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Coastal Landform System Sustainability Project:

An Analysis of Activities Permitted on Coastal Landforms on Cape Cod, Massachusetts in 1999

by

James F. O'Connell

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

August 2000

Technical Report

Funding was provided by the Sea Grant Program
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Executive Summary

In their natural state, the coastal landform systems of Cape Cod are self-sustaining. However, recognition that humans have become intrinsic agents in the evolution of coastal landscapes is significant. There is a great need to understand how individual actions on a small scale (lot-by-lot) basis affect the sustainability of coastal landform systems, such as coastal dunes, beaches, coastal banks, barrier beaches, saltmarshes, and coastal floodplains. However, there are few investigations relative to this scale.

This study illustrates the vast extent of human alterations to coastal landforms on Cape Cod. As a result of analyzing 318 Orders of Conditions issued for activities permitted on and adjacent to coastal landforms in all 15 Cape Cod towns in 1999, it documents and quantifies the gains and losses to coastal landform system sustainability.

The study documents the types of activities presently taking place on and adjacent to our coastal landforms and their potential affects, and potential mitigation being required by local commissions to minimize these affects. It also documents the trade-offs and balances oftentimes necessary in the application of performance standard based regulations governing activities proposed on coastal landforms. Because our quantitative understanding of coastal landform function is still evolving, particularly on a small-scale lot-by-lot basis, many decisions are oftentimes made using best professional judgement (if available) without the predictive capability to know what the impact will be to the applicant's or neighboring property and resources.

It is hoped that the results of this study will assist local, state, and federal coastal resource managers and regulators, as well as the public, in gaining insight into the interactions of human activities and natural coastal landform system function leading towards improved coastal resource management. The project participants stated that during the course of this study the sharing of information among them was invaluable. It is hoped that the sharing of information in this study with a broader audience will also be utilized for improved coastal landform system management.

Introduction and Purpose

In the past, waves, tides, relative sea level, sediment size, sediment sources and sinks, and landform type controlled the configuration of our coasts. Now human actions are a significant factor, on par with natural forces in many places, in controlling the shape and function of our shores and coastal landforms. In fact, human activities are the dominant short-term controlling factor in many places.

The environmental, recreational, and aesthetic values of beaches, dunes, barrier beaches, coastal banks, saltmarshes, and coastal floodplains to the local, state, and national economy and culture are clearly recognized by the public as well as by the government agencies that enforce a wide variety of regulations designed to protect these resources.

But despite a formidable array of protective measures, these critical resources appear to be undergoing a process that perhaps can best be described as 'unsustainable' resource development (i.e., human alterations that lessen the natural value of the resources for future generations). Examples include seawall and revetment construction that, on an eroding shore, will eventually eliminate the fronting beach, and home construction in a dune field that will alter the form of the dune, eliminate stabilizing vegetation, and alter winds and, thus, depositional patterns of dune sands with unpredictable impacts to the dunes' natural beneficial function. It appears that most human actions when developing on coastal landforms are designed to reduce landform mobility in an effort to protect buildings and infrastructure, although mobility may be increased during construction phases when stabilizing vegetation is removed (Nordstrom, 1999).

On the other hand, some communities are undertaking or investigating procedures designed to re-establish sustainability of their coastal landforms as a result of previous activities. For example, removing roads on barrier beaches to allow dune growth, thus permitting the natural landward migration of barrier beaches (Figure 1, Page 6), or requiring elevation of structures in dune fields to allow dune sands to migrate and continue to be sediment sources for adjacent dunes.

Activities and permit conditions associated with development and use of coastal landforms that attempt to minimize or reduce alterations to the beneficial function of the coastal landform system appear to be gaining wide attention. However, to adequately protect our coastal landforms and more importantly to preserve the beneficial functions of the overall coastal landform system for future generations we must know how coastal landforms evolve naturally and how our present activities are affecting their evolution (i.e., sustainability).

Are our activities on coastal landforms detracting from or adding to their beneficial functions on a short- and/or long-term basis? Where does Cape Cod stand in this regard? Most observers say that the area is experiencing a net loss of resource sustainability, but the data required to substantiate the statement do not exist, not to mention the data required to determine the rate of change of sustainability.

Figure 1

Thus, the goals of the Cape Cod Coastal Landform System Sustainability Study were to:

1. Quantify, on a town by town basis, the gains and losses of Cape Cod coastal landform system sustainability resulting from decisions of local resource management and regulatory agencies;
2. Identify the state and local policies and/or regulations (or lack thereof) that have resulted in these gains and losses;
3. Describe permit conditions and/or technical approaches that may assist in maintaining coastal landform system sustainability; and,
4. Identify future research needs that will add to our understanding of the interaction between coastal landform function and human actions that may assist in optimum management of our coastal landform systems.

Framework and Background

'Mobility' is the key to ensuring the value of coastal environments for ecological and most human use values, in the sense that the dynamic nature of beaches and dunes (and other coastal landforms) is responsible for their physical characteristics and aesthetic appeal. It is a paradox that stability of beaches (and other coastal landforms) becomes the goal once humans attach specific values to them. Attention is often directed toward preserving the inventory of natural features rather than the processes that created them (Nordstrom, 1998).

In their natural state, all coastal landforms (including banks, beaches, dunes, barrier beaches, saltmarshes, and land subject to coastal storm flowage) provide beneficial functions and values. These beneficial functions and values include storm damage prevention and flood control for landward resources and structures, wildlife habitat, pollution prevention, recreation, ecological and aesthetic values. In their natural state, coastal landforms are self-sustaining and, thus, naturally maintain these values and functions. That is, coastal landforms evolve by changing shape and volume, and adjusting to the natural forces of winds, waves, tides, and currents that are acting upon them. They exist in a state of *dynamic equilibrium* with these forces until these forces change. A new balance or equilibrium is then achieved. This results in their natural beneficial functions remaining optimized/maximized.

On the other hand, human desire to live along the shore and utilize its resources has resulted in structures and infrastructure being located in hazardous or sensitive coastal locations, such as erosion-prone areas or areas subject to storm waves and surge (FEMA-mapped velocity zones), and flooding. As a result, maximum protection from storm surge, flooding and erosion, beyond what a natural coastal landform may be able to provide, is oftentimes desired. For example, dunes may not be able to provide the level of protection to landward buildings or structures or naturally rebuild to pre-storm conditions quickly enough as desired by landward property owners.

Numerous technical studies have measured and described the interaction of coastal processes and coastal landforms, thereby documenting coastal landform evolution. Thus, the fundamental scientific principles necessary to understand the beneficial functions of coastal landform systems are reasonably well known. However, little attention has been devoted to differences in coastal evolution at the scale of individual landforms (Nordstrom, 1998).

Nordstrom (1998; 2000) provided a detailed compendium of human activities that alter coastal landforms with a brief explanation of the landform characteristics that were altered by each activity. His conclusion was 'mobility' (of coastal landforms) was the key to ensuring the value of coastal environments. However, a quantification of the gains and losses of coastal landform sustainability (i.e., their natural beneficial functions) due to human alterations of these coastal landforms was not conducted. He suggested that it is important to examine activities in communities that have adopted successful compromise solutions that accommodate both human uses and landform mobility.

In addition, a study evaluating the effectiveness of coastal zone management programs nationwide was recently completed (Hershman, et al., 1999). As a part of that comprehensive study, state coastal program effectiveness in protecting natural beaches, dunes, bluffs, and rocky shores was undertaken (Bernd-Cohen and Gorden, 1999). The conclusion of that study, based on process indicators and limited case examples, was that coastal programs are, for the most part, effectively addressing the goal of protecting beach and dune resources. However, importantly, it revealed that "coastal state and federal agencies are not routinely collecting the types of outcome data that were identified as valuable in measuring on-the-ground results in achieving national resources protection objectives." On-the-ground outcome indicators were too sparse to allow an outcome effectiveness determination of coastal landform (system) sustainability.

This study is an important first step towards filling this gap.

Selected Massachusetts Policies and Regulations Governing Activities on Coastal Landforms

In order to appreciate the results of this coastal landform sustainability study and the criteria by which ratings for permitted activities in this study were applied, important selected regulations which guide local decisions for activities on or adjacent to coastal landforms will be briefly discussed.

In response to natural forces, the ability of coastal landforms to erode, reshape, and migrate landward and laterally, actions that optimize their beneficial functions, is the basis for environmental policies and regulations that govern activities on or adjacent to coastal landforms in Massachusetts (Giese and Smith, 1980).

The principal suite of regulations and policies required to be met for proposals on or adjacent to coastal landforms in Massachusetts are the state Wetlands Protection Regulations (310 CMR 10.00 et seq.), local wetland protection by-laws, and the Massachusetts Coastal Zone Management (MCZM) Program Policies. In addition, the state Wetlands Conservancy Program has mapped wetlands, including coastal landforms, and has placed restrictions on specific activities in these areas to preserve their public interests. On Cape Cod, the Cape Cod Commission's (regional planning agency) Regional Policy Plan contains strict standards for large development projects, or projects located in environmentally sensitive areas.

MCZM policies include criteria for the protection of coastal landforms that reduce the potential for coastal hazards and are considered state environmental policy for the coastal zone. As a 'networking' CZM program, the applicable MCZM policies are considered part of the application of the state Wetlands Protection Regulations. The interpretation and application of the Wetlands Protection Regulations (herein after referred to as WPRs) shall be consistent to the maximum extent permissible with the policies of the MCZM Program (310 CMR 10.22). Regulatory jurisdiction of the MCZM Policies, however, only coincide with federal jurisdiction (or federal activities affecting the coastal zone) which, for the most part, do not extend landward of the high tide line. Thus, the WPRs and local wetland bylaws are the most widely applicable regulatory standards that govern activities on or adjacent to coastal landforms and therefore were the primary focus of this study.

