Northeast Beaches: a balancing act

Woods Hole Oceanographic Institution
Woods Hole
Massachusetts 02543
23 to 26 October 2002

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Table of Contents by First Author

Table of Contents by Date and Session

Thursday 24 October Morning

Thursday 24 October Afternoon

Friday 25 October Morning

Friday 25 October Afternoon

Saturday 26 October Morning

Great Gull Bank: Balancing Multiple Use of a Shoal with the Renourishment of Assateague Island, Maryland

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Severe erosion and shoreline migration have been occurring on the northern part of Assateague Island since the mid-1930s, when 2 jetties were constructed at the Ocean City Inlet, which separates Assateague and Fenwick Islands. The jetties blocked the southward longshore sand flow and began starving the barrier island. Between 1933 and the present, parts of the Assateague Island shoreline have shifted westward more than 1,300 ft., resulting in major physical and biological changes that would not have occurred under natural coastal conditions. Most of Assateague Island became a National Seashore in 1965 under the jurisdiction of the National Park Service (NPS).

With increased erosion came the specter of breaching. Material dredged from the Inlet and adjacent channels was placed on Assateague Island at various times by the U.S Army Corps of Engineers (USACE) from the1950s through the 1980s. The infamous Ash Wednesday storm of 1962 breached the island and required an emergency repair of over 1 million cubic yards (cy) of sand. In 1998, the USACE and NPS had to place 134,000 cy of sand on an emergency basis to prevent another breach. To find a long-term solution to this problem, the USACE began a regional feasibility study in 1991 of the erosion at Assateague and other coastal management issues in the Ocean City-Assateague Island area. The study resulted in a two-phase comprehensive sediment management plan to restore the Island to as close to its natural condition as possible.

The first or short-term phase of the plan will provide a one-time infusion of sand to replace part of that which was lost over the nearly 70 years since the opening of the Ocean City Inlet. During the first phase, 1,800,000 cy of sand will be placed along the northern-most 7 mi. of Assateague Island, starting in September 2002. Concurrently, the Maryland Department of Natural Resources will also place 100,000 cy of sand on the dune line at Assateague State Park, which adjoins the Phase I project area. The borrow area selected for the project is Great Gull Bank, a sand shoal lying 4-5 mi. east of the center of the Island and 6 mi. southeast of Ocean City. Sand for the emergency restoration project in 1998 also came from Great Gull. The second or long-term phase will bypass 185,000 cy annually to replicate the natural longshore sediment flow to Assateague. The sand for this phase will come from the Ocean City Inlet's ebb and flood shoals, nearby navigation channels and the updrift fillet of Ocean City Beach.

Great Gull Bank measures 3.5 mi. long, 1 mile at its widest point, and has an area of 2.2 mi^2. The shoal is detached from the shore and oriented 40° from north. It is an asymmetric feature, with its eastern flank about twice as steep as its western flank. Water depths over the Bank range from 17 to 50 ft. A "fish haven" or artificial reef was established on the northwestern third of the shoal in which various types of debris have been placed over a 1.5-mi.^2 area to create a fish-spawning habitat. This part of the Bank is a popular spot for private and commercial party boats from the Ocean City area.

Concerned that near-shore sand was becoming depleted, the State of Maryland began investigating Great Gull Bank and other shoals in Federal waters (beyond 3 n.mi.) in 1993 as part of a cooperative program with the Minerals Management Service (MMS). Geophysical surveys were completed in 1994 and 7 vibracores were obtained on Great Gull Bank by the USACE in 1995. Based on this information, sand volumes for the shoal were calculated by the State as: 15 million cy of "high potential" sand (mean grain size or mgs <1.84 phi) and 19.2 million cy of "moderate potential" sand (1.84-2.0 phi) for a total of 34.2 million cy of potentially usable sand. The USACE drilled an additional 17 cores on Great Gull in 1997 and determined that enough sand is available for the Phase I project that will match the mgs of 1.62 phi for the natural beach of northern Assateague Island. The USACE now estimates that 22 million cy of beach-fill quality sand remains in the shoal.

In 2001, the MMS issued leases for the use of sand in Great Gull Bank to the NPS and the State of Maryland for the Phase I work. Special stipulations were written in the leases to ensure that the shape of the shoal is preserved and the artificial reef area was avoided. These include limiting dredging to the southeastern flank and avoiding the crest of the shoal. Dredging will also be limited to -45 ft. mean lower low water and to 6 ft. below present contours. The first phase of the project will be monitored for 5 years.

There are no plans to use sand from Great Gull Bank in the future other than for emergency beach repair for Assateague after severe storms. However, due to its proximity to Ocean City beaches, it could serve as a sand source for future renourishment projects there.

Short-term Fluctuations in Beach Volume along the South Shore of Long Island: Implications for the Sediment Budget

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Volumetric change was calculated from Atlantic Coast of New York Monitoring Project (ACNYMP) beach profiles along the south shore of Long Island over a three-year period to infer patterns and trends in the sediment budget. For 351 monitoring stations between Rockaway Inlet and Montauk Point (Figure 1), beach volume was calculated from the monument to the shoreline datum (NGVD 1929) and from the shoreline to the 24-foot depth contour. Change in both sub-aerial and sub-aqueous compartments of the profile were calculated between survey seasons (Spring and Fall of each year) and for the longest term possible with the available data (Fall 1995-Fall 1998) to infer rates of cross-shore transport. Volume change calculated from the monument to the –24 ft depth contour was denoted as "residual volume change." Given that the depth of closure for the study area is shallower than 24 feet (excluding portions of Montauk), the residual volume change should represent the amount of volume change unaccounted for by cross-shore transport. Residual volume change was then extrapolated along the coast; total residual volume change was calculated to determine the net volume change for the region. Cumulative residual volume change was calculated in the direction of longshore transport determine where losses/gains were occurring. Total residual volume change ranged from -55 to 43 m^3/m. The sum of seasonal changes during the study interval was near zero (3.6 m^3/m). These values are reasonable considering average volumetric change of the beach profile in this region. Spatial patterns showed the influence of inlets, one large sink was located at the site of a transient rip-cell. Alongshore periodicities are present in the data with wavelengths over 10 kilometers. These periodicities appear to migrate in the direction of longshore transport over time.

Evolution of the Cocagne Bar, on the Southeast Coast of New Brunswick, Between 1839 and 2001

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Sea-level rise, storm surges and sediment crises lead to rapid shoreline recession along the low-lying sandy coasts of the Gulf of St. Lawrence. In southeastern New Brunswick, sandy barriers have showed an average recession rate of 0.87 m/yr during the second half of the 20th century. However, most barriers have maintained during that period their geomorphological integrity. The Cocagne Bar has been an exception (Fig. 1A). In fact, this small sand spit (1.3 km long and 50 m wide) has been completely destroyed over the last decade. Because of its small size and dynamic nature, the Cocagne Bar has never had a high potential for tourist development, but has always been an ideal site for studying mechanisms of spit evolution.

The Cocagne Bar was first studied by G. Hunter (1975), a private consultant who was hired by the provincial government to document the environmental impacts of beach mining in eastern New Brunswick. When examining the morphology and extend of the spit platform, Hunter has speculated that the Cocagne Bar was a relict of a much longer (3 km) baymouth bar. His works have also showed that the proximal section of the bar was rapidly migrating landward (1945-1971: 2.23 m/yr), and its middle section occasionally used as a quarry site (1968-1969: 1,280 m^3/yr). As a result of his works, the New Brunswick Quarriable Substances Act was modified to stop beach mining around the province's coastline.

In order to acquire new data on the short (5-15 years) and long-term (50-150 years) evolution of the Cocagne Bar, DNRE's Geological Surveys Branch has initiated in 2002 a mapping project using digital photogrammetry (CARIS-GIS). Eight aerial photos (1945, 1954, 1963, 1973, 1976, 1983, 1995, and 2001) and one bathymetric map (1839) were selected to determine the historical positions of the bar's shoreline (mean high water line). All photos and maps were scanned at a resolution of 1-m ground pixel, and a total of 22 control points were used to geo-reference and rectify the digital images. The maximum error associated with the relative positioning of the bar's shoreline is 5 m on the aerial photos and 50 m on the bathymetric map.

Our preliminary results indicate that, between 1839 and 2001, the Cocagne Bar has showed an average recession rate of 5.67 m/yr. In fact, on the 1839 map (Fig. 1B), the bar is presented as a small tombolo (1.2 km long), which would have been located at the outer edge of today's spit platform. On the 1945 photo, the bar appears as a small spit (1.3 km long) and is characterized by a relatively wide proximal section, which seems to be a relict of a larger bar (1.8 km long?). It is possible that the distal section of that bar was destroyed during the 1938 catastrophic storm surge. Between 1945 and 1973, the Cocagne Bar has maintained its geomorphological integrity, despite its rapid landward migration (3.22 m/yr). On the 1976 photo, the bar shows its first major breach of the second half of the 20th century. The beach mining activities could have been the cause of that breach, which has permanently separated the distal end from the rest of the bar. On the 1995 photo (Fig. 1B), a second major breach is visible, but this time in the proximal section of the bar. This breach seems to have been critical in the bar's destruction process.

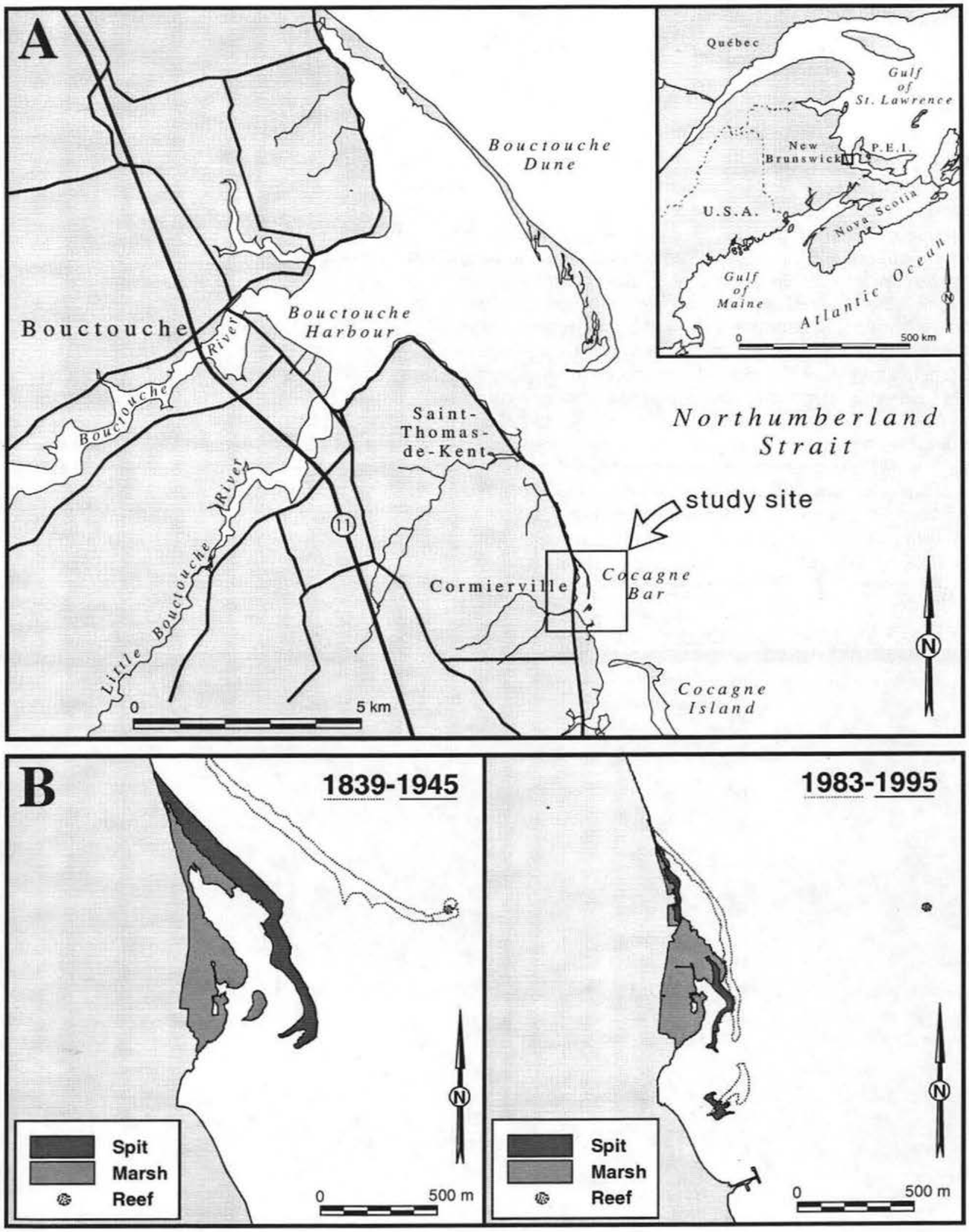

Figure. 1 (A) Location of the Cocagne Bar on the southeast coast of New Brunswick. (B) Major changes in the position and configuration of the Cocagne Bar.

Sediment Bypassing and Progradation Downdrift of a Wave-attenuating Rock Jetty

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Erosion downdrift of coastal engineering structures has been widespread and well established. However, an anomalous response to one such structure has been documented at the Cape Lookout National Seashore in North Carolina. In the early 1900s a rock jetty was built to serve as an attached breakwater to attenuate wave energy and provide a harbor of refuge to ships during hurricanes and extratropical storms. Subsequently, Power Squadron Spit began to develop in the lee of the jetty and continues to prograde rapidly. Contemporaneously, adjacent littoral cells have undergone recurrent shoreline retreat. The rock jetty was built prior to Cape Lookout being classified as a national seashore and is an excellent natural laboratory to examine a human-made coastal engineering structure along an otherwise undeveloped coast. A 10-month field study of Power Squadron Spit was conducted and included: a bathymetric survey of the study area, shoreline change monitoring, sediment sampling, trenching. Beach profiles were taken monthly and during one spring to neap cycle, daily. Photogrammetric analyses were done on a suite of aerial photographs from 1940 to 1998 to ascertain historic shoreline position, coastal and nearshore morphology and surficial area change. Historic aerial photographs and field observations document extensive sediment bypassing, during quiescent as wells as energetic periods, and large scale progradation in spite of the jetty's wave attenuating properties. Both the downdrift and updrift sides of the jetty were found to have a dynamic and extensive system of nearshore and welding bars. From 1940 to 2001 approximately 14×10^6 m^3 of sediment were incorporated into Power Squadron Spit, at an average of 230,000 m^3 per year.

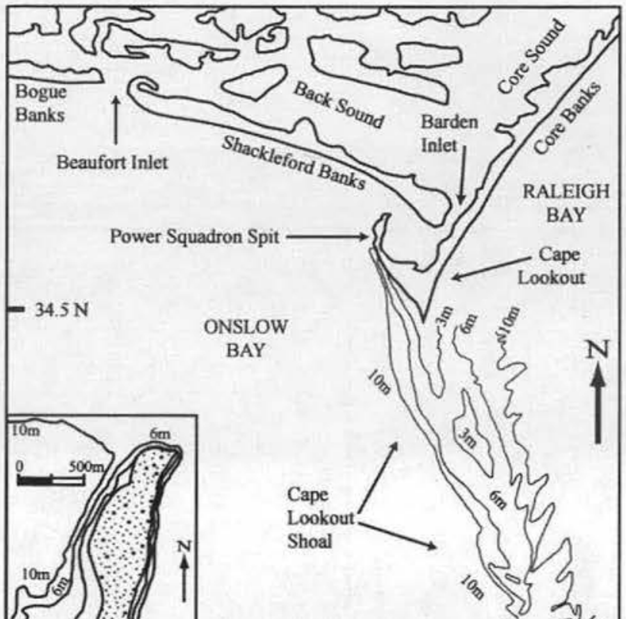

Figure 1. Cape Lookout, North Carolina and surrounding region, bathymetry of Cape Lookout Shoal after McNinch and Wells, (1999). Inset: shoreline and bathymetry of Power Squadron Spit.

