Great Bay National Estuarine Research Reserve Management Plan

National Estuarine Reserve Research System

Great Bay

U.S. Department of Commerce

Great Bay

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GREAT BAY
NATIONAL ESTUARINE RESEARCH RESERVE
MANAGEMENT PLAN

NATIONAL ESTUARINE RESERVE RESEARCH SYSTEM

State of New Hampshire
Judd Gregg, Governor

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Also, thanks to those individuals and local, state and federal government representatives who reviewed this document and offered valuable comments.

Foreward

This management plan serves as a source of information about the Great Bay Research Reserve and the various programs/activities planned for the site in the next few years. The Final Environmental Impact Statement (FEIS), prepared in February, 1988, established the boundary for the Reserve and outlined the general framework for the management plan. This document updates the resource information in the FEIS, expands on the proposed research and education activities/programs and summarizes the policies and regulations which will guide the management of the Reserve.

The management plan will be reviewed and updated periodically to ensure not only that it is meeting the overall goals and objectives of the Reserve but that it is achieving more effective management through the experience gained by present operations. As part of the review process, program evaluations by NOAA will serve to assess program achievements and future management and operation of the Reserve.

Readers of this document are encouraged to contribute any comments. For copies of the plan, you may contact:

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Great Bay Estuarine System

UNITED STATES DEPARTMENT OF COMMERCE
The Under Secretary for
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Washington, D.C. 20230

DESIGNATION OF THE GREAT BAY
NATIONAL ESTUARINE RESEARCH RESERVE

Consistent with the provisions of Section 315 of the Coastal Zone Management Act, 16 U.S.C. 1461, the State of New Hampshire has met the following conditions to establish the Great Bay National Estuarine Research Reserve.

1) Great Bay is a representative estuarine ecosystem that is suitable for long-term research and contributes to the biogeographical and typological balance of the National Estuarine Reserve Research System.

2) New Hampshire state law provides long-term protection for reserve resources to ensure a stable environment for research.

3) Designation of Great Bay as a reserve will serve to enhance public awareness and understanding of estuarine areas and provide suitable opportunities for public education and interpretation.

4) The State of New Hampshire has complied with the requirements of the regulations relating to designation of a National Estuarine Research Reserve.

Accordingly, I hereby designate the area of Great Bay as a National Estuarine Research Reserve, the boundaries of which are specified in the final management plan.

John A. Knauss
Under Secretary for Oceans
and Atmosphere

I. Executive Summary

The Great Bay National Estuarine Research Reserve (GBNERR) includes 4,471 acres of tidal waters and mudflats and approximately 48 miles of shoreline. Eight hundred acres of upland within the boundary represent the range of different resources/environments in the estuary, including salt marsh, tidal creeks, islands, woodlands and open fields. The water area includes all of Great Bay, the small channel from the Winnicut River and large ones from the Squamscott and Lamprey Rivers which meet in the center of the Bay to form a channel which connects to Little Bay at Adams Point. The Great Bay estuary derives its freshwater inflow from these rivers. It is a large, shallow estuarine embayment with an average depth of nine feet but deeper channels extend to around 58 feet. Approximately one half of Great Bay is exposed at low tide with most of the intertidal being mudflat. The tidal range of the estuarine system varies slightly from 6.5 feet at Dover Point to 6.8 feet at the mouth of the Squamscott River. Great Bay is typical of northern New England estuaries in having a variety of marine plant communities. Great Bay is dominated by intertidal mudflats with substantial areas of intertidal macroalgae. Within Great Bay, salt marsh occurs predominately as a thin fringe along the uppermost intertidal, although extensive salt marshes are present along the Squamscott River, Lubberland and Crommett Creeks.

The GBNERR is a cooperative federal/state program established by Congress to promote estuarine research, education and management. Presently, there are 17 Reserves nationwide. These areas are set aside for two important reasons; to provide opportunity for long-term research as a means to addressing coastal management issues and to serve as places where the general public can come to learn about estuaries. The preparation of a management plan is a key requirement of the Reserve in order to ensure that the research and education agendas which are being implemented address the overall goals of the Reserve. While traditional uses (fishing, boating . . .) within the Reserve will continue to be regulated by existing local, state and federal regulations, the Reserve can contribute to overall coastal decision-making through an effective research and education program.

The GBNERR is in a unique position to utilize existing facilities and programs by strengthening its ties with the University of New Hampshire's Jackson Lab and Sea Grant Extension Program. A major focus of the Reserve's education agenda in the first two years will be on education outreach activities in cooperation with UNH Sea Grant and the marine docents. Some programs/activities discussed in the management plan include expanding existing Sea Grant education programs, such as Sea Trek and the Floating Lab, to include information on the Reserve. Targeting of the Reserve's key land and water areas for specific interpretive activities and compiling a central resource directory are also priorities in the first year.

Research priorities will emphasize coordination of existing research efforts while providing direction in emphasizing the role of research in estuarine conservation and management. Some of the priorities described in the management plan include the establishment of a comprehensive monitoring program and synthesizing existing baseline information. Some of the projects which will be encouraged include preparation of a bathymetric chart for the estuary, conducting aerial surveys with other agencies to monitor shoreline vegetation and land use patterns, and

the investigation of the effects of both nutrient loading and sediment input.

The NH Department of Fish and Game, Marine Fisheries Division, will be responsible for the implementation of the majority of the components described in the plan. The Office of State Planning has continued to act as the lead agency in preparation of this plan and directing the easement acquisitions in the key land and water areas.

II. Introduction

A. Purpose and Scope of Plan

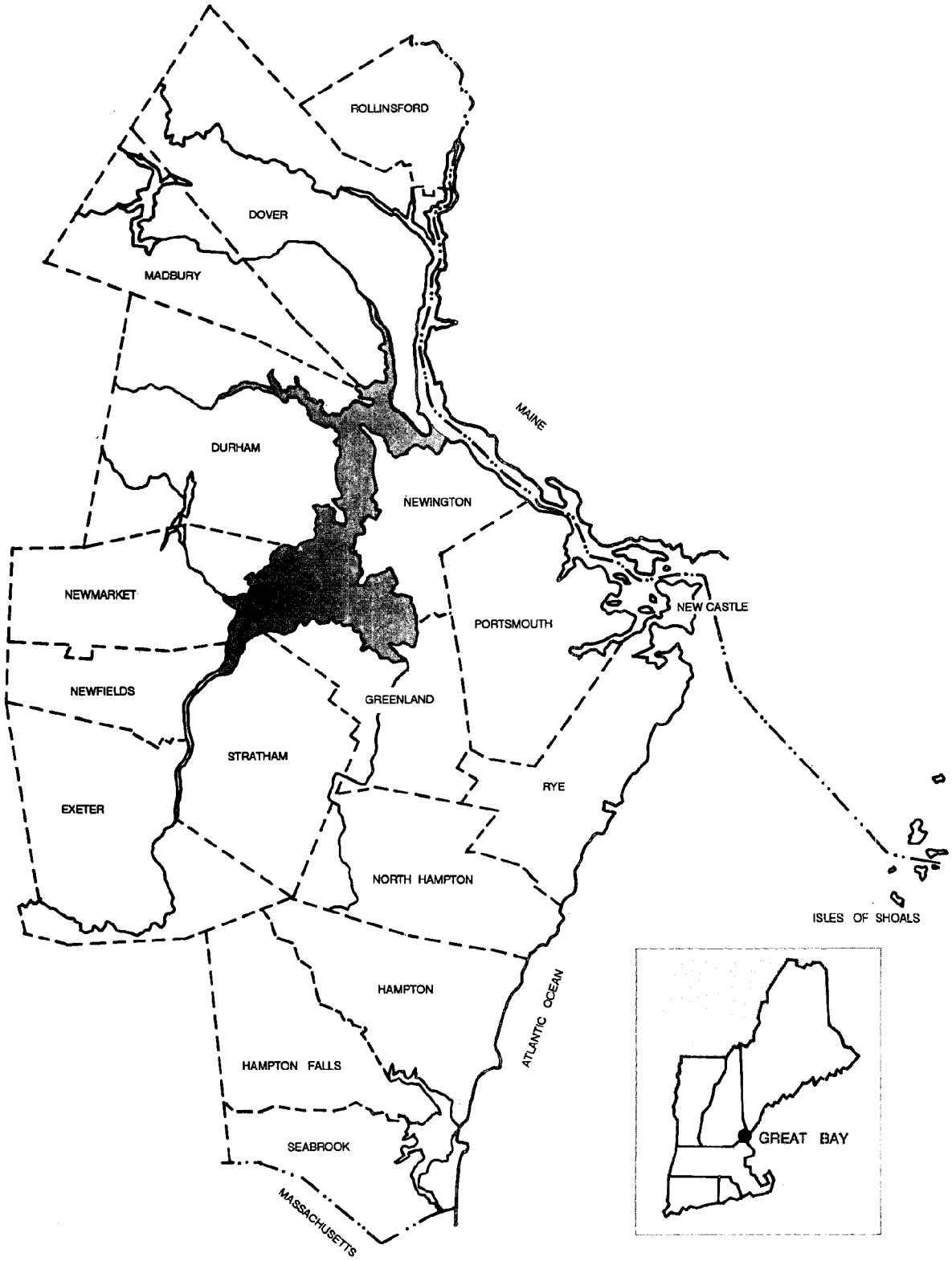
National estuarine reserves are areas set aside for long-term research, education, and interpretation through a cooperative Federal-state effort. A primary aim of these research and education projects is to provide information to the state that is useful for decision-makers concerning the management or protection of estuarine resources. The Great Bay National Estuarine Research Reserve (GBNERR) is one of four sites in New England - Waquoit Bay, Massachusetts, Narragansett Bay, Rhode Island, and Wells, Maine (Figure 1). General procedures for selecting, nominating, and administering these sites are presented in the National Estuarine Research Reserve Program Regulations (15 CFR Part 921). The preparation of a management plan is a key requirement of these regulations and a means of ensuring that planned activities and development within a reserve conform to the original intent of the program.

Beyond the federal requirement of a management plan, effective resource management relies on a plan to set a certain philosophy which guides its actions over time. The value of the written plan is that it translates this philosophy into specific strategies or courses of action for those involved in the management of the area. The overall philosophy of this plan is to guide the development of a coordinated program of research, education and resource protection within the Great Bay Research Reserve by balancing two key variables: Setting attainable goals and objectives and enhancing resource protection of the estuarine environment.

Flexibility in the design of the plan itself is necessary since management actions may be affected by staff experience, new data, emerging issues, funding ability, and other concerns. Certain assumptions have been made in the preparation of this plan, specifically in the research and education sections. Variable funding for staff and program development may affect specific aspects of Reserve operations/management. The phasing and the scope of programs/activities may need to be adjusted based on such unforeseeable developments. However, the goals and objectives of this plan will still serve as the barometer in measuring the plan's overall effectiveness and the State of New Hampshire's commitment to establish and manage the GBNERR.

Communication and coordination are important components of the implementation of the programs/activities described in the plan; communication through public education programs and activities and coordination between state and federal agencies with regulatory responsibilities in the estuarine system. While traditional uses (fishing, hunting, boating . .) within the Reserve will continue to be regulated by existing local and state laws and guided by policies incorporated into the Management Plan, establishment of the Research Reserve can provide key information to coastal decision-makers in two ways: Promoting research projects which address coastal issues and concerns and ensuring that these research results are available via public education efforts to those involved in resource/land use planning at the local, state and federal levels.

Figure 1. LOCATION OF GREAT BAY IN NEW ENGLAND



New Hampshire Office of State Planning

B. Background/History of Great Bay Management Plans

Since the early 1940's, the State has been concerned about the planning and management of the Great Bay area. In 1941, the New Hampshire Legislature adopted a "Joint Resolution to Make a Long Range Plan for the Development of Great Bay," and charged the State Planning and Development Commission (which has evolved into the Office of State Planning) to develop this plan. As a result, two reports were prepared for the Legislature, in 1943 and 1945, which contained recommendations for future development of the area. The final report, The Great Bay Plan, referred to the estuary as "the greatest undeveloped recreational resource in all of New England" and put forth a comprehensive plan for recreational, residential, commercial and industrial development. This ambitious plan included eight major components:

- make it more accessible;
- correct its pollution;
- improve its fisheries;
- check the erosion of its lands;
- determine the need for dams;
- improve its land use;
- provide an estimate of costs and stages of development; and
- establish an Authority charged with its [the plan's] effective development

Perhaps the most notable recommendation of this plan was for a system of three dams to be constructed in the estuary (one at the mouth of the Squamscott River, one at the mouth of the Bellamy River and one underneath the General Sullivan Bridge) to enhance the recreational value of Great and Little Bays and these two rivers. The plan also recommended State acquisition of over 3,000 acres for a State park, hotel and entertainment facilities at several locations around the Bay, and a regional Great Bay Authority to implement the various recommendations. The price tag: approximately $5 million over a 15 year period. The 1945 Plan was never carried out in its total scope. However, some of the specific recommendations - particularly for pollution control - have since been implemented.

In the 1960's, there was renewed interest in a development plan for Great Bay. In November of 1964, a wide range of State and local organizations sponsored a "Great Bay Day" at the University of New Hampshire for a public discussion of past studies and future development potential. In 1965, the New Hampshire Legislature passed two bills pertaining to Great Bay - one establishing an interim committee to study the feasibility of an inland waterway from Lake Winnipesaukee to Great Bay, and one requesting the State to develop a comprehensive development plan for the Great Bay area. As a part of the development plan, the Governor requested - and received - assistance from the Army Corps of Engineers to study navigational needs in the estuarine system. While these efforts did bring state and local interests together to discuss the future of the area, they did not result in any concrete action toward coordinated planning or management. As in the 1940's, the focus of these planning efforts was on the recreation potential of what was considered an underutilized resource.

The 1970's brought about another chapter in the State's planning efforts for Great Bay, this time with the emphasis on resource management. With the advent of the National Coastal Zone Management Program, New Hampshire began developing a plan for managing the State's coastal resources, including both the Atlantic Coast/Portsmouth Harbor area and the Great Bay estuarine system. This resulted in a Coastal Program for managing the recreational, residential, commercial, industrial and natural resources along the Atlantic coast. Extension of the Program to the Great Bay area has recently been approved by the federal Office of Ocean and Coastal Resource Management.

The State began exploring the possibility of including Great Bay as a part of the National Estuarine Reserve Research System in 1982. This cooperative federal-state program was established by Congress to promote estuarine research, education and management via a system of designated sites around the country. What separates the current planning programs

from the previous ones in the 1940's and 1950's is the emphasis on resource management as opposed to resource development. Both of the previous efforts focused on developing the recreational, residential, commercial and/or industrial potential of the Great Bay area. Establishing the Great Bay National Estuarine Research Reserve and extending the NH Coastal Program to include the estuary ensures cooperative program efforts to manage the natural, cultural, historic and aesthetic resources of Great Bay in an effort to improve coastal decision-making. This will result in those communities around the Bay becoming eligible for funding of coastal related projects which will increase the opportunities at the local level to better address coastal issues.

Proceeding with the process of establishing Great Bay as a National Estuarine Research Reserve and the writing of this management plan was based on a consensus by all involved parties that:

- Great Bay contains a unique variety of habitats and indigenous species;
- the boundary should not be so large as to be unmanageable nor involve sites so separated from one another that comprehensive management would be difficult;
- tidal waters to the limits of mean high tide are already under the jurisdiction of the state and the quality of the water is monitored on a regular basis;
- local ordinances and state authorities can provide oversight for any proposed future land development of upland areas; and
- several landowners are willing to convey easements to provide additional preservation of unique sites which will enhance the value of the GBNERR.

Local support for the proposed Reserve is very strong. Letters and comments from various organizations and groups expressing their support of the GBNERR were received at the State's public meeting on the draft of this plan held on February 17, 1989.

In addition, a significant project for the conservation of New Hampshire's resources has been advanced which complements the objectives of the Reserve. The Trust for New Hampshire Lands/Land Conservation Investment Program (LCIP) has been established as a private/public organization whose main purpose is to preserve the natural resource areas by means of direct purchase of lands and/or land rights throughout the state. Over 2 1/2 million dollars in private funding has been raised to launch the administration of the program and recent legislation provides $20 million dollars from the state's budget surplus to fund the program for two years. The 1989 Legislature is presently considering additional funding for the LCIP through bonding. Designation of the GBNERR will present unique opportunities to harness State/Federal efforts for the conservation of Great Bay as a unique resource. The Trust's land agent is coordinating acquisitions within the Great Bay area with Reserve staff to ensure that some of the properties within the Reserve's key land and water areas are the Trust's priority areas as well.

The GBNERR will provide New Hampshire with an opportunity to be a part of the national system while developing this plan for Great Bay that is suited to the particular opportunities and limitations of the area. The project provides federal/state matching funds for developing the management plan and for carrying out the research, education and resource protection components of the plan. It also provides access to information gathered in studying and managing other estuaries around the country, and it makes available to other states the information and experiences from Great Bay.

The following sections outline major components of the management plan to be implemented over the next few years. The guidelines suggested in this plan as the priorities for research and education will ensure that all actions undertaken over the next 5 years address important issues, meet Reserve goals and objectives or are a step towards achieving the long range protection of the area.

III. Management Background

A. The Site

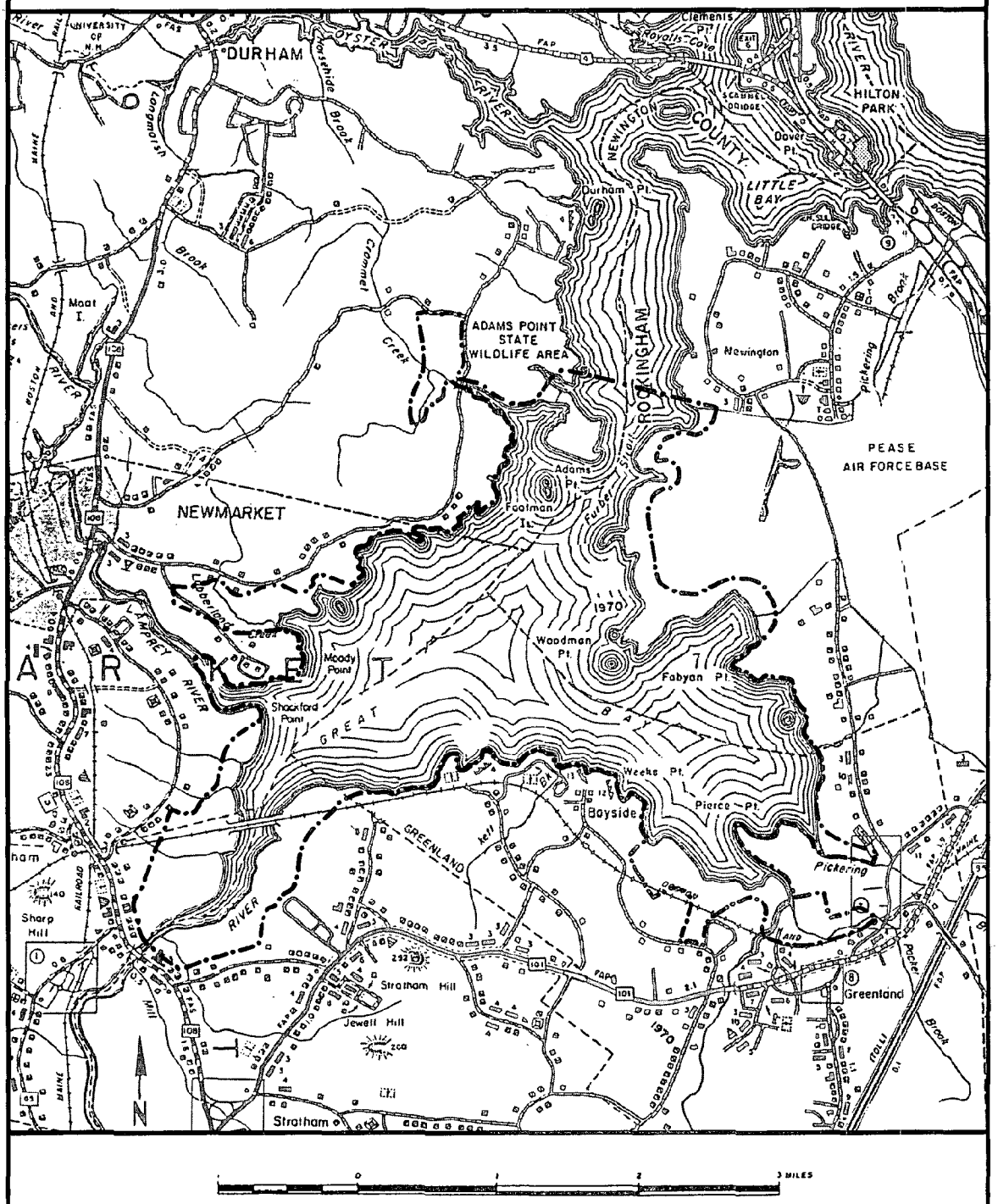
The boundary of the Reserve needs to provide long term protection of the key land and water areas, represent the diversity of flora, fauna and habitat found in the estuary, and give a focus to the research and education aspects of the project.

The GBNERR includes five selected key upland areas around the estuary, together with the tidal waters and mud flats of the estuary (Figure 2). This represents approximately 4,471 acres of tidal waters/mud flats and approximately 48 miles of shoreline. The water portion includes all of Great Bay, the small channel from the Winnicut River and large ones from the Squamscott and Lamprey Rivers which meet in the center of the Bay to form a main channel which connects to Little Bay at Adams Point. The shoreline and upland portions include sites in the towns around the estuary, ranging in size from 1 to 300 acres and in character from a wildlife management area owned by the State of New Hampshire to a pristine salt marsh along Lubberland Creek in Newmarket. The selection of the key land and water areas of the Great Bay Research Reserve was based on the following criteria:

- taken together, they represent the range of different resources and environments in the estuary (salt marsh, tidal creeks, islands, woodlands, open fields, etc.).
- the inclusion of some of the areas, notably the marsh sites, will provide long-term protection for important estuarine resource areas; and
- the different sites can provide opportunities for interpreting the many features of the estuary and for explaining how the estuarine system functions.

View of Great Bay from Adams Point

Figure 2: BOUNDARY
Great Bay National Estuarine Research Reserve



Key Land and Water Areas Analysis*

1. Adams Point/Crommet Creek

Town - Durham

Size and Ownership - ~ 300 acres: 82 acres State land (Fish and Game Department); 200 acres private land.

General Description - Approximately one third of this site is Adams Point, an open area of land managed as wildlife habitat by the Fish and Game Department. The site is comprised of 20 acres of field, 15 acres salt marsh and 45 acres of woodlands. The property was originally acquired as a waterfowl hunting and management area in 1961. Hunting of other wildlife species is not permitted. The University of New Hampshire has been granted a 99 year lease for 2 acres of land at the Point on which the Jackson Estuarine Laboratory was constructed. The remaining acres of the site is the adjacent Crommet Creek area, a very pristine tidal creek/marsh complex adjacent to an upland habitat of fields and woodlands.

Special Features - Adams Point offers panoramic views of both Little Bay and Great Bay. The area represents a range of habitats in a small area, including a rocky shore, mud flats, islands, salt marsh, tidal creek and upland fields/woodlands.

Also, the following rare plants and animals** have been identified along the shores of the Point and the Creek.

Adams Point

- Robust Knotweed (*Polygonum robustius*)
- Hairy Brome Grass (*Bromus pubescens*) - found at 5 sites in New Hampshire, one here at Adams Point.
- Lined Bulrush (*Scirpus pendulus*)- found at 5 sites in New Hampshire, 2 sites at Adams Point.
- Lens Sedge (*Carex lenticularis var albimontana*)

Crommet Creek

- Prolific Knotweed (*Polygonium prolificum*) - found at 3 sites in New Hampshire, all in the estuary.
- Salt marsh Gerardia (*Agalinus maritima*) - found at 12 sites in New Hampshire, only 1 in Reserve.
- Dwarf Glasswort (*Saliconia bigelovii*) - found at 8 sites in New Hampshire, only 1 in Reserve.
- Four-Toed Salamander (*Hemidactylium scutatum*)
- Hog-nosed Snake (*Heteroden platyrhinos*)

Primary Use/Benefit - For Adams Point, the continuing management of the area as wildlife habitat will be supported by inclusion as a Reserve site - general public access, which exists now, will be provided for in such a way that it does not interfere with the primary use and that people visiting the area learn about the wildlife management practices and needs - also, the continuing research efforts of Jackson Lab will be supported by the Great Bay Research Reserve. For Crommet Creek, the primary benefit of inclusion as a key area will be long-term protection for this important natural area. Approximately five acres of land adjacent to the Reserve have been donated by a landowner to the University of New Hampshire for the construction of an Outdoor Education Center. Some of the Reserve's educational activities may be coordinated with the University's Outdoor Education Program (see Education section).

2. Lubberland Creek/Moody Point

Town - Newmarket

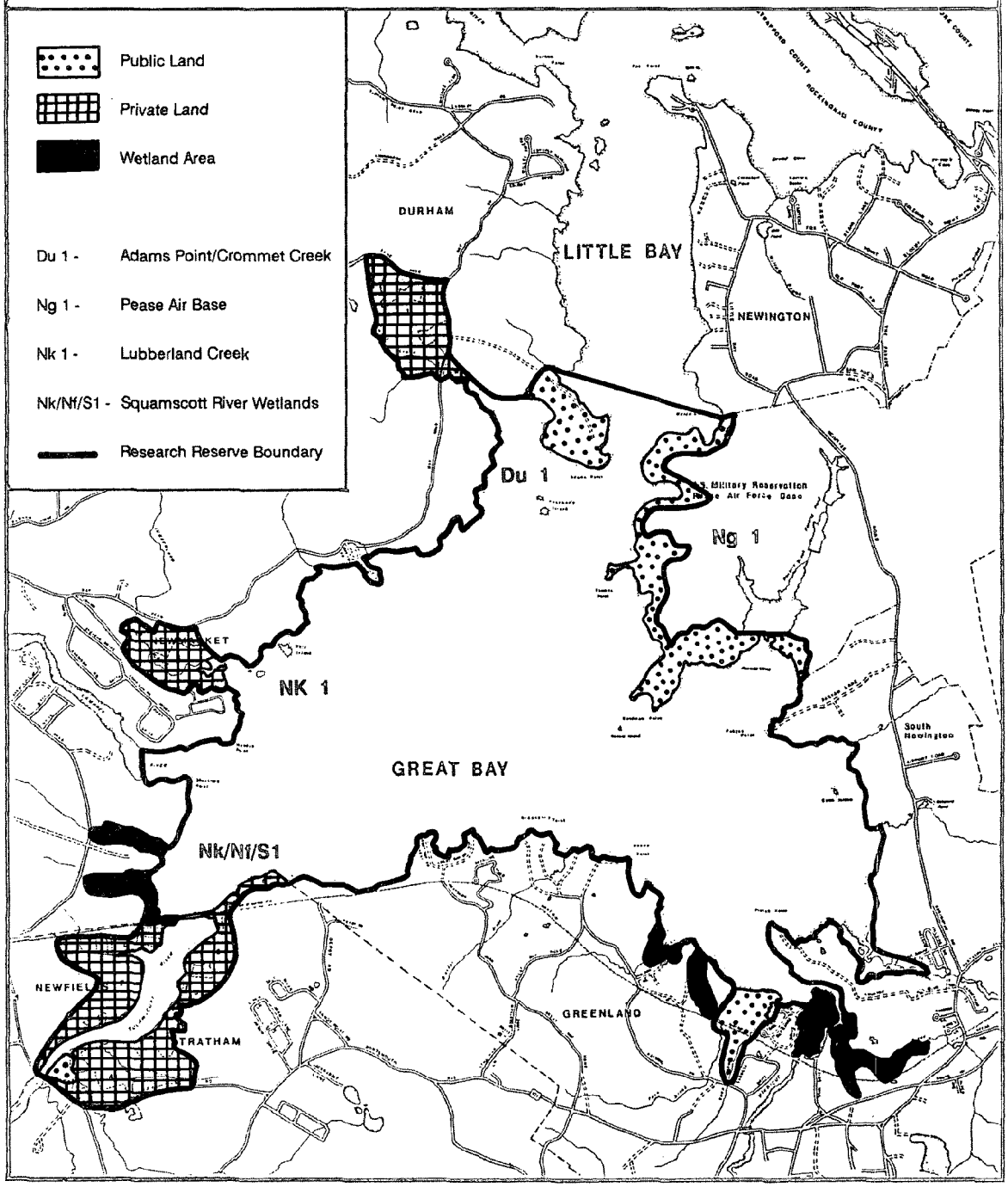
Size and Ownership - ~ 100 acres private land

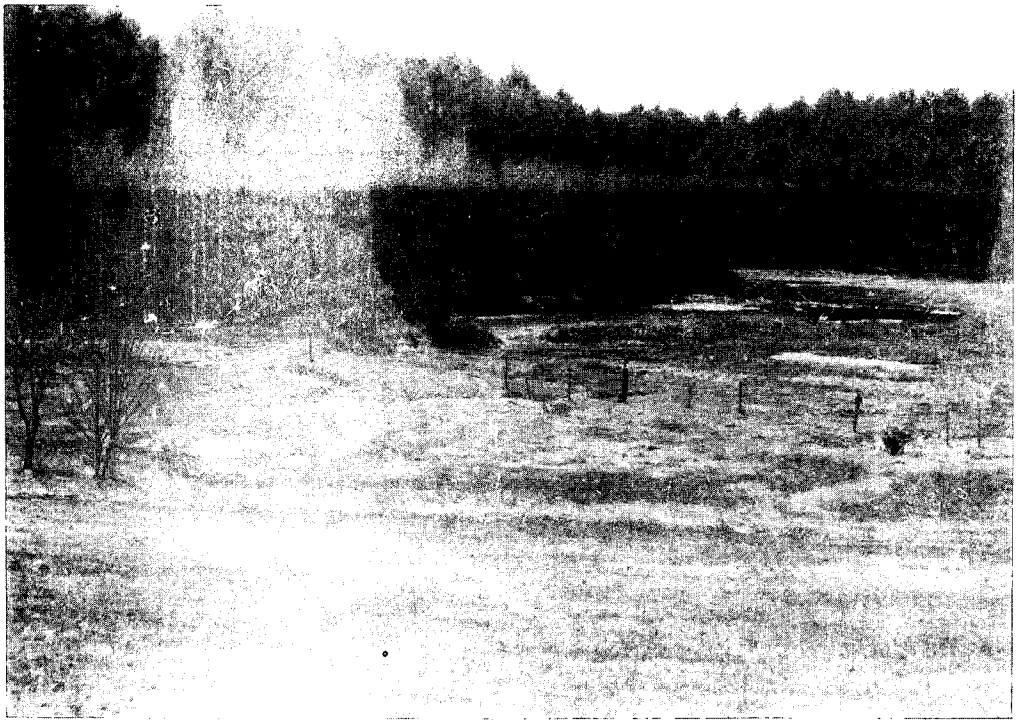
General Description - The marsh at the mouth of this tidal creek is one of the three largest stands of saltmarsh around the estuary, and with the adjacent open land is a very scenic area. The fringe marshes and stands of *Iva*

* See Figure 3 for location of key land and water areas

** Rare plants and animals identified by the Natural Heritage Inventory, NH Department of Resources and Economic Development.

Figure 3: GBNERR KEY LAND AND WATER AREAS

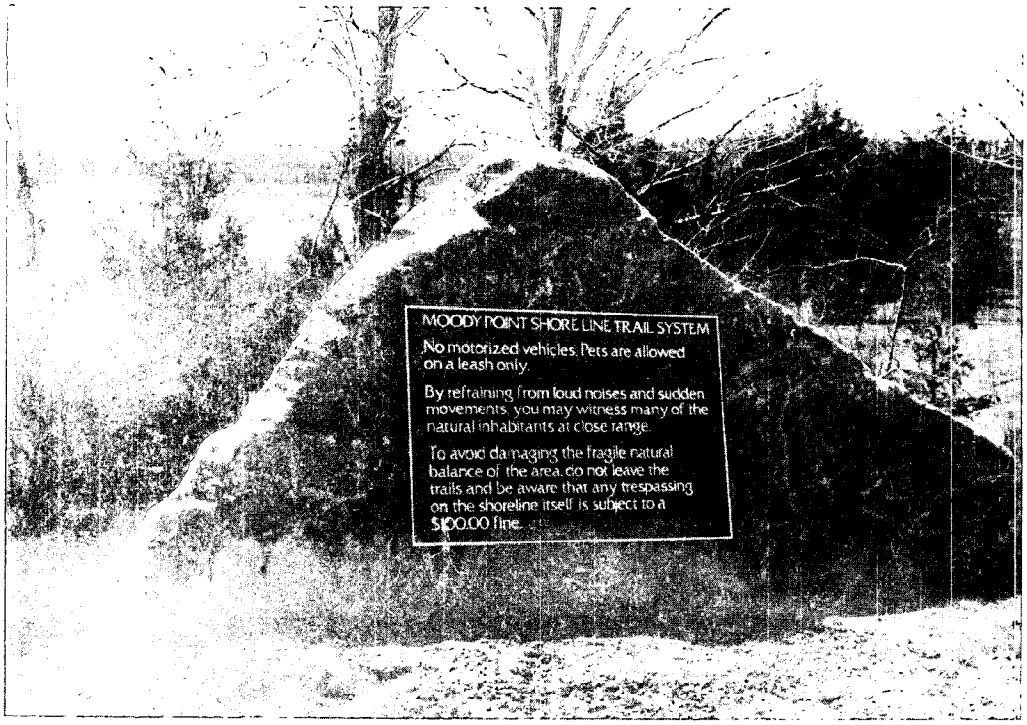




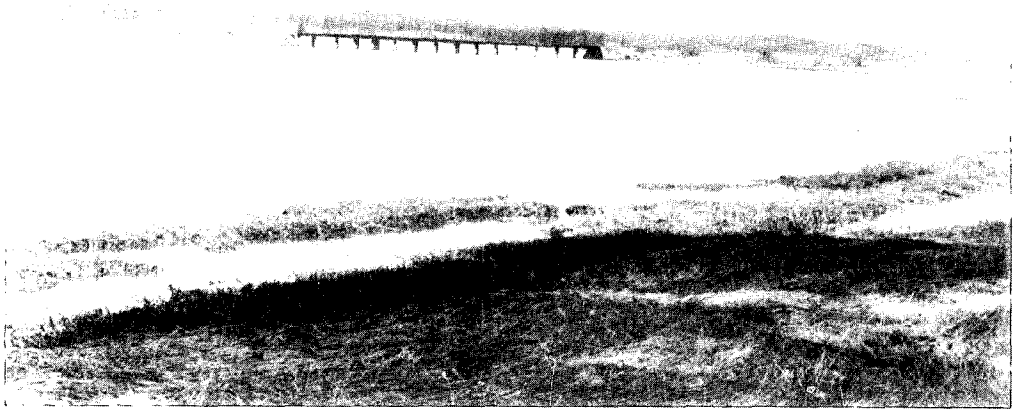
Crommett Creek from the Browne/Beckwith property

Lubberland Creek and adjacent saltmarsh

Shoreline of the Lubberland Creek/Moody Point key land and water area



Trail system sign along the perimeter of Lubberland Creek/Moody Point



Looking toward Great Bay and Boston and Maine railroad bridge from bank of the Squamscott River

Site of the University of New Hampshire's future Outdoor Education Center on property adjacent to GBNERR

Frutescens growing along the strand lines represent 80 - 85 percent of the total population of this plant in New Hampshire. There are two rare plants located along the shoreline:

- Marsh Elder (*Iva frutescens*) - see above comment
- Large Salt marsh Aster (*Aster tenufolius*) - only known site in New Hampshire is in the estuary. This site is the northern limit of its range.

Special Features - The site is very popular with many different species of waterfowl. The area has been identified by the Department of Fish and Game as important habitat. A great deal of research at this marsh has been conducted by Jackson Laboratory personnel.

Primary Use/Benefit - Including this site in the Reserve can provide long-term protection for one of the more important stands of salt marsh in the estuary.

A nature/interpretive trail has been designed by a private landowner at Moody Point.

3. Squamscott River Wetlands

Town(s) - Newfields, Stratham

Size and Ownership - ~ 350 acres private land

General Description - The salt marsh along both sides of the mouth of the Squamscott River represents approximately one half of all the marsh in the estuarine system (over 400 acres here) - the predominant land uses in this area are agricultural and large-lot residential.

Special Features - This complex of extensive salt marsh and adjacent farmland is prime migratory waterfowl habitat. Wooded shorelines in close proximity to this area provide perching sites for wintering bald eagles, a federally endangered species. In addition, four rare plants have been identified in this area:

- Marsh Elder (*Iva frutescens*) - found at 6 sites in New Hampshire, 5 in the estuary.
- Stout Bulrush (*Scirpus robustus*) - found at 4 sites in New Hampshire, all in the estuary.
- Small Spike-rush (*Eleocharis parvula*) - found at 4 sites in New Hampshire, 1 in the estuary. Only 3 other sites exist for the plant in the state. The site is an undisturbed, Spartina salt marsh of high scenic quality.
- Exserted Knotweed (*Polygonum exsertum*) - found at 2 sites in New Hampshire, both in the estuary.

Primary Use/Benefit - including this site within the Reserve will preserve one of the most productive components of the estuarine system.

4. Pease Air Force Base

Town - Newington

Size and Ownership - ~ 300 acres federal land

General Description - This portion of Pease Air Force Base right on Great Bay is primarily wooded - it is managed as a conservation/recreation area for Air Force personnel and their families. The current status of the closure of Pease is discussed further in section III.D on Reserve Uses.

Special Features - The shoreline of Pease is one of the few places in the estuary where bluffs can be found - it also has several sheltered coves, which again are rare in the estuary. The portion of Pease that is on the Bay is the largest single tract of land in the estuary and represents a long stretch of undeveloped shoreline. The area provides examples of nearly every type of shoreline found in the estuary, including small coves, rocky promontories, woodlands, open field, wetland areas, and both steep and shallow-sloping areas. Directly across from the Pease shoreline, and part of the Air Base ownership, is Nannie Island which has been the site of a nesting colony of Common Terns (a state-listed endangered species) as recently as 1980, although it is not currently being used. In addition, the mudflats off of the southern portion of Pease are some of the most productive oyster beds in the Bay.

The Pease shoreline is critical to the wintering population of Bald Eagles. Ongoing monitoring by the Audubon Society of N.H. has documented use of trees along the entire Pease shoreline, with 7- 8 trees used consistently for perching every year. In addition, two sections of Pease shoreline have been used for night roosting by wintering Bald Eagles.

Primary Use/Benefit - While general public access to Pease Air Base is not permitted and will not be pursued, the features of the area can be examples used in the Reserve's educational programs. Access for research and educational activities associated with the Research Reserve is subject to approval by Base personnel. It is important to note that the 300 acres of Pease within the Reserve boundary was drawn in keeping with the present military use of the property. When the Base eventually closes, a larger area of the shoreline area should be evaluated for inclusion within the Reserve.

B. Regional Setting: Location and Access

The site of the GBNERR is accessible both visually and physically from several locations. US Route 4 to the north and the State Highways (Route 101 on the south, Route 151 on the southeast and Route 108 on the west) and other radiating roads assure good access from various points in the state. In addition, boat access from public launching sites provides excellent opportunities to view the estuary. The objectives of the GBNERR with regard to access are to provide slight improvements to already existing access sites and to manage them in balance with research and education activities. For discussion purposes, the different types of access will be addressed within the following classifications - access for traditional uses (recreational activities, hunting, fishing . . .) and access for research and educational activities. Table 1 and the accompanying maps describe and locate existing access points.

Access for Traditional Uses

There are five public boat launch points on Great Bay and other conservation land and pedestrian access points as well.

Access for Research and Educational Activities

Additional access for research and education activities related to the GBNERR includes a trail around Adams Point, availability of a nature trail at one of the key land and water areas in Newmarket, and use of properties under conservation easement in the key land and water areas. This combination of sites creates a unique opportunity for users to experience the area, while still maintaining the integrity of the estuarine system. These sites are discussed in more detail in the educational component of the plan. It should be noted that public access and access for research and education activities on private properties under conservation easement will be negotiated with individual landowners as part of the easement deeds.