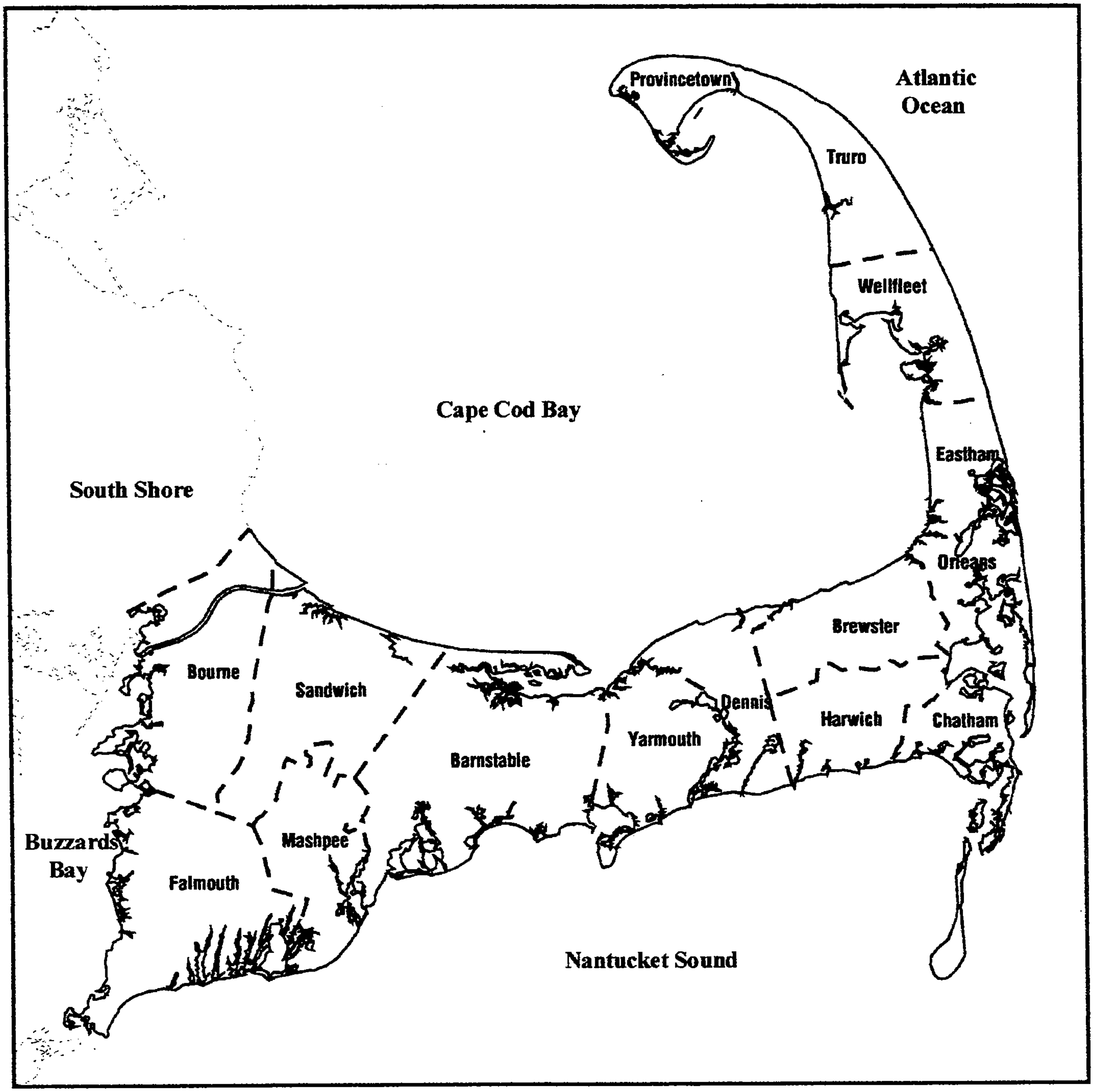
The WPRs protect the critical characteristics (beneficial functions) of wetlands, including in part, coastal banks, beaches, dunes, barrier beaches, saltmarshes, and land subject to coastal storm flowage (the 100-year coastal floodplain). The standards of the WPRs are intended to ensure that development along the coastline is located, designed, built, and maintained in a manner that protects the public interests in coastal resources (310 CMR 10.21), including coastal landforms.

As a home rule state, local communities in Massachusetts are required to adopt and administer the state wetlands regulations as 'minimum' standards. At the local level, the community's conservation commission administers the WPRs. The commission is a volunteer board of three to seven members appointed by the selectmen or city council. On the state level, the Department of Environmental Protection (DEP) oversees administration of the WPRs. The local conservation commission ensures that proposed activities will not alter resource areas and diminish the public interests (beneficial functions) they provide by reviewing projects on a case-by-case basis according to the regulations (DEP, 1997). The regulations govern many types of activities in resource areas, including for example, vegetation removal, regrading, construction of houses, additions, decks, seawalls, walkways, piers, and docks. Basically, any type of activity that may alter a resource area in any way is subject to review by the local conservation commission.

Each local conservation commission generally retains a conservation commission agent or administrator. This agent generally visits each site and prepares site observations and recommendations for the commission's permit decision when an application for a permit is filed. The commission then issues a permit known as an Order of Conditions. Given the level of involvement, it was determined that the most appropriate participants for this study would be the conservation commission agents and administrators. Each of the agents and administrators in the 15 towns on Cape Cod (Figure 2, Page 10); agreed to participate and are listed in Appendix A (Page 42).

Below is a description of the coastal landforms addressed in this study. A brief summary of the WPRs standards, including the protected critical characteristics and public interests that conservation

Figure 2



Cape Cod Towns

commissions use to permit (generally with conditions) or deny an activity on a coastal landform or within its buffer zone (an area within 100 feet of a coastal landform) is also included.

Characteristics of Selected Coastal Landforms Protected by Regulations

Coastal Bank (310 CMR 10.30)

Definition: The seaward face or side of an elevated landform, other than a coastal dune, that lies at the landward edge of a coastal beach, land subject to tidal action, or other wetland.

Public interests: Storm damage prevention; flood control.

Critical characteristics: One type of coastal bank identified in the WPRs is a coastal bank subject to vigorous wave activity. This type of coastal bank serves as a major continuous sediment source for coastal beaches, coastal dunes, and barrier beaches. This is a naturally occurring process necessary to the continued existence of beaches, dunes, and barrier beaches that, in turn, dissipate storm wave energy, thus protecting structures and coastal wetlands landward of them from storm damage and flooding. Thus, its protected critical characteristic is its *ability to erode* and provide sediment to other coastal landforms.

A second type of coastal bank identified in the WPRs is a bank that is not subject to vigorous wave action, but instead erodes primarily as a result of wind and rain runoff. Its height and stability acts as a buffer or natural wall, which protects uplands areas from storm damage and flooding. Thus, the *stability* of this type of bank that protects landward resources is its critical characteristic, primarily protected by preserving its vegetative cover. Elevated walkways are encouraged in the regulations for this resource.

Coastal Dunes (310 CMR 10.28)

Definition: Any hill, mound, or ridge of sediment landward of a coastal beach deposited by wind action or storm overwash. Coastal dune also means sediment deposited by artificial means and serving the purposes of storm damage prevention and flood control.

Public interests: Storm damage prevention, flood control, and protection of wildlife habitat.

Critical characteristics: The ability to erode in response to coastal beach conditions, volume, form - which must be allowed to be changed by wind and natural water flow, vegetative cover, ability to move landward and laterally, and bird nesting habitat.

Coastal Beaches (310 CMR 10.27)

Definition: Unconsolidated sediment subject to wave, tidal, and coastal storm action which forms the gently sloping shore of a body of salt water and includes tidal flats. Coastal beaches extend from the mean low water line landward to the dune line, coastal bank line, or seaward edge of existing man-made structures, when the structures replace one of the above lines, whichever is closest to the ocean.

Public interests: Storm damage prevention, flood control, and protection of wildlife habitat. Tidal flat areas of coastal beaches also include protection of marine fisheries and land containing shellfish.

Critical characteristics: Volume (quantity of sediment), form, ability to respond to wave action, and distribution of sediment grain size, water circulation, water quality, and relief and elevation for tidal flats.

Barrier Beaches (310 CMR 10.29)
Definition: Narrow low-lying strip of land generally consisting of coastal beaches and coastal dunes extending roughly parallel to the trend of the coast. It is separated from the mainland by a narrow body of fresh, brackish, or saline water of a marsh system. A barrier beach may be joined to the mainland at one or both ends.
Public interests: Storm damage prevention, flood control, marine fisheries, wildlife habitat, and protection of marine fisheries and land containing shellfish.
Critical characteristics: Ability to respond to wave action, including storm overwash sediment transport, and all other critical characteristics of beaches and dunes.

Saltmarshes (310 CMR 10.32)
Definition: Coastal wetland that extends landward up to the highest high tide line, that is the highest spring tide of the year, and is characterized by plants that are well adapted to or prefer living in saline soils. Dominant plants within saltmarshes are salt meadow cord grass (*Spartina patens*) and/or saltmarsh cord grass (*Spartina alternaflora*). A saltmarsh may contain tidal creeks, ditches, and pools.
Public interests: Storm damage prevention, protection of marine fisheries and wildlife habitat, land containing shellfish.
Critical characteristics: Distribution and composition of vegetation, substrate (peat), and productivity.

Land Subject to Coastal Storm Flowage (LSCSF) (i.e., 100-year coastal floodplain). While LSCSF is listed as a protected coastal landform (wetland resource) in the regulations, there are no performance standards, definition, public interests, or critical characteristics stated. A task force was, however, convened to address this lack and in 1995 submitted 'recommendations' to the state for consideration (O'Connell, 1997). The following is excerpted from those recommendations.
Definition: Land subject to any inundation caused by coastal storms up to and including that resulting from the 100-year flood, surge of record, or flood of record, whichever is greater. The seaward limit is mean low water.
Public interests: Storm damage prevention, flood control, prevention of pollution, and protection of wildlife habitat.
Critical characteristics: Topography, soil characteristics, vegetation (including composition), erodibility, permeability, ability to dissipate storm wave energy, flood volume storage in hydraulically restricted areas, and ability to allow other protected wetland resource areas and coastal landforms to migrate landward in response to relative sea level rise.

Project Methodology

To achieve the goals of the Coastal Landform System Sustainability Project, a questionnaire was developed (Appendix B, Page 43) to produce the data necessary to estimate the gains and losses of coastal landform sustainability. The conservation agent for each town completed a questionnaire for each activity permitted by the community's conservation commission. In this project, 318 Orders of Conditions (permits) issued for activities on or adjacent to coastal landforms by the participating 15 Cape Cod towns in 1999 were analyzed.

The questionnaire includes identifying data, such as applicant name, address, map and parcel, project description, and date of permit, and then poses questions relating to possible impacts from the activity on coastal landforms. While it is recognized that coastal landforms provide a myriad of beneficial functions, such as storm damage prevention/reduction, flood control, wildlife habitat, recreational, and aesthetic and intrinsic values, only the physical functions of storm damage prevention/reduction and flood control were evaluated in this study. It was considered that if these functions are affected, then all others are as well.

As noted on the questionnaire in Appendix B, one to three specific questions were developed for each coastal landform type (i.e., one question for coastal bank, two for coastal beach, three for coastal dune, etc). The questions relate to each coastal landform characteristic that contributes to its beneficial functions. For example, vegetative cover contributes to the growth, volume, and stability of coastal dunes by providing conditions favorable to sand deposition. Dune volume and form, in turn, contribute to the beneficial functions or public interests of storm damage prevention and flood control to landward resources and structures by preventing storm wave inundation and overtopping. Activities adversely affecting vegetative cover of a dune, by house construction with appurtenances for example, causes the dune to become destabilized and its beneficial functions to be significantly reduced or eliminated. Conversely, if an existing building on a solid foundation is reconstructed and elevated on open pilings in a dune, although still an adverse impact to dune function, the ability of the dune to function more naturally has been enhanced. In order to evaluate the degree of impact from an activity on a coastal landform, a 'ranking scheme' was developed (see Table 1).

Table 1

Ranking Scheme for Permitted Coastal Activities

0.5 — very minor	2.0 — significant
1.0 — minor	2.5 — very significant
1.5 — somewhat significant	3.0 — major

For example, the questionnaire (Appendix B) asks, 'will this activity enhance or impede the vegetative cover of the dune?' The evaluator must determine whether the activity (such as house construction) will adversely impact the dune's vegetative cover and, thus, the dune's sustainability (i.e., affect its beneficial functions). Adverse impacts, such as impeding or destroying dune vegetation, received a negative rating. If the activity was determined to enhance the vegetative cover and, thus, enhance the dune's beneficial function it received a positive ranking. 'No impact' was also an option.