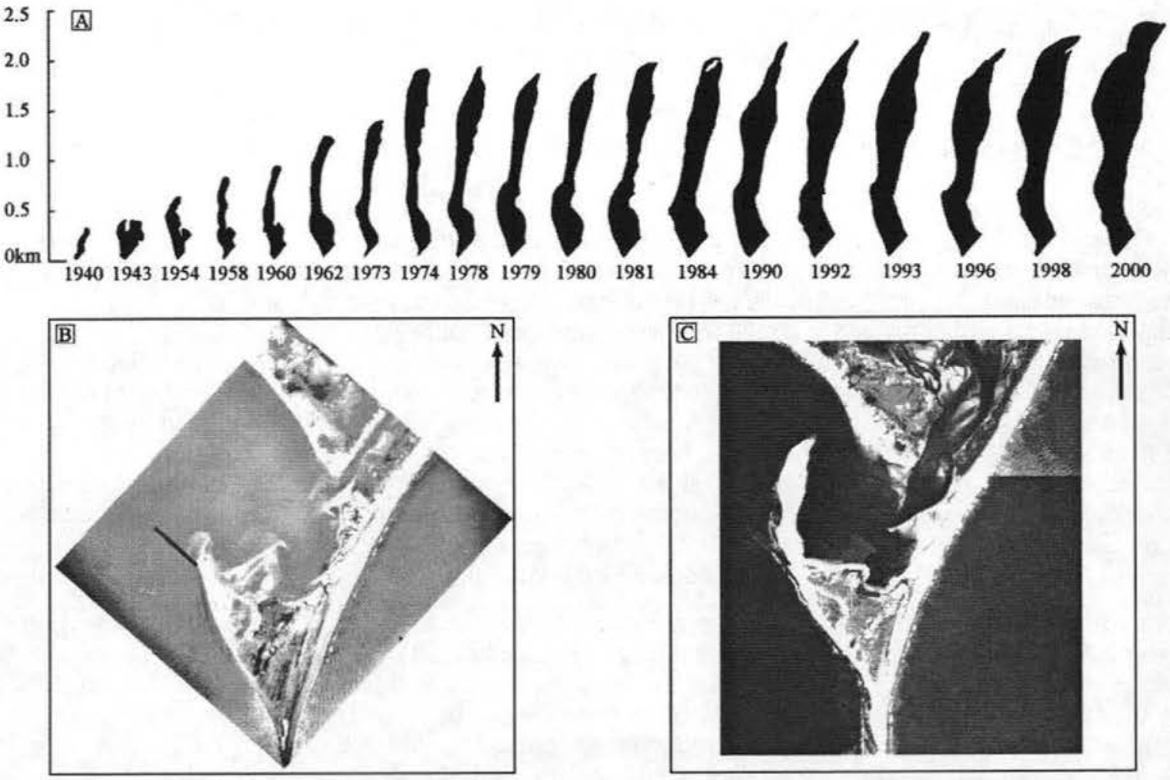

Figure 2. A: Evolution of Power Squadron Spit. B: Aerial photograph of Cape Lookout (1940). C: Digital Orthophoto Quadrangle (DOQ) of Cape Lookout (1998). Jetty highlighted for reference.

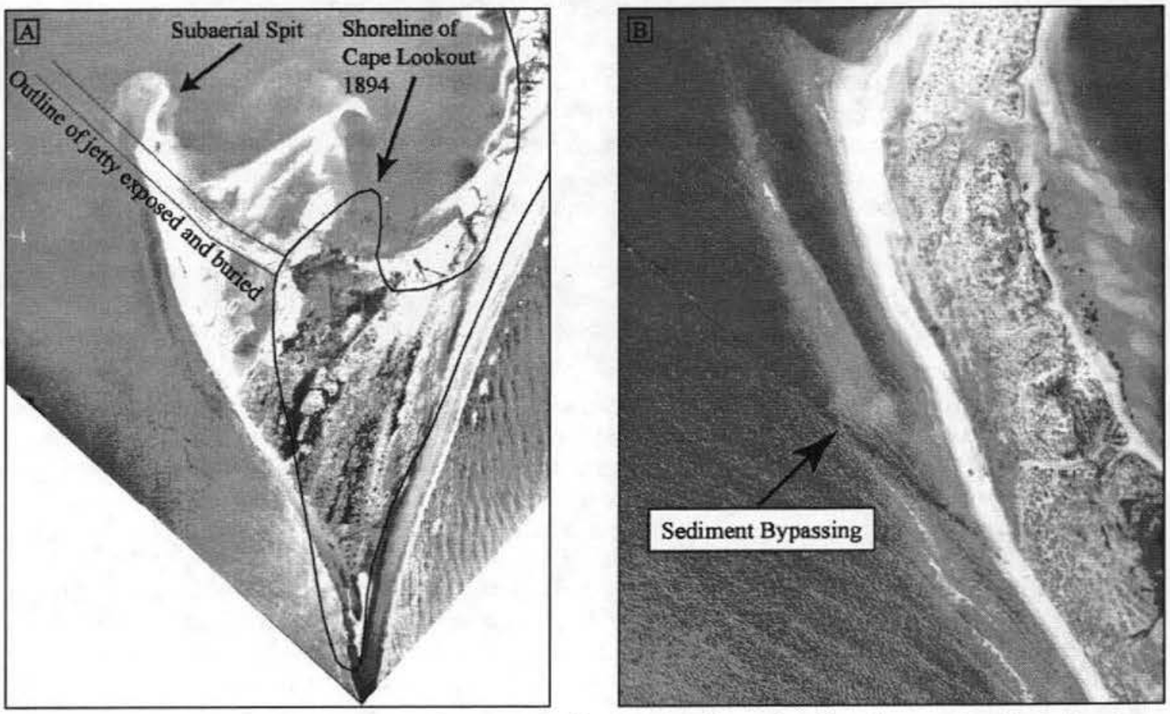

Figure 3. A: Aerial Photograph of Cape Lookout (1940) with 1894 shoreline and outline of exposed and buried portions of rock jetty. B: Aerial Photograph of the rock jetty at Cape Lookout (1996). Sediment readily bypasses jetty. At high tide jetty is awash, which was the intended design.

Coastal Processes Evaluation in Development of a Long-term Beach Management Plan, Sandwich, MA

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The beaches in the Town of Sandwich, comprised primarily of Town Beach and Springhill Beach, have a history of erosion. In 1909, the Cape Cod Canal, and it's two adjoining jetties, were constructed updrift of the Sandwich Town beaches causing an interruption in the natural longshore sediment transport from northwest to southeast. This interruption is the primary source of coastal erosion along Sandwich beaches. By taking shoaled dredge material from the Cape Cod Canal and placing it on downdrift beaches, a portion of the sediment that would have been transported naturally will be restored to the "starved" littoral system of the Sandwich shoreline. The USACE is responsible for routine maintenance dredging of the Cape Cod Canal to a depth of –34 ft NGVD. In past years, material dredged by the USACE from the eastern end of the Canal has been dumped offshore in an approved open water disposal site. For the Canal's next dredge cycle, the USACE plans to maintenance dredge approximately 100,000-150,000 cubic yards of clean sand from the east end of the Canal. To take advantage of this beach compatible material, the Town of Sandwich is working cooperatively with the USACE to permit placement of the dredged material on Town of Sandwich beaches.

In addition, the Sandwich Harbor inlet, separating Town Beach and Springhill Beach, recently breached (1991) immediately east of the historic channel (Figure 1). Stabilization of the inlet is required to reduce the potential for upland flooding, minimize downdrift erosion, maximize beach nourishment lifetime, promote beach stability, and stabilize inlet migration. The unique nature of this coastline, consisting of sediment starved beaches, groin structures, endangered species habitat, a breached inlet, and a large updrift feature (Cape Cod Canal), makes for a complex balancing of sound engineering design, environmental impact minimization, appropriate beach usage, long-term stability, and benefits. Therefore, the development of an overall beach management plan consisted of the evaluation of a wide variety of coastal processes. The detailed, long-term, comprehensive beach management plan for the Town of Sandwich is being used not only to implement the beneficial reuse of the Cape Cod Canal dredged material, but also to explore additional solutions to the historical erosion experienced at the Sandwich beaches.

The primary goal of the beach management plan is to reestablish a naturally sustainable beach/inlet system that includes an adequate storm buffer as well as a source of sediment for downdrift beaches. The plan includes an evaluation of the physical processes, a detailed alternatives analysis, a conceptual design for the preferred alternative(s), creation of additional critical species habitat, permitting of the selected alternative, and appropriate beach maintenance and usage. Beach nourishment design is based on the historical shoreline change information and an evaluation of local wave and sediment transport patterns in the nearshore zone. An alternatives analysis is being performed to consider engineering aspects, as well as environmental impacts, of each possible solution. The alternatives analysis focuses on producing the most viable and most appropriate solution for each section of the Sandwich shoreline.

The Sandwich Harbor inlet restabilization was evaluated in concert with the beach nourishment design to maximize nourishment lifetime and beach stability. Because of a history inlet channel migration and breaching, evaluation of alternatives for stabilizing and/or relocating the Sandwich Harbor inlet were an important aspect of the overall beach management plan. Woods Hole Group performed a bathymetric survey, an inlet stability analysis, and a hydrodynamic model to assess the present stability of the inlet and evaluate potential alternatives for the inlet entrance (Figure 2). A preliminary analysis of the inlet system indicated that restoring the inlet channel to pre-breach conditions (between the jetties) likely would not be an optimum alternative. Based on the results of the inlet alternative analysis, an engineered solution was designed to maximize beach stability, reduce potential upland flooding, stabilize inlet migration, provide additional endangered species habitat, maximize beach nourishment lifetime, optimize natural bypassing, and maintain tidal flushing.

Figure 1. Aerial photograph of Sandwich Harbor Inlet indicating breach from existing structures and thalweg migration to the southeast (2001).

Communication, cooperation, and close coordination with numerous government agencies, local officials, sub-contractors, and the client is essential to the successful completion and implementation of the beach management plan. Regular meetings with the key officials and proactive participation in public forums, where the interests of Sandwich beaches are addressed, are another major component of the overall project. Design specifics and mitigation measures necessary to avoid and/or minimize adverse impacts to the local resource areas were developed as part of the EIR process. Engineering and scientific (physical, biological, etc.) analyses and data collection requirements were completed to ensure the project is consistent with and complies with the local, state, and federal environmental policies. The goal is to construct the project during the fall/winter of 2003/2004 in accordance with USACE dredging of the Cape Cod Canal.

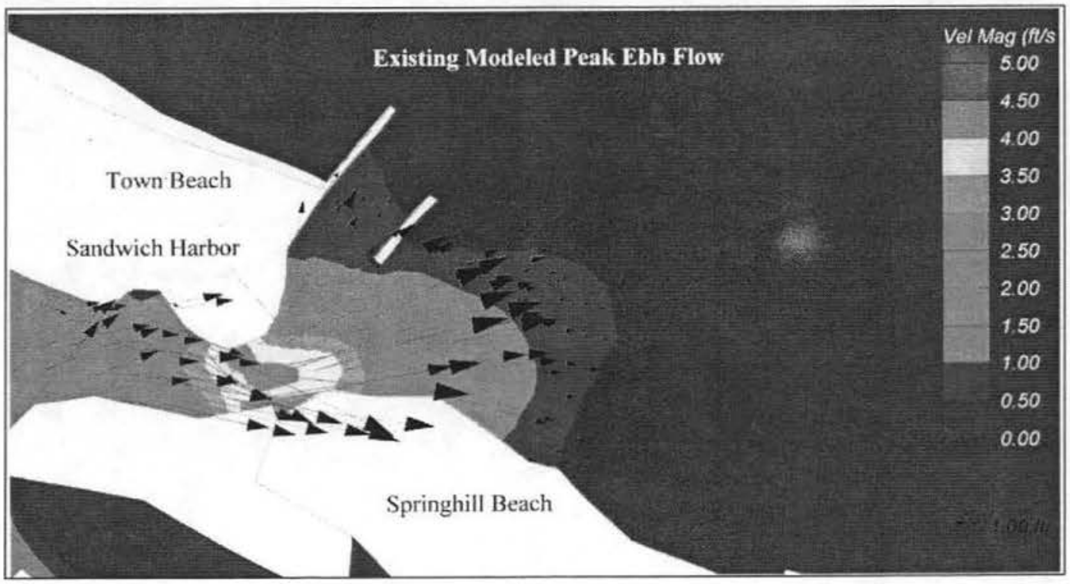

Figure 2. Hydrodynamic Model results for existing conditions at Sandwich Harbor Inlet.

Geological Records of Coastal Erosion in the Northeast

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The past century has been marked by an unprecedented extent of natural and man-induced changes along world's coastlines, however the relative contribution of various environmental factors to specific coastal responses on decadal to millennial scales is poorly understood. Although some coastal localities in New England have been mapped as early as 1500-1600 A.D., present analyses of historical shoreline change rely on geodetic survey charts compiled within the past 200 years and aerial photography covering less than 100 years. Since many barrier systems have existed at or near their present positions for at least 3,000-4,500 years, more than 90% of their natural history is archived, with varying degrees of preservation, in coastal sedimentary sequences. Knowledge of the former positions of eroded shorelines, as well as distribution of historical and relict tidal inlets and storm breaches, is essential for assessing long-term coastal behavior. It has been shown that some barrier segments adjacent to active tidal inlets experience episodes of rapid and dramatic erosion and that these regions must have their own setbacks, independent of oceanside shoreline changes. Traditionally, former inlet sites have been identified using historical documents, geomorphic evidence, or extensive coring efforts. However, surficial signatures of erosional shorelines and inlet channels may be drastically modified or obliterated by natural processes (overwash, dune migration, vegetation) or man-made alterations. Sediment cores are expensive to obtain and offer point-source information, often missing subsurface features of limited spatial extent, such as lag deposits of inlet channels or concentrations of heavy minerals diagnostic of buried storm scarps.

With the advent of new subsurface imaging technology, such as ground-penetrating radar (GPR), high-resolution continuous records of the upper 5-10 m of the barrier lithosome can be obtained. Although the electromagnetic radar signal is attenuated by saltwater, relatively high permeability and width of many barrier systems allow for freshwater conditions to dominate the shallow subsurface, making GPR a viable geophysical tool. In recent years, this technology, complemented with sediment cores, has been used successfully in coastal-stratigraphic research in the Northeast. Subsurface images reveal buried berm and dune scarps, extensive storm-generated unconformities, and relict inlet channels. These geological indicators of shoreline erosion and retreat, which punctuated over 4,000 years of coastal evolution, must be considered in present-day hazard assessment studies.

Have We Lost The Balance Between Fairness, Common sense and Protecting the Functions of a Beach?

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Presently, we lack a dynamic management process that evolves as we learn. Instead we have static rules and regulations that are cumbersome to change to meet specific ecological situations and therefore are subject to interpretations suited to the influences on the regulators. These influences can be political, economic, scientific and organizational bias. These influences result in erosion of beach functions and respect for government and the rule of law.

In the last year I have been told by regulators that a dune is a beach, that dredging is fill and that fine sand must be placed above MHW and below MLW at the same site. We have seen the banning of dogs on beaches but the invasion of SUVs to the extent that mothers fear for a child's safety. We have seen professional experts and established regulators participate in gaming exercises where the same project and information results in different answers from each group. We have seen developers flaunt environmental protections while environmental restoration efforts are bogged down in endless questions. Answering these questions eventually bankrupts these efforts and results in degraded habitats that once yielded so much for those willing to live in a symbiotic relationship.