Table 1. ESTUARINE ACCESS AREAS

A. Boat access via public lands

SITE	#	Size	Community	Ownership	Section Of Estuary	Comments
Adams Point	A1	82 acres	Durham	State	Great Bay	Boat ramp, limited parking
Newmarket	A2	1 acre	Newmarket	Town	Lamprey River	Limited parking
Newfields	A3	acre	Newfields	Town	Squamscott River	Limited parking
Greenland* Town Landing	A4	1 acre	Greenland	Town	Winnicut River	Suitable only for car-top boats
Chapman's Landing	A5	7 acres	Stratham	State	Squamscott River	Limited facilities

B. Conservation land

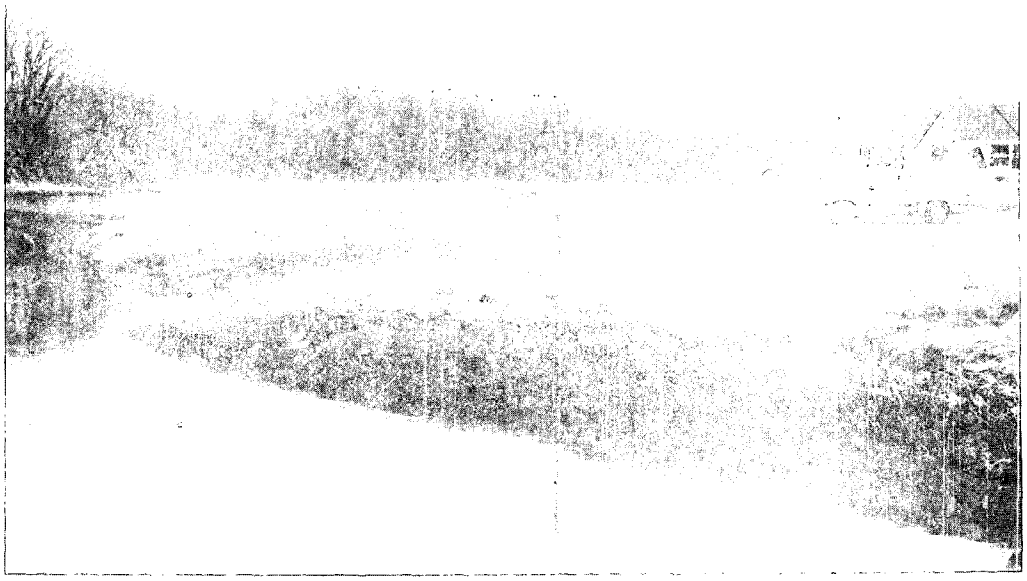
SITE	#	Size	Community	Ownership	Section Of Estuary	Comments
Adams Point	B1	82 acres	Durham	State	Great Bay	Largest single parcel of public land open to public, valuable wildlife habitat
Lamprey River Access	B2	1 acre	Newmarket	State	Lamprey River	Access to site difficult
Great Bay Access	B3	40 acres	Greenland	State	Great Bay	Valuable wildlife habitat
Greenland Conservation Land	B4	7 acres	Greenland	Town	Great Bay	7 acres of wetlands, access to site on private land

C. Other Areas

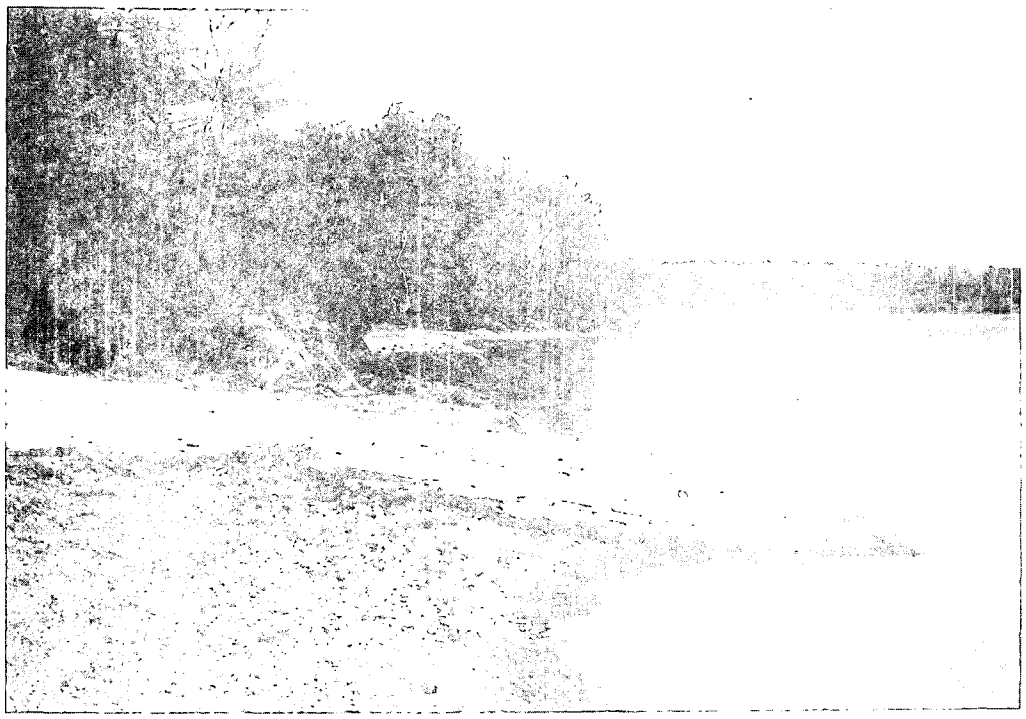
SITE	#	Size	Community	Ownership	Section Of Estuary	Comments
Depot Road	C1	acre	Greenland	Town	Great Bay	Restricted to foot access for sportsmen, no parking
Pease	C2	1100 acres	Newington	Federal	Great Bay	Air Force Base, recreation area for base personnel, extensive woodlands

* Outside Reserve Boundaries, but still provides access to the Bay

Newmarket town landing along the Lamprey



Chapman's Landing area along the Squamscott River



Adams Point boat access area

Figure 4: GREAT BAY ACCESS AREAS

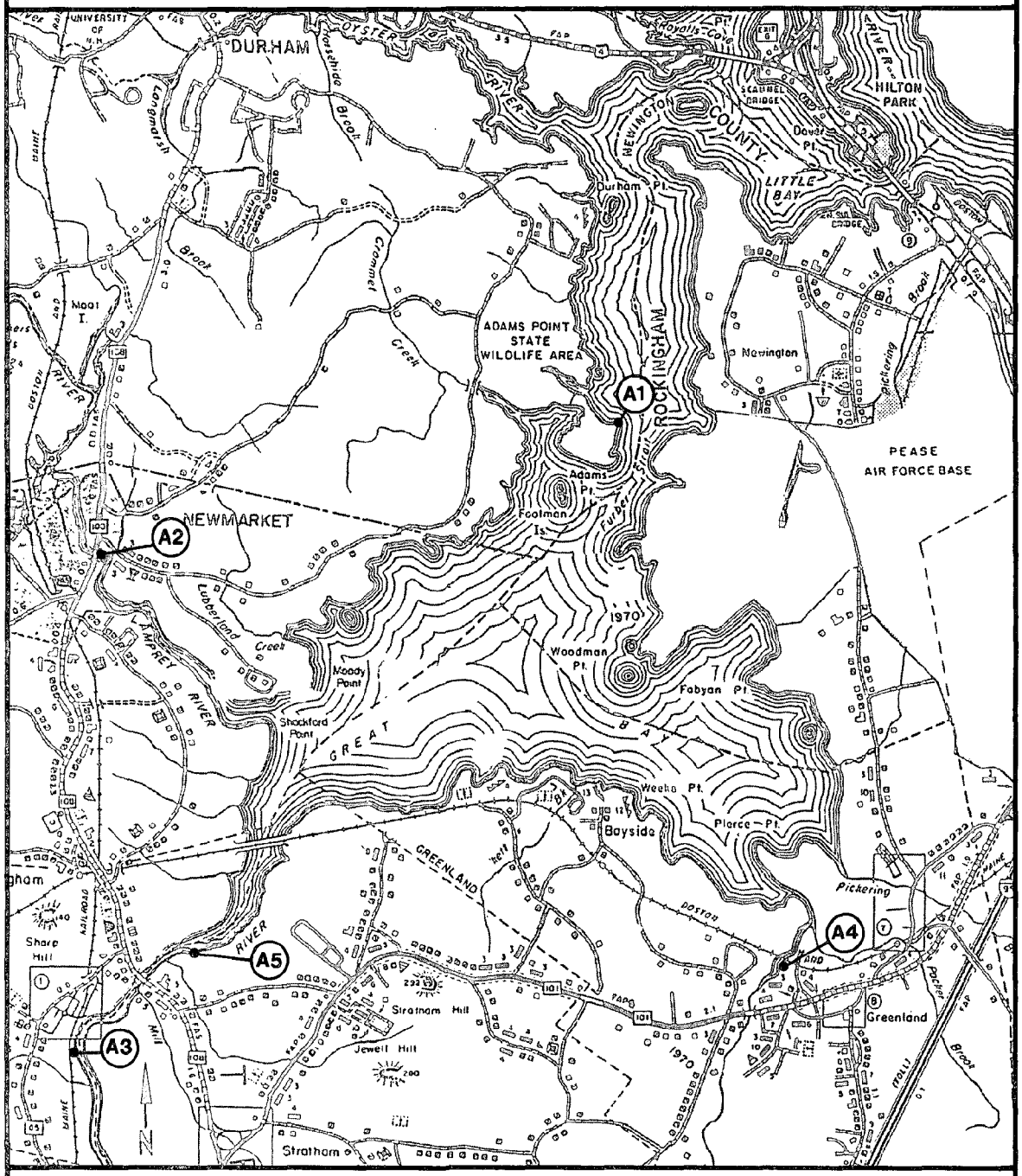
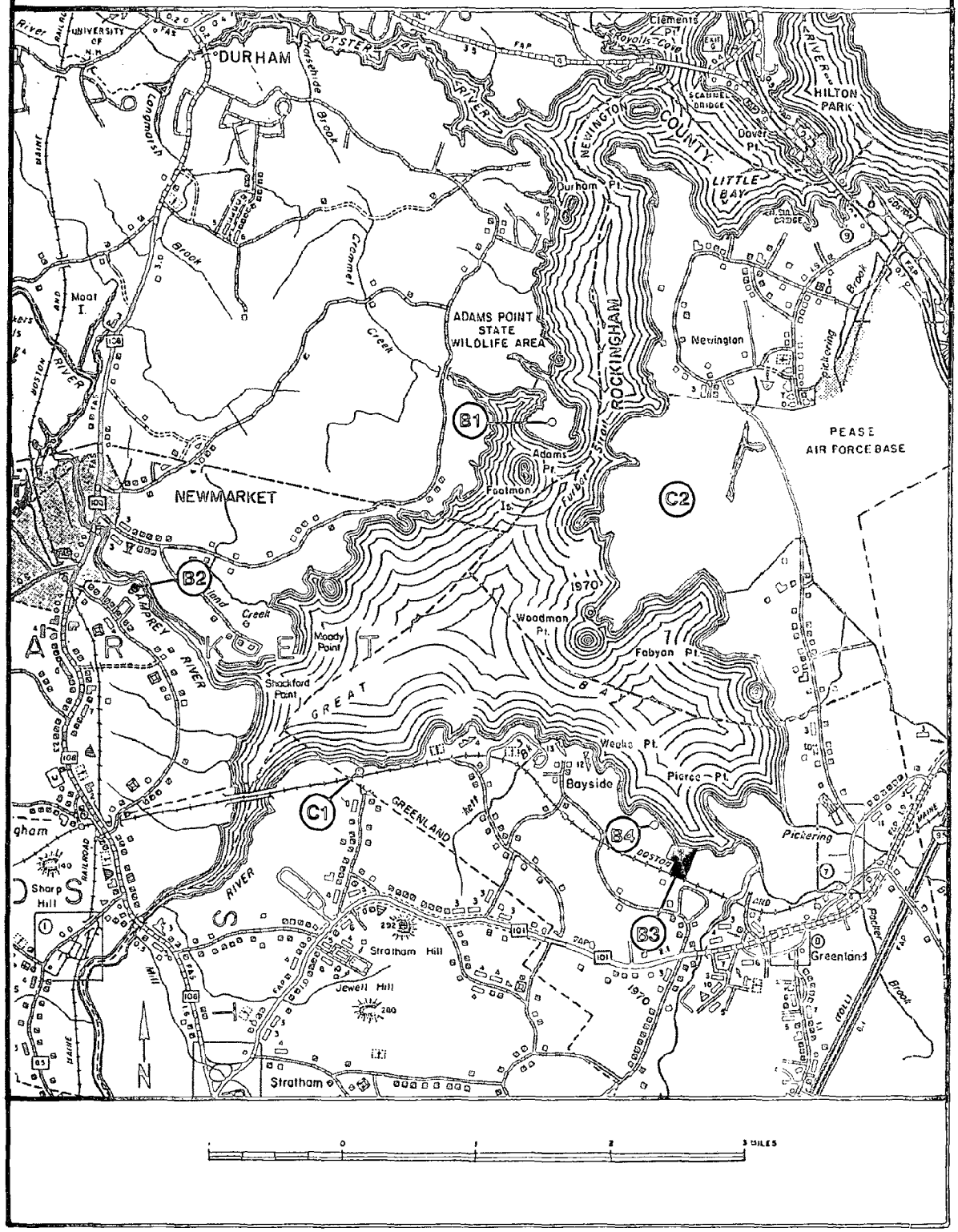


Figure 5: GREAT BAY CONSERVATION AREAS



C. Environment of the Great Bay Estuary

1.GENERAL DESCRIPTION

An estuary is defined as a coastal area where freshwater inflow mixes with seawater (Ketchum 1951)*. As a result, the primary parameter structuring the estuarine environment is salinity variation. Within northern temperate estuaries (e.g. the Great Bay estuary) substantial salinity variations occur on diurnal (tidal), monthly (lunar) and annual (seasonal) scales. Additionally, there may be episodic low salinity extremes produced by rainfall or spring snow/ice melt. The characteristics of the drainage basin surrounding an estuary further distinguish the variability of salinity regimes by affecting runoff amounts and patterns. Organisms that occur within estuaries must be able to tolerate or avoid salinity extremes.

Estuaries may be formed as a result of several geological processes. The most common estuarine type is the drowned river valley formed by rising sea level inundating an existing river drainage. Locally, sea level has been rising since the end of the last glaciation resulting in the formation of numerous Gulf of Maine estuaries, including Great Bay (Texas Instruments, Inc. 1974). The Great Bay estuary, extending 25 km (15 mi) (Brown and Arellano 1979) from the coast at New Castle, NH, to the upper Great Bay, represents a major geographic feature of the southeastern New Hampshire coastal zone (Figure 1). Historically, the economic development of many parts of coastal New Hampshire have been intimately tied to the ability of commerce to utilize Great Bay as an inexpensive route to the ocean. Additionally, substantial harvests of finfish and shellfish have come directly from the Bay. In spite of the major historical economic uses of Great Bay itself and the surrounding drainage basins, the estuary remains a relatively pristine and healthy environment. In view of the substantial human impact (e.g. pollution and wetland loss) on many estuaries in the middle-Atlantic region of the coastal US, Great Bay offers an important example of an essentially unperturbed, natural estuarine ecosystem. Relatively little salt marsh surrounding Great Bay has been lost to development. Although there are historic references to the impact of water-born particulate pollutants (e.g. sawdust) negatively impacting Great Bay mudflat communities (Jackson 1944), these practices have long since ended.

The Great Bay estuary derives its freshwater inflow from seven major rivers (Table 2). Three of these flow directly into Great Bay, i.e. the Lamprey, Squamscott and Winnicut Rivers. The remainder flow into the estuary between Furber Strait and the open coast, i.e. the Salmon Falls, Cocheco, Bellamy, and Oyster Rivers. Even so, the flows from the latter four rivers directly affects Great Bay through tidal flushing. Overall, the seven rivers drain an area of 2410 km^2 (930 mi^2), two-thirds of which is located within New Hampshire, the remainder being in southern Maine (Reichard and Celikkol 1978). Estuarine tidal waters cover approximately 45 km^2 (17 mi^2) with a 161 km (100 mi) shoreline. Because of the dynamic nature of an estuary, pollution at any point within the drainage basin or throughout the estuary itself will ultimately impact the entire system. Thus, it is important to acknowledge the need to manage an estuary as a total system rather than an individual embayment.

The Great Bay estuary (Figure 2) extends

Table 2

Drainage Area of Rivers Entering the Great Bay Estuary

(Modified from Brown and Arellano 1979)

River basin	km^2	mi^2
Lamprey	542.6	209.5
Squamscott	331.0	127.8
Oyster	78.0	30.1
Bellamy	85.0	32.8
Cocheco	471.6	182.1
Salmon Falls	392.4	151.5
Piscataqua	414.4	160.0

* See Appendix B for listing of references in this section.

from the mouth of the Piscataqua River between Kittery, Maine, and New Castle, New Hampshire, inland to the junction of Little Bay and the Piscataqua. Little Bay extends from Dover Point turning sharply at Cedar and Fox Points near the mouth of the Oyster River. Little Bay ends at Furber Strait near Adams Point. Great Bay begins immediately inland or "upstream" of Furber Strait. Thus, while the GBNERR only includes Great Bay proper, an increased understanding of the interconnection and dependency of Great Bay to the other segments of the estuarine system is crucial to management of the Reserve.

Great Bay (Figure 2), starting at Furber Strait, is a large, shallow, estuarine embayment having a tidal volume of 393 x 106 m^3 (EBASCO Services, Inc. 1968). The Bay has an average depth of 2.7 m (8.85 ft), however, deeper channels extend to 17.7 m (58 ft). Channels from the Lamprey, Squamscott and Winnicut Rivers intersect near the center of the Bay to form the main channel which connects to Little Bay at Furber Strait. Strong tidal currents occur at Furber Strait since the tidally flushed water from Great Bay must pass through a restricted outlet. A similar tidal flow restriction occurs at Dover Point where Little Bay meets the Piscataqua River. At this site the channel is 430 m (0.27 mi) wide with a maximum depth of 10.5 m (34 ft). The Great Bay estuary has a low tide volume of 166 x 106 m^3 and a high tide volume of 230 x 106 m^3 (Brown and Arellano 1979).

The water surface of Great Bay covers 2307 x 104 m^2 (8.9 mi^2) at mean high water and 1093 x 104 m^2 (4.2 mi^2) at mean low water (Turgeon 1976). Approximately 50% of the aerial surface of Great Bay is exposed as mudflat at low tide. Additionally, extensive intertidal salt marsh borders much of the mouth of the Squamscott River, Crommett and Lubberland Creeks. Several small islands (i.e. Nannie, Swan, Vols, and the Footman Islands) occur within the Bay.

2. METEOROLOGY

The average annual air temperature in the Great Bay area is 7.8° C (46° F). Monthly average air temperatures vary from 20° to 22.8° C (68° to 73° F) in July and August to -7.8° to -2.8° C (18° to 27° F) in January and February (NH Water Supply and Pollution Control Commission 1975).

Average annual precipitation in the Durham area during 1941 to 1970 was 41.55 in (1.06 m) (Normandeau Assoc., Inc. 1975). Only minor differences in precipitation (i.e. approximately 1 in, 0.025 m) occur between months. February is the driest and November the wettest month (Texas Instruments, Inc. 1974). The driest year on record was 1941 with 23.95 in (0.61 m) precipitation and the wettest year was 1954, 60.18 in (1.53 m) (Texas Instruments, Inc. 1974). Snowfall in Durham averages 56 in (1.42 m) (NH Water Supply and Pollution Control Commission 1975).

Winds are predominantly from the west and northwest. However, in July southeasterly winds prevail (Texas Instruments, Inc. 1974).

3. GEOLOGY

The region surrounding the Great Bay is included in the Seaboard Lowland section of the New England Province (Fenneman 1938, Novotny 1969). Elevations in the area are generally under 200 ft. Most hills are either bedrock covered with glacial till or drumlins.

The most recent glaciation of the area ended during the Wisconsin stage of the Pleistocene epoch (10,000 to 20,000 yr B.P.) (Texas Instrument, Inc. 1974). The glaciation proceeded through the area in a southeasterly direction, resulting in the orientation of the many drumlins in the area. Substantial amounts of glacial till were deposited as the glacier receded.

Bedrock surrounding Great and Little Bays is primarily metamorphic, consisting of dark-gray slate of the Kittery formation visible as outcrops along the northern and western shores and in the Pierce Point area of Greenland. The Eliot formation, also dark-gray slate, can be seen along the shores of Stratham and Newington. A fold in the Eliot formation, the Great Bay syncline, passes through Newington to Thomas Point, under Great Bay, then into Stratham near Bracketts Point. Immediately to the north and west of Great and Little Bays, a granitic intrusion of Exeter diorite comprising the Exeter pluton (i.e. part of the Hillsboro plutonic series) is present (Novotny 1969). Large outcrops of the slate described above

serve as an important source of stable substratum for macroalgal attachment and contribute to the shingle beach common around Great Bay.

Crustal depression in New Hampshire from glacial weight was on the order of 12.2 m (40 ft). After glacial melt, crustal rebound occurred and is complete today. The Seacoast Region of New Hampshire rebounded approximately 61 m (200 ft) after the loss of the glacial overcover. However, the uplift was not uniform throughout the region and Great and Little Bays represent a sag in the surface (Novotny 1969). The low-lying area was filled by rising sea level from glacial melting. Thus, the Great Bay estuary is representative of a drowned-river valley.

Present sea level was reached approximately 3,000 to 5,000 years B.P. During the period 6,300 to 3,400 yr B.P. sea level rise in the Northeast was on the order of 0.80 m (31.5 in) per 100 yr. For the past 3,000 years this rate has slowed to 0.035 m (1.4 in) per 100 yr. Projections of further sea level rise by the year 2100 range from 0.55 to 3.44 m (1.8 to 11.3 ft) (NH Office of State Planning 1987).

A major feature of north temperate estuaries is the presence of extensive intertidal mudflats. Approximately one-half of Great Bay is exposed at low tide; most of the intertidal area is mudflat. The fine sediment brought into the estuary primarily by river runoff and shore erosion is deposited in the relatively calm estuarine environment resulting in extensive intertidal flats. Tidal currents are of greatest influence within the channels and minimize subtidal sediment deposition. A marked seasonal variation of sediment deposition/resuspension occurs throughout the Great Bay (Anderson 1983). During winter, ice cover of the intertidal zone minimizes sediment resuspension. However, spring ice out and subsequent wind-mediated erosion result in substantial movements of resuspended sediment (Anderson 1983). Bioturbation and sediment-binding by algal mats rather than physical processes predominate during summer months. As temperatures decrease during the fall, biological processes become less important and storm-mediated resuspension again causes intertidal flat erosion (Anderson 1983).

Soil associations surrounding Great Bay include Merrimac-Buxton along the south and east shores of Newington and Greenland, Hollis-Warwick-Buxton in Greenland and Stratham, and Hollis-Charlton-Buxton-Merrimac-Scantic from Stratham through Newfields and Newington to Durham (Texas Instruments, Inc. 1974). The Merrimac-Buxton association consists of soils that are nearly level or gently sloping and are well-drained on glacial till or moderately well-drained on silts and clays. The Hollis-Warwick-Buxton soil association consist of well-drained soils on shallow glacial till or silts and clays. Hollis-Charlton-Buxton-Merrimac-Scantic soils are shallow to deep, excessively drained to well-drained soils in upland areas as well as moderately well-drained to poorly drained soils of marine silt and clay deposits (Texas Instruments, Inc. 1974).

4. HYDROLOGY

The major sources of freshwater inflow are the seven rivers entering the Great Bay estuary (described above). River flow varies seasonally with the greatest volumes occurring as a result of spring runoff. However, throughout most of the year, the tidal component in the estuary dominates over freshwater influence. Thus, freshwater input represents only 2% or less of tidal prism volume (Reichard and Celikkol 1978, Brown and Arellano 1979) although the percentage varies seasonally.

Stream flow entering the Great Bay estuary is gauged at the Oyster, Lamprey, and Salmon Falls Rivers (Normandeau Assoc., Inc. 1975). Historical river flow data are presented in Table 3. Approximately 50% (i.e. 0.508 m, 20 in) of the average annual precipitation in the Great Bay estuary drainage basin enters the estuary as stream flow (NH Water Supply and Pollution Control Commission 1975).

Great Bay is a mesotidal estuary with the average tidal range varying from 2.5 m (8.2 ft) at the mouth of the estuary to 2.0 m (6.6 ft) at Dover Point, increasing slightly to 2.1 m (6.9 ft) at the mouth of the Squamscott River (Reichard and Celikkol 1978). Differences in tidal phase and amplitude are minor between Dover Point and the Squamscott River (Reichard and Celikkol 1978). Tidal currents

are greatest at Dover Point and in the Piscataqua River (1.5 to 2.0 m/s) and decrease in Little Bay (0.75 m/s). Because of the channel restriction at Furber Strait, the currents here are greater than in Little and Great Bays. Thus, speeds of 1.0 m/s or greater occur at Adams Point but decrease to 0.5 m/s in Great Bay (Reichard and Celikkol 1978). Due to the Coriolis effect on water movement, flood tide currents are concentrated on the north and west shores of Great and Little Bays while ebb tide currents are on the eastern shore. Strong tidal currents act to limit vertical stratification throughout the estuary during most of the year. Partial stratification may occur during periods of intense freshwater runoff, particularly at the upper tidal reaches of rivers entering the Bay.

The flushing time for water entering the head of the estuary is 58 tidal cycles (26.0 days) during low river flow and 48.5 (25.1 days) during high river flow (Brown and Arellano 1979). Turgeon (1976) estimated a flow time of four days for a particle to traverse 4 km (2.5 mi) in the mid-estuary.

Water temperature and salinity vary seasonally and diurnally (with the tidal cycle). Within Great Bay salinity may vary from essentially 0 $^{o/oo}$ during extreme spring runoff to 30 $^{o/oo}$. Similarly, temperature has a marked pattern of seasonal variation from a winter low of -1.9° C (freezing point of salt water) to 28°-30° C in the summer. The relative shallowness of Great Bay allows for rapid warming in the spring-summer and cooling in the autumn-winter. Time series analyses of hydrographic trends in the Great Bay estuary during 1973 to 1982 showed significant changes in water temperature and salinity (Loder *et al.* 1983a). Over the period studied, water temperature in Great Bay decreased 0.17° C per year while salinity rose (at Dover Point) 0.34 $^{o/oo}$ per year (Loder *et al.* 1983a). Both trends, i.e. to colder more saline water, may be indicative of either local river-flow changes or regional trends affecting the Gulf of Maine (Loder *et al.* 1983a).

A long-term database of dissolved nutrient concentrations throughout the Great Bay estuary has been collected by the Jackson Estuarine Laboratory and the University of New Hampshire (Norall and Mathieson 1976, Loder and Glibert 1977, Daly *et al.* 1979, Daly and Mathieson 1979, Loder *et al.* 1979, 1983a, 1983b, Norall *et al.* 1982). Dissolved nitrate, nitrite, ammonia, phosphate (total and reactive), oxygen and silicate show substantial seasonal variation within Great Bay. No significant long-term trends were apparent from time series analyses of dissolved oxygen, ammonia, phosphate, nitrate, nitrite, or silicate (Loder *et al.* 1983a). Thus, while sewage inflow to the Great Bay estuary increased during 1973 to 1982 (Table 4), no increased nutrient-loading was apparent (Loder *et al.* 1983a) which was attributed to the flushing potential of the estuary.

Table 3

Gauged Stream Flow Data

(Modified from Normandeau Associates, Inc. 1979)

Drainage	Period of Record	Discharge (cfs)		
		Mean	Max (daily flow)	Min
Salmon Falls R.	1968-1978	204.0	3500	19 .00
Oyster R.	1934-1977	19.2	862	0.23
Lamprey R.	1934-1977	278.0	5490	1.00

Table 4. WASTEWATER VOLUMES ENTERING THE GREAT BAY ESTUARY

(Modified from Lodger *et al.* 1983a)

Community Served[a]	Treatment Level	Mean Daily Flow on 10^6 gal/day Design	1973	1982	Receiving Water	Start-Up Year
New Hampshire						
Dover	Primary	3.92	1.62	1.93	Cocheco R.	1955
Durham	Primary	1.35	1.16	--	Oyster R.	1965-1980
Durham	Secondary	2.50	--	0.83	Oyster R.	1981
Epping#	Secondary	0.15	0.10	0.11	Lamprey R.	1971
Exeter	Secondary	2.50	1.36	1.12	Squamscott R.	1965
Farmington	Secondary	0.35	--	0.32	Cocheco R.	1978
Newmarket	Primary	0.85	0.31	0.30	Lamprey R.	1971
Newington	Secondary	0.30	--	0.08	Piscataqua R.	1980
Pease AFB	Secondary	1.20	.077	0.72	Piscataqua R.	1953
Portsmouth (Pierce Island)	Primary	1.50	2.09	5.6	Portsmouth Harbor	1964
Portsmouth ((Seacrest)	Primary	0.45	0.21	0.30	Piscataqua R.	1964
Rollinsford#	Secondary	0.15	0.08	0.04	Salmon Falls R.	1867
Somersworth#	Secondary	2.40	1.02	1.47	Salmon Falls R.	1967
Small Volume Others#	Primary	0.20	--	0.06		
Maine						
Berwick#	Secondary	0.60	0.48	0.80	Salmon Falls R.	1975
South Berwick	Primary	0.45	--	0.19	Salmon Falls R.	1965
Kittery	Secondary	1.22	0.61	0.65	Portsmouth Harbor	1970
TOTAL		**17.6**	**10.00**	**16.8**	**Cumulative Great Bay**	

[a]Communities labeled with a # indicate that effluent is discharged upstream of the dam defining head-of-tide.

5. VEGETATION

Macroalgae

Great Bay is typical of northern New England estuaries in having a variety of marine plant communities. More southern estuaries (i.e. south of Cape Cod) are dominated by salt marsh and have limited areas of stable substratum for macroalgal attachment. Within Great Bay, substantial intertidal populations of the fucoid macroalgae, *Ascophyllum nodosum* and *Fucus vesiculosus*, occur along the shingle and rocky intertidal. An extensive record of seaweed species occurring within the Great Bay estuary has been compiled (Appendix A, Table 1) (Mathieson and Hehre 1986, Mathieson and Penniman 1986).

Ascophyllum nodosum is intolerant of extreme wave exposure and generally requires sheltered to semi-exposed shorelines to reach its maximum development. Thus, the sheltered habitat of Great Bay allows extensive growth of *A. nodosum*. Throughout the estuary, the percent cover of *Ascophyllum* varies from 2.5 to 97.8% within the mid-intertidal zone (NH Fish and Game Department 1981). The standing crop of fucoids throughout the Bay has a range of 0-5,474 g dry wt/m^2 (average 2,073 g dry wt/m^2) (NH Fish and Game Department 1982). Maximum seasonal growth of *Ascophyllum* occurs during spring and fall in Great Bay (Mathieson *et al.* 1976). *Ascophyllum* plants may be quite long-lived in some areas persisting for 15 years (Baardseth 1970). Within Great Bay *Ascophyllum* is heavily pruned annually by ice. The distal tips of fronds freeze into ice cover and are then torn free when ice-out occurs (Mathieson *et al.* 1982). During extreme winters, the annual loss of biomass by ice-rafting may represent one-half the winter *Ascophyllum* standing crop (Mathieson *et al.* 1982). The ice-mediated pruning of *Ascophyllum* results in estuarine plants being shorter and bushier than their coastal counterparts (Mathieson *et al.* 1982). Fragments of *Ascophyllum* torn loose by ice-pruning may enter the detrital cycle as described above, or they may lodge among *Spartina alterniflora* culms and grow, forming the unattached form *Ascophyllum nodosum* ecad *scorpioides* (Chock and Mathieson 1983). In certain areas of the Bay the biomass of ecad *scorpioides* in the upper intertidal can reach 89.6 g dry wt/0.1 m^2 (Chock and Mathieson 1983).

Ascophyllum produces an abundance of reproductive cells over an annual cycle (Baardseth 1970). Lateral shoots termed receptacles bear the gametes which are released during March-May within Great Bay (Mathieson *et al.* 1976). During the episodic loss of reproductive structures an amount of plant material detaches that may equal the standing biomass of vegetative plant material (Josselyn and Mathieson 1978). Thus, *Ascophyllum nodosum*, as well as other fucoids in Great Bay, is extremely important to the estuarine detrital food web by producing substantial quantities of organic material (Josselyn 1978, Josselyn and Mathieson 1978, 1980) with a relatively high nitrogen content (i.e. up to 4% of ash-free dry weight) (Hardwick-Witman and Mathieson 1986). Furthermore, intertidal seaweeds such as *Ascophyllum* and *Fucus*, release large quantities of dissolved organic matter, that may be utilized by heterotrophic microorganisms. The dissolved organic matter from intertidal seaweeds is a major component of surface "slicks" frequently observed in estuaries and nearshore waters.

In addition to being important to the primary productivity of northern estuaries, *Ascophyllum* provides structural complexity to intertidal habitats (Baardseth 1970). In muddy intertidal zones of northeastern estuaries, the limited stable substratum available for algal or invertebrate attachment, makes valuable any surfaces that will support colonization. A variety of smaller seaweeds (e.g. *Pilayella littoralis* and *Ectocarpus siliculosus*) are epiphytic upon *Ascophyllum* (Mathieson and Hehre 1986). The small, filamentous seaweeds potentially contribute a substantial proportion of total annual intertidal primary production (Chock and Mathieson 1983). A variety of invertebrates also colonize intertidal fucoids. The shade and cover provided by *Ascophyllum* fronds at low tide acts to protect smaller species from drying out rapidly during low tide. This amelioration of desiccation allows some species (e.g. *Chondrus crispus*) to extend higher into the intertidal zone than in open, un-

vegetated areas.

Within the low intertidal to upper subtidal zone on stable rocky substrata, Irish moss, *Chondrus crispus,* is an important algal colonizer. Although *Chondrus* extends subtidally, the most abundant subtidal macroalga within Great Bay is *Gracilaria tikvahiae* (Penniman *et al.* 1986). *Gracilaria* occurs abundantly in the subtidal at several sites throughout Great Bay (e.g. Adams Point-Footman Islands, Thomas Point, and Nannie Island). The occurrence of subtidal seaweeds in Great Bay is limited by the lack of stable substrata - the subtidal being predominantly fine sediment. *Gracilaria*, as well as a variety of other subtidal seaweeds, grows attached to oyster shells, small rocks, discarded bottles and sunken logs. Because of extreme turbidity, the lower distribution of seaweeds is quite limited in Great Bay versus the open coast (Mathieson and Penniman 1986).

As water temperatures warm during the summer, growth of *Gracilaria* may reach 10%/day in Great Bay (Penniman *et al.* 1986). Growth of *Gracilaria* is primarily limited by water temperature and irradiance, while dissolved nutrients (i.e. nitrogen and phosphorus) do not appear to limit production (Penniman 1983, Penniman and Mathieson 1987). No quantitative studies have been conducted to determine standing crops of subtidal seaweeds throughout Great Bay.

A variety of seaweed species occur within Great Bay that are absent on the open Atlantic coast north of Cape Cod (Penniman *et al.* 1985). These species, which have a disjunct distributional pattern, may represent relict populations that were more widely distributed during a previous time when coastal water temperatures were warmer (i.e. during a "hypsithermal period" 5000 yr B.P.) (Bousfield and Thomas 1975). The seaweeds grow and reproduce during the warm summer and are able to tolerate colder winter temperatures. Examples of species that exhibit such disjunct distributional patterns include *Gracilaria tikvahiae, Bryopsis plumosa, Dasya baillouviana, Chondria tenuissima, Lomentaria clavellosa, Lomentaria orcadensis* and *Polysiphonia subtilissima* (Penniman *et al.* 1985, Mathieson and Hehre 1986). Several of these taxa also occur in the Great Salt Bay at the head of the Damariscotta River in Maine, an area somewhat similar to Great Bay. The disjunct distributional pattern described for the seaweeds is also found for several marine/estuarine invertebrates (Bousfield and Thomas 1975, Turgeon 1976). Specifically, the American oyster, *Crassostrea virginica,* only occurs naturally along the U.S. coast north of Cape Cod in Great Bay and the Damariscotta River. It should be noted that these disjunct plant and animal populations have probably been reproductively isolated from the widespread southern populations since the period of warmer coastal water temperatures. A second explanation for these distributions is that some of the disjunct populations may be organisms carried with American oysters possibly introduced into Great Bay during the early 1900's (Turgeon 1976).

Microalgae

Phytoplankton are a major component of primary production within estuaries. Little data are available concerning phytoplankton species composition, abundances, or production within Great Bay. During 1970 to 1978 as part of a baseline study to determine the potential environmental impact of an electric power generating station located on the Piscataqua River in Newington, several measurements of phytoplankton populations were taken (Normandeau Assoc., Inc. 1971-1980). As part of this study, phytoplankton species composition (retained on 0.076 mm net or as whole water samples), chlorophyll *a* concentrations and primary production as 14C uptake were measured at five stations throughout the Great Bay estuary (reduced to one in 1978).

Phytoplankton species composition within the estuary (Appendix A, Table 2) is dominated by diatoms (e.g. 96% of total abundance during 1978, Normandeau Assoc., Inc. 1979a, 1979b). Specific dominant net phytoplankton taxa are *Chaetoceros* species, *Skeletonema costatum* and *Ceratium* species, the former two groups are diatoms, while the latter is a dinoflagellate. Whole water phytoplankton samples were dominated by *Skeletonema costatum.* High numbers of pennate diatoms also occurred in the water column (e.g. *Navicula* spp. and

Fragilaria spp.) an indication of resuspension of benthic forms. The diatom, *Detonula confervacea*, was a major component of the winter-spring inner estuarine phytoplankton community during 1971 to 1973 (Donovan 1974). *D. confervacea* dominated over *Thalassiosira* spp. in areas of lower salinity. *Detonula* was infrequent during 1971 to 1973 at more coastal stations in the estuary (Donovan 1974).

In the Piscataqua River shifts in species composition occurred with tidal phase. Blooms of estuarine taxa dominated during ebb tide stages, conversely neritic species were predominant during flood tides (Normandeau Assoc., Inc. 1980). Cell numbers during blooms were generally 104 to 106 cells/liter. During 1976 to 1978, two periods of phytoplankton blooms were evident during later spring and late summer/fall (Normandeau Associates, Inc. 1979a, 1979b). Late spring and autumn blooms were dominated by *Chaetoceros* spp. while *Skeletonema costatum* peaked in late summer (Normandeau Assoc., Inc. 1976).

Throughout the estuary phytoplankton primary production was greatest during April to July, declining through the August and September with a slight increase in October (Normandeau Associates, Inc. 1978a, 1978b). Average annual phytoplankton production was greatest in Great Bay (14 mg C/m^3/h on ebb tide) versus more coastal stations (Normandeau Assoc., Inc. 1978a, 1978b). Chlorophyll *a* values were similarly distributed (6 mg/m^3, surface ebb tide sample in Great Bay) (Normandeau Assoc., Inc. 1978a, 1978b). Within the mid/upper estuary chlorophyll *a* concentrations varied during 1973 to 1981 from 1 to 14 mg/m^3, with an average of 5 mg/m^3 (Loder *et al.* 1983a). These values are comparable to two other Gulf of Maine estuaries (i.e. Sheepscot and Damariscotta River Estuaries, Maine, Loder *et al.* 1983a).

Another important microalgal component of the estuarine flora are diatoms and other microscopic algae occurring on mudflats. These microalgae may contribute a substantial portion of total estuarine primary production. However, within north temperate Atlantic estuaries very little quantitative information is available on the magnitude of epibenthic microalgal production.

Salt Marsh

North of Cape Cod, Massachusetts, salt marshes are progressively less important to total estuarine primary production than further south on the Atlantic Coast and in Gulf coast estuaries. However, the Wells National Estuarine Sanctuary, Maine, is somewhat atypical of Gulf of Maine estuaries in having a relatively high proportion of salt marsh habitat. In contrast, as described above, Great Bay is dominated by intertidal mudflats with substantial areas of intertidal macroalgae. Nonetheless, 3.39 km^2 (837.5 acres) of salt marsh surround Great and Little Bays and the Squamscott River (NH Fish and Game Department 1982). Within the boundaries of the GBNERR extensive salt marshes are present along the Squamscott River, 1.62 km^2 (400.8 acres), and Lubberland and Crommett Creeks. In Great Bay, salt marsh occurs more commonly as a thin fringe along the uppermost intertidal (Chock and Mathieson 1983).

Salt marshes in Great Bay are dominated by the *Spartina* species, *S. alterniflora* (smooth cord grass) and *S. patens* (salt meadow hay). Both species are perennial grasses, annually producing large amounts of organic matter that may be exported from the marshes into the detrital food web or that is deposited within the marshes and contributes to the underlying marsh peat (Nixon 1982, Teal 1986).

Maximum standing biomass of *Spartina alterniflora* occurs during July to August in Great Bay. Maximum mean above-ground *S. alterniflora* biomass within Great and Little Bays was approximately 400 g dry wt/m^2 during 1980 to 1982 (NH Fish and Game Department 1981, 1982). These data are equivalent to measurements of production in other New England salt marshes (i.e. Maine, McGovern 1978; Rhode Island, Oviatt *et al.* 1977). Below-ground standing crop (i.e. roots and rhizomes), which is quite variable geographically (Nixon 1982), has not been assessed. *S. alterniflora* flowers during July to September (Chock 1975, NH Fish and Game Department 1981, 1982).

Since most marshes surrounding Great Bay are relatively narrow in aerial width and because of the large tidal amplitude in the region, most of the marsh grass standing crop is

probably exported from the marshes to the estuary (Nixon 1982). Furthermore, annual ice scouring of the intertidal marsh surface removes most remaining *Spartina* culms which are then exported during spring tidal cycles associated with ice melt. Ice cover and scour of the intertidal salt marsh also removes portions of the surface peat, which may be rafted into the lower intertidal or subtidal areas that are too deep for survival of *Spartina* (Hardwick-Witman 1985). Hardwick-Witman (1986) determined that 11% of the surface area of an intertidal mudflat bordering Crommett Creek (Adams Point) was pieces of ice-rafted salt marsh peat. During spring ice-out overall movement of the peat islands was from the high to low intertidal (Hardwick-Witman 1986). Therefore, ice-rafted marsh segments may be deposited within the intertidal zone and are potentially a major means of propagation of salt marsh within the Great Bay (Hardwick-Witman 1985, 1986). Furthermore, several dominant intertidal species (e.g. *Fucus vesiculosus* and *Geukensia demissa*) are carried within ice-rafted marsh peat (Hardwick-Witman 1985).

A variety of other plant species are found in Great Bay salt marshes (Appendix A, Table 3). Unlike the extensive *Spartina* grass monocultures typical of more southern salt marshes, Great Bay marshes have a greater diversity of species and thus appear more as a mosaic of plant distributions. Furthermore, several species found within Great Bay salt marshes are classified as rare or endangered species (Appendix A, Table 4).

Soil types of coastal New Hampshire salt marshes were described by Breeding *et al.* (1974). Marshes bordering streams such as the Squamscott River and Crommett and Lubberland Creeks are generally sulfihemists. The fringing marshes, common around the Bay, also have sulfihemist soils of varying thicknesses and overlaying a variety of substrata (i.e. mud, sand, bedrock). The sulfihemist soil type has slow internal drainage, a very high water table and contains high amounts of organic matter and sulfidic minerals.

Eelgrass

Eelgrass, *Zostera marina*, is an important component of the estuarine environment. Production from eelgrass enters the estuarine/nearshore detrital food web, eelgrass leaves serve to slow water flow and enhance sediment deposition, and root systems further stabilize sediments. Eelgrass beds provide structural diversity within the estuary as substrata for algal and invertebrate attachment, as well as protection for larval fish and invertebrates from predators. Eelgrass is distributed throughout the Great Bay estuary (NH Fish and Game 1981, 1982).

Several extensive *Zostera* beds occur within Great Bay (NH Fish and Game Department 1981, 1982, Short *et al.* 1986). However, unit aerial biomass is greater at more coastal sites (NH Fish and Game Department 1981, 1982). Additionally, during 1980 to 1982 and continuing to the present, a decrease in the abundance of eelgrass within Great Bay has been noted (NH Fish and Game Department 1981, 1982, Short *et al.* 1986). Maximum biomass occurs during July and a minimum in March (e.g. 30 g dry wt/m^2 in March versus 100 g dry wet/m^2 in July at Weeks Point in Great Bay, NH Fish and Game Department 1982). Lengths of individual plants of *Zostera marina* are shorter within Great Bay versus stations on Little Bay and the Piscataqua River (NH Fish and Game Department 1982). Riggs and Fralick (1975) observed a temporal progression of flowering in *Zostera* populations with populations nearest the coast flowering three months earlier than those farthest into Great Bay.

Surveys by the New Hampshire Fish and Game Department noted a decline of 44% in maximum (July) standing crop of *Zostera* from 1981 to 1982 (NH Fish and Game Department 1982). A "wasting disease" in eelgrass populations throughout the Great Bay estuary has been reported (Short *et al.* 1986, 1987). A more widespread loss of eelgrass occurred during the 1920-1930's along both shores of the north Atlantic (Milne and Milne 1951).

Upland

The boundaries of the GBNERR include several upland areas (e.g. Adams Point, areas bordering Crommett Creek and the Pease Air Force Base shoreline). No specific studies have documented the upland vegetation within the Reserve boundaries. However, a flora of Strafford County, NH, was compiled by Hodgdon (1932).

The region is characterized as a transition zone between the deciduous forest to the south and the coniferous forest to the north (Texas Instruments, Inc. 1974). Common tree species within the area include white pine (*Pinus strobus*), red oak (*Quercus rubra*), red pine (*Pinus resinosa*), hemlock (*Tsuga canadensis*), red maple (*Acer rubrum*), gray birch (*Betula populifolia*) and quaking aspen (*Populus tremuloides*) (Texas Instruments, Inc. 1974). A more complete listing of the common upland vascular plants found within Strafford County, NH, is presented in Appendix A, Table 5. Furthermore, several threatened or endangered plant species occur within the boundaries of the Reserve (Appendix A, Table 4).

6. FAUNA

Intertidal and Subtidal Invertebrate Fauna

Substratum type (i.e. mud/sand versus rock) is an important determinant of species composition within Great Bay. Rock and shingle substrata are populated by epibenthic organisms, while mud and sand have both epibenthic and infaunal components.

Typical muddy intertidal dominants throughout most of the Great Bay estuary (based on retention by a 1 mm screen) are *Macoma balthica, Mya arenaria, Nephtys caeca* and *Nereis virens*, with *Clymenella torquata, Gemma gemma* and *Scoloplos* spp. being occasionally abundant (Normandeau Assoc., Inc. 1973). Typical rocky shore dominants are *Littorina littorea, Mytilus edulis* and *Semibalanus balanoides*. Within Great Bay, however, *Semibalanus, Macoma, Mytilus,* and *Littorina littorea* occur in low numbers and *Crassostrea virginica, Geukensia demissa* and *Mulinia lateralis* replace the more coastal species.

Population structure of the intertidal fauna within Great Bay is distinct from more coastal sites (Normandeau Assoc., Inc. 1976). The small bivalve, *Gemma gemma*, is the most abundant intertidal infaunal organism in Great Bay (e.g. 800/0.0078 m^2) and *Hydrobia minuta* is the most abundant gastropod.

