Evaluation of
Restorable Salt Marshes
in New Hampshire

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(Formerly the USDA Soil Conservation Service)

Study Sponsors:
Rockingham County Conservation District
Strafford County Conservation District
Audubon Society of New Hampshire
New Hampshire Wetlands Bureau

Other Cooperating Agencies and Organizations:

University of New Hampshire
UNH Jackson Estuarine Laboratory
Wells (Maine) National Estuarine Research Reserve
New Hampshire Office of State Planning
Great Bay National Estuarine Research Reserve
USDI Fish and Wildlife Service

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1.0 INTRODUCTION

1.1 Purpose of Study

The purpose of the study was to inventory and evaluate non-natural restrictions to tidal flow in the vegetated tidal marshes (salt marshes) of New Hampshire. It also sought to determine the restoration potential of those marshes that have deteriorated in ecological value as a result of being restricted in the past. The study focused on restrictions to tidal flow because the daily flux of seawater is the lifeblood of a salt marsh. When impediments to tidal flow are created, profound changes take place; the marshes may degrade to the point where they no longer provide their characteristic suite of functions and values such as wildlife habitat or visual/aesthetic quality. If restrictions are severe enough, marshes may be replaced by brackish or fresh water wetlands, usually of lower ecological value.

1.2 Study Sponsors

Study sponsors were the Audubon Society of New Hampshire, the New Hampshire Wetlands Bureau, and the Rockingham and Strafford County Conservation Districts. Specialists of the USDA Natural Resources Conservation Service (NRCS) performed the majority of the fieldwork and technical analysis. Students involved in the Senior Projects course at the University of New Hampshire (UNH) assisted with the collection of field data. Personnel from the Audubon Society of New Hampshire, the UNH Jackson Estuarine Laboratory, and the Wells (Maine) National Estuarine Research Reserve also participated.

1.3 Study Authority

NRCS assistance to units of government for this type of study is authorized by Section 6 of Public Law 83-566. In New Hampshire, the scope of this assistance is further defined by a Joint Coordination Agreement between the NRCS and the New Hampshire State Conservation Committee. NRCS and other federal agency involvement is also guided by Executive Order 11988, Floodplain Management; and Federal Level Recommendation 5(b) of "A Unified National Program for Floodplain Management," U.S. Water Resources Council, March 1986.

2.0 BACKGROUND

2.1 New Hampshire's Salt Marsh Resources

In New Hampshire, salt marshes are found along the state's 18-mile Atlantic coast, along the Piscataqua and Cocheco Rivers, and around the Great/Little Bay estuary and its tributaries. The inset in Figure 1 shows the area of the state covered by the study as well as the area covered by each map (plates 1-5) found in Appendix A.

Estimates of the total acreage of salt marshes in the state vary depending on how the estimate was made. A 1954 survey conducted by the U.S. Fish and Wildlife Service and the NH Department of Fish and Game identified 5,660 acres of salt marsh. That inventory, however, measured only wetlands larger than 40 acres in size. A more recent estimate by the NRCS shows approximately 6,200 acres of salt marsh in New Hampshire. This estimate is based on soil mapping conducted by the NRCS as part of the National Cooperative Soil Survey Program.

Although, from a distance, salt marshes appear to be flat, featureless meadows, this is deceiving. These marshes are, in fact, complex ecosystems delicately balanced between marine and terrestrial environments and are the primary grassland ecosystem in the Northeast. They have adapted to a part of the landscape that regularly undergoes dramatic changes in salinity, water level, and temperature.

Marshes develop on sediment deposits in protected coastal waters that, along the New Hampshire coast, commonly occur behind rocky spits, sand bars and barrier beaches. Marshes formed behind these barriers are called back barrier marshes. Most of the sediment in these marshes is either marine sediment washed in by tides or organic material built up in the marsh itself. Some of the marine sediment consists of soil particles previously eroded from upland that has been washed out to sea.

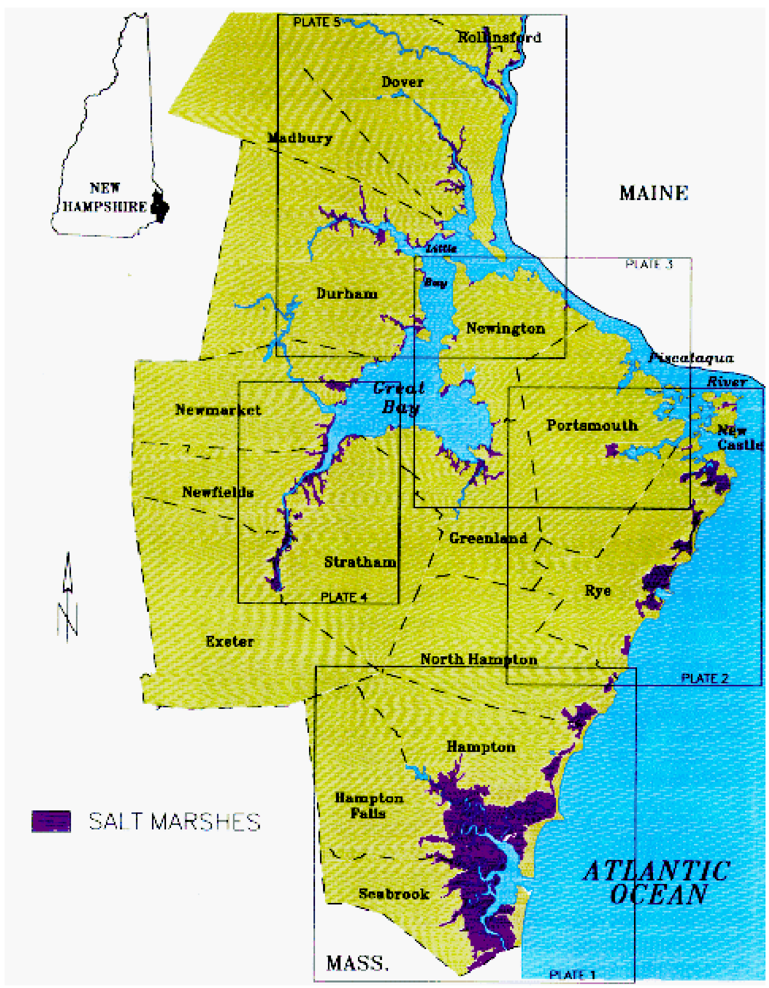

Figure 1 - Salt Marsh Restoration Study Area

The marshes along the Great/Little Bay Estuary and its tributaries are called estuarine marshes. A major source of sediment for marsh development in estuarine marshes is soil particles from upland or shoreline erosion. In addition, organic sediment is produced by the marsh itself.

In geologic terms, salt marshes are relatively young ecosystems that have developed over the last three to four thousand years. They are part of the re-colonization by plants and animals following the melting of the most recent glaciers some 10 to 15 thousand years ago.

Historically, the marshes have been in a dynamic balance with the rise in sea level, which has occurred in New England over the last thousand years. As the sea level rose, salt marshes moved inland, maintaining the same relative position with respect to tides. Along the coast it is possible to visit marshes occupying areas that were once inland forested wetlands but, because of the rising sea level, are now subject to periodic tidal flooding. Future inland migration of many of these wetlands is problematic given the present level of human development around them.

When undisturbed, the marshes are typically laced with a network of tidal creeks that drain fresh water from the marsh and provide a conduit for tidal water to be distributed throughout the wetlands. Generally, the salinity of surface and ground water within a salt marsh is 18 parts per thousand (ppt) or greater. The term brackish marsh is used in this document to describe tidal marshes having salinities below 18 ppt. but greater than 0.5 ppt. When left undisturbed, marshes have a greater capacity to maintain themselves.

Although appearing flat, marshes actually rise slightly in elevation from seaward to landward. Along this elevation gradient, the frequency of tidal flooding decreases resulting in a distribution of plant species that tends to be arranged in zones reflecting varying degrees of tolerance to inundation by salt water. Based on the frequency of this inundation, salt marshes can be divided conveniently into low marshes and high marshes.

Low marshes typically are found as fringes along tidal creeks or estuaries where the surface elevation is below the level of normal mean high tide. As a result, these marshes are flooded at each high tide or twice daily.

The plant most commonly associated with low marshes in New Hampshire is a tall form of salt marsh cordgrass (*Spartina alterniflora*). Over time, as this grass grows, dies and subsequently sinks into the mud, layers of organic material and trapped sediment are formed causing the surface of the marsh to rise. As the marsh elevation rises and the depth of tidal inundation decreases, low marsh may develop eventually into high marsh.

The point at which the marsh elevation equals that of normal high tide marks the seaward edge of high marsh. Unlike low marsh, high marsh is inundated only several times every other week during spring tides or by storm tides (surges).

High marsh has a more complex plant community than low marsh. At marsh elevations near normal high tide there is usually a zone dominated by salt meadow cordgrass (*Spartina patens*) or the short form of salt marsh cordgrass. Continuing inland, the next vegetation zone, flooded even less frequently and therefore less saline, is dominated by spike grass (*Distichlis spicata*) and black grass (*Juncus gerardii*). Finally, there may be a transition zone in which species adapted to infrequent inundation or slightly brackish conditions grow. This landward border of a salt marsh may be transition to upland, brackish wetland, or freshwater wetland depending on local conditions.

Interspersed through the high marsh are pannes or intertidal pools that retain water between the infrequent flooding tides. In some cases these pools may become very saline because of evaporation. Glasswort (*Salicornia spp*.) and Widgeon grass *(Ruppia maritima*) occur in pannes. Waterfowl eats both plants with Widgeon grass being an especially important food item.

It is important to note that all of the low and high marsh plant species discussed above can grow in fresh water but cannot compete with inland plants. Long term, the salt marsh plant community survives only in areas where salinity is greater than about 18 ppt.