We have seen the amendment of regulations that now requires public notification for a project up to four times in the Environmental Monitor, two times in local papers in addition to direct mailing to abutters. These regulations also result in the same project information and notification being sent to the same regulators two to three times. The comment periods for these redundant notices can extend permit periods to the point that projects cannot be implemented while adding no additional environmental protection. A discussion of specific regulatory cases illustrates the ineptness of the present system.

We need to think out of the box to address these issues. We need to have organizational experts and educators help. This is not a task for scientists, bureaucrats, politicians or self-interests alone, as it has been in the past.

Simply put, the varied interests in beaches can only be fairly balanced by the rule of law informed by science. However, the reality of the limits of our scientific knowledge and the influences of political, bureaucratic and economic interests on our laws and regulations can result in mismanagement of our beaches and loss of the benefits of public access, storm protection and habitat preservation.

Is this situation beyond our control, its imperfection merely mirroring the imperfection of our human existence? Can we do better by adding common sense through participatory decision-making or some other form of ecological learning? Can we do better by adding fairness through even handed application of laws and regulations?

The rich complexity of the ecology of the beach is reflected in the complexity of interests in beaches. This is a dynamic geological, biological and ethnological vortex. Is our level of organizational expertise up to the task of establishing maintaining and evolving management approaches to this complex situation?

All of these questions are born out of my own experience as an environmental restorer and innovator, government regulator and project planner and advocate over the last 25 years in Massachusetts. Presently, whether you are a dune buggy enthusiast, a bird watcher, or sun worshipper, homeowner or professional, there is I believe significant dissatisfaction with the way beaches are managed in Massachusetts. I do not presume to have the answer to these questions. I think the answers should evolve out of a new process for interest participation in decisions affecting the tools of management including decision processes and static rules and regulations. A fundamental characteristic of this process should be education so that ecological and ethnological lessons are learned overtime influencing the evolution of management. This cycle of learning should be integrated into management. The new system of management would involve participatory processes and regulations informed by feedback and feed forward loops. Presently, management system inadequacies in applying new science or impacts information eventually result in enough dissatisfaction that a conference or symposium may be held. If it is successful a working group may be formed and a positive change in management processes and regulations may result. The process is forever behind the system as it adapts and changes to management and other forces. A more dynamic approach would integrate feedback and feed forward learning loops into the management system.

We will explore examples of these dynamic management approaches from around the country and examine their relevance to beach management in the hopes that the system we are attempting to manage can teach us how best to succeed. My experiences in environmental restoration project management and environmental organizational development (to name a few, the solare shellfish hatchery on Martha's Vineyard, the Mass Bays Local Governance Committee structure, the Shellfish Bed Restoration Program) will inform the presentation of alternative management models.

River Bluff Protection Using Improved Geotextile Tubes and Coir Erosion Control Blankets

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Over a period of 20 years, erosion had removed nearly 50 feet of bluff from a property along the Cohansey River. The Cohansey River is a tidally influenced river in southern New Jersey, which drains to the Delaware Bay.

Bluff erosion can be caused by several factors such as ground water seepage, overland runoff, currents and wave attack. It was determined that the primary reason for the progressive erosion was waves attacking the base of the bluff resulting in instability and eventual sloughing of the bank. The design of a protective structure for the bluff would need to prevent erosion of the base and stabilize the bank. The top of the bluff is approximately 22 feet above the river.

The tidal range at the project site is approximately 4 feet with Mean High Water (MHW) occurring at +2.99 feet North American Vertical Datum (NAVD) 1988. The base elevation for the tubes was 0 ft NAVD 1988 and the tubes would be filled to a top elevation of +5.5 feet NAVD. At high tide, the construction site is underwater, therefore several aspects of the project would have to be completed during low tide. The work area at the base of the bluff was very narrow, saturated and very soft in spots. Additionally, river currents could be expected during the winter season.

The Design. Since the primary cause of the erosion was sloughing of the bank, a structure was required which could withstand wave attack and associated overtopping. The design waves for this site were determined to be relatively small. The bluff is comprised of highly erodable clays and sandy silts. The bluff faces west at a bend in the river.

Several options were considered. A cost comparison of rock, gabions and geotextile tubes was conducted. The narrow work area, construction access restrictions and cost of materials favored the geotextile tube option. There was very little room to work at the river's edge. The contractor, Coastal Management, Inc., was sensitive to the property owner's desire to not destroy landscaping at the top of the bluff. The use of tubes allow minimal disturbance.

Geotextile tubes, when uncovered, are susceptible to debris damage. In recognition of this, several designs were considered to armor the tube. A new, vinyl-coated, polyester fabric, ProtecShield II was chosen for its durability and aesthetic properties. The ProtecShield II was sewn to the geotextile tube on its exposed face, in the factory.

Installation. Prior to installing the tube, a scour apron was to be deployed at the base elevation. During the grading of the foundation, a localized area of extremely soft, saturated soil was found. Sand was placed in the soft spot, but the soil strength could not be improved sufficient to carry the weight of the equipment. A geotextile separation and reinforcement fabric was deployed and a 6-inch layer of sand placed above the geotextile. This allowed a 28-ton bucket loader to finish grading the foundation. A small trench near the bluff was dug to provide stability to the tube while filling. The scour apron was deployed within the trench, extending toward the river. An anchor tube was filled with sand at the river's edge.

The tube was then deployed and hydraulically filled using normal filling techniques. A hopper located on top of the bluff created the sand slurry, which was pumped into the tube. Another benefit of the ProtecShield II was that the fill ports could be glued closed using commercially available PVC adhesive.

Completion. After filling the tubes to the desired height, the bluff was graded, and covered with a woven coir mat over a nonwoven coconut erosion control blanket. Ivy was then planted into the bluff face.

Large-scale Beach Replenishment Programs – Case Studies

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Beach replenishment projects are rapidly becoming more common in Massachusetts and in the northeastern United States. With this increased interest has come the realization of complex issues surrounding beach replenishment. This is particularly true for large-scale projects involving community-wide efforts and sponsorship. These types of projects potentially present planning, design, environmental, and construction-related challenges. To expand local knowledge and help provide a wider basis for planning beach replenishment projects, this paper presents case studies for two particular projects in FL, where there is a relatively mature state-sponsored program for large-scale beach replenishment projects.

Challenges associated with beach replenishment projects are diverse. In the planning process, it is challenging to determine whether replenishment is a viable alternative, what stretch of coast is in need of protection, where sand may be obtained, and whether a project can be completed in a manner consistent with environmental values and regulations for the area. Beach replenishment is a practical and proven method for long-term coastal erosion management. Although properly designed structures or other alternative solutions can potentially improve the longevity of sand in a particular area, only beach replenishment can provide the necessary sand into sand-starved systems.

Funding models also are diverse, in terms of who pays for the project and how costs are allocated. Developing an acceptable financing program is key to the implementation of a beach replenishment project. These projects require a long-term financial commitment to support replenishment over the project horizon. Beach replenishment projects provide three distinct types of benefit: (1) storm protection benefit to coastal property, (2) recreational benefit to the total community, and (3) environmental benefits to the ecosystem. These benefits can be used to allocate the costs to individual beneficiary groups and identify the appropriate funding sources.

Once a project is planned and funded, the engineering design process is equally as complex. For instance, the design of a beach replenishment project is site-specific. It is a challenge to quantify the governing forces as the basis for specifying appropriate lengths, widths, and heights of required sand replenishment, as well as the appropriate expected design life. The planning and design processes also must be accomplished in such a manner as to minimize environmental impacts in accordance with governing regulations. Prevailing environmental conditions and the potential for impact also are very site-specific, and, as such, present challenges to applicants and regulatory staff tasked with permitting and/or reviewing beach replenishment projects. Even selecting an appropriate and efficient construction methodology is sometimes complex. In addition, once a project is constructed, there are often monitoring and compliance reporting requirements that must be developed to meet the particular project's needs.

Resolving all of the complexities associated with a beach project can be extremely difficult, especially in Massachusetts where relatively few large-scale projects have been implemented. Often, the most efficient basis for planning a replenishment project comes from experiences on other projects. As such, two particular large-scale replenishment projects will be discussed.

The first case study that will be presented is for Jupiter Island, FL, where a large-scale replenishment program has been ongoing since the early 1970s. Particularly interesting features of the Jupiter Island program are related to:

- the funding program (local taxing district);
- engineering design specifics (need for large-scale replenishment, existence of hot spots, and importance of sand grain size);
- environmental concerns (nearshore hardbottom and nesting sea turtles);
- combination with other regional shoreline management programs, such as the federal USACE management of the updrift St. Lucie Inlet.

The second case study that will be presented is for Indian River County, FL, which is currently in the process of implementing a countywide beach management plan that includes several large-scale beach replenishment projects. Particularly interesting features of the Indian River County program include:

- the funding program (local, state, federal cost-sharing plan)
- the regional planning approach (four (4) project areas selected for replenishment over a 30 project horizon)
- environmental concerns (extensive nearshore resources exist along the proposed project lengths)
- the development of a public outreach program to bring together special interests groups, concerned citizens, etc.

Finally, a portion of the paper will be geared toward providing in-field examples and photographs of large-scale beach replenishment construction techniques and practices. This portion of the paper is intended to increase the exposure of the audience to beach replenishment practices.

Assessing Coastal Vulnerability to Future Sea-level Rise in the Cape Cod National Seashore

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Recent estimates of future sea-level rise based on climate model output suggest an increase in global eustatic sea level of between 15 and 95 cm by 2100, with a "best estimate" of 48 cm (IPCC, 2001). This is more than double the rate of eustatic rise for the past century (Douglas, 1997; Peltier and Jiang, 1997). Thus, sea-level rise is predicted to have a large, sustained impact on coastal evolution, particularly on developed coasts. At the same time coastal populations and development are expected to increase.

Identification of regions where physical changes are likely to occur due to future sea-level rise applies to many of the decisions the park will be making regarding coastal management in both the short- and long-term. This study applies a relatively simple, objective method, a Coastal Vulnerability Index (CVI), to identify those portions of the Cape Cod National Seashore (CACO) at risk from the effects of rising sea level. The CVI has previously been applied to the U.S. Atlantic, Pacific and Gulf of Mexico Coasts (Hammar-Klose and Thieler, 2001). This index is based upon an assessment of the following variables: coastal geomorphology, regional coastal slope, rate of sea-level rise, wave and tide characteristics and historical shoreline change rates. The input data for this study were assembled from MassCZM, NOS, the Army Corps of Engineers, NGDC, and the USGS. Data are stored in 1minute grid cells and transferred to a 1:70,000 shoreline for mapping purposes.

Each grid cell is assigned a risk value for each specific data variable and the coastal vulnerability index (CVI) is calculated as the square root of the product of the ranked variables divided by the total number of variables as

$$CVI = \sqrt{((a*b*c*d*e*f)/6)}$$

where, a = geomorphology, b = coastal slope, c = relative sea-level rise rate, d = shoreline erosion/accretion rate, e = mean tide range, and f = mean wave height. This method yields numerical data that cannot be equated directly with particular physical effects. It does, however, highlight those regions where the various effects of sea-level rise might be the greatest.

Table 1 shows the six physical variables listed above and their integer ranking values that are used to calculate an index value. For the CACO coast, regional coastal slopes >0.12 percent are considered to be very low risk; regional slopes <0.02 percent are considered to be very high risk. The rate of relative sea-level rise is ranked using the modern rate of eustatic rise (1.8 mm/yr) as very low risk. Since this is a global or "background" rate common to all shorelines, the sea-level rise ranking is unlikely to vary within CACO. Shorelines with erosion/accretion rates between -1.0 and +1.0 m/yr are ranked as moderate. Increasingly higher erosion or accretion rates are ranked as correspondingly higher or lower risk. Tidal range is ranked such that microtidal coasts are high risk and macrotidal coasts are low risk. Mean wave height rankings range from very low (<0.55 m) m to very high (>1.25 m).

The CVI scores are divided into low, moderate, high, and very high-risk categories based on quartile ranges and visual inspection of the data. Figure 1 shows a histogram of the percentage of CACO shoreline in each risk category.

The mapped CVI values show numerous areas of very high vulnerability, particularly at Nauset Beach, Nauset Marsh, Great Island, Jeremy Point, Monomoy Island, and the southern portion of Herring Cove Beach. All of these areas are very popular with park visitors. The highest-vulnerability areas are typically lower-lying beach locations and marshes; their susceptibility is primarily a function of geomorphology and coastal slope. The areas of lowest vulnerability occur in the northern section of the park, along the Atlantic Ocean. Here, high bluffs rise 35-45 m above the beach.

CACO protects a dynamic natural environment. The maps and data show where physical changes are most likely to occur as sea level rises and can be used by park managers to assess objectively the natural factors that contribute to the evolution of the coastal zone within the Cape Cod National Seashore.

	Ranking of coastal vulnerability index				
	Very low	Low	Moderate	High	Very high
VARIABLE	1	2	3	4	5
Geomorphology	Rocky, cliffed coasts Fiords Fiards	Medium cliffs Indented coasts	Low cliffs Glacial drift Alluvial plains	Cobble beaches Estuary Lagoon	Barrier beaches Sand Beaches Salt marsh Mud flats Deltas Mangrove Coral reefs
Coastal Slope (%)	>0.12	0.12 - 0.06	0.06 - 0.04	0.04 -0.02	< 0.02
Relative sea-level change (mm/yr)	< 1.8	1.8 - 2.5	2.5 - 3.0	3.0 - 3.4	> 3.4
Shoreline erosion/ accretion (m/yr)	>2.0 Accretion	1.0 -2.0	-1.0 - +1.0 Stable	-1.1- -2.0 Erosion	< - 2.0
Mean tide range (m)	> 6.0	4.1 - 6.0	2.0 - 4.0	1.0 -1.9	< 1.0
Mean wave height (m)	<0.55	0.55 - 0.85	0.85 - 1.05	1.05 -1.25	>1.25

Table 1. Rankings of each variable included in the Coastal Vulnerability Index used for CACO.

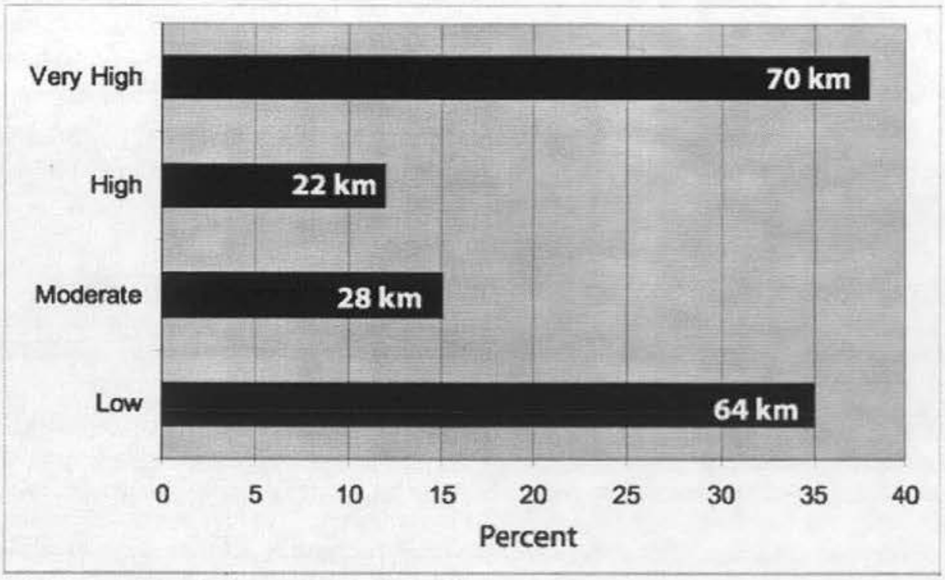

Figure 1. Histogram showing the percentage of each risk category within the Cape Cod National Seashore based on the CVI values of each shoreline segment. Shoreline lengths in each category are given in kilometers.