It is important to note that each activity was ranked based on existing site conditions. For example, an elevated dune walkway potentially results in a degree of loss of sunlight to underlying dune vegetation resulting in some loss of underlying vegetation. A degree of human-induced dune destabilization and partial loss of its beneficial function potentially results. Thus, a negative rank most often resulted for a dune walkway due to the loss of dune vegetation and destabilization from such an activity. However, if existing site conditions revealed that pedestrian foot traffic was already occurring and dune vegetation had already been destroyed resulting in significant dune gullying and blowout, then a proposed elevated boardwalk may benefit additional vegetative growth and dune stability. In this case, based on existing site conditions a positive rating would most likely have been applied.

In addition, each coastal site varies somewhat in its landform characteristics. For example, the natural functioning of a 'primary frontal dune' is critical to storm damage prevention and flood control to landward areas, whereas the function of a secondary or tertiary dune may be less critical at this time. This is particularly relevant for comparison of the function and critical characteristics of dunes within and outside of the coastal floodplain where public interest varies. Outside of the coastal floodplain, dunes do not provide storm damage prevention and flood control interests, at least not at this time.

Furthermore, along the glaciated Massachusetts shore, coastal landform type can change dramatically over very short distances. For example, coastal banks (elevated landforms deposited by glacial activity) oftentimes grade into coastal dunes. So, dune material may overlie coastal bank deposits for some linear shoreline distance with the coastal bank eventually giving way to pure dune deposits. In these cases, the functional values of the landform can be quite different from lot to lot. Thus, ratings for similar activities can differ from lot to lot in a similar resource type over short distances.

Another consideration in the ranking of an activity is the subjectivity or experience of the individual conducting the ranking. Local conservation commission agents or administrators were determined to be the most appropriate individuals to rank each activity primarily because they conduct site visits when an application for a permit is received, and subsequently advise their conservation commission members during their deliberations on permit conditions. Thus, their experience with a wide array of projects and local conditions is usually quite extensive.

It should also be noted that the regulations used to evaluate each permitted activity are performance standard based. That is, for the most part, they do not 'explicitly' prohibit specific activities (although several 'grandfathering' prohibitions are stated). For example, the WPRs regulations for coastal dunes state, in part, that any alteration of, or structure on, a coastal dune or within 100 feet of a coastal dune shall not have an adverse effect on the coastal dune by: (b) disturbing the vegetative cover, or (c) causing any modification of the dune form that would increase the potential for storm or flood damage. Thus, an evaluation for an activity proposed on a coastal dune that would destroy 'some' dune vegetation or would alter it form must also "...increase the potential for storm or flood damage." This type of evaluation results in differing opinions of what constitutes 'an increase in potential storm or flood damage,' and, thus, inconsistencies in application of the regulations (i.e., value judgements by each evaluator). This is demonstrated in the results of this study.

Consistency in ranking, or lack of, was discussed through periodic meeting discussions of all project participants. One-on-one meetings and discussions, as well as field visits in some cases, with Sea Grant's Coastal Processes Specialist and study participants were periodically conducted throughout the study period. During these, technical issues were discussed and attempts made not to interfere with conservation agent ratings.

Results and Discussion

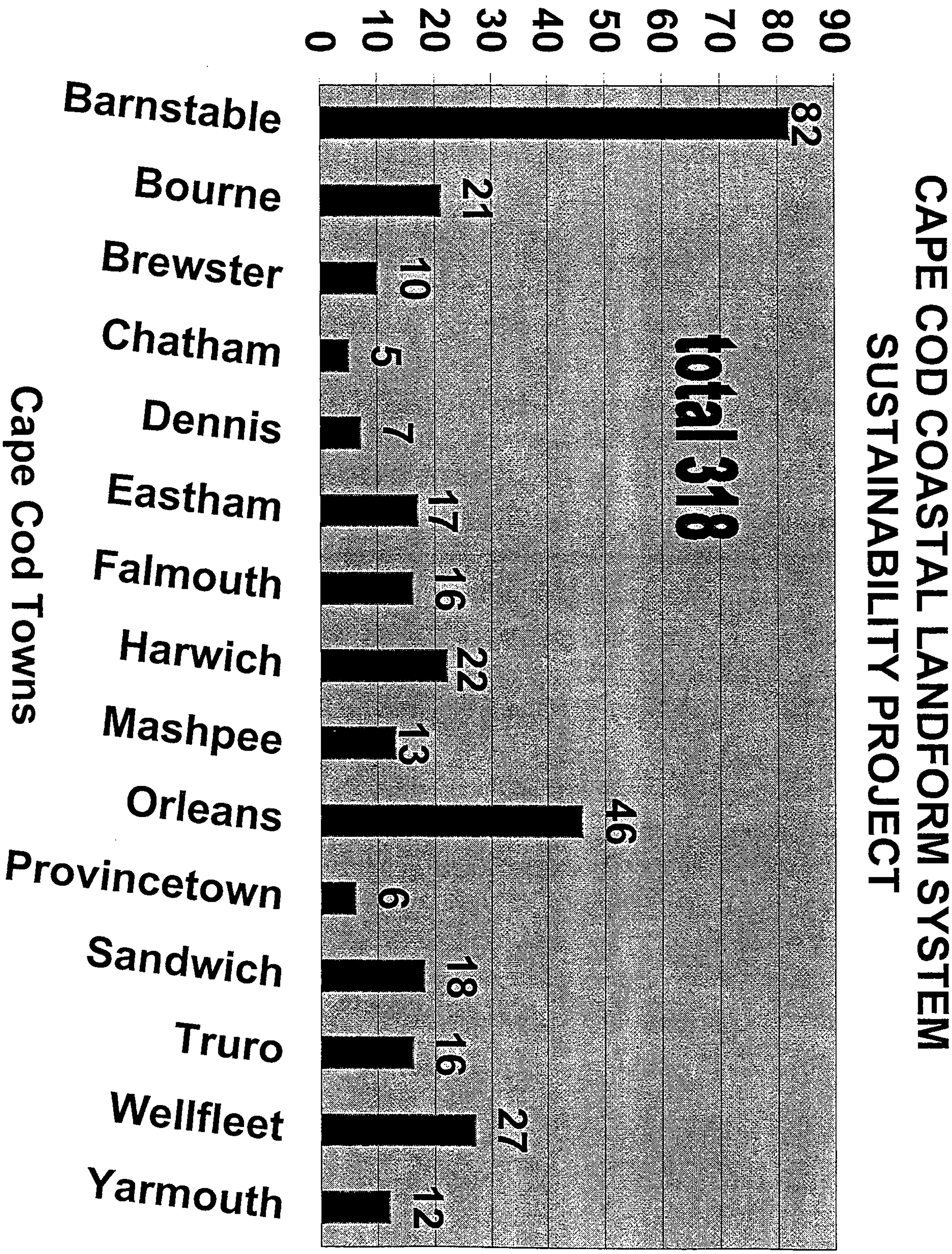
A total of 318 permits (local Orders of Conditions) issued in 1999 for activities on or adjacent (buffer zone) to coastal landforms were analyzed from the 15 Cape Cod towns that participated in the study. For each permitted activity the town's conservation agent or administrator completed a questionnaire. The distribution of the number of Orders of Conditions permitted on or adjacent to coastal landforms for each town in 1999 is presented on Figure 3 (Page 16). It is important to note that this is only a one year (1999) "snapshot" of the number and type of activities permitted on Cape Cod. Furthermore, the number of activities does not relate to the complexity or degree of impact(s) from activities on the beneficial functions or sustainability of coastal landforms.

Communities also determine the level of required information and whether permits are even required for certain activities in the buffer zone (an area 100 feet landward of coastal landforms). Some communities do not require a full permit application or an Order of Conditions for certain activities in the buffer zone, while others require full review and permitting. The Massachusetts Department of Environmental Protection issued Policy 99-1 (March 1999) relating to filing procedures for activities proposed within the buffer zone.

Collectively, 47 specific activities were permitted (many with conditions) on Cape Cod in 1999 (Appendix C, Page 47). Each activity was ranked according to the 'ranking scheme' on Table 1. A ranking from +3.0 to -3.0 was allowed for each individual question on the questionnaire. For example, as noted on the project questionnaire in Appendix B, there are three questions for coastal dune. Therefore, a maximum potential summary rating for a coastal dune for a single activity ranges from +9.0 to -9.0, whereas, for coastal bank there is only one question allowing a total rating for coastal bank between +3.0 to -3.0. It is important to note that the 'score' for each activity is the *sum* of all of the ranking for *each* question for each landform type.

Figure 3

of OOCs for Projects on Coastal Landforms 1999



The 47 permitted activities are listed in Appendix C. Beside the permitted activity in Appendix C are the ratings for that specific activity given by each town by coastal landform type. Each town is denoted by a one or two letter character in parentheses beside each rating based on the abbreviations in Table 2.

Table 2

Abbreviations for Participating Towns on Cape Cod

Ba = Barnstable	E = Eastham	P = Provincetown
Bo = Bourne	F = Falmouth	S = Sandwich
Br = Brewster	H = Harwich	T = Truro
C = Chatham	M = Mashpee	W = Wellfleet
D = Dennis	Or = Orleans	Y = Yarmouth

The number on the right-hand side of the town abbreviation in Appendix C is the number of individual permits (Orders of Conditions) issued for that specific activity. For example, (E4) means that the town of Eastham issued 4 separate permits in 1999 for that specific activity. BZ indicates 'buffer zone' which is defined as an area within 100 feet of a coastal landform. NI indicates 'No Impact.'

Data Analysis of Results by Permitted Activity

The following is a brief analysis of the ratings given to each permitted activity by coastal landform type for all towns. (The Grand Totals Summary Table is provided on Table 3 (Page 18) and is discussed later in this report.) A brief explanation of the reasoning for the ratings is also provided below. The ranking system below (negative or positive numbering) follows the scheme provided on Table 1.