Recent studies (1980-1982) by the NH Fish and Game Department found that subtidal soft sediment communities in Great Bay contained (based on retention by a 0.5 mm screen) primarily the polychaetes *Streblospio benedicti* and *Heteromastus filiformis* and the amphipods *Ampelisca abdita/vadorum* (NH Fish and Game Department 1982). *Streblospio* and *Heteromastus* densities were greatest during the summer, *Ampelisca* is at a minimum at that time. Maximum abundance of *Heteromastus* within Great Bay was 23.2/0.0078 m^2 (NH Fish and Game Department 1982). Soft-shell clams, *Mya arenaria,* are found throughout Great Bay, with maximum densities of 6.4/0.0078 m^2 (NH Fish and Game Department 1981).

Large oyster beds (*Crassostrea virginica*) occur within the Great Bay estuary. The highest densities of oysters (i.e. 203/$m^{2)}$ are in the southwest part of Great Bay where sizes ranged from 80.0 to 99.9 mm (NH Fish and Game Department 1982). Oyster abundances in Great Bay decreased from 1980-1981 to 1981-1982 (NH Fish and Game Department 1982).

During 1980-1981, ninety-one species of intertidal and one hundred fourteen subtidal infauna were collected throughout the Great Bay estuary by the NH Fish and Game Department (1981). In a subsequent investigation, a total of only sixty-seven intertidal and eighty-two subtidal species were found (NH Fish and Game Department 1982) (Appendix A, Tables 6 and 7). Both studies were based upon organisms retained by a 0.5 mm screen. During 1980-1981 samples were collected monthly, while during 1981-1982 only bimonthly sampling was conducted. The decreased frequency of sampling may explain the lower species numbers observed in the 1981-1982 investigation. The 1981-1982 collections contained polychaetes (45%), crustacea (26%), bivalves (15%), and gastyopods (11%).

Hardwick-Witman and Mathieson (1983)

compared the epibenthic species composition of the intertidal zone over a gradient extending from the mouth of the Piscataqua River into Great Bay. Within Great Bay the dominant epibenthic intertidal invertebrates were *Ilyanassa obsoleta, Geukensia demissa, Crassostrea virginica, Balanus eberneus, Littorina littorea, L. saxatilis* and *L. obtusata*. Dominant macroalgal species included *Ascophyllum nodosum, Fucus vesiculosus, Hildenbrandia rubra* and a filamentous algal mat. *Spartina alterniflora* predominated in the high intertidal. The species were divided into three distinct elevational zones: an upper *Spartina-Fucus-L. saxatilis* zone, a mid *Ascophyllum-Geukensia-L. littorea* zone and a lower *Ilyanassa-Crassostrea* zone (Hardwick-Witman and Mathieson 1983).

As described above for several seaweed species, the warm summer waters within Great Bay allow the persistence of several invertebrate species more common further south along the open Atlantic coast (Bousfield and Thomas 1975). Gable and Croker (1977, 1978) described the ecology of the salt marsh amphipod *Gammarus palustris*. Great Bay is the northern limit of the species' distribution (Gable and Croker 1977). Turgeon (1976) commented on the occurrence of disjunct populations of several primarily warm-water invertebrate species within the Great Bay, e.g. *Balanus improvisus, Crassostrea virginica, Urosalpinx cinerea, Tellina agilis, Molgula manhattensis, Cliona sp.* and *Polydora* sp. These disjunct taxa may represent relict populations from a period 10,000 to 6,000 yr B.P. when coastal water temperatures were warmer (*sensu* Bousfield and Thomas 1975) or they may only be present due to human introduction of oysters and associated fauna (and flora) (Jackson 1944).

Within the estuary there is commercial fishing for lobsters (*Homarus americanus*) and rock crabs (*Cancer irroratus*), as well as recreational fishing for oysters (*Crassostrea virginica*). Historically there was a fishery for soft-shell and razor clams (Jackson 1944) but harvesting is now limited by reduced clam densities and closures of beds due to bacterial pollution.

A study on the colonization of artificial substrata placed in the Great Bay estuary was conducted by Normandeau Assoc., Inc. (1972-1978). During 1972, fouling panels at Adams Point were colonized by colonial diatoms, especially *Melosira moniliformis*, a spionid polychaete, *Polydora ligni*, amphipods, especially, *Corophium* sp., *Amphithoe* sp., *Jassa falcata, Coremapus versiculatus* and *Hemiaegina minuta*, as well as the coelenterate *Tubularia crocea* (Appendix A, Table 8). Marked seasonal succession was observed (Normandeau Assoc., Inc. 1978a. 1978b). *Balanus* sp. and *Mytilus edulis* were rare at Adams Point but abundant on fouling panels in the outer estuary (Normandeau Assoc., Inc. 1973).

Zooplankton

Zooplankton numbers varied from 1000 to 10,000/m^3 during 1975 in Great Bay (Normandeau Assoc., Inc. 1976). Abundance increased throughout the spring, peaking in early summer and declining sharply in later summer. A total of 32 zooplankton taxa were detected within Great Bay (Appendix A, Table 9) - fewer than at more outer estuarine sites (Normandeau Assoc., Inc. 1976). Throughout the estuary, holoplankton (those forms which spend their entire lives in the zooplankton community) accounted for 73% of the zooplankton. Dominants were copepod nauplii (29%), *Pseudocalanus minutus* (14%), *Oithona similis* (8%), tintinnid protozoans (7%) and *Temora longicornis* (2%). Meroplankton (forms which enter the zooplankton for only a portion of their life histories, e.g. to reproduce) comprised 22% of the zooplankton, including polychaete larvae (11%), gastropod larvae (5%), cirriped larvae (2%) and bivalve larvae (5%). Tychoplankton (organisms which are only temporarily suspended into the zooplanktonic community), primarily harpacticoid copepods, represented 5% of zooplankton (Normandeau Assoc., Inc. 1976).

Turgeon (1976) monitored meroplanktonic abundances in the Great Bay estuary during 1970 through 1973. The numbers of bivalve larvae generally decreased from the mouth of the estuary into Great Bay (Turgeon 1976). Bivalve larval numbers were greatest in July and September. Early stage bivalve larvae occurred in the near-surface, while later stages were in deeper waters.

Barnacle nauplii (*Semibalanus balanoides*) are one of the first meroplankton forms to appear seasonally, during February (Turgeon 1976), coinciding with the spring phytoplankton bloom. Trocophores and early stage spionid polychaete larvae appear in April through May having highest densities within the inner estuary (Turgeon 1976). Mollusc larvae are most abundant during June through July with a second peak abundance in September. Prosobranch veliger numbers peak during June and July and are most abundant within the inner estuary. Concentrations of 2500 veligers/100 liters are reached in Great Bay waters, probably primarily *Ilyanassa obsoleta* (Turgeon 1976). These patterns were consistent during 1970-1973 (Turgeon 1976) although absolute numbers varied year-to-year.

Turgeon (1976) identified two distinct meroplanktonic communities. One predominated in the outer estuary and a second in Great Bay although there was overlap in the middle estuary. Larval populations were most dense and species composition most varied during February to July and again during September through November.

Larval abundances of soft-shell clam, *Mya arenaria*, were seasonally bimodal (Turgeon 1976). Oyster larvae, as well as larvae of several other bivalves, migrate vertically depending upon the tidal stage. Movement up in the water column at flood tide and downward with ebbing tide allows retention within the inner estuary (Turgeon 1976). Larvae of warm water species, such as *Crassostrea virginica, Geukensia demissa, Molgula manhattensis* and *Balanus improvisus*, were detected infrequently by Turgeon during 1970 to 1973 (Turgeon 1976).

Ichthyofauna

The NH Fish and Game Department (1981), using a variety of sampling techniques to collect finfish throughout the Great Bay estuary during 1980-1981, identified a total of fifty-two species (Appendix A, Table 10). During 1981-1982 using only beach seines and otter trawls, the NH Fish and Game Department (1982) collected thirty-two finfish species. Atlantic silverside (*Menidia menidia*) was the most abundant species, particularly during autumn. Other abundant finfish in the Great Bay estuary included (in order of abundance):

Fundulus heteroclitus	Common killifish, mummichog
Apeltes quadracus	Four-spined stickleback
Gasterosteus aceleatus	Three-spined stickleback
Pungitius pungitius	Nine-spined stickleback
Osmerus mordax	Smelt
Pseudopleuronectes americanus	Winter flounder
Microgadus tomcod	Atlantic tomcod
Liopsetta putnami	Smooth flounder
Alosa pseudoharengus	Alewife
Myoxocephalus aenaeus	Grubby

A similar overall list of finfish species for the Great Bay estuary was tabulated during 1970-1978 by Normandeau Associates, Inc. (1971-1979).

Resident finfish species occurring throughout the estuary include silversides, sticklebacks, common killifish, winter flounder and grubby. Anadromous species include smelt and alewife. Adult and juvenile smelt occur year-round throughout the estuary, while adult alewife occur in May to June and juveniles from May through November (NH Fish and Game Department 1981, 1982).

Commercial fisheries in the Great Bay estuary include herring, American eel and smelt. Striped bass, smelt, Coho salmon, and winter flounder are the most important recreational fisheries. Coho salmon were first stocked in the Great Bay estuary during 1969 by the NH Fish and Game Department (NH Fish and Game Department 1981).

During 1973-1979 a variety of fish larvae (Appendix A, Table 11) were collected throughout the Great Bay estuary in conjunction with the environmental impact assessment of the Newington Generating Station (Normandeau Assoc., Inc. 1980). Larvae of American sand lance (*Ammodytes americanus*) were the

most common during 1975-1979, followed by radiated shanny (*Ulvaria subbifurcata*), smooth flounder (*Liopsetta putnami*) and smelt (*Osmerus mordax*) (Normandeau Assoc., Inc. 1980).

Avifauna

A diverse avifauna occurs throughout southeastern New Hampshire (Appendix A, Table 12). Surveys by the NH Fish and Game Department recorded forty-three species using the estuary's waters and intertidal areas during 1982 (Appendix A, Table 13). Mean monthly abundances varied from 322 in June to 3,319 during March (NH Fish and Game Department 1982). The highest numbers of species occurred during April and September coincident with spring and fall migrations, respectively. (Ice cover during the winter severely restricts the areas in Great Bay utilized by birds.) Common species include:

Larus argentatus	Herring gull
Anas rubripes	American black duck
Phalacrocorax auritus	Double-crested cormorant
Ardea herodias	Great blue heron
Corvus brachyrhynchos	American crow

Abundant overwintering migrants include:

Branta canadensis	Canada goose
Aythya marila	Greater scaup
Bucephala albeola	Bufflehead
Bucephala clangula	Common goldeneye
Anas rubripes	American black duck
Anas platyrhynchos	Mallard
Mergus serrator	Red-breasted merganser

Functionally, the avian groups observed within Great Bay may be divided into five categories: seabirds, waterfowl, wading birds, terrestrial and shore birds. (Appendix A, Table 13) (NH Fish and Game Department 1981, 1982).

Seabirds (i.e. cormorants and gulls) are common year-round within Great Bay. Herring gulls (*Larus argentatus*) had a maximum mean monthly abundance of 432 during September (NH Fish and Game Department 1982). Great black-backed gulls (*Larus marinus*) are also common within the estuary. The common tern (*Sterna hirundo*) occurs in Great Bay during later spring and summer. Terns have nested in the past on Nannie Island in Great Bay (NH Fish and Game Department 1981). Double-crested cormorants (*Phalacrocorax auritus*) are common in Great Bay during April to November.

Waterfowl are most abundant in the estuary during the fall and winter months. Black ducks (*Anas rubripes*) are in high abundance from August (maximum abundance 895) through March. During winter large numbers (900) of Canada geese (*Branta canadensis*) occur in Great Bay. A major source of food for overwintering geese may be the abundant intertidal green seaweeds, e.g. *Ulva lactuca* and *Enteromorpha* spp. (Penniman, personal observation).

Greater scaup (*Aythya marila*) are present during late summer to spring. Other relatively common waterfowl include bufflehead (*Bucephala albeola*), common goldeneye (*Bucephala clangula*), mallard (*Anas platyrhynchos*) and red-breasted merganser (*Mergus serrator*).

The great blue heron (*Ardea herodias*) is the most prominent wading bird, occurring primarily from April to October. Other wading species include snowy egrets (*Egretta thula*), green-backed heron (*Butorides striatus*), black-crowned night heron (*Nycticorax nycticorax*), glossy ibis (*Plegadis falcinellus*), greater and lesser yellowlegs (*Tringa melanoleuca* and *T. flavipes*) and least sandpiper (*Calidris minutilla*).

Common terrestrial species utilizing the estuary are the American crow (*Corvus brachyrhynchos*) and the belted kingfisher (*Megaceryle alcyon*). Adams Point also has a large population of ruffed grouse (*Bonasa umbellus*) (Texas

Instruments, Inc. 1974).

Endangered and Threatened Bird Species

Several endangered and threatened bird species utilize Great Bay as habitat at various times of the year. The estuary supports the largest winter population of bald eagles and is one of the best documented wintering sites for bald eagles in New England. Regularly used areas within the GBNERR boundary include the entire shore of Pease Air Force Base, a section of shore in Durham, the Squamscott River, and several islands within the estuary. Ospreys, common loons and pied-billed grebes forage in the Bay during migration. Common terns have nested on Nannie Island and the Footman Islands as well as on several islands in Little Bay in the recent past, although none are nesting there at present. Migrating Northern Harriers use the saltmarshes and agricultural land for foraging. Sedge Wrens and Henslow's Sparrows ocasionally occur in short grass habitats around the Bay.

Mammals and Other Terrestrial Vertebrates

Harbor seals (*Phoca vitulina*) are observed frequently throughout the Great Bay estuary particularly at a rock ledge near the mouth of the Oyster River (Normandeau Assoc., Inc. 1974b, Texas Instruments, Inc. 1974, NH Fish and Game Department 1982).

Terrestrial mammals which utilize Great Bay include raccoons, whitetail deer, red fox, woodchuck, muskrats, chipmunks, grey squirrels, cottontail rabbits, mink, otter and beaver. Whitetail deer are very common in Durham and Adams Point with several over-wintering yards present in the area (Texas Instruments, Inc. 1974). In Appendix A, Table 14 enumerates the common terrestrial mammals in the seacoast region of New Hampshire. A checklist of New Hampshire amphibians and reptiles is included in Appendix A, Table 15.

7. THREATENED/ENDANGERED SPECIES

Plant and animal species listed as threatened or endangered have been discussed in previous sections. A complete listing of these species is included as Appendix A, Table 4.

It should be mentioned that the disjunct estuarine invertebrate and seaweed species discussed in previous sections are limited to only several locations north of Cape Cod, Massachusetts. In fact, *Crassostrea virginica* (American oyster) and *Dasya baillouviana* (a red seaweed) are species listed as part of the Maine Critical Areas Program (Cowger 1975, Vadas 1977).

D. Reserve Uses

The Great Bay National Estuarine Research Reserve has a rich New England tradition and presently supports many scientific, recreational, and educational uses, all dependent on the estuarine environment and its resources. The diversity of its present and past uses contributes greatly to the uniqueness of the estuary and is an important factor in the development of this management plan.

1. TRADITIONAL

In order to appreciate the impact of the strong cultural tradition on the Reserve, it is important to look back at the entire region's history. Observing the arbitrary boundaries of the Reserve does not serve to convey the wealth of both the history and lore of the area.

A descriptive picture of the Reserve can best be painted using some of the words set down over a hundred years ago, by the earliest inhabitants of the region. The Atlantic coastline of New Hampshire is only "eighteen miles long as a seagull might fly it,[1]" but the bays and inlets extending far inland add another eighty miles of saltwater shore. This inland system is "arranged like 5 spindling fingers;" the 5 rivers mix fresh water from interior New Hampshire with sea water forced up the Piscataqua on a seven-foot tide to form "that remarkably salty lake composed of Broad Cove, Little Bay, and Great Bay."[2] The system may be "rudely represented as a man's left hand and wrist laid upon

[1] SPNEA, in-house report, Piscataqua Planning Project, Phase I Report, (April, 1981)
[2] John P. Adams, Drowned Valley: The Piscataqua River Basin, (Hanover, 1976)

the table, back upwards and fingers wide apart. The thumb would stand for the Salmon Falls River, the forefinger for Bellamy River, the second finger for Oyster River, the third for Lamprey River and the fourth for Exeter or Squamscot River; while the palm of the hand would represent Great Bay, into which most of the streams pour their waters, and the wrist of the Piscataqua proper."[3]

The name of the Piscataqua River "is from the Indians. It is not a river because the tides flow in and out to Great Bay . . the correct name is a drowned valley."[4]

The Piscataqua region that 17th century explorers and settlers found was incredibly rich in resources. Not only did the coastal waters and waters of Great Bay yield great quantities of fin and shellfish, the shores were covered by pine forests, with white pine far more awesome than the scrubby second-growth found today. These white pine were invaluable as masts and spars for building the British Royal Navy's ships. Consequently, the commercial value of the region led to a merchant-dominated society in contrast to the Puritan communities to the south in Massachusetts.

The abundant resources of the region were utilized in a number of ways. Most of the rivers had at least one ship building concern located along their banks. The Towns of Exeter and Durham sent many fine ships down their rivers to the Piscataqua, and out to sea, never to return to the towns as the rivers were too shallow and narrow to permit the passage of heavily-laden ships.

Salt marsh farming utilized the nutritious marsh hay found along the banks of Great Bay and its rivers for livestock, the rich river soil for crops and the proximity to the water for transporting produce. Two of the Reserve's key land and water areas (Squamscott River and Crommet Creek) were important salt marsh farming sites. Additionally, Crommet Creek was once known as Mill Creek, an indication of the lumbering and timber milling that went on in the area. The importance of these early commercial ventures is reflected in the name of a residence near Crommet Creek built on an old (approximately 1690) house site. "Salty" refers to the salterns, or salt licks, which were a valuable commodity in the colonial farm and barter economy. As settlers moved inland up the tidal rivers, more milling concerns developed. By the early 1800's Salem, Massachusetts merchants had founded textile companies along the Lamprey River in Newmarket.

The vessel used for transportation of hay, timber, people, etc. was the gundalow. Heavy and broad-bottomed, this local craft was ideally suited to the shoaly conditions of the rivers and Great Bay. Plying the river systems that served as natural roadways for commerce and communication, the gundalow was an integral part of the river and coastal traffic which tied the regions together for almost three hundred years. One of the last gundalow captains was Edward H. Adams. His family resided for 120 years at Adam's Point, and in this century ran a guest house for summer visitors. From this early beginning, tourism became an important economic factor in the region in the mid-1800's, and the natural resources that had originally brought people to the area continue to attract visitors today.

2. EXISTING

As mentioned in previous sections, the water-dependent uses of the estuary (including Little Bay) consist of limited commercial and recreational fishing, clamming/oystering, bird hunting and watching, and boating. Transportation and storage of petroleum products is confined to the Piscataqua River, which is outside of the GBNERR's boundary. Commercial fishing in the estuary is limited. There is some lobstering at Little Bay and there is some taking of rainbow smelt, river herring and American eel on a commercial basis. The estuary is very popular for recreational fishing and shellfishing. There are several sportsmen's groups that actively fish the estuary, as well as many individuals - from the area and from out-of-state

[3] Charles E. Clark, The Eastern Frontier: the Settlement of Northern New England 1610-1763 (New York, 1970)
[4] Adams, Drowned Valley

- who fish and/or harvest the oysters, clams and mussels.

Although limited public access to the shoreline, particularly in the upper estuary, does restrict hunting somewhat, duck hunting is a significant seasonal activity. The Bay is also a very popular area for birdwatching. More intensive boating activity in the estuary is mainly outside of the Great Bay Research Reserve boundary - in the lower portions of Little Bay, the Piscataqua River and Portsmouth Harbor. While there is boating in the upper estuary, the extensive mud flats in Great Bay and the shallow channels in the rivers at low tide tend to discourage all but the most experienced boaters. There is a small marina in Greenland and five public boat launches in the estuary (see regional setting section).

With the exception of seasonal homes, such as those at Brackett and Weeks Points, the character of the shoreline around Great Bay is predominantly a mixture of residential property, agricultural land and woodlands.

There are three main reasons for the pattern of development around the estuary: local land use controls that place certain restrictions on shoreline development, the ability - and conviction - of many landowners to retain large parcels of land, and the recreational limitations of the Great Bay estuary at low tide (mud flats, narrow channels). The towns, via their land use controls, have classified shoreline uses for residential, agricultural and conservation purposes only. Many of these parcels, despite subdivision pressure, are still 50-100 acres or more because many of the landowners are deeply committed to preserving their own homestead and the open character of the area.

Projections for future use and development of the estuary indicate a moderate rate of growth for the area (see Table 5). From 1970 to 1980 the eight-town region grew from 38,721 to 44,475, an increase of 15 percent during the decade. From 1980-1990, it is projected to grow another 24 percent to 55,020, and by the year 2000, an additional 22 percent growth in population is expected, bringing the population to 67,036. The Department of Transportation expects a doubling of the average daily traffic across the General Sullivan Bridge by the year 2000. A Recreational Boating Needs Assessment carried out for the State in 1981 projected a need for approximately 100 additional moorings in the estuary by 1990.

This growth translates into more construction activity, more housing and more use of the estuary for recreational purposes. While these changes do not necessarily represent a serious threat to the health of the estuary, the impact on the system points directly to the importance of establishing the GBNERR.

3. RESEARCH AND EDUCATION

The special qualities of the estuary have attracted many different organizations and government agencies who have conducted several scientific and educational activities. Detailed histories of both these areas are located in the research and education sections respectively.

4. MILITARY

The location of Pease Air Force Base (PAFB) encompasses approximately 3,000 acres of Newington lands, 1,500 of Portsmouth, and several hundred acres in Greenland. The site includes what was once farmland, forestry, and a 300 acre airport which opened in the early 1930's to serve as a city airport for Portsmouth. In early 1951, the Air Force began considering the construction of a large bomber base in New Hampshire. After several years of controversy, and a cessation of work on the project due to a cut-back in federal funds, the base was completed in 1956. The addition of many jobs to the local economy is often noted as one of the benefits of PAFB. Recent developments have occurred concerning closure and final disposition of Pease Air Force Base. On January 5, 1989 the Secretary of Defense accepted the Commission's recommendations and the Air Force has initiated implementation of this decision. For purposes of this document references to Pease remain unchanged as the property will remain in its present status for the next few years. Reserve staff will continue to be available to state, federal and local officials for technical information and support on the ecological significance of the Pease shoreline.

Table 5. POPULATION GROWTH IN GREAT BAY COMMUNITIES

	US Census					Projections			
	1960	1970	Percent Change 1960-1970	1980	Percent Change 1970-1980	1990	Percent Change 1980-1990	2000	Percent Change 1990-2000
Dover	19,131	20,850	9	22,377	7	25,838	16	30,534	16
*Greenland	1,196	1,784	49	2,129	19	2,934	38	3,884	32
Madbury	556	704	27	987	40	1,296	31	1,658	28
*Newfields	737	843	14	817	-3	1,036	27	1,330	28
*Newington	1,045	798	-24	716	-10	861	20	1,069	24
*Newmarket	3,153	3,361	7	4,290	28	6,371	48	7,983	25
*Stratham	1,033	1,512	46	2,507	66	4,122	64	5,992	45
TOTAL	32,033	38,721	20	44,475	15	55,020	24	67,036	22

* Towns included in proposed boundary

Source: 1960, 1970 and 1980 U.S. Census
NH Office of State Planning, May, 1987 (for projections)

IV. The Plan

A. Administration

The following administrative framework for the Reserve recognizes the need for cooperation and coordination in order to achieve effective management. The proposed administration for the Reserve will ensure that the functions required to implement this plan - research/education activities, land acquisition, resource protection - are coordinated with the necessary agencies/organizations which are presently active within the estuary.

1. ADMINISTRATIVE FRAMEWORK FOR RESERVE

The overall operation and management of the Great Bay Research Reserve is the responsibility of the New Hampshire Fish and Game Department. As mentioned several times in this plan, implementation of the management plan requires a cooperative effort between several state regulatory agencies, the University of New Hampshire and a Great Bay Research Reserve Advisory Committee appointed by the Reserve's management agency. Coordination and cooperation from all involved parties is critical to the implementation of the management plan as its proposed structure relies on existing authorities and state laws and programs. Figure 6 outlines the proposed management structure for the GBNERR.

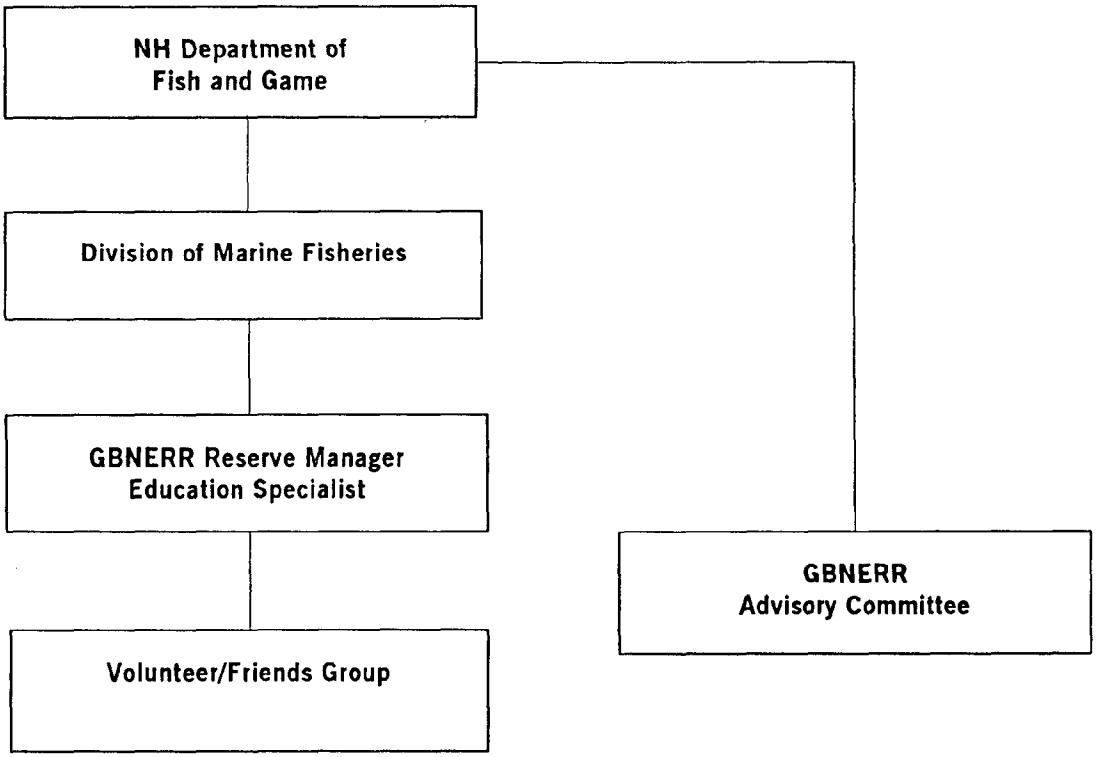
Overall Administration/Coordination

Administrative responsibility for the management of the GBNERR is through the New Hampshire Fish and Game Department for several reasons. Namely, Fish and Game regulates hunting and fishing activities in the State, can acquire land for protective purposes or hold conservation easements for the Reserve, and has sufficient land management authority to administer the project. The Department presently owns several parcels of land within the Great Bay National Estuarine Research Reserve's proposed boundary: Adams Point in Durham, an 80 acre peninsula of land acquired by Fish and Game as a waterfowl hunting and management area; Chapman's Landing in Stratham, a public boat launch site along the Squamscott River; and several access/rights of way to Great Bay. As both a property owner in Great Bay, a regulatory authority over hunting and fishing activities and an administrator of other Departmental programs related to resource protection, the Department of Fish and Game is ideally suited to manage the GBNERR. Appendix C contains the MOU between NOAA and the Fish and Game Department formally accepting management responsibility. In addition, Fish and Game staff already participates in estuarine research and conservation education and is well qualified to implement the research and education plans for the Reserve.

In addition to acting as the management authority, Fish and Game will also serve as the contact with the federal agency that administers the National Estuarine Reserve Research System once the operation and management phase is underway.

The Great Bay National Estuarine Research Reserve will be in a unique position to utilize existing facilities and programs which will strengthen its management plan (i.e. the University of New Hampshire's Jackson Estuarine Laboratory and planned Outdoor Education Center, and the Sea Grant Extension Program which already provides some estuarine education programs). Present plans call for housing the Reserve

Figure 6. GBNERR MANAGEMENT STRUCTURE



staff in the Fish and Game facilities in Durham (see page 66 for further discussion). However, the state will continue to explore the feasibility of an on-site visitor center to house the Reserve staff and program. The key to the project's administration will be clearly defined responsibilities and coordination with other State agencies, the University of New Hampshire, the towns within the proposed boundary, the Great Bay Estuarine System Conservation Trust and other private organizations. Overall coordination is being accomplished in two ways: 1) formal agreements (see Appendix C) between the Fish and Game Department and the University of New Hampshire's Sea Grant Extension Program and Jackson Estuarine Laboratory as they relate to the University's present operation of research and education programs in Great Bay; and 2) informally through its research/education activities with other groups who are active within the Reserve.

2. PHASING/BUDGET

Planning for the phases needed to implement this management plan requires a detailed explanation as another state agency, the Office of State Planning, has assumed the lead agency role through the initial planning and acquisition phase for the Reserve. For readibility, the phases have been organized into the following subject areas: Planning/Acquisition and Management/Operations.

Planning/Acquisition

The first phase began in September 1987, with the state receiving its first acquisition award from NOAA. The focus of this phase is on preparing this management plan and negotiating and finalizing the conservation easements necessary to establish "adequate state control" over the key land and water areas. The Office of State Planning (OSP) has assumed the lead agency role in this phase for the Reserve, and will continue to oversee the acquisitions until they are completed. Upon completion of this phase, the New Hampshire Fish and Game Department will assume responsibility for the management and operation of the Reserve. As a part of the planning phase for this project, OSP is contacting private landowners in the identified key land and water areas concerning their participation in the project through conservation easements or land donations. The strategy pursued by OSP is detailed in a later section. It is expected that all acquisitions will be completed by 1990.

For the public lands within the proposed boundary, agreements are being pursued (Appendix C) with Pease Air Force Base, and the towns which own property within the proposed boundary (Stratham and Greenland) to ensure access for Reserve programs and activities.

Another component of this phase may be the beginning of support for the research and education activities. Some possible activities include initial preparation of educational material and programs on Great Bay resources and support of the baseline monitoring program at Jackson Estuarine Laboratory.

Management/Operations

The primary task of this second phase will be full support for staff to carry out the research and education objectives. Several options for the focus of the education programs for the GBNERR are discussed further in the education section. The planning for the location of Reserve programs will take place during this second phase. As with establishing the system of sites, operation of education/interpretive programs will require the support and cooperation of many different interests. Specific responsibilities of the Fish and Game Department are to oversee the implementation of the management plan, carry out the research and education agendas, manage the Reserve sites according to the agreements developed with the various landowners, and work with the appropriate groups to address the important issues in the estuary. National Estuarine Reserve Research System funds are available on a 50/50 matching basis to support these tasks. However, after five years the federal funds for operation and management cease and the State assumes full responsibility for

this aspect of the program. Table 6 outlines in more detail the phases for implementation of the Reserve program.

Budget/Phasing

The following budget strategy is based on the costs of administering and managing the Reserve to the year 1994. These costs are just estimates at this point and should be reviewed as such. Presently, the State is involved in the budget process for FY 90 and FY 91 (New Hampshire operates on a 2 year budget cycle).

Included in these basic operating costs are two staff positions which are described below and some development funds for implementing the education/research priorities. The priorities which will be implemented by Reserve Staff are described in the education/research areas of the management plan.

3. STAFF REQUIREMENTS

An adequate staff is essential in meeting the Great Bay Research Reserve's education and research objectives. The project will be directed by a Research Reserve Manager whose responsibilities will include:

- acting as a liaison for state and federal agencies and other interested groups to improve cooperation and coordination in implementing the Reserve's management plan;
- carrying out administrative duties related to performance reports, grant applications, record keeping, scheduling of events, etc.;
- acting as staff support for the Reserve's Advisory Committee;
- directing the Reserve's education/research programs;
- oversight of any volunteers/paid staff; and
- monitoring of any research activities in the Bay.

Depending on funding availability, the approach to other staffing needs will be to hire an education specialist, either part or full-time, and to provide some financial support through the University of New Hampshire for education/interpretive and research programs. Inasmuch as the University is already involved in estuarine education and research, Reserve funds will be used to sup-

1st year	Basic Operating Costs	$100,000	State:	50,000
			NOAA:	50,000
2nd year	Basic Operating Costs	$100,000	State:	50,000
			NOAA:	50,000
3rd year	Basic Operating Costs	$100,000	State:	50,000
			NOAA:	50,000
4th year	Basic Operating Costs	$100,000	State:	50,000
			NOAA:	50,000
5th year	Basic Operating Costs	$125,000	State:	75,000
			NOAA	50,000
Next 6-10 years - State will assume full operation costs for Research Reserve.				

Table 6. GBNERR IMPLEMENTATION PHASES

PLANNING/ACQUISITION PHASE

September, 1987 - June, 1990

- negotiate and obtain easements to include private lands in system of Reserve sites;
- complete and adopt reserve management plan;
- negotiate memorandums of agreement to include public lands in system of Reserve sites;
- obtain executive order by Governor;
- establish working group to assist in preparation of management plan;
- plan for location of Reserve's educational/research activities;
- complete final planning for education/interpretive location(s)
- coordinate Reserve's research and education activities with existing UNH Sea Grant Extension Program/Jackson Estuarine Laboratory.

MANAGEMENT/OPERATIONS PHASE

July 1989- September, 1994

- provide full support of research and education staff and for tasks necessary to meet research and education goals and objectives;
- complete any easement negotiations regarding Reserve sites;
- carry out the research and education agendas established by the plan's priorities;
- conduct ongoing management of the Reserve sites according to the negotiated agreements;
- determine the feasibility of operating an on-site visitor's center;
- conduct ongoing administration of the Reserve, and coordinate the various parties involved in GBNERR implementation;
- use the Reserve as the vehicle to address the important issues in the estuary;
- assist organizations/agencies eligible for research and education grants through NERRS; and
- conduct any needed public access improvements.

port and build on this experience and expertise rather than duplicate any of these efforts. The basic needs for the Reserve's education program are as follows:

- an Education Specialist to lead tours of the estuary, develop outreach programs, organize workshops and other special events, and work with researchers to interpret their projects for use in public education programs; and
- volunteers to assist in leading interpretive tours of the estuary and to assist the Education Specialist and help researchers with any field work.

Depending on funding availability, some support for training the existing Marine Docents, a network of volunteers specializing in marine and estuarine education, will be initiated.

4. EXISTING JURISDICTIONS

The Great Bay Research Reserve is relying on promoting the coordination between state, federal and local officials/ agencies with resource management responsibilities in the Reserve as the major vehicle in maintaining and enhancing the health and productivity of the estuary. Since the Reserve is relying on existing jurisdictions, this section includes an overview of the state and local resource protection responsibilities and regulations in the Great Bay estuarine system and describes the process for improving coordination among those agencies.

In addition to this listing of state regulations, there are other state programs/boards which directly affect resource protection of the GBNERR.

Fish and Wildlife Management

The management of marine fisheries is administered through the laws, regulations and programs of the Department of Fish and Game (F&G). Certain regulations governing the management of some species, such as the minimum allowable size for lobsters, are contained directly in state legislation and it is the responsibility of the Department of Fish and Game to enforce these legislated regulations. A Marine Fisheries Division is established within the Department. Policy and program recommendations for shore fisheries are made to the Fish and Game Commission by the Advisory Committee on Shore Fisheries.

Protection of fish, plant and wildlife habitats on submerged lands in wetlands and other habitats (i.e. beaches, dunes, and rocky shores) is an explicit purpose of the authority of the Wetlands Board.

Aquacultural activities are controlled by the Department of Fish and Game through a license issued by the director of the Department. The license application requires sufficient information to determine the compatibility of the project with existing natural resources and with present or potential uses of the area. Conditions for the license include requiring safeguards to protect established runs of anadromous fish and to guard against release into state waters of any fish that might be diseased.

Threatened and Endangered Species

The saltmarshes, tidal waters and related land areas provide habitat for certain animal and plant species that are threatened or endangered with extinction. The New Hampshire Endangered Species Program was established as a cooperative project of the NH Department of Fish and Game and the Audubon Society of New Hampshire in 1980, to carry out the provision of the 1979 NH Endangered Species Conservation Act. The New Hampshire Native Plant Protection Act of 1987 provides protection of native plant species designated as endangered, threatened, or of "special concern." Any peace officer may enforce the provisions of the Act which prohibits the taking, possession, transportation, processing, or sale of such species without required and valid federal and state permits.

The Federal Endangered Species Act requires federal agencies such as the Federal Highway Administration and the Army Corps

of Engineers to certify that their projects and permits will have no detrimental effect on federal listed species.

The National Marine Fisheries Service tracks the movement of threatened and endangered marine species and regulates the taking and other operations which may impact these species.

Unique Natural Areas

There are natural areas in the Great Bay estuary which have a uniqueness in the state or region which make then deserving of special management.

In accordance with 1986 legislation, the Department of Resources and Economic Development (DRED) is required to utilize the Nature Conservancy's inventory of unique and natural areas to designate those areas which are to be preserved under the state Natural Heritage Program. DRED shall be assisted in administering the program by a committee composed of representatives of: the Nature Conservancy, the Society for the Protection of New Hampshire Forests, the Audubon Society of New Hampshire, the New Hampshire Association of Conservation Commissions, the Department of Fish and Game, the Office of State Planning, and DRED. The goal of this program is to carry out the policy stated above. In doing so, the program also affords the state another avenue of balancing land use and resource protection. The Nature Conservancy is responsible for the inventory of rare plants used by the GBNERR to aid in identifying its key land and water uses.

The New Hampshire Natural Areas Council is an association of state and private agencies concerned with establishing protection priorities for natural areas in the state, coordinating protection efforts, and promoting research and public awareness and understanding. All the organizations represented in the Council provide valuable input and data to the regulatory processes by testifying and presenting evidence for consideration in regulatory cases.

Council on Resources and Development

The Council on Resources and Development (CORD) is an interagency board responsible for coordinating actions and resolving conflicts between state agencies in addressing resource management, growth and development issues. The Council is authorized to consult on common problems in the field of natural resources and their development; consult and negotiate with any federal or state agency concerned with the Council's problems, studies, or reports; conduct studies and recommend changes to effectively coordinate the work of member agencies; and resolve differences or conflicts concerning water management or supply which result from the work of any agency represented on the Council. The eleven members of the council represent various resource related state agencies. Recommendations for effective coordination adopted by a majority of the council are binding on the affected agency.

The Governor has directed CORD to adopt policies regarding the preservation of the Great Bay area and to implement these policies (Executive Order 83-8). Once the GBNERR is officially designated by NOAA, an Executive Order will be issued which will direct state agencies to coordinate any actions within the Research Reserve with other state agencies and obligate each agency to carry out its respective responsibilities in accordance with the Reserve's management plan.

The New Hampshire Coastal Program

The NH Coastal Program has recently received approval to extend its boundaries to the Great Bay estuarine system. In general, the Coastal Program was established to ensure that state agency capital investment, regulatory and management decisions in the Great Bay estuary are consistent with other coastal policies and that they recognize and preserve the rural character and scenic beauty of the area. This is accomplished by improving the administration of existing laws and regulations involving regulatory, resource management and public investment decisions. One area where the GBNERR

Table 7. ACTIVITIES UNDER EXISTING STATE LAW

Regulated Activities	Description	Statute	Administrative Agency
Archaeological Excavations	Field excavations on State lands on the bottom of State waters	227-C	Division of Historical Resources
Boat Moorings	Boating and mooring sites within tidal waters or harbors of the State	271-A	Port Authority
Dams and Reservoirs	Construction or reconstruction of dams and reservoirs	482:3	Water Resources Council (DES)
Dredge and Fill Disturbing Terrain Near Waterfront	Dredging, excavating, mining, filling, transporting of forest products or undertaking construction in or on the border of surface waters of the State, or altering the characteristic of the terrain.	149:8a	Water Supply and Pollution Control Division (DES)
Wetlands Dredge and Fill	Construction, filling, excavation or dredging of surficial or subsurface materials in areas adjacent to State waters.	483-A	Wetlands Board (DES)
Road Construction Across Public Waters Division	Construction of public highways, access roads or private ways, access roads or private ways across a watershed tributary to a lake, pond or reservoir used for public drinking water.	148:25-a	Water Supply and Pollution Control Division (DES)
Sewage Treatment Facilities	Construction of any new public sewage installation or sewage treatment facility or repair of existing one.	148:25	
Solid Waste Facilities (DES)	Solid waste disposal, storage, treatment and processing sites.	149-M	Division of Waste Management

Regulated Activity	Description	Statute	Administrative Agency
Subdivision/Waste Disposal Systems	Design and installation of subsurface sewage or waste disposal systems; subdivision of land.	149-E	Water Supply and Pollution Control Division (DES)
Timber Harvesting	Cutting of more than 50 percent of timber in areas adjacent to great ponds, streams, rivers, brooks and public highways.	224	Department of Resources and Economic Development
Waste Disposal	Discharge and disposal of sewage or waste into surface and ground waters of the State.	149:8	Water Supply and Pollution Control Division (DES)
Water Supply Systems	Construction or modification of any public water supply system.	148:25	

can work cooperatively with the Coastal Program is in providing key information to coastal decision-makers in two ways: Promoting joint research projects which address coastal issues and ensuring that the data and results reach the decision-makers at the local, state and federal levels.

5. EVALUATION OF RESERVE PROGRAM

a. Introduction

The management plan needs to provide mechanisms to evaluate its own effectiveness as well as its own revisions. The purpose of an evaluation is to tell us which programs/activities work and which do not and points the way to better formulation of policy and programs. The evaluation itself is intended to be useful to several different groups:

1. Funding organizations;
2. Local users of the estuary;
3. Program participants; and
4. Program staff

While every two years an evaluation on the overall Reserve program is conducted by the federal government, it is still valuable for the staff to conduct an "in-house" evaluation on the Reserve program's effectiveness in meeting the overall goals and objectives. How this can be accomplished follows.

b. Methods of Evaluation

How to conduct the evaluation, what is being measured and what to do with the evaluation once it is completed are all important components of the evaluation.

Evaluations generally concentrate on measuring changes in program participants and commonly use measures of attitudes, values, knowledge and skills as they relate to program goals. For the GBNERR, the overall goals are to provide information about the significance of the estuary as a means to promoting compatible uses and to provide scientific information which can contribute to better coastal management decision-making. The methods of evaluation research by GBNERR staff will generally rely on observation, interviews and questionnaires to collect information about program participants, who they are, what they did in the program, and what their attitudes and behaviors are before and after program participation. Program records showing attendees at workshops, seminars, lecture series, etc. and other documents (minutes of meetings, news articles, etc.) will be used as measurements as well.

Evaluation can never provide all the answers. What it can do is point out any failures of existing programs and point out the need for change. Evaluation results can assist Reserve staff in designing new programs, altering existing ones or affirming existing programs.

B. RESOURCE PROTECTION

1. STRATEGIES

Enhancement of protection of the estuarine environment and resources of the Great Bay Research Reserve is the highest priority to management. Improving the present level of protection is dependent on two strategies:

- Fostering land protection efforts in the Reserve by acquiring properties through conservation easements in the key land and water areas; and
- Providing adequate public participation as a means to promoting compatible uses of the Reserve and to coordinating research/education activities already taking place within the Reserve.

a) Acquisition Strategy

A key resource protection strategy in establishing the Great Bay Research Reserve is to insure long-term protection and management of the area through land acquisition. This will be accomplished by negotiating agreements with the owners of key land and water areas to ensure protection of the overall estuarine system.