2.2 Causes and Effects of Salt Marsh Deterioration

Many of New Hampshire's salt marshes have been damaged by human activity, some to the point where they no longer provide the myriad of beneficial functions and values with which they have long been associated. Negative impacts to salt marshes include, but are not necessarily limited to, the following:

- restrictions to tidal flow
- filling
- draining
- increased nutrient inputs
- increased and, in some cases, decreased sediment inputs
- introduction of invasive plant species
- excess freshwater runoff

Although the scope of this study was limited to problems and opportunities relative to restrictions, any or all of the factors listed above can cause a salt marsh to deteriorate. A change in the species composition is one of the primary indicators of marsh deterioration. In New Hampshire, the existence of significant populations of common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), or narrow leaf cattail (T*ypha angustifolia*) is a good indicator that this is occurring (see Figure 2). These plants, which normally occupy a niche in the transition zone between salt and freshwater marshes, may invade the salt marsh under conditions of reduced salinity. When such plants invade a marsh they tend to dominate and eventually crowd out the characteristic salt marsh vegetation. These invasive species have a low value for wildlife and, by crowding out the salt marsh species, reduce the overall value of the marsh.

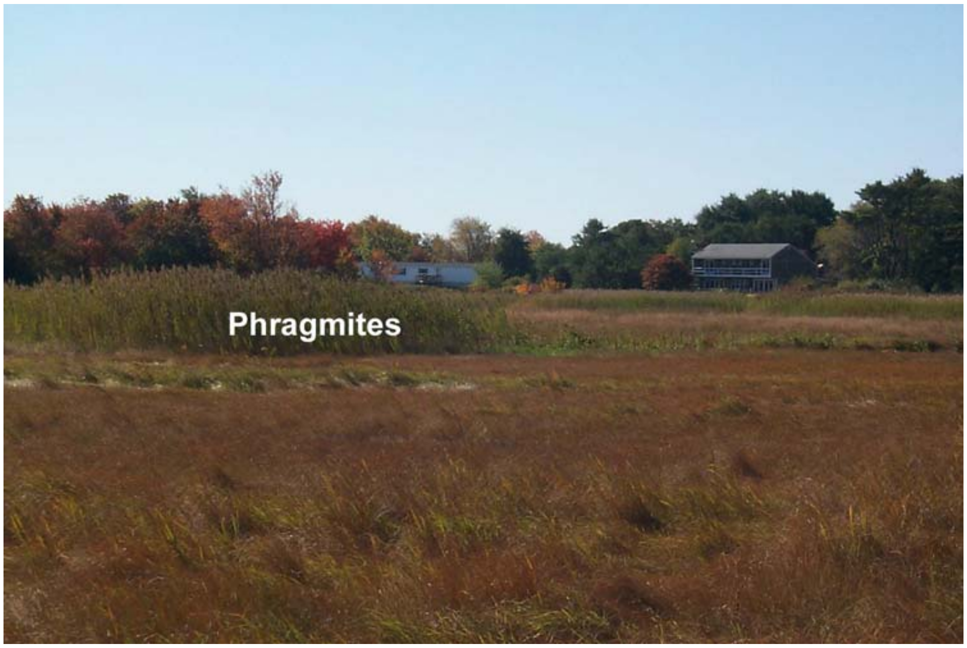

Figure 2 - Phragmites invades a tidally restricted New Hampshire Salt Marsh

2.3 Benefits and Values of Salt Marshes

Salt marshes occupy only about 0.1 percent of the entire area of New Hampshire. For their rarity alone they are a valuable natural resource, but the benefits derived from these wetlands go well beyond their scarcity. Native Americans regularly hunted and foraged in tidal marshes taking fish, shellfish, birds, and other wildlife. With the arrival of European settlers, salt marshes were harvested for their grasses for use as hay and animal bedding. Modern day residents benefit from the wildlife habitat, aesthetic quality, shoreline anchoring, and other functions which salt marshes still provide.

A recent report (Dorobek, 1994) has documented the relationship between the destruction of wetlands and the declining level of the Nation's fish production. In New England, there is also a documented link between years of abundant freshwater flows from wetland areas into inshore habitats and good lobster harvests. Other studies (U.S. EPA, 1993) have estimated that, nationwide, 71 percent of the commercial fish value is derived from species dependent to some degree on coastal wetlands.

The importance of salt marshes to fisheries in the Gulf of Maine, which extends roughly from Cape Cod to the Bay of Fundy and includes the Georges Bank, is not well understood. It is believed, however, that salt marshes are important to local, near shore fisheries for at least three reasons. First, salt marshes export organic matter (detritus) which may be an important microbial food source in estuarine and near shore marine ecosystems. Second, salt marshes harbor several species of "minnows" such as mummichogs (*Fundulus heteroclitus*) and Atlantic silversides (*Menidia menidia*) which are food sources for larger fish. Third, salt marshes serve as nurseries/refuges for such important fish as winter flounder (*Pseudopleuronectes americanus*) and alewife (*Alosa pseudoharengus*).

All salt marshes are, of course, not equally important to the fisheries of the Gulf of Maine. The functioning of an individual salt marsh depends on a number of factors, one of which may be its openness to tidal flow. The free exchange of tidal water allows maximum potential for nutrient exchange, fish habitat, etc. given the individual characteristics and position in the landscape of the particular marsh.

In 1991, the total dockside value of fish landed in the U.S. exceeded $3.3 billion (U.S.D.A., 1992). This provided the foundation of a $26.8 billion fishery processing and sales industry, an industry responsible for creating hundreds of thousands of jobs (U.S. EPA, 1993). In New England alone, the dockside value of fish landed was estimated at $594 million (U.S.D.A, 1992). Although the monetary contribution of the salt marshes to this value is unknown, it is apparent that even a small contribution would result in significant economic benefits.

There has been no known site-specific attempt to quantify the economic benefits of any of the New Hampshire salt marshes. Their location, size, and proximity to developed areas and recreational facilities would no doubt result in significant variations from one marsh to another. Such an attempt goes far beyond the scope of this study.

This study did, however, document that, collectively, towns along the New Hampshire seacoast are spending over $100,000 annually for control of mosquitoes, green head flies, and other pests that emanate from the marshes and other wetland areas (personal communication, L. Brooks, S. MacGregor and M. Morrison, Pest Control Specialists, NH Seacoast communities, 1993). Discussions with some of those responsible for this work indicate that many of these dollars are spent in marsh areas that are not functioning properly, where lack of tidal flow creates stagnant breeding pools devoid of insectivorous fish. The lack of adequate drainage in some of the marshes also produces unpleasant odors associated with decaying vegetation. The local nickname of "Stinky Creek" for the Parsons Creek system is well known and very appropriate at certain times of the year.

2.4 Previous Restoration Efforts

Over the last 20 years there have been a number of efforts initiated to restore some of the state's damaged salt marshes. Success was rather limited at first, but has been improving as public sentiment and a good spirit of interagency cooperation have worked in favor of the restoration movement.

The Little River salt marsh on the Hampton-North Hampton town line was the subject of several studies during the early 1980's, resulting in the purchase of part of the marsh. However, due to complexity and cost, no increase in saltwater flow to the marsh was attained. A proposal to modify the Philbrick Pond salt marsh opening in North Hampton was also thwarted due to landowner opposition.

In the late 1980's, a group of agencies and organizations cooperated to restore a 15 to 20 acre portion of the Awcomin marsh in Rye. This marsh had been damaged by spoil disposal during the 1941 and 1962 dredging of Rye Harbor. Using funding from the NH

Coastal Program and the U.S. Fish and Wildlife Service, project sponsors removed dredged spoil and dikes and restored the tidal ditch network. Another recent effort, on the Stuart Farm in Stratham, is a good example of landowner and agency cooperation to restore a marsh in a private setting. The flap on a tide gate installed some 30-years ago to restrict flooding of agricultural land was removed and an additional culvert was installed to allow salt-water access to a 10 acre marsh.

3.O STUDY PROCEDURES

3.1 General

The study involved the field identification of sites that appeared to be restricting tidal flows and an engineering field survey of the structures (openings) and their relationship to the tide elevation. A simplified modeling procedure was developed to analyze the degree of restriction of each opening and a preliminary estimate of the cost of corrective measures was prepared.

A field evaluation of the environmental health of the associated marsh segments (evaluation units) was conducted and an analysis of economic and social impacts was prepared. The locations of the restrictions and the evaluated marsh segments were digitized into a Geographic Information System (GIS) format and a database of physical and analytical information gathered in the study was assembled. The results were tabulated in several sets of tables useful for making decisions and setting priorities for future salt marsh restoration efforts.

3.2 Inventory Process

Potentially impaired sites were identified by using the latest NRCS soil survey data for Rockingham and Strafford Counties and the USGS quadrangle maps of the area. These data were supplemented by the 1974 Soil Survey of New Hampshire Tidal Marshes and the mapping associated with the Phase 1 Report of the Coastal Wetlands Mapping Program. With the exception of sites accessible only by air or hover craft, sites located upstream of a road, railroad, dam, or other obstruction were field visited to determine any evidence of impairment and the degree of obstruction. Initial data collected were related to the nature of the impairment, the estimated size of the opening, the acreage of the upstream marsh segment(s), and an initial assessment of marsh health.

From the initial inventory of approximately 100 marsh restrictions, 84 were selected for further evaluation. For these marshes an engineering survey relating the size and shape of the opening(s) to the elevation of the marsh was conducted. All of the information was entered into a database with each restriction and each affected marsh segment cataloged separately. The restrictions and marsh segments were then grouped into systems which consist of one or more restrictions and evaluation units, which, were it not for restrictions to flow, would be interconnected and subject to the same tidal flows without impediment. Twenty systems were identified, with some containing only one evaluation unit and others, as many as 21. As an example, Figure 3 shows the relationship between restrictions and evaluation units in a part of the Hampton/Seabrook marsh system.