The number in parentheses following the word 'rating' in the explanation below is the number of activities permitted for each rating. It is important to note that the number in parentheses is not necessarily the actual number of projects, but is the number of times landforms will be impacted as a result of that activity. For example, in Activity 1 on Page 19, there were actually four armoring projects (i.e., revetments, bulkheads, etc.) all permitted on coastal banks. However, secondary impacts were recognized that would occur to the beach and land subject to coastal storm flowage (LSCSF) as a result of armoring the coastal bank. So, the impact to beach and LSCSF were rated as well for armoring the coastal banks, resulting in the opinion that nine separate landforms (banks, beaches, and LSCSF) will be impacted. Furthermore, multiple activities are commonly part of one single permit application. For example, one permit application in Eastham included armoring a coastal bank with sandbags and a pile-supported walkway down a coastal bank: the Order of Conditions/permit required beach nourishment

Cape Cod COASTAL LANDFORM SYSTEM SUSTAINABILITY PROJECT: *GRAND TOTALS*

(all Orders of Conditions Analyzed in 1999)

TOWN	# of OOCs rev'd 1999	*Bank*	*Beach*	*Dune*	*Barrier Beach*	*Salt marsh*	*Coastal Flood plain*	# of projects in buffer zone (BZ)
Barnstable	82	-3.5	-4.5	-26.0	-17.5	-17.5	-15.5	(31 BZ to bank)
Bourne	21	NI	NI	(no proj)	- 3.0	+2.5	+/- = 0	(6 BZ to bank)
Brewster	10		-1.5	+10.5	(no proj)	(no proj)	(no proj)	(3 BZ to bank)
Chatham	5	-1.0	+/- = 0					(no BZ projects reviewed)
Dennis	7	-1.0	+1.0	-2.5	(no proj)	(no proj)	(no proj)	(no BZ projects reviewed)
Eastham	17	-1.5	+2.0	-0.5	(no proj)	-4.0	-1.5	(6 BZ to bank)
Falmouth	16	-2.0	-2.0	-3.5	-2.5	+1.5	-1.5	(1 BZ to bank)
Harwich	22	-3.0	+6.0	-2.0	No proj	-2.0	-1.5	(9 BZ to bank)
Mashpee	13		(no proj)	+4.5	(no proj)	(no proj)	NI (1 proj)	(6 BZ to bank)
Orleans	46	-1.0	-2.0	NI (1 proj)	(No proj)	NI (1 proj)	-2.0	(27 BZ to bank)
P-Town	6		+3.0	-2.5				(no BZ projects reviewed)
Sandwich	18		-3.0	-9.5	-7.5	+1.5	-2.0	(2 BZ to bank)
Truro	16	-4.5	-3.5	-16.5	-14.5	-1.5	-0.5	(2 BZ to bank)
Wellfleet	27	-7.5	-12.0	+4.5	No proj	-2.5	-2.5	(8 BZ to bank)
Yarmouth	12	-0.5	+5.5	+7.0	+4.0	-3.0	NI	(8 BZ to bank)
GRAND TOTALS	# proj 318	**bank -25.5**	**beach -11.0**	**dune -36.5**	**barrier -41.0**	**marsh -25.0**	**LSCSF -27.0**	+ sustaining landform system - not sustaining landform system

Positive (+): sustaining the beneficial functions of the coastal landform system

Negative (-): not sustaining the beneficial functions of the coastal landform system

TABLE 3: Grand Total Ratings for Orders of Conditions Analyzed in 1999

to compensate for the armored coastal bank and loss of source sediment to the beach. So, three activities were a part of that one permit, ultimately affecting three separate coastal landforms (bank, beach, and LSCSF).

It will be helpful to refer to Appendix C for the following descriptions.

1. *New (hard) armoring of a sediment source w/o nourishment*:

Number of Ratings: (9) negative

Range: -2.5 to -0.5 (for bank, beach, and LSCSF (100-year coastal floodplain)).

Hard armoring includes revetments, bulkheads, seawalls, and geotextiles (sandbags, longuard tubes, geotubes, etc.). Although considered somewhat temporary, geotextiles (Figure 4, Page 20) were included because they cause similar effects as revetments and seawalls. In fact, due to their higher wave reflection factor relative to a rough-faced revetment, they may temporarily increase storm-induced fronting beach scour. A *sediment source* is a landform, such as a coastal bank (bluff) which, as a result of erosion, provides sediment (generally sand and pebble) to other downdrift coastal landforms, such as beaches and dunes. Eroding coastal banks presently provide the primary source of sediment for beaches, dunes, and barrier beaches in Massachusetts (Figure 5, Page 20). By armoring a sediment source with a revetment, for example, some elevated degree of erosion will result to other downdrift coastal landforms by depriving them of sediment which otherwise would be provided if the coastal bank were not armored. By armoring the coastal bank, its sustainability or critical function of eroding and, thus, supplying sediment to other coastal landforms, has been eliminated. Furthermore, eliminating primary source material for other coastal landforms (beaches and dunes) will adversely affect them by reducing their volume and, thus, altering their form. Their beneficial functions of storm damage prevention and flood control will be adversely affected, consequently, their sustainability will, in turn, be adversely affected.

Therefore, armoring a sediment source (with or without requiring a commensurate volume of sediment to be placed on a fronting beach) eliminated its natural sustainability and, therefore, received negative ratings by all towns for all projects during the study period (see question under coastal bank in the questionnaire in Appendix B). The rating varied based on the perceived importance of the material that would no longer be supplied by the landform being armored.

Although a commensurate volume of material that the coastal bank would have provided is generally required as a condition of a permit to armor an eroding coastal bank, it was noted that adherence to this condition in perpetuity is difficult if not impossible to track. A level of non-compliance had been noted, but to what degree is unknown. To avoid this, commissions have, in some appropriate cases, allowed only bank 'toe' armoring. This way the upper portions of the coastal bank will continue to erode and supply sediment to the system during storms, when the system needs it most to reduce storm damage. Bank nourishment to replace the eroded material is then conducted.

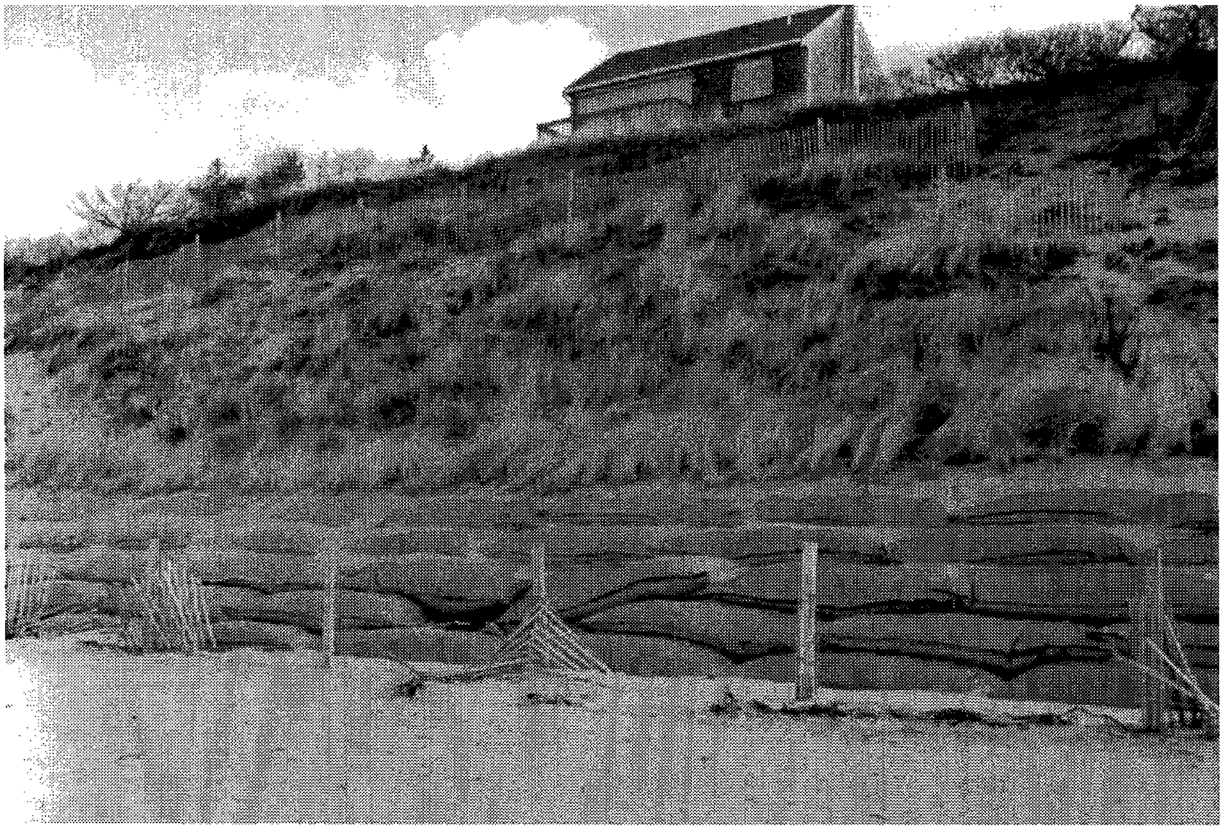


Figure 4

Figure 5

Note: Massachusetts' Wetlands Protection Regulations (310 CMR 10.00 et. seq.) prohibit armoring of eroding coastal banks that are supplying sediment to other coastal landforms if the armoring is proposed to protect a building constructed after August 10, 1978 (promulgation date of the Coastal Wetlands Protection Regulations). Although not explicitly stated in the regulations, for the most part, armoring of beaches and dunes is prohibited based on performance standards in these regulations, and prohibition has been the general practice. All permitted armoring during the project period took place on coastal banks, not beaches, dunes, or LSCSF. The negative ratings given to beaches and LSCSF are due to anticipated secondary impacts resulting from the loss of source material (and, thus, volume and diminished function) as a result of the armored coastal bank. This reasoning applies to the next three armoring related activities as well (see Activities 2, 3, and 4).

2. *Reconstruct (hard) armoring of a sediment source w/o nourishment:*

Number of Ratings: (11) negative; (3) no impact

Range: -3.0 to NI (all for bank, beach and barrier beach). (See note in Activity 1.)

This activity received negative and NI (no impact) ratings by all towns for all projects. The negative ratings were given due to existing site conditions when a structure was in disrepair to a point where some volume of sediment was being eroded and, consequently, being provided to downdrift landforms. A 'no impact' was assessed when the armoring was dilapidated but not to a point where sediment was being provided to downdrift landforms. Keep in mind that ratings for this type of project were supposed to be given based on existing site conditions.

Note: During discussions it was debated that armoring without nourishment could be positive in a case where a fronting saltmarsh could be adversely impacted (smothered) by material eroding from a coastal bank. This opinion was not unanimous, however. It was agreed that projects must be evaluated on a site-by-site basis.

3. *New armoring (hard) with nourishment:*

Number of Ratings: (14) negative

Range: -0.5 to -3.5 for bank and beach.

Most Massachusetts coastal communities require an applicant proposing new armoring to calculate the erosion rate of a coastal bank and provide the volume of sediment that would have been provided to downdrift coastal landforms if the armoring were not in place. The Order of Conditions then conditions approval on the required placement, periodically and in perpetuity, of a commensurate volume of compatible sediment on the beach fronting the coastal bank that is to be armored. (See note in Activity 1.)

New armoring, even with a beach nourishment requirement, received negative ratings by all towns because the primary beneficial function of providing sediment to downdrift coastal landforms by an eroding coastal bank (i.e., its contribution to the sustainability of the landform system) has been eliminated. Requiring a commensurate volume of nourishment is an artificial replacement for the natural coastal bank function. Furthermore, requiring artificial nourishment in place of the natural sediment supply is a compromise. For the 'coastal landform system' to optimally function, the eroding coastal bank material is required in the system during the coastal storm in order to reduce wave energy and, thus, wave-related damage to natural resources and structures. Most nourishment takes place during the spring season to maximize recreational beach width. This practice has been acceptable, but not optimum.

Conservation commission agents have also noted the difficulty of follow-up monitoring to ensure compliance years after the armoring has been constructed. The fact that the legal process to ensure condition compliance is difficult and costly was discussed. Furthermore, on-going erosion in a sediment-starved system will eventually result in the loss of fronting beach (forced high water against the armoring). Many examples exist in Massachusetts. It is often difficult to access a coastal site with heavy equipment necessary to conduct small nourishment projects, thereby precluding adhering to permit conditions. This is particularly relevant when no beach exists at high tide.