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Developing Best Management Practices for Beach Nourishment in Massachusetts

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Non-structural alternatives such as beach nourishment are strongly encouraged in Massachusetts by local, state, and federal regulatory agencies as the preferred method of storm damage protection and flood control. However, the site-specific conditions (e.g. erosion rate, grain size distribution, wave climate) and proximity of other resources (e.g. eelgrass, shellfish) must be considered to avoid unintended impacts to sensitive resource areas.

The Massachusetts Office of Coastal Zone Management is working in conjunction with representatives from the Massachusetts Department of Environmental Protection and the Massachusetts Division of Marine Fisheries to establish best management practices (BMPs) for beach nourishment. The term beach nourishment is generally used to refer to the process of adding sand to a beach. There are two primary types of nourishment in Massachusetts. The most common type is the beneficial re-use of clean, compatible sediment from a nearby dredging project to augment the volume of a beach or dune resource area. Beach nourishment can also refer to a designed, engineered project where a specified volume of sand is added to a beach and dune system to provide a desired level of storm damage protection. For the purposes of clarity, the term beach fill will be used to refer to the former practice and beach nourishment will be used to refer to the latter.

The intent of establishing BMPs is to 1) provide guidance to those proposing beach fill or beach nourishment regarding ways to ensure better longevity and therefore better cost-effectiveness for the project and 2) provide guidance to those designing the project regarding the state's thinking on minimizing the potential adverse impacts (if any) to natural resource areas.

For beach fill and beach nourishment projects, the most important factor is the grain size distribution of the fill material as compared to the native beach material, also referred to as sediment compatibility. In beach fill projects, it is state policy to place clean, compatible sediments on adjacent beaches to keep the material in the littoral system. However, if the sediments are placed in a location where they would not be stable due to a lack of good compatibility, then the potential result can be unintended adverse impacts on other natural resources such as eelgrass, shellfish, or salt marsh. For beach nourishment projects one of the primary goals is to create a storm damage buffer that is as stable as possible. The stability of sediments placed on a beach is directly related to the grain size. Material that is finer than the existing sediment can be used for both types of projects, but it may move very quickly into other areas and result in 1) adverse impacts to other natural resource areas due to movement of sand onto resources, 2) lack of protection from storms if the sediment does not stay where placed, and/or 3) make a project more costly to maintain if the goal it to maintain a specific volume of beach sediment for storm protection.

Some spreading out or movement of sediment offshore and alongshore should be expected when it is placed on a beach. The grain size, slope, and placement method will contribute to the amount of shifting that occurs and how quickly it occurs. It is important to know where and how quickly the sediment to be placed on a beach will move in order to assess if it meets the project goals and if it may have impacts to adjacent resource areas. If the material is placed at a slope that is steeper than the existing beach slope, the profile will naturally try to re-establish a shallower slope, resulting in the appearance that the material eroded or was lost. The rapid movement of sediment can also result in unintended impacts on adjacent resource areas due to burial. For beach fill projects, if only small quantities of sediment are placed along a relatively small stretch of shoreline, the sediment will tend to spread out, resulting in a relatively small net gain in volume to the intended beach and adjacent beaches.

Representatives from the Massachusetts Department of Environmental Protection, the Massachusetts Division of Marine Fisheries, and the Massachusetts Office of Coastal Zone Management are developing the BMPs to provide technical guidance to applicants as well as those reviewing proposals for beach fill or beach nourishment. The development of these guidelines should help to minimize the potential adverse impacts to natural and cultural resources as well as streamlining the design, permitting and implementation of beach fill and beach nourishment projects.

From Seasonal Windows to Regional Management Plans: The Evolution of an Adaptive Management Strategy for Beach Nourishment Projects

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Since the 1980's, the New York District and its State Partners have constructed major shore protection projects utilizing beach nourishment to reduce storm damage. Increased concern for preserving and enhancing coastal habitats, particularly those used by endangered species, has resulted in the evolution of management strategies for these critical resources. This presentation reviews the refinement of measures to protect endangered species and advance their recovery within an adaptive management framework. Examples from the Atlantic Coast of New Jersey, Sections I (Sea Bright to Ocean Township) and II (Asbury Park to Manasquan Inlet) and the Westhampton Beach Interim Project; will be used to illustrate this development. Current efforts to coordinate interagency management plans involving many levels of local government will be reviewed.

Bluff Evolution of the Boston Harbor Islands

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The geomorphic environment responsible for the evolution of the Boston Harbor Islands is influenced by a broad range of processes that operate on vastly different spatial and temporal scales. A classification system that breaks down the processes into a logical framework that accounts for these differences will clarify the surface process history and the current factors operating on the eroding shorelines.

A hierarchical classification of the dominant process-response elements within a drumlin-bluff geomorphic system was initially identified by Pinet et al. (1998). The classification system has been applied to the Boston Harbor Islands, which have a similar drumlin-bluff surface process history. This analysis established a framework for the numerous processes eroding the exposed drumlin bluffs and can be used to assess the impact a particular process (factor) has on the overall retreat of the shorelines.

The bluffs that make up the shorelines of the Boston Harbor Islands are eroded in one of two ways; sediment is removed either by wave notching and slumping, or through a rill and gully system. The nature of this response is governed by a multitude of processes operating at different scales. The regional processes responsible for reworking sediment around the islands are storms, wind-generated waves, boat wakes, and tidal currents all operating in a regime of accelerated sea-level rise. Locally, factors such as the composition of the sediment, the bluff stratigraphy, the percent eroded of the drumlin deposit, and geotechnical properties of the sediment can cause the bluff to be more susceptible to erosion.

Fieldwork data documenting the mechanisms of bluff retreat and historical aerial photograph analysis detail both the short and long-term evolution of the island shorelines. This information will be of value for future planning of park facilities as well as contributing to the preservation of important natural and cultural resources.

Coupled Volunteer Beach Profile Data and Offshore Wave and Current Measurements on 10 Beaches in the Western Gulf of Maine: Results of the First Three Years

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In 1999 we began a Sea Grant-funded experiment to involve non-geologist volunteers in a study of beach erosion/accretion in Maine. Our purposes were: 1) to acquaint homeowners and other beach users with the nature and collection of scientific data (as opposed to anecdotes), as well as: 2) to gather observations of beach change. The first purpose addresses the lack of familiarity between the "regulated" (property owners on Maine's beaches) and the "regulators" (scientists and state managers of the coastal zone). By uniting in a common effort we hoped that mutual respect would be increased, and lawsuits and beach-damaging legislation eliminated. We developed a web site (www.geology.um.maine.edu/beach/) to display the data to maintain interest in the project and make the information available to the media and public at large. The second goal reflects the fact that it is impossible for university of Maine scientists to measure the topography of beaches regularly because of shear logistics and cost difficulties. The University of Maine is several hours' drive from the beaches of southern Maine, and there are insufficient numbers of scientists to profile 10 beaches in a single day. Hence, there is considerable value to employing a group of volunteers for this task. We planned a State-of-Maine's-Beaches meeting at the end of each year to view the data and discuss beach issues. We have three years of beach profiling data as of July, 2002.

To understand the causes of changes in the beach profiles we deployed current and wave measuring devices offshore of the beaches during the first two years of work. These provided us with quantitative measures of the height and period of waves and the currents associated with waves and tides.

Our results with the program have been generally excellent. The data gathered by the volunteers is of high quality and, as described below, complements the offshore wave and current data. There have been no serious disputes between homeowners and the state during the period of measurement, but oceanographic conditions have also been unusually calm during this time.

Our results focus on the change in beaches as a consequence of storms. The western Gulf of Maine experiences three distinct varieties of stormy meteorological events that strongly impact beaches: 1) frontal passages, 2) northeast storms, and 3) southwest storms. Lacking data on the response of shorelines to these events, scientists have had difficulty interpreting historic shoreline changes, or predicting future changes. This has made it especially difficult to convince property owners to accept beach development restrictions from the State. The first 2 years of data indicate that frontal passages and southwest storms generally cause upwelling of nearshore water and net bottom water movement (and sand) toward the beach. Northeast storms result in downwelling and offshore-directed bottom water (and sand) movement. Annual variation in the relative abundance of these weather systems strongly influences sediment accretion and erosion trends. During the first year of observations, frontal passages and southwest storms dominated, and beaches generally accreted. With the onset of more northeast storms in year two, more erosion was observed in association with those events, though no exceptionally large events occurred. Historical analyses demonstrate that major periods of beach erosion are associated with patterns of numerous northeast storms.

Four Years Later: An Update on Dredging and Disposal Strategies for Aunt Lydia's Cove, Chatham, Massachusetts

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Following the 1987 breach of Nauset Beach and formation of the new inlet, access to the Chatham Municipal Fish Pier became severely restricted as a flood tidal delta formed within Chatham Harbor and began to migrate northward into Aunt Lydia=s Cove (Humphries et al, 1998). The Town was forced to conduct numerous small and mid-scale mechanical and hydraulic dredging projects to maintain access to this important commercial fish offloading facility. Due to the severe navigation restrictions to the commercial fishing vessels imposed by the shoals, the New England Division of the U.S. Army Corps of Engineers developed a small draft (-8 feet mllw by 100 feet) navigation project for Aunt Lydia's Cove. In 1995, the Corps hydraulically dredged 120,000 cys from the mooring anchorage and entrance channel. Unfortunately, the flood shoal continued to form and the entrance channel portion of the project had all but filled in a matter of a few months.

After documenting the migration of the flood-tidal delta into the federal navigation channel, the Town of Chatham obtained permits for a "zone of future dredging" in December 1999. As a result, maintenance dredging could take advantage of the natural channels as they developed and migrated. This approach would also minimize the frequency and the volume of dredging as the ebb and flood currents assist in maintaining the channel.

Another unique aspect of the permit was the inclusion of a comprehensive set of beneficial use disposal options. Disposal areas were identified for a variety of dredging methods, quantities, and placement locations. Since the dredged material is clean beach quality sand, a consistent goal of the disposal plan was to provide disposal options that would place the material onto either eroded sandy shorelines or within the nearshore littoral system. Ultimately, a total of 14 disposal sites were identified which provided a combination of direct beach disposal and open water disposal, in addition to more distant truck hauled disposal sites following dewatering efforts. This group of sites was developed to support the three primary anticipated dredging methods of hydraulic pipeline, hopper, and mechanical bucket dredging. Multiple sites also provided flexibility in managing where the sand would be placed based on limited site capacities as well as a prioritization of need. These were the first permits of their type issued in the Commonwealth of Massachusetts which incorporated the concept of the "dredging zone" with multiple beneficial use disposal sites.

Since the spring of 1998, the Town has dredged portions of either the entrance channel or the mooring basin of the Fish Pier on ten separate occasions. This includes seven dredge projects using the Barnstable County hydraulic pipeline dredge "Codfish" (total quantity removed is approximately 61,000 cys), and three annual dredge events by the Corps of Engineers special purpose hopper dredge "Currituck" (total quantity removed approximately 160,000 cys.). This high frequency is the result of the highly dynamic shoal system, the need for smaller scale direct beach discharge projects due to limited disposal capacities, as well as the need to husband limited Town funds. These factors further enhanced the value of the flexible dredge permit because the Town has been able to maximize the duration of the dredged channel through some innovative designs in the dredge cut. For example, based on a better understanding of the shoaling patterns and trends, deposition basins and asymmetrical channel designs have been utilized to target areas with the highest shoaling rates.

This aggressive dredging strategy seems to be producing the desired results of providing consistent navigation access through a highly mobile shoal system. The combination of the smaller scale pipeline projects, coupled with what is now becoming routine larger scale dredging projects by the Corps= hopper dredge, is proving successful for this harbor. In addition, the disposal plans have restored and maintained many highly eroded shorelines throughout the community, further highlighting the value of beneficial use of dredged material.

The next few years will require continued diligence in developing dredging strategies that take into account the changing dynamics of the flood shoal complex. Over the past three years, the flood shoal has essentially become bisected by an ebb spill-over lobe, which may modify the shoaling characteristics of the entrance channel. In addition, the tidal flow along the channel directly fronting the Fish Pier appears to be developing into a more ebb dominated system (Pendleton, 2002). This may have been influenced by the dredge projects that have established more efficient flow through the flood tidal delta. However, this recent ebb dominated flow is redistributing sand that had initially formed shallow flats north of the Fish Pier after the new inlet formation. This sand now appears to be migrating south into the mooring basin in the form of linear bars causing the loss of active mooring locations for some of the commercial vessels.

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The Clean New England Beach Initiative and Tiered Monitoring Programs

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A tremendous amount of work has been accomplished in the last decade to identify and address sources of bacteria (and pathogen) contamination to recreational and shellfish waters through a variety of regulatory and planning programs. Despite these efforts, too many beaches are still closed to the public for swimming during both wet and dry weather. During the summer of 2001, based on statistics provided by the New England states, there were more than 700 "Beach-days" cumulatively in New England at which a freshwater or marine beach was closed, or an advisory posted. These postings were primarily caused by exceedances of public health-based thresholds of indicator bacteria. The causes of these exceedances are often fecal contamination of storm water, but non-human sources of indicator bacteria are also of concern.

Spurred by the availability of federal funding for beach monitoring, assessment and public notification through the federal BEACH Act of 2000*, EPA New England in 2002 launched a ***Clean New England Beach Initiative*** to reduce public exposure to water-borne pathogens at swimming beaches. To meet this goal, EPA is working closely with state and municipal environmental and public health agencies to reduce the number of beach closures. The components of the initiative are:

1. Ensure states and municipalities monitor water quality at beaches, assess sources of pathogens and notify the public of water quality conditions consistent with EPA's performance criteria using funds provided by federal BEACH grants to coastal states;
2. Control non-point and storm water pollution sources that contribute to beach closures.
3. Establish a "Flagship" beaches program to highlight good beach management and monitoring practices at one to five coastal beaches per state;
4. Promote high quality monitoring and assessment methods for bacteria indicators and pathogens;
5. Promote information transfer and communication; and
6. Involve and educate the public and municipalities on their role – in pollution control, cleanup efforts, monitoring and advocacy.

EPA will focus its efforts on providing technical assistance to state and municipal environmental and public health agencies for assessment and monitoring as needed and as funds allow, and will back up its assistance efforts with regulatory and enforcement tools where appropriate.

For states to receive funding through the Beach grants, they must meet performance criteria published by EPA in 2002 for monitoring, assessment and public notification. For example, states must use the EPA-recommended indicator bacteria *enterococci*, which has been shown in epidemiological studies to be more closely associated with swimming-related illnesses, than the traditional indicator bacteria fecal coliform. Another key criterion is to develop and apply a risk-based beach evaluation and classification program to beach monitoring. This tiered monitoring program recommends that monitoring frequency should increase with greater risks (e.g. known pathogen sources) or exposure (i.e. beach use). This presentation will describe efforts that coastal New England states have made in classifying beaches according to risk principles and how the classification has influenced existing and planned monitoring designs.

* The Federal BEACH Act is the Beaches Environmental Assessment and Coastal Health Act of 2000.