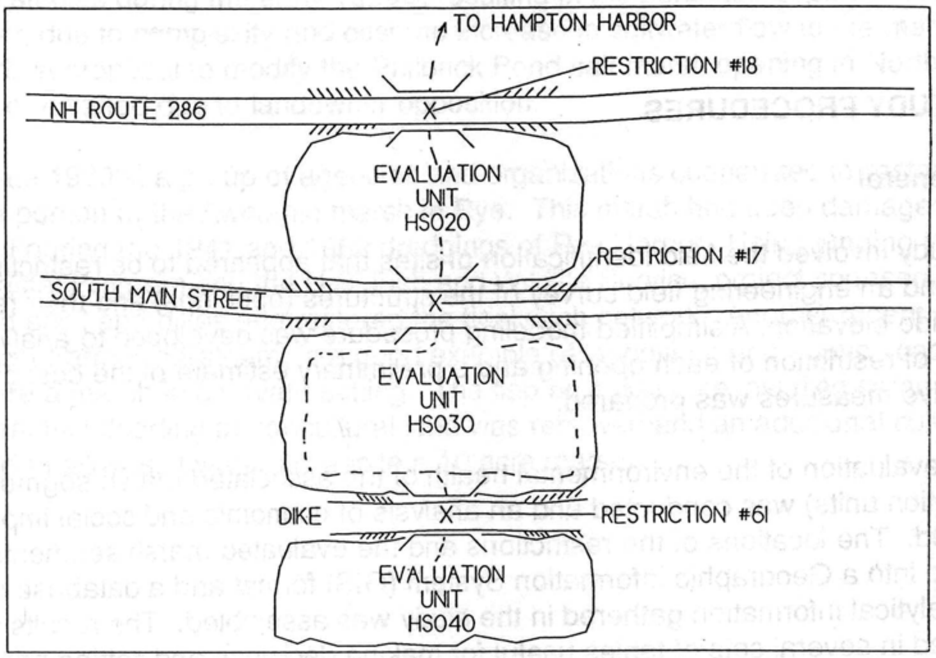

Figure 3 – Relationship of Restrictions and Evaluation Units

3.3 Engineering Analysis

A simplistic hydraulic model was developed to analyze the relative restrictiveness of the surveyed openings. The model evaluated an opening's capability to pass a tide, which rises to a National Geodetic Vertical Datum (NGVD) elevation 5.0, a tide, which can be expected to occur or be exceeded on about 10 days every month. Where openings and restrictions were in series, a storage routing routine was utilized to evaluate the segments of marshes and restrictions as well as the entire system's interactions through the evaluation tide cycle. Appendix B in the back of this report contains more information on the hydraulic evaluation procedures, including assumptions made and any limitations in its use.

From this analysis, 50 openings were found to be restrictive to the passage of the evaluation tide. Figure 4 shows, for example, an opening that is not only inadequate in size, but also partially blocked by displaced boulders. Recommended corrective measures and associated cost estimates were developed for 39 of the 50 restrictive openings. Of the remaining 11, six were determined to be impractical to modify, four were found to need further study before a recommendation could be made, and one's restrictive effect is offset if an adjacent restriction is enlarged.

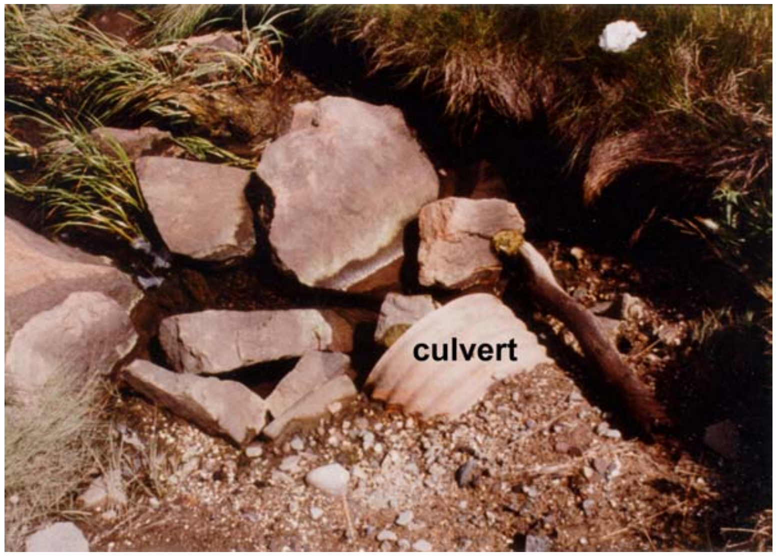

Figure 4 – Severely Restricted Opening to a New Hampshire Salt Marsh

A conceptual cost estimate was developed for each recommended measure based on materials judged as best suited for each site. The cost estimates assume installation by competitively-bid contract and do not include engineering design, contract administration, land rights, utility modification, or monitoring.

3.4 Environmental Analysis

Each evaluation unit was field visited to evaluate the current status of the plant community. The type of plants present, the degree of encroachment by invasive species, the apparent trend of deterioration, and the dominant surrounding land use were noted. The information was entered into the database and used in the selection of marsh segments for further analysis. See Appendix B in the back for an explanation of the criteria used in this analysis.

The main output of the study is presented in Table 2, beginning on page 16, which shows the costs and marsh acreages that would benefit from potential restoration efforts. This information will be useful in working with towns to set priorities and further define the feasibility of individual projects. Existing federal and state programs should be adequate to provide cost sharing for several of the more expensive measures, given a longer term program time frame.

Following the main body of the report are two appendices that contain additional information related to the study. Appendix A contains maps showing the location of the various restrictions and salt marsh segments evaluated. Appendix B, Study Methodology, describes how the data were collected and analyzed. It is intended primarily for, but not necessarily limited to, those involved in the technical aspects of salt marsh restoration.

3.5 Economic and Social Evaluation

Each restriction and associated marsh segment was evaluated with respect to the economic and social factors that might affect their potential for restoration. The evaluation considered two primary elements, flood potential and land rights. The flood potential evaluation considered the probability that a structure (building) located near the marsh would be flooded should the restriction be removed. The land rights evaluation considered known objections by landowners/abutters to the removal of restrictions, the need for structural relocation in order to remove restrictions, and the general probability of induced flooding.

3.6 Database and GIS Application

The Microsoft Access Relational Database Management System for Windows, Version 1.1, was selected as the repository of the physical and analytical data collected and developed. This database allows for easy recall and display of the basic data. It will also analyze, categorize and sort data, and produce customized reports. This database will also handle future information needs of the study.

Salt marsh restoration study maps were produced using digital geographic data from several sources. The salt marsh and coastal layers were derived from the National Cooperative Soil Surveys digitized at Complex Systems Research Institute, University of New Hampshire from source maps at a scale of 1:20,000. Corrections to the derived salt marsh layer to reflect current land cover conditions and the digitization of restriction sites were done at the NRCS office in Durham, New Hampshire. The USGS provided transportation network data digitized at 1:24000 scale. The maps were produced using Geographic Resource Analysis Support System (GRASS) software.

4.0 STUDY FINDINGS AND RECOMMENDATIONS

4.1 General

The study found that there are numerous locations where salt marshes have been degraded due to restrictions to tidal flow. While many may be expensive to rectify, there are several opportunities where locally sponsored and funded projects could fully restore the marshes affected. Others will require a more complex and longer term planning and implementation effort and a pooling of resources by federal, state, and local entities. Before any restoration effort is undertaken there is a need to consider other factors which have not been addressed in this report. Such factors include, for example, the effectiveness of existing impoundments in removing bacteria and nutrients from the water column and the specific impacts on flooding from any restriction modifications.

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4.2 Magnitude of the Problem

The study found that there are 50 locations where non-natural restrictions impact the daily flux of the tide, which is the lifeblood of a healthy salt marsh ecosystem. These restrictions, many of which have been in place for years, affect over 1,300 acres, 20 percent of the total remaining salt marshes in New Hampshire. Such restrictions are detrimental to the quality of this valuable resource.

Of the 50 restrictions, 45 are located along the Atlantic Coast and impact approximately 1,214 acres (93 percent of the total) while five, affecting about 98 acres, are located along the Piscataqua River or within the Great/Little Bay estuary. Hampton and Rye contain the largest number of restrictions and affected acreage's (Table 1).

Town road crossings are responsible for the greatest number of restrictions, 22, although the acreage affected, 366, is much less than that affected by state maintained highways. The state highway system is responsible for 15 restrictions (583 acres), most of which are located on Route 1A as it winds its way up the New Hampshire coast. There are also several located further inland along the state-maintained U.S. Route 1 corridor. Railroad crossings are responsible for four of the restrictions (257 acres) with private roads or others responsible for nine (105 acres).

Table 1 shows the numbers of restrictions and acres of salt marsh affected by town and jurisdiction in the study area.

4.3 Adequacy of Tidal Inlets to NH Salt Marshes

The primary findings of the study are presented in Table 2, Adequacy of Tidal Inlets to NH Salt Marshes, which shows the linkages between individual restrictions and associated marsh segments, the adequacy of restrictions, and their relationships to other restrictions in the systems. Corrective actions and estimated costs of actions are also given as well as unit costs per acre of salt marshes benefited. The table headings are described in the "Explanation of Terms in Table 2" on page 26.

It is apparent from the table that the unit costs of restoring salt marshes vary considerably. Some evaluation units can be restored quite economically while others may be prohibitively expensive. Others, still, have been termed as "not practical" or "needs further study" because of the complex issues involved.

Some segments can be improved by removing minor amounts of debris or other material that partially clog an otherwise adequate opening. Others will require major bridge or culvert work to obtain the necessary hydraulic conveyance for adequate tidal flushing. It should once again be noted that the estimated costs developed in this study are for comparison purposes only and, given exclusions discussed in Section 3.3, may differ significantly from the actual cost of any restoration effort.