Looking toward Crommett Creek/Great Bay from Reserve's easement acquisition #1.

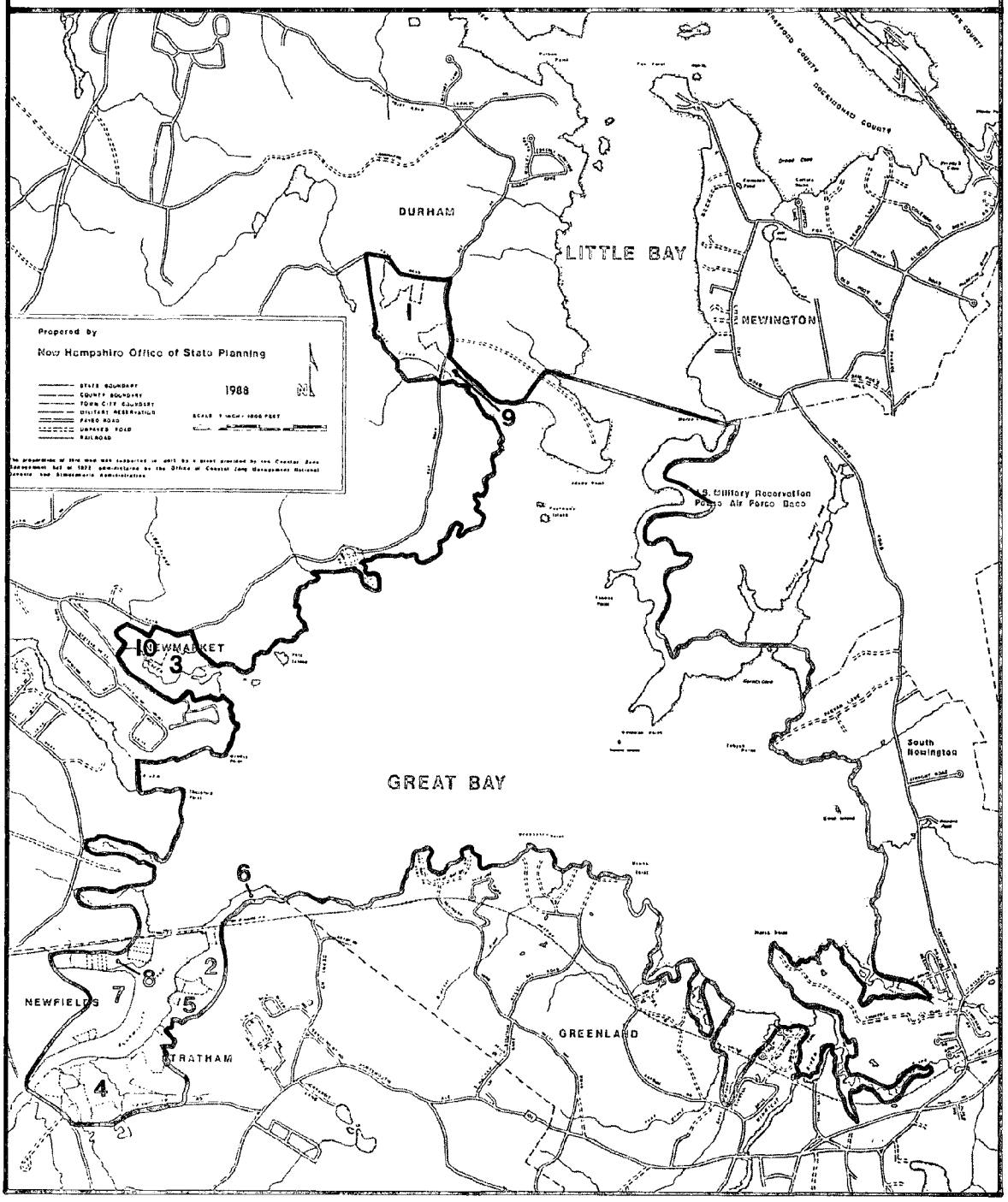
Background view of Squamscott River from property #4

Squamscott River from property #4

Easement Acquisition #5 in Stratham

Easement acquisition #2 along the Squamscott River key land and water area.

Figure 7: GBNERR ACQUISITION SITES



For example, the Adams Point/Crommet Creek sites include State and private land. The overall objectives are to provide long-term protection for the marshes and the Creek, to support State wildlife management and to provide an interpretive marsh walk along the Point. For the State land specifically, the continued management of the land as wildlife habitat and improvement of access for sportsmen and the general public are important priorities. For the private land, a combination of field, marsh and woodland, long-term protection via a conservation easement is the focus.

The desired end product of discussions concerning the public lands within the proposed boundary for the Reserve has been discussed in previous sections. The Memorandums of Agreement with the affected towns and Pease Air Force Base are included in Appendix C. Significant clauses in the Agreements with the towns provide the Reserve with a right of first refusal to acquire any public land within the Reserve's boundary and to provide access for research and education. The agreement with Pease describes the procedure to follow in obtaining access for research and education activities associated with the Reserve. This agreement is effective until Base closure. For the private lands, the goal is to develop an arrangement with the landowners for achieving the Project's objective of protecting key areas (i.e. water and marshes) from development. The primary arrangement that is being pursued is the conservation easement, an agreement by the landowner to place development or other restrictions on all or a portion of the property in exchange for tax breaks and/or financial reimbursement. The restrictions in the easement deed are permanent and bind all future owners. The restrictions are enforceable by the State of New Hampshire. The other alternative is donation of land to the Great Bay Research Reserve with associated tax breaks for landowners.

Ten properties have been identified in the key land and water areas (Figure 7). One easement (#2) was donated in 1985 to the State and is being held by the Strafford County Conservation District. One other easement (#5) was donated to the Society for the Protection of New Hampshire Forests in 1986. This easement was recently transferred in early 1989 to the State for inclusion in the Reserve. The value of this easement will be available to the State as a match for other acquisitions. Both of these easements are located on the Stratham side of the Squamscott River and total approximately 125 acres (Figure 7). The easement on property #1 was completed in June, 1988. Negotiations on two more properties (#4 and #10) are completed and under easement. These properties (#4 and #10)sucessfully applied for partial state funding through the Land Conservation Investment Program. The other five properties will be under negotiation during 1989/1990 by Reserve staff.

Due to the extremely high value of shorefront property within the Reserve boundary, conservation easements and donations will generally be pursued in negotiations.

b) Public Participation

An important strategy of the Reserve is to provide for public input into the program/activities offered by the Reserve staff. One role of public participation will be the appointment of an advisory group to assist Reserve staff in defining issues and making recommendations on research/education priorities; in effect, formalizing the exchange process between Reserve staff and the public.

While a forum for public participation will also be provided for through the evaluation process and other informal contact with users and organizations, the advisory group's responsibility will be to enhance communication and cooperation among its members and affiliated agencies and groups. Specific responsibilities will include soliciting public input into the ongoing planning process for Great Bay Research Reserve activities, providing

assistance on the preparation of the management plan and any revisions, performance reports or evaluations, seeking financial support for the research/education programs and evaluating proposed research projects.

Members of the Committee will be selected by the managing state agency to fully represent the varied interests and users of the Bay (i.e. UNH Outdoor Education Program; UNH Sea Grant; UNH Jackson Estuarine Laboratory; Audubon Society of New Hampshire; Strafford and Rockingham County Conservation Districts; New Hampshire Department of Resources and Economic Development; Department of Environmental Services Division of Water Supply and Pollution Control Wetlands Board; Office of State Planning; local governments; landowners; and other conservation groups) (Great Bay Trust, Salmon Unlimited, NH Wildlife Federation, Forest Society . . .), sportsmen's organizations and other recreation user groups.

C. Management Issues and Concerns

Steps towards assessing the effectiveness of Reserve management are to first inventory what the present issues/ concerns are, how the Reserve can help to address them, who to involve, and subsequently how to provide the information to decision-makers and the general public. This information has been organized into a matrix format (Table 8). The recommended actions are described further under the appropriate education and research program areas.

D. EDUCATION

1. GOALS AND OBJECTIVES

Better management through education is the principal theme of the education plan for the Reserve.

If the public is more aware of how an estuarine system functions and why it is such an important resource area, then they are more likely to properly use the area and support its management. To guide the development and implementation of the education plan, goals and specific objectives have been developed.

Goal 1: To make available a range of opportunities for the public and government agencies to learn about the Great Bay estuarine system and the need for its wise use and management through the Great Bay National Estuarine Research Reserve.

Goal 2: To identify the need, gather the information, develop the educational tools, and disseminate the information to the public and government agencies which have decision-making authority over Great Bay and other coastal resources.

Objectives:

1) Work closely with scientists conducting research within the Reserve in order to facilitate the translation of relevant research projects and results into the various education programs for the Reserve;

2) Establish a visitor/education site which interprets the natural and cultural history and the implications for the future of the estuary. This will serve as a focal point of the education efforts for the Reserve;

3) Provide the public with a variety of on-site educational experiences (trails, workshops, lectures, and school field trips) that interpret the past, present and future resources and uses of the estuary. Where appropriate, passive recreation experiences may be provided as part of the overall educational experience;

Table 8. GBNERR MANAGEMENT CONCERNS AND ACTIONS

MANAGEMENT CONCERN	ACTIONS	WHO TO INVOLVE
Public Awareness of the Reserve The Reserve needs to establish its identity for residents and visitors, the general public and state and regional agencies.	Update as necessary and distribute orientation and other interpretive documentation on the Reserve.	F & G
	Work with existing organizations and agencies with responsibilities and/or programs on Great Bay to include information on the Research Reserve.	F & G

MANAGEMENT CONCERN	ACTIONS	WHO TO INVOLVE
The possible impacts of increased visitor use on significant Reserve resources. Increased visitor use of the Reserve is expected over the next few years. Increased use in specific areas during certain seasons could affect the viability of some resources.	Through the Reserve's research priorities, identify specific areas and activities to receive priority for resource protection.	MEMD DES JEL F & G
	Increase public awareness of resource protection objectives, priorities, and regulations through the Reserve's education programs.	Sea Grant F & G
	Monitor visitor use in the Reserve.	F & G

MANAGEMENT CONCERN	ACTIONS	WHO TO INVOLVE
Maintain productivity and diversity of the estuary. Understanding and preserving this productivity and diversity are major goals of the Reserve. The Reserve will work to maintain, enhance, and improve understanding the productivity and diversity of the estuary.	Continue acquisitions in those areas identified as key land and water areas within the Research Reserve.	MEMD OSP LCIP
	Develop a research agenda which ensures that results from projects/activities reach officials who are responsible for land use decisions which may affect the estuarine system.	MEMD JEL F & G DES OSP (Coastal Program)

F & G - NH Department of Fish and Game
DES - NH Department of Environmental Services
JEL - UNH Jackson Estuarine Laboratory
Sea Grant - UNH Sea Grant Extension Program

MEMD - Marine and Estuarine Management Division, NOAA
LCIP - Land Conservation Investment Program
OSP - NH Office of State Planning

MANAGEMENT CONCERN	ACTIONS	WHO TO INVOLVE
The need to continue to coordinate surveillance and enforcement activities within the Reserve. The Reserve is an area with overlapping state/federal jurisdictions. These factors and the nature of the resources and activities that are regulated require continued coordination of surveillance and enforcement activities. Coordination can help focus this activity on the Reserve's priorities and therefore, effective management.	Continue to work with state and federal agencies and New Hampshire's Coastal Program to improve the coordination of surveillance and enforcement activities by:	OSP DES F & G
	Assessing options for cooperative agreements (or changes to existing agreements) between state and federal agencies to enhance resource protection; and	MEMD F & G
	Appointing members of relevant state and federal agencies to Reserve's advisory committee.	F & G

MANAGEMENT CONCERN	ACTIONS	WHO TO INVOLVE
The need to assess available resource information and organize it into a comprehensive data base for the Reserve. The Reserve Manager will need a convenient and comprehensive data base which can be referred to on a day-to-day basis, and which can be updated with the results of on-going research.	Improve access to information needed for management.	F & G
	Develop cooperative agreements for exchanging information on fisheries, surveillances and enforcement activities, and research with Jackson Estuarine Laboratory, appropriate state/federal agencies and private organizations working on research/educational projects within the Reserve.	F & G

4) Provide and promote multidisciplinary educational experiences through the above on-site efforts, as well as through an outreach program (mobile displays, news media, and school presentations) that will generate widespread awareness of and appreciation for:

   a) Great and Little Bays and the rivers that flow into them as a complex, interconnected system;

   b) the importance of the estuary to the many species of plants, fish, birds and other wildlife that inhabit the estuary during all or a part of their life cycle;

   c) the importance of maintaining a healthy, productive estuary which will support multiple uses by the commercial and recreational fishing industry, sportsmen and other recreational users, scientists and the general public;

   d) the historical role of the estuary in the development of the Great Bay area - how this role has changed over time and the effect of human activity on the estuarine system; and

   e) the need for a balanced approach to managing the multiple uses of the estuary.

5) Encourage government agencies, institutions, organizations and individuals with an interest in Great Bay to participate in cooperative ventures and information exchange with the Great Bay National Estuarine Research Reserve and other Research Reserves on estuarine education/interpretation (co-sponsored programs, coastweek activities and advisory committee participation, etc.).

2. EDUCATION HISTORY

Before pursuing the role of the Reserve in estuarine education and public awareness, it is important to first review the educational programs and activities presently in place. Area school teachers, farmers, fishermen and hunters have viewed the area encompassing the Reserve as an ideal informal classroom, and have used it as such. In a formal sense, however, the educational use of Great Bay's various ecosystems began to gain momentum only in the past eight years.

The resources of the Great Bay Estuarine System and how the lands surrounding it have been utilized as an educational focus for various programs and activities are described below.

PUBLIC EFFORTS

University of New Hampshire

The University of New Hampshire's Jackson Estuarine Laboratory is located on the tip of Adam's Point, affording a perfect location for ongoing research on Great Bay. Staffed by faculty and graduate researchers from the University of New Hampshire, the Lab is the site of much graduate and undergraduate education. Each semester for the last four to five years, 150 students in Introductory Oceanography classes come to the Lab to gain experience in research and to learn about the Great Bay estuarine system. Lab components of classes in sedimentation, marine ecology, and marine phycology are also located at the Lab. In addition, many other departments at the University conduct cruises of Great Bay out of the Lab over the course of the academic year. Research projects involve students in a variety of ways, either as paid lab assistants or with opportunities for undergraduate and graduate independent research projects.

University level courses are offered through the Division of Continuing Education (DCE), Elderhostel, and through institutes of higher education from other states (Eastern Connecticut State and the University of Connecticut at Stamford conducted courses in boreal ecology and marine phycology, respectively, in the Great Bay Reserve). Courses for the general public provide information about the natural history of the Great Bay estuary and the Piscataqua River area. In 1979, Frank Mitchell from the University of New Hampshire Cooperative Extension/4-H Program conducted one of the first marine camping programs in the

area. The marine awareness program took 15-20 participants, aged 13 to 16, on day trips to various marine ecosystems throughout the region, including the estuarine system represented by Great Bay. To date, continuation of this course has not been pursued.

The UNH Physical Education Department is developing a Center for Excellence in Outdoor Education on land donated by Evelyn Browne adjacent to the Reserve. Located in upland habitat, the Center will include a central building, a storage building, and a ropes course. The ropes course is already in use, and is experienced by groups as diverse as emotionally handicapped youth, corporate management personnel, area school groups and special needs adults. The major focus of the Center is to promote the field of outdoor education, and to encourage the therapeutic and educational process of using the outdoors as a medium of learning. Although this may be seen as a new trend, Ms. Browne has been using her lands as a source of experiential learning for her university students for the past thirty years. Altogether, 35 majors will be represented at both the graduate and undergraduate level when programs at the Center are fully instituted.

The UNH Sea Grant Extension programs are the source of important efforts to educate the public about the resources of the Great Bay area. With a joint focus on educating educators and decision-makers, and providing quality experiences for student and adult learners, UNH Sea Grant Extension employs two marine education specialists. An integral component of their programs is the UNH Marine Docents, a group of specially trained volunteers who provide extensive marine education outreach lecture programs. Presently, the docents consist of 54 volunteers from 18 communities in New Hampshire and Southern Maine. They receive 5 months of training in marine topics and communication skills with annual "update" sessions. The Docents receive some of their training at Jackson Laboratory and on Great Bay, and often have speakers at their training sessions who update them on the Lab's current research. The Docents conduct SEATREK outreach lecture programs on a number of marine-related topics; the SEATREK programs include tours of Jackson Lab and a slide-lecture presentation on Great Bay. The nature of SEATREK programs is such that they "travel well" and consequently civic groups, youth organizations, and classroom audiences from all over northern New England, as well as the local seacoast area, are represented in a tally of those requesting presentations on Great Bay. The docents offer tours of Great Bay and some of the tributaries to the public as part of the annual Coastweek activities. The docents are also involved in the more informal educational aspects of visits to Jackson Lab and tours of Great Bay by participants at UNH Parents' Weekend and Alumni Weekend, as well as by representatives of state and local government.

Another important component of Sea Grant Extension is the Floating Lab Program (FLP). The FLP and its extensive Resource Manual provide an introductory oceanography curriculum for grades 7-12, and includes a teacher workshop and three hour sampling trip aboard a 70 foot fishing boat. Great Bay is beginning to be used as a sampling area in an estuarine version of the FLP.

State of New Hampshire

The lands surrounding Great Bay are held by a number of owners. The State of New Hampshire holds the land at Adam's Point through the Department of Fish and Game. These lands were purchased through duck hunting funds in 1961, and are maintained through plantings and cultivation as prime waterfowl habitat. Although Adam's Point is open to the public, any activity there is secondary to wildlife management, and permission must be granted through the Department of Fish and Game when groups wish to use the land for other activities. There is a

perimeter trail around the Point which is maintained by Fish and Game, and which affords access to the water's edge for pedestrians.

It should also be noted here that the Department's five year plan ('86-'90) from its Division of Information and Education includes plans for an Aquatic Resource Education Program. This would include use of Project WILD'S Aquatic Education Guide.* Use of this Guide serves as "an invitation to explore and understand the fascinating worlds of water and the aquatic habitats they support." To date, cooperative efforts between Fish and Game and the University of New Hampshire have resulted in several Project WILD teacher training workshops in the seacoast area.

PRIVATE EFFORTS

Great Bay Estuarine System Conservation Trust

The Great Bay Estuarine System Conservation Trust (GBESCT) is a private, non-profit citizens group whose membership is drawn largely from the Seacoast area. The GBESCT's mandate is "to conserve the land and water resources of Great Bay." In the fulfillment of that goal, the GBESCT has been an advocate for the Bay on a wide variety of issues that affect the estuary.

The Trust has actively sponsored talks and workshops relating to the protection of water and air quality and critical marine habitat around Great Bay estuary for the past five to six years and continues to support the establishment of the GBNERR.

Piscataqua Gundalow Project

One group interested in tying together the past history of the Great Bay region with the present state of the estuary and its riverways is the Piscataqua Gundalow Project. The Piscataqua Gundalow Project evolved as a support group for the construction of a reproduction of the rivercraft which had once been ubiquitous in the region. The gundalow is sometimes seen as a symbol of the Piscataqua region and the Project has become an important source for regional history.

The Project presents public programs in communities around Great Bay, which comprise a large part of the Piscataqua region where the gundalow's ports were found. Under the terms of a grant from the National Endowment for the Humanities, the Piscataqua Gundalow Project put together travelling exhibits and slide/tape programs which include references to the region's natural history along with regional history and the story of how the gundalow was constructed.

The UNH Marine docents receive training from the Project, and several docents give programs and tours for the Project.

Audubon Society

The Audubon Society of New Hampshire (ASNH), an independent, non-profit state conservation organization, has long conducted field trips and participated in other public and educational efforts promoting the uniqueness of Great bay and the importance of protecting it. Since 1970, ASNH has maintained a 43-acre wildlife sanctuary on Great Bay at the mouth of the Bellamy River which has been the focus of many of its field trips in the area. All ASNH activities are open to the public as well as members. Local field trips are now being organized by the ASNH Seacoast Chapter which also offers educational programs in the seacoast area.

In addition, ASNH has conducted Bald Eagle monitoring within the Great Bay estuary since the winter of 1982-83. ASNH and Fish and Game Department work with Pease Air Force Base land planners and private landowners around the Bay to

* Project Wild is an interdisciplinary, environmental and conservation program which includes problem solving and activities designed to assess man's positive and negative impact upon a resource.

protect habitat and minimize disturbance to the wintering eagle population. Education and public relations activities resulting from the Bald Eagle monitoring program are critical to maintaining eagle habitat in Great Bay.

Boating

The broad expanse of Great Bay invites exploration by boat. Although many choose to explore on their own, others take advantage of the existence of two small cruise ship companies which operate out of Portsmouth, and offer cruises into Great Bay. The Isles of Shoals Steamship Company, previously known as "Viking Cruises," has operated in the area for 25 years. Portsmouth Harbor Cruises advertises an Inland River Cruise which also visits Great Bay, and includes discussion of the birdlife of the inland rivers. Both of these companies offer general admission tours, as well as special group and school group tours.

Operating on the waters of Great Bay for the past two years, the New England Sailing School offers instruction in basic to advance sailing. The school is affiliated with the American Sailing Association, which means that certified instructors teach to an international standard. Public charter of sailboats is available through the school for its graduates or other accredited sailors.

Miscellaneous

Great Bay also offers diverse attractions for passive recreation. One of the activities which brings groups to Adam's Point is wildflower walks. Garden clubs throughout the region come to walk through the area, and are often aided by a wildflower map of Adam's Point put together by Durham resident, Maggie Bruce. Mrs. Bruce has presented programs for French Interhostel, the Association of Retired Americans, and the UNH Marine Docents. Several of the marine docents present programs on the wildflowers of Adam's Point to interested groups.

3. ASSESSMENT

A comprehensive education plan needs to balance an assessment of existing educational efforts with the varied needs of its public. For the education efforts of the Reserve to be effective, they need to rely on this assessment of the existing programs described in the previous section before establishing any priorities. They also need to reach a wide and varied audience with informative - and enjoyable - programs, as well as be consistent with the character of the estuary. The various audience and user groups to be addressed by the Reserve education programs are identified as follows:

- estuarine landowners and other Bay area residents;
- other New Hampshire residents;
- elderly;
- nonschool youth and leaders;
- daycare center youth and staff;
- students and teachers;
- special needs;
- local officials from the towns around the estuary;
- realtors and developers;
- users of the estuary (sportsmen, commercial fishermen, boaters, nature watchers);
- tourists visiting or passing through the area;
- conservation, recreation, and historical groups; and
- state and federal agencies with responsibilities in the estuary.

To reach these audiences will require offering programs for a variety of educational experiences. The following matrix inventories the present levels of estuarine education within the region. This matrix should be viewed as a tool for measuring where there are unmet needs or gaps in the present level of education programs being offered by various groups in the estuary.

Table 9. ASSESSMENT MATRIX

	ORIENTATION	LIVING RESOURCES	ESTUARINE PROCESS	PEOPLE IN THE RESERVE	MANAGEMENT OF THE SYSTEM
EDUCATION INTERESTS Day Care Students, Elementary through HighSchool Teachers Non-School Youth and Leaders Special Needs Adult Students		* UNH Sea Grant[1] DCE[2] * Audubon[6] * State of NH Fish & Game[7]	* UNH Sea Grant[1] Jackson Lab[3]	* UNH Jackson Lab[3] Outdoor Education Center[4] Elderhostel[5]	
USER INTERESTS Local Landowners Other NH Residents Historical Conservation Recreational		* UNH Sea Grant[1] * Audubon[6] * Great Bay Trust[8]	* UNH Sea Grant[1] * Great Bay Trust[8]	* Piscataqua Gundalow Project[11] * Society for the Preservation of New England Antiquities[12]	
REGULATORY/LAND USE INTERESTS Realtors Developers Town & Local Officials State & Federal Agencies		* UNH Sea Grant[1]	* Great Bay Trust[8]	* State of NH Coastal Program[9]	

The format of the matrix is based on the Themes and Messages for Reserve Interpretation from James Dobbin Associates' work on Channel Island National Marine Sanctuary Management Plan. The category Orientation refers directly to the Reserve, where it is, and what to do there; Living Resources includes the flora and fauna found in the Reserve; Estuarine Process details the physical processes of the estuary, (i.e. hydrology, soils and energy flow in the estuary); People in the Reserve includes prehistoric cultures, recent history, and human use of the Reserve today; and Management of the System defines the roles of administering agencies, managers and visitors as they relate to the Reserve.

	ORIENTATION	LIVING RESOURCES	ESTUARINE PROCESS	PEOPLE IN THE RESERVE	MANAGEMENT OF THE SYSTEM
TRADITIONAL USER GROUPS Boaters Sportsmen Commercial Fishermen Tourists		* State of NH Fish & Game[7] * Boating[10] Isles of Shoals Steamship Co. Portsmouth Harbor Cruises New England Sailing School		* Piscataqua Gundalow Project[11] * Society for the Preservation of New England Antiquities[12]	

ASSESSMENT MATRIX FOOTNOTES

1 In 1987, the UNH docents reached approximately 1,115 people through 35 Salt Marsh Seatrek slide programs, 12 tours of Jackson Estuarine Laboratory, and 4 tours of Great Bay on the research vessel Jere Chase.

2 UNH's Division of Continuing Education course, Natural History of Great Bay, enrolled approximately 40 people in 1988.

3 Approximately 400 students per year enroll in university-level courses which visit Jackson Estuarine Laboratory.

4 The Center for Excellence in Outdoor Education involved 250 individuals from a variety of audiences in outdoor education programs in the first 6 months of 1988.

5 Elderhostel is a national program offering educational opportunities for people over 60. Approximately 80 individuals enrolled in a course on Great Bay in the summer of 1988.

6 Audubon Society of New Hampshire offers approximately 6 programs annually to their membership and the general public in the Great Bay region.

7 The State of New Hampshire's Department of Fish and Game offered approximately 25 aquatic education programs (i.e. Project WILD, "Let's Go fishing") to approximately 400 people in 1987.

8 The Great Bay Estuarine System Conservation Trust holds 4 meetings annually, and publishes 4 newsletters per year.

9 The State of New Hampshire's Coastal Program works towards supplying towns with technical assistance (i.e. workshops, grants, publications) on issues related to coastal management.

10 Local cruise ship companies offer tours of the Piscataqua River area, including Great Bay, 115 times, reaching approximately 5,500 people, during the summer and autumn months.

11 The Piscataqua Gundalow Project offered tours of the gundalow 20 hours/week for 4 weeks during the summer of 1988, while the vessel was in Portsmouth. School groups totaling approximately 250 children utilized the vessel for special projects (i.e. York, Maine's living history week; Exeter, New Hampshire's 350th anniversary celebration).

12 The Society for the Preservation of New England Antiquities has five historic properties in the Piscataqua region, and occasionally sponsors special exhibits of the properties. Approximately 7,000 people visited their properties in 1987.

a. Existing Program Limitations

Although the educational efforts for the Reserve area may initially appear to be sufficient, a careful reading reveals some notable gaps. Obviously, Orientation and Management of the System categories exhibit large gaps which will begin to be filled when the GBNERR is in place. Those who use the area around the Reserve now, and the local landowners, developers and conservation commissions who work with them, all need to understand how the GBNERR works, and what the establishment of the Reserve will mean to them.

Educational interests would be well served by the simple compilation of available education materials; presently, there is no central site or agency identified with the estuary. Consequently, groups interested in visiting the Reserve may not be provided with sufficient information on the diverse educational opportunities that can be offered within the estuarine environment. Existing programs tend to reach only those audiences with a prior interest in some facet of the estuary (i.e. Audubon - birds, Fish and Game - fish, waterfowl Sea Grant - marine topics). This could be expanded to meet the needs of growing numbers of individuals within education groups. The decision-makers of today and those who will be decision-makers in the future can benefit from a broad-based program targeted to meet their specific needs.

4. PRIORITIES

The following priorities were developed by looking at the programs already in place (as listed in the matrix) which are seeking to address issues of awareness and education about the estuarine system. In addition, interviews and discussions were held with members of the advisory committee and other groups and individuals* whose interests are connected with the past, present and future of Great Bay. Finally, the existing efforts and the input from the discussions were balanced with the goals and objectives for the Great Bay National Estuarine Research Reserve. The results were organized into the following table format which serves as an outline in addressing the Reserve's education priorities. A timetable for implementation of the priorities is outlined in Table 11.

5. PROPOSED PROGRAMS AND ACTIVITIES

Detailed below is a more specific discussion of the programs and activities which implement the priorities. For ease of discussion, the priority each program/activity addresses is highlighted.

COOPERATIVE EFFORTS

Priority - Resource Directory

The necessity for cooperative efforts to be a major part of the education planning is clear in light of all that needs to be done. Limited resources, time and personnel demand creative solutions. Conversely, where one group is already involved in a specific facet of estuarine education, duplication of effort benefits no one. Therefore, some form of interagency cooperation is a critical first step in implementing the fol-

* Society for the Preservation of New England Antiquities, Carolyn Hughes
Department of Education, University of New Hampshire, Dr. Michael Andrews
Maine Audubon Society, Carey Hotalling
Tijuana River National Estuarine Research Reserve, Pat Flanagan
Old Woman Creek National Estuarine Research Reserve, Linda Feix
Tom Arter, Northwood, New Hampshire
Nancy Befort, Newmarket, New Hampshire
Mrs. Franklin Beck, Greenland, New Hampshire

Table 10. EDUCATION PRIORITIES

PRIORITIES	AUDIENCE	METHOD OF IMPLEMENTATION
Establish information clearinghouse/resources file at visitor/education site	General public/education interests/government agencies	Continue to improve interagency communication and information exchange through Reserve's advisory committee
Develop a variety of promotional materials including: • brochures • regular news releases in local papers • a Reserve newsletter • interpretive posters • slide presentations	General public especially landowners, fishermen, developers, local officials	Work in cooperation with information personnel in Fish and Game, UNH, etc.
Encourage and expand current programs	Nonschool youth leaders, UNH (CES, students, docents, researchers), private organizations, government agencies	Develop MOA's where appropriate (i.e. Sea Grant)
Conduct informal "neighborhood" forums on how Reserve's land acquisition program works	Bay area land owners	Reserve staff with assistance of Landowners, Great Bay Trust and Trust for NH Lands
Develop a series of evening programs and/or day-long conferences for the public on topics including negotiating impacts of development	Users of estuary, local/state officials, realtors and developers, Bay area and other NH residents	Reserve staff with assistance of Coastal Program and representatives of advisory committee to "host" series
Develop educational programs, designed primarily for teachers' training, which take participants out to various sites; implement "researcher -in-the-schools" program in area high schools, as follow-up, invite qualified students to assist researcher	Teachers and High School Students	Reserve staff in cooperation with other groups/organizations; Jackson Estuarine Lab or other appropriate researchers to help develop a series of presentations
Provide a historical overview of the region's development, expecially the interaction of people and resources	General Public/No Specific Audience	Exhibits, i.e. the gundalow exhibit, and cooperative efforts with Society for the Preservation of New England Antiquities

Table 11. IMPLEMENTATION OF GBNERR EDUCATION PROGRAMS/ACTIVITIES

	EDUCATION OUTREACH	ON-SITE
First Year	• Expand Seatrek • Provide tour boat operators with material • Work with Audubon to provide bird list • Research and information collection on history of region • Begin interpreting Reserve environment	• Organize boat trips in Reserve • Develop interpretive signs
Second Year	• Actively recruit upper grade "audiences" in SeaTreks • Develop living resource inventory of Reserve area • Print material on history of region	• Implement teacher training based on FLP • Develop curriculm materials for teachers
Third Year	• Displays of history of region • Work with JEL to set up guidelines for researcher-in-the-school program	• Coordinate programs for youth groups • Develop teacher training program
Fourth Year	• Implement researcher-in-the-school program	• Begin planning a residential program
On-going	• Involve docents in JEL research • Provide speakers and printed material to landowners • Incorporate Reserve information into hunter and aquatic classes • Make information about Reserve available to fishermen • Publish a newsletter at regular intervals	

lowing proposed programs and activities. The compilation of a directory of all groups and agencies involved in the Reserve area is the highest priority from the results of discussions with the working group and other individuals. This document can be a valuable information tool and would be a logical first product of interagency cooperation and the newly established Reserve.

EDUCATION OUTREACH

Education outreach is best done through a cooperative effort which will maximize communication among agencies and interest groups now involved in the Reserve area. The University of New Hampshire leads this list, with the Jackson Estuarine Lab and Sea Grant's SEATREK offering the most visible efforts. Non-school youth groups and private organizations, such as Audubon Society, are also currently involved in education programs within the Reserve. Listed below are specific recommendations.

Priority - Encourage and Expand Current Programs

- Expand SEATREK offerings to include more information on the estuary as a system; edit "Great Bay" and "Salt Marsh" programs for use with upper grades; actively solicit more middle and high school audiences.
- Involve docents in current Jackson Estuarine Laboratory research, with some encouraged to track a researcher and develop presentations on that research.
- Provide tour-boat operators with any printed material and bring them up to date on GBNERR.
- Work with Audubon Society to compile current results of eagle monitoring program and bird list for general distribution.
- Develop living resource inventory of Reserve area from Natural Heritage Inventory.

Priority - Provide a Historical Overview of the Region's Development

- Provide Society for the Preservation of New England Antiquities with printed materials; incorporate information on GBNERR into displays in their properties in the region.

Priority - Conduct Forums on How Reserve's Land Acquisition Program Works

- Provide speakers and/or printed material in conjunction with Trust for NH Lands to explain easements, nature of Reserve program to area landowners.

Priority - Develop a Variety of Promotional Materials

- Incorporate information about Reserve into Fish and Game's Hunter Safety classes and Aquatic Resource Education programs.
- Make information about the Reserve available to fishermen, clammers, at Fish Pier. Publish a newsletter at regular intervals.

Priority - Develop Education Programs

- Work with Jackson Lab to set up guidelines for researcher-in-the-school program.

ON-SITE EDUCATION PROGRAMS IN THE RESERVE

Adam's Point is an open area of land managed as wildlife habitat by the Fish and Game Department. It is the most likely spot for education programs within the Reserve. Its assets include a representative variety of habitat (open field, salt marsh and woodland) and its proximity to Jackson Estuarine Lab and Crommet Creek, a very pristine tidal creek/marsh complex. Adam's Point also offers panoramic views of both Little Bay and Great Bay.

Drawbacks to using this site include an access road which is a single lane winding through a wooded area. Parking at the Lab is already limited, and access to Adam's Point during hunting season is restricted. Possible alternatives to Adam's Point for education programs would include Moody Point and properties under easement.

Education programs in the Reserve will always be constrained by the sensitivity of the ecosystem to overuse and disturbance. Any education program should seek to both work within these constraints, and seek to encourage others to act within the same constraints.

Priority - Develop a Variety of Promotional Materials

- Begin to interpret the Reserve environment with maps and brochures that note optimum interpretive/educational opportunities within the Reserve (see Table 12, Themes for Reserve Interpretation for more details).

Priority - Encourage and Expand Current Programs

- Implement a teacher training program based on Sea Grant's Floating Lab Program (FLP). Investigate the possibility of teacher/scientist cooperation in FLP.

Priority - Develop Education Programs

- Organize boat trips in the Reserve, led and coordinated by the Reserve Manager. Boats could leave from Adam's Point or Chapman's Landing.
- Coordinate programs for youth groups, i.e. Scouts, 4-H, local recreation departments.
- Begin planning a residential program which could be operated in conjunction with the Center for Excellence in Outdoor Education.
- Develop interpretive signs at appropriate sites within the Reserve.
- Develop other training programs and curriculum materials designed primarily for teachers, which take participants out to various sites. This is a high priority as the greatest magnifier in education is the teacher who shares awareness and knowledge with students.

EDUCATION PROGRAMS AT RESERVE CENTER

The core of the education program should be a focal point for activities/programs to introduce the public to the estuary and explain the dynamics of the estuarine system. It will also direct people to other educatio/informational facilities around the region. The immediate option for location of Reserve Staff is the new seacoast headquarters for the NH Department of Fish and Game. Located near the University in Durham, the facility houses several offices, display space, a small laboratory, and a conference room with a capacity of 50-75 people which is suitable for lectures, slide shows and other presentations.

Programs out of the facility would include administration of previously mentioned educational outreach and on-site programs as well as coordination with research. Any interpretive displays should follow the Themes and Messages found on the following pages. While it is recognized that the proposed exhibits and materials described below are not to be implemented immediately due to costs in the initial years, they are listed here as possible activities down the

Table 12. THEMES AND MESSAGES FOR RESERVE INTERPRETATION

Orientation

What is the Reserve?	How to Get There	What to Do There	Method of Communication
• Definition • It is different from or similar to a park? A preserve? • How big is it? What does it include? • What are its boundaries? • Uniqueness of Great Bay	• What are the major access points? • Where can I park? • Where are the trailheads?	• What can I expect to see? When? • What can I do? What are the best places and times? • What can I not do? • What other information is available?	• Brochures • Maps • Press Releases • Newsletters

Living Resources

Vegetation	Invertebrates and Fishes	Birds and Mammals	Method of Communication
• Salt marsh vegetation and upland communities/mud flats/rocky intertidal • How do communities here differ from other salt marshes • Examples of species adaptation to estuarine environment (tolerances, etc.)	• Species associated with various habitats • Intertidal invertebrate identification • Salt marsh insects • Estuarine fish	• Waterfowl and shorebird identification • Protected species • Species life history and special adaptations of salt marsh species	• On-site exhibits, tours • Multi-media presentations • Fact sheets • Abbreviated field guides

Estuarine Process

Hydrology	The Soil Environment	Energy Flows	Method of Communication
• What are the watersheds? • How does the flow regime vary seasonally? Annually? • *Saltwater and freshwater* balance • Watershed changes and system response	• What are the different soil environments • Soil salinities • Sedimentation	• Basic food webs • Unique aspects of primary productivity (algal mats) • Changes in energy flow	• Maps (i.e. relief) • Research abstracts • Computer simulation • Curriculum materials

People in the Reserve

Prehistoric Cultures	Recent History	Human Use of the Reserve Today	Method of Communication
• What evidence is there of *past cultures depending on* reserve resources? • Were there different cultures in the area? Did these change with time?	• 17th century history and *nearby settlements* • Changing land uses in the past centuries • Agricultural development in the estuary • Historical floods and droughts	• The value of multiple compatible use (possibilities/threats of change) • Agriculture today • Estuarine Research • Birding in the Reserve • Canoeing, fishing, hunting, boating • Resource study, photography • History of wise use	• Lecture series • Curriculum materials • Rotating exhibits including gundalow exhibit

Management of the System

The National Estuarine Reserve Research System

- Who administers the program?
- What are the other estuarine research reserves in New England? In the US?
- Why do we have reserves?
- Who is the Reserve Manager?

Coordinated Management

- Who owns the Reserve?
- What do the various public agencies do?
- What is being done now to better manage the Reserve (i.e. resource protection)?
- What kinds of research is taking place in the estuary?
- Why is land being acquired?
- How is everything coordinated?

What Visitors Can Do to Help

- Participating in visitor surveys and monitoring projects
- Providing comments on exhibits and tours
- Following regulations
- Letting others know about the Reserve Brochures

Method of Communication

- Brochures
- Guided Tours
- Newsletters
- Volunteer group

road. The potential for expansion to the existing facility in Durham is possible should the need exist in future years.

Priority - Establish Information Center/Resources File

- Walk-around physical model of the estuary.
- Aquarium with examples of the fish and shellfish that inhabit the estuary.
- "Hands-on" display with examples of the flora/fauna found in and around Great Bay.
- Information on the different uses of the estuary and the importance of the Bay area.
- Directory to the other sites included in the system and a guide to the particular features of each one (including any education/interpretive facilities).
- Photographs and other information on the variety of fish and wildlife that use the estuary and any unique features of the area.

Priority - Develop a Series of Exhibits for the Public

- Revolving exhibits of research projects and their importance to the estuary.
- Directory for scientific, historical, cultural, geographic and socioeconomic information on the area as well as the other Reserve sites in the system.
- An exhibit tracing the role of the estuary in the historical development of the Bay area;

6. GUIDELINES FOR RESERVE'S PROMOTIONAL MATERIALS

Because it is so important for the Reserve to establish its identity, special attention is given here to the materials which should orient visitors and residents to educational programs and activities. Interpretive messages are specific topics or ideas illustrating a theme. The messages considered most important are those questions that came to mind before, during and after a visit. Not all questions can be anticipated since they will vary considerably with the background, skill and familiarity with the estuarine environment of the individual visitors. Questions will also vary depending on where and when the visit takes place (i.e. on-site within the Reserve, outreach program or at another facility). Yet there are some recurring questions which will form the basic content for Reserve promotional materials and exhibits. These are summarized in the following Table "Themes and Messages for Reserve Interpretation." This table should be viewed as the guiding document for development of any promotional materials.

Support Strategies for Education

The establishment of a "Friends" group to support the education efforts of the Reserve will be very important for purposes of both funding and staffing. Nonprofit status is imperative for fund-raising purposes, and efforts could include events, sales through an on-site bookstore, raffles, and grant applications. The National Estuarine Research Reserve System is one source for possible funding. Local industry should be included in fund-raising efforts, and might be encouraged to sponsor specific programs or displays. An "adopt-a-school" program could be established to provide financial assistance to schools who need help in order to participate in Reserve programs. The State of New Hampshire could help by providing Wallop-Breaux funding for aquatic education. The University of New Hampshire also offers the potential for staffing support through work-study and internship programs. Cooperative efforts in funding with other groups and agencies affiliated with the Reserve should be explored.

This education plan is predicated on the assumption that an education specialist will be employed to assist the Reserve Manager in implementing the proposed programs/activities. It is important to note that supplementing this staff with volunteers for some of the Reserve's

education programs is a great opportunity that should not be ignored. Volunteer staff have shown themselves in many places and programs to be both professional in their abilities and energetic in their support. Any volunteer program in the Reserve should look to the volunteer program from the University of New Hampshire Marine Program as a model. The UNH Marine Docents spend five months of training in a broad array of Marine topics ranging from maritime history to the latest information about seafoods. Training sessions are taught by University professors and others in marine-related professions. Presentation skills are also a part of the training.

A possible scenario (Figure 8) for a Reserve volunteer program could involve a cooperative effort. Reserve volunteers would join the docents for an initial training period in marine topics. Reserve volunteers would then go on to more in-depth training about Great Bay and the Reserve's programs, while the UNH Marine Docents would continue to support estuarine educational efforts through their SEATREK presentations.

7. SPECIAL PROGRAMS RELATED TO RESEARCH

Research within the Reserve is an important component as one of the goals of NERRS is to develop an improved understanding of estuaries and the many functions they serve.

Information on the results of research activities within the Research Reserve needs to be made available to local and state officials and interested educators as well as the general public in order to effectively contribute to improved coastal management decision-making. While some of the activities below have been described earlier, they are repeated here as the link of research projects with public awareness/educational programs is crucial to the mission of the Reserve program.

Printed Material

a. In-house publication of research projects and results. Possibility of Sea Grant communicator providing write-ups.

b. Routine press releases re: research (one outlet might be Boston Globe's Monday Science Section, esp. Billboard).

c. Fact sheets and posters made available to general public and legislators.

d. Establish and maintain a central clearinghouse to house research results and other information pertinent to Great Bay for easy access by researchers and general public.

e. Newsletter (quarterly or twice yearly) sent to interested persons and supporters of Reserve.

f. Annual Report developed by Reserve Manager with a summary of each funded research project including results, conclusions, and total amount of funds awarded.

