recreation sites and facilities that have `deteriorated to the point where health and safety are endangered or the community's range of quality recreation service is impaired. Grant funds may be used to remodel, rebuild or develop existing recreation areas and facilities. UPARR grants are awarded on a 70/30 (Federal/local) matching basis.
www.ncrc.nps.gov/uparr

Art and Cultural Funding for Trails and Greenways

Many organizations seek ways to incorporate more of their community into their trail and greenway design. One way to do this is to celebrate the cultural and historic uniqueness of communities. There are many funding opportunities for these types of projects. The National Endowment of the Arts funds arts programs, and provides many links to other federal departments and agencies that offer funding opportunities for arts and cultural programs, as well as brownfields, sustainable community, transportation funding programs. On their site, there are program case studies describing how they have accessed funding for programs.

9.2 STATE FUNDS

Maine Department of Environmental Protection (DEP) Wetland Program Development Grants

Projects Considered: Purpose is to build capacity of all levels of government to develop and implement effective, comprehensive programs for wetland protection and management in Maine. Should address regulation, monitoring and assessment, restoration, wetland water quality standards, public-private partnerships, or coordination among agencies.

Due Date: January 9, 2002

Funds Available: a total of $100,000 for 2002 for 5-10 projects is available

Application: www.state .me.us/dep/blwq/grants.htm or Jeanne DiFranco, Maine DEP, Southern Maine Regional Office, 312 Canco Rd, Portland, Maine 04103 (207) 822-6424

Contact: jeanne.l.difranco@state.me.us

Notes: not for land acquisition, purchase of easements, or inventory or mapping.

Maine Department of Conservation

Maine Department of Conservation offers several grant possibilities for educational and recreational projects.

9.3 PRIVATE FUNDING SOURCES

Turner Foundation, both Water and Toxin Program and Habitat Program

Projects Considered: Water and Toxin Program: protection of water bodies, watersheds, and ocean from contamination, degradation or other abuse, to strengthen advocacy, outreach and technical capabilities, habitat restoration, fish and wildlife protection, pollution prevention; Habitat Program: support of ecosystem wide habitat protection, locally developed strategies for private and public lands, efforts to understand the relationships between wildlife habitat and economic stability.

Due Date: Rolling, Dec 15, March 15, June 15, and September 15

Funds Available: not listed

Application: at www.turnerfoundation.org/turner/application.html

Contact: Program Department, Turner Foundation, One CNN Center, Suite 1090, South Tower, Atlanta, GA 30303 (404) 681-9900

Notes: no land acquisition, funds both general support and project-specific, no media projects, focus is national projects with local ones as secondary.

The Heinz Endowment

Projects Considered: protection and/or restoration of essential watersheds in ways that safeguard freshwater ecosystems and create regional programs to increase protection efforts by the community

Due Date: rolling

Funds Available: not listed

Application: www.heinz.org

Contact: Melissa Crawford, 412-338-2615, info@heinz.org, The Heinz Endowments, 30 CNG Tower, 625 Liberty Ave, Pittsburgh, PA 15222

Notes: requires initial letter of inquiry before full application.

Watershed Assistance Grants, River Network

Projects Considered: those that support the growth and sustainability of watershed partnerships

Due Date: closed for 2001, potential for July 2002

Funds Available: $1,500 to 30,000

Application: wag@rivernetwork.org

Contact: WAG Program, River Network, 520 SW 6th Ave, 1130, Portland OR, 97204, 503-241-3506 ext 47, www.rivernetwork.org

Notes: vague descriptions of projects.

Ducks Unlimited- MARSH (Matching Aid to Restore States Habitat)

Projects Considered: to develop, maintain, restore and preserve wetlands and associated upland habitats with priority given to projects that protect or restore habitats within the North American Waterfowl Management Plan

Due Date: not given

Funds Available: matching, amount available based on a percentage of DU net annual grassroots fundraising per state per year as well as unused MARSH funds from the previous year

Application: www.ducks.org/conservation/marsh.asp

Contact: Grace Bottitta, 5 Hall Place #2, Exeter, NH 03833, (603) 778-0032, gbottita@ducks.org

Notes: prefer projects from a list of existing approved projects, prefer phone consultation before submitting application.

The Conservation Assistance Tools is sponsored by a consortium of organizations and government agencies. It provides a wealth of information about fundraising. The Foundation Center is a national non-profit clearinghouse for information on foundation and corporate giving. A few examples of available grants are listed below.