Table 1 - Number of Restrictions and Acres of Salt Marsh by Municipality

Municipality	Total		State		Town		Railroad		All Other	
	#	Acres	#	Acres	#	Acres	#	Acres	#	Acres
Dover	1	19.2	-	-	1	19.2	-	-	-	-
Durham	1	25.2	1	25.2	-	-	-	-	-	-
Hampton	11	624.6	3	241.2	6	173.4	2	210.0	-	-
Hampton Falls	1	12.4	1	12.4	-	-	-	-	-	-
New Castle	5	16.9	-	-	2	6.3	-	-	3	10.6
Newington	1	43.1	-	-	-	-	-	-	1	43.1
North Hampton	5	216.1	2	147.0	2	46.6	-	-	1	22.5
Rye	18	280.1	7	154.6	8	109.1	-	-	3	16.4
Seabrook	5	63.7	1	2.3	2	7.3	1	41.4	1	12.7
Stratham	2	10.3	-	-	1	4.6	1	5.7	-	-
Total	**50**	**1311.6**	**15**	**582.7**	**22**	**366.5**	**4**	**257.1**	**9**	**105.3**

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
<u>Bass Beach</u>									
BB010									
	28	Rye	BB010	Inadequate	1	4.9	RCP	$70,000	$14,286
BB020									
	28	Rye	BB010	Inadequate	1	5.6	RCP	$70,000	$12,500
	29	Rye	BB020	Adequate		0.0	None		
<u>Bellamy River</u>									
BR010									
	118	Dover	BR010	Adequate	1	0.0	None		
BR020									
	118	Dover	BR010	Adequate	1	0.0	None		
	119	Dover	BR020	Adequate	2	0.0	None		
<u>Berry's Brook</u>									
BK010									
	47	Rye	BK010	Adequate	1	0.0	None		
BK030									
	47	Rye	BK010	Adequate	1	0.0	None		
	48	Rye	BK030	Adequate	2	0.0	None		
<u>Crommet Creek</u>									
CC010									
	114	Durham	CC010	Adequate	1	0.0	None		
<u>Eel Pond</u>									

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
EP010	31	Rye	EP010	Inadequate	1	44.3	Not Practical		
Foss Brook									
FB010									
	105	Greenland	FB010	Adequate	1	0.0	None		
Fresh Creek									
FC010									
	120	Dover	FC010	Inadequate	1	19.2	Needs		
Hampton/Seabrook									
HS010									
	19	Seabrook	HS010	Adequate	1	0.0	None		
HS020									
	18	Seabrook	HS020	Adequate	1	0.0	None		
HS030									
	18	Seabrook	HS020	Inadequate	1	2.3	CMP	$15,000	$6,522
	17	Seabrook	HS030	Inadequate	2	4.6	RCP	$15,200	$3,304
						6.9		**$30,200**	**$4,377**
HS040									
	18	Seabrook	HS020	Inadequate	1	2.3	CMP	$15,000	$6,522
	17	Seabrook	HS030	Inadequate	2	4.6	RCP	$15,200	$3,304
	61	Seabrook	HS040	Inadequate	3	2.7	CMP	$3,600	$1,333
						9.6		**$33,800**	**$3,521**
HS050									
	6	Seabrook	HS050	Adequate	1	0.0	None		

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
HS060									
	6	Seabrook	HS050	Adequate	1	0.0	None		
	7	Seabrook	HS060	Inadequate	2	12.7	Cleanout	$500	$39
HS070									
	8	Seabrook	HS070	Inadequate	1	41.4	Add 1 RCP	$14,700	$355
HS080									
	9	Hampton	HS080	Adequate	1	0.0	None		
HS090									
	9	Hampton	HS080	Adequate	1	0.0	None		
	11	Hampton	HS090	Inadequate	2	0.0	Not Practical		
HS100									
	12	Hampton	HS100	Adequate	1	0.0	None		
	10	Hampton	HS100	Adequate	1	0.0	None		
HS110									
	12	Hampton	HS100	Adequate	1	0.0	None		
	10	Hampton	HS100	Adequate	1	0.0	None		
	5	Hampton	HS110	Inadequate	2	231.5	Dredge	$1,000	$4
HS120									
	12	Hampton	HS100	Adequate	1	0.0	None		
	10	Hampton	HS100	Adequate	1	0.0	None		
	5	Hampton	HS110	Inadequate	2	231.5	Dredge	$1,000	$4
	1	Hampton	HS120	Inadequate	3	16.6	RCP/2	$23,700	$1,428
						248.1		**$24,700**	**$100**
HS130									
	12	Hampton	HS100	Adequate	1	0.0	None		

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
	10	Hampton	HS100	Inadequate	1	210.0	Dredge	$1,000	$5
	5	Hampton	HS110	Inadequate	2	231.5	Dredge	$1,000	$4
	1	Hampton	HS120	Inadequate	3	22.2	RCP/2	$23,700	$1,068
	20	Hampton	HS130	Adequate	4	0.0	None		
						463.7		**$25,700**	**$55**
HS140									
	4	Hampton	HS140	Adequate	1	0.0	None		
HS150									
	60	Hampton	HS150	Inadequate	1	11.1	Remove CMP	$5,000	$450
	2	Hampton	HS150	Inadequate	1	0.0	None		
HS160									
	3	Hampton	HS160	Inadequate	1	7.6	Clean out	$500	$66
HS170									
	16	Hampton	HS170	Adequate	1	0.0	None		
HS180									
	16	Hampton	HS170	Adequate	1	0.0	None		
	13	Hampton	HS180	Inadequate	2	117.0	Concrete Box	$64,400	$550
HS190									
	16	Hampton	HS170	Adequate	1	0.0	None		
	13	Hampton	HS180	Inadequate	2	117.0	Concrete Box	$64,400	$550
	14	Hampton	HS190	Inadequate	3	0.0	Not Practical		
HS200									
	16	Hampton	HS170	Adequate	1	0.0	None		
	13	Hampton	HS180	Inadequate	2	117.0	Concrete Box	$64,400	$550
	14	Hampton	HS190	Inadequate	3	0.0	Not Practical		
	21	Hampton	HS200	Inadequate	4	0.0	Not Practical		

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
HS210									
	15	Hampton	HS210	Inadequate	1	2.5	Clean out	$500	$200
Herod's Cove									
HC010	101	Newington	HC010	Inadequate	1	43.1	Further Study		
Little Harbor									
LH010	57	New Castle	LH010	Inadequate	1	1.3	CMP	$7,000	$5,385
Little River									
LR010	25	N Hampton	LR010	Inadequate	1	146.9	Concrete Box	$1,000,000	$6,807
LR020									
	22	Hampton	LR020	Inadequate	1	0.0	Not Practical		
	25	N Hampton	LR010	Inadequate	1	146.9	Concrete Box	$1,000,000	$6,807
	23	N Hampton	LR020	Inadequate	2	34.5	Concrete Box	$21,800	$632
						181.4		**$1,021,800**	**$5,633**
LR030									
	25	N Hampton	LR010	Inadequate	1	146.9	Concrete Box	$1,000,000	$6,807
	22	Hampton	LR020	Inadequate	1	0.0	Not Practical		
	23	N Hampton	LR020	Inadequate	2	34.5	Concrete Box	$21,800	$632
	24	Hampton	LR030	Inadequate	3	12.1	RCP	$13,300	$1,099
						193.5		**$1,035,100**	**$5,349**
Oyster River									

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
OR010									
	115	Durham	OR010	Inadequate	1	25.2	Remove		
OR020									
	116	Durham	OR020	Adequate	1	0.0	None		
OR030									
	117	Durham	OR030	Adequate	1	0.0	None		
Parson's Creek									
PC010									
	40	Rye	PC010	Adequate	1	0.0	None		
PC020									
	40	Rye	PC010	Adequate	1	0.0	None		
	63	Rye	PC020	Inadequate	2	8.4	Widen	$500	$60
PC030									
	40	Rye	PC010	Adequate	1	0.0	None		
	64	Rye	PC030	Adequate	2	0.0	None		
PC040									
	40	Rye	PC010	Adequate	1	0.0	None		
	41	Rye	PC040	Inadequate	2	4.8	Remove	$3,200	$667
PC050									
	40	Rye	PC010	Adequate	1	0.0	None		
	41	Rye	PC040	Inadequate	2	4.8	Remove	$3,200	$667
	42	Rye	PC050	Inadequate	3	63.1	Concrete Box	$73,400	$1,163
						67.9		**$76,600**	**$1,128**
PC060									
	40	Rye	PC010	Inadequate	1	77.4	Dredge	$30,000	$388

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
	41	Rye	PC040	Inadequate	2	4.8	Remove	$3,200	$667
	42	Rye	PC050	Inadequate	3	63.1	Concrete Box	$73,400	$1,163
	46	Rye	PC060	Inadequate	4	5.6	Concrete Box	$23,600	$4,214
						150.9		**$130,200**	**$863**
PC070									
	40	Rye	PC010	Inadequate	1	77.4	Dredge	$30,000	$388
	41	Rye	PC040	Inadequate	2	4.8	Remove	$3,200	$667
	42	Rye	PC050	Inadequate	3	63.1	Concrete Box	$73,400	$1,163
	45	Rye	PC070	Inadequate	4	4.2	Concrete Box	$19,300	$4,595
						149.5		**$125,900**	**$842**
PC080									
	40	Rye	PC010	Inadequate	1	77.4	Dredge	$30,000	$388
	41	Rye	PC040	Inadequate	2	4.8	Remove	$3,200	$667
	42	Rye	PC050	Inadequate	3	63.1	Concrete Box	$73,400	$1,163
	44	Rye	PC080	Inadequate	4	3.0	Concrete Box	$23,200	$7,733
						148.3		**$129,800**	**$875**
PC090									
	40	Rye	PC010	Inadequate	1	77.4	Dredge	$30,000	$388
	41	Rye	PC040	Inadequate	2	4.8	Remove	$3,200	$667
	42	Rye	PC050	Inadequate	3	63.1	Concrete Box	$73,400	$1,163
	43	Rye	PC090	Inadequate	4	3.0	Concrete Box	$27,400	$9,133
						148.3		**$134,000**	**$904**
Paul Brook									
PB010									
	122	Newington	PB010	Adequate	1	0.0	None		

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
Philbrick Pond									
PP010									
	26	N Hampton	PP010	Inadequate	1	0.1	RCP	$115,000	
PP020									
	26	N Hampton	PP010	Inadequate	1	0.1	RCP	$115,000	
	27	N Hampton	PP020	Inadequate	2	33.5	RCP	$15,000	$448
						33.6		**$130,000**	**$3,869**
Portsmouth Harbor									
PH010									
	51	New Castle	PH010	Inadequate	1	1.7	Concrete Box	$17,700	$10,412
PH020									
	51	New Castle	PH010	Inadequate	1	4.5	Concrete Box	$17,700	$3,933
	52	New Castle	PH020	Adequate	2	0.0	None		
PH030									
	50	New Castle	PH030	Inadequate	1	0.0	Not Practical		
PH040									
	49	New Castle	PH040	Inadequate	1	4.7	Concrete Box	$17,200	$3,660
PH050									
	49	New Castle	PH040	Inadequate	1	4.7	Concrete Box	$17,200	$3,660
	56	New Castle	PH050	Inadequate	2	5.0	Concrete Box/2	$125,100	$25,020
						9.7		**$142,300**	**$14,670**
PH060									
	49	New Castle	PH040	Inadequate	1	4.7	Concrete Box	$17,200	$3,660