Displays/Exhibits

a. Have an exhibit of current research at Center (create awareness of scientific research in Reserve).

b. Interactive computers with programs designed by researchers.

c. Videotapes of researchers at work (especially in cases where it would be hard to get people out in the field).

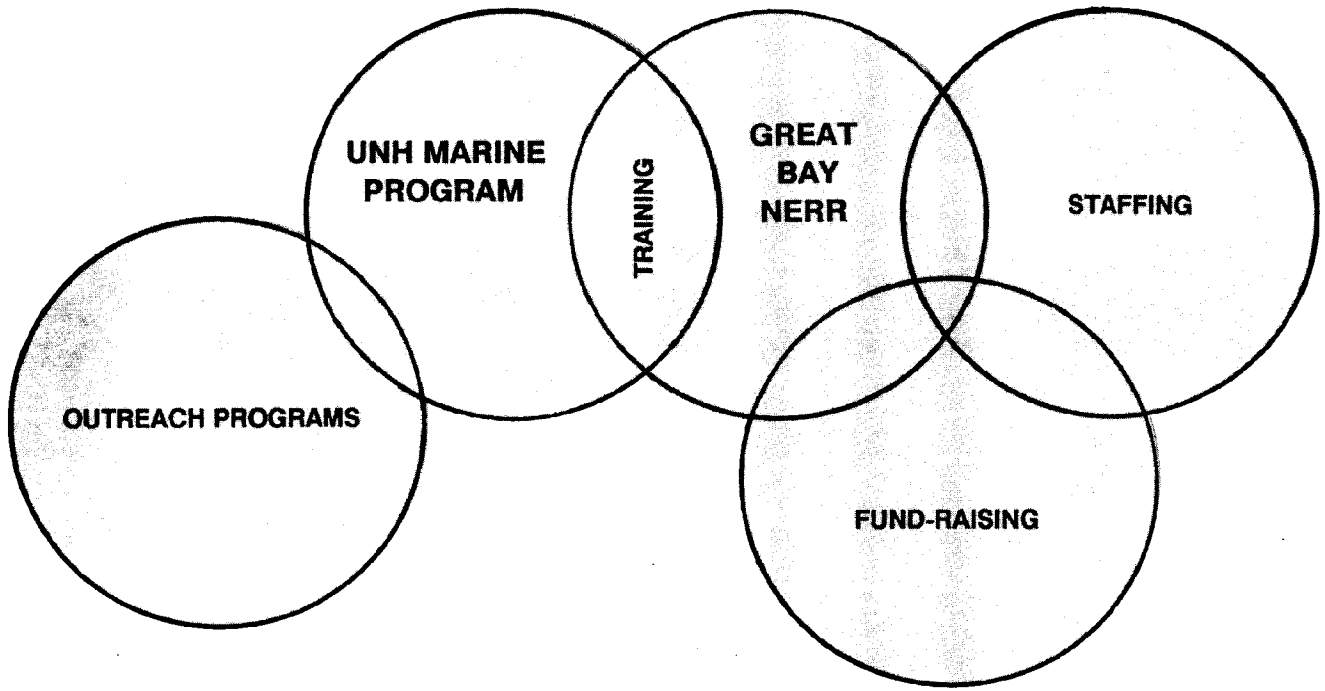
d. Displays of field research in the Reserve itself (non-permanent stands or bulletin boards) also included as an insert in field notes.

e. Different displays for research from cooperating agencies and organizations, i.e. Audubon, etc.

"Projects" which work with researchers

a. Interact with hunters, eg. researchers ask for partial gullets of waterfowl for eelgrass research.

Figure 8: MODEL FOR VOLUNTEER SUPPORT



b. Work with aquaculture interests - utilize local aquaculturist in research on oysters.

c. Invite 4-H, Scout groups to help with specific projects, especially concerning human impacts on fish, birds, mammals within Reserve.

d. Enlist local industries' help on researching chemical substances within the Reserve.

e. Research changes in amounts of fresh water due to changing land uses with developers and town conservation commissions.

f. Gather data from and share information with local yacht clubs and marinas on changes in navigation hazards.

g. Encourage volunteer participation in field research, eg. people helping gather information for Audubon's peregrine day.

h. Train volunteers to share research with fishing, hunting, and industrial use interest groups (volunteers will have to interview researchers to develop their presentations).

Programs

a. Regular tours of Jackson Estuarine Laboratory.

b. Floating Lab-type program in Reserve, using researchers working with teachers, especially on monitoring projects.

c. Seminar series presented by researchers (it may be possible to include the responsibility of presenting general interest talks as part of grant conditions for research).

d. Bring research results to educators through workshops, symposiums, research forums.

e. Present research at annual reserve meeting to share results on national level.

f. Volunteers could lead specific groups to research sites to observe research in progress (this would have to be prearranged and carefully done).

g. Researcher-in-the-schools - after in-school presentations by researchers, interested individuals (in limited numbers) could attempt to earn positions as research assistants at the lab. An adequate amount of lead time for both students and researchers would be important, as would specific and limited responsibilities for the students - baseline monitoring research would be one example.

h. Infuse research into education through on-going training, eg. birds and small mammals in uplands habitat.

The above assumes an education coordinator who will be able to work closely with the Reserve Manager in order to facilitate the link between research projects and the Reserve's public awareness/education programs. Further, it is important to keep in mind that much of this type of research is generally slow and not very spectacular. There is still basic work to be done in many areas which will be important in monitoring the estuary.

E. Research

1. GOALS AND OBJECTIVES

Research is an essential component of the long-term, comprehensive and effective management of the Research Reserve. While this research plan will be guided by the overall goal of the Reserve System to establish and manage estuarine areas for long-term research, education and interpretation, a more specific goal pertinent to the Great Bay has been established.

Goal: To promote, engage in and coordinate research efforts directed at understanding the ecology of the Great Bay estuary and those processes affecting estuaries in general.

Objectives:

1) Identify the priorities for research in the estuary and encourage their investigation. The research priorities within the GBNERR should reflect both those established by the National Estuarine Reserve Research System and research needs specific to the Great Bay National Estuarine Research Reserve. Projects within the Reserve should make effective use of past research results and address data gaps in understanding processes within the Great Bay estuary and assist in the management of the estuary;

2) Support baseline monitoring of the pertinent physical, chemical and biological variables within the Great Bay National Estuarine Research Reserve which would allow detection, quantification and identification of deleterious environmental impacts;

3) Establish contact and improve coordination and cooperation among groups with estuarine research interests. Specifically, enhance collaboration between the University of New Hampshire, other universities and colleges, private organizations and state and federal agencies with research or regulatory responsibilities in estuarine systems;

4) Develop an active recruiting program to attract researchers to the Great Bay National Estuarine Research Reserve which emphasizes the role of research in estuarine resource conservation and management;

5) Incorporate pertinent research results into the Reserve's educational and interpretive programs and enhance the availability and relevance of this information in addressing management concerns and increasing public awareness;

6) Serve as a source of materials relevant to the Great Bay estuary;

7) Ensure that data and results from Reserve's research projects are made available to local, state, and federal agencies responsible for resource planning within the region; and

8) Foster coordinated regional or national research programs with other Reserves.

2. HISTORY OF RESEARCH ACTIVITIES WITHIN THE GREAT BAY*

The focus of early research efforts within the Great Bay estuary was an overall description of the Bay's environment for the NH Marine Fisheries Commission (Jackson 1944). An earlier report by C.F. Jackson (1922) included a preliminary checklist of the finfish of Great Bay. Several graduate student theses were completed dealing with a variety of fisheries projects within the estuary (e.g. Goodrum 1941, Murphy 1944, Staples 1946, Krochmal 1949, Rosewater 1956). Early botanical studies relevant to Great Bay included a flora of Strafford County (Hodgdon 1932) and three studies on New Hampshire salt marsh ecology (Davis 1956, Fogg 1964, Vagenas 1969).

More recent studies within the Great Bay estuary have centered on projects by the

* See Appendix E for Research Bibliography

University of New Hampshire's Jackson Estuarine Laboratory, the NH Department of Fish and Game, and the NH Water Supply and Pollution Control Division. Research projects at the Jackson Estuarine Laboratory have been directed by several UNH faculty and their graduate students.

Extensive studies of sedimentary processes in the Great Bay have been conducted by F.E. Anderson and students (Anderson 1970, 1972, 1973, 1974a, 1974b, 1975, 1976, 1979, 1980, 1981, 1983, 1984, Sasseville and Anderson 1976, Shevenell and Anderson 1985). Zoological studies at the Jackson Estuarine Lab have concentrated on mudflat and sandy beach ecology (Croker 1969, 1972, Croker *et al.* 1975, Gable 1972, Gable and Croker 1977, 1978, Behbehani 1978, Black 1979, 1980, McBane 1981, Behbehani and Croker 1982, McBane and Croker 1983), protozoan systematics and ecology (Borror 1965a, 1965b, 1966, 1968, 1972, 1975, 1978, 1979, 1980, Wicklow and Borror 1977, Borror and Evans 1979, Martinez 1980, Borror and Wicklow 1983), and flounder genetics (Hoornbeek and Burke 1982, Hoornbeek *et al.* 1982, Hoornbeek and Klein-MacPhee 1986). A major botanical emphasis at JEL has resulted in a wide variety of studies concerning the ecology, systematics and physiology of estuarine plants (Hehre 1969, 1972, Hehre and Mathieson 1970, Burns 1971, Fuller 1971, Mathieson and Burns 1971, 1975, Burns and Mathieson 1972a, 1972b, Fuller and Mathieson 1972, Fralick 1973, Fralick *et al.* 1974, Blair 1975, 1983, Chock 1975, Fralick and Mathieson 1975, Mathieson and Norall 1975a, 1975b, Mathieson and Tveter 1975, 1976, Niemeck 1975, Chock and Mathieson 1976, 1979, 1983, Mathieson *et al.* 1976, 1977, 1981a, 1981b, 1982, 1983, 1984, Niemeck and Mathieson 1976, 1978, Tveter and Mathieson 1976, Kilar 1977, Cheney and Mathieson 1978, Josselyn 1978, Josselyn and Mathieson 1978, 1980, Kilar and Mathieson 1978, 1981, O'Shea 1978, Mathieson 1979, 1982, Tveter Gallagher and Mathieson 1980, Blair *et al.* 1982, Mathieson and Hehre 1982, 1983, 1986, Sideman 1982, Hardwick Witman and Mathieson 1983, 1986, Penniman 1983, Sideman and Mathieson 1983, 1985, Hardwick Witman 1984, 1985, 1986, Zechman 1984, Zechman and Mathieson 1984, Penniman *et al.* 1985a, 1985b, 1986, Shannon 1985, Mathieson and Penniman 1986, Short *et al.* 1986, 1987, Penniman and Mathieson 1987).

A wide variety of hydrographic and nutrient chemistry studies of Great Bay were initiated by the University of New Hampshire (Celikkol and Reichard 1976, Glibert 1976a, 1976b, Norall and Mathieson 1976, Reichard and Celikkol 1976, 1978, Loder and Glibert 1977, 1980, Swenson *et al.* 1977, Loder *et al.* 1978, 1982, 1983a, 1983b, Reichard 1978, Brown and Arellano 1979, 1980, Daly and Mathieson 1979, 1981, Daly *et al.* 1979, Swift *et al.* 1979, Loder and Reichard 1981, Norall *et al.* 1982, Swift and Brown 1983a, 1983b). Many of these were part of a Great Bay Estuarine Field Program that was primarily funded by the UNH Sea Grant Program.

A proposed oil refinery for Durham, New Hampshire, and an associated oil terminal at the Isles of Shoals resulted in several preliminary impact studies conducted throughout the New Hampshire Seacoast (Bolt Beranek and Newman, Inc. 1974, Fluor Corporation, Ltd. 1974, Gulf Interstate Engineering Company 1974, Kling Planning 1974, Normandeau Associates, Inc. 1974b, 1974c, Purvin and Getz, Inc. 1974, Texas Instruments, Inc. 1974, University of New Hampshire 1974).

In conjunction with the impact assessment of the Newington Generating Station on the Piscataqua River a wide series of environmental studies were conducted throughout the Great Bay estuary (EBASCO, Inc. 1968, Jackson and Moreland, Inc. 1970, Normandeau Associates, Inc. 1971, 1972, 1973, 1974a, 1975a-c, 1976a-c, 1977a-d, 1978a-d, 1979a-i, 1980, United States Army Engineer Division 1972a, 1972b, Mathieson *et al.* 1976, Turgeon 1976). These studies represent the most comprehensive enumeration of aquatic species found throughout the Great Bay estuary.

Jackson Estuarine Laboratory at Adams Point

Recent inventory studies by the New Hampshire Department of Fish and Game have provided an extensive overview of major habitat extent and abundances of dominant species (NH Department of Fish and Game 1981a, 1981b, 1982).

As outlined in Appendix E, Research Bibliography, there have been major inventory and baseline monitoring studies of the Great Bay estuary both in terms of biotic and physicochemical parameters. However, relatively little of the inventory level information has been synthesized to allow an overall understanding of the factors controlling the processes affecting the estuarine environment.

3. RESEARCH FACILITIES AND PROGRAMS

Jackson Estuarine Laboratory

The Jackson Estuarine Laboratory (JEL) is situated on Adams Point overlooking Furber Strait. Constructed in 1970, JEL currently houses a variety of faculty, research scientists and staff that represent the UNH Departments of Earth Sciences, Botany and Plant Pathology, Zoology and Microbiology.

JEL is ideally suited as a site for estuarine research. Scientists at the Laboratory have immediate access to rocky/shingle intertidal, salt marsh, eelgrass, and mudflat habitats - all of which are found at Adams Point. Furthermore, the Laboratory is equipped with an extensive flowing seawater (i.e. estuarine water) system. Water is pumped from approximately 40 ft deep and 200 ft offshore from JEL and flows into six large holding tanks in a third floor loft where some settling of suspended sediment occurs. The water then flows by gravity into several 50 and 100 gallon flow-through trays on the ground floor or into a variety of tanks outside the Laboratory. JEL has recently received funds to construct a greenhouse that will contain tanks where estuarine plants can be cultured with natural irradiance. The Laboratory continuously monitors incident irradiance and influent water temperature and salinity.

JEL is well equipped with a variety of analytical instrumentation. Major pieces of equipment include a Carlo-Erba model 1500 carbon-nitrogen-sulfur analyzer, an Elzone model 180XY particle counter, a Beckman liquid scintillation counter, several Endeco continuous salinity-temperature-depth recorders, two Marsh-McBirney electromagnetic current meters, a Beckman model 35 double beam spectrophotometer, a Turner Designs flow-through chamber fluorometer. Other general laboratory equipment (e.g. balances, microscopes, ovens, furnaces, pH meters, etc.) are available at JEL. In addition to the flow-through seawater trays and tanks, there are several large constant temperature incubators for culture or storage of estuarine organisms.

JEL houses a small library and conference room. The library includes a variety of texts that deal with marine and estuarine ecology. JEL subscribes to the journals Estuarine, Coastal and Shelf Science, Estuaries and Marine Pollution Bulletin. Several microcomputers and printers are used at JEL and, via telephone lines, connections can be made to the mainframe computers (VAX) housed on the UNH campus.

JEL has a docking facility with crane. Several small research boats are based at Adams Point, including a 12 ft aluminum skiff and a 14 ft fiberglass dory. Two larger vessels are moored at JEL, a 19 ft fiberglass work boat, the R/V Compass Rose and a 25 ft boston whaler, the R/V Adams Point. The 45 ft R/V Jere A. Chase, UNH's primary research vessel, is frequently used by JEL.

Research at JEL centers upon estuarine and marine ecology and aquaculture. A major project currently being initiated by JEL is a biological and physicochemical monitoring study of Great Bay. During 1973 to 1981 an extensive hydrographic monitoring program throughout the entire estuary was conducted by JEL and UNH. Other previous research projects conducted by JEL are described in the section on the History of Great Bay Research Activities and are referenced in the Research Bibliography.

Coastal Marine Laboratory

The University of New Hampshire has recently completed construction of a coastal laboratory facility at Fort Constitution in New Castle, NH. The Coastal Marine Laboratory has an extensive flowing seawater system and a small analytical laboratory. A major use of this facility will be the culturing of marine organisms in full strength coastal seawater (unavailable at JEL).

Institute of Marine Science and Ocean Engineering

The focus for marine research within UNH is the Institute of Marine Science and Ocean Engineering (IMSOE) The Jackson Estuarine Lab and Coastal Marine Lab, as well as a freshwater research facility and the UNH participation in the Shoals Marine Laboratory, is coordinated through IMSOE.

Institute for the Study of Earth, Oceans and Space

The Institute for the Study of Earth, Oceans and Space (EOS) is an organization fostering interdisciplinary research of global system behavior. A variety of marine and estuarine research projects have been conducted by EOS faculty and research scientists.

University of New Hampshire

The University of New Hampshire has a long history of major research and educational involvement in marine science. UNH supports and maintains the various laboratories and academic research institutes described above. Marine research and education is conducted within the Departments of Zoology, Microbiology, Chemistry, Earth Sciences, Botany and Plant Pathology, Civil Engineering, Chemical Engineering and Mechanical Engineering. These departments offer a wide variety of undergraduate and graduate marine educational opportunities. Faculty, research scientists and graduate students have contributed to the extensive base of information describing the Great Bay estuary and the NH coastal region.

UNH participates in the National Sea Grant College Program in conjunction with the University of Maine. As a Sea Grant College, UNH maintains a substantial infrastructure to support marine research, education and extension advisory goals.

New Hampshire Department of Fish and Game

The NH Department of Fish and Game is responsible for managing the fish and wildlife resources of the State including its coastal zone. Specifically, the Marine Division has responsibility for coastal issues. The Department has conducted a variety of research projects to support their resource management activities. During 1980-1982 the Department of Fish and Game compiled an extensive inventory of the major biota of the Great Bay estuary. Other research projects have included oyster bed enhancement, salt marsh restoration and studies of endangered bird species conducted in collaboration with the NH Audubon Society. The Department of Fish and Game operates several boats on Great Bay to support their management and research activities.

New Hampshire Office of State Planning

The NH Office of State Planning and the NH Coastal Zone Management Program have supported a variety of research projects within the Great Bay estuary and the NH seacoast.

For example, OSP has supported environmental monitoring programs within the estuary and a study of the impact of potential future sea level rise on coastal NH.

New Hampshire Department of Environmental Services, Water Supply and Pollution Control Division

The NH Water Supply and Pollution Control Division (NH WSPCD) conducts applied research in the Great Bay estuary to support its water quality monitoring responsibilities. The NHWSPCD maintains a research vessel and mobile laboratory to monitor bacteriological water quality within the estuary and rivers. Other projects have included an extensive oil spill control study within the Piscataqua River and a variety of studies on water quality and river runoff within the Great Bay estuary drainage basin.

Audubon Society of New Hampshire

The Audubon Society of New Hampshire (ASNH), in collaboration with the NH Department of Fish and Game, has conducted long-term studies of endangered bird species within Great Bay. In particular, ASNH has maintained an ongoing multi-year program to monitor over-wintering activity of bald eagles within southern NH, including the Great Bay estuary. Additionally, ASNH, in cooperation with the Department of Forest Resources of the University of New Hampshire, conducted a statewide breeding atlas during 1981 to 1986 that included the entire shoreline of Great Bay.

4. RESEARCH PRIORITIES

The research priorities for the GBNERR represent an emphasis on synthesizing existing baseline information on the Great Bay, supplementing gaps in the data base, and establishing an environmental monitoring program. Additionally, other research areas are described that address obtaining an increased understanding of the estuarine environment in order to enhance management of the Reserve.

Thus, the following research priorities represent the initial emphasis of the research program within the GBNERR. The priorities are guidelines for research activities that will be supported by the Reserve. The priorities have been chosen and ranked through extensive discussions with the Great Bay Working Group and a variety of concerned individuals and organizations (e.g. Jackson Estuarine Laboratory, UNH Institute of Marine Science and Ocean Engineering, New Hampshire Office of State Planning, New Hampshire Department of Fish and Game, New Hampshire Division of Environmental Services, Audubon Society of New Hampshire, and the Great Bay Estuarine Sys-

tem Conservation Trust). Research priorities for the Reserve will be reviewed and adjusted every two years as discussed in the section on Administrative Guidelines for Research.

Initial research priorities are divided into three major areas:

1) Synthesis of Existing Baseline Information and Obtaining Supplementary Data where Necessary.

Rationale

The Great Bay estuary has been previously studied by several major research groups that include the University of New Hampshire, Jackson Estuarine Laboratory, NH Department of Fish and Game and Normandeau Associates, Inc. (see Bibliography of Research on the Great Bay estuary). A substantial historic data base is available concerning the physical properties of the Bay, including sedimentology, hydrography, and nutrient concentrations. In addition, there is an extensive inventory of seaweed species, as well as standing crop and distributional data of dominant estuarine plants and animals. An important initial stage in establishing a continuing research program within the Great Bay National Estuarine Reserve is to synthesize the existing data in a coherent and easily accessible database. The data should be readily available to all researchers and resource managers interested in the Great Bay environment. Synthesis of the existing research information for the Great Bay will not only help to ensure that past research efforts are not duplicated but will also provide a strong conceptual foundation for subsequent research directions. Additionally, synthesis of historic research and monitoring information concerning the Great Bay estuary may make more readily apparent potential changes in environmental variables.

Research Approach

In order to accomplish the synthesis of existing baseline information and to supplement specific gaps in that data, the following research areas have been given high priority for the initial stages of research within the Great Bay Reserve.

a) Synthesis of Existing Habitat Data

Synthesize existing data on abundances and distributions of major plant and animal communities within the Great Bay. Supplement previous data with surveys of communities that are not currently included (e.g. subtidal macroalgae). Coordination of biological survey data with hydrographic information (e.g. salinity) to allow establishment of location and extent of estuarine habitat types within the Great Bay. The habitat types should include salt marsh, intertidal flat, phytoplankton, eelgrass, rocky intertidal, subtidal flat and rock.

b) Delineate Current Sources of Sewage Pollution

Compile existing data on sewage input into the estuary as a means of better delineation of sources and of establishing areas where greater monitoring efforts are required. Coliform concentrations are currently the primary means of determining bacteriological water quality. However, probable future changes in regulatory policies indicate that counts of enterococci will replace or supplement traditional bacteriological monitoring methods. Any such project conducted within the Great Bay should measure both coliform and enterococci levels.

c) Develop Detailed Bathymetric Chart of Great Bay

Develop and maintain a detailed bathymetric chart for the Great Bay estuary that should also include overlays of habitat type, salt marsh/mudflat boundaries, sediment type and depth. The chart will act as a baseline to document changes in sea level rise, sedimentation patterns, and vegetation or shellfish bed occurrence.

d) Detail Currents Throughout Great Bay

Determine the mean direction(s) and strength(s) of bottom and surface currents within the subtidal and intertidal areas of Great Bay during neap, mean and spring tides.

e) Detail Land Use Patterns for Estuary Drainage Basin

Mapping of the drainage basin including land use types and pollutant sources. These data are currently being collected by the NH Department of Environmental Services on a state-wide basis and therefore it will only be necessary to extract and synthesize information relevant to the Great Bay estuary.

f) Coordinate Research Groups and Activities

Enhance coordination of existing research activities (University, state, local, federal and private) within the Great Bay estuary and facilitate application of research data to resource management.

2) Establish a Comprehensive Monitoring Program for the Great Bay

Rationale

Although, as described above, there have been several monitoring programs previously conducted within the Great Bay, such historic data are only of limited use in understanding the effects of changes currently taking place in and around the estuary. It is therefore extremely important to establish an ongoing monitoring project that will allow researchers and resource managers to gain an understanding of the dynamics and interrelationships of biotic and abiotic variability within the Great Bay estuary. The Jackson Estuarine Laboratory has recently (i.e. July 1988) initiated a pilot biological and physiochemical monitoring program at two sites in the Great Bay (i.e. Adams Point and the Squamscott River). All data collected by monitoring projects within the Reserve will be added to the above-described database and be readily available for use by interested individuals.

Only by coordinated environmental monitoring can the processes affecting estuarine ecology be separated into various temporal components (i.e. seasonal, episodic, longer-term cyclical, etc.). Understanding environmental trends is essential in determining possible anthropogenic perturbations of estuarine systems. Furthermore, experimental studies of estuarine ecology are greatly strengthened by having an appreciation of natural variation and trends.

The extensive areas of intertidal flat within the Great Bay estuary are one characteristic that distinguishes the Great Bay from more southern estuaries along the Atlantic Coast. Both monitoring and experimental research with the Reserve should emphasize studies of the intertidal flat habitat.

Research Approach

The environmental monitoring program conducted within the Great Bay Reserve should include the following components. The research activities included in the monitoring section represent continuing programs whereas the baseline projects described above are generally one-time projects.

The following research projects have been designated as having high priority during the initial stages of the Reserve's research program.

a) Physicochemical and Biological Monitoring

Baseline monitoring of physical, chemical and biological variables within the Great Bay estuary. The monitoring program should include a synthesis of previous research efforts within the Great Bay.

b) Aerial Surveys

Conduct annual aerial surveys of Great Bay in order to catalog shoreline vegetation and land use patterns. Several other agencies also perform

aerial surveys in the general area of Great Bay (e.g. USDA ASCS). The survey program established by the Reserve should only supplement, not duplicate, the other projects.

c) Monitor Water Sources into Estuary

Monitoring of volume and water quality of major freshwater runoff inputs (i.e. riverine) into the Great Bay. Establishment and use of existing gauging stations on the major rivers (i.e. Lamprey, Squamscott, and Winnicut) that empty into the Great Bay in order to quantify fresh water runoff into the estuary. Additionally, coastal seawater influx into the Great Bay should be estimated.

d) Ecology of Vertebrate Species

Determine food sources, habitat use and seasonal occurrences of avian and terrestrial vertebrate consumers, particularly waterfowl and wintering bald eagles. Estimate seasonal carrying capacity of Great Bay for avifauna.

The following activities are designated as research priorities that should be addressed during the third and four years of the Reserve's initial research program.

a) Monitor Sediment Flux

Detailed monitoring of particle (i.e. sediment) flux throughout the Great Bay estuary. Sediment flux studies should include particle flux measurements associated with storm, spring runoff and resuspension events as well as ice effects.

b) Ice Effects

Effects of ice on intertidal and shallow subtidal biological communities. Ice dynamics within the Great Bay have a major impact on structuring shoreline communities that should be quantified.

3) Ecological Investigations of Factors Effecting the Productivity and Diversity of the Estuary

Rationale

Understanding and preserving the productivity and diversity of the Great Bay estuary are major goals of the Reserve's research program. Information obtained from the above-described baseline investigations and monitoring activities will be important components in accomplishing the goals. Multidisciplinary, long-term, experimental projects must also be conducted that will utilize the baseline and monitoring data and yield a greater understanding of the processes controlling the dynamics of estuarine communities. These research projects will ultimately supply resource managers with the information and tools necessary to preserve and protect the Great Bay.

Research Approach

The research activities described in this section include projects that are multidisciplinary and long-term in nature. While several research areas listed below are given high priority, it is acknowledged that long-term studies are required and it is likely that the research topics will remain high priority in subsequent evaluations.

The following research activities are designated as having high priority.

a) Control of Primary Production

Establish factor(s) controlling primary production of major plant communities (i.e. salt marsh, eelgrass, subtidal and intertidal macroalgae, intertidal microalgae, phytoplankton) within the Great Bay. The effects of both nutrient loading and sediment input should be investigated.

b) Nutrient Cycling/Production Relationships

Determine factors affecting nutrient cycling and productivity (primary and secondary) relationships of the intertidal flat habitat.

c) Primary/Secondary Production Relationships

Establish the relationship between primary and secondary production within the Great Bay estuary, especially with respect to fin fish and shellfish production and habitat.

The following projects are given priority for study beginning during the third and fourth years of the Reserve's research program.

a) Relationships Between Sediments and Intertidal Flats

Determine the role of intertidal flats as "storage sites" for sediment. The large intertidal flat areas within the Great Bay estuary act as sites where particles are deposited and released as a function of biological and physical events.

b) Ecology of Disjunct Species

The Great Bay is a habitat for several seaweed species that are primarily subtropical in distribution but occur within the Bay due to the summer warm waters. These species are reproductively isolated from their corresponding southern counterparts and represent relict populations. The habitat requirements, distributions and population genetic diversity of these unique species should be quantified in order to conserve the Great Bay populations.

c) Sediment/Habitat Relationships

Determine the relationships between sediment types, sedimentation patterns (e.g. seasonal) and habitat types within the Great Bay.

5. RESOURCE MANAGEMENT - AN OVERVIEW

Several major resource management concerns have been identified for the GBNERR. The management issues have been discussed in detail in preceding sections and will be summarized herein:

1) Assess and Synthesize the Existing Resource Information Available for Great Bay

A substantial body of knowledge (primarily inventory level) has been collected for the Great Bay estuary. It is essential that these data be synthesized in such a manner as to make them readily available to the Reserve's staff. The information is crucial in providing the foundation to design future research projects for the estuary and in communicating the environmental characteristics of Great Bay to the public.

Synthesis and presentation of the existing data will aid the Reserve's education program increasing public awareness of the Great Bay resource. Effective utilization of the existing information on the ecology of the Great Bay is central to the resource management concerns described below.

2) Maintaining the Productivity and Diversity of the Great Bay Estuary

Understanding and preserving the productivity and diversity of the estuary are major goals of the Reserve. The Reserve's research priorities, as well as the research goals and objectives, have been chosen to reflect this management concern.

Both current and future shoreline and drainage basin land use policies will affect estuarine productivity. Through research programs, such as the monitoring of critical environmental parameters in the estuary, a baseline of information can be established that will allow for detection of possible future degradation. The major areas of human impact upon the Great Bay environment include:

a) Drainage basin and shoreline land use patterns;

b) Point (e.g. sewage outfall) and nonpoint pollution sources affecting both Great Bay and associated tributaries;

c) Increased recreational boating; and

d) Recreational harvesting of fish, shellfish and wildlife (e.g. duck and goose hunting)

The information from environmental monitoring and research will be communicated to the local public and to resource managers through the coordination of the Reserve's education and research programs. For example, timely synthesis of monitoring project data will assist in detection of possible water nutrient chemistry or sediment loading changes from land development or point source pollution.

3) Public Awareness of the Reserve

As described above, effective synthesis of existing data on the Great Bay and utilization by the Reserve's education program will provide an immediate, substantial source of information to enhance public awareness, appreciation and sensitivity to the Great Bay estuarine environment. Furthermore, it will be essential for Reserve staff to incorporate data from the Great Bay monitoring project and future research projects into the educational program in a timely manner.

4) Impact of Visitor Use on Reserve Resources

Increased public use of the Great Bay (e.g. recreational boating) is occurring. Furthermore, Research Reserve activities may result in increased public impact upon Great Bay resources. Research programs, such as the Great Bay monitoring project, will be necessary to assess any possible impacts of the above-described activities. Public awareness of protection objectives, priorities and regulations via the Reserve's education program (effectively utilizing research results) can serve to minimize negative impact.

Thus, the research goals and objectives as reflected in the Reserve's research priorities have been established through consultation with a wide range of concerned groups and individuals (e.g. Jackson Estuarine Laboratory, UNH Institute of Marine Science and Ocean Engineering, New Hampshire Office of State Planning, New Hampshire Department of Fish and Game, New Hampshire Division of Environmental Services, Audubon Society of New Hampshire, and the Great Bay Estuarine System Conservation Trust) to address the resource management concerns summarized above. As described in the section on Research Administration, detailed procedures are presented to both assess the accomplishment of existing and to draft future research priorities. Incorporation of research project results into the Reserve's education program will allow for enhanced awareness by both the public and coastal decision-makers of Great Bay resource management concerns.

Additionally, inclusion of representatives from resource management authorities (appropriate state and federal agencies) on the GBNERR Advisory Committee will help to ensure that future research priorities will reflect coastal management concerns.

6. MONITORING PROGRAM

Background

The estuarine environment is typified by large variability in many environmental characteristics. Seasonal, diurnal, and episodic temporal variability act to structure the habitat. Additionally, embayment morphology, tidal current regimes and freshwater input contribute to substantial spatial heterogeneity in hydrographic, chemical, and biological parameters. To adequately understand the functional characteristics and long-term trends within estuarine systems, baseline monitoring of key biotic and abiotic variables is essential.

Within the Great Bay estuary substantial monitoring activities have been conducted previously. Additionally, the Jackson Estuarine Laboratory has initiated (i.e. July 1988) a pilot biological and physicochemical monitoring project at two sites in the Great Bay. Data from the pilot project will serve as a strong foundation for monitoring conducted by the Reserve. Monitoring programs initiated by the GBNERR will be designed to accommodate existing baseline information.

Specifically, past monitoring projects within the Great Bay estuary include:

1) Monitoring of numerous abiotic and biotic characteristics by the Public Service Company of New Hampshire in conjunction with the environmental impact assessment of the Newington power generating station during 1970 to 1978 (e.g. Normandeau Associates, Inc. 1979. Newington Generating Station 316 Demonstration);

2) Monitoring of several hydrographic and water chemistry variables at seven stations (throughout the entire estuarine system) during 1973 to 1981 by the University of New Hampshire's Jackson Estuarine Laboratory (e.g. Norall, T.L., A.C. Mathieson and C.E. Penniman. 1982. Nutrient and Hydrographic Data for the Great Bay Estuarine System, New Hampshire-Maine Part I September, 1973 - December, 1975. Jackson Estuarine Laboratory Contribution no. 150);

3) Ongoing and historical monitoring of Great Bay estuary bacteriological water quality by the New Hampshire Water Supply and Pollution Control Division and the Public Health Service (e.g. NH Water Supply and Pollution Control Commission. 1979. 1978 Sampling Data for Tidewater Portion Piscataqua River Basin and Coastal Tributaries);

4) Several hydrographic studies of current and tidal flow patterns within the Great Bay estuary (e.g. Swenson, E., W.S. Brown and R. Trask. 1977. Great Bay Estuarine Field Program 1975 Data Report Part 1: Currents and Sea Levels. UNH Sea Grant Tech. Rep. UNH-SG-157); and

5) An extensive inventory of major biological components throughout the estuary by the New Hampshire Department of Fish and Game during 1980 to 1981 (e.g. NH Department of Fish and Game 1982. Great Bay Estuary Monitoring Survey, 1981-1982).

Monitoring programs conducted by the GBNERR will be structured in great part by the substantial historical data base described above.

Monitoring Strategy

Reserve staff will establish and conduct a comprehensive environmental monitoring program with appropriate assistance from the Jackson Estuarine Laboratory, the Department of Environmental Services/ New Hampshire Water Supply and Pollution Control Division. Integration of the Reserve's monitoring program with any on-going related projects will act to minimize duplication.

Specific areas of interest for a Great Bay monitoring program are as follows:

1) Hydrographic, Water Chemistry and Sediment Flux Data

Establishment of two permanent monitoring stations at which several hydrographic and water chemistry variables, including temperature, salinity, dissolved oxygen, pH, dissolved ammonium, nitrate, and phosphate, phytoplankton pigments, suspended load, turbidity, irradiance and current direction and velocity could be measured. One station should be established in the area of Furber Strait as representative of the major channel portions of the Great Bay and a second within the Squamscott River in order to gain data from the area with the largest salt marsh habitat within the Reserve boundaries.

Two *in situ* continuous monitors should be requested to monitor temperature, salinity and light at the two permanent stations. The other variables would be monitored at monthly intervals throughout a tidal cycle. Additionally, tidal heights at Adams Point are continuously recorded by the Jackson Estuarine Laboratory.

While the Furber Strait and Squamscott River stations can serve as the permanent base for the hydrographic and water chemistry portion of the Reserve's monitoring program, other stations, particularly related to riverine input (e.g.

Lamprey, Winnicut), could be established as equipment and staff are available.

2) Freshwater Input

Quantification of the freshwater drainage from the Squamscott, Lamprey and Winnicut Rivers, as well as Crommett Creek, needs to be part of the monitoring program. Funds will be requested to establish gauging stations to determine fresh water input volumes from the major rivers draining into the Great Bay estuary. Research will be encouraged to determine ground water flow into the Great Bay estuary (see Research Priorities).

3) Meteorological Data

A meteorological monitoring station within the boundaries of the GBNERR is recommended. Due to microgeographical variation, it is advantageous to have on-site monitoring rather than depend upon off-site meteorological stations (i.e. University of New Hampshire, Durham campus and Pease Air Force Base, Newington). Continuous monitoring of wind speed and direction and amount of precipitation should be conducted. Incident solar irradiance is currently collected by the Jackson Estuarine Laboratory.

4) Biological Sampling

Biotic monitoring of the GBNERR should include the establishment of permanent stations associated with the two above-described hydrographic sites. One station should be established at Adams Point and a second at the Squamscott River both within the Reserve boundaries. The Adams Point intertidal station would be representative of rocky and shingle habitat within the Great Bay, while the Squamscott Station would represent salt marsh communities. Since tidal flats are the major intertidal community within the Great Bay, intertidal mudflat communities should be sampled at both the Adams Point and Squamscott River stations.

At Adams Point, intertidal sampling should include seasonal (i.e. quarterly) enumeration of macrofaunal and floral coverage within the high and low intertidal zones. Percent cover of macroflora and fauna would be recorded in ten replicate 0.25 m^2 quadrats within each zone. Infaunal organisms would be sampled seasonally from the low intertidal mudflat at Adams Point. Six replicate cores need to be collected and major faunal components enumerated after sieving through 0.5 mm mesh.

The salt marsh community at the Squamscott River should be monitored seasonally. Ten replicate 0.06 m^2 quadrats would be sampled within the high and low marsh to represent *Spartina patens* and *S. alterniflora* communities, respectively. Sampling entails cropping plant material at ground level from each replicate quadrat. Each sample needs to be sorted by species and plant lengths, reproductive status recorded and dry weights determined. Intertidal mudflat infaunal abundances should be sampled as described above.

A shallow subtidal sampling station for eelgrass, *Zostera marina*, should be established in the Adams Point - Footman Islands area. Seasonal samples of above-ground eelgrass biomass would be determined by cropping plant material within ten replicate 0.1 m^2 quadrats. Samples should be sorted in order to separate epiphytic algae from the eelgrass and the biomass of each component would be determined after drying.

Fish trawls need to be conducted seasonally at Furber Strait. Tows should be of ten to fifteen minute duration. Samples will be identified to species and lengths and weights determined.

5) Aerial surveys

Photographic aerial surveys of the GBNERR should be conducted annually in late summer during a period of spring low tides. Such a survey would allow enumeration of salt marsh habitat, shallow subtidal plant communities, and record possible developmental encroachment upon intertidal and upland areas.

The GBNERR monitoring program can establish an environmental database for the Great Bay estuary that will be available to local, state and federal agencies to assist in management decisions. The monitoring information can aid in attracting research projects to the Great Bay by providing long-term information unavailable for most other northeastern embayments. Additionally, the baseline data would be incorporated into the Reserve's educational programs.

The above-described monitoring activities will be coordinated by the NH Department of Fish and Game (GBNERR staff) and conducted in conjunction with the Jackson Estuarine Laboratory and other state and federal agencies as appropriate. GBNERR staff will be responsible for preparation of annual data reports representing yearly compilations of information from the monitoring program.

Monitoring Program Data Management

The GBNERR will serve to coordinate and catalog existing baseline information on the Great Bay estuary. A computer database needs to be established to allow information collected in the above-described monitoring program to be readily accessible by interested individuals and organizations.

Currently, the Jackson Estuarine Laboratory maintains a computer database containing information from the water chemistry and hydrographic monitoring program conducted by the Laboratory from 1973 to 1981. These data should serve as the foundation for other base-line information (e.g. the Great Bay Estuary Monitoring Survey conducted by the New Hampshire Department of Fish and Game) as well as data gathered through the Reserve's environmental monitoring program.

A database containing geographic characteristics of the Great Bay would allow environmental data to be retrieved and presented as map overlays. Such a system may be established utilizing the SAS statistical/graphics program as has been done for the Chesapeake Bay. Additionally, the above-described database should be expanded by Reserve staff to include available remote-sensing information.

Synthesis of monitoring data will aid in the determination of future research priorities and will greatly assist all research activity within the Great Bay. Furthermore, analysis and synthesis of monitoring data by Reserve staff should be conducted in order to determine what parameters are directly related to the health of the estuary (e.g. bacteriological counts affecting shellfish harvesting areas and related to amounts of sewage outfall).

7. GUIDELINES FOR RESEARCH ACTIVITIES

Administrative effort for the research program within the GBNERR consists of three general tasks:

1) Research project description: all research projects conducted within the Great Bay Reserve will be encouraged to follow specific guidelines;

2) Review of proposals submitted to the NERRS; evaluation of research projects conducted within the Great Bay National Estuarine Research Reserve and submitted for funding to the National Estuarine Reserve Research System; and

3) Evaluation of research priorities; a biannual (every two years) review and adjustment of research priorities for the Great Bay Reserve will be undertaken.

The primary responsibility for these administrative tasks will be with the Reserve Manager under the direction of the Director of Marine Fisheries within the NH Department of Fish and Game. Additionally, an Advisory Committee will assist in the review of research proposals and evaluation of research priorities.

Specific guidelines for the above-described research program's administrative responsibilities are detailed below.

1) Research Project Description

The intent of the research project description is to ensure that research activities conducted within the GBNERR are consistent with the Reserve's Management Plan. The project description will also serve to minimize conflicts and overlap between research projects. Prospective researchers are strongly encouraged to visit the Reserve and discuss proposed research projects with the Reserve Manager.

All research projects conducted by individuals, institutions or agencies within the boundaries of the GBNERR are encouraged to file a research project description (see Appendix F). If the research project described in the project description represents a funding request proposal, inclusion of a copy of the proposal is requested.

The research project description will include the following information for each project:

a) name, institutional affiliation and address of principal investigator;

b) names of all associated personnel;

c) title and brief synopsis (limit three pages) of the proposed project including specific descriptions of

i) research objectives,

ii) research methods, including descriptions (if appropriate) of biotic (i.e. species and numbers) or abiotic samples (e.g. water, sediments, rocks, soils, etc.),

iii) if experimental or sampling equipment (e.g. continuous monitors, exclusion cages, etc.) are to be placed within the Reserve during the proposed project, a description of the protocol for their maintenance and removal at end of the project

iv) area(s) within the Reserve to be investigated (detailed on map of Reserve included in application form) and details for access to those areas - e.g. sampling sites, monitoring stations, etc.; and

v) project duration.

d) evidence of the principal investigator obtaining all relevant collection or alteration permits (where appropriate), including permission to cross privately owned land.

2) Review of Research Proposals Submitted to National Estuarine Research Reserve System

The National Estuarine Research Reserve System annually solicits proposals for funding of research projects to be conducted within the System's Reserves. Investigators submit proposals directly to the Marine and Estuarine Management Division (i.e. MEMD) of the National Ocean Service, National Oceanic and Atmospheric Administration. The proposals are sent by the MEMD to reserve managers and scientific peer reviewers. Reserve managers are responsible for reviewing the proposals on the basis of individual reserve management guidelines and research priorities.

The GBNERR Manager, members from the GBNERR Advisory Committee with research interests and other individuals or agencies with estuarine research backgrounds will review the above-described research proposals based upon the following criteria:

a) Adherence to management guidelines of the GBNERR Management Plan, and

b) Relevance of the proposed project to the research priorities described within the GBNERR Management Plan.

Investigators planning to submit proposals to MEMD for research within the GBNERR are strongly encouraged to discuss their prospective projects with the Reserve Manager prior to proposal submission. As part of the preliminary discussion, the Reserve

Manager will encourage the investigator to file a research project description.