4. *Reconstruct (hard) armoring w/nourishment: no nourishment previously required:*

Number of Ratings: (1) Negative

Range: -2.0

As a result of education and direct observations, many coastal communities in Massachusetts now realize the critical importance of sediment eroded from coastal banks to the continued existence of beaches, dunes, barrier beaches, and the bays and estuaries that exist as a result of barrier beaches. As a result, several Cape Cod communities are requiring that applicants for projects proposing to 'reconstruct' armoring provide a volume of compatible sediment to the fronting beach commensurate with the volume which otherwise would have eroded from the coastal bank. Several communities, however, voiced that it is difficult to ultimately defend instituting a new permit condition that was not part of the original permit conditions. In addition, several communities find it difficult to defend instituting a new permit condition for reconstruction when the benefit of small nourishment volumes is not obvious, particularly in cases where on-going erosion has resulted in forced high water against a revetment or seawall. In this case, the nourished material is quickly absorbed into the littoral system, resulting in no obvious, visual benefit. However, although the material may appear to 'disappear,' the material is playing an important role in dissipating storm wave energy in the nearshore zone or downdrift. Benefits are realized to the overall 'system' by cumulatively supplying compatible sediment that would otherwise have been provided.

5. *Reconstruct bulkhead:*

Number of Ratings: (4) no impact

Range: no impact

In locations where bulkhead reconstruction was proposed (e.g. bay and estuarine shorelines), conservation commission agents did not feel there was an impact over existing conditions.

Note: Even in estuarine environments, sediment input to the system is important. With present relative sea level rise of approximately one vertical foot per 100 years in Massachusetts (Giese, et. al., 1987), beach and inter-tidal areas could be eliminated absent sediment input from eroding coastal banks. Fine-grained bank material supplies the substrate on which sandier material rests in the inter- and sub-tidal areas, as well as substrate for marine organisms. The importance of estuarine coastal bank erosion was demonstrated when it was documented that approximately 6 miles of inter-tidal area has been lost in Mobile Bay, Alabama, over the last 60 years as a result of bulkhead armoring of that estuarine system (Douglass and Pickel, 1999).

6. *New house on a solid foundation:*

Number of Ratings: (47) buffer zone/no impact; (6) negative; (13) no impact; (2) buffer zone/negative
Range: 0 to -6.0 (in dunes, barrier beaches and LSCSF)

New home construction was the highest number of proposals for activities identified during this project. However, most were located in the buffer zone (within 100 feet of the landward edge of a coastal landform). All new houses proposed in the buffer zone were rated 'no impact' on the adjacent coastal landforms. However, new houses in dunes and on barrier beaches received negative ratings due the adverse impact on the mobility of dune sands to achieve the dunes' beneficial functions, primarily storm damage reduction and flood control. Buildings replace the dune and reduce the source area for wind blown sand (Morton, et al., 1994), and they alter wind direction and speeds, thereby altering depositional patterns (Nordstrom and McCluskey, 1984; 1985). The direct effect of buildings is related to their location on the beach/dune profile and their method of construction, including foundation type, size, shape, materials, and density (Nordstrom, 2000). All houses proposed in LSCSF (100-year coastal floodplain) were proposed in the A-zone. All houses, except one, proposed in the A-zone of LSCSF received a no impact rating. Relocating a house landward, particularly in a dune or barrier beach area, would result in the structure being located in a less active area and, thus, could be considered positive as it may have less of an adverse affect on the resource function.

7. *New house on pile foundation:*

Number of Ratings: (5) negative
Range: -2.5 to -6.0 (for dune, barrier beach and LSCSF)

Pile supported houses are, for the most part, permitted on coastal landforms in Massachusetts. The Massachusetts State Building Code, as well as the requirements of the National Flood Insurance Program (of which all Massachusetts coastal communities participate), requires the lowest horizontal structural member or lowest floor (depending on the flood zone) be at or above the 100-year flood elevation. In areas such as dunes or barrier beaches (regardless of the flood zone designation), a state policy requires that the lowest portion of a building be a minimum of two feet above existing grade on open pilings or columns to allow dune migration and, thus, function. However, due to shading effects, dune vegetation is generally adversely affected, which can result in destabilization and a loss of natural dune stability and function (i.e., sustainability). Wind direction and speed and, thus, deposition patterns of dune sands is also affected. Mobility of dune sands as a result of eolian (wind-blown) forces under the structure may actually temporarily increase.

Note: Pile supported houses in dunes and on barrier beaches have been periodically denied based on review pursuant to the WPRs primarily relating to appurtenances, such as the septic system and driveway, which as solid structures or requiring removal of dune volume could not meet performance standards.

8. *Addition on solid foundation:*

Number of Ratings: (54) buffer zone/no impact; (17) negative; (7) no impact; (2) buffer zone/negative
Range: 0 to -6.0

Similar to new house proposals on solid foundations in Activity 6, this activity saw the highest number of filings. Projects located within buffer zones received no impact ratings. However, additions in dunes and on barrier beaches adversely affected stabilizing vegetation and interfered with dune mobility and migration required for optimization of its beneficial functions and, thus, sustainability. Additions on solid foundations also interfered with the beneficial functions of the coastal floodplain as well, particularly in the FEMA-mapped velocity zone where wave direction can be altered by the solid structure, possibly adversely affecting structures or resources which otherwise may not have been affected.

9. *Addition on pile foundation:*

Number of Ratings: (5) negative; (3) positive; (1) no impact
Range: +4.5 to -2.5 (dunes, barrier beach, and LSCSF)

Similar to new pile-supported house proposals in Activity 7, the majority of proposals received negative ratings in dune, barrier beach, and LSCSF. However, several positive ratings were given. This apparently reflects the 'value judgements' in ratings described in the Project Methodology section.

10. *Elevate existing house on piles* (Figure 6, Page 25):

Number of Ratings: (4) positive; (2) negative; (2) buffer zone/no impact
Range: +1.0 to -5.0

The majority of proposals received positive ratings. While a house on pilings can alter natural depositional patterns of wind blown sands, it was largely determined that depositional patterns were already altered and severely affected by the existing house on the solid foundation, as well as the total loss of dune function. In addition, by elevating the existing house from a solid foundation onto open pilings, dune function would be somewhat enhanced, particularly the ability of dune sands to migrate under the pile structure and through the lot to assist adjacent dune development. However, positive ratings were not consistent as some communities gave negative ratings due to the adverse impact of houses on pilings to dune function and barrier beach migration.

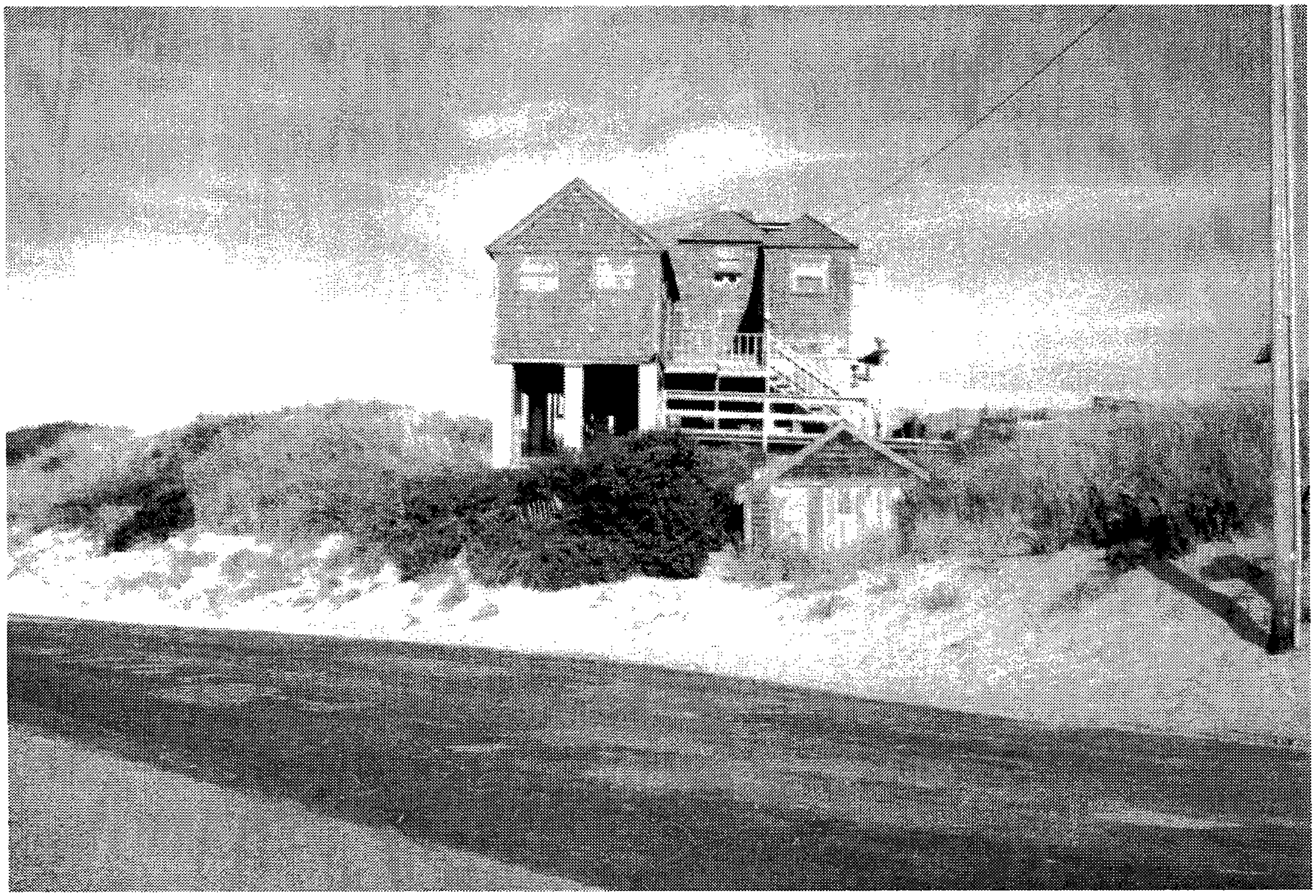


Figure 6

11. *Rebuild building no expansion:*

Number of Ratings: (26) buffer zone/no impact; (4) negative; (4) no impact

Range: dune: no impact to -5.0: barrier beach -3.5: LSCSF -0.5 to no impact

All proposals in the buffer zone received 'no impact' rating. Negative ratings were given for this activity in dune and barrier beach areas, and a majority 'no impact' in LSCSF.

12. *Relocate structure (e.g. house):*

Number of Ratings: (1) positive; (1) negative; (1) no impact; (3) buffer zone/no impact

Range: +1.0 to -1.0, and no impact in buffer zones.

The ratings for relocating a structure depended on the direction of the relocation. Moving the structure landward generally resulted in it being located to a less active, less mobile area (i.e., from a frontal dune to a back dune area). One relocated house from an area of wave activity (velocity zone) to an A-zone (stillwater flooding) resulted in a positive rating, while one relocation in a dune area resulted in a negative rating due to the loss of vegetation.

13. *New subsurface septic system installation:*

14. *Subsurface septic upgrade:*

Number of Ratings: (28) buffer zone/no impact; (2) buffer zone/negative; (7) negative;

Range: no impact to -1.0 in buffer zone; -0.5 to -3.0

Although separate activities, these were placed together due to the similarity of impacts. Septic system installations and upgrades in mobile landforms (i.e., dune, beach, barrier beach) received negative ratings due to the displacement of sandy source material and the adverse impact to the potential migration of these landforms. Minor adverse impacts were rated for installations in LSCSF. No impact was determined in the buffer zone.