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
	56	New Castle	PH050	Inadequate	2	9.9	Concrete Box/2	$125,100	$12,636
	55	New Castle	PH060	Adequate	3	0.0	None		
						14.6		**$142,300**	**$9,747**
PH070									
	54	New Castle	PH070	Adequate	1	0.0	None		
Rye Harbor									
RH010									
	37	Rye	RH010	Adequate	1	0.0	None		
RH020									
	37	Rye	RH010	Adequate	1	0.0	None		
	38	Rye	RH020	Inadequate	2	1.0	CMP/2	$600	$600
RH030									
	37	Rye	RH010	Adequate	1	0.0	None		
	35	Rye	RH030	Inadequate	2	9.4	Concrete Box	$41,400	$4,404
RH040									
	37	Rye	RH010	Adequate	1	0.0	None		
	35	Rye	RH030	Inadequate	2	9.4	Concrete Box	$41,400	$4,404
	34	Rye	RH040	Inadequate	3	13.1	Concrete Box	$16,600	$1,267
						22.5		**$58,000**	**$2,578**
RH050									
	37	Rye	RH010	Adequate	1	0.0	None		
	35	Rye	RH030	Inadequate	2	9.4	Concrete Box	$41,400	$4,404
	34	Rye	RH040	Inadequate	3	13.1	Concrete Box	$16,600	$1,267
	33	Rye	RH050	Inadequate	4	10.6	CMP	$3,900	$368
						33.1		**$61,900**	**$1,870**

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
RH060									
	37	Rye	RH010	Adequate	1	0.0	None		
	35	Rye	RH030	Inadequate	2	9.4	Concrete Box	$41,400	$4,404
	34	Rye	RH040	Inadequate	3	13.1	Concrete Box	$16,600	$1,267
	33	Rye	RH050	Inadequate	4	10.6	CMP	$3,900	$368
	32	Rye	RH060	Inadequate	5	4.1	RCP	$7,300	$1,780
						37.2		**$69,200**	**$1,860**
RH070									
	37	Rye	RH010	Adequate	1	0.0	None		
	36	Rye	RH070	Inadequate	2	5.1	CMP	$6,800	$1,333
RH080									
	37	Rye	RH010	Adequate	1	0.0	None		
	62	Rye	RH080	Inadequate	2	4.3	RCP	$6,200	$1,442
RH090									
	39	Rye	RH090	Adequate	1	0.0	None		
Sagamore Creek									
SC010									
	59	Rye	SC010	Inadequate	1	9.0	RCP	$14,000	$1,556
SC020									
	53	Portsmouth	SC020	Adequate	1	0.0	None		
Shaw Brook									
SB010									
	104	Greenland	SB010	Adequate	1	0.0	None		

Table 2 Adequacy of Tidal Inlets To New Hampshire Salt Marshes

Evaluation Unit (EU)	Restriction Number	Town	EU U/S of Restriction	Inlet Adequacy	Order to Restore	Restorable Acres	Corrective Action	Restoration Cost	Unit Cost
Squamscott River									
SR010									
	106	Stratham	SR010	Inadequate	1	5.7	Further Study		
SR020									
	107	Stratham	SR020	Adequate	1	0.0	None		
SR030									
	108	Stratham	SR030	Inadequate	1	4.6	RCP	$4,600	$1,000
SR040									
	109	Stratham	SR040	Adequate	1	0.0	None		
SR050									
	110	Stratham	SR050	Adequate	1	0.0	None		
SR060									
	111	Stratham	SR060	Adequate	1	0.0	None		
SR070									
	112	Stratham	SR070	Adequate	1	0.0	None		
SR080									
	121	Stratham	SR080	Adequate	1	0.0	None		
SR090									
	113	Newfields	SR090	Adequate	1	0.0	None		
Winnicut River									
WR010									
	102	Greenland	WR010	Adequate	1	0.0	None		
WR020									
	103	Greenland	WR020	Adequate	1	0.0	None		

4.4 Program Opportunities and Implementation Potential

There are many program opportunities available to provide assistance to towns and individuals wishing to improve and restore the quality of New Hampshire's salt marshes. Many stem from the numerous federal and state laws and regulations that have been enacted over the last 20 years.

The New Hampshire Coastal Program, which partially funded the recent Awcomin marsh restoration, should continue to be a primary source of assistance for these efforts. This program receives federal funding through the National Oceanic and Atmospheric Administration (NOAA). The New Hampshire Office of State Planning administers these funds. Grant money is available to fund qualified projects, such as salt marsh restoration, in coastal communities. The New Hampshire Department of Fish and Game may also be a source of funds for marsh restoration. Fish and Game has several programs related to wildlife management in addition to connections with sportsman's groups willing to fund marsh restoration activities.

The U.S. Fish and Wildlife Service should also continue to be a source of assistance. Its "Partners For Wildlife" program can provide technical assistance and funding to restore salt marshes. Removal of fill, control of phragmites, culvert replacement and open marsh water management are examples of restoration techniques that can be funded through this program. The Coastal Wetlands Planning, Protection and Restoration Act can also provide grants for wetland restoration. Other federal agencies such as the Environmental Protection Agency, Department of Agriculture and Corps of Engineers may also provide both planning and implementation assistance.

The Federal Highway Administration through its programs authorized by the Intermodal Surface Transportation Efficiency Act can contribute highway funds for wetland conservation and mitigation efforts. These funds, administered by the New Hampshire Department of Transportation, are for locally sponsored projects in conjunction with the Regional Planning Commissions.

The diversity of programs available appears to be adequate to fund all but perhaps the most expensive restoration efforts given a longer term program perspective.

4.5 Recommendations

The study sponsors should meet individually with the towns in the study area to discuss the findings of this study. The towns need to evaluate the feasibility of, and support for, the restoration of each site in their jurisdiction. Projects with local support should be categorized into those that the town can carry out on their own and those that, because of expense or complexity, may require an interagency effort. Those with no support should be deleted from active consideration, with possible reconsideration at some future date.

The study sponsors also need to meet with the federal and state agencies responsible for the potential implementation programs reviewed in Section 4.4. Those restoration projects, with strong local support but requiring additional planning and/or installation cost sharing, should be reviewed and decisions made concerning priorities for assistance.

Significant accomplishments in salt marsh restoration, even over the long term, will require coordination at the local level. The Districts or the Regional Planning Agencies playing a coordinating role in the context of any long-term restoration effort could facilitate such coordination.

Because there is much yet to learn about the response of salt marsh ecosystems to restoration, and because it takes time for marshes to recover from the effects of tidal restriction, it is essential to monitor restoration sites over the long term. We suggest at a minimum that data be collected prior to the restoration project and in years 1, 5 and 10 after project completion. Minimal measurements should include data on water table depth and salinity, percent cover of plant species, and the extent of tidal flooding on spring and neap tides. Additional data would include measurements of plant species biomass, and fish abundance in marsh channels. Data should be collected both at the site being restored, and at a suitable reference site. The reference site is a healthy site selected to provide benchmarks against which to measure restoration success. These data allow assessment of the rate and extent of recovery achieved by the restoration project. In order for the data to be useful, considerable thought should be given to the number and location of samples collected, and the timing of sample collection with respect to season and tide. Examples of simple salt marsh monitoring methods and sampling designs are available from NRCS and the New Hampshire Coastal Program.

The restoration of salt marshes that have been significantly damaged by human activity will continue to be a challenge. Their scarcity in New Hampshire and the unique position that they occupy on the landscape, however, would seem to justify a significant amount of effort. Some of the marshes will be easy to restore, while others may have deteriorated beyond restoration potential. The brunt of the work will only be accomplished by the collective and dedicated efforts of local, state and federal organizations and individuals.

5.0 LIST OF PREPARERS

This report was prepared primarily by the NRCS New England Water Resources Planning Staff and the New Hampshire NRCS Technical Staff, both located in Durham, New Hampshire. Table 3, List of Preparers, below identifies and lists qualifications of those individuals who were directly responsible for providing significant input to the preparation of the report.

Table 3 - List of Preparers

Name	Title	Education	Experience
Alan R Ammann	Wildlife Biologist	Ph.D. - Animal Nutrition MSF - Forestry (Wildlife Ecology) BS - Zoology	Biologist, 15 years Soil Conservationist Certified Wildlife Biologist Professional Wetland

			Scientist
Dale R. Goodwin	Civil Engineer	BS - Civil Engineering	Civil Engineer, 27 yrs. Registered Professional Engineer
Lynn A. Howell	Public Affairs Specialist		Public Affairs Specialist, 6 yrs
John A. Mengers	Water Resources Planner		Water Resources Staff Leader, l4yrs. Water Resources Coordinator, 2 yrs. Engineer, 10 yrs. Registered Professional Engineer
John L. O'Neill	Agricultural Economist	BS Economics	Agricultural Economist, 22 yrs
Donald H. Richard	Cartographer/GIS Specialist	BS Geography	G1S Specialist, 3 yrs.
Gregory H. Smead	Civil Engineer	BS Civil Engineering	Civil Engineer, 27 yrs
George W. Stevens	Hydraulic Engineer	BS Agricultural Engineering	Hydraulic Engineer, 30 yrs.