Design of a Composite Shore Protection Structure to Address Multiple Beach and Shorefront Interests

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Northeast beaches and their adjacent coastal areas must support a wide variety of uses and need to provide multiple benefits. Recreational, environmental, historic, storm protection and economic resources must all be considered when developing a shore protection program for a coastal beach and adjacent upland areas.

The Fourth Cliff Recreation Area is operated by the US Air Force for the benefit of military personnel and their families. The Fourth Cliff Recreation Area is located at the tip of the Fourth Cliff coastal bluff in Scituate, Massachusetts. In some locations the coastal bluff is up to 60 feet high. Erosion of the coastal bluff has progressed to the point where historic defense structures may become unstable if the erosion is allowed to continue.

Design of a shore protection program had to consider the impact of the shore protection project on adjacent beaches, navigation channel, and sensitive coastal habitats. Recreational use of the beach needed to be maintained, the historic structures required a high level of storm protection, and difficult construction access needed to be considered. In addition, the US Air Force is concerned with on-going maintenance costs and funding for any shore protection system.

The initial assessment of the site identified two (2) primary mechanisms causing the erosion of the coastal bluff: rainfall/upland storm water run-off and storm waves destabilizing the toe of the bluff.

In order to address the various concerns with a shore protection system as well as the different causes of the erosion, a composite shore protection structure was developed. In order to address upland storm water run-off, a drainage system is proposed at the top of the coastal bank to divert storm water away from the bank. The slope of the coastal bank will be cut back and vegetated to provide more protection from rainfall erosion. In order to protect the toe of the bank from wave erosion during storm events, a riprap revetment was selected. In order to mitigate the impacts of the proposed bank stabilization structures on adjacent beaches and sensitive coastal habitats, as well to provide toe protection for the revetment, a cobble/granular berm will be incorporated into the design. The proposed shore protection structure cross section is shown in Figure 1.

The paper will describe the geomorphology of the site; methods used to analysis the coastal processes acting on the site; and the other shore protection alternatives that were considered for the project. The design considerations imposed by each of the resource interests will be discussed in detail. The paper will also describe the balancing of these resources that lead to the development of the composite shore protection structure for the Fourth Cliff Recreation Area.

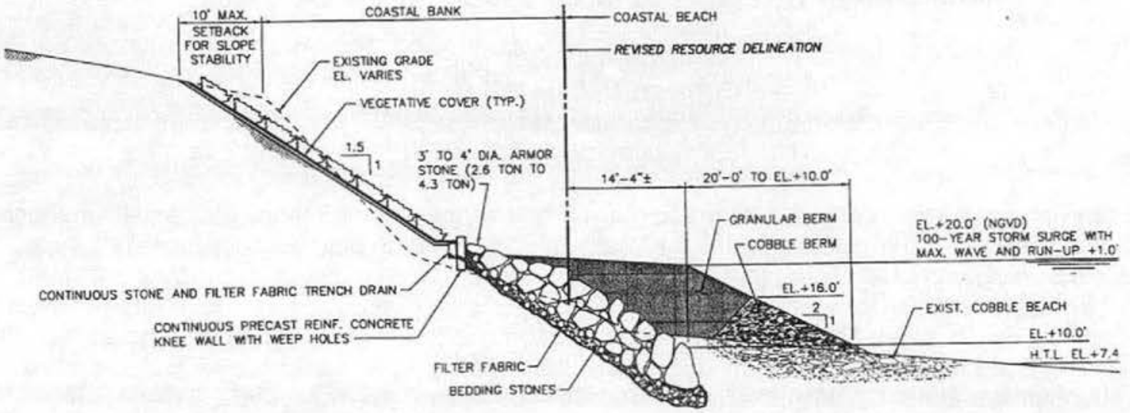

Figure 1. Section through composite shore protection structure. Not to scale.

Integrating Piping Plover and Least Tern Conservation Into Long-term Management Strategies For Massachusetts' Beaches

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The past 15 years have seen increased efforts to recover and conserve populations of coastal waterbirds on beaches of the northeastern United States and Canada. Conservation programs for Piping Plovers (*Charadrius melodus*) and Least Terns (*Sterna antillarum*) are of interest to beach managers and users because of society's empathy for wildlife and our ability to significantly modify coastal ecosystems. Piping Plovers, Least Terns, and their habitats are protected by state and federal laws, and programs to recover and conserve their populations have grown and evolved since the mid-1980's. These programs seek to increase abundance and reproductive success of both species by maintaining abundant, high-quality habitat and reducing disturbance and mortality caused by human recreation and predation. Management to protect birds from recreational activities includes fencing of nesting and chick-rearing areas, partial or complete closures to off-road vehicles during the breeding season, restrictions on pets and fireworks, and public education. Coastal stabilization and dune building activities often degrade plover and tern habitat by altering natural processes of dune and beach erosion and accretion. Beach nourishment may improve or degrade plover and tern habitat, depending on timing, location, elevation, and slope. Predation continues to be a major limiting factor for both species; management to reduce predation has been only partially successful.

In 2001, 495 pairs of Piping Plovers and 3,420 pairs of Least Terns nested at over 100 beaches in Massachusetts. This represents approximately a third of the Piping Plovers and a quarter of the Least Terns breeding along the Atlantic Coast of the U.S. and Canada. Intensive management during the past 15 years has quadrupled the number of breeding Piping Plovers in Massachusetts and has increased Least Tern numbers by 60%. These increases have been achieved on beaches that are collectively used by hundreds of thousands of recreationists each year. State and federal endangered species laws and Massachusetts' Wetlands Protection Act have been effective regulatory tools for protecting plovers, terns, and their habitats. MassWildlife and the U.S. Fish and Wildlife Service have developed written guidelines to assist landowners in managing recreational activities on beaches where plovers and terns nest. Although recreational use of off-road vehicles is largely incompatible with beach-nesting bird conservation, effective protection has been possible with only minimal restrictions on pedestrian access. Through regulatory processes we are able to condition dredging, beach nourishment, dune building, and other projects to avoid adverse effects to, and in some cases enhance, plover and tern habitat. Coastal waterbird conservation in Massachusetts is carried out by a network of federal and state agencies, county and municipal governments, private conservation organizations, university researchers, and private landowners. Protection of plovers and terns benefits other beach-dwelling animals and plants, including migrating shorebirds, beach and dune vegetation, and the Northeastern Beach Tiger Beetle (*Cicindela dorsalis*), a threatened species. Biologists and beach managers face the challenge of implementing multiple-use strategies that include long-term protection for beach-nesting birds, given the unrelenting threats faced by these species.

Improving Plant Diversity on Coastal Sand Dunes

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In the mid 1960's, the USDA Soil Conservation Service (now the Natural Resources Conservation Service) established a plant testing facility in Cape May Court House, NJ to develop vegetative solutions erosion problems of the mid-Atlantic coastal plain. Initially all efforts were focused on addressing storm damage to sand dunes. This facility soon identified and tested a collection of American beachgrass (Ammophila breviligulata) which performed extremely well on sand dunes along the oceanfront. The selection was given the cultivar name 'Cape' after its place of origin, Cape Cod, MA. This plant cultivar has performed almost too well for nearly thirty years. Its near perfect performance and ease of establishment has escalated this plant to being literally the only species extensively planted on coastal sand dunes from Maine to North Carolina.

Coastal communities with fixed sand dune maintenance and replenishment budgets often choose the short-term convenience of working with one species, over long-term ecologically correct approaches. However, it is short sighted to plant only American beachgrass (*Ammophila breviligulata*). Beachgrass is an aggressive pioneer species (4 to 6 ft. or lateral spread annually); surviving the sterile environment of newly formed sand dunes. Very few additional species can survive this harsh niche of the environment. However, as dunes mature and advance seaward, sand accumulation slows, depriving established beachgrass their needed nutrients. Often the result is a decline in the health of plants in older stands. This is a naturally occurring process where additional light seeded native species would then typically drift into these backdune areas and become established, but houses now stand in the place where this needed seed bank once grew. Unfortunately, the ease by which Am. beachgrass planting units establish and its short-term effectiveness have made it difficult to persuade landowners and municipalities to consider the use of other plant species for sand dune restoration.

Over the years (30 to 40 years) it has been observed that throughout its native range Am. beachgrass is susceptible to decline after six to eight years when artificially established. In response, the Cape May PMC has been focusing on developing additional plant species and educating and encouraging the public of the advantages of diversifying the plant species of their sand dunes rather than relying on the traditional beachgrass monocultures. This process has and will continue to result in additional dune species becoming commercially available in coming years through efforts of the Cape May Plant Materials Center.

American beachgrass (*Ammophila breveligulata*) is best adapted in the foredune where sands are constantly shifting and occasional overwash occurs. Interplanting other adapted species on the backside of the foredune, provides a seed source of additional plants to assist in the successional process. These species may include grasses such as; bitter panicgrass (*Panicum amarum*), coastal panicgrass (*Panicum amarum var. amarulum*), switchgrass (*Panicum virgatum*), saltmeadow cordgrass (*Spartina patens*), coastal bluestem (*Schizachyrum scoparium var. littoralis*), dune wildrye (*Elymus virginicus*) and forbs such as seaside goldenrod (*Solidago sempervirens*), partridge pea (*Cassia fasciculata*), evening primrose (*Onethera humifusa*), beach pea (*Lathyrus japonicus*), trailing wild bean (*Strophostyles helvola*). These plant species are available from specialized nurseries as potted and/or bareroot plants. Seeding technology is also being developed for many of these species. For instance, coastal panicgrass (*Panicum amarum var. amarulum*) has been successfully seeded between rows of beachgrass on beach replenishment projects in the Mid-Atlantic coast. Within three to five years, coastal panicgrass dominates much of the backdunes where beachgrass has lost vigor.

For dunes where adequate width is achieved (greater than 100 feet), shrubs such as bayberry (*Myrica pensylvanica*), beach plum (*Prunus maritima*), rugosa rose (*Rosa rugosa*), and winged sumac (*Rhus copallina*) can be added for long-term stabilization. These species are generally planted as containerized material. Shrubs need not be planted on a tight spacing as the herbaceous plants but rather scattered throughout the planting area in more natural groupings to provide a seed source.

The challenge in promoting a species rich restoration does not hinge on quality of plant materials. It seems most communities are content with the materials and methods traditionally utilized on their sand dunes until failure strikes. To correct pathological outbreaks, beachfront managers seek simple quick-fixes, rather than adjust planning philosophy. To assist beachfront communities in becoming aware of improved techniques for protecting their sand dunes with diversification methods will be a hard up-hill struggle. Sand dune restoration is not as simple as establishing a native community of plants, but involves managing the sand budget (the ocean gives it and takes it away). True coastal dune restoration must consider the natural dynamics of this ecosystem. The plant species inhabiting certain niches have evolved and adapted to these locations, and require specific environmental conditions to survive establishment and persist.

For years, residents and municipalities of the Mid-Atlantic & Southern NE coastal areas have accepted the use of American beachgrass as the sole protector of their expensive properties from ocean born storms. With thirty years of test and development experience, the USDA-NRCS Cape May Plant Materials Center staff has taken a position to change the approach and attitude the public has towards protecting their valuable coastal sand dunes. It will be challenging, but through creative marketing and promotional tactics the information hopefully will be accepted.

The first step in promoting a new and improved technology must be successful demonstrations for beach managers. However, demonstrations alone will not win the confidence and support of the public administrators. Continuing public education programs and presentations on sand dune restoration are needed to clarify and reinforce concepts initiated in demonstrations. The audience spoken to must be understood; most beach managers are not plant scientists or ecologists. These local and state administrators decide what will happen on their dunes. Helping these resource managers understand the concepts and forces of succession will assist them in grasping new ideas and approaches. The Cape May PMC staff is readily available to discuss and promote plant species diversity for the Mid-Atlantic and Southern New England sand dunes.

Application of a Simple Numerical Model to the Prediction of Seasonal Shoreline Changes in the Northeast

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The utility of a simple numerical model for predicting seasonal shoreline changes is investigated. The shoreline evolution model is based upon previous research, which indicates that beaches respond in an approximately exponential manner to steady state forcing. This characteristic exponential response has been observed in the lab (Swart 1974, Dette & Uliczka 1987) and is also characteristic of the shoreline evolution predicted by several numerical models for the case of increasing water levels and constant breaking wave conditions (Kriebel & Dean 1985, Larson & Kraus 1989). These empirical observations lead to an analytic equation of the form:

$$\frac{dy(t)}{dt} = k_{\alpha}\left(y_{eq}(t) - y(t)\right)$$

where k_{α} is a rate constant governing the speed of the process, and $y_{eq}(t)$ is the equilibrium response for a given forcing. The equilibrium response varies in time due to changes in the forcing, but is assumed constant on the interval over which the equation is applied. By making several restrictive assumptions, most notably that $y_{eq}(t)$ could be represented by a maximum shoreline response function y_{eq}, multiplied by a unit-amplitude function of time, f(t), Kriebel and Dean (1993) solved this equation analytically, but only for a limited number of forcing functions. A numerical approach is pursued herein, which allows several of the restrictive assumptions to be lifted.

In solving the proposed equation, the rate constant k_{α} is allowed to take on different values for erosion, k_e, and accretion, k_a, in order to account for the difference in the time scales of these two processes. The equilibrium shoreline response, $y_{eq}(t)$, is calculated using a modified version of the Bruun Rule, and reflects changes in both the incident wave conditions as well as simultaneous changes in the local water surface elevations. The two rate constants, along with a third unknown (relating the initial shoreline position to the equilibrium shoreline position), are evaluated numerically by minimizing the error between sets of model hindcasts and historical shoreline data.

The model has been applied to several data sets in Florida and California, and has proven to be successful in predicting the nature of the observed shoreline changes. The model outputs a time-series of shoreline positions, which is subsequently analyzed using various spectral analysis and filtering techniques. A spectral analysis performed on the predicted shorelines indicates that the most significant changes occur with a period of approximately one year. Several other significant peaks in the spectra are associated with periods of 6-months, 2.5-years, and 7-years. A filter is applied to the predicted shoreline time series to separate the underlying long period (>9 month) trends, from the chaotic short period oscillations. Analyses of the results indicate that while the model's overall accuracy is good, it is most successful at reproducing the more regular long period trends observed in the historical data sets.

The results of applying the model to several northeast datasets is presented herein. The model's usefulness and applicability to beaches of the northeast region will be discussed in context with local factors at each location. In particular the seasonal shoreline changes predicted by the model are compared with previous studies.

Application of the proposed model to the prediction of seasonal shoreline changes is but one of many potential uses for a simple, efficient, and accurate model such as the one presented. Ideally such a model could be applied in conjunction with real-time marine observations and forecasts to create an index capable of accurately predicting the erosion potential associated with severe weather conditions.

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New Shoreline Change Data and Analysis for the Massachusetts Shore with Emphasis on Cape Cod and the Islands: Mid-1800s to 1994

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The U.S. Geological Survey, Woods Hole Oceanographic Institution Sea Grant Program, and Cape Cod Cooperative Extension plotted a new, recent shoreline along approximately 1,000 miles of Massachusetts' ocean-facing shore. The shoreline used in this study was digitized from full-color, digital orthophotographs that were generated from National Ocean Service aerial photographs taken in 1994. Using GIS, the new shoreline was incorporated into an existing, historic shoreline change database previously generated by Leatherman (1984) and described in Benoit (1987), and O'Connell (1997). Transects were drawn perpendicular to the shorelines at 40 meter intervals along the shore and the data statistically analyzed utilizing an enhanced version of the Digital Shoreline Analysis System (DSAS) originally developed by the U.S. Geological Survey (Thieler & Danforth, 1994), and subsequently modified by Van Dusen (1996). In general, four to five historic shoreline positions mapped between the mid-1800s to 1994 were used to analyze shoreline changes along the Massachusetts shore. Seventy-six shoreline change maps with accompanying data tables and a Technical Report were produced (Thieler et al, 2001; Schupp, et al., 2001; O'Connell, et al, 2002). The project was funded by the Massachusetts Office of Coastal Zone Management.