15. *Replace subsurface septic system:*

Number of Ratings: (3) no impact: (3) buffer zone/no impact; (1) negative

Range: 0 to -3.5

For the most part, no impact was given for replacements due to existing impacts already occurring. A negative was given for a septic system replacement in a barrier beach.

16. New mounded septic system:

17. Replace mounded septic system:

Rating: (2) no impact

Range: no impact

Only one of each activity was proposed and both were located in the A-zone of LSCSF. In a coastal A-zone where stillwater flooding is dominant, compensatory displacement is generally not significant enough to be an issue. Compensatory storage requirement is an issue in a coastal A-zone only where a hydraulic constriction exists. In addition, unlike in a velocity zone where wave action can interact with the mounded structure and wave refraction can possibly result in adverse impacts to adjacent property and resources, A-zones lack (or have minimal) wave action, consequently, scour and wave diversion is not a significant consideration.

18. New elevated walkway down coastal bank (Figure 7, Page 28):
19. Reconstruct elevated coastal bank walkways:
Number of Ratings: (15) no impact; (7) positive; (5) negative
Range: +1.0 to -2.0, and no impact

These activities were placed together due to similarity of impacts.

Opinions and ratings varied for this activity. Some communities noted rain runoff-induced scour around pilings used for elevated coastal bank walkways and suggest at-grade bank walkways to applicants, while others have not observed adverse impacts. Orientation relative to sun angle, height of the walkway, and plank spacing was a consideration in assessing potential impacts to underlying vegetation from shading and thus bank stability. The rating for this activity also depended on existing site conditions. For example, if pedestrian access was taking place down the face of the coastal bank, then vegetation was generally being adversely impacted (i.e., loss of vegetation and, thus, bank destabilization). In this case a positive rating was given.

20. *New elevated dune walkway:*
Number of Ratings: (7) negative; (1) positive: (1) no impact
Range: +1.5 to -3.0 and no impact

Although this activity is specifically stated as permitable under the state Wetlands Protection Regulations, the majority of ratings for this activity were negative primarily due to loss of underlying vegetation as a result of shading and, thus, destabilization of dunes. Height above grade, geographic orientation relative to maximum sun angle, and plank spacing are considerations in the degree of potential impact to underlying dune vegetation. However, similar to elevated bank walkways (Activity 18), a rating could depend on existing site conditions such as existing pedestrian use. Furthermore, it was stated in discussion that the public generally uses elevated walkways and, thus, avoids massive destruction of dune vegetation in other adjacent dune areas. In this case a community or evaluator (i.e., conservation agent) may give a positive rating for this activity.

21. *At-grade dune walkway:*
Number of Ratings: (4) negative
Range: -2.0 to -3.5

Due to direct loss of dune vegetation, the impedance of the exchange of sediment between the dune and an adjacent coastal beach, and impacts to dune migration and function, all proposals for this activity received negative ratings for all communities. However, as in Activity 20, it was again stated if

Figure 7

the public uses the at-grade walkway, adverse impacts to dune vegetation in adjacent areas could be avoided.

22. *New elevated walkway over beach (e.g. to a pier):*

Number of Ratings: (4) no impact; (3) negative

Range: no impact to -1.0

This activity received no impact to very minor and minor adverse impact ratings. In discussions, public trust rights to laterally cross the beach in the inter-tidal area for specific purposes were noted as problematic. In Massachusetts, public trust rights for fishing, fowling, and navigation exist in the inter-tidal area. Beach is defined as including the inter-tidal area. Nordstrom (2000) noted several studies where scour was measured around pilings due to waves and currents.

23. *Existing pier*

Number of Ratings: (3) no impact

Range: no impact

For purposes of this project, activities were rated only to the low water line (i.e., only the beach area). Therefore, most participants did not rate this activity. Impacts, if any, for the few piers that were rated were already existing.

24. Elevated walkway over saltmarsh (catwalk):

Number of Ratings: (13) negative; (1) no impact

Range: -0.5 to -3.5

The majority of communities ranked this activity negative due to potential effects on the growth of underlying saltmarsh vegetation primarily as a result of shading, as well as disturbance to the peat substrate. Height above the marsh, geographic orientation relative to maximum sun angles, and plank spacing are considerations in the extent of potential impact. Participant responses varied. Some stated that if elevated walkways were not permitted, then the alternative of walking directly on the marsh may result in more damage to the marsh. Others stated that if the walkway were not constructed, then walking on the marsh would be very limited with negligible impact.

25. Dune nourishment:

Number of Ratings: (4) positive; (3) negative; (1) buffer zone/no impact

Range: -2.5 to +5.0

Adding sediment and, thus, volume to a dune generally received positive ratings due to the potential enhancement to the beneficial functions of storm damage prevention and flood control to landward resources and structures provided by coastal dunes, particularly the foredune. According to the Army Corps of Engineers, large reductions in wave overtopping are affected by small increases in foredune crest elevations (Corps of Engineers, 1984). However, the nourished sediment must be compatible (i.e., relatively similar grain size). Finer grain material, particularly very fine-grained sediment or silt, may erode under minor wind and wave conditions resulting in potential adverse impacts to adjacent saltmarsh vegetation, as noted by one community involving a pre-existing dredge material disposal site.

26. Beach nourishment:

Number of Ratings: (8) positive; (1) negative

Range: -1.0 to +6.0

Similar to dune nourishment, beach nourishment is generally viewed as a positive activity due to the enhanced beneficial functions of beaches by adding compatible sediments. The project questionnaire asked whether the activity would increase the volume of the beach sediment. Only several engineered beach nourishment projects have taken place in Massachusetts over the last decade or so. The ratings for this activity were for the beneficial re-use of compatible dredged material from nearby tidal inlets.

27. Coastal bank nourishment and vegetate:

Number of Ratings: (2) Positive

Range: +2.0

Adding material to a coastal bank is generally viewed as positive as additional material is available to be eroded and supplied to the fronting beach. Although vegetating may temporarily decrease erosion of a sediment source coastal bank, storm wave action will ultimately erode the bank material, and this action is permitted as general practice. As mentioned earlier, coastal bank armoring is prohibited on eroding coastal banks to protect buildings that were constructed after August 10, 1978 (promulgation date of the Coastal Wetlands Protection Regulations). As a result, either relocation of the threatened building or bank nourishment are the viable alternatives.

28. Bank stabilization using non-structural alternatives, such as bio-logs:

Number of Ratings: (6) Negative

Range: -0.5 to -4.0

Similar to armoring coastal banks with structural measures, it was determined that this activity also prevented material from eroding from the coastal bank, thereby depriving downdrift landforms of primary source material. It was recognized, however, that the impact was temporary, as non-structural bank erosion control alternatives are generally temporary in nature. One statement was that this activity would be a positive if it prevented sediment running into a saltmarsh and possibly smothering vegetation.

29. New dock:

Number of Ratings: (3) negative

Range: -0.5 to -2.5

Shading impacts and potential impacts to the growth of marsh vegetation, as well as impacts to the peat layer, resulted in negative ratings for all proposals. Height above the marsh surface, geographic orientation relative to maximum sun angle, and plank spacing are considerations in the extent of impact. This project type considered activities only to the low water line.

30. *Replace elevated walkway or pier:*

Number of Ratings: (3) negative; (2) no impact; (1) positive

Range: -2.5 to +1.5

Impacts to the underlying marsh vegetation and impacts to the peat layer resulted in a majority of negative ratings. One proposal was on the beach and received a 'no impact' rating.

31. *Jetty reconstruction:*

Number of Ratings: (6) negative; (1) positive

Range: -5.0 to +0.5

It was agreed that this activity had adverse impacts to the sustainability of the coastal landform system. Negative effects are translated downdrift by the trapping of littoral drift material, the distance downdrift depending primarily on the length and height of the jetty. However, the updrift beach generally accretes, enhancing the function of that part of the landform.

32. *Jetty extension:*

Number of Ratings: (1) negative

Range: -1.5

For the reasons stated in Activity 30, a negative rating was given.

33. *Groin construction: reconstruction:*

Number of Ratings: (1) Negative

Range: -1.0

Trapping of littoral drift and thus depriving the immediate downdrift beach and dune of source material resulted in a negative rating. (Note that state WPRs require that following groin construction, the updrift area (filet) is required to be immediately filled and maintained to entrapment capacity.)

34. *Drainage pipe reconstruction and extension into the inter-tidal area:*

Number of Ratings: (1) negative

Range: -1.5

Similar to groins, extending structures across the beach and into the inter-tidal area causes similar impedance of littoral drift and loss of sediment, particularly immediately downdrift of the structure in the shadow zone. In the case in this study, the drainage pipe helped alleviate repetitive flooding occurring in a landward neighborhood.

35. *New storm drain:*

Number of Ratings: negative

Range: -2.0

One new storm drain was constructed across a coastal beach and received a negative rating due to displacement of beach sand with the discharge pipe. In part, an applicable regulatory standard to meet in Massachusetts is that no project shall not have an adverse effect on the beneficial functions of storm damage prevention and flood control provided by coastal beaches as a result of decreasing the volume of any coastal beach. There was apparently no feasible alternative to a discharge pipe across the beach, as the area where this proposal took place consists entirely of coastal dune and beach.

36. *Improve drainage system:*

Number of Ratings: (3) positive; (3) no impact; (1) negative; (1) buffer zone/no impact

Range: +1.5 to -1.0

Impacts to beach and saltmarsh received positive ratings, bank and LSCSF received no impact ratings, and coastal bank received negative rating. The impacts from this activity were based on site-specific conditions. For example, saltmarsh vegetation was being adversely impacted by unmitigated discharge from a storm drain discharge. With improvements, such as a splash apron in the area at the end of the discharge pipe, the discharged water velocity was reduced improving conditions for vegetation growth.

37. *Stabilize coastal bank with vegetation:*

Number of Ratings: (1) negative

Range: -0.5

Stabilizing a coastal bank with vegetation is a generally accepted practice to assist in stabilizing an eroding bank face. However, the question asked in this project was, will this activity impede or permit the erosion of the coastal bank by wave action (and thereby impact the supply of sediment to an adjacent coastal landform)? While vegetating a coastal bank face would minimally slow erosion of the bank face, it is considered temporary in nature. Under storm wave conditions the bank will erode. However, a 'very minor' rating was given due to the minor amount of sediment that would be temporarily inhibited from eroding and supplying adjacent landforms. Again, this demonstrates the value judgement oftentimes applied with performance standard based regulations as described in the Project Methodology section.

38. *Stabilize dune with plants and fencing:*

Number of Ratings: (13) positive

Range: +0.5 to +6.0

Interestingly, stabilizing a coastal dune with vegetation and sand fencing, as in Activity 37, would temporarily reduce the exchange of sediment between the dune and an adjacent coastal beach (a negative for Question 3 under dune in the questionnaire). However, positives will result for Questions 1 and 2 for dunes (see Questionnaire in Appendix B), which ask whether this activity would enhance (positive) or impede (negative) vegetative cover, and will this activity decrease (negative) or increase (positive) the volume of the dune. It was determined that by taking measures that will ultimately add volume to the dune (sand fencing and vegetation), when the exchange of sediment was necessary (under storm conditions) the increased volume would help the coastal landform system, and the reduction in sediment exchange is considered temporary. Therefore, cumulative positive ratings prevailed in all communities for this activity. Note also that this action is explicitly allowed in the WPRs.