A major emphasis of the management plan for the GBNERR is to encourage investigators to conduct research within the Reserve. To promote this goal, the Reserve Manager will distribute an annual announcement to coincide with the solicitation of research proposals by MEMD. The mailing will include a list of current research priorities within the Great Bay Reserve and a research application. The Reserve Manager will maintain a list of the interested regional research community to be used for the mailing.

The Research Committee of the GBNERR will consist of five representatives from the regional estuarine research community. The Committee will include members of the overall GBNERR advisory committee with research interests and other individual representatives designated by the Director of the Marine Division of the NH Department of Fish and Game.

3) Evaluation and Alteration of Research Priorities

The GBNERR Manager with the cooperation of the Advisory Committee, will prepare a biannual (every two years) preliminary research status report describing research activities within the Great Bay Reserve. The preliminary report will include suggestions (made by the Reserve Manager and Advisory Committee) for research priorities to be undertaken during the next two years. The Reserve Manager will circulate the preliminary report to regional estuarine researchers and resource managers. After a thirty day comment period, the Reserve Manager and Advisory Committee will complete the biannual GBNERR Research Status Report. The final report will include a compilation of research priorities for the next two years. The research priorities should address significant resource management concerns within the Great Bay Reserve and also reflect the estuarine research initiatives designated by the National Estuarine Research Reserve System. The Reserve Manager and the Advisory Committee will use the current research priorities as guidelines in reviewing Great Bay research proposals submitted to the MEMD. Evaluation and alteration of research priorities will be conducted on a biannual basis in order to better coordinate with the duration of most research projects (i.e. at least two rather than one year).

Appendix A.

Resource Tables

TABLE 1

Species of Macroalgae Algae Occurring within the Great Bay Estuary

(Modified from Mathieson and Penniman 1986).

DIVISION: CHLOROPHYTA

Blidingia minima
Bryopsis plumosa
Capsosiphon fulvescens
Chaetomorpha brachygona
Chaetomorpha linum
Chaetomorpha melagonium
Chaetomorpha picquotiana
Cladophora albida
Cladophora pygmaea
Cladophora sericea
Enteromorpha clathrata
Enteromorpha compressa
Enteromorpha flexuosa ssp. flexuosa
Enteromorpha flexuosa ssp. paradoxa
Enteromorpha intestinalis
Enteromorpha linza
Enteromorpha prolifera
Enteromorpha torta
Entocladia viridis
Kornmannia leptoderma
Microspora pachyderma
Monostroma grevillei
Monostroma pulchrum
Mougeotia sp.
Oedogonium sp.
Percursaria percursa
Rhizoclonium riparium
Rhizoclonium tortuosum
Spirogyra sp.
Spongomorpha arcta
Ulothrix flacca
Ulothrix speciosa
Ulva lactuca
Ulvaria obscura
Ulvaria oxysperma
Urospora penicilliformis
Urospora wormskioldii

DIVISION: PHAEOPHYTA

Ascophyllum nodosum
Ascophyllum nodosum ecad scorpioides
Chorda tomentosa
Chordaria flagelliformis
Dictyosiphon foeniculaceus
Ectocarpus siliculosus
Elachista fucicola
Fucus distichus ssp. edentatus
Fucus distichus ssp. evanescens
Fucus spiralis
Fucus vesiculosus
Fucus vesiculosus var. spiralis
Giffordia granulosa
Giffordia sandriana
Laminaria digitata
Laminaria longicruris
Laminaria saccharina
Myrionema strangulans
Petalonia fascia
Petalonia zosterifolia
Petroderma maculiforme
Pilayella littoralis
Protectocarpus speciosus
Pseudolithoderma extensum
Punctaria latifolia
Ralfsia bornetii

Ralfsia clavata
Ralfsia verrucosa
Scytosiphon lomentaria var. complanatus
Scytosiphon lomentaria var. lomentaria
Sorocarpus micromorus
Sphacelaria cirrosa
Spongonema tomentosum

DIVISION: RHODOPHYTA

Ahnfeltia plicata
Antithamnion cruciatum
Antithamnionella floccosa
Audouinella membranaceae
Audouinella purpurea
Audouinella secundata
Audouinella violacea
Bangia atropurpurea
Bonnemaisonia hamifera
Callithamnion byssoides
Callithamnion hookeri
Callithamnion tetragonum
Ceramium rubrum
Ceramium strictum
Ceratocolax hartzii
Chondria baileyana
Chondrus crispus
Clathromorphum circumscriptum
Cystoclonium purpureum var. cirrhosum
Cystoclonium purpureum forma stellatum
Dasya baillouviana
Dermatolithon pustulatum
Dumontia contorta
Erythrotrichia carnea
Erythrotrichia ciliaris
Fosliella lejolisii
Gigartina stellata
Gloiosiphonia capillaris
Goniotrichum alsidii
Gracilaria tikvahiae
Gymnogongrus crenulatus
Hildenbrandia rubra
Lomentaria baileyana
Lomentaria clavellosa
Lomentaria orcadensis
Membranoptera alata
Palmaria palmata
Petrocelis cruenta
Peyssonnelia rosenvingii
Phycodrys rubens
Phyllophora pseudoceranoides
Phyllophora truncata
Phymatolithon laevigatum
Phymatolithon lenormandii
Polyides rotundus
Polysiphonia denudata
Polysiphonia elongata
Polysiphonia flexicaulis
Polysiphonia harveyi
Polysiphonia lanosa
Polysiphonia nigra
Polysiphonia nigrescens
Polysiphonia novae-angliae
Polysiphonia subtilissima
Polysiphonia urceolata
Porphyra leucosticta
Porphyra miniata
Porphyra umbilicalis
Porphyra umbilicalis forma epiphytica
Pterothamnion plumula
Ptilota serrata
Rhodomela confervoides
Rhodophysema elegans
Sacheria fucina

TABLE 2

Phytoplankton Species Collected During 1977 by Net and Whole Water Sampling within the Great Bay Estuary

(Modified from Normandeau Assoc., Inc. 1978).

Class: BACILLARIOPHYCEAE

Order: CENTRALES

- Actinoptychus undulatus
- Biddulphia alternans
- Biddulphia aurita
- Ceratulina bergonii
- Chaetoceros affinis
- Chaetoceros atlanticus
- Chaetoceros brevis
- Chaetoceros compressus
- Chaetoceros concavicornis
- Chaetoceros danicus
- Chaetoceros debilis
- Chaetoceros decipiens
- Chaetoceros diadema
- Chaetoceros furcellatus
- Chaetoceros laciniosus
- Chaetoceros lauderi
- Chaetoceros lorenzianus
- Chaetoceros lorenzianus f. forceps
- Chaetoceros similis
- Chaetoceros socialis
- Chaetoceros teres
- Chaetoceros spp.
- Corethron hysterix
- Coscinodiscus spp.
- Ditylum brightwellii
- Detonula confervacea
- Detonula sp.
- Eucampia zodiacus
- Guinardia flaccida
- Leptocylindrus danicus
- Lithodesmium undulatum
- Melosira moniliformis
- Melosira nummuloides
- Paralia sulcata
- Porosira glacialis
- Rhizosolenia alata
- Rhizosolenia delicatula
- Skeletonema costatum
- Thalassiosira nordenskioeldii
- Thalassiosira rotula
- Thalassiosira spp.

Order: PENNALES

- Amphora spp.
- Asterionella formosa
- Asterionella glacialis
- Bacillaria paxillifer
- Campylodiscus echeneis
- Climacosphenia moniligera
- Cocconeis scutellum
- Cylindrotheca closterium
- Fragilaria oceanica
- Fragilaria spp.
- Grammatophora marina
- Gyrosigma balticum
- Gyrosigma fasciola
- Gyrosigma/Pleurosigma spp.
- Isthmia nervosa
- Licmophora abbreviata
- Licmophora flabellata
- Navicula crucigera
- Navicula spp.
- Nitzschia delicatissima

Nitzschia longissima
Nitzschia paradoxa
Surirella spp.
Rhabdonema arcuatum
Rhabdonema adriaticum
Nitzschia seriata
Thalassionema nitzschioides
unspecified Pennales

Class: CHRYSOPHYCEAE

Order: OCHROMONADALES

Dinobryon spp.
Olisthodiscus luteus

Order: DICTYOCHALES

Dictyocha fibula
Distephanus speculum
Ebria tripartita

Class: DINOPHYCEAE

Order: GYMNODINIALES

Amphidinium crassum
Gymnodinium spp.

Order: PROROCENTRALES

Prorocentrum micans
Prorocentrum triestinum

Order: PERIDINIALES

Ceratium furca
Ceratium fusus
Ceratium horridum
Ceratium longipes
Ceratium minutum
Ceratium spp.
Ceratium tripos
Protoperidinium conicum
Protoperidinium depressum
Protoperidinium trochoideum
Protoperidinium spp.

Order: DINOPHYSIALES

Dinophysis norvegica

Class: HAPTOPHYCEAE

Order: PRYMNESIALES

Phaeocystis pouchetii

Class: CRYPTOPHYTA

Order: CRYPTOMONADALES

Chroomonas spp.

Class: CHLOROPHYCEAE

Order: ZYGNEMATALES

Staurastrum paradoxum

Class: CYANOPHYCEAE

Order: CHROOCOCCALES

Agmenellum sp.

Order: OSCILLATORIALES

Arthrospira subsalsa

Class: EUGLENOPHYCEAE

Order: EUGLENALES

Eutreptia spp.
Eutreptiella spp.

TABLE 3

Major Plant Species Occurring within New Hampshire Salt Marshes

(Modifed from Breeding *et al.* 1974).

Acnida cannabina	Water hemp
Aster subulatus	Annual salt marsh aster
Aster tenuifolius	Perennial salt marsh aster
Atriplex glabriuscula	Orach
Atriplex patula	Orach
Bassia hirsuta	Hairy smotherweed
Carex scoparia	Sedge
Carex hormathodes	Marsh straw sedge
Cladium mariscoides	Twig rush
Distichlis spicata	Spike grass
Eleocharis halophila	Salt marsh spike-rush
Eleocharis parvula	Dwarf spike-rush
Eleocharis smallii	Small's spike-rush
Elymus virginicus	Virginia rye grass
Euphorbia polygonifolia	Seaside spurge
Gerardia maritima	Seaside gerardia
Glaux maritima	Sea milkwort
Hordeum jubatum	Squirrel-tail grass
Iva frutescens	Marsh elder
Juncus balticus	Baltic rush
Juncus canadensis	Canadian rush
Juncus gerardii	Black grass
Lathyrus japonicus	Beach pea
Limonium nashii	Sea lavender
Lythrum salicaria	Purple loosestrife
Myrica pensylvanica	Northern bayberry
Panicum virgatum	Switchgrass
Phragmites australis	Common reed
Plantago maritima	Seaside plantain
Polygonum aviculare	Knotweed
Polygonum ramosissimum	Bushy knotweed
Potamogeton pectinatus	Sago pondweed
Prunus maritima	Beach plum

Puccinellia maritima	Seashore alkali grass
Puccinellia paupercula	Alkali grass
Quercus alba	White oak
Quercus bicolor	Swamp white oak
Ranunculus cymbalaria	Seaside crowfoot
Rosa rugosa	Rugosa rose
Rosa virginiana	Low rose
Ruppia maritima	*Widgeon grass*
Sanguisorba canadensis	Canadian burnet
Salicornia bigelovii	Dwarf glasswort
Salicornia europaea	Common glasswort
Salicornia virginica	Perennial glasswort
Scirpus americanus	Three-square bulrush
Scirpus acutus	Hard-stemmed bulrush
Scirpus atrovirens	Bulrush
Scirpus cyperinus	Wool grass
Scirpus maritimus	Salt marsh bulrush
Scirpus paludosus	Bayonet-grass
Scirpus robustus	Salt marsh bulrush
Scirpus validus	Soft-stemmed bulrush
Smilax rotundifolia	Common greenbrier
Solidago sempervirens	Seaside goldenrod
Spartina alterniflora	Salt water cord grass
Spartina patens	Salt meadow grass
Spartina pectinata	Fresh water cord grass
Spergularia canadensis	Common sand spurrey
Spergularia marina	Salt marsh sand spurrey
Suaeda linearis	Sea blite
Suaeda maritima	Sea blite
Suaeda richii	Sea blite
Toxicodendron radicans	Poison ivy
Triglochin maritima	Seaside arrow grass
Typha angustifolia	Narrow-leaved cattail
Typha latifolia	Broad-leaved cattail
Zannichellia palustris	Horned pondweed
Zostera marina	Eelgrass

TABLE 4

Threatened or Endangered Plant and Animal Species Occurring within the Great Bay National Estuarine Research Reserve

(Modified from US Department of Commerce, 1987)

Plants:

Prolific knotweed (*Polygonum prolificum*) - found at three sites in Hampshire, all in the estuary

Salt marsh gerardia (*Gerardia maritima*) - found at 12 sites in New Hampshire, two in the estuary

Eastern lilaeopsis (*Lilaeopsis chinensis*) - found at two sites in New Hampshire, one in the estuary

Downy foxglove (*Aureolaria virginica*) - found at eight sites in New Hampshire, two in the estuary

Small-crested sedge (*Carex cristatella*) - found at six sites in New Hampshire, one in the estuary

Missouri rock-cress (*Arabis missouriensis*) - found at eight sites in New Hampshire, two in the estuary

Turk's-cap lily (*Lilium superbum*) - found at only one site in New Hampshire

Large-spored quillwort (*Isoetes macrospora*) - found at four sites in New Hampshire, one in the estuary

Hairy brome-grass (*Bromus pubescens*) - found at five sites in New Hampshire, two in the estuary

Dwarf glasswort (*Salicornia bigelovii*) - found at eight sites in New Hampshire, two in the estuary

Lined bulrush (*Scirpus pendulus*) - found at six sites in New Hampshire, five in the estuary

Marsh elder (*Iva frutescens*) - found at six sites in New Hampshire, five in the estuary

Shore sedge (*Carex lenticularis* var. *albi-montana*)

Robust knotweed (*Polygonum robustius*)

Large salt marsh aster (*Aster tenuifolius*) - found at only one site in New Hampshire

Stout bulrush (*Scirpus robustus*) - found at four sites in New Hampshire, all in the estuary

Small spike-rush (*Eleocharis parvula*) - found at four sites in New Hampshire, one in the estuary

Small knotweed (*Polygonum exertum*) - found at two sites in New Hampshire, both in the estuary

Animals:

Bald eagle (*Haliaeetus leucocephalus*)

Common tern (*Sterna hirundo*)

Common loon (*Gavia immer*)

Eastern hognose snake (*Heterodon platyrhinos*)

Four-toed salamander (*Hemidactylium scutatum*)

TABLE 5

Common upland overstory and understory vascular plant species in Strafford County, NH by habitat

(modified from Hodgdon 1932 in Texas Instruments, Inc. 1974).

A specific list for the upland area within the Reserve boundaries is not presently available.

DRY UPLAND FOREST

Primary Overstory Species

Acer rubrum	Red maple
Betula alleghaniensis	Yellow birch
Betula lenta	Sweet birch
Betula papyrifera	Paper birch
Betula populifolia	Gray birch
Carya ovalis	Sweet pignut
Carya ovata	Shagbark hickory
Fagus grandifolia	American beech
Fraxinus americana	White ash
Picea glauca	White spruce
Picea rubens	Red spruce
Pinus resinosa	Red pine
Pinus strobus	White pine
Populus tremuloides	Quaking aspen
Pyrus malus	Apple
Quercus alba	White oak
Quercus rubra	Red oak
Quercus velutina	Black oak
Salix alba	White willow
Sassafras albidum	White sassafras
Tsuga canadensis	Hemlock

Primary Understory Species

Aralia nudicaulis	Wild sarsparilla
Berberis vulgaris	Common barberry

Castanea dentata	Chestnut
Comptonia peregrina	Sweet-fern
Dennstaedtia punctilobula	Hay-scented fern
Gaultheria procumbens	Teaberry
Hamamelis virginiana	Witch hazel
Juniperus communis	Common juniper
Kalmia angustifolia	Sheep laurel
Lycopodium complanatum	Trailing evergreen
Myrica pensylvanica	Bayberry
Prunus pensylvanica	Pin cherry
Prunus virginiana	Choke cherry
Pteridium aquilinum	Bracken fern
Quercus ilicifolia	Scrub oak
Rubus pubescens	Dwarf raspberry
Toxicodendron radicans	Poison ivy
Vaccinium angustifolium	Lowbush blueberry
Viburnum acerifolium	Maple-leaved viburnum

WET-LOWLAND FOREST

Primary Overstory Species

Acer rubrum	Red maple
Betula alleghaniensis	Yellow birch
Betula lenta	Sweet birch
Betula papyrifera	Paper birch
Carpinus caroliniana	American hornbeam
Chamaecyparis thyoides	Atlantic white cedar
Nyssa sylvatica	Blackgum
Picea mariana	Black spruce
Salix alba	White willow
Salix nigra	Black willow
Tsuga canadensis	Hemlock
Ulmus americana	American elm

Primary Understory Species

Alnus rugosa	Speckled alder
Cornus amomum	Silky dogwood
Cypripedium sp.	Lady slipper
Gaultheria procumbens	Teaberry
Ilex verticillata	Swamp winterberry
Kalmia angustifolia	Sheep laurel
Lycopodium obscurum	Ground pine
Mitchella repens	Patridge berry
Osmunda cinnamomea	Cinnamon fern
Polytrichum commune	Hairy cap moss
Rosa sp.	Rose
Smilax rotundifolia	Common greenbrier
Vaccinium corymbosum	Highbush blueberry
Viburnum alnifolium	Dockmackie
Viburnum cassinoides	Wild raisin
Viburnum recognitum	Arrow-wood
Vitis sp.	Grape

OPEN AND OVERGROWN FIELDS

Overstory Species

Betula populifolia	Gray birch
Juniperus communis	Common juniper
Juniperus virginiana	Red cedar
Prunus serotina	Black cherry
Prunus virginiana	Choke cherry
Viburnum sp.	Viburnum
Rhus typhina	Sumac

Ground Cover Species

Achillea millefolium	Common yarrow
Amaranthus retroflexus	Amaranth
Ambrosia artemisiifolia	Common ragweed

Aster sp.	Aster
Dactylis glomerata	Orchard grass
Daucus carota	Queen Anne's lace
Festuca rubra	Red fescue
Oxalis corniculata	Creeping lady's sorrel
Phalaris arundinacea	Reed canary grass
Phleum pratense	Common timothy
Poa pratensis	Kentucky bluegrass
Solidago sp.	Goldenrod
Spiraea alba	Meadow sweet
Trifolium pratense	Red clover

TABLE 6

Intertidal Invertebrate Species Collected (Retained on a 0.5 mm Screen) in the Great Bay Estuary over June 1981 to May 1982 During Great Bay Estuary Monitoring Survey

(Modified from NH Fish and Game Dept. 1982).

PHYLUM: RHYNCHOCOELA

Nemertea spp.

PHYLUM: ANNELIDA

Class: Polychaeta

Aglaophamus neotenus
Ampharete spp.
Aricidea catherinae
Capitella capitata
Chaetozone spp.
Clymenella torquata
Eteone heteropoda
Eteone spp.
Exogone hebes
Fabricia sabella
Heteromastus filiformis
Lumbrineris tenuis
Nephtys picta
Nereis diversicolor
Nereis zonata
Nereis spp.
Paraonis fulgens
Pholoe minuta
Phyllodoce mucosa
Phyllodoce spp.
Praxillella gracilis
Prionospio steenstrupi
Pygospio elegans
Scolelepis squamatus
Scoloplos spp.
Spio spp.
Streblospio benedicti

Class: Oligochaeta

unidentified Oligochaeta spp.

PHYLUM: MOLLUSCA

Class: Gastropoda

Haminoea solitaria
Hydrobia minuta
Ilyanassa obsoleta
Littorina littorea
Lunatia heros
Odostomia spp.

Class: Bivalvia

Gemma gemma
Lysonia hyalina
Macoma balthica
Modiolus modiolus
Mulinia lateralis
Mya arenaria
Mytilus edulis
Tellina agilis

PHYLUM: ARTHROPODA

Class: Crustacea

Ampelisca abdita/vadorum
Corophium spp.
Crangon septemspinosa
Cumacea spp.

Cyathura polita

Edotea triloba

Gammarus mucronatus

Harpinia spp.

Leucon americanus

Leucon nasicoides

Microdeutopus gryllotalpa

Microdeutopus spp.

Oxyurostylis smithi

Photis macrocoxa

unidentified Copepoda spp.

unidentified Ostracoda spp.

PHYLUM: HEMICHORDATA

Class: Enteropneusta

Saccoglossus kowalevskii

TABLE 7

Subtidal Invertebrate Species Collected (Retained on a 0.5 mm screen) in the Great Bay Estuary over June 1981 to May 1982 During Great Bay Estuary Monitoring Survey

(Modified from NH Fish and Game Dept. 1982).

PHYLUM: RHYNCHOCOELA

Nemertea spp.

PHYLUM: ANNELIDA

Class: Polychaeta

Aglaophamus circinata
Aglaophamus neotenus
Ampharete spp.
Aricidea catherinae
Capitella capitata
Chaetozone spp.
Clymenella torquata
Eteone heteropoda
Eteone longa
Eteone spp.
Exogone hebes
Fabricia sabella
Harmothoe spp.
Heteromastus filiformis
Hypaniola grayii
Lumbrineris tenuis
Nephtys paradoxa
Nephtys picta
Nephtys spp.
Nereis diversicolor
Nereis zonata
Nereis spp.
Pholoe minuta
Phyllodoce maculata
Phyllodoce mucosa
Phyllodoce spp.
Polydora ligni
Polydora spp.
Prionospio steenstrupi
Prionospio spp.
Pygospio elegans
Scolelepis squamatus
Scolelepis spp.
Spio spp.
Streblospio benedicti
Tharyx acutus

Class: Oligochaeta

unidentified Oligochaeta spp.

PHYLUM: MOLLUSCA

Class: Gastropoda

Haminoea solitaria
Hydrobia minuta
Hydrobia spp.
Ilyanassa obsoleta
Littorina littorea
Lunatia heros
Lunatia spp.
Nassarius trivittatus
Odostomia spp.

Class: Bivalvia

Cerastoderma pinnulatum
Ensis directus
Gemma gemma
Lysonia hyalina

Macoma balthica

Modiolus modiolus

Mulinia lateralis

Mya arenaria

Nucula tenuis

Nucula spp.

Solemya velum

Tellina agilis

PHYLUM: ARTHROPODA

Class: Crustacea

Ampelisca abdita/vadorum

Caprella spp.

Corophium spp.

Crangon septemspinosa

Cumacea spp.

Cyathura polita

Diastylis polita

Edotea triloba

Gammarus mucronatus

Gammarus spp.

Harpinia spp.

Leptognatha caeca

Leucon americanus

Leucon nasicoides

Microdeutopus gryllotalpa

Microdeutopus spp.

Oxyurostylis smithi

Photis macrocoxa

unidentified Copepoda spp.

unidentified Ostracoda spp.

PHYLUM: HEMICHORDATA

Class: Enteropneusta

Saccoglossus kowalevskii

TABLE 8

Species Collected from Artificial Hard Substrata at Adams Point During 1972 within the Great Bay Estuary

(Modified from Normandeau Associates, Inc. 1973)

Acmaea testudinalis
Amphitrite sp.
Ampithoe sp.
Anomia aculeata
Callopora aurita
Campanularidae
Caprella linearis
Ceramium sp.
Coremapus versiculatus
Corophium sp.
Crisia eburnea
diatoms
Electra crustulenta
Embletonia pallida
flatworms
Folliculina sp.
Gammarus oceanicus
Gammarus mucronatus
halacarid mites
harpacticoids
Hemiaegina minuta
Idotea phosphorea
immature gastropods
Jaera marina
Jassa falcata
Melita nitida
Microdeutopus gryllotopa
mytilids
nematodes
Nereis sp.
Polydora ligni
protozoa
rotifers
Semibalanus balanoides
Tendepedidae
Tubularia crocea
Ulva lactuca
unknown red algae
unknown hydroid
unknown nudibranch

TABLE 9

Dominant Zooplankton in the Great Bay Estuary During 1979

(Modified from Normandeau Associates, Inc. 1980)

Acartia hudsonica females	H
Acartia hudsonica males	H
Acartia spp. copepodites	H
Anomia spp. veligers	M
Bivalve umbone veligers, undifferentiated	M
Bivalve straight-hinge veligers	M
Calanus finmarchicus copepodites	H
Cirripedia cyprids	M
Cirripedia nauplii	M
Copepod nauplii, undifferentiated	H
Eurytemora spp. copepodites	H
Evadne spp.	H
Foraminifera	T
Gastropoda veligers	M
Harpacticoida	T
Hiatella spp. veligers	M
Microsetella norvegica	H
Modiolus modiolus veligers	M
Mytilus edulis veligers	M
Oithona spp. females	H
Oithona spp. nauplii	H
Oithona spp. copepodites	H
Podon spp.	H
Polychaete larvae	M
Polychaete eggs	M
Pseudocalanus spp. females	H
Pseudocalanus spp. copepodites	H
Pseudocalanus/Calanus nauplii	H
Rotifera	H
Tintinnida	H

(H = holoplankton,
M = meroplankton,
4T = tychoplankton)

TABLE 10

Finfish Collected Throughout the Great Bay Estuary by the NH Department of Fish and Game During July, 1980, to October, 1981

(Modified from NH Fish and Game Department 1981)

Alewife	*Alosa pseudoharengus*
American shad	*Alosa sapidissimo*
American eel	*Anguilla rostrata*
American sand lance	*Ammodytes americanus*
Atlantic Sturgeon	*Acipenser oxyrhynchus*
Atlantic herring	*Clupea harengus*
Atlantic cod	*Gadus morhua*
Atlantic menhaden	*Brevoortia tyrannus*
Atlantic salmon	*Salmo salar*
Atlantic silverside	*Menidia menidia*
Atlantic tomcod	*Microgadus tomcod*
Black sea bass	*Centropristis striata*
Blueback	*Alosa aestivalis*
Bluefish	*Pomatomus saltatrix*
Bluegill	*Lepomis macrochirus*
Brook trout	*Salvelinus fontinalis*
Brown bullhead	*Ictalurus nebulosus*
Chain pickerel	*Esox niger*
Chinook salmon	*Oncorhynchus tshawytscha*
Coho salmon	*Oncorhynchus kisutch*
Common killifish	*Fundulus heteroclitus*
Cunner	*Tautogolabrus adspersus*
Fallfish	*Semotilus corporalis*
Four-spined stickleback	*Apeltes quadracus*
Golden shiner	*Notemigonus crysoleucas*
Grubby	*Myoxocephalus aenaeus*
Largemouth bass	*Micropterus salmoides*
Little skate	*Raja erinacea*
Lumpfish	*Cyclopterus lumpus*
Mullet	*Mugil cephalus*

Nine-spined stickleback	*Pungitius pungitius*
Northern pipefish	*Syngnathus fuscus*
Pollock	*Pollachius virens*
Pumpkinseed	*Lepomis gibbosus*
Rainbow trout	*Salmo gairdneri*
Rock eel	*Pholis gunnellus*
Sea raven	*Hemitripterus americanus*
Sea lamprey	*Petromyzon marinus*
Smallmouth bass	*Micropterus dolomieui*
Smelt	*Osmerus mordax*
Smooth flounder	*Liopsetta putnami*
Spottail shiner	*Notropis hudsonius*
Squirrel hake	*Urophycis chuss*
Striped bass	*Morone saxatilis*
Striped killifish	*Fundulus majalis*
Three-spined stickleback	*Gasterosteus aculeatus*
White hake	*Urophycis tenuis*
White sucker	*Catostomus commersoni*
White perch	*Morone americana*
Windowpane	*Scophthalmus aquosus*
Winter flounderu	*Pseudopleuronectes americanus*
Winter skate	*Raja ocellata*
Yellow perch	*Perca flavescens*

Table 11

Larval Fish Collected in the Great Bay Estuary During 1973 to 1979

(Modified from Normandeau Associates, Inc. 1980)

Alosa sp(p).	Alewife/blueback herring
Ammodytes americanus	American sand lance
Anguilla rostrata	American eel (elver)
Apeltes quadracus	Four-spined stickleback
Aspidophoroides monopterygius	Alligator fish
Brevoortia tyrannus	Atlantic menhaden
Brosme brosme	Cusk
Clupea harengus	Atlantic herring
Cryptacanthodes maculatus	Wrymouth
Cyclopterus lumpus	Lumpfish
Enchelyopus cimbrius	Four-bearded rockling
Fundulus heteroclitus	Mummichog
Gadus morhua	Atlantic cod
Gasterosteus aculeatus	Three-spined stickleback
Glyptocephalus cynoglossus	Witch flounder
Hemitripterus americanus	Sea raven
Hippoglossoides platessoides	American dab
Limanda ferruginea	Yellowtail
Liopsetta putnami	Smooth flounder
Liparis sp(p).	Sea snail species
Lophius americanus	American goosefish
Melanogrammus aeglefinus	Haddock
Menidia menidia	Atlantic silverside
Merluccius bilinearis	Silver hake
Microgadus tomcod	Atlantic tomcod
Myoxocephalus aenaeus	Grubby, little sculpin
M. scorpius	Shorthorn sculpin
M. octodecemspinosus	Longhorn sculpin
Myoxocephalus spp.	Sculpin species
Osmerus mordax	Smelt

Poronotus triacanthus	Butterfish
Pholis gunnellus	Rock eel, gunnel
Pollachius virens	Pollock
Prionotus carolinus	Common searobin
Pseudopleuronectes americanus	Winter flounder
Scomber scombrus	Mackerel
Scophthalmus aquosus	Windowpane
Sebastes marinus	Redfish
Stichaeus punctatus	Arctic shanny
Syngnathus fuscus	Commmon pipefish
Tautoga onitis	Tautog
Tautogolabrus adspersus	Cunner
Triglops murrayi	Moustache sculpin
Ulvaria subbifurcata	Radiated shanny
Urophycis sp(p).	Hake species (red, white, spotted)

TABLE 12

Birds of Southeastern New Hampshire

(Modified from Dearborn 1903 in Texas Instruments, Inc. 1974)

Common loon
Red-throated loon
Red-necked grebe
Horned grebe
Pied-billed grebe
Razorbill
Dovekie
Double-crested cormorant
Great cormorant
Whistling swan
Mute swan
Canada goose
Snow goose
Mallard
American black duck
Gadwall
American widgeon
Canvasback
Wood duck
Blue-winged teal
Green-winged teal
Greater scaup
Lesser scaup
Common goldeneye
Bufflehead
Oldsquaw
Harlequin duck
Common eider
King eider
White-winged scoter
Surf scoter
Black scoter
Ruddy duck
Hooded merganser
Common merganser
Red-breasted merganser
American coot
Common gallinule
Northern gannet
Parasitic jaeger
Glaucous gull
Great black-backed gull
Herring gull
Ring-billed gull
Bonaparte's gull
Common tern
Least tern
Caspian tern
Great blue heron
Great egret
Snowy egret
Green-backed heron
Black-crowned night heron
American bittern
Glossy ibis
Clapper rail
Virginia rail
Sora
Yellow rail
Golden plover
Black-bellied plover
Ruddy turnstone

Semipalmated plover
Killdeer
Piping plover
American woodcock
Common snipe
Dowitcher
Red knot
Marbled godwit
Hudsonian godwit
Whimbrel
Willet
Greater yellowlegs
Lesser yellowlegs
Solitary sandpiper
Stilt sandpiper
Sanderling
Buff-breasted sandpiper
Pectoral sandpiper
Dunlin
Purple sandpiper
Spotted sandpiper
Least sandpiper
Semipalmated sandpiper
White-rumped sandpiper
Baird's sandpiper
Western sandpiper
Red phalarope
Northern phalarope
Ruffed grouse
Ring-necked pheasant
Northern goshawk
Sharp-shinned hawk
Cooper's hawk
Northern harrier
Red-tailed hawk
Red-shouldered hawk
Broad-winged hawk
Rough-legged hawk
Osprey
Bald eagle
Turkey vulture
Merlin
American kestrel
Common screech owl
Great horned owl
Snowy owl
Barred owl
Long-eared owl
Short-eared owl
Saw-whet owl
Mourning dove
Rock dove
Yellow-billed cuckoo
Black-billed cuckoo
Whip-poor-will
Nighthawk
Ruby-throated hummingbird
Belted kingfisher
Common flicker
Pileated woodpecker
Red-headed woodpecker
Yellow-bellied sapsucker
Hairy woodpecker
Downy woodpecker
Arctic three-toed woodpecker
Eastern kingbird
Great crested flycatcher
Eastern phoebe
Yellow-bellied flycatcher
Alder flycatcher

Least flycatcher
Eastern pewee
Olive-sided flycatcher
Horned lark
Water pipit
Tree swallow
Bank swallow
Barn swallow
Cliff swallow
Purple martin
Chimney swift
American crow
Northern raven
Blue jay
Black-capped chickadee
White-breasted nuthatch
Red-breasted nuthatch
Tufted titmouse
Brown creeper
House wren
Winter wren
Sedge wren
Golden-crowned kinglet
Ruby-crowned kinglet
Blue-gray gnatcatcher
Northern mockingbird
Gray catbird
Brown thrasher
American robin
Wood thrush
Hermit thrush
Swainson's thrush
Veery
Eastern bluebird
Northern shrike
Loggerhead shrike
Cedar waxwing
Yellow-throated vireo
Solitary vireo
Red-eyed vireo
Warbling vireo
Black-and-white warbler
Golden-winged warbler
Blue-winged warbler
Orange-crowned warbler
Nashville warbler
Northern parula warbler
Yellow warbler
Magnolia warbler
Black-throated blue warbler
Yellow-rumped warbler
Black-throated green warbler
Blackburnian warbler
Chestnut-sided warbler
Bay-breasted warbler
Blackpoll warbler
Pine warbler
Palm warbler
Ovenbird
Northern water-thrush
Connecticut warbler
Mourning warbler
Common yellowthroat
Wilson's warbler
Canada warbler
American redstart
Bobolink
Eastern meadowlark
Red-winged blackbird
Rusty blackbird

Common grackle
Brown-headed cowbird
European starling
Northern oriole
Scarlet tanager
House sparrow
Northern junco
Lapland longspur
Snow bunting
Northern cardinal
Red crossbill
White-winged crossbill
Common redpoll
Hoary redpoll
House finch
Purple finch
Pine grosbeak
Evening grosbeak
Pine siskin
American goldfinch
Rose-breasted grosbeak
Indigo bunting
Rufous-sided towhee
White-throated sparrow
White-crowned sparrow
Chipping sparrow
Savannah sparrow
Grasshopper sparrow
Henslow's sparrow
Sharp-tailed sparrow
Vesper sparrow
American tree sparrow
Field sparrow
Fox sparrow
Lincoln's sparrow
Swamp sparrow
Song sparrow

TABLE 13

Bird Species Sighted During July, 1980, through June, 1981, During the Great Bay Estuary Monitoring Survey Conducted by the NH Fish and Game Department

(Modified from NH Fish and Game Department 1981)

SEABIRDS	
Great black-backed gull	*Larus marinus*
Herring gull	*Larus argentatus*
Ring-billed gull	*Larus delawarensis*
Bonaparte's gull	*Larus philadelphia*
Common tern	*Sterna hirundo*
Great cormorant	*Phalacrocorax carbo*
Double-crested cormorant	*Phalacrocorax auritus*

WATERFOWL AND DIVING BIRDS	
Mute swan	*Cygnus olor*
Canada goose	*Branta canadensis*
Snow goose	*Chen caerulescens*
Mallard	*Anas platyrhynchos*
American black duck	*Anas rubripes*
Common pintail	*Anas acuta*
American widgeon	*Anas americana*
Blue-winged teal	*Anas discors*
Green-winged teal	*Anas crecca*
Wood duck	*Aix sponsa*
Canvasback	*Aythya valisineria*
Greater scaup	*Aythya marila*
Lesser scaup	*Aythya affinis*
Ring-necked duck	*Aythya collaris*
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*Bucephala islandica*
Bufflehead	*Bucephala albeola*
Oldsquaw	*Clangula hyemalis*
Black scoter	*Melanitta nigra*

White-winged scoter	*Melanitta deglandi*
Surf scoter	*Melanitta perspicillata*
Common merganser	*Mergus merganser*
Red-breasted merganser	*Mergus serrator*
Hooded merganser	*Lophodytes cucullatus*
Common loon	*Gavia immer*
Red-throated loon	*Gavia stellata*
Horned grebe	*Podiceps auritus*
Pied-billed grebe	*Podilymbus podiceps*

WADING BIRDS

American bittern	*Botaurus lentiginosus*
Glossy ibis	*Plegadis falcinellus*
Snowy egret	*Egretta thula*
Great blue heron	*Ardea herodias*
Green-backed heron	*Butorides striatus*
Black-crowned night heron	*Nycticorax nycticorax*

TERRESTRIAL BIRDS

Black-bellied plover	*Pluvialis squatarola*
Killdeer	*Charadrius vociferus*
Solitary sandpiper	*Tringa solitaria*
Spotted sandpiper	*Actitis macularia*
Greater yellowlegs	*Tringa melanoleuca*
Lesser yellowlegs	*Tringa flavipes*
Dowitcher	*Limnodromus spp.*
Ruddy turnstone	*Arenaria interpres*
Pectoral sandpiper	*Calidris melanotos*
Dunlin	*Calidris alpina*
Sanderling	*Calidris alba*
Least sandpiper	*Calidris minutilla*
Semipalmated sandpiper	*Calidris pusilla*

SHORE BIRDS

Common snipe	*Capella gallinago*
Mourning dove	*Zenaida macroura*
Belted kingfisher	*Megaceryle alcyon*
Eastern kingbird	*Tyrannus tyrannus*
Barn swallow	*Hirundo rustica*
Tree swallow	*Iridoprocne bicolor*
Rough-winged swallow	*Stelgidopteryx ruficollis*
American crow	*Corvus brachyrhynchos*
European starling	*Sturnus vulgaris*
House sparrow	*Passer domesticus*
Red-winged blackbird	*Agelaius phoeniceus*
Common grackle	*Quiscalus quiscula*
Sharp-tailed sparrow	*Ammospiza caudacuta*
Northern harrier	*Circus cyaneus*
Red-tailed hawk	*Buteo jamaicensis*
Bald eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*

TABLE 14

Mammals Found in Southeastern New Hampshire

(Modified from the University of New Hampshire, 1974)

Bats	
Red bat	*Lasiurus borealis*
Hoary bat	*Lasiurus cinereus*
Eastern pipistrel	*Pipistrellus subflavus*
Big brown bat	*Eptesicus fuscus*
Little brown myotis	*Myotis lucifugus*
Small-footed myotis	*Myotis subulatus*
Keen myotis	*Myotis keeni*
Silver-haired bat	*Lasionycteris noctivagans*
Shrews and Moles	
Hairytail mole	*Parascalops brewei*
Starnose mole	*Condylura cristata*
Shorttail shrew	*Blarina brevicauda*
Pygmy shrew	*Microsorex hoyi*
Smoky shrew	*Sorex fumeus*
Northern water shrew	*Sorex palustris*
Masked shrew	*Sorex cinereus*
Rodents	
Woodland jumping mouse	*Napaeozapus insignis*
Deer mouse	*Peromyscus maniculatus*
Meadow jumping mouse	*Zapus hudsonius*
White-footed mouse	*Peromyscus leucopus*
House mouse	*Mus musculus*
Norway rat	*Rattus norvegicus*
Boreal redback vole	*Clethrionomys gapperi*
Meadow vole	*Microtus pennsylvanicus*
Pine vole	*Pitymys pinetorum*
Southern bog lemming	*Synaptomys cooperi*
Muskrat	*Ondatra zibethica*
Beaver	*Castor canadensis*

Porcupine	*Erethizon dorsatum*
Woodchuck	*Marmota monax*
Southern flying squirrel	*Glaucomys volans*
Northern flying squirrel	*Glaucomys sabrinus*
Eastern chipmunk	*Tamias striatus*
Red squirrel	*Tamiasciurus hudsonicus*
Eastern gray squirrel	*Sciurus carolinensis*

Rabbits

Snowshoe hare	*Lepus americanus*
Eastern cottontail	*Sylvilagus floridanus*
New England cottontail	*Sylvilagus transitionalis*

Carnivores

Raccoon	*Procyon lotor*
Gray fox	*Urocyon cinereoargenteus*
Red fox	*Vulpes fulva*
Bobcat	*Lynx rufus*
Striped skunk	*Mephitis mephitis*
River otter	*Lutra canadensis*
Fisher	*Martes pennanti*
Mink	*Mustela vison*
Shorttail weasel	*Mustela erminea*
Longtail weasel	*Mustela frenata*
Coyote	*Canis latians*

Deer

Whitetail deer	*Odocoileus virginianus*

Seals

Harbor seal	*Phoca vitulina*

TABLE 15

Reptiles and Amphibians Found in Southeastern New Hampshire

(Modified from the University of New Hampshire 1974 and C. Smith, A.S.N.H., personal communication)

Reptiles

Turtles	
Common snapping turtle	*Chelydra serpentina serpentina*
Wood turtle	*Clemmys insculpta*
Spotted turtle	*Clemmys guttata*
Stinkpot	*Sternotherus odoratus*
Eastern painted turtle	*Chrysemys picta picta*
Eastern box turtle	*Terrapene carolina carolina*
Blandings turtle	*Emydoidea blandingi*
Snakes	
Northern red-bellied snake	*Storeria occipitomaculata*
Northern brown snake	*Storeria dekayi dekayi*
Northern water snake	*Natrix sipedon sipedon*
Eastern garter snake	*Thamnophis sirtalis sirtalis*
Eastern ribbon snake	*Thamnophis sauritus sauritus*
Northern ringneck snake	*Diadophis punctatus edwardsi*
Northern black racer	*Coluber constrictor constrictor*
Eastern smooth green snake	*Opheodrys vernalis vernalis*
Eastern milk snake	*Lampropeltis triangulum triangulum*
Eastern hognose sake	*Heterodon platyrhinos*

Amphibians

Salamanders	
Red-spotted newt	*Notophthalmus viridescen viridescens*
Jefferson salamander	*Ambystoma jeffersonianum*
Spotted salamander	*Ambystoma maculatum*
Northern dusky salamander	*Desmognathus fuscus fuscus*
Red-backed salamander	*Plethodon cinereus cinereus*
Northern spring salamander	*Gyrinophilus porphyriticus porphyriticus*

Four-toed salamander	*Hemidactylium scutatum*
Blue-spotted salamander	*Ambystoma laterale*
Northern two-lined salamander	*Eurycea bislineata bislineata*

Toads and Frogs

American toad	*Bufo americanus*
Northern spring peeper	*Hyla crucifer crucifer*
Gray treefrog	*Hyla versicolor*
Pickerel frog	*Rana palustris*
Northern leopard frog	*Rana pipiens*
Green frog	*Rana clamitans melanota*
Wood frog	*Rana sylvatica*
Bull frog	*Rana catesbeiana*
Fowler's toad	*Bufo woodhousei fowleri*

Appendix B.

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Appendix C.