The maximum time span of the data is 152 years (1842 – 1994). The results of this study reveal that approximately two-thirds of the Massachusetts shore analyzed is eroding, with 68% of the shore exhibiting a long-term erosional trend, 30% showing long-term accretion, and 2% showing no net change (Figure 1).

Cape Cod and the Islands of Martha's Vineyard and Nantucket somewhat mirror the statewide trend for changes along their linear length of shoreline (Figure 1). However, importantly, shoreline change rates vary considerably along the Massachusetts shore, as suggested by a standard deviation of 4.04 for the long-term average annual shoreline change rate of –0.58 ft/yr calculated for the entire 753 miles (30,354 transects) analyzed in this study. Forty-two percent of the data fall within the +/- 0.4 ft/yr uncertainty range based on Crowell, et al., (1991).

In some areas, erosion rates have accelerated based on a comparison study of previous data that was conducted in 1997 (O'Connell, 1997). The highest consistent (unidirectional) long-term average annual erosion rates are found along Nantucket's southwest shore at approximately –12 ft/yr, with a landward movement of the shoreline of up to 1,600 feet since 1846. However, many areas exhibit short-term trend reversals (accretion to erosion, and vice versa) in shoreline change. For example, Transect #29445 on Nantucket shows a relatively stable shore based on the long-term average annual shoreline change rate of +0.07 ft/yr. However, the shoreline accreted 215 feet between 1846 and 1887, then subsequently eroded 180 feet between 1887 and 1994. Thus, caution and professional judgment, as well knowledge of local coastal processes and human-induced shoreline alterations that interfere with sediment sources or sediment transport, must be factored in when interpreting and using long-term shoreline change rates, particularly in areas that exhibit trend reversals. Oftentimes, short-term rates may be more appropriate to use in trend reversal circumstances (Thieler, et al., 2001; O'Connell, et al., 2002).

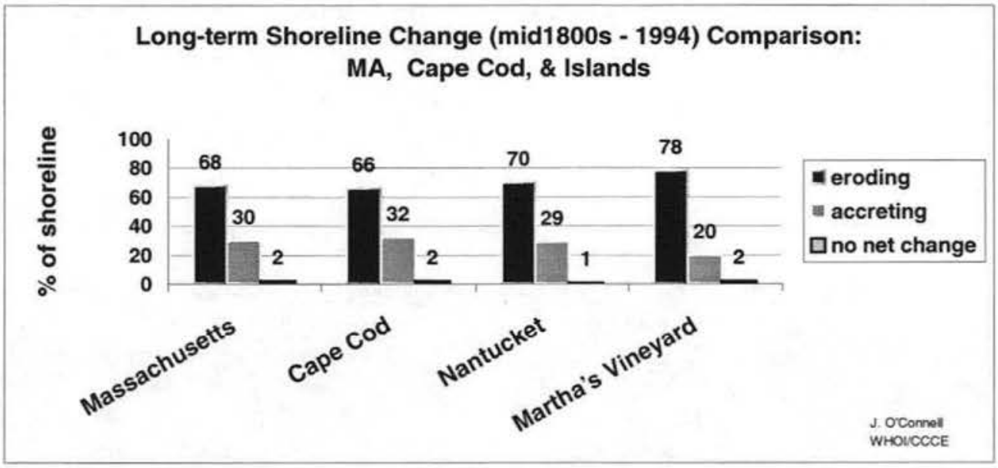

Figure 1. Percent of linear length of shoreline that is eroding, accreting, and show no net long-term shoreline change.

This presentation will describe the data sources used to map historic shorelines in Massachusetts, the methodology used to both plot a new shoreline and analyze the long-term historical data, the cautions necessary when interpreting and applying shoreline change data (particularly when trend reversals occur) with site-specific examples along the Massachusetts shore. Data analyses showing long-tern shoreline change trends and rates for Massachusetts, as well as the communities on Cape Cod, and the Islands of Martha's Vineyard and Nantucket will be presented.

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Beach & Dune Profiling Monitoring: A Massachusetts Citizen Monitoring Effort to Document Short-term Changes to Beaches and Dunes

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Understanding the dynamics of how beaches and dunes change seasonally, as well as pre- and post-storm, allows coastal homeowners and communities to determine appropriate and effective dune enhancement and restoration measures. Beach and dune profile monitoring using a modified Emory Method is a quick, low-cost method to quantify and understand the dynamics of beaches and dunes over time.

The Woods Hole Oceanographic Institution Sea Grant Program has begun coordinating a regional beach and dune profile-monitoring program, recruiting and training homeowner organizations, students, non-profit organizations, and municipal officials. The program is both an educational and baseline data gathering initiative. An instructional bulletin on how to set-up and conduct dune and beach profiles has been developed for volunteers (O'Connell, 2001). Presently, nine networked beach and dune profile monitoring programs are taking place in communities on Cape Cod and the Massachusetts South Shore. Dune and beach profile monitoring programs are ongoing in the towns of Hull, Marshfield, Duxbury, Sandwich, East Dennis, Eastham, Truro, Chatham, and Falmouth.

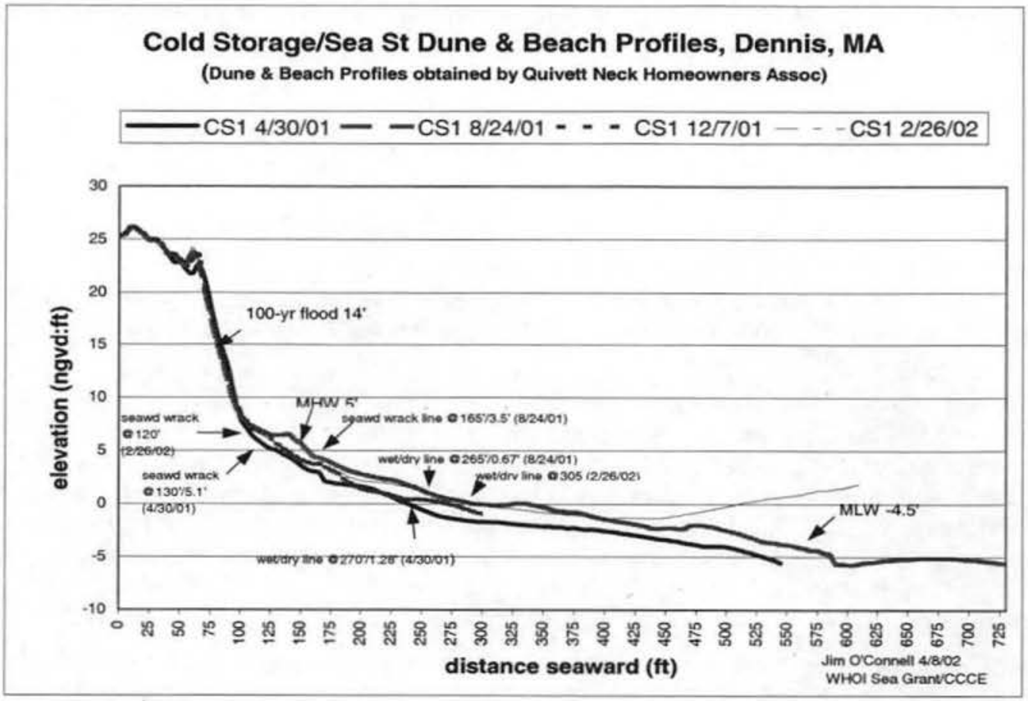
Beach and dune profile data have many applications. Profile data are essential in determining the level of storm protection an existing dune may provide, and in assessing the volume of sand that could be added to a dune to supplement storm protection to a specified level. In addition, coastal scientists use a feature on the beach, e.g. wet/dry interface or wrack line, to measure sequential shoreline changes from aerial or orthophotographs. These beach features, used to approximate the high water line, can migrate significantly from season to season, and month to month. Even day-to-day variations in the position of the high water line can be significant on gently sloping beaches.

Pajak and Leatherman (2002) measured a range of high water line positions of 33 meters, with the largest range in any given month of 13 meters in their study. Sequential beach profiles over a long period of time can quantify changes in the location of these beach features, and assist in more accurate shoreline change mapping. Sequential beach profile data obtained over a long period of time can also be used to correlate with long-term shoreline change data obtained from aerial or orthophotographs. The disclosure of long-term trends in shoreline position is a primary goal (of beach profiling), but it is also one that requires many years of regular observations (Bokuniewicz, 1998). The technique is also oftentimes used to monitor downdrift beaches as a permit condition to assess impacts from coastal engineering structures. Pre- and post-storm volumetric changes can also be quantified and assist in calibrating coastal models.

A beach and dune profiling program can provide an understanding of site-specific beach and dune dynamics and will foster improved communication between shorefront property owners, community officials, regulators, students, and other stewards of coastal resources. The data and understanding will also provide input to effective beach management plans.

An example of dune and beach profiles taken over a 10 month period, with specific beach features identified, i.e. 100-year flood elevation, wrack line, mean high water line, and the wet/dry interface, is shown in Figure 1.

This presentation will discuss the changes measured from several dune and beach profile monitoring programs over the past several years in communities in Massachusetts, and discuss the implications for application of the data.



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Shoreline Management for Conflicting Uses on a Retrograding Barrier Beach, Duxbury Beach, Massachusetts

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Duxbury Beach is one of the few long stretches of sandy shoreline along the Massachusetts south shore that is accessible to beach-goers, fishermen, and off-road vehicles. The beach is also the only road connection to two communities, Gurnet and Saquish.

Duxbury Beach is also a premier habitat for the shorebird, Piping Plover *(Charadrius melodus)*. The Piping Plover is an endangered species whose diminished population is attributable to loss of habitat. Plovers typically nest on exposed or partially-vegetated, flat sandy areas on beaches and overwash areas. They are particularly vulnerable to disturbance by off-road and human activities.

This retrograding barrier system began forming sometime prior to 3,700 yr BP. It is a sand-starved system with few new sources of sediment. In the present regime of accelerated sea-level rise, the resulting barrier is narrow and overwashed during every major coastal storm. Ground-Penetrating Radar (GPR) surveys indicate at least 18 paleo-tidal inlets have formed along the barrier, although none exists today.

Storm overwash impacts have resulted in a loss of access to the shore by the range of beach users, including local residents and emergency community vehicles. Subsequent to 1991, the beach has been intensively managed to prolong the stability of this barrier. Management efforts have included multiple generations of dune building since 1978 such that nearly all of the supratidal topography of the barrier is man-made. With the exception of the beachface, Duxbury Beach is an engineered barrier environment.

The inherent conflicts in the barrier beach's multiple uses are resolved by management of the resource. The most fragile use is shorebird habitat, which may be limited by 1) dune construction and dune planting necessary to prevent flooding and 2) interactions with beach users. Nonetheless, over the past ten years there has been an increase in the number of nesting sites. Presently, the major impacts to nests are natural factors including large predators such as foxes and coyotes; storm tides; and potential impacts by small predators.

Methodical data collection of shorebird patterns indicates that the largest number of shorebirds (averaging 75%) nest on the ocean side of the barrier. Nests are typically located 3 to 6 m away from dense dune vegetation. The birds nest in open areas with a range of substrates from gravel to sand. Frequently, nests are located with an element of camouflage such as a patch of gravel in sand or adjacent to an isolated cluster of vegetation.

All nests are provided protection, including signage, fencing, or exclosures with repellants. Whereas, the exclosures are successful at keeping large predators from the nests, they have no impact on the small mammals, such as mice, that may play a major role in predation. Monitors are stationed at each throughout each day to provide protection and collect data on the habits and fate of the fledglings. In addition to individual nest monitors, there are three uniformed Endangered Species Officers (ESO's) with police powers.

Nesting habitat is maintained through symbolic fencing seaward of the dune vegetation on the ocean side. This fencing keeps vehicles and pedestrians away from the upper backbeach, which has the added benefit of encouraging natural accretion on the engineered dunes. The loss of open overwash areas has been compensated by a range of techniques, including different dune-grass planting patterns with open spaces, ranging from large circles of grass with open spaces between, to extensive chevron patterns across foredunes. There is no evidence that these practices have encouraged nesting or provides safer passageways. In the past three years, artificial habitats have been created on the backbarrier by placing a layer of sand over vegetated areas. Successful artificial habitats which are at least 75 ft in diameter and 150 ft from other habitat areas have attracted nests. These artificial habitats have been maintained by adding a layer of sand, although removing vegetation (although problematic in other ways) can also establish a potential nesting surface. In the past two years, birds have also nested on the flanks and crests of newly-constructed dunes on the ocean side of the beach as well. The birds showed no preference for white natural dune sand compared to yellow imported sand.

The preferred feeding habitat is the bayside, which contains extensive saltmarsh areas, large wrack deposits, and exposed mud flats where most foraging takes place. Whereas, Plovers primarily nest in open areas on the ocean side, they regularly pass through heavily vegetated areas to cross the barrier. There has been no evidence of predation from birds crossing the vegetated barrier.

The intensive management of the beach through monitoring, data collection, enforcement, and controlling traffic and areas of beach use is focused on preserving and enhancing shorebird habitat. Over ten years of shorebird data, including four years of controlled data, is catalogued on a GIS base to identify trends or preferences in the shorebird population. These data are also maintained on a website to assist with data sharing and education of the public. This management has increased number of nests and successful fledges over the past decade without excluding the public from using much of the shoreline most of the time. As a result, we believe that we have built a level of cooperative understanding and support from the pedestrian and ORV populations using Duxbury Beach. The funds for this management come from the sale of off-road vehicle permits, so the successful multiple-use management of the beach is self-sustaining.

Beach Morphology Variation Along the Saco Bay Littoral Cell

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Sandy pocket-beaches comprise nearly 2 percent of the Maine coastline; however, they provide numerous economic, environmental, and recreational benefits. These beaches are typically confined into 'littoral cells' by tidal inlets and rocky headlands. Saco Bay, which includes approximately 8 miles of arcuate shoreline bound by Fletchers Neck and the Saco River in the south and the Scarborough River and Prouts Neck in the north, comprises the largest sand beach and salt marsh system in Maine (Figure 1). The primary source of sediment to the beaches in the bay is the Saco River (Kelley *et. al.*, 1995). The bay exhibits a dominant northerly-directed longshore transport direction (Barber, 1995; Kelley *et. al.*, 1989).

In 1869, the United States Army Corps of Engineers (Corps) initiated construction of shore-perpendicular jetties in an attempt to stabilize the inlet to prevent channel shoaling, thereby providing safe navigation for shipping. The structures have precluded the natural flow of sediment into the bay system by diverting sediment farther offshore and into deeper water, making the onshore movement of sediment a much more difficult process. Since construction, it appears that the federal jetties have caused accelerated erosion rates on the order of 2-3 feet per year at Camp Ellis, a small beachfront community situated adjacent to the northern jetty (Duffy and Dickson, 1995). Substantial environmental, economic, and social impacts have resulted. Erosion has claimed over 30 homes in the last 100 years at Camp Ellis, and the problem continues today, amplified each winter season by northeast storms that batter the southern Saco Bay shoreline.

Existing morphologic trends and topographic features along the Saco Bay shoreline were identified using Light Detection and Ranging (LIDAR) data provided by the NOAA Coastal Services Center. Shorelines from aerial photographs were digitized and shoreline changes determined. By combining shoreline changes with beach profile data, volumetric estimates of changes in the subaerial-to-intertidal beach were made, in addition to future possible positions of shorelines.