39. *Landscaping:*

Number of Ratings: (10) buffer zone/no impact; (1) buffer zone/positive; (1) positive

Range: no impact to +1.0

Most impacts took place in the buffer zone for this activity with 'no impact' ratings. Positive ratings were given for a project in the buffer zone to a coastal bank, and a project on a coastal bank because it was determined that landscaping added to the stability of a 'vertical buffer' type coastal bank.

40. *New well:*

Number of Ratings: (1) no impact (bank)

Range: no impact

No impact was determined due to the subsurface nature of this activity and, therefore, no impact to the function of the landform.

41. *Gas main installation:*

Number of Ratings: (3) negative; (3) buffer zone/no impact

Range: -1.0 to buffer zone/no impact

It was determined that sand volume displacement in a coastal beach and the inhibition to the landward migration of a barrier beach were negative impacts. The LSCSF resource was an overlay on dune and barrier beach resources. Thus, an inhibition to the landward migration of dunes and barrier beach in response to relative sea level rise, overwash, and eolian processes were considered negative impacts over the long-term.

42. *Water intake pipe:*

Number of Ratings: (1) negative

Range: -0.5 (dune)

'Very minor' sand volume displacement in this coastal dune was considered a negative impact to its beneficial function.

43. *Bury utility pipes:*

Number of Ratings: (1) negative

Range: -2.0

This activity took place in a saltmarsh and, therefore, involved disturbance to the peat layer. As a result, possible impacts to vegetation resulted in a negative rating.

44. *Paving:*

Number of Ratings: (1) buffer zone/no impact

Range: no impact

This activity took place in the buffer zone to a saltmarsh.

45. *Remove telephone poles:*

Number of Ratings: (1) no impact

Range: no impact

This activity took place in a saltmarsh and the poles were cut off at grade. There was no impact beyond existing conditions.

46. *Remove retaining wall:*

Number of Ratings: (1) positive

Range: +1.5 (barrier beach)

This activity took place on a barrier beach. As a result of removal of the retaining wall, the ability of the barrier beach to migrate landward in response to relative sea level rise, overwash, and eolian processes was enhanced, as well as more natural deposition of sediment.

47. *Remove oil tank:*

Number of Ratings: (1) positive

Range: +1.0 (barrier beach)

This activity took place on a barrier beach and is similar, in part, to Activity 45 allowing the barrier to more naturally migrate landward.

48. Remove asphalt:

Number of Ratings: (2) positive

Range: +1.0 to +1.5 (dune and barrier beach)

This activity took place on a dune within a barrier beach. However, unlike Activities 45 and 46, the activity took place on the surface instead of subsurface which resulted in impacts to both dune and barrier beach. Removing an impermeable surface permits the exchange of sediment between the dune and beach, as well as facilitates vegetative growth, resulting in a positive rating to its beneficial function or sustainability.

Based on the above activity ratings, Appendix D (Page 52) is a Summary Rating for Permitted Activities Identifying Impact (positive or negative) on Coastal Landform Sustainability. The 'rating scheme' identified in Table 1 is also reproduced on this chart. Note on the chart that a *double asterisk* denotes the primary coastal landform upon which the specific activity took place and, therefore, received the primary impact. A *single asterisk* denotes a secondary impact. A *question mark* denotes a 'possible' impact if that particular landform is adjacent to the primary landform. For example, the first activity listed in Appendix D is 'new coastal (hard) armoring of a sediment source without nourishment.' The armoring took place on the coastal bank in all cases and, therefore, the bank received a double asterisk, while secondary impacts are anticipated for beach as a result of the loss of source sediment from the bank. A question mark is listed for dune, barrier beach, and saltmarsh denoting a potential impact if these landforms exist in close proximity to the bank that was armored.

Grand Totals Summary: Implications

Table 3 is the Grand Totals (mathematical sum) for all activities/permits for 1999 submitted by all participating Cape Cod communities. As noted, 318 permits were analyzed. Positive ratings suggest that the coastal landform and the system within which it resides are being sustained (i.e., the beneficial functions of the landforms are being protected by the decisions). Conversely, negative ratings suggest that the sustainability of the landform and its system are not being adequately protected (i.e., the beneficial functions of the landforms are being diminished by the collective decisions).

As noted on Table 3, although positive ratings exist within the table, cumulative negative ratings were summed for all coastal landforms. What this suggests is that, collectively, the natural functioning of certain 'coastal landform systems' are not being sustained on Cape Cod. In other words, the results suggest that the beneficial functions of the coastal landform system, as well as the beneficial functions of many of the individual coastal landforms that comprise the 'system' where specific activities are taking place, are not being sustained.

The Massachusetts Wetlands Protection Regulations, local wetlands by-laws, and MCZM policies which guide permit decisions for most activities on or adjacent to coastal landforms in Massachusetts, are designed to preserve the beneficial functions of coastal landforms to protect certain public interests as described in the section on Selected Massachusetts Policies and Regulations Governing Activities on Coastal Landforms.

To explicitly state that the results of this study suggest that we are not sustaining the natural functions of our coastal landforms is accurate. Many of the performance standards in the WPRs require that the activity "shall not have an adverse effect (on the critical characteristics of the coastal landform) by..." altering critical specific coastal landform characteristics. However, in reality, minimal adverse effect appears to be acceptable. In addition, many activities that have recognized adverse effects are accepted as part of living along the shore and are explicitly permitted in the regulations. Examples include elevated pedestrian walkways down coastal banks and on dunes, groins, and jetty extensions, although the anticipated adverse impacts from these activities must be 'minimized'. In addition, decisions are often practicable and may consider societal, economic, and takings issues in addition to the environmental concerns. For example, while it is recognized that house construction (on pilings), including appurtenances such as driveways and subsurface septic systems on coastal dunes, have adverse impacts, they have been permitted in certain coastal dune areas. They have, however, been denied in certain sensitive and hazardous dune locations as well. Septic systems, for example, are prohibited in velocity zones of foredune areas under the state's Sanitary Code.

To strictly apply the 'no adverse effect' standard written in the regulations for most coastal landforms would mean halting and prohibiting all activities on all coastal landforms. "Adverse effect" is defined in the regulations (310 CMR 10.23) as a greater than negligible change in the resource area or one of its characteristics or factors that diminishes the value of the resource areas to one or more of the specific interests of MGL c. 131, s. 40 as determined by the issuing authority. "Negligible" means small enough to be disregarded. Given the legalities of private property interests and economic and societal considerations, "it would be fruitful and prudent to examine ways to develop or use the shoreline in a manner that maintains or restores natural sediment transfers and accommodates mobility of landforms and their tendency to grow and be altered" (Nordstrom, 1999).

While based on this study, Massachusetts, or at least Cape Cod, does not appear to be sustaining its coastal landforms, many successful compromise solutions have been developed in Massachusetts based on the above principle. For example, requiring elevated houses in dunes, elevating walkways, initially filling groin compartments to entrapment capacity and requiring them to be kept to entrapment capacity while discouraging their construction in the first place, are all techniques that are commonly used. State Executive Order 181 for Barrier Beaches, in part, prohibits new development in velocity zones of primary dunes on barrier beaches and prohibits most coastal engineering structures on barrier beaches. Although an executive order does not hold the force of law, it sends a strong message on state policy initiatives. Structural armoring is also, for the most part, prohibited in coastal dunes and on beaches, and is explicitly prohibited on eroding coastal banks which supply sediment to other coastal landforms to protect building constructed after the promulgation date (August 1978) of the WPRs.

So, given that certain activities have been rated as reducing the natural sustainability of coastal landform systems, and are anticipated to continue to do so, the question remains: has Massachusetts, and specifically have the communities on Cape Cod, arrived at the optimum balance of compromises and mitigation methods to maximize the sustainability of the coastal landform system while allowing certain activities and development to continue?

Conclusions

This study illustrates the vast extent of human alterations to coastal landforms. Obviously, any human use of a coastal landform will affect its natural sustainability, some activities having more, others less effect. Human use and occupation of coastal landforms has been occurring for eons, but has significantly increased in the last several decades. Historically, approximately 75% of development in Massachusetts has occurred in its coastal zone (Massachusetts Department of Environmental Management, 1986), and over 50% of its population presently resides in the coastal zone. Predictions are that these trends will continue to increase. The population growth of Cape Cod (Barnstable County) has been the highest of all counties in Massachusetts, increasing sevenfold since 1920. The growth has been paralleled by new home construction of 35,000 housing units from 1980 to 1990 and continued during the 1990s with 1,500 new units each year (Woods Hole Research Center, 2000).

Despite a widely shared opinion that we are not sustaining the natural beneficial functions of our coastal landforms, documenting the impacts of our cumulative effects on Cape Cod coastal landforms, or those of any coastal community for that matter, is not an easy undertaking. Local officials may not have the time to quantitatively measure and document impacts to coastal landform systems, especially in addition to their normal daily duties. For example, although the Town of Falmouth was listed as issuing 16 Orders of Conditions for activities on or adjacent to coastal landforms in 1999, the 1999 Annual Town Report states that the conservation commission heard a total of 186 requests for determination of applicability of the Wetlands Protection Regulations for both inland and coastal wetlands (213 last year), received 115 Notices of Intent (permit applications: 131 last year), issued 65 amendments to existing permits, issued 114 Certificates of Compliance, 12 extensions to existing permits, 81 administrative reviews, 9 emergency certifications, 15 enforcement orders, and held 39 public hearings. The 1999 Town of Harwich Annual Report listed in excess of 173 site inspections undertaken in response to 69 Notices of Intent for both inland and coastal proposals, culminating in 33 public meetings of the conservation commission. Some commissions are also responsible for developing rules and regulations for the use of open space, and a myriad of other town activities. Apparently, each town on Cape Cod follows a similar trend to some degree.

Furthermore, it has been documented in this study that trade-offs and balances in the strict application of regulations governing activities on coastal landforms are oftentimes acceptable, with unpredictable outcomes. For example, pile supported dune walkways were, for the most part, given negative ratings for impacts to dune vegetation resulting in some degree of dune instability from that activity. However, as discussed during this study, the alternative of not allowing that activity may be more detrimental. This is often the case for other categories of activities as well.

Additional targeted research is necessary focusing on the short- and long-term effects of specific activities on a lot-by-lot basis.

As stated by Nordstrom (2000), recognition that humans have become intrinsic agents in the evolution of coastal landscapes is significant in that it places the problem of restoring the value of these landscapes squarely on human action, requiring management approaches that work with, rather than against, natural processes. Are natural landscapes a myth along developed coasts? Human actions are now an integral part of the coastal environment. Is 'coastal landform system sustainability' now a synthesis of both natural and human-altered forms? If so, we need to be able to predict the impacts of human actions on coastal landforms from both large and small-scale projects.