Memorandums of Understanding

MEMORANDUM OF UNDERSTANDING
BETWEEN
THE STATE OF NEW HAMPSHIRE
AND
THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
CONCERNING THE
ESTABLISHMENT AND ADMINISTRATION OF
THE GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE

WHEREAS, the State of New Hampshire has determined that the waters and related coastal habitats of Great Bay provide unique opportunities to study natural and human processes occurring within an estuarine ecosystem; and

WHEREAS, it is the finding of the State of New Hampshire that the resources of Great Bay and the values they represent to the citizens of New Hampshire and the United States will benefit from the management of Great Bay as a National Estuarine Research Reserve; and

WHEREAS, the National Oceanic and Atmospheric Administration (NOAA), US Department of Commerce has concurred with that finding and pursuant to its authority under Section 315 of the Coastal Zone Management Act of 1972, as amended (CZMA), P.L. 92-583, 16 U.S.C. 1461, and in accordance with implementing regulations at 15 CFR 921.30, may designate Great Bay as a National Estuarine Research Reserve; and

WHEREAS, the Governor, State of New Hampshire, has designated the Office of State Planning to act on behalf of the State in matters concerning the initial acquisition and development award for the Great Bay National Estuarine Research Reserve, the boundaries of which are delineated in the proposed Reserve Management Plan (Plan); and

WHEREAS, the Department of Fish and Game, as the agency designated in the Plan and by the State of New Hampshire responsible for managing the Great Bay National Estuarine Research Reserve, acknowledges the need and requirement for continuing State-Federal cooperation in the long-term management of the site in a manner consistent with the purposes sought through its designation.

NOW, THEREFORE, in consideration of the mutual covenants contained herein it is agreed by and between the State of New Hampshire and NOAA, effective on the date of the designation of the Great Bay National Estuarine Research Reserve, as follows:

ARTICLE I: State/Federal Roles in Reserve Management

A. The Department of Fish and Game, as the principal contact for the State of New Hampshire in all matters concerning the Great Bay National Estuarine Research Reserve, will serve to ensure that the Reserve is managed in a manner consistent with the goals of the National Estuarine Research Reserve System and the management objectives of the Plan. Its responsibilities for Plan implementation will include the following:

1. Effect and maintain a process through the Council on Resources and Development (CORD) for coordinating the roles and responsibilities of all State agencies involved in the management of the Reserve, including but not limited to:

   a. Enforcement programs regulating water quality, fish and wildlife habitat protection, sport and commercial fisheries, and non-consumptive recreational activities;

   b. The on-site administration of facilities, programs, and tasks related to Reserve management;

   c. Activities and programs conducted pursuant to the State's Federally-approved coastal management program authorized under Section 306 of the CZMA; and

   d. Research agenda developed and implemented in accordance with corresponding elements of the proposed Plan;

2. As the Governor's designee under 15 CFR 921.50 and recipient State entity in matters concerning all financial assistance awards authorized under Section 315 of the CZMA, apply for, budget, and allocate such funds received for operation and management, and research;

3. Prepare and submit to NOAA for its approval an operational strategy which in coordination with the Plan describes how the State of New Hampshire intends to meet its long-term commitment to the management of the Reserve. The strategy, at a minimum, will describe the following:

   a. The procedures developed in accordance with MEMD guidelines and proposed by the State as a means for prescribing contingency responses to emergency conditions that exceed routine Plan implementation; and

   b. The Plan's continuing function, after Federal financial assistance for operations and management ends, as a vehicle for carrying out the mission of the national program; i.e. (i) how the State intends to coordinate Reserve management with its coastal resource management decisionmaking process; (ii) the anticipated work program, priorities, and sources of funding for ensuring the continued maintenance of the Reserve; and (iii) the means relied upon by the State to assure NOAA that real property acquired with Federal Funds for the purposes of the Reserve will continue to be used in a manner consistent with 15 CFR 921.21(e);

4. Serve as principal negotiator on issues involving proposed boundary changes and/or amendments to the Plan;

5. Submit annual reports to NOAA on the Reserve describing, in accordance with 15 CFR 921.34, program performance in Plan implementation and a detailed work program for the following year of Reserve operations, including budget projections and research efforts;

6. Respond to NOAA's requests for information and to evaluation findings made pursuant to Section 312 of the CZMA; and

7. In the event that it should become necessary, based on findings of deficiency, serve as the point-of-contact for the State of New Hampshire in actions involving the possible withdrawal of Reserve designation, as provided at 15 CFR 921.35.

8. Within NOAA, the Marine and Estuarine Management (MEMD), Office of Ocean and Coastal Resource Management (OCRM), will serve to administer the provisions of Section 315 of the CZMA to ensure that the Great Bay National Estuarine Research Reserve is managed in accordance with the goals of the National Estuarine Reserve Research System and the Plan. In carrying out its responsibilities, the MEMD will:

   1. Subject to appropriation and availability, provide financial assistance to the State, consistent with 15 CFR 921 Subparts D, E, and F, for managing and operating the Reserve;

   2. Serve as the point-of-contact for NOAA in discussion regarding applications for and any financial assistance received by the State under Section 315 of the CZMA, including any and all performance standards, compliance schedules, or Special Award Conditions deemed appropriate by NOAA to ensure the timely and proper execution of the proposed work program;

   3. Participate in periodic evaluations scheduled by OCRM in accordance with Section 312 of the CZMA to measure the State's performance in Plan implementation and its compliance with the terms and conditions prescribed in financial assistance awards granted by NOAA for the purposes of the Reserve and advise appropriate OCRM staff of existing or emerging issues which might affect the State's coastal management program; and

ARTICLE II: Real Property Acquired for the Purposes of the Reserve

A. The State of New Hampshire agrees to the conditions set forth at 15 CFR 921.21(e) which specify the legal documentation requirements concerning the use and disposition of real property acquired for Reserve purposes with Federal funds under Section 315 of the CZMA.

ARTICLE III: Program Evaluation

A. During the period that Federal financial assistance is available for Reserve operations and management, OCRM will schedule, pursuant to 15 CFR 921.34, periodic evaluations of the State's performance in meeting the conditions of such awards and progress in implementing the Plan and the provisions of this MOU. Where findings of deficiency occur, NOAA may initiate action in accordance with the procedures established at 15 CFR 921.35.

B. After Federal financial assistance under Section 315 of the CZMA is no longer available for the operation and management of the Reserve, OCRM will continue to evaluate, pursuant to Section 312 of the CZMA and the corresponding provisions of 15 CFR 921, the Department of Fish and Game's performance in implementing the Plan and strategy committing the State to the long-term management of the Great Bay National Estuarine Research Reserve. Where findings of deficiency occur, NOAA may initiate action in accordance with the procedures established at 15 CFR 921.35.

IN WITNESS THEREOF, the parties hereto have caused this Memorandum to be executed.

Peter L. Tweedt, Director
Office of Ocean and Coastal Resource Management
National Oceanic and Atmospheric Administration
US Department of Commerce

4-28-88
Date

Donald Normandeau, Exec. Director
New Hampshire Department of of Fish and Game

3-31-88
Date

Joseph A. Uravitch, Chief
Marine and Estuarine Management Division
Office of Ocean and Coastal Resource Management
National Oceanic and Atmospheric Administration
US Department of Commerce

4/21/88
Date

Witness

3-31-88
Date

MEMORANDUM OF UNDERSTANDING
BETWEEN
PEASE AIR FORCE BASE
AND
THE STATE OF NEW HAMPSHIRE

Whereas, the State of New Hampshire and NOAA intend to establish and manage a National Estuarine Research Reserve pursuant to Section 315 of the Coastal Zone Management Act of 1972,as amended, and the implementing regulations at 15 CFR Part 921;

Whereas, the State of New Hampshire intends to request the inclusion of 300 acres of primarily woodland that is owned by the Department of Defense at the Pease Air Force Base in Newington, New Hampshire;

Whereas, according to the policies and regulations of the National Estuarine Reserve Research System, if designation and management of a proposed national estuarine reserve will not conflict with use and control of federally owned lands, such cooperation and coordination is encouraged to the maximum extent feasible; and

Whereas, according to the policies and regulations of the National Estuarine Reserve Research System, if federally owned lands are a part of or adjacent to the area proposed for designation as a national estuarine Reserve, or if the control of land and water uses on such lands is necessary to protect the natural system within the Reserve, the state is encouraged to contact the federal agency maintaining control of the land to request cooperation in providing coordinated management policies.

Whereas, the State of New Hampshire and Pease Air Force Base believe that the provisions of the Plan dealing with the geographic area within the Reserve boundaries are consistent with the goals of the National Estuarine Reserve Research System.

Now, therefore, it is mutually agreed as follows:

The boundaries of the Great Bay Research Reserve will be established to include the aforementioned approximately 300 acres of woodlands of Pease Air Force Base. Attachment A delineates the area within the Pease Air Force Base that is included in the Great Bay Research Reserve.

To the maximum extent practicable, activities on that part of Pease Air Force Base included within Reserve boundaries will be carried out in accordance with the Base Comprehensive Plan.

Nothing in this Agreement shall be construed as in any way impairing the general powers of regulation and control by Department of Defense of property under its ownership.

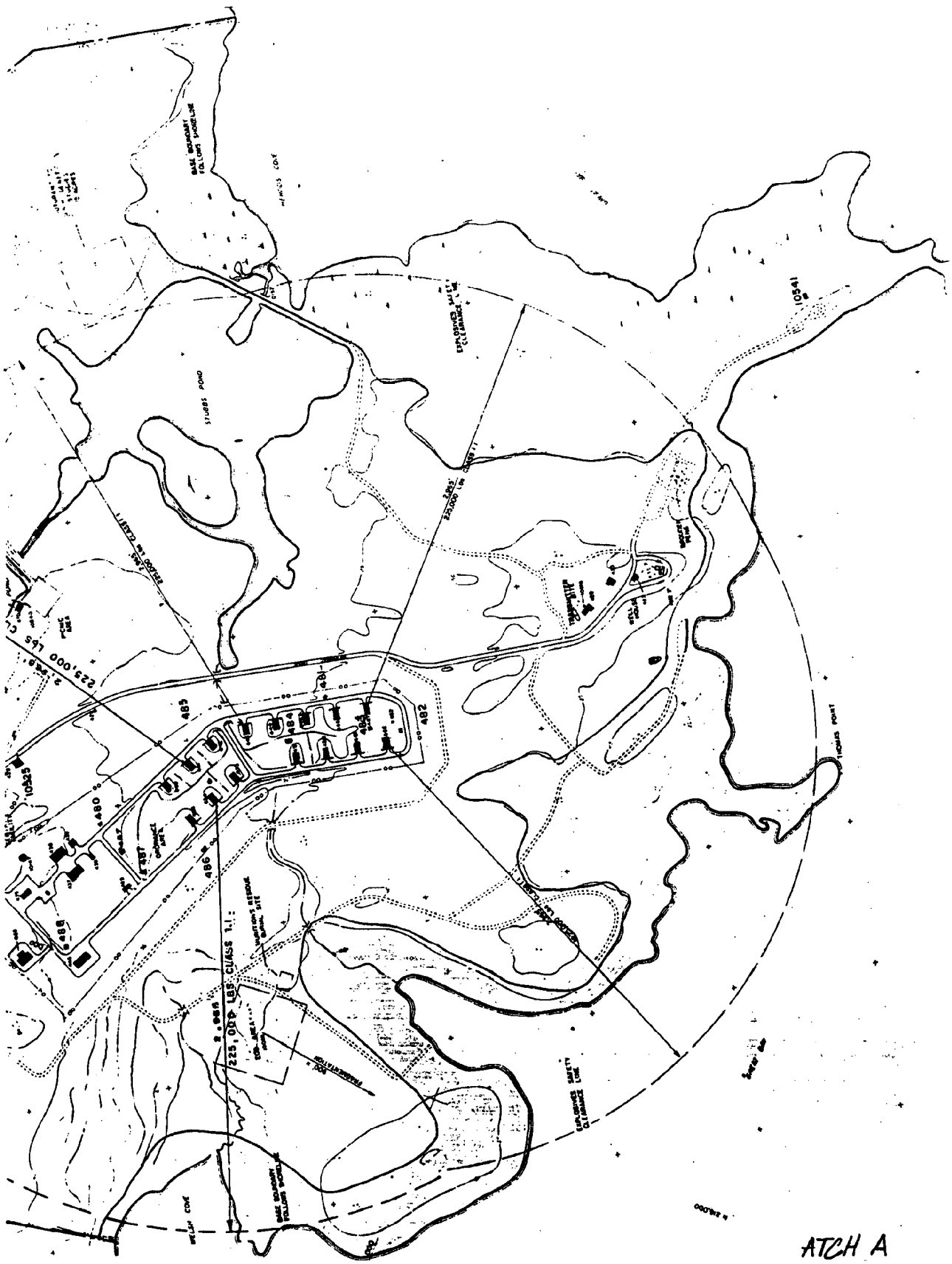
Access for research and education activities associated with the Great Bay National Estuarine Research Reserve will be made available only upon written application to the Civil Engineering unit of Pease Air Force Base fourteen (14) days or more prior to any proposed activity. Response to the application shall be through a telephone call placed by the applicant to the Base Community Planner (603/430-4264) seven (7) days or more prior to the proposed activity. Permission shall be granted only to the extent such use is compatible with the Base Comprehensive Plan.

It is understood and agreed to by all parties that this agreement shall remain in effect only so long as Pease Air Force Base, New Hampshire, remains open and under the control of the United States Air Force.

Orin L. Godsey 23 JAN 89
ORIN L. GODSEY, Colonel, USAF Date
Commander, 509th Bombardment Wing
Pease Air Force Base, New Hampshire

Robert W. Varney
Robert W. Varney Date
Director, Office of State Planning

Donald A. Normandeau 2/14/89
DONALD NORMANDEAU Date
Executive Director, New Hampshire
Department of Fish and Game



STUBBS POND
225,000 LBS CLASS 1.1
EXPLOSIVES SAFETY CLEARANCE LINE
THOMAS POINT
WELSH COVE

ATCH A

MEMORANDUM OF UNDERSTANDING
BETWEEN
STATE OF NEW HAMPSHIRE
AND
TOWN OF STRATHAM
REGARDING THE
GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE

This Agreement entered into on the 9th day of 1988, by and between the Office of State Planning, hereinafter OSP, and the Town of Stratham, hereinafter the Town, for the purpose of establishing the relationship between the State of New Hampshire and the Town regarding property located within the boundary of the Great Bay National Estuarine Research Reserve, hereinafter the Reserve.

WITNESSETH THAT,

Whereas the State of New Hampshire and NOAA intend to establish and manage a National Estuarine Research Reserve pursuant to Section 315 of the Coastal Zone Management Act of 1972, as amended, and the implementing regulations at 15 CFR Part 921;

Whereas the State of New Hampshire intends to request the inclusion of approximately 2 acres of wetland owned by the Town within the boundaries of the Reserve; and

Whereas the parties believe that the purposes of the Reserve are substantially compatible with the purposes of the Town's management of said property.

NOW THEREFORE, IT IS MUTUALLY AGREED, as follows:

The boundaries of the Great Bay National Estuarine Research Reserve shall be established to include 2 acres of wetland located in Stratham.

The Town and the State of New Hampshire shall cooperate as follows:

A. Town land may be made available to Reserve personnel, including researchers, upon written application to the Town for permission to enter said property 14 days or more prior to any proposed activity. The applicant shall be informed of a decision 7 days or more prior to the proposed activity. Such permission shall be granted only to the extent such use is compatible with the Town's management of said property.

B. The Town may continue to manage the property and enforce all applicable laws, regulations and policies.

C. In consultation with Town officials, the New Hampshire Fish and Game Department shall carry out its activities related to the management of the Reserve, including Town property, consistently with the goals of the Reserve. The New Hampshire Fish and Game Department, the Town and NOAA shall, to the maximum extent practicable, manage the Reserve consistently with the federal guidelines.

D. Should the Town proceed to dispose of said property, the Great Bay National Estuarine Research Reserve project shall be notified and afforded the right of first refusal to acquire said property.

E. This Agreement becomes effective on the date of signing of the last signature below and shall continue in effect until terminated. The Agreement shall be terminated upon the exclusion of the Town land from the Reserve.

F. Nothing in this Agreement shall be construed as in any way impairing the general powers of supervision, regulation and control by the Town of property under its ownership.

IN WITNESS WHEREOF, the parties subscribe their names below:

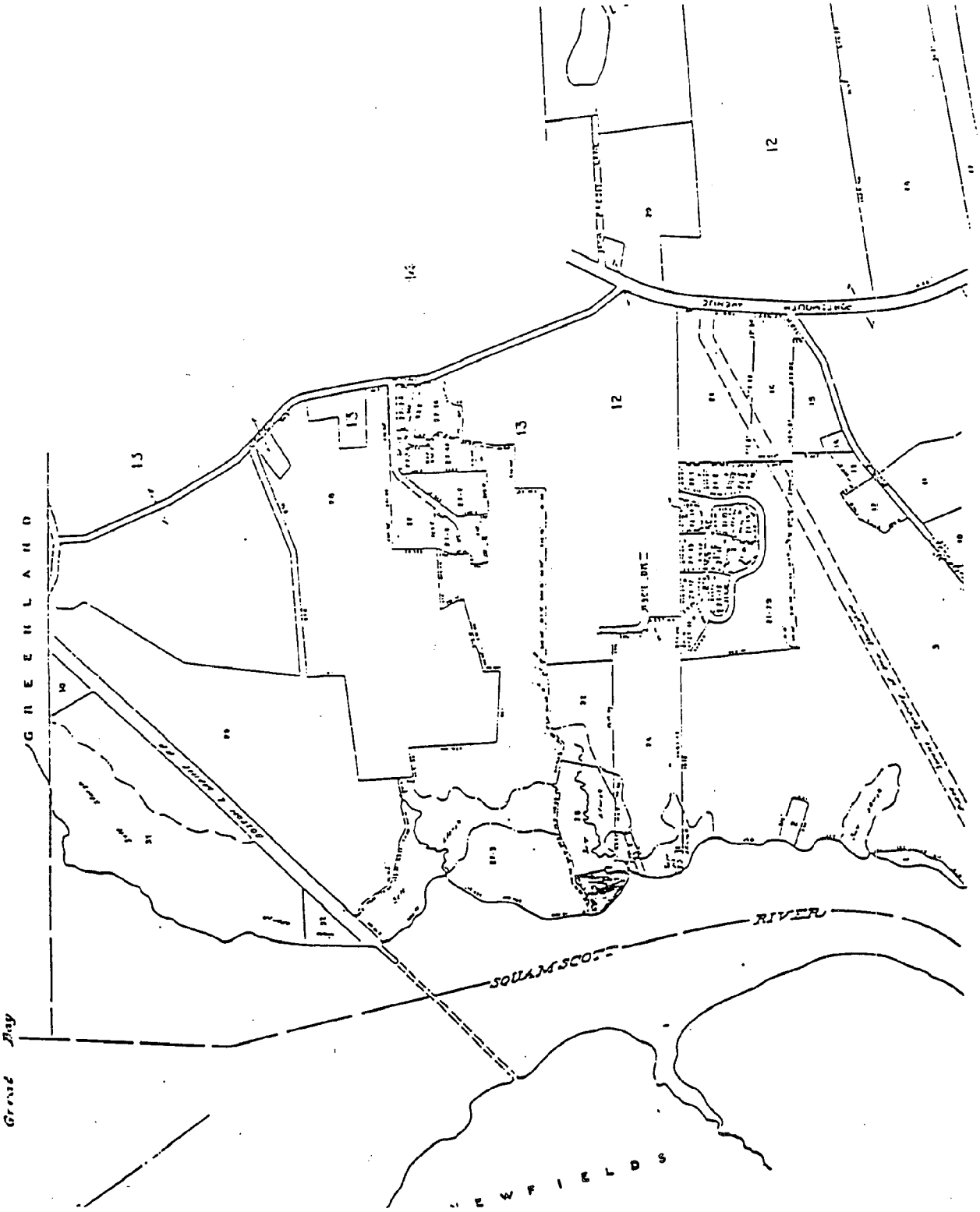
Chairman, Board of Selectmen
Town of

Witness

8/9/88
Date

8/15/88
John E. Dabuliewicz, Director Date
Office of State Planning

8/26/88
Donald Normandeau, Exec. Director Date
NH Department of Fish and Game


GREENLAND
SQUAMSCOTT RIVER
Great Bay
NEWFIELDS
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MEMORANDUM OF UNDERSTANDING
BETWEEN
UNIVERSITY OF NEW HAMPSHIRE
COOPERATIVE EXTENSION SERVICE
AND
STATE OF NEW HAMPSHIRE
FISH AND GAME DEPARTMENT

Whereas, the State of New Hampshire and the National Oceanic and Atmospheric Administration (NOAA) intend to establish and manage a National Estuarine Research Reserve pursuant to Section 315 of the Coastal Zone Management Act (CZMA) of 1972, as amended, and the implementing regulations at 15 CFR Part 921;

Whereas, the State of New Hampshire has determined that the waters and unique habitats of Great Bay provide unique opportunities to foster education awareness and provide research on the functions of an estuarine system;

Whereas, the State of New Hampshire is responsible for management of the Great Bay National Estuarine Research Reserve and acknowledges the need for cooperation on estuarine research and education with the University of New Hampshire in a manner consistent with the purposes sought through its designation and management plan;

Whereas, the State of New Hampshire recognizes the role of the University of New Hampshire in enhancing research and education opportunities within the Research Reserve;

Now, therefore, it is mutually agreed as follows:

1. A marine education specialist affiliated with the University's Sea Grant Extension Program shall be appointed to the Great Bay Research Reserve Advisory Committee;

2. Reserve properties under conservation easement shall be made available to Sea Grant Extension staff and UNH Marine Docents for research and educational purposes as long as such use is compatible with the goals and objectives of the Reserve's management plan;

3. As part of the review process of the Reserve's management plan, Sea Grant Extension staff shall provide the state with technical assistance in revising research and the educational component of the plan;

4. The Reserve manager or an appropriate designee shall be appointed to the University's Marine Education Advisory Committee;

5. In a mutual effort to coordinate research education activities, cooperative programming on estuarine related topics shall be pursued by the Reserve and Sea Grant Extension staff and UNH Marine Docents;

6. Sea Grant projects funded by Section 315 of CZMA will be periodically evaluated as set forth in Section 312 of CZMA.

7. This Agreement becomes effective on the date of signing of the last signature below and shall continue in effect until terminated. The Agreement shall be terminated only upon withdrawal of designation of the Great Bay National Estuarine Research Reserve by NOAA.

Peter Horne, Director
Cooperative Extension Service
University of New Hampshire

8/14/89
Date

Donald Normandeau, Ph.D.
Executive Director
Fish and Game Department

8/21/89
Date

Brian Doyle, Program Leader
Sea Grant Extension Program

8/10/89
Date

MEMORANDUM OF UNDERSTANDING
BETWEEN THE
UNIVERSITY OF NEW HAMPSHIRE
JACKSON ESTUARINE LABORATORY
AND THE
STATE OF NEW HAMPSHIRE
FISH AND GAME DEPARTMENT

Whereas, the State of New Hampshire and the National Oceanic and Atmopsheric Administration (NOAA) intend to establish and manage a National Estuarine Research Reserve pursuant to Section 315 of the Coastal Zone Management Act (CZMA) of 1972, as amended, and the implementing regulations at 15 CFR Part 921;

Whereas, the State of New Hampshire has determined that the waters and unique habitats of Great Bay provide unique research opportunities to study natural processes within an estuarine system;

Whereas, the State of New Hampshire is responsible for management of the Great Bay National Estuarine Research Reserve and acknowledges the need and requirements for continuing State cooperation of the site with the University of New Hampshire, in a manner consistent with the purposes sought through its designation and management plan;

Whereas, the State of New Hampshire recognizes the role of the University of New Hampshire in enhancing education and research opportunities within the Research Reserve;

Now, therefore, it is mutually agreed as follows:

1. The Director of Jackson Estuarine Laboratory shall be appointed to the Great Bay Research Reserve Advisory Committee;

2. Reserve properties under conservation easement shall be made available to Jackson Estuarine Laboratory staff for research and educational purposes as long as such use is compatible with the goals and objectives of the Reserve's management plan.

3. As part of the periodic review and update of the Reserve's management plan, Jackson Estuarine Laboratory shall provide the State with technical assistance in revising the priorities for research and education activities;

4. In a mutual effort to coordinate research and education projects within the Reserve, Jackson Estuarine Laboratory shall provide the State with a periodic log of non-Reserve research and education projects being conducted within the estuarine system. The State shall, in turn, provide the same information to Jackson Estuarine Laboratory;

5. The State of New Hampshire shall consult with Jackson Estuarine Laboratory staff during the evaluation process of National Estuarine Reserve Research System research proposals to be submitted to NOAA;

6. Subject to funding availability, the State shall support the Jackson Estuarine Laboratory's monitoring program within the Great Bay Research Reserve.

7. Research projects funded by Section 315 of CZMA will be periodically evaluated as set forth in Section 312 of CZMA.

8. This Agreement becomes effective on the date of signing of the last signature below and will continue in effect until terminated. The agreement shall be terminated only upon withdrawal of designation of the Great Bay National Estuarine Research Reserve by NOAA.

James D. Morrison

James Morrison, Ph.D.
Associate Vice President for Research
University of New Hampshire

August 12, 1989
Date

Donald A. Normandeau

Donald Normandeau, Ph.D.
Executive Director
Fish and Game Department

8/21/89
Date

Appendix D.

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Appendix E.

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Appendix F.

Research Guidelines

GREAT BAY ESTUARINE NATIONAL RESEARCH RESERVE
RESEARCH PROJECT DESCRIPTION

Date: _____

I) Personnel

Principal Investigator: _____

Institutional Affiliation: _____

Address: _____

_____

Phone: _____

Associated Personnel: _____

_____

_____

II) Project Description

Research Project Title: _____

_____

Research Objectives: _____

_____

Research Methods (include description on any biotic or abiotic samples to be taken, placement of any monitoring devices or experimental apparatus and protocol for maintenance and removal): (attach additional sheets)

Research Location: (illustration on page F-3)

Research Project Duration: _____

III) Relevant Permits

Research Project Location Access (describe means of access to research location, if access involves crossing privately owned land attach evidence of permission):

_____

_____

_____

Research Collection Permits (if research project requires collection permits, attach copies).

Signature of Principal Investigator: _____

Date: _____

Description of Research Project Location

FOR ADMINISTRATIVE USE ONLY

Date Application Received: _____

Names and comments of any technical/scientific reviewers (attach separate sheet if necessary):

_____

_____

Action (if conditional approval, attach separate sheet for recommendations):

_____

Date of Action: _____

Appendix G.

NOAA Regulations

required for this notice of final rulemaking. The regulations set forth procedures for identifying and designating national estuarine sanctuaries, and managing sites once designated.

These rules do not directly affect "small government jurisidictions" as defined by Pub. L. 96–354, the Regulatory Flexibility Act, and the rules will have no effect on small businesses.

(C) Paper Work Reduction Act of 1980 (Pub. L. 96–511)

These regulations do not impose any information requirements of the type covered by Pub. L. 96–511 other than those already approved by the Office of Management and Budget (approval number 0648–0121) for use through September 30, 1986.

(D) National Environmental Policy Act

NOAA has concluded that publication of these rules does not constitute a major Federal action significantly affecting the quality of the human environment. Therefore, an environmental impact statement is not required.

List of Subjects in 15 CFR Part 921

Administrative practice and procedure, Coastal zone, Environmental protection, Natural resources, Wetlands.

(Federal Domestic Assistance Catalog Number 11.420 Estuarine Sanctuary Program)

Dated: February 29, 1984.

Paul M. Wolff,

Assistant Administrator for Ocean Services and Coastal Zone Management.

Accordingly, 15 CFR Part 921 is revised as follows:

PART 921—NATIONAL ESTUARINE SANCTUARY PROGRAM REGULATIONS

Subpart A—General

Sec.
921.1 Mission and goals.
921.2 Definitions.
921.3 National Estuarine Sanctuary Biogeographic Classification Scheme and Estuarine Typology.
921.4 Relationship to other provisions of the Coastal Zone Management Act and to the National Marine Sanctuary Program.

Subpart B—Preacquisition: Site Selection and Management Plan Development

921.10 General.
921.11 Site selection.
921.12 Management Plan development.

Subpart C—Acquisition, Development, and Preparation of the Final Management Plan

921.20 General.
921.21 Initial acquisition and development awards.

Subpart D—Sanctuary Designation and Subsequent Operation

Sec.
921.30 Designation of National Estuarine Sanctuaries.
921.31 Supplemental acquisition and development awards.
921.32 Operation and management: Implementation of the Management Plan.
921.33 Boundary changes. Amendments to the Management Plan, and addition of multiple-site components.
921.34 Program evaluation.
921.35 Withdrawal of designation.

Subpart E—Research Funds

921.40 General.
921.41 Categories of potential research projects: evaluation criteria.

Subpart F—General Financial Assistance Provisions

921.50 Application information.
921.51 Allowable costs.
921.52 Amendments to financial assistance awards.

Appendix 1—Biogeographic Classification Scheme
Appendix 2—Typology of National Estuarine Areas

Authority: Sec. 315(l), Pub. L. 92–583, as amended; 86 Stat. 1280 (16 U.S.C. 1461(1)).

Subpart A—General

§ 921.1 Mission and goals.

(a) The mission of the National Estuarine Sanctuary Program is the establishment and management, through Federal-state cooperation, of a national system of estuarine sanctuaries representative of the various regions and estuarine types in the United States. Estuarine sanctuaries will be established to provide opportunities for long-term research, education, and interpretation.

(b) The goals of the Program for carrying out this mission are:

(1) Enhance resource protection by implementing a long-term management plan tailored to the site's specific resources;

(2) Provide opportunities for long-term scientific and educational programs in estuarine areas to develop information for improved coastal decisionmaking;

(3) Enhance public awareness and understanding of the estuarine environment through resource interpretive programs; and

(4) Promote Federal-state cooperative efforts in managing estuarine areas.

(c) To assist the states in carrying out the Program's goals in an effective manner, the National Oceanic and Atmospheric Administration (NOAA) will coordinate a research and education information exchange throughout the national estuarine sanctuary system. As part of this role, NOAA will ensure that information and ideas from one sanctuary are made available to others in the system. The network that will be established will enable sanctuaries to exchange information and research data with each other, with universities engaged in estuarine research, and with Federal and state agencies. NOAA's objective is a system-wide program of research and monitoring capable of addressing the management issues that affect long-term productivity of our Nation's estuaries.

(d) Multiple uses are encouraged to the degree compatible with the sanctuary's overall purpose as provided in the management plan and consistent with subsections (a) and (b), above. Use levels are set by the individual state and analyzed in the management plan. The sanctuary management plan (see § 921.12) will describe the uses and establishes priorities among these uses. The plan shall identify uses requiring a state permit, as well as areas where uses are encouraged or prohibited. In general, sanctuaries are intended to be open to the public; low-intensity recreational and interpretive activities are generally encouraged.

(e) Certain manipulative research activities may be allowed on a limited basis, but only if specified in the management plan and only if the activity is consistent with overall sanctuary purposes and the sanctuary resources are protected. Manipulative research activities require the prior approval of the state and NOAA. Habitat manipulation for resource management purposes is not permitted within national estuarine sanctuaries.

(f) While the Program is aimed at protecting natural, pristine sites, NOAA recognizes that many estuarine areas have undergone ecological change as a result of human activities. Although restoration of degraded areas is not a primary purpose of the Program, some restorative activities may be permitted in an estuarine sanctuary as specified in the management plan.

(g) NOAA may provide financial assistance to coastal states, not to exceed 50 percent of all actual costs, to assist in the designation and operation of national estuarine sanctuaries (see section 921.51(e)). Three types of awards are available under the National Estuarine Sanctuary Program. The *preacquisition award* is for site selection and draft management plan preparation. The *acquisition and development award* is intended primarily for land acquisition and construction purposes. The *operation and management award* provides funds to assist in implementing the research, educational, and administrative

programs detailed in the sanctuary management plan. Under the Act, the Federal share of funding for a national estuarine sanctuary shall not exceed $3,000,000. At the conclusion of Federal financial assistance, funding for the long-term operation of the sanctuary becomes the responsibility of the state.

(h) Lands already in protected status by another Federal, state, local government or private organization can be included within national estuarine sanctuaries only if the managing entity commits to long-term non-manipulative management. Federal lands already in protected status cannot comprise the key land and water areas of a sanctuary (see § 921.11(c)(3)).

§ 921.2 Definitions.

(a) "Act" means the Coastal Zone Management Act, as amended, 16 U.S.C. 1451 *et seq.* Section 315(1) of the Act, 16 U.S.C. 1461(1), establishes the National Estuarine Sanctuary Program.

(b) "Assistant Administrator" (AA) means the Assistant Administrator for Ocean Services and Coastal Zone Management, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, or his/her successor or designee.

(c) "Coastal state" means a state of the United States in, or bordering on, the Atlantic, Pacific, or Arctic Ocean, the Gulf of Mexico, Long Island Sound, or one or more of the Great Lakes. For the purposes of this title, the term also includes Puerto Rico, the Virgin Islands, Guam, the Commonwealth of the Northern Marianas, and the Trust Territories of the Pacific Islands, and American Samoa (see 16 U.S.C. 1454(4)).

(d) "Estuary" means that part of a river or stream or body of water having unimpaired connection with the open sea, where the sea water is measurably diluted with fresh water derived from land drainage. The term also includes estuary-type areas of the Great Lakes, see 16 U.S.C. 1454(7).

(e) "National Estuarine Sanctuary" means and area, which may include all or the key land and water portion of an estuary, and adjacent transitional areas and uplands, constituting to the extent feasible a natural unit, set aside as a natural field laboratory to provide long-term opportunities for research, educational, and interpretation on the ecological relationships within the area (see 16 U.S.C. 1454(8)).

§ 921.3 National Estuarine Sanctuary Biogeographic Classification Scheme and Estuarine Typologies.

(a) National estuarine sanctuaries are chosen to reflect regional differences and to include a variety of ecosystem types. A biogeographic classification scheme based on regional variations in the nation's coastal zone has been developed. The biogeographic classification scheme is used to ensure that the National Estuarine Sanctuary System includes at least one site from each region. The estuarine typology system is utilized to ensure that sites in the Program reflect the wide range of estuarine types within the United States.

(b) The biogeographic classification scheme, presented in Appendix 1, contains 27 regions. Figure 2 graphically depicts the biogeographic regions of the United States.

(c) The typology system is presented in Appendix 2.

§ 921.4 Relationship to other provisions of the Coastal Zone Management Act and to the National Marine Sanctuary Program.

(a) The National Estuarine Sanctuary Program is intended to provide information to state agencies and other entities involved in coastal zone management decisionmaking pursuant to the Coastal Zone Management Act, 16 U.S.C. 1451 *et seq.* Any coastal state, including those that do not have approved coastal zone management programs under section 306 of the Act, is eligible for an award under the National Estuarine Sanctuary Program (see § 921.2(e)).

(b) Where feasible, the National Estuarine Sanctuary Program will be conducted in close coordination with the National Marine Sanctuary Program (Title III of the Marine Protection, Research and Sanctuaries Act, as amended, 16 U.S.C. 1431–1434), also administered by NOAA. Title III authorizes the Secretary of Commerce to designate ocean waters as marine sanctuaries to protect or restore such areas for their conservation, recreational, ecological, or esthetic values. National marine and estuarine sanctuaries will not overlap, though they may be adjacent.

Subpart B—Preacquisition: Site Selection and Management Plan Development

§ 921.10 General.

(a) A state may apply for a preacquisition award for the purpose of site selection and preparation of documents specified in § 921.12 (draft management plan and environmental impact statement (EIS)). The total Federal share of the preacquisition award may not exceed $50,000, of which up to $10,000 may be used for site selection as described in § 921.11. Financial assistance application procedures are specified in Subpart F.

(b) In selecting a site, a state may choose to develop a multiple-site sanctuary reflecting a diversity of habitats in a single biogeographic region. A multiple-site sanctuary also allows the state to develop complementary research and educational programs within the multiple components of its sanctuary. Multiple-site sanctuaries are treated as one sanctuary in terms of financial assistance and development of an overall management framework and plan. Each individual component of a proposed multiple-site sanctuary shall be evaluated separately under § 921.11(c) as part of the site selection process. A state may propose to establish a multiple-site sanctuary at the time of the initial site selection, or at any point in the development or operation of the estuarine sanctuary, even after Federal funding for the single component sanctuary has expired. If the state decides to develop a multiple-site national estuarine sanctuary after the initial acquisition and development award is made on a single site, the proposal is subject to the requirements set forth in § 921.33. It should be noted, however, that the total funding for a multiple-site sanctuary remains at the $3,000,000 limit; the funding for operation of a multiple-site sanctuary is also limited to the $250,000 standard (see § 921.32(b)).

§ 921.11 Site selection.

(a) A state may use up to $10,000 in Federal preacquisition funds to establish and implement a site selection process which is approved by NOAA.

(b) In Addition to the requirements set forth in Subpart F, a request for Federal funds for site selection must contain the following programmatic information:

(1) A description of the proposed site selection process and how it will be implemented in conformance with the biogeographic classification scheme and typology (§ 921.3);

(2) An identification of the site selection agency and the potential management agency; and

(3) A description of how public participation will be incorporated into the process (see § 921.11(d)).

(c) As part of the site selection process, the state and NOAA shall evaluate and select the final site(s). NOAA has final authority in approving such sites. Site selection shall be guided by the following principles:

(1) The site's benefit to the National Estuarine Sanctuary Program relative to the biogeographic classification scheme

and typology set forth in § 921.3 and Appendices 1 and 2:

(2) The site's ecological characteristics, including its biological productivity, diversity of flora and fauna, and capacity to attract a broad range of research and educational interests. The proposed site should, to the maximum extent possible, be a natural system:

(3) Assurance that the site's boundaries encompass an adequate portion of the key land and water areas of the natural system to approximate an ecological unit and to ensure effective conservation. Boundary size will vary greatly depending on the nature of the ecosystem. National estuarine sanctuaries may include existing Federal or state lands already in a protected status where mutual benefit can be enhanced, see § 921.51(e)(2). Importantly, however, NOAA will not approve a site for potential sanctuary status that is dependent upon the inclusion of currently protected Federal lands in order to meet the requirements for sanctuary status (such as key land and water areas). Such lands may only be included within a sanctuary to serve as a buffer or for other ancillary purposes:

(4) The site's importance for research, including proximity to existing research facilities and educational institutions: (*Comment:* NOAA is developing more detailed criteria for selecting potential national estuarine sanctuaries based upon research characteristics. Once these criteria are developed, a notice of their availability will be published in the Federal Register).

(5) The site's compatibility with existing and potential land and water uses in contiguous areas: and

(6) The site's importance to education and interpretive efforts, consistent with the need for continued protection of the natural system.

(d) Early in the site selection process, the state must seek the views of affected landowners, local governments, other state and Federal agencies, and other parties who are interested in the area(s) being considered for selection as a potential national estuarine sanctuary. After the local government and affected landowners have been contacted, at least one public meeting shall be held in the area of the proposed site. Notice of such a meeting, including the time, place, and relevant subject matter, shall be announced by the state through the area's principal news media at least 15 days prior to the date of the meeting and by NOAA in the Federal Register.

§ 921.12 Management Plan development.

(a) After the selected site is approved by NOAA and the state, the state may request the remainder of the preacquisition funds to develop the draft management plan and environmental impact statement. The request must be accompanied by the information specified in Subpart F and the following programmatic information:

(1) An analysis of the site based on the biogeographic scheme/typology discussed in § 921.3 and set forth in Appendices 1 and 2:

(2) A description of the site and its major resources, including location, proposed boundaries, and adjacent land uses. Maps, including aerial photographs, are required:

(3) A description of the public participation process used by the state to solicit the views of interested parties, a summary of comments, and, if interstate issues are involved, documentation that the Governor(s) of the other affected state(s) has been contacted:

(4) A list of all sites considered and a brief statement of the basis for not selecting the non-preferred sites: and

(5) A draft management plan outline (see subsection (b) below) and an outline of a draft memorandum of understanding (MOU) between the state and NOAA detailing the Federal-state roles in sanctuary management during the period of federal funding and expressing the state's long-term commitment to operate and manage the sancturay.

(b) After NOAA approves the state's request to use the remaining preacquisition funds, the state shall begin developing a draft management plan. The plan will set out in detail:

(1) Sanctuary goals and objectives, management issues, and strategies or actions for meeting the goals and objectives:

(2) An administrative section including staff roles in administration, research, education/interpretation, and surveillance and enforcement.

(3) A research plan, including a monitoring design:

(4) An interpretive plan (including interpretive, educational and recreational activities):

(5) A plan for public access to the sanctuary:

(6) A construction plan, including a proposed construction schedule, and drawings of proposed developments. If a visitor center, research center or any other facilities are proposed for construction or renovation at the site, a preliminary engineering report must be prepared:

Note.—Information on preparing a preliminary engineering report (PER) is provided in "Engineering and Construction Guidelines for Coastal Energy Impact Program Applicants" (42 FR 64830 (1977)), which is supplied to award recipients:

(7) An acquisition plan identifying the ecologically key land and water areas of the sanctuary, priority acquisitions, and strategies for acquiring these areas. This plan should identify ownership patterns within the proposed sanctuary boundaries: land already in the public domain: an estimate of the fair market value of land to be acquired: the method of acquisition, or the feasible alternatives (including less-than-fee techniques) for the protection of the estuarine area: a schedule for acquisition with an estimate of the time required to complete the proposed sanctuary: and a discussion of any anticipated problems:

Note.—As discussed in § 921.11(c)(3), if protected lands are to be included within the proposed sanctuary, the state must demonstrate to NOAA that the site meets the criteria for national estuarine sanctuary status independent of the inclusion of such protected lands.

(8) A resource protection plan detailing applicable authorities, including allowable uses, uses requiring a permit and permit requirements, any restrictions on use of the sanctuary, and a strategy for sanctuary surveillance and enforcement of such use restrictions, including appropriate government enforcement agencies:

(9) If applicable, a restoration plan describing those portions of the site that may require habitat modification to restore natural conditions: and

(10) A proposed memorandum of understanding (MOU) between the state and NOAA regarding the Federal-state relationship during the establishment and development of the national estuarine sanctuary, and expressing the long-term commitment by the state to maintain effectively the sanctuary after Federal financial assistance ends. In conjunction with the MOU and where possible under state law, the state will consider taking appropriate administrative or legislative action to ensure the long-term protection of the sanctuary. The MOU shall be signed prior to sanctuary designation. If other MOUs are necessary (such as with a federal agency or another state agency), drafts of such MOUs also must be included in the plan.

(c) Regarding the preparation of an environmental impact statement (EIS) under the National Environmental Polic Act on a national estuarine sanctuary proposal, the state shall provide all

necessary information to NOAA concerning the socioeconomic and environmental impacts associated with implementing the draft management plan and feasible alternatives to the plan. Based on this information, NOAA will prepare the draft EIS.

(d) Early in the development of the draft management plan and the draft EIS, the state shall hold a meeting in the area or areas most affected to solicit public and government comments on the significant issues related to the proposed action. NOAA will publish a notice of the meeting in the **Federal Register** and in local media.

(e) NOAA will publish a **Federal Register** notice of intent to prepare a DEIS. After the draft EIS is prepared and filed with the Environmental Protection Agency (EPA), a Notice of Availability of the DEIS will appear in the **Federal Register**. Not less than 30 days after publication of the notice, NOAA will hold at least one public hearing in the area or areas most affected by the proposed sanctuary. The hearing will be held no sooner than 15 days after appropriate notice by NOAA of the meeting has been given in the principal news media and in the **Federal Register**. After a 45-day comment period, a final EIS is prepared by NOAA.

Subpart C—Acquisition, Development, and Preparation of the Final Management Plan

§ 921.20 General.

After NOAA approval of the site, the draft management plan and the draft MOU, and completion of the final EIS, a state is eligible for an acquisition and development award to acquire land and water areas for inclusion in the sanctuary and to construct research and educational facilities in accordance with the draft management plan. The acquisition and development award has two phases. In the initial phase, state performance should work to meet the criteria required for formal sanctuary designation, i.e., acquiring the key land and water areas as specified in the draft management plan and preparing the final plan. These requirements are specified in § 921.30. The initial acquisition and development phase is expected to last no longer than two years after the start of the award. If necessary, a longer time period may be negotiated between the state and NOAA. After the sanctuary is designated, funds may be used to acquire any remaining land and for construction purposes.