American Greenways Kodak Awards Program

Grants of $500 to $2500 are available for local greenways projects. Grants can be used for almost any activity that serves as a catalyst for local greenway planning, design, or development. www.conservationfund.org

Bikes Belong

Bikes Belong Coalition will accept applications for grants of up to $10,000 each, and will consider successor grants for continuing projects. www.bikesbelong.org

Oracle Corporate Giving Program

Oracle provides grants to medical research, endangered animal protection, environmental protection, and K-12 math, science, and technology education. Past recipients have included trail groups. www.oracle.com/corporate/giving/community/

PowerBar's Direct Impact on Rivers and Trails Program (D.I.R.T.)

PowerBar's Direct Impact on Rivers and Trails Program (D.I.R.T.) provides grants ranging from $2,000 - $5,000 in support of efforts to protect, preserve and restore recreational lands and waterways. www.powerbar.com/whoweare/

Recreational Equipment Incorporated (REI*)*

Recreational Equipment Incorporated (REI) awards seed grants of $200 to $2,000 to state and local conservation groups for projects that enhance river protection.

Contact: National Rivers Coalition, American Rivers, Inc., 801 Pennsylvania Ave., SE, Washington, DC 20003

The Rockefeller Family Fund (www.rffund.org) has a new (2001) grant program known as the Belvedere Fund. The Belvedere Fund is dedicated to helping state and regional environmental organizations build their capacity and effectiveness. See the program's web site for complete application information.

Trust for Public Land. The Trust for Public Land web site (www.tpl.org) suggests numerous funding possibilities that are relative to the marsh restoration project e.g., Land and Water Conservation Fund, Migratory Bird Conservation Fund.

Additional information on funding is available at:
www.trailsandgreenways.org/TAG_active_pages/TechnicalAssistance/main.asp

10.0 BIBLIOGRAPHY

Athayde , D.N. , P.E. Shelly, E.D. Driscoll, D. Gaboury and G.B. Boyd. 1983. Results of the Nationwide Urban Runnoff Program : Final Report USEPA. USEPA Water Planning Division Washington , DC.Banner, A. and J. Libby. 1995. Identification of important habitats in the lower Casco Bay (Maine) watershed. U.S. Fish and Wildlife Service, Gulf of Maine Project.

Banner, A. and S. Schaller. U.S. Fish and Wildlife Service Gulf of Maine Watershed Habitat Analysis. 2000. U.S. Fish and Wildlife Service Gulf of Maine Program, Falmouth, Maine.

Banner, A. 1998. Identification of important habitats in southern coastal Maine (Cape Elizabeth to Kittery). 1998 USFWS) Gulf of Maine Program, Falmouth, ME.

Bart, D. and J.M. Hartman. 2000. Environmental determinants of *Phragmites australis* expansion in a New Jersey salt marsh: an experimental approach. OIKOS 89: 59-69.

Bohlen, C., S. Accongiagioco, M. Donadio, J. Evans, D. Levin, J. Macias, E. Miquasky, G. Shyloski, E. Sprecher, and H. Vogel. 1998. Current condition of and restoration opportunities in the Upper Dunstan River Marsh, Scarborough, Maine. Bates College Environmental Studies Program, Bates College, Lewiston, Maine.

Bryan, R.R. 1999. Scarborough marsh: Historical impacts, current conditions, and restoration potential. Maine Audubon Society, Falmouth, Maine.

Bryan, R.R., M. Dionne, R. Cook, J. Jones and A. Goodspeed. 1997. Maine Citizens Guide to Evaluating, Restoring, and Managing Tidal Marshes (Maine Citizens Tidal Marsh Guide). Maine Audubon Society, Falmouth, Maine.

Bozenhard, P. 1980, revised 1996. Management plan for the Scarborough Wildlife Management Area, Wildlife Region A. Maine Department of Inland Fisheries and Wildlife.

Cook, R.A., A.J. Lindley Stone, and A.P. Ammann. 1993. Method for the evaluation and inventory of vegetated tidal marshes in New Hampshire. Audubon Society of New Hampshire.

Daiber, F.C. 1982. Animals of the tidal marsh. Van Nostrand Reinhold Co., NY,NY. 422 pp.

DeMaynadier, P., and T. Hodgman. 1999. A survey of rare, threatened and endangered fauna in Maine: central interior, midcoast and Penabscot Bay reiongs. Maine Dept. Inland Fisheries and Wildlife and Maine Natural Areas Program.

Duane, Thomas and Luna B. Leopald 1978. Water in Environmental Planning. San Francisco CA: W.H. Freeman and Company

Ecology of Scarborough Marsh. Maine Audubon Society, Falmouth, Maine.

Evaluation of restorable salt marshes in New Hampshire. 1994 (reprinted 1999). USDA Soil Conservation Service, Washington, DC.