An analysis of morphologic variations and shoreline changes shows that the littoral cell can be divided into three general regions: 1) Hills Beach in Biddeford; 2) Camp Ellis Beach, Ferry Beach, and Kinney Shores; and 3) Ocean Park, Old Orchard Beach, Surfside, Grand Beach, and Pine Point. It appears that the majority of erosion occurs within Camp Ellis Beach and a portion of Ferry Beach in Region 2, while the majority of Regions 1 and 3 appear to be accretive in nature.

Based on identified morphologic trends, several recommendations for the management of Saco Bay's sandy beaches are presented. Finally, scenarios proposed by the Corps to alleviate the erosion problems experienced at Camp Ellis Beach are presented. The Corps, in association with local stakeholders, federal, and state agency personnel, have developed these solutions.

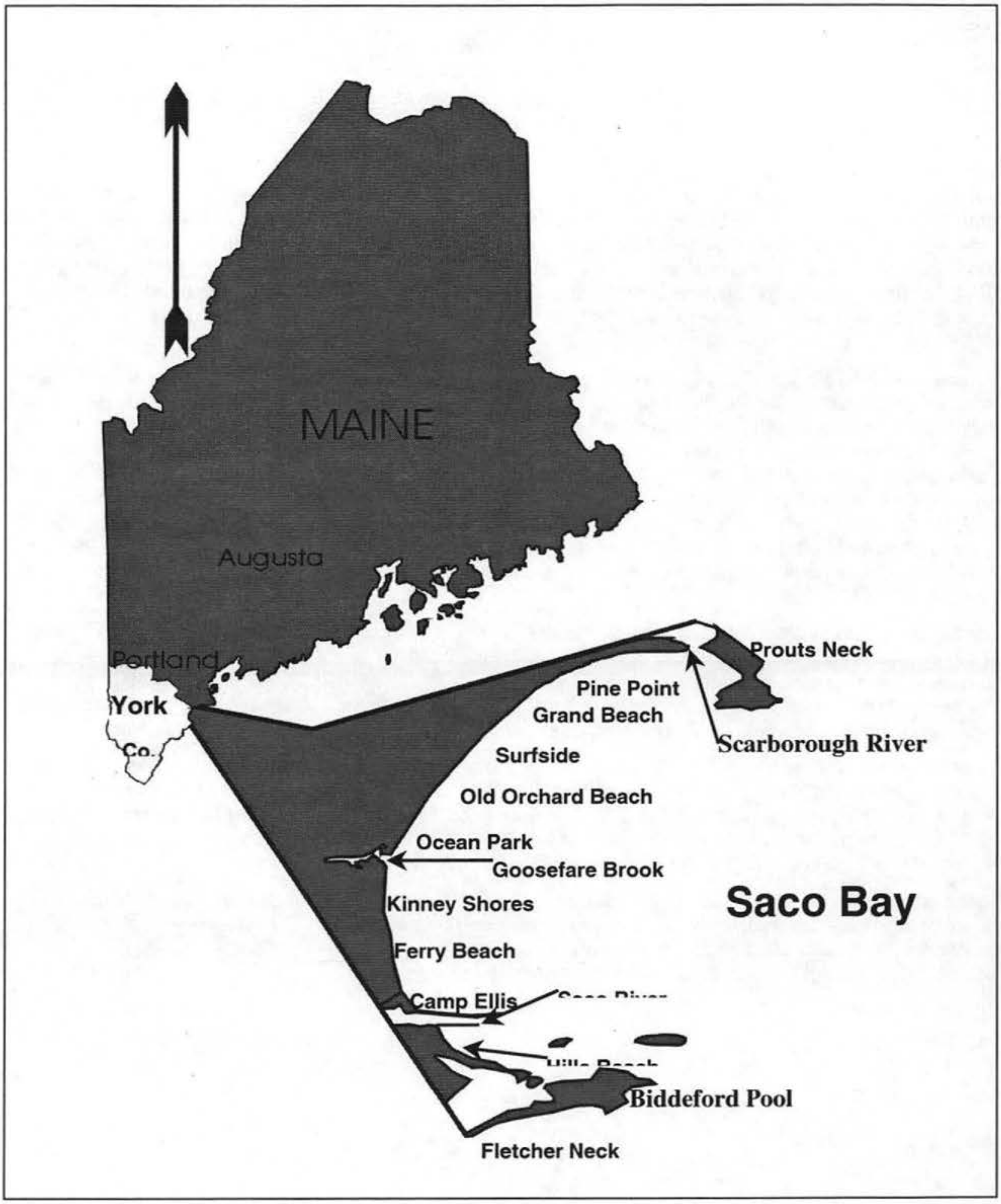

Figure 1. State of Maine site location map, including a close-up of the Saco Bay littoral cell, which is bound by Fletcher Neck to the south and Prouts Neck to the north. Camp Ellis is marked in red, on the north side of the Saco River.

Community Coast Watching

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CoastWatchers, is a volunteer-staffed shoreline change monitoring program, organized and run by the Waquoit Bay National Estuarine Research Reserve. Beginning in September 2000 we have since completed two annual monitoring seasons and will start our third in October 2002. The program is both scientific and educational, its purpose being to broaden community expertise while building a long-term coastline database. Its goals are to familiarize a team of local citizens in the science and methods of coastal geology and to charge it with the task of keeping precise track of shoreline changes along the entire three-mile stretch of the Reserve's southern coast bordering Vineyard Sound. The typical team member is retired and active in other community volunteer efforts. Every two months throughout the winter (October to April) the Reserve-supervised team of 6-10 volunteers carries out a series of measurements at 73 stations from Eel Pond Inlet at the western end of Washburn Island in Falmouth to the eastern boundary of the South Cape Beach State Park opposite Flat Pond in Mashpee. The field measurements, take a total of about 8 hours to complete, with the work usually divided over 2-3 days of one week. Data entry, management, and analysis are done by the Reserve staff at this time.

The study area is mostly barrier beach with beachgrass- (*Ammophila breviligulata*) covered aeolian sand dunes backed by protected bays and saltmarshes, with the exception of about 300 feet of hundred feet of exposed coastal bank or headland (glacial outwash deposit). The main tidal inlet to Waquoit Bay nearly bisects the study area and has 1000-foot long protective jettys on both banks. A 500-foot long paved town beach parking lot also fronts part of the study area. Unvegetated sand piles dumped by the town in front of the parking lot are frequently replenished throughout the winter months as these artificial dunes erode during storms. Otherwise, the rest of the study area is in a natural state, lacking revetments, groins, docks, or other shoreline protective structures.

At the start of program, base-stations or permanent benchmarkers were installed in the back barrier area (typically 100+ feet landward from the high tide line). These stations were positioned roughly parallel to the shoreline every 200 feet along the entire study area. The base-stations were surveyed relative to other permanent landmarks and also precisely located (Latitude, Longitude) using GPS. Our team uses two complementary survey methods to monitor shoreline change – both carried out near the time of low tide. The first, which we have devised ourselves, is dubbed here as the "Key Beach Feature" technique, and the other is a version of the standard "Emory-stick" beach profiling method.

The first method, designed for rapid yet dense spatial coverage, takes advantage of some prominent and commonly recognized landform features of the beachscape – particularly those found on sandy barrier beaches (Figure 1). Using a reel tape and traversing seaward in a perpendicular line to the shoreline, we make horizontal distance measurements starting from the back barrier base-station to four critical points on the beach: **1) Foredune Crest**: the crest (highest point) of the foredune ridge (the most seaward sand dune); **2) Vegetation Limit**: the most seaward position of beach vegetation (usually beachgrass, but sometimes shrubs in an eroding scarp); **3) Berm Crest**: the most seaward convex break in slope between the backshore (the relatively flat or low slope area above the mean high-tide line where you can safely lay your beach towel) and the beachface (the most sloping part of the intertidal, wave-active beach where you don't lay your beach towel for long unless you like it wet); **4) Toe of the Foreshore**: the sharp concave break in slope between the high-sloping beachface and the very low slope sub- or inter-tidal flat – at our site this location approximates the position of mean low water. Of these four features, the foredune crest position is most stable taking up to years to noticeably accrete seaward, though it can retreat landward quickly if the locale is undergoing severe erosion. The vegetation limit is also relatively stable but measurably responds at least seasonally to erosion or accretion – the fast spreading rhizomes of beachgrass colonizing the backshore areas of accreting areas, or receding back quickly during storms. In contrast, the berm crest and toe of the foreshore are quite dynamic features, responding on tidal to meteorological timescales with changing wave conditions and fortnightly tidal cycles. However, over the long-term (annual+) both the dynamic and the more stable features respond in approximate unison to changes in shoreline position.

The Key Beach Feature approach is somewhat crude (position precision is observer dependent and is about + or – 2 feet) but can be carried out in about 5 minutes or less per station by a single surveyor at each of the 73 stations 4 times a year – conveniently characterizing a large section of the coastline on a fine spatial scale. However, these data are horizontal measurements and do not directly gauge vertical or volumetric changes in the beach from which sediment budgets can be derived. To accomplish this we use the second method, a simplified but standard variation of beach profiling, which takes more time and so is carried out at fewer stations (about every 5th station or 800-feet apart). The crux of the Emory-stick method is the use of an unobstructed ocean horizon as a remote level line for establishing a local vertical datum (Figure 2). In one of its simplest versions, it only requires a reel measuring tape, a vertical surveying rod (we use a 15-foot rod, graduated in feet and inches) and only two people -- one for holding the vertical rod at predetermined horizontal distances from the base-station, and one, standing at the base-station and looking seaward, for precisely sighting the intersection of the ocean horizon line with the height of the vertical rod. The heights so measured (at regular horizontal intervals from the base-station) are then the vertical distance between the height of the sighter's eyes and the ground height at the location of the vertical rod. Assuming the ground elevation at the base-station to be the local datum, then relative heights at each horizontal interval can be obtained by subtracting the measured horizon height on the rod from the height of the sighter's eyes above the ground at the base-station (Local Ground Elevation = Sighter's Eye Height – Horizon Height).

There are any number of adaptations to these two beach survey methods that can be tailored to each locale for greater accuracy and convenience. The use of standard fill-out forms for the volunteers is helpful in both guiding and standardizing each survey, while making it easier to log the data for later archiving and analysis. Also, towards the idea that community monitoring should include ways to make the data and its analysis accessible to its members so that they can "see" the changes as they measure them, we have been developing some summary tables of past surveys for quick comparison in the field. These same tables also allow for quick quality control because large measurement differences from prior surveys raise an immediate flag to possible measurement error (or an important change) – which can then be corrected (or verified) in the field. Community efforts at monitoring shoreline change have the potential to be an important approach for acquiring detailed scientific knowledge about coastal evolution, while at the same time dispensing that knowledge within communities that need it to guide coastal resource management.

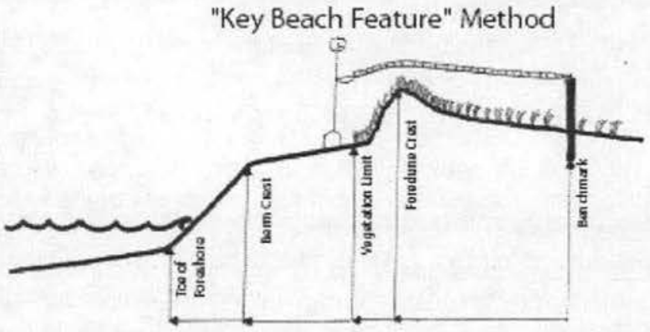

Figure 1

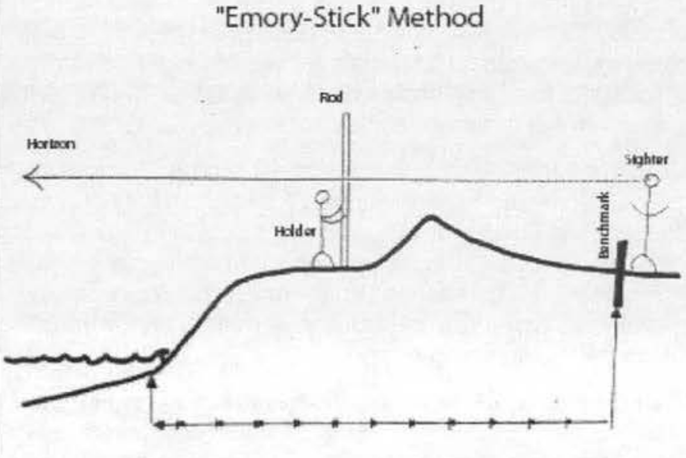

Figure 2

Restoration of Tidal Flows to Increase Bio-Diversity of Coastal Habitats

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Coastal habitats within New England and Cape Cod embrace a wide variety and diversity that range from shellfishing grounds, beaches, dunes, and salt marshes. The complexity of these ecosystems provides valuable areas for refuge, nesting, and foraging for wide variety of species. Many of these habitats act as nurseries for juveniles and as a result, degradation of these habitats may have a severe impact on many of the species we desire to observe, encourage to propagate, or simply harvest when coming to the coast.

Coastal habitats in New England and on Cape Cod are presently experiencing unprecedented pressure from developers, tourists, and existing developments. Historically there has been a public demand to provide access to beaches and wetlands for fishing, hunting, bird watching, and recreation. In order to satisfy public and private demands for access, many roads were constructed directly across the tidal wetlands. Many times the roads were built in an expedient manner with little regard for the impact on the wetlands habitat. As a result, many wetlands within New England have been severely impacted as a direct result of the public demand for access. One of the most notable impacts is the restriction of tidal flows to marshes that has resulted from the construction of roads across marshes and the tidal creeks that provide tidal waters to these systems.

The severity of tidal restrictions is widely varying and has occurred for a multitude of reasons; however, in some instances a section of tidal marshes may be completely cut off by an access road. In most cases, a culvert or series of culverts were installed to allow tidal waters to access the marsh through the road embankment. In general, culverts were not designed to provide unrestricted tidal flows. But were designed more to ensure the marsh drained over a period of days, so that the road embankment did not impound water that could turn anoxic and have offending smells.

Until recently, coastal habitats including salt marshes have been studied primarily from a biological perspective. These habitats are complex ecosystems that support a wide diversity of flora and fauna. Only recently has the effect of restricting tidal flows to these complex ecosystems been studied. The effects are wide-ranging and complex. Some of the effects are reduced tidal heights and decreased flushing. Reduced tidal flows may also decrease fish access, impound water, increase mosquito production, reduce sedimentation, decrease flushing/water quality, and increase probability of invasion by invasive species such as Purple Loosestrife and *Phragmites.*

Over the past several years there has been a desire to open these systems to unrestricted tidal flows. Restoring these impacted systems by reopening them to unrestricted tidal flows may restore the marsh system but have unacceptable effects on the community infrastructure that may have developed around the resource as the result restricted tidal flows. Additionally, many of the coastal ecosystems are linked and as result plant and animal communities may have transitioned from tidal to fresh water communities.

Two salt marsh systems were examined to assess the impacts of restoring tidal flows. The two marshes are located in Scarborough, Maine, and Mashpee, Massachusetts. The investigations collected field data and numerically modeled the tidal systems to determine if tidal restrictions existed within the marsh, the best method restore tidal flows, the impact of restoring tidal flows, and the potential impact to the vegetative communities. The results of the study showed that restoring the tidal flows to the salt marsh would increase biodiversity and reduce the invasion of invasive species.

Microbial Source Tracking: New Technology for a Persistent Water Quality Problem in Two Southern Maine Coastal Watersheds

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Introduction

This presentation will:

- discuss the public health threats and economic impact of bacterial contamination to swim beach water quality and clam harvesting,
- describe the limitations of conventional fecal testing methods,
- provide an overview of Microbial Source Tracking (MST) as an innovative method of investigating fecal-related pathogens in riverine, estuarine and marine waters,
- detail the specific results of ribotyping analyses conducted on environmental samples collected from two coastal watersheds in southern Maine.