§ 921.21 Initial acquisition and development awards.

(a) Assistance is provided to aid the recipient in: (1) Acquiring land and water areas to be included in the sanctuary boundaries; (2) minor construction, as provided in paragraphs (b) and (c) of this section; (3) preparing the final management plan; and (4) up to the point of sanctuary designation, for initial management costs, e.g., implementing the NOAA approved draft management plan, preparing the final management plan, hiring a sanctuary manager and other staff as necessary, and for other management-related activities. Application procedures are specified in Subpart F.

(b) The expenditure of Federal and state funds on major construction activities is not allowed during the initial acquisition and development phase. The preparation of architectural and engineering plans, including specifications, for any proposed construction is permitted. In addition, minor construction activities, consistent with paragraph (c) of this section also are allowed. The NOAA-approved draft management plan must, however, include a construction plan and a public access plan before any award funds can be spent on construction activities.

(c) Only minor construction activities that aid in implementing portions of the management plan (such as boat ramps and nature trails) are permitted under the initial acquisition and development award. No more than five (5) percent of the initial acquisition and development award may be expended on such facilities. NOAA must make a specific determination, based on the final EIS, that the construction activity will not be detrimental to the environment.

(d) Except as specifically provided in paragraphs (a)–(c) of this section, construction projects, to be funded in whole or in part under the acquisition and development award, may not be initiated until the sanctuary receives formal designation, see § 921.30.

Note.—The intent of these requirements and the phasing of the acquisition and development award is to ensure that substantial progress in acquiring the key land and waters areas has been made and that a final management plan is completed before major sums are spent on construction. Once substantial progress in acquisition has been made, as defined by the state in the management plan, other activities guided by the final management plan may begin with NOAA's approval.

(e) Deeds for real property acquired for the sanctuary under acquisition funding shall contain substantially the following provision:

Title to the property conveyed by this deed shall vest in the [recipient of the CZMA Section 315 award or other Federally-approved entity] subject to the condition that the property shall remain part of the Federally-designated [name of National Estuarine Sanctuary]. In the event that the property is no longer included as part of the sanctuary, or if the sanctuary designation of which it is part is withdrawn, then the National Oceanic and Atmospheric Administration or its successor agency, in conjunction with the State, may exercise any of the following rights regarding the disposition of the property:

(i) The recipient may be required to transfer title to the Federal Government. In such cases, the recipient shall be entitled to compensation computed by applying the recipient's percentage of participation in the cost of the program or project to the current fair market value of the property; or

(ii) At the discretion of the Federal Government, (a) the recipient may either be directed to sell the property and pay the Federal Government an amount computed by applying the Federal percentage of participation in the cost of the original project to the proceeds from the sale (minus actual and reasonable selling and fix-up expenses, if any, from the sale proceeds); or (b) the recipient may be permitted to retain title after paying the Federal Government an amount computed by applying the Federal percentage of participation in the cost of the original project to the current fair market value of the property.

Note.—Fair market value of the property must be determined by an independent appraiser and certified by a responsible official of the state, as provided by OMB Circular A-102 Revised, Attachment F.

(f) Prior to submitting the final management plan to NOAA for review and approval, the state should hold a public meeting in the area affected by the estuarine sanctuary. NOAA will publish a notice of the meeting in the **Federal Register** and in the local media.

Subpart D—Sanctuary Designation and Subsequent Operation

§ 921.30 Designation of National Estuarine Sanctuaries.

(a) The AA shall designate an area as a national estuarine sanctuary pursuant to Section 315 of the Act, based upon written findings that the state has met the following conditions:

(1) A final management plan has been approved by NOAA;

(2) Sanctuary construction and access policies, § 921.21(b)–(d), have been followed;

(3) Key land and water areas of the proposed sanctuary, as identified in the management plan, are under state control; and

(4) An MOU between the state and NOAA ensuring a long-term commitment by the state to the

sanctuary's effective operation and implementation has been signed.

(b) A notice of designation of a national estuarine sanctuary will be placed in the Federal Register and in the local media.

(c) The term "state control" in § 921.30(a)(3) does not necessarily require that the land be owned by the state in fee simple. Less-than-fee interests and regulatory measures may suffice where the state makes a showing that the lands are adequately controlled consistent with the purposes of the sanctuary.

§ 921.31 Supplemental acquisition and development awards.

After sanctuary designation, and as specified in the approved management plan, the state may request a supplemental acquisition and development award for construction and acquiring any remaining land. Application procedures are specified in Subpart F. Land acquisition must follow the procedures specified in § 921.21(e).

§ 921.32 Operation and management: implementation of the Management plan.

(a) After the sanctuary is formally designated, the state may apply for assistance to provide for operation and management. The purpose of this phase in the national estuarine sanctuary process is to implement the approved final management plan and to take the necessary steps to ensure the continued effective operation of the sanctuary after direct Federal support is concluded.

(b) Federal funds of up to $250,000, to be matched by the state, are available for the operation and management of the national estuarine sanctuary. Operation and management awards are subject to the following limitations:

(1) No more than $50,000 in Federal funds per annual award; and

(2) No more than ten percent of the total amount (state and Federal shares) of each operation and management award may be used for construction-type activities (i.e., $10,000 maximum per year).

§ 921.33 Boundary changes, amendments to the Management Plan, and addition of multiple-site components.

(a) Changes in sanctuary boundaries and major changes to the final management plan, including state laws or regulations promulgated specifically for the sanctuary, may be made only after written approval by NOAA. If determined to be necessary, NOAA may require public notice including notice in the Federal Register and an opportunity for comment. Changes in the boundary involving the acquisition of properties not listed in the management plan or final EIS require public notice and the opportunity for comment; in certain cases, an environmental assessment may be required. Where public notice is required, NOAA will place a notice in the Federal Register of any proposed changes in sanctuary boundaries or proposed major changes to the final management plan and ensure that a notice is published in the local media.

(b) As discussed in § 921.10(b), a state may choose to develop a multiple-site national estuarine sanctuary after the initial acquisition and development award for a single site has been made. Public notice of the proposed addition in the Federal Register and local media, and the opportunity for comment, in addition to the preparation of either an environmental assessment or environment impact statement on the proposal will be required. An environmental impact statement, if required, will be prepared in accordance with section 921.12 and will also include an administrative framework for the multiple-site sanctuary that describes the complementary research and educational programs within the sanctuary. If NOAA determines, based on the scope of the project and the issues associated with the additional site, that an environmental assessment is sufficient to establish a mulitple-site sanctuary, then the state shall develop a revised management plan as described in § 921.12(b). The revised management plan will address the sanctuary-wide goals and objectives and the additional component's relationship to the original site.

§ 921.34 Program evaluation.

(a) Performance during the term of the operation and management award (or under the initial acquisition and development award, if the sanctuary is not designated within two years) will be evaluated annually by the Program Office and periodically in accordance with the provisions of Section 312 of the Act to determine compliance with the conditions of the award and overall progress in implementing the management plan.

(b) To ensure effective sanctuary oversight after the major federal funding expires, the state is required to submit an annual report on the sanctuary. The report should detail program successes and accomplishments in meeting the policies and activities described in the sanctuary management plan. A work plan, detailing the projects to be undertaken the next year to meet the Program goals and the state's role in ongoing sanctuary programs, should also be included. Inadequate annual reports will trigger a full-scale management audit with a site-visit. On a periodic basis, NOAA will also conduct a full-scale Section 312 evaluation with a site visit and public meeting.

§ 921.35 Withdrawal of designation.

(a) Upon a finding by the Program Office through its programmatic evaluation (§ 921.34) that a national estuarine sanctuary is not meeting the mandate of Section 315 of the Act, the national Program goals or the policies established in the management plan, NOAA will provide the state with a written notice of the deficiency. Such a notice will explain the deficiencies in the state's approach, propose a solution or solutions to the deficiency and provide a schedule by which the state should remedy the deficiency. The state shall also be advised in writing that it may comment on the Program Office's finding of a deficiency and meet with Program officials to discuss the finding and seek to remedy the deficiency.

(b) If the issues cannot be resolved within a reasonable time, the Program Office will make recommendation regarding withdrawal of designation to the AA. A notice of intent to withdraw designation, with an opportunity for comment, will be placed in the Federal Register.

(c) The state shall be provided the opportunity for an informal hearing before the AA to consider the Program Office's recommendation and finding of deficiency, as well as the state's comments on and response to the recommendation and finding.

(d) Within 30 day after the informal hearing, the AA shall issue a written decision regarding the sanctuary. If a decision is made to withdraw sanctuary designation, the procedures specified in § 921.21(e) regarding the disposition of real property acquired with federal funds shall be followed.

Subpart E—Research Funds

§ 921.40 General.

(a) To stimulate high quality research within designated national estuarine sanctuaries, NOAA may find research on a competitive basis to sanctuaries having an approval final management plan. Research funds are intended to support significant research projects that will lead to enhanced scientific understanding of the sanctuary environment, improved coastal decisionmaking, improved sanctuary management, or enhanced public appreciation and understanding of the sanctuary ecosystem. Research opportunities will be identified in final

management plans for national estuarine sanctuaries. Research funds will be used to fill obvious voids in available data, as well as to support creative or innovative projects.

(b) Research funds are provided in addition to any funds available to the state under the operation and management or acquisition and development awards. Research funds must be matched by the state, consistent with § 921.51(e)(iii) ("allowable costs"). Individual states may apply for funding for more than one research project per sanctuary.

§ 921.41 Categories of potential research project; evaluation criteria.

(a) While research funds may be used to start-up long-term projects, they are not intended as a source of continuing funding for a particular project over time. Emphasis will be placed on projects that are also of benefit to other sanctuaries in the system. Proposals for research under the following categories will be considered:

(1) Establishing a Data Base and Monitoring Program (e.g., studies related to gathering and interpreting baseline information on the estuary. Funds are available to establish a data base and monitoring system; however, the long-term support for such a system must be carried out as part of overall sanctuary implementation);

(2) Estuarine Ecology (e.g., studies of the relationships between estuarine species and their environment, studies of biological populations community relationships, studies on factors and processes that govern the biological productivity of the estuary);

(3) Estuarine Processes (e.g., studies on dynamic physical processes that influence and give the estuary its particular physical characteristics, including studies related to climate, patterns of watershed drainage and freshwater inflow, patterns of water circulation within the estuary, and studies on oceanic or terrestrial factors that influence the condition of estuarine waters and bottoms);

(4) Applied Research (e.g., studies designed to answer specific management questions); and

(5) Socioeconomic Research (e.g., studies on patterns of land use, sanctuary visitation, archaeological research).

(b) Proposals for research in national estuarine sanctuaries will be evaluated in accordance with criteria listed below:

(1) Scientific merits;

(2) Relevance or importance to sanctuary management or coastal decisionmaking;

(3) Research quality (i.e., soundness of approach, environmental consequences, experience related to methodologies);

(4) Importance to the National Estuarine Sanctuary Program;

(5) Budget and Institutional Capabilities (i.e., reasonableness of budget, sufficiency of logistical support); and

(6) In addition, in the case of long-term monitoring projects, the ability of the state or the research grant recipient to support the grant beyond this initial funding.

Subpart F—General Financial Assistance Provisions

§ 921.50 Application information.

(a) The maximum total Federal funding per sanctuary is $3,000,000 for the preacquisition, acquisition and development, and operation and management awards. The research funding under § 921.40 is excluded from this total.

(b) Only a state Governor, or his/her designated state agency, may apply for national estuarine sanctuary financial assistance awards. If a state is participating in the national Coastal Zone Management Progam, the recipient of an award under Section 315 of the Act shall consult with the state coastal management agency regarding the application.

(c) No acquisition and development award may be made by NOAA without the approval of the Governor of the state, or his/her designated agency, in which the land to be acquired is located.

(d) All applications are to be submitted to: Management and Budget Group, Office of Ocean and Coastal Resource Management, National Ocean Service, National Oceanic and Atmospheric Administration, 3300 Whitehaven St., NW., Washington, D.C. 20235.

(e) An original and two copies of the complete application must be submitted at least 120 working days prior to the proposed beginning of the project. The Application for Federal Assistance Standard Form 424 (Non-construction Program) constitutes the formal application for preacquisition, operation and management, and research awards. The Application for Federal Assistance Standard Form 424 (Construction Program) constitutes the formal application for land acquisition and development awards. The application must be accompanied by the information required in Subpart B (preacquisition), Subpart C and Section 921.31 (acquisition and development), and § 921.32 (operation and management), as applicable. All applications must contain back up data for budget estimates (Federal and non-Federal shares), and evidence that the application complies with the Executive Order 12372, "Intergovernmental Review of Federal Programs." In addition, applications for acquisition and development awards must contain:

(1) State Historic Preservation Office comments;

(2) Appraisals and title information;

(3) Governor's letter approving the sanctuary proposal; and

(4) Written approval from NOAA of the draft or final management plan.

The Standard Form 424 has been approved by the Office of Management and Budget (Approval number 0648-0121) for use through September 30, 1988.

§ 921.51 Allowable costs.

(a) Allowable costs will be determined in accordance with OMB Circulars A-102, "Uniform Administrative Requirements for Grants-in-Aid to State and Local Governments", and A-87, "Principles for Determining Costs Applicable to Grants and Contracts with State, Local, and Federally Recognized Indian Tribal Governments"; the financial assistance agreement; these regulations; and other Department of Commerce and NOAA directives. The term "costs" applies to both the Federal and non-Federal shares.

(b) Costs claimed as charges to the award must be reasonable, beneficial and necessary for the proper and efficient administration of the financial assistance award and must be incurred during the awards period, except as provided under preagreement costs, subsection (d).

(c) Costs must not be allocable to or included as a cost of any other Federally-financed program in either the current or a prior award period.

(d) Costs incurred prior to the effective date of the award (preagreement costs) are allowable only when specifically approved in the financial assistance agreement. For non-construction awards, costs incurred more than three months before the award beginning date will not be approved. For construction and land acquisition awards, NOAA will evaluate preagreement costs on a case-by-case basis.

(e) General guidelines for the non-Federal share are contained in OMB Circular A-102, Attachment F. The following may be used by the state in satisfying the matching requirement:

(1) *Preacquisition Awards.* Cash and in-kind contributions (value of goods

and services directly benefiting and specifically identifiable to this part of the project) are allowable. Land may not be used as match.

(2) *Acquisition and Development Awards.* Cash and in-kind contributions are allowable. In general, the fair market value of lands to be included within the sanctuary boundaries and acquired pursuant to the Act, with other than Federal funds, may be used as match. The fair market value of privately donated land, at the time of donation, as establishment by an independent appraiser and certified by a responsible official of the State (pursuant to OMB Circular A-102 Revised, Attachment F) may also be used as match. Appraisals must be performed according to Federal appraisal standards as detailed in NOAA regulations and the "Uniform Appraisal Standards for Federal Land Acquisitions." Costs related to land acquisition, such as appraisals, legal fees and surveys, may also be used as match. Land, including submerged lands, already in the state's possession, in a fully-protected status consistent with the purposes of the National Estuarine Sanctuary Program, may be used as match only if it was acquired within a one-year period prior to the award of preacquisition or acquisition funds and with the intent to establish a national estuarine sanctuary. For state lands not in a fully-protected status (e.g., a state park containing an easement for subsurface mineral rights), the value of the development right or foregone value may be used as match if acquired by or donated to the state for inclusion within the sanctuary.

A state may initially use as match land valued at greater than the Federal share of the acquisition and development award. The value in excess of the amount required as match for the initial award may be used to match subsequent supplemental acquisition and development awards for the estuarine sanctuary.

(3) *Operations and Management Awards; Research Funds.* Cash and in-kind contributions (directly benefiting and specifically identifiable to this phase of the project), except land, are allowable.

§ 921.52 Amendments to financial assistance awards.

Actions requiring an amendment to the financial assistance award, such as a request for additional Federal funds, revisions of the approved project budget, or extension of the performance period must be submitted to NOAA on Standard Form 424 (OMB approved number 0748-0121 for use through September 30, 1986) and approved in writing.

Appendix 1—Biographic Classification Scheme

Acadian

1. Northern Gulf of Maine (Eastport to the Sheepscot River).
2. Southern Gulf of Maine (Sheepscot River to Cape Cod).

Virginian

3. Southern New England (Cape Cod to Sandy Hook).
4. Middle Atlantic (Sandy Hook to Cape Hatteras).
5. Chesapeake Bay.

Carolinian

6. Northern Carolinas (Cape Hatteras to Santee River).
7. South Atlantic (Santee River to St. John's River).
8. East Florida (St. John's River to Cape Canaveral).

West Indian

9. Caribbean (Cape Canaveral to Ft. Jefferson and south).
10. West Florida (Ft. Jefferson to Cedar Key).

Louisianian

11. Panhandle Coast (Cedar Key to Mobile Bay).
12. Mississippi Delta (Mobile Bay to Galveston).
13. Western Gulf (Galveston to Mexican border).

Californian

14. Southern California (Mexican border to Point Concepcion).
15. Central California (Point Concepcion to Cape Mendocino).
16. San Francisco Bay.

Columbian

17. Middle Pacific (Cape Mendocino to the Columbia River).
18. Washington Coast (Columbia River to Vancouver Island).
19. Puget Sound.

Great Lakes

20. Western Lakes (Superior, Michigan, Huron).
21. Eastern Lakes (Ontario, Erie).

Fjord

22. Southern Alaska (Prince of Wales Island to Cook Inlet).
23. Aleutian Islands (Cook Inlet to Bristol Bay).

Sub-Arctic

24. Northern Alaska (Bristol Bay to Damarcation Point).

Insular

25. Hawaiian Islands.
26. Western Pacific Island.
27. Eastern Pacific Island.

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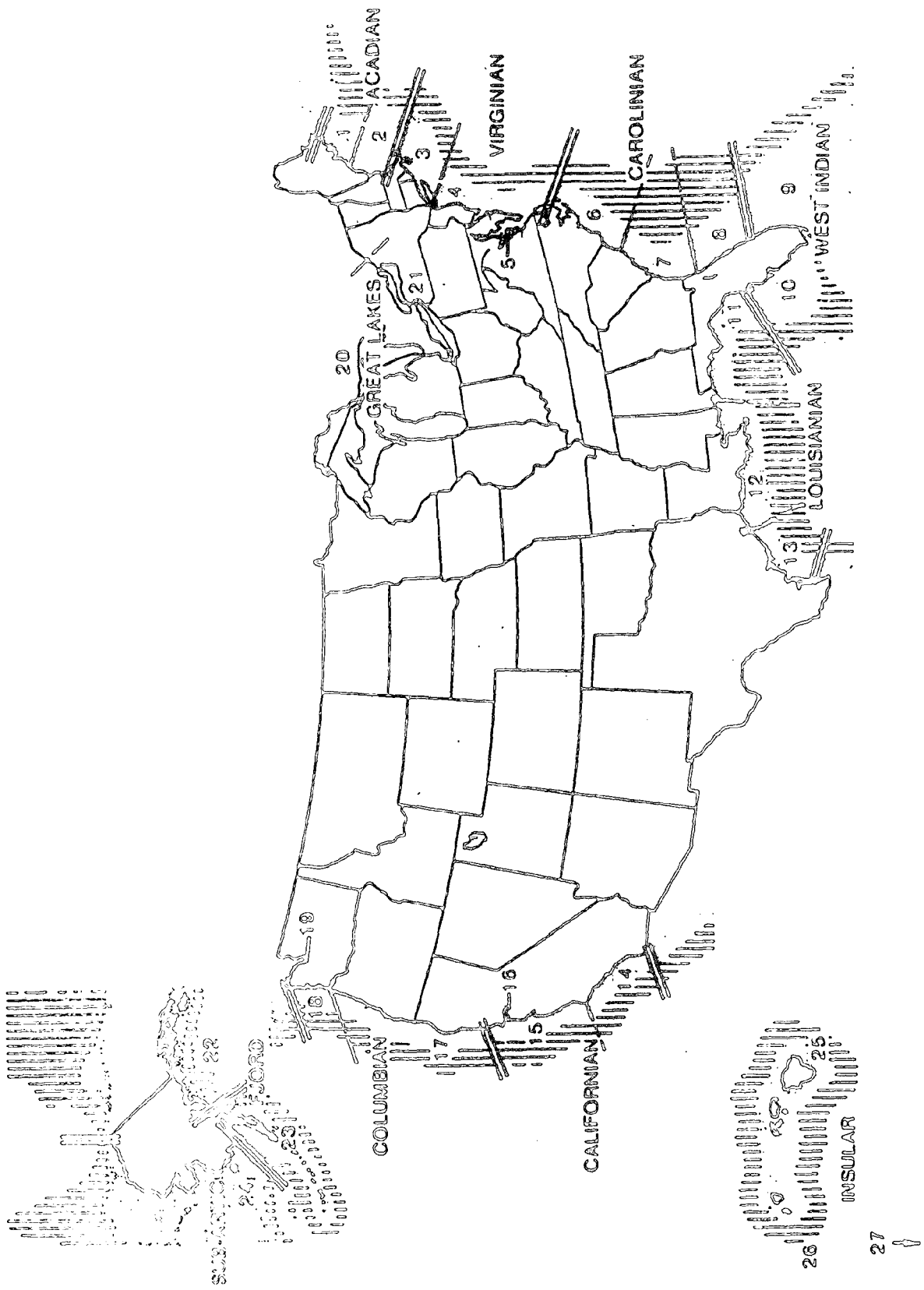

Figure 1. Biogeographic Regions of the United States.

Appendix 2—Typology of National Estuarine Areas

This typology system reflects significant differences in estuarine characteristics that are not necessarily related to regional location. The purpose of this type of classification is to maximize ecosystem variety in the selection of national estuarine sanctuaries. Priority will be given to important ecosystem type as yet unrepresented in the sanctuary system. It should be noted that any one site may represent several ecosystem types or physical characteristics.

Class I—Ecosystem Types

Group I—Shorelands

A. *Maritime Forest-Woodland:* This type of ecosystem consists of single-stemmed species that have developed under the influence of salt spray. It can be found on coastal uplands or recent features, such as barrier islands and beaches, and may be divided into the following biomes:

1. *Northern Coniferous Forest Biome:* This is an area of predominantly evergeens such as the sitka spruce (*Picea*), grand fir (*Abies*), and white cedar (*Thuja*), with poor development of the shrub and herb layers, but high annual productivity and pronounced seasonal periodicity.

2. *Moist Temperate (Mesothermal) Coniferous Forest Biome:* Found along the west coast of North America from California to Alaska, this area is dominated by conifers, has a relatively small seasonal range, high humidity with rainfall ranging from 30 to 150 inches, and a well-developed understory of vegetation with an abundance of mosses and other moisture-tolerant plants.

3. *Temperate Deciduous Forest Biome:* This biome is characterized by abundant, evenly distributed rainfall, moderate temperatures which exhibit a distinct seasonal pattern, well-developed soil biota and herb and shrub layers, and numerous plants which produce pulpy fruits and nuts. A distant subdivision of this biome is the *pine edaphic forest* of the southeastern coastal plain, in which only a small portion of the area is occupied by climax vegetation, although it has large areas covered by edaphic climax pines.

4. *Broad-leaved Evergreen Subtropical Forest Biomes:* The main characteristic of this biome is high moisture with less pronounced differences between winter and summer. Examples are the hammocks of Florida and the live oak forests of the Gulf and South Atlantic coasts. Floral dominants include pines, magnolias, bays, hollies, wild tamarind, strangler fig, gumbo limbo, and palms.

B. *Coast Shrublands:* This is a transitional area between the coastal grasslands and woodlands and is characterized by woody species with multiple stems a few centimeters to several meters above the ground developing under the influence of salt spray and occasional sand burial. This includes thickets, scrub, scrub savanna, heathlands, and coastal chaparral. There is a great variety of shrubland vegetation exhibiting regional specificity:

1. *Northern Areas:* Characterized by *Hudsonia*, various erinaceous species, and thickets of *Myrica*, *Prunus*, and *Rosa*.

2. *Southeast Areas:* Floral dominants include *Myrica*, *Baccharis*, and *Ilex*.

3. *Western Areas: Adenostoma*, *Arcotyphylos*, and *Eucalyptus* are the dominant floral species.

C. *Coastal Grasslands:* This area, which possesses sand dunes and coastal flats, has low rainfall (10 to 30 inches per year) and large amounts of humus in the soil. Ecological succession is slow, resulting in the presence of a number of seral stages of community development. Dominant vegetation includes mid-grasses (2 to 4 feet tall), such as *Ammophila*, *Agropyron*, and *Calamovilfa*, tall grasses (5 to 8 feet tall), such as *Spartina*, and trees such as the willow (*Salix* sp.), cherry (*Prunus* sp.), and cottonwood (*Populus deltoides*). This area is divided into four regions with the following typical strand vegetation:

1. Arctic/Boreal: *Elymus;*
2. Northeast/West: *Ammophila;*
3. Southeast/Gulf: *Uniola;* and
4. Mid-Atlantic/Gulf: *Spartina patens.*

D. *Coastal Tundra:* This ecosystem, which is found along the Arctic and Boreal coasts of North America, is characterized by low temperatures, a short growing season, and some permafrost, producing a low, treeless mat community made up of mosses, lichens, heath, shrubs, grasses, sedges, rushes, and herbaceous and dwarf woody plants. Common species include arctic/alpine plants such as *Empetrum nigrum* and *Betula nana*, the lichens *Cetraria* and *Cladonia*, and herbaceous plants such as *Potentilla tridentata* and *Rubus chamaemorus*. Common species on the coastal beach ridges of the high arctic desert include *Dryas intergrifolia* and *Saxifrage oppositifolia*.

This area can be divided into two main subdivisions:

1. *Low Tundra:* characterized by a thick, spongy mat of living and undecayed vegetation, often with water and dotted with ponds when not frozen; and

2. *High Tundra:* a bare area except for a scanty growth of lichens and grasses, with underlying ice wedges forming raised polygonal areas.

E. *Coastal Cliffs:* This ecosystem is an important nesting site for many sea and shore birds. It consists of communities of herbaceaous, graminoid, or low woody plants (shrubs, heath, etc.) on the top or along rocky faces exposed to salt spray. There is a diversity of plant species including mosses, lichens, liverworts, and "higher" plant representatives.

Group II—Transition Areas

A. *Coastal Marshes:* These are wetland areas dominated by grasses (Poacea), sedges (Cyperaceae), rushes (Juncaceae), cattails (Typhaceae), and other graminoid species and is subject to periodic flooding by either salt or freshwater. This ecosystem may be subdivided into: (a) tidal, which is periodically flooded by either salt or brackish water; (b) non-tidal (freshwater); or (c) tidal freshwater. These are essential habitats for many important estuarine species of fish and invertebrates as well as shorebirds and waterfowl and serves important roles in shore stabilization, flood control, water purification, and nutrient transport and storage.

B. *Coastal Swamps:* These are wet lowland areas that support mosses and shrubs together with large trees such as cypress or gum.

C. *Coastal Mangroves:* This ecosystem experiences regular flooding on either a daily, monthly, or seasonal basis, has low wave action, and is dominated by variety of salt-tolerant trees, such as the red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia nitida*), and the white mangrove (*Laguncularia racemosa*). It is also an important habitat for large populations of fish, invertebrates, and birds. This type of ecosystem can be found from central Florida to extreme south Texas to the islands of the Western Pacific.

D. *Intertidal Beaches:* This ecosystem has a distinct biota of microscopic animals, bacteria, and unicelluar algae along with macroscopic crustaceans, mollusks, and worms with a detritus-based nutrient cycle. This area also includes the driftline communities found at high tide levels on the beach. The dominant organisms in this ecosystem include crustaceans such as the mole crab (*Emerita*), amphipods (Gammaridae), ghost crabs (*Ocypode*), and bivalve molluscs such as the coquina (*Donax*) and surf clams (*Spisula* and *Mactra*).

E. *Intertidal Mud and Sand Flats:* These areas are composed of unconsolidated, high organic content sediments that function as a short-term storage area for nutrients and organic carbons. Macrophytes are nearly absent in this ecosystem, although it may be heavily colonized by benthic diatoms, dino-flagellates, filamentous blue-green and green algae, and chaemosynthetic purple sulfur bacteria. This system may support a considerable population of gastropods, bivalves, and polychaetes, and may serve as a feeding area for a variety of fish and wading birds. In sand, the dominant fauna include the wedge shell *Donax*, the scallop *Pecten*, tellin shells *Tellina*, the heart urchin *Echinocardium*, the lug worm *Arenicola*, sand dollar *Dendraster*, and the sea pansy *Renilla*. In mud, faunal dominants adapted to low oxygen levels include the terebellid *Amphitrite*, the boring clam *Playdon*, the deep sea scallop *Placopecten*, the quahog *Mercenaria*, the echiurid worm *Urechis*, the mud snail *Nassarius*, and the sea cucumber *Thyone*.

F. *Intertidal Algal Beds:* These are hard substrates along the marine edge that are dominated by macroscopic algae, usually thalloid, but also filamentous or unicellular in growth form. This also includes the rocky coast tidepools that fall within the intertidal zone. Dominant fauna of these areas are barnacles, mussels, periwinkles, anemones, and chitons. Three regions are apparent:

1. *Northern Latitude Rocky Shores:* It is in this region that the community structure is best developed. The dominant algal species include *Chondrus* at the low tide level, *Fucus* and *Ascophyllum* at the mid-tidal level, and *Laminaria* and other kelp-like algae just beyond the intertidal, although they can be exposed at extremely low tides or found in very deep tidepools.

2. *Southern Latitudes:* The communities in this region are reduced in comparison to

those of the northern latitudes and possesses algae consisting mostly of single-celled or filamentous green, blue-green, and red algae, and small thalloid brown algae.

3. *Tropical and Subtropical Latitudes:* The intertidal in this region is very reduced and contains numerous calcareous algae such as *Porolithon* and *Lithothamnion*, as well as green algae with calcareous particles such as *Halimeda*, and numerous other green, red, and brown algae.

Group III—Submerged Bottoms

A. *Subtidal Hardbottoms:* This system is characterized by a consolidated layer of solid rock or large pieces of rock (neither of biotic origin) and is found in association with geomorphological features such as submarine canyons and fjords and is usually covered with assemblages of sponges, sea fans, bivalves, hard corals, tunicates, and other attached organisms. A significant feature of estuaries in many parts of the world is the oyster reef, a type of subtidal hardbottom. Composed of assemblages of organisms (usually bivalves), it is usually found near an estuary's mouth in a zone of moderate wave action, salt content, and turbidity. If light levels are sufficient, a covering of microscopic and attached macroscopic algae, such as kelp, may also be found.

B. *Subtidal Softbottoms:* Major characteristics of this ecosystem are an unconsolidated layer of fine particles of silt, sand, clay, and gravel, high hydrogen sulfide levels, and anaerobic conditions often existing below the surface. Macrophytes are either sparse or absent, although a layer of benthic microalgae may be present if light levels are sufficient. The faunal community is dominated by a diverse population of deposit feeders including polychaetes, bivalves, and burrowing crustaceans.

C. *Subtidal Plants:* This system is found in relatively shallow water (less than 8 to 10 meters) below mean low tide. It is an area of extremely high primary production that provides food and refuge for a diversity of faunal groups, especially juvenile and adult fish, and in some regions, manatees and sea turtles. Along the North Atlantic and Pacific coasts, the seagrass *Zostera marina* predominates. In the South Atlantic and Gulf coast areas, *Thalassia* and *Diplanthera* predominate. The grasses in both areas support a number of epiphytic organisms.

Class II—Physical Characteristics

Group I—Geologic

A. *Basin Type:* Coastal water basins occur in a variety of shapes, sizes, depths, and appearances. The eight basic types discussed below will cover most of the cases:

1. *Exposed Coast:* Solid rock formations or heavy sand deposits characterize exposed ocean shore fronts, which are subject to the full force of ocean storms. The sand beaches are very resilient, although the dunes lying just behind the beaches are fragile and easily damaged. The dunes serve as a sand storage area, making them chief stabilizers of the ocean shorefront.

2. *Sheltered Coast:* Sand or coral barriers, built up by natural forces, provide sheltered areas inside a bar or reef where the ecosystem takes on many characteristics of confined waters—abundant marine grasses, shellfish, and juvenile fish. Water movement is reduced, with the consequent effects of pollution being more severe in this area than in exposed coastal areas.

3. *Bay:* Bays are larger confined bodies of water that are open to the sea and receive strong tidal flow. When stratification is pronounced, the flushing action is augmented by river discharge. Bays vary in size and in type of shorefront.

4. *Embayment:* A confined coastal water body with narrow, restricted inlets and with a significant freshwater inflow can be classified as an embayment. These areas have more restricted inlets than bays, are usually smaller and shallower, have low tidal action, and are subject to sedimentation.

5. *Tidal River:* The lower reach of a coastal river is referred to as a tidal river. The coastal water segment extends from the sea or estuary into which the river discharges to a point as far upstream as there is significant salt content in the water, forming a salt front. A combination of tidal action and freshwater outflow makes tidal rivers well-flushed. The tidal river basin may be a simple channel or a complex of tributaries, small associated embayments, marshfronts, tidal flats, and a variety of others.

6. *Lagoon:* Lagoons are confined coastal bodies of water with restricted inlets to the sea and without significant freshwater inflow. Water circulation is limited, resulting in a poorly flushed, relatively stagnant body of water. Sedimentation is rapid with a great potential for basin shoaling. Shores are often gently sloping and marshy.

7. *Perched Coastal Wetlands:* Unique to Pacific islands, this wetland type, found above sea level in volcanic crater remnants, forms as a result of poor drainage characteristics of the crater rather than from sedimentation. Floral assemblages exhibit distinct zonation while the faunal constituents may include freshwater, brackish, and/or marine species. Example: Aunu'u Island, American Samoa.

8. *Anchialine Systems:* These small coastal exposures of brackish water form in lava depressions or elevated fossil reefs, have only a subsurface connection to the ocean, but show tidal fluctuations. Differing from true estuaries in having no surface continuity with streams or ocean, this system is characterized by a distinct biotic community dominated by benthic algae such as *Rhizoclonium*, the mineral encrusting *Schizothrix*, and the vascular plant *Ruppia maritima*. Characteristic fauna, which exhibit a high degree of endemicity, include the mollusks *Theodoxus neglectus* and *T. cariosus*, the small red shrimp *Metabetaeus lohena* and *Halocaridina rubra*, and the fish *Eleotris sandwicensis* and *Kuhlia sandvicensus*. Although found throughout the world, the high islands of the Pacific are the only areas within the U.S. where this system can be found.

B. *Basin Structure:* Estuary basins may result from the drowning of a river valley (coastal plains estuary), the drowning of a glacial valley (fjord), the occurrence of an offshore barrier (bar-bounded estuary), some tectonic process (tectonic estuary), or volcanic activity (volcanic estuary).

1. *Coastal plains estuary:* Where a drowned valley consists mainly of a single channel, the form of the basin is fairly regular, forming a simple coastal plains estuary. When a channel is flooded with numerous tributaries, an irregular estuary results. Many estuaries of the eastern United States are of this type.

2. *Fjord:* Estuaries that form in elongated, steep headlands that alternate with deep U-shaped valleys resulting from glacial scouring are called fjords. They generally possess rocky floors or very thin veneers of sediment, with deposition generally being restricted to the head where the main river enters. Compared to total fjord volume, river discharge is small. But many fjords have restricted tidal ranges at their mouths, due to sills, or upreaching sections of the bottom which limit free movement of water, often making river flow large with respect to the tidal prism. The deepest portions are in the upstream reaches, where maximum depths can range from 800 m to 1200 m, while sill depths usually range from 40 m to 150 m.

3. *Bar-bounded Estuary:* These result from the development of an offshore barrier, such as a beach strand, a line of barrier islands, reef formations, a line of moraine debris, or the subsiding remnants of a deltaic lobe. The basin is often partially exposed at low tide and is enclosed by a chain of offshore bars or barrier islands, broken at intervals by inlets. These bars may be either deposited offshore or may be coastal dunes that have become isolated by recent sea level rises.

4. *Tectonic Estuary:* These are coastal indentures that have formed through tectonic processes such as slippage along a fault line (San Francisco Bay), folding, or movement of the earth's bedrock, often with a large inflow of freshwater.

5. *Volcanic Estuary:* These coastal bodies of open water, a result of volcanic processes, are depressions or craters that have direct and/or subsurface connections with the ocean and may or may not have surface continuity with streams. These formations are unique to island areas of volcanic origin.

C. *Inlet Type:* Inlets in various forms are an integral part of the estuarine environment, as they regulate, to a certain extent, the velocity and magnitude of tidal exchange, the degree of mixing, and volume of discharge to the sea. There are four major types of inlets:

1. *Unrestricted:* An estuary with a wide, unrestricted inlet typically has slow currents, no significant turbulence, and receive the full effect of ocean waves and local disturbances which serve to modify the shoreline. These estuaries are partially mixed, as the open mouth permits the incursion of marine waters to considerable distances upstream, depending on the tidal amplitude and stream gradient.

2. *Restricted:* Restrictions of estuaries can exist in many forms: bars, barrier islands, spits, sills, and more. Restricted inlets result in decreased circulation, more pronounced longitudinal and vertical salinity gradients, and more rapid sedimentation. However, if the estuary mouth is restricted by depositional features or land closures, the incoming tide may be held back until it suddenly breaks forth into the basin as a

tidal wave, or *bore*. Such currents exert profound effects on the nature of the substrate, turbidity, and biota of the estuary.

3. *Permanent:* Permanent inlets are usually opposite the mouths of major rivers and permit river water to flow into the sea. Sedimentation and deposition are minimal.

4. *Temporary (Intermittent):* Temporary inlets are formed by storms and frequently shift position, depending on tidal flow, the depth of the sea and sound waters, the frequency of storms, and the amount of littoral transport.

D. *Bottom Composition:* The bottom composition of estuaries attests to the vigorous, rapid, and complex sedimentation processes characteristic of most coastal regions with low relief. Sediments are derived through the hydrologic processes of erosion, transport, and deposition carried on by the sea and the stream.

1. *Sand:* Near estuary mouths, where the predominating forces of the sea build spits or other depositional features, the shores and substrates of the estuary are sandy. The bottom sediments in this area are usually coarse, with a graduation toward finer particles in the head of the estuary. In the head region and other zones of reduced flow, fine silty sands are deposited. Sand deposition occurs only in wider or deeper regions where velocity is reduced.

2. *Mud:* At the base level of a stream near its mouth, the bottom is typically composed of loose muds, silt, and organic detritus as a result of erosion and transport from the upper stream reaches and organic decomposition. Just inside the estuary entrance, the bottom contains considerable quantities of sand and mud, which support a rich fauna. Mud flats, commonly built up in estuarine basins, are composed of loose, coarse, and fine mud and sand, often dividing the original channel.

3. *Rock:* Rocks usually occur in areas where the stream runs rapidly over a steep gradient with its coarse materials being derived from the higher elevations where the stream slope is greater. The larger fragments are usually found in shallow areas near the stream mouth.

4. *Oyster shell:* Throughout a major portion of the world, the oyster reef is one of the most significant features of estuaries, usually being found near the mouth of the estuary in a zone of moderate wave action, salt content, and turbidity. It is often a major factor in modifying estuarine current systems and sedimentation, and may occur as an elongated island or peninsula oriented across the main current, or may develop parallel to the direction of the current.

Group II—Hydrographic

A. *Circulation:* Circulation patterns are the result of the combined influences of freshwater flow, tidal action, wind and oceanic forces, and serve many functions: nutrient transport, plankton dispersal, ecosystem flushing, salinity control, water mixing, and more.

1. *Stratified:* This is typical of estuaries with a strong freshwater influx and is commonly found in bays formed from "drowned" river valleys, fjords, and other deep basins. There is a net movement of freshwater outward at the top layer and saltwater at the bottom layer, resulting in a net outward transport of surface organisms and net inward transport of bottom organisms.

2. *Non-stratified:* Estuaries of this type are found where water movement is sluggish and flushing rate is low, although there may be sufficient circulation to provide the basis for a high carrying capacity. This is common to shallow embayments and bays lacking a good supply of freshwater from land drainage.

3. *Lagoonal:* An estuary of this type is characterized by low rates of water movement resulting from a lack of significant freshwater influx and a lack of strong tidal exchange because of the typically narrow inlet connecting the lagoon to the sea. Circulation, whose major driving force is wind, is the major limiting factor in biological productivity within lagoons.

B. *Tides:* This is the most important ecological factor in an estuary, as it affects water exchange and its vertical range determines the extent of tidal flats which may be exposed and submerged with each tidal cycle. Tidal action against the volume of river water discharged into an estuary results in a complex system whose properties vary according to estuary structure as well as the magnitude of river flow and tidal range. Tides are usually described in terms of their cycle and their relative heights. In the United States, tide height is reckoned on the basis of average low tide, which is referred to as *datum*. The tides, although complex, falls into three main categories:

1. *Diurnal:* This refers to a daily change in water level that can be observed along the shoreline. There is one high tide and one low tide per day.

2. *Semidiurnal:* This refers to a twice daily rise and fall in water that can be observed along the shoreline.

3. *Wind/Storm Tides:* This refers to fluctuations in water elevation to wind and storm events, where influence of lunar tides is less.

C. *Freshwater:* According to nearly all the definitions advanced, it is inherent that all estuaries need freshwater, which is drained from the land and measurably dilutes seawater to create a brackish condition. Freshwater enters an estuary as runoff from the land either from a surface and/or subsurface source.

1. *Surface water:* This is water flowing over the ground in the form of streams. Local variation in runoff is dependent upon the nature of the soil (porosity and solubility), degree of surface slope, vegetational type and development, local climatic conditions, and volume and intensity of precipitation.

2. *Subsurface water:* This refers to the precipitation that has been absorbed by the soil and stored below the surface. The distribution of subsurface water depends on local climate, topography, and the porosity and permeability of the underlying soils and rocks. There are two main subtypes of surface water:

a. *Vadose water:* This is water in the soil above the water table. Its volume with respect to the soil, is subject to considerable fluctuation.

b. *Groundwater:* This is water contained in the rocks below the water table, is usually of more uniform volume than vadose water, and generally follows the topographic relief of the land, being high below hills and sloping into valleys.

Group III—Chemical

A. *Salinity:* This reflects a complex mixture of salts, the most abundant being sodium chloride, and is a very critical factor in the distribution and maintenance of many estuarine organisms. Based on salinity, there are two basic estuarine types and eight different salinity zones (expressed in parts per thousand—ppt).

1. *Positive estuary:* This is an estuary in which the freshwater influx is sufficient to maintain mixing, resulting in a pattern of increasing salinity toward the estuary mouth. It is characterized by low oxygen concentration in the deeper waters and considerable organic content in bottom sediments.

2. *Negative estuary:* This is found in particularly arid regions, where estuary evaporation may exceed freshwater inflow, resulting in increased salinity in the upper part of the basin, especially if the estuary mouth is restricted so that tidal flow is inhibited. These are typically very salty (hypersaline), moderately oxygenated at depth, and possess bottom sediments that are poor in organic content.

3. *Salinity zones (expressed in ppt):*

a. *Hypersaline*—greater than 40 ppt.

b. *Euhaline*—40 ppt to 30 ppt.

c. *Mixohaline:* 30 ppt to 0.5 ppt.

(1) Mixoeuhaline—greater than 30 ppt but less than the adjacent euhaline sea.

(2) Polyhaline—30 ppt to 18 ppt.

(3) Mesohaline—18 ppt to 5 ppt.

(4) Oligohaline—5 ppt to 0.5 ppt.

d. *Limnetic:* Less than 0.5 ppt.

B. *pH Regime:* This is indicative of the mineral richness of estuarine waters and fall into three main categories:

1. *Acid:* Waters with a pH of less than 5.5.

2. *Circumneutral:* A condition where the pH ranges from 5.5 to 7.4.

3. *Alkaline:* Waters with a pH greater than 7.4.

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