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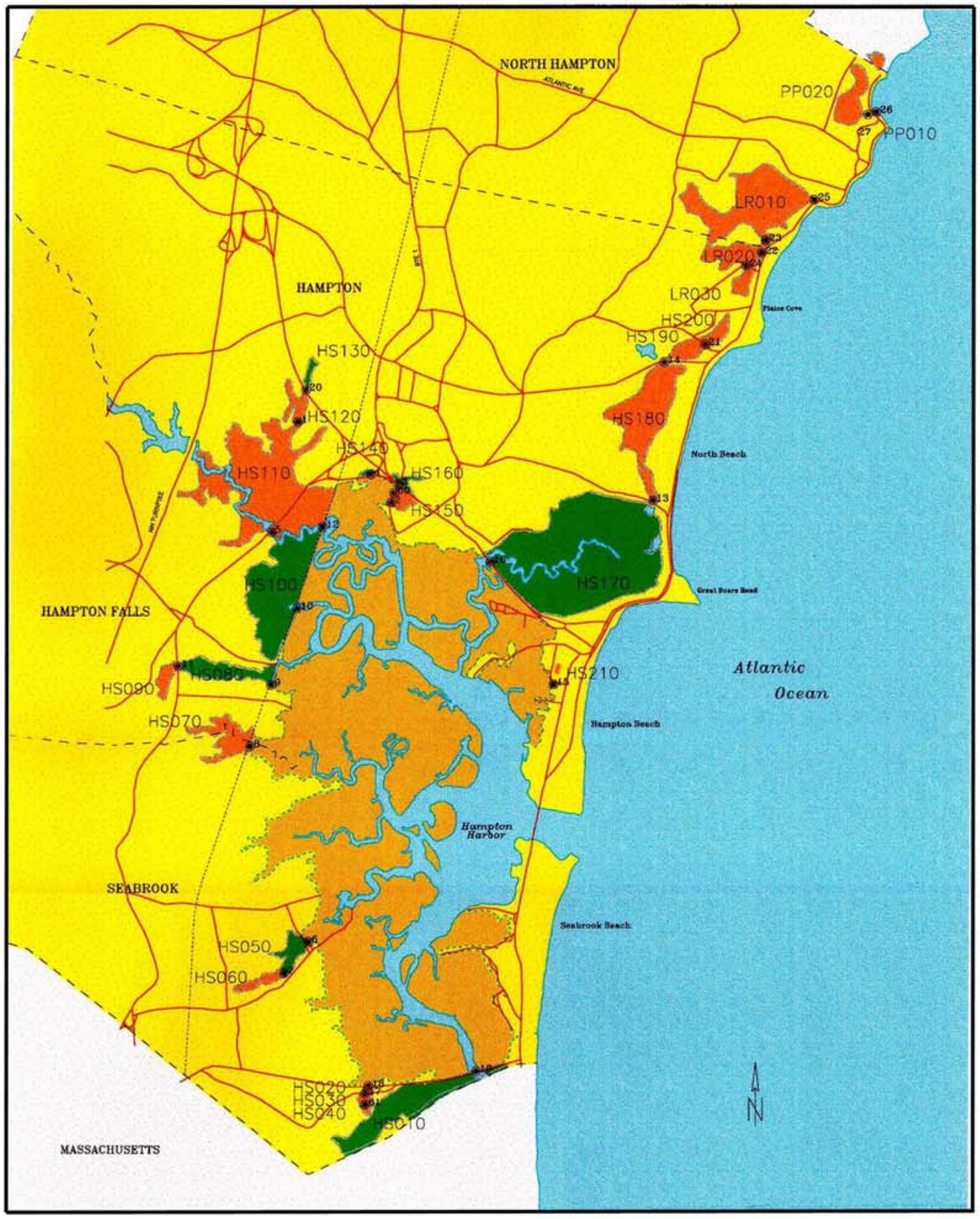
7.0 APPENDIX A – SALT MARSH MAPS (PLATES 1-5)

- Salt Marshes and Coastline derived from the National Cooperative Survey
- Maps produced using GRASS.MAPGEN software at the USDA Natural Resources Conservation Service, Durham, NH
- Color laser maps produced from scans of maps in first printing that were originally printed by Current Graphics Inc., Greenland, NH



SALT MARSHES AND TIDAL INLETS IN NORTH HAMPTON, HAMPTON, HAMPTON FALLS AND SEABROOK, NEW HAMPSHIRE

SALT MARSHES AND COASTLINE DERIVED FROM THE NATIONAL COOPERATIVE SOIL SURVEY
MAP PRODUCED USING GRASS/MAPGEN SOFTWARE AT THE SOIL CONSERVATION SERVICE OFFICE IN DURHAM, NH

USDA, SOIL CONSERVATION SERVICE

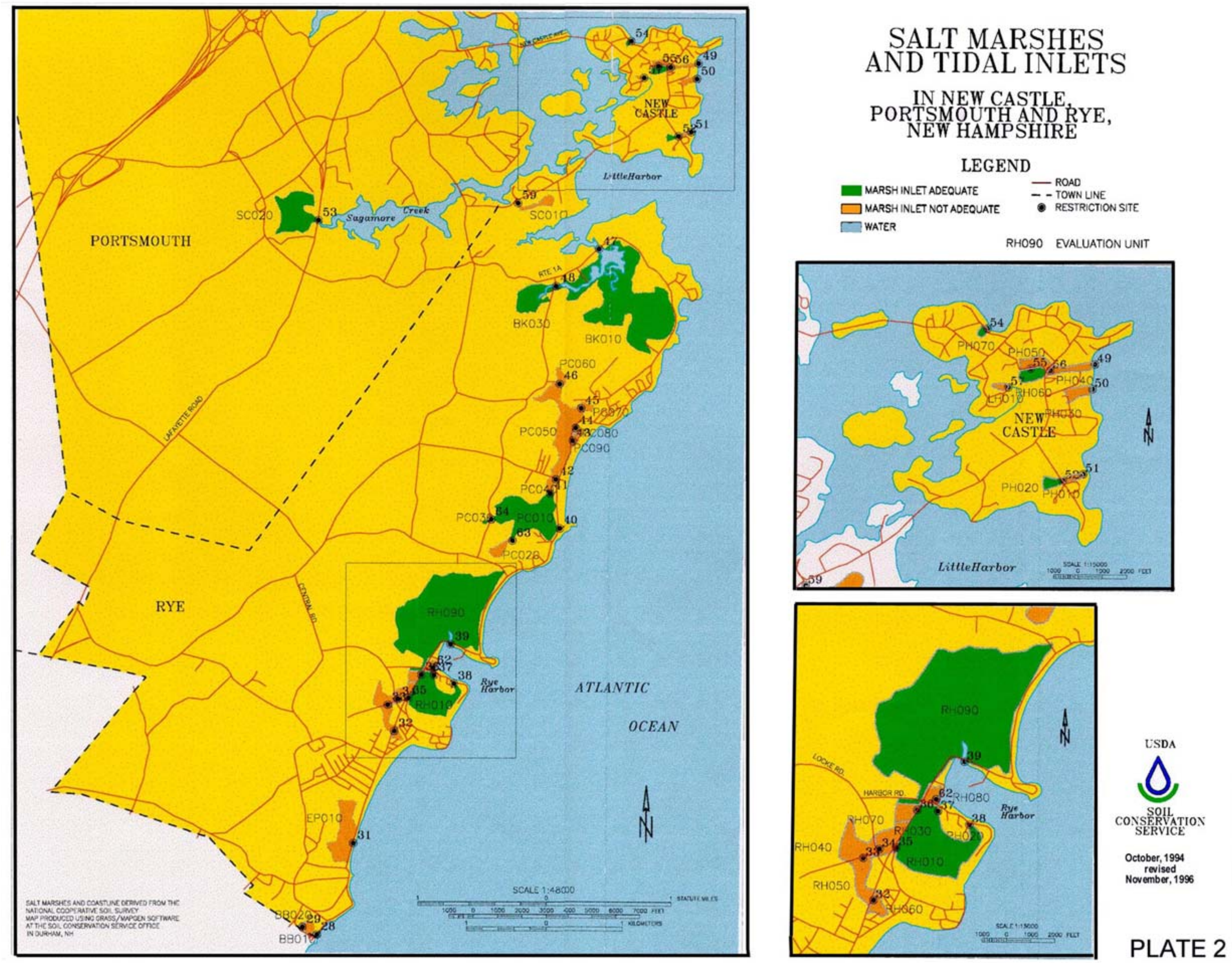
SCALE 1:48000

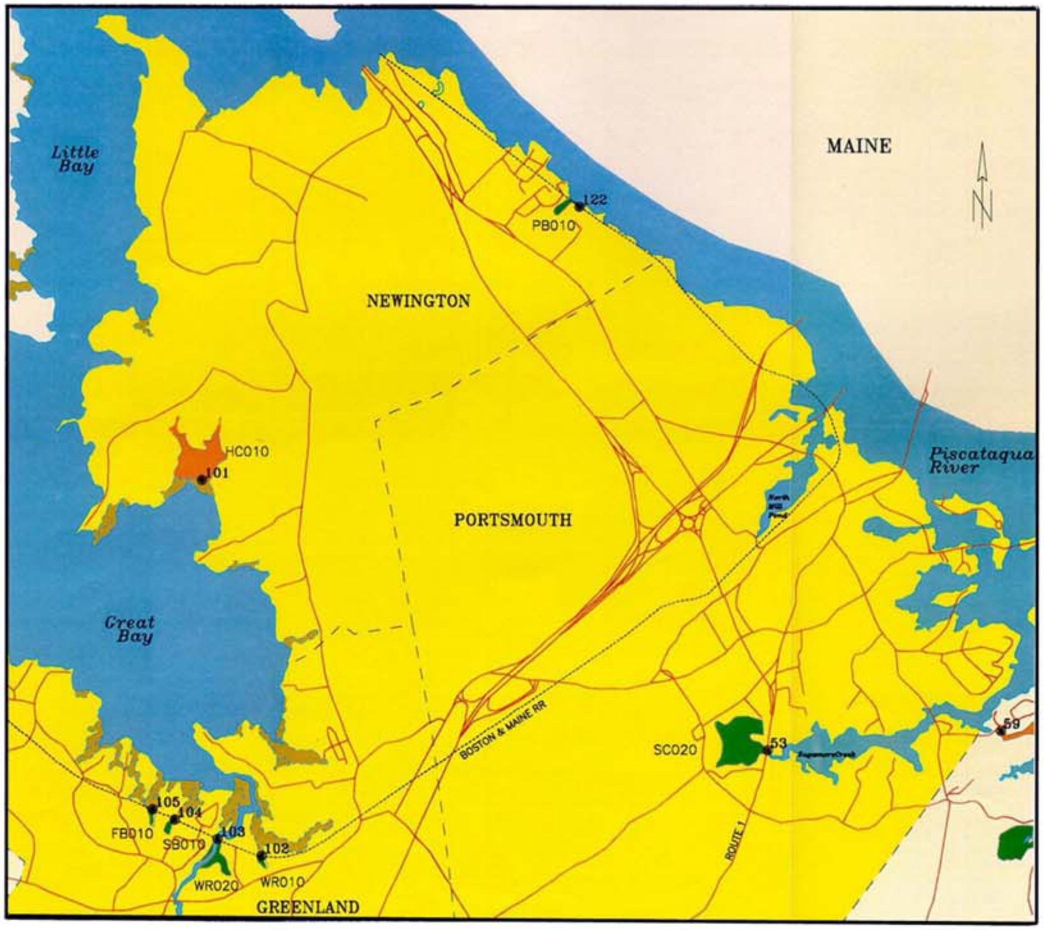
LEGEND

- MARSH INLET ADEQUATE
- MARSH INLET NOT ADEQUATE
- UNAFFECTED SALT MARSH
- WATER
- ROAD
- RAILROAD
- TOWN LINE
- ● RESTRICTION SITE
- HS180 EVALUATION UNIT