Bacterial Contamination's Regional and National Impact

According to EPA, nonpoint source (NPS) pollution is the primary water quality problem in the US today, causing forty percent of all nationally surveyed waters to be unfit for swimming or fishing (USEPA - http://www.epa.gov/OWOW/NPS/facts/point1.htm). Much of this NPS pollution is fecal-related bacteria, which are associated with risk of disease from swimming in or consuming shellfish from these waters. Also according to EPA, a third of all Americans visit coastal areas each year, making a total of 910 million trips while spending about $44 billion. Beach tourism is a significant part of these coastal economies.

There are several potential sources of these bacteria: fecal matter from wildlife or pets that accumulates on land to be washed into waterways during storms or snowmelt; leaking septic systems or sewer pipes, particularly during heavy rains; overboard discharges from homes or boats; and municipal wastewater facilities that may be overwhelmed by elevated influent levels due to heavy precipitation.

Limitations of Conventional Fecal Testing Methods

When using standard testing methods, bacteria from distinct host species are indistinguishable. There are at least four commonly used tests for bacteria in water. Total coliform is not fecal specific. Fecal coliform has poor correlation with gastrointestinal illness. *E. coli* does not survive as long as viruses in marine waters. Enterococcus is found in significant levels in feces of humans and animals, but none of these test methods differentiate animal from human sources when routine analyses are performed. Without identifying the origin of the contamination, mitigation activities may be misdirected or ineffective.

Overview of Microbial Source Tracking

Microbial Source Tracking (MST) refers to a group of molecular, genetic and chemical methods that identify specific strains of bacteria or viruses in the environment and attribute them to likely host species. These techniques have multiple applications, including identifying the source(s) of indicator bacteria as human, domestic animal, wildlife, or to support sanitary surveys of bathing beaches and shellfish growing areas.There are two basic groups of MST methods: genotypic and phenotypic. Genotypic methods (such as ribotyping and polymerase chain reaction) distinguish among bacterial and/or viral samples based directly on their genetic makeup. Phenotypic methods distinguish among bacteria based on secondary characteristics (such as antibiotic resistance). Both methods use a library of bacteria from known sources for correlation with environmental bacteria.

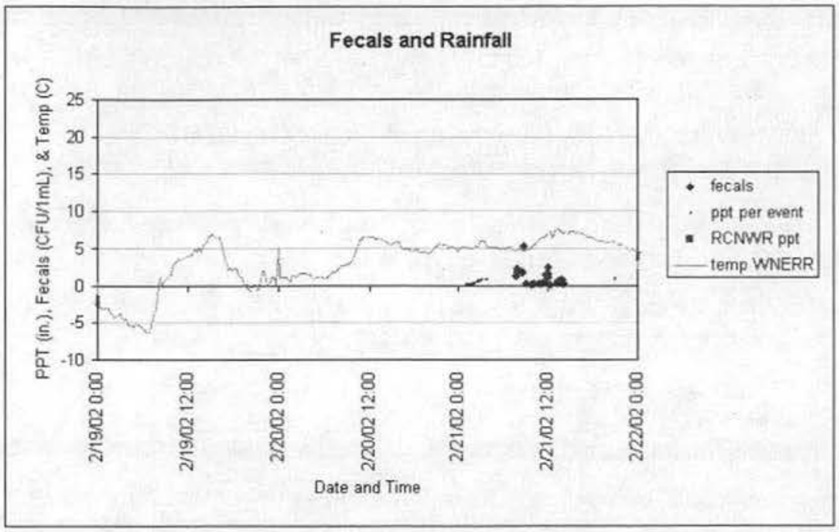
Microbial Source Tracking in Two Southern Maine Coastal Watersheds

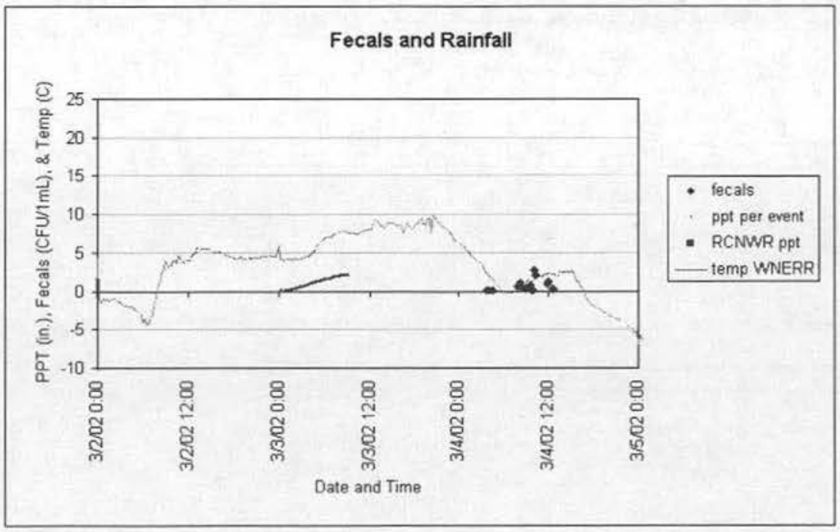
The primary goal of this project is to explore the use of one particular genotypic MST technique (rRNA ribotyping) to better identify the sources of fecal bacteria found in the Webhannet Estuary watershed and the Little River Estuary watershed in Wells, Kennebunk and Sanford, Maine.

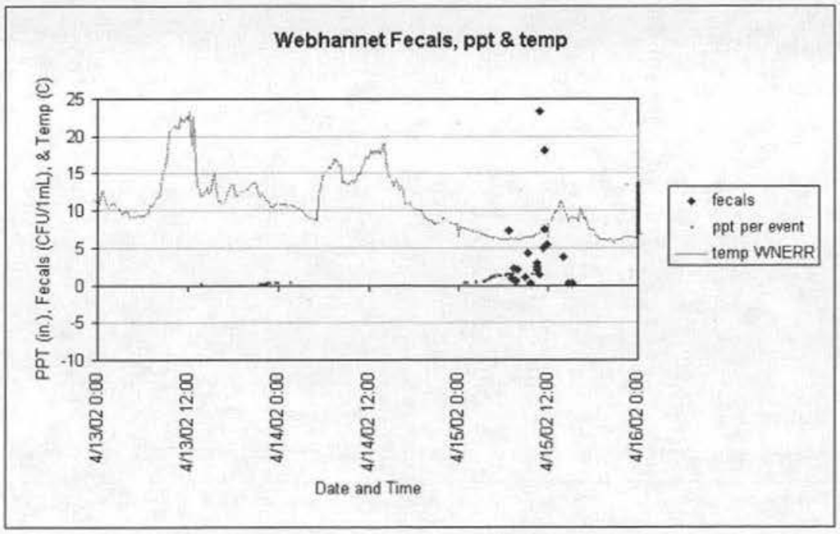
Project staff at the Wells National Estuarine Research Reserve collect environmental samples of fecal material from targeted mammalian and avian species in the watersheds to develop a known-source reference library. Water samples are collected twice per month from the riverine, estuarine and marine waters and processed via membrane filtration to enumerate fecal coliform and *E. coli* bacteria . Bacteria are then isolated from samples with moderate and high colony counts. Isolates are then sent to Jackson Estuarine Lab at the University of New Hampshire and genetically analyzed through ribotyping. In this process, isolate DNA is extracted and cut by restriction enzymes, separated by gel electrophoresis and then probed for detection of highly conserved rRNA genes. The resulting banding patterns form a "genetic fingerprint" for each unknown isolate, which is compared to known-source library samples. Final source attribution is accomplished through statistical analysis of the similarity of banding patterns.

MST can potentially provide regulatory agencies and municipal officials with specific information as to the origins of NPS; thus promoting more effective remediation planning, resulting in improved swim beach water quality and safer shellfish consumption.

This project began in September 2001, and is currently underway. By September 2002, all sampling in the Webhannet watershed will be complete, and certain MST results will be available to resource managers by October 2002. Therefore, initial results of ribotyping analyses would be presented in our session.







Figures at left describe selected preliminary results of fecal coliform bacteria in streams of the Webhannet Estuary watershed (Wells, Maine) relative to air temperature and precipitation.

fecals: fecal coliform bacteria (CFU per 1 mL) from membrane filtrations.

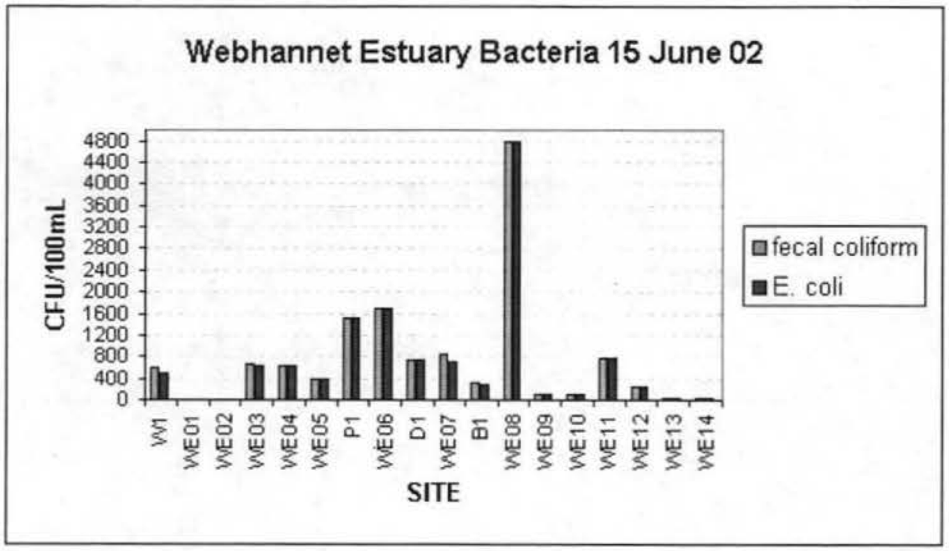
ppt per event: precipitation levels recorded at Wells NERR.

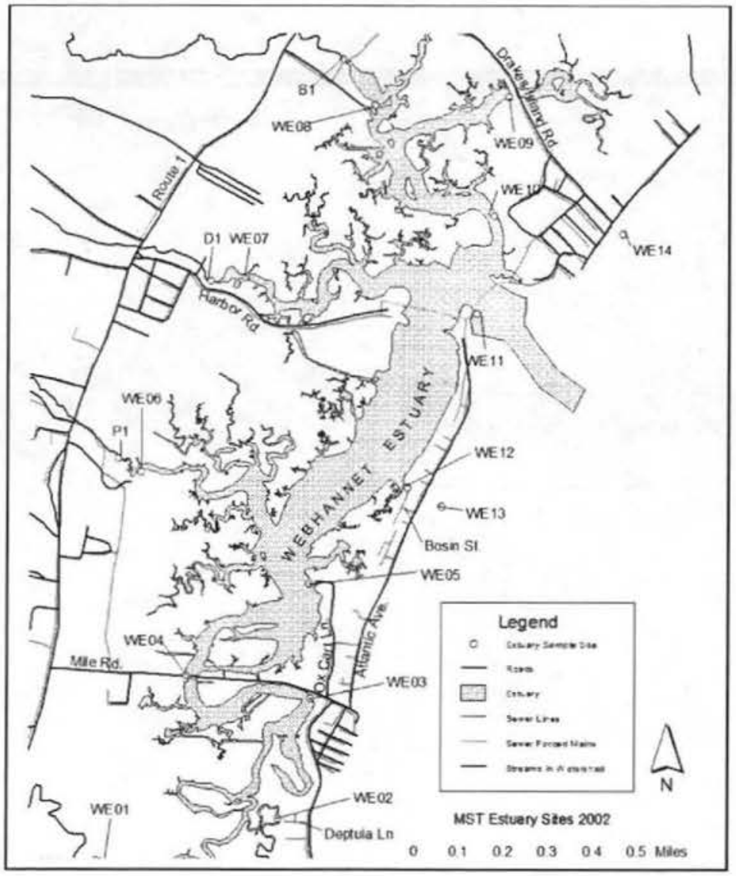
temp WNERR : temperature recorded at Wells NERR.

RCNWR ppt: precipitation recorded at Rachel Carson NWR (does not appear on these graphs).

Figures below describe results of bacteria testing in the Webhannet Estuary and the four main streams that feed it. Both *E. coli* and fecal coliform bacteria are enumerated for each site. When sample WE08 was taken, 47 goose droppings were noted adjacent to the sample site.

The sites codes are as follows: **W1** = mouth of Webhannet R., **P1** = mouth of Pope's Creek, **D1** = mouth of Depot Brook, **B1** = mouth of Blacksmith Brook. **WE** sites are all in the Webhannet Estuary.





Regulatory Aspects of Shoreline Erosion and Stabilization Projects in Massachusetts

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This paper will focus on the environmental permitting processes and realities of coastal beach preservation and shoreline stabilization/erosion control techniques advanced by both private property owners and governmental entities under the Massachusetts regulatory program, both at the State and the local municipal levels. These permitting efforts will review the State regulatory programs under the Massachusetts Wetlands Protection Act, the Chapter 91 Waterways Regulatory Program, the Massachusetts Environmental Policy Act Program and Coastal Zone Management Consistency Review and also the local permitting under Home Rule by municipal Conservation Commissions under local Wetlands Bylaws. The paper will review traditional shoreline protection "hard" structures such as seawalls, revetments and groins and also other "soft" stabilization techniques that have been utilized in the recent years in Massachusetts. Additionally, a review of more innovative technologies that are being permitted both in other parts of the United States and overseas and which are presently being considered for various project sites in Massachusetts will be covered. These more innovative systems both involve stabilization/protection efforts at the coastal bank, dune or on the coastal beach, and also in the subtidal zone including wave energy dispersion technologies and sand mining efforts.

As Massachusetts has an intensive regulatory program at the both the State and the local level (in addition to the Federal level), this review will discuss the difficulties in any beach stabilization/erosion control program that may be advanced by property owners or governmental entities, whether to protect private property, roadways, airports, wastewater treatment facilities or other significant coastal developments. The issue of coastal protection is of significant concern in Massachusetts at this time and has been the topic of much review and discussion, including the January 2001 workshop held through the Woods Hole Oceanographic Institute entitled "Can Humans and Coastal Landform Co-exist?," of which author of this paper was one of the presenters in a mock project presentation dealing with permitting of proposed coastal projects in Massachusetts. The concept of "coastal landform systems stability" as advanced by WHOI will be considered in its relationship to the existing regulatory programs that exist at the State and local level in Massachusetts for these projects.

Additionally, this paper will review existing and forthcoming applications within the State and local regulatory programs and the viable permitting options that exist. Due to the significant erosion impacts that have occurred in Massachusetts in the recent few years, including to the south coast of Cape Cod and Nantucket, of which the author has been actively involved for a number of property owners, this discussion will be extremely timely in discussing the present permitting climate in Massachusetts and also what innovative technologies are presently be considered. Additionally, the topic of constitutional takings law under Federal and Massachusetts law will also be broached within this paper but is not considered a primary discussion point.

In terms of the actual presentation at the conference, it is anticipated that actual or modified mock examples of permitting projects will be utilized. Given the pressing need of such projects to advance and in looking at what options are available for beach preservation and coastal erosion, including onshore coastal bank, dune and beach installations, energy dispersion techniques in the wave zone and possible offshore sand mining operations, relevant examples involving pressing regulatory and property rights issues will make for a lively and timely presentation.

Index of Authors

First Authors are in **Bold**

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