While our quantitative understanding of coastal landform function is still evolving, we do possess a reasonably thorough qualitative understanding of the critical characteristics and beneficial functions of coastal landforms, and the necessity of a coastal landform ethic of mobility. This understanding has at least allowed us to develop methods to attempt to live with coastal landform processes, while enjoying the many benefits associated with use and appreciation of our coast. For example, while a house in a coastal dune most definitely affects natural dune sustainability, we know enough to require it to be placed on open pilings to allow some measure of dune sand migration. It will ultimately adversely affect dune function. However, is the societal and economic will strong enough to prohibit all development on all coastal landforms? This remains a site by site decision.

Massachusetts regulations, policies, and bylaws governing activities on coastal landforms have been based on identification of their critical characteristics in order to preserve certain public interests (e.g. storm damage prevention, flood control, preservation of wildlife habitat, prevention of pollution, etc.). These standards are based on requiring the mobility of coastal landforms. Yet, it appears that in a strict sense that we are not sustaining our coastal landforms. If we desire our decisions to ultimately maximize or optimize coastal landform system sustainability in the face of continuing development on and adjacent to these valuable landforms, we must begin an intensive program to research and monitor the impacts (positive and negative) of small scale activities to help guide our future decisions.

Suggestions for Improvements for Similar Future Studies

Several improvements to the Project Questionnaire are suggested for future studies of this type. One, the questionnaire cover page could include a more elaborate description of the project or activity to significantly reduce follow-up time by assisting in categorizing the activities. Quite a bit of follow-up with participants was necessary to clearly determine specific project parameters, particularly for multi-faceted projects. In addition, based on Massachusetts' regulations, coastal banks are divided into two categories: 1. An eroding, sediment source bank and, 2. A non-eroding, vertical buffer bank (see the Coastal Bank section in Characteristics of Selected Coastal Landforms Protected by Regulations). Only questions relating to the sediment source coastal bank were asked in the questionnaire (Appendix B). This required judgement by the author in grouping the questionnaire results into one bank type category.

It would be interesting to include and analyze Superceding Orders of Conditions issued by the state Department of Environmental Protection in order to determine what type of activities are considered deleterious or supportive to the beneficial functions of coastal landforms. These superceding orders take precedent over local order of conditions, but can also be appealed. (Appeal procedures are outlined in the WPRs.)

In addition, permit denials were not considered in this study. It would be valuable and helpful to future potential applicants to document what type of activities are considered non-compliant with the performance standards of the WPRs.

Future Research Needs

The scientific literature abounds with research focusing on the broad scale understanding of the complex interactions between winds, waves, tides, storms, and relative sea level, and the resultant longshore currents, sediment transport, and shoreline change. The interaction between coastal engineering structures and coastal processes and the predictive capability of computer models have also gained much attention. However, the scales of many of these studies appear to have limited direct application for use by a local coastal resource manager or regulator on a lot-by lot basis. On the other hand, results of research or monitoring on a lot-by-lot basis may not provide the coastal landform systems analysis required to understand how an individual human alteration affects changes in the overall system or littoral cell.

There is a great need on the local level to understand how individual actions on a lot-by-lot basis in Massachusetts affect adjacent property. There are few investigations relative to this scale. For example, the effects of houses on wind flow patterns and aeolian transport in dunes. Those that do exist provide little quantitative data on processes (Nordstrom, 2000). Many decisions are being made on a daily basis across the country on whether to permit development or alterations on individual coastal landforms. Cumulatively, these decisions have far greater effect in the long-term than perhaps the mega-projects that so often receive wide public attention. These small scale alterations and developments will have more of an effect on the landform system as time passes, while the shoreline and associated coastal landforms migrate landward in response to relative sea level rise in Massachusetts. Most local resource decisions are made using best professional judgement without the predictive capability to know what the impact will be to neighboring property and resources.

Are the effects of a house on a solid foundation more adverse to storm damage prevention and flood control to landward and adjacent resources and structures than a pile supported house? If yes, how high should a house be elevated to allow a dune to more naturally function?

Following the armoring of a coastal bank that was providing sediment to adjacent coastal landforms, how much and when should a commensurate volume of sediment be introduced back into the littoral system?

Does a seasonal at-grade dune boardwalk cause more or less impact to the beneficial functions of a coastal dune than a permanent elevated walkway?

Should saltmarsh catwalks be prohibited due to the potential impacts to underlying vegetation in favor of seasonal at-grade walkways or pedestrian use on the marsh surface itself?

Large-scale dune nourishment projects may prevent landward barrier beach migration, affecting its longevity. Should this practice be disallowed?

Many of the above questions were asked in the course of this study by the individuals that must make daily decisions on whether to permit small-scale human alterations to individual coastal landforms. Increased emphasis on monitoring the results of human alterations to individual coastal landforms, before and after the alteration, on a small scale is needed. This information would be invaluable in assisting local resource managers in their daily decisions.

Lastly, but importantly, broad-scale education and guidelines on the role of the *mobility* of coastal landforms in achieving their optimum beneficial functions would serve all interests.

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COASTAL LANDFORM SYSTEM SUSTAINABILITY PROJECT

***** **Participants** *****

Barnstable	Rob Gatewood Fred Stepanis Darcy Karle	Conservation Commission Admin Conservation Assistant Conservation Agent
Bourne	Nina Coleman	Conservation Commission Agent
Brewster	Steve McKenna	Conservation Commission, Chair
Chatham	Coleman Yeaw	Conservation Commission
Dennis	George McDonald	Natural Resources Officer
Eastham	Henry Lind	Natural Resources Officer
Falmouth	Peggy Emslie Mark Kaspzayk	Conservation Administrator Conservation Commission Agent
Harwich	Jane Harris	Conservation Commission Agent
Mashpee	Bob Sherman	Conservation Commission Agent
Orleans	Jeannie Wood	Conservation Commission Admin
Provincetown	Roger Dias	Conservation Commission Agent
Sandwich	Mark Galkowski	Conservation Commission Agent
Truro	Bob Bednarak	Conservation Commission
Wellfleet	John Chatham	Conservation Commission Agent
Yarmouth	Brad Hall	Conservation Administrator
WHOI Geology/ Geophysics	Graham Giese	Marine Research Geologist
Cape Cod Commission	Heather McElroy	Planner
WHOI Sea Grant	Jim O'Connell	Coastal Processes Specialist
Former participants: (before leaving positions)	Tina Balog Jo Ann Muramoto Julie Early	Brewster Conservation Commission Agent Falmouth Conservation Administrator Cape Cod Commission

PROJECT SUMMARY SHEET

CCC #:
Town:

APPLICANT NAME:

ADDRESS:

MAP AND PARCEL:

CONSERVATION COMMISSION /DEP FILE #: **DATE OF ORDER OF CONDITIONS:**

PROJECT DESCRIPTION (where appropriate, please indicate type of structure):

New construction/Reconstruction (new structure, relocation of structure, elevate structure on piles, new septic system, septic upgrade)
Walkways (new down bank, reconstruct down bank, new elevated over dune, at grade over dune)
New coastal armoring/Reconstruct coastal armoring (with nourishment, without nourishment)
Nourishment (beach, dune, bank with vegetation, bank without vegetation)
Stabilization (bank with biologs, banks with vegetation, dune with vegetation)
Beach grading/screening
Grading, excavation, clearing, landscaping
Dredging
Other:

Resource Area	Project is in:		Summary of Responses to Questions on Work Sheets			
	Buffer Zone	Resource Area	Q 1	Q 2	Q 3	Sum
Coastal Bank						
Coastal Beach						
Coastal Dune						
Barrier Beach						
Salt Marsh						
Land Subject to Coastal Storm Flowage						
Other:						

WORK SHEET: COASTAL BANKS

Impacts	Pos	Neg	NA	Rank*	Remarks
1. Will this activity impede (Neg) or permit (Pos) the erosion of the coastal bank by wave action (& thereby impact the supply of sediment to an adjacent coastal landform)?					

COASTAL DUNES

Impacts	Pos	Neg	NA	Rank	Remarks
1. Will this activity enhance (Pos) or impede (Neg) the vegetative cover of the dune?					
2. Will this activity decrease (Neg) or increase (Pos) the volume of the dune?					
3. Will this activity impede (Neg) or permit (Pos) the exchange of sediment between the dune and an adjacent coastal beach?					

* .5 = very minor, 1 = minor, 1.5 = somewhat significant, 2 = significant, 2.5 = very significant, 3 = major impact

WORK SHEET:
COASTAL BEACH

Impacts	Pos	Neg	NA	Rank*	Remarks
1. Will this activity enhance (Pos) or impede (Neg) the alongshore or cross-shore transport of sediment by wave action?					
2. Will this activity decrease (Neg) or increase (Pos) the volume of beach sediment?					

BARRIER BEACH

*Refer also to Coastal Dune and Coastal Beach, if applicable.

Impacts	Pos	Neg	NA	Rank	Remarks
1. Will this activity enhance (Pos) or impede (Neg) the deposition of sediment having the effect of increasing or decreasing the height (elevation) of the barrier beach?					
2. Will this activity impede (Neg) the landward migration of the barrier beach?					

* .5 = very minor, 1 = minor, 1.5 = somewhat significant, 2 = significant, 2.5 = very significant, 3 = major impact

WORK SHEET: SALT MARSH

Impacts	Pos	Neg	N A	Rank*	Remarks
1. Will this activity enhance (Pos) or impede (Neg) the growth of salt marsh vegetation?					
2. Will this activity disturb (Neg) the peat layer of the salt marsh?					
3. Will this activity enhance (Pos) or impede (Neg) tidal flow into the marsh?					

LAND SUBJECT TO COASTAL STORM FLOWAGE

Impacts	Pos	Neg	N A	Rank	Remarks
1. Will this activity enhance (Pos) or impede (Neg) the natural migration of a coastal beach, coastal dune or salt marsh onto land subject to coastal storm flowage?					

* .5 = very minor, 1 = minor, 1.5 = somewhat significant, 2 = significant, 2.5 = very significant, 3 = major impact

List of Permitted Activity & Ratings Identifying Impacts on Coastal Landform Sustainability

Cape Cod COASTAL LANDFORM SYSTEM SUSTAINBILITY PROJECT: 1999

	Activity Rating by Coastal Landform (see Table 1 for ranking numbers) (see Table 2 for town abbreviations in parentheses)					
PERMITTED ACTIVITY	***Bank***	***Beach***	***Dune***	***Barrier***	***Saltmarsh***	***LSCSF***
New coastal (hard) armoring of sediment source w/o nourishment	-2.0 (Ba) -1.5 (D) -0.5 (D) -1.0 (Or)	-2.5 (Ba) -1.0 (E) -1.0 (Or)				-2.5 (Ba) -1.5 (E)
Reconstruct (hard) armoring of sediment source w/o nourishment	-0.5 (Ba) NI (F) -0.5 (D) NI (F) -1.0 (F) -1.5 (H2) NI (F)	-2.0 (F) -1.5 (T) -1.0 (H) -1.0 (Or2)		-3.0 (T)		
New armoring (hard) w/nourishment	-2.0 (E4) -1.5 (W2) -2.5 (W)	-1.0 (E4) -0.5 (W) -1.5 (W) -3.5 (W)				
Reconstruct (hard) armoring w/nourishment: no nourishment previously req'd	-2.0 (W)					
Reconstruct bulkhead	NI (M2) NI (Bo)		NI (P)			
New house solid foundation	BZ:NI (Ba6) BZ:NI (H) BZ:NI (M3) BZ:NI (Or) BZ:NI (Br) BZ:NI (E) BZ