OCTOBER, 1994
REVISED NOVEMBER, 1996

PLATE 1


SALT MARSHES
AND TIDAL INLETS
IN NEW CASTLE,
PORTSMOUTH AND RYE,
NEW HAMPSHIRE
LEGEND
MARSH INLET ADEQUATE
MARSH INLET NOT ADEQUATE
WATER
ROAD
TOWN LINE
RESTRICTION SITE
RH090 EVALUATION UNIT
PORTSMOUTH
RYE
NEW CASTLE
ATLANTIC
OCEAN
Sagamore Creek
Little Harbor
Rye Harbor
LAFAYETTE ROAD
CENTRAL RD.
RTE 1A
LOCKE RD.
HARBOR RD.
SC020
SC010
BK030
BK010
PC060
PC050
PC090
PC010
PC020
EP010
RH090
RH010
RH080
RH070
RH030
RH040
RH050
PH070
PH050
PH040
PH020
SCALE 1:48000
SALT MARSHES AND COASTLINE DERIVED FROM THE NATIONAL COOPERATIVE SOIL SURVEY
MAP PRODUCED USING GRASS/MAPGEN SOFTWARE AT THE SOIL CONSERVATION SERVICE OFFICE IN DURHAM, NH
USDA
SOIL CONSERVATION SERVICE
October, 1994
revised
November, 1996
PLATE 2



SALT MARSHES AND TIDAL INLETS

IN GREENLAND, NEWINGTON AND PORTSMOUTH, NEW HAMPSHIRE

LEGEND

- MARSH INLET ADEQUATE
- MARSH INLET NOT ADEQUATE
- UNAFFECTED SALT MARSH
- WATER
- ROAD
- RAILROAD
- TOWN LINE
- ● RESTRICTION SITE
- HC010 EVALUATION UNIT

STATUTE MILES
FEET
KILOMETERS

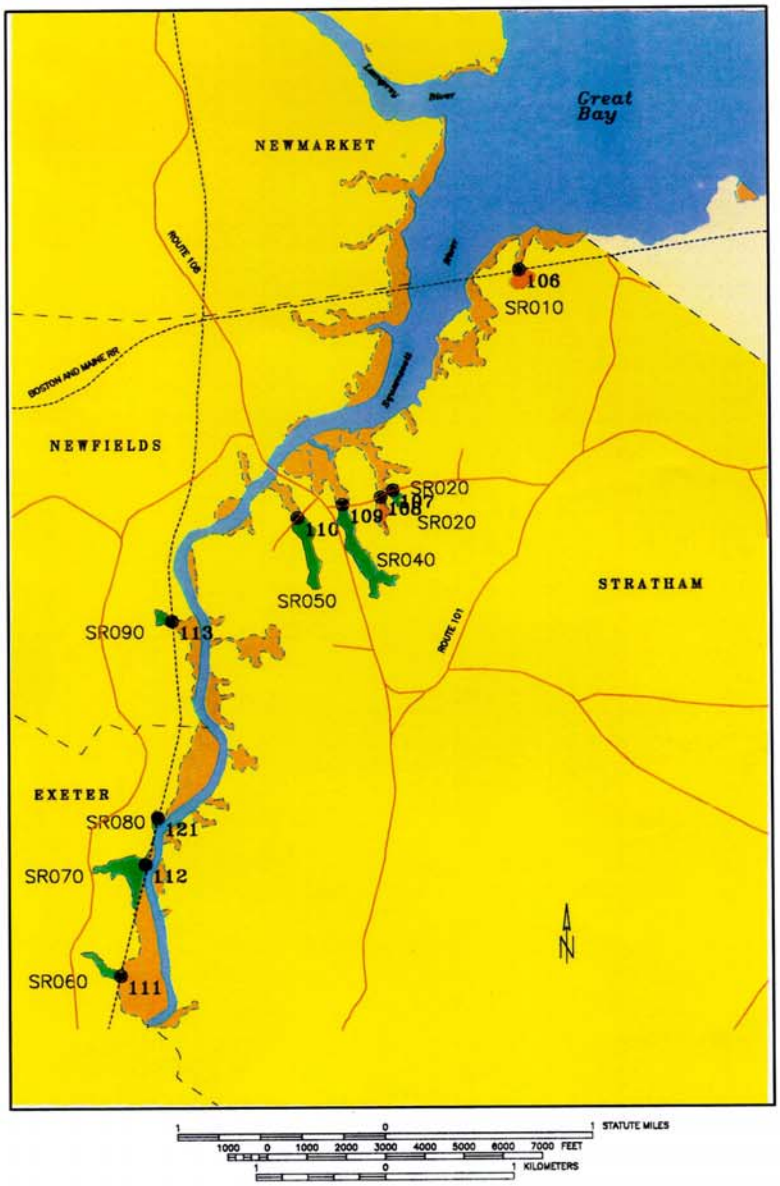
SCALE 1:48000

SALT MARSHES AND COASTLINE DERIVED FROM THE NATIONAL COOPERATIVE SOIL SURVEY
MAP PRODUCED USING GRASS/MAPGEN SOFTWARE AT THE SOIL CONSERVATION SERVICE OFFICE IN DURHAM, NH

USDA, SOIL CONSERVATION SERVICE

OCTOBER 1994

PLATE 3



SCALE 1:48000

USDA, SOIL CONSERVATION SERVICE

OCTOBER 1994

SALT MARSHES AND TIDAL INLETS

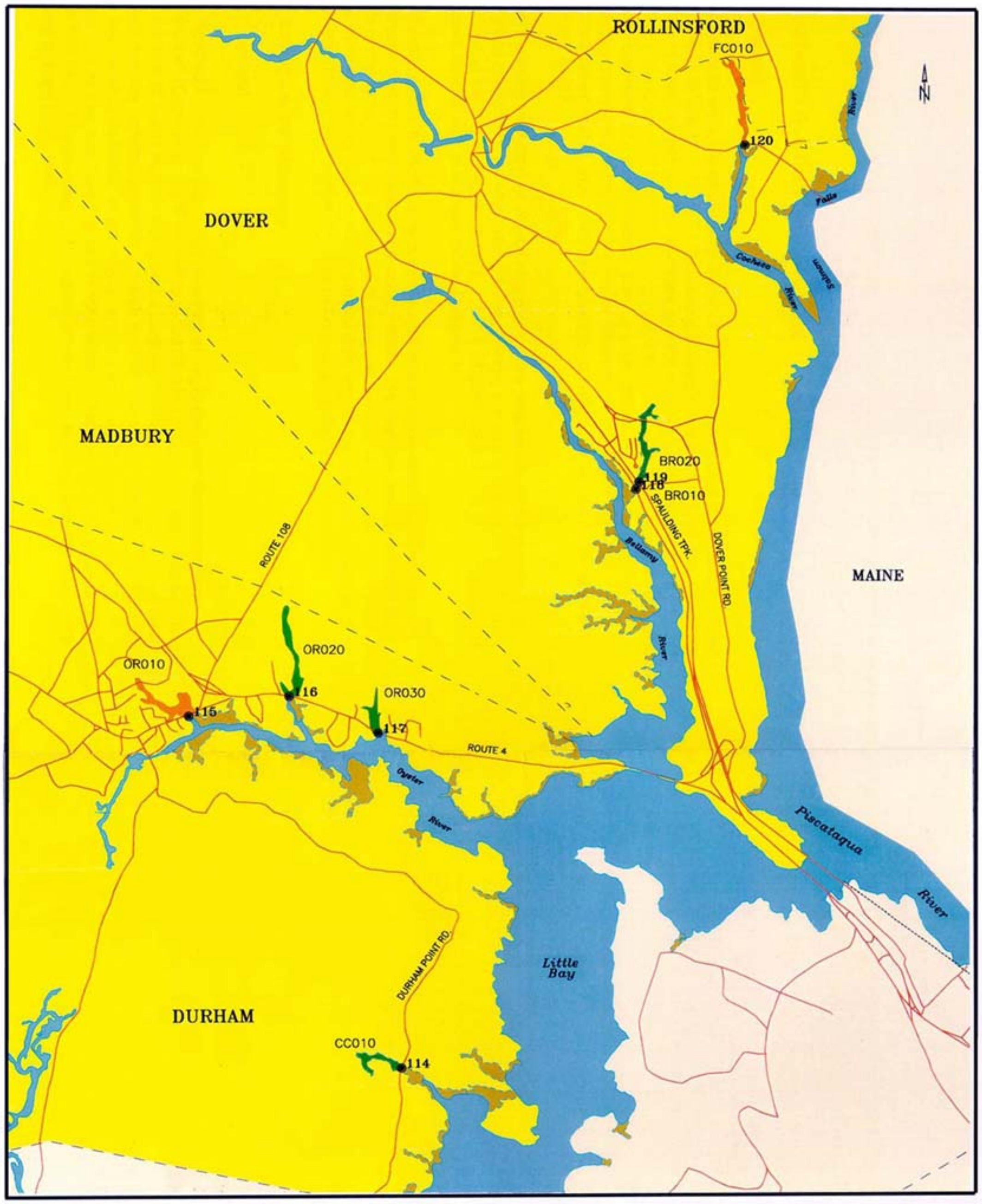
IN EXETER, NEWFIELDS, NEWMARKET AND STRATHAM, NEW HAMPSHIRE

LEGEND

- MARSH INLET ADEQUATE
- MARSH INLET NOT ADEQUATE
- UNAFFECTED SALT MARSH
- WATER
- ROAD
- RAILROAD
- TOWN LINE
- RESTRICTION SITE
- SR020 EVALUATION UNIT