Federal funding opportunities for habitat protection and restoration. 2000. U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Falmouth, Maine.

Field Checklist of Birds. 2001**.** Maine Audubon Society's Scarborough Marsh Nature Center, Falmouth, Maine.

Friends of Scarborough Marsh. November 2000. Meeting Minutes.

Friends of Scarborough Marsh, Libby River Watershed Survey Steering Committee. 2000. Libby River Watershed Survey Draft Report.

Gulf of Maine Coastal Program fact sheet. 2000. U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Falmouth, Maine.

Habitat restoration in Maine. 2000. U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Falmouth, Maine.

Harbor, Jonathan M 1994. A Practical Method for Estimating Land Use Change on Surface Runnoff, Groundwater Recharge and Wetland Hydrology. Journal of the American Planning Association. 60 1 : 95-108

Hogdon, F. 2001. The Scarborough Airport. Website: www.scarboroughmaine.com/historical/airport.html.

Identifying, mapping, protecting and restoring habitat in the Gulf of Maine watershed. 2000. U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Falmouth, Maine.

Informational meeting, Linda Woodward. 7 February, 2001. Director, Maine Audubon Society's Scarborough Marsh Nature Center, Falmouth, Maine.

Informational visit. 13 February, 2001. Scarborough Historical Society, Scarborough, Maine.

Karr, P. and J. Clark. An oasis of wilderness: Scarborough Marsh. 1995. Down East Magazine.

Linnell, S. 1994. A survey of impounded salt marshes in southern Maine. Masters Project, Antioch New England Graduate School.

Maine Department of Marine Resources (DMR). 2000. Fecal coliform data from 1993-2000. Falmouth, Maine.

Miller, W.B, and F.E.Egler. 1950. Vegetation of the Wequetequock-Pawcatuck tidal marshes, Connecticiut. Ecol. Monogr. 20:143-172.

Moore, E. 1996. *Phragmites australis*. Friend or Foe. Unpubl. Report.

NOAA/EPA. National Oceanic and Atmospheric Administration and Environmental Protection Agency. 1988. Strategic Assessment of Near Coastal Waters, Chapter 3, Susceptibility and Concentration Status of Northeast Estuaries to Nutrient Discharges. NOAA: Washington, D.C.

Neckles, H., and M.Dionne. 1999. Regional standards to identify and evaluate tidal wetland restoration in the gulf of Maine. Global Programme of Action Coalition for the Gulf of Maine, Workshop. Wells National Estuarine Research Reserve. 21 pp + App.

Normandeau Associates Inc. 1994. A dredged material management study for coastal Maine and New Hampshire. U.S. Army Corps of Engineers, New England Division, Waltham, Massachusetts.

Omernick, J.M. 1977. Nonpoint Source Stream Nutrient Relationship: A Nationwide Study. Corvallis, OR, US Environmental Protection Agency, 150 pp.

Paerl, H.W. 1993. Emerging role of atmospheric deposition in coastal eutrophication: biogeochemical and trophic perspectives. Can. J. Fish. Aquat. Sci., 60:2254-2269.

Rachel Carson NWR and southern Maine: identifying and protecting habitat for endangered, threatened, and declining fish and wildlife species. 2000. U.S. Fish and Wildlife Service Gulf of Maine Coastal Program, Falmouth, Maine.

Rapid Watershed Planning Handbook- A Comprehensive Guide for Managing Urbanizing Watersheds, 1998, Center for Watershed Protection.

Reckow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling Phosphorus Loading and Lake Response Underncertainty: A Manual and Compilation of Export. Coefficients. US EPA 440/5-80-011. Washington D.C.

Redfield, A.C. 1972. Development of a New England salt marsh. Ecol. Monogr. 42:201-237.

Scarborough Comprehensive Plan. 1993. Scarborough Planning Commission, Scarborough, Maine.

Scarborough Conservation and Public Lands (map). 2001. Coastal Mosaic Project. Wells National Estuarine Research Reserve (WNERR).

Schueler, T 1994. The Importance of Imperviousness. Watershed Protection Techniques, 1, No (3) 100-111

Snow, J. 1980. Secrets of a Salt Marsh. Guy Gannett Publishing Co., Portland, Maine.

Summer Programs. 2000. Maine Audubon Society's Scarborough Marsh Nature Center, Falmouth, Maine.

Teal, J.T., and B.L. Howes. Salt marsh values: retrospection from the end of the last century. In Weinstein, M.P., and D.A. Kreeger (eds). Concepts and controversies in tidal marsh ecology. Kluwer Academic Publ. Dordrecht, The Netherlands. pp. 9-19.

Technical Paper 4, Non Point Education for Municipal Officials, Haddam, CT.