SALT MARSHES AND COASTLINE DERIVED FROM THE NATIONAL COOPERATIVE SOIL SURVEY
MAP PRODUCED USING GRASS/MAPGEN SOFTWARE AT THE SOIL CONSERVATION SERVICE OFFICE IN DURHAM, NH

PLATE 4



SALT MARSHES AND TIDAL INLETS IN DOVER, DURHAM, MADBURY AND ROLLINSFORD, NEW HAMPSHIRE

SALT MARSHES AND COASTLINE DERIVED FROM THE

SCALE 1:48000

1 0 1 STATUTE MILES

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETERS

LEGEND

- MARSH INLET ADEQUATE
- MARSH INLET NOT ADEQUATE
- UNAFFECTED SALT MARSH
- WATER
- ROAD
- RAILROAD

8.0 APPENDIX B – STUDY METHODOLOGY

8.1 General

Potential sites were identified using the latest NRCS soil survey data for Rockingham and Strafford Counties, the USGS 71/2 minute quadrangle maps, the 1974 Soil Survey of New Hampshire Tidal Marshes, and the mapping associated with the Phase 1 Report of the Coastal Wetlands Mapping program, New Hampshire. All accessible sites located upstream of a road, railroad, dam, or other obstruction were field visited to determine the degree of impairment and/or obstruction. Initial data collected included the estimated size of both the opening and marsh as well as an assessment of marsh health.

From the initial inventory, 84 marsh restrictions were selected for additional analysis. For these restrictions, an engineering survey relating the size of the opening(s) to the elevation of the marsh was conducted. A more detailed assessment of the intrusion of invasive species was also made for these marshes.

A simplistic hydraulic model evaluated the relationship between the size and depth of the marsh opening and the acreage of the marsh. The marshes were then rated (on a scale of one to ten) on the restrictiveness of their opening. These data were arrayed against the environmental data and 50 marshes were selected for both restoration cost analyses and economic and social impact determination.

8.2 Ecological Investigations

8.2.1 General

The “Method for the Evaluation and Inventory of Vegetated Tidal Marshes in New Hampshire” (Cook et al. 1993) describes a classification scheme for salt marshes. In this scheme all marshes associated with a particular opening to the ocean, Great Bay, or tidal river are considered part of a marsh system. Each marsh system is subdivided into evaluation units based on boundaries created by roads, railroads or other restrictions to tidal flow (see Figure 3 in main report). That classification scheme has been followed in this inventory. System names are taken primarily from the tidal rivers flowing through the system.

For example, the Parson’s Creek system includes all of the present and former salt marshes associated with Parson’s Creek. The evaluation units are given an identifier based on the initials of the stream combined with a number (e.g. P010, P020, P030, etc.).

8.2.2 Plant Community Status

Field visits were made to all of the evaluation units identified in the inventory to obtain an estimate of the current status of the plant community. Specifically the following information was obtained:

1. the type of plant community present in the present or former high marsh (e.g. salt marsh, brackish marsh, open fresh water, etc.);
2. a visual estimate of the percentage of the present or former high marsh occupied (percent areal coverage) by invasive plants, specifically common reed (Phragmites australis), narrow leaf cattail (*Typha angustifolia*), and purple loosestrife (Lythrum salicaria);
3. the predicted trend in the present or former high marsh (e.g. continued salt marsh, brackish marsh with increasing invasives, fresh marsh with invasives continue to dominate, etc.);
4. the dominant surrounding land uses; and
5. relevant comments.

The determination of whether a particular marsh was salt marsh, brackish marsh, or fresh marsh was made primarily on the basis of the observable vegetation. In a few cases, this was confirmed by salinity measurements made with a Yellow Springs Instruments Model 33 conductivity/salinity meter.

The presence of a high percentage of invasive plant species in evaluation units with restricted flow (as determined by hydraulic modeling) was taken as confirmation that tidal flow had indeed been significantly restricted. In some cases, hydraulic analyses showed a restriction to be significant, but the plant community did not show a large percentage of invasive species. One possible explanation for this is an apparent time lag between the restriction of tidal flow and the appearance of invasive species. The Little River marsh has been severely restricted for at least 60 years, but portions of the marsh, which are now completely taken over by invasive species, were still functioning salt marsh as recently as 15 years ago (Frank Richardson, New Hampshire Wetlands Bureau, personal communications).

The same situation existed at Awcomin marsh at Rye Harbor before the current restoration effort. A portion of the marsh was diked and used as a spoil area for material dredged from the harbor in the early 1940's. A large part of this area remained vegetated with salt meadow cordgrass until about 10-15 years ago. From that time up until the restoration project began in 1991, phragmites had displaced cordgrass over a large area and it appeared that this invasion would continue until there was little or no viable salt marsh within the dike.

8.3 Hydrologic Investigations

Time and dollar limitations necessitated a shortcut approach for evaluating the relative flow restrictiveness of the 84 conduits affecting normal tidal movement within the New Hampshire salt marshes. Assumptions used in the analysis included:

1. a tidal depth over marsh necessary for viable salt marshes;
2. the length of time that the above depth is necessary; and
3. the datum basic to an efficient, yet adequate survey of the restrictive features.

The tidal height chosen, based on literature review, was the tide cycle necessary to cover unrestricted marshes to a depth of 0.33 feet. Based on surveys of marshes in Hampton and North Hampton, the elevation of such a tide would be 5.0 feet NGVD. Tides of at least this height can be expected 10 days out of a typical month.

The minimum frequency that a marsh needs to be visited by the chosen tide was set at seven days per month. The evaluation tide that occurs with this frequency has the shape of a typical tide (cosine function from mathematical analysis) and a peak height of 5.35 feet NGVD (7 days per month). Conduits that allow this evaluation tide to cover the inland marshes to 5.0 feet NGVD, were classified as nonrestrictive.

The conduit surveys were based on a datum of 0.33 feet below the tidal height necessary for nurturing a viable salt marsh. As a result, all surveys were referenced to the elevation of the salt marsh at the site being surveyed. The elevation of all salt marshes was assumed equal to that of the Hampton marshes (approximately 4.7 feet NGVD). This becomes unrealistic as one moves inland to Great Bay and its tributaries, but it allows the evaluation hydrograph used in this study to remain undiminished as it applied at these inland locations. One could assume that inland marshes are a function of the tidal action that nurtures them and thus, as tidal cycles dampen, marsh elevations should also decrease. It was easier, and probably as accurate, in that it is relative rather than absolute restrictiveness being evaluated.

The results were based on storage routing of the evaluation hydrograph through the combinations of marshes and restrictions that would be encountered as the ocean goes through one tidal cycle. For simplicity, the modeling procedure ignored fresh water inflow from upland sources and the evaluation of tides other than the evaluation tide. Prior to making modifications to conduits with substantial upland drainage areas and/or direct access to the ocean, a more detailed hydraulic analysis should be undertaken.

8.4 Engineering Investigations

The engineering field surveys were conducted during the fall and early winter of 1993 by an NRCS engineer and technician or by UNH students under the direction of an NRCS engineer. A standard self-leveling level, 25-foot fiberglass rod, and cloth tape were used to obtain all measurements. All elevation measurements were referenced to an assumed datum of the salt marsh. Information gathered included conduit type, size, length, invert elevations, multiple marsh elevations, invasive species elevations and locations, road elevations, and sketches showing the relative location of shots taken and basic conduit details. All data were recorded on a specially designed form to ensure uniformity and completeness. Because these data formed the basis of not only the engineering analyses but part of the database as well, they will be maintained at the same location (NRCS, Federal Building, Durham, NH 03824) as the database for future use.

8.5 Socioeconomic Investigations

The investigations associated with the evaluation discussed in section 3.5 were limited primarily to on-site visual observation of all structures located adjacent to the marshes. Conducting detailed engineering field surveys for the purpose of obtaining actual building elevation data was beyond the scope of this study.

In terms of the flood potential portion of the investigation, each restriction was given one of three ratings described as follows:

- high - there is a high probability that structures adjacent to the marsh will be flooded if a restriction is removed.

- medium - the potential for induced flooding can be ascertained only through detailed engineering field surveys.

- low - there are no structures located adjacent to the marsh or the structures present are so high in elevation that the risk of induced flooding is highly unlikely.

For the land rights ratings, three factors were used: flood potential, land owner/abutter objections, and the probability of structural relocation being required for construction associated with restriction removal. It should be noted, for example that, in all cases where a flood potential rating is high, the land rights rating is a 3; the reverse is not true. Land rights ratings are described as follows:

1. A low flood potential rating, with no or unknown land owner/abutter objections, or no building relocation required relative to restriction removal.
2. Same as 1 above, but with a medium flood potential rating.
3. A high flood potential rating and/or known land owner/abutter objections and/or restriction removal will necessitate the relocation of buildings.

A land rights rating of “1” is the preferred rating for a good restoration project.
The land rights ratings are also part of the database maintained at the NRCS, Federal Building, Durham, New Hampshire 03824.

8.6 Cost Estimates

The restoration cost represents the estimated direct cost of implementing the corrective action. Conceptual cost estimates were developed for each restriction. They are based on materials judged best for each site. Alternative measures could be considered in design.

These estimates are for comparison purposes in this study only. They include the cost of installing the recommended measure by a contractor. Costs could differ significantly if municipal or state crews do the work.

Estimates do not include the costs of engineering design, administration, land rights (easements, purchases, or induced flood damages), utility modifications or monitoring. Also not included, are any costs associated with marsh management. These could include ditching and channel enlargement to assure that tidal flows have access to all parts of the marsh.