The Long Island Wetland Restoration Initiative. 2000. U.S. Fish and Wildlife Service's Long Island National Wildlife Refuge Complex.

Volunteer Manual, Shellfish Sanitation Program. **XXXX.** Maine Department of Marine Resources.

Ziepniewski, J. 1995. Libby River watershed water quality management study. The Town of Scarborough, Maine.

Personnal Communications

Andrews, John. 2000. Eastern Trail Alliance. Saco, Maine.

Barker, Seth. 2000. Maine DMR. Augusta, Maine.

Bentley, Steve. 2000. Historian. Saco, Maine.

Bohlen, Curtis. Assistant Professor of Environmental Studies, Bates College, Lewiston, Maine.

Boland, John. 2001. Fishery Biologist. Maine Inland Fish and Wildlife. Augusta, Maine.

Bozenhard, Phil. 2000. Wildlife Biologist. Maine Inland Fish and Wildlife. Gray, Maine.

Brinker, Lysle. 2001. Amateur Field Ornithologist. Cumberland, Maine.

Corbeau, Dave. 2001. Harbor Master and Clam Warden. Town of Scarborough, Maine.

Cummings, Susan. 2001. Planning Department. City of South Portland, Maine.

Delaware, Becky. 2000. Scarborough Historical Society. Scarborough, Maine.

Dennis, Mary Ellen. 2000. Maine Department of Environmental Protection. Augusta, Maine.

Docherty, Molly. 2000. Maine Natural Areas Program (NAP). Augusta, Maine.

Dumont, Eugene. 2001. Maine IF&W. Augusta, Maine.

Emery, Wanda. 2001. Planning Department. Town of Buxton, Maine.

Fefer, Stewart. Project Leader. USFWS Gulf of Maine Coastal Program. Falmouth, Maine.

Fossum, Deborah. 2001. Town Planner. Town of Gorham, Maine.

Hamblen, Bob. 2001. City Planner. City of Saco, Maine.

Heatherly, Pam. 2001. Bridge Program. Maine Department of Transportation (DOT).

Hertz, Elizabeth. 2001. State Planning Office (SPO). Augusta, Maine.

Houston, Robert. 2000. USFWS, Yarmouth, Maine.

Kellogg, Zip. 2001. Research Librarian. University of Southern Maine, Portland, ME.

Livingston, Laura. 2001. Water Quality Specialist, Division of Marine Resources. Boothbay Harbor, Maine.

Mallar, Roger. 2001. Friends of Scarborough Marsh. Scarborough, Maine.

McDermott, Sean. 2001. National Marine Fisheries Service (NMFS).

Morelli, Peter. 2001. Director of Economic Development. Scarborough, ME.

Pinkham, Emily. 2001. Maine Natural Areas Program. Augusta, Maine.

Redway, Tad. 2001. Town Planner. Town of Old Orchard Beach, Maine.

The Scarborough, Maine Historical Society, Scarborough, Maine. 2001. Informational visit.

Smith, Mike. 2000. Department of Environmental Protection. Maine.

Smith, Susan. GIS Specialist, Wells National Estuarine Research Reserve. Wells, Maine.

Summer, Chris. 2001. GIS Specialist. Greater Portland Council of Governments (GPCOG). Portland, Maine.

Swaney, Laurene. 2001. Coastal Mosaic Project, Scarborough Conservation Land Trust. Scarborough, Maine.

Wight, Mike. 2001. Maine Department of Transportation, Augusta, ME.

Williams, Doug. 2002. Scarborough Conservation Commission. Scarborough, ME.

Winter, Lois. 2001. USFWS Gulf of Maine Coastal Program, Falmouth, Maine.

Witham, Wendell. Scarborough Historical Society, Scarborough, ME.

Woodard, Linda. 7 February, 2001. Director. Maine Audubon Society's Scarborough Marsh Nature Center, Falmouth, Maine. Informational meeting.

Zipnewski, Joe. Town Planner. Town of Scarborough, Maine.

Internet Resources

The Scarborough Airport. Website: www.scarboroughmaine.com/historical/airport.html.

The Scarborough Land Conservation Trust. Website: www.scarboroughmaine.com/slct/index.htm. 2001.

The Scarborough Maine Historical Society and Museum. Website: www.scarboroughmaine.com/historical. 2001.

Scarborough marsh: keeping it healthy. Maine Audubon Society's Scarborough Marsh Nature Center. Website: www.maineaudubon.org.

Friends of Scarborough Marsh: www.scarboroughmaine.com/marsh

APPENDIX A

REPRESENTATIVE PHOTOGRAPHS OF SCARBOROUGH MARSH PROJECT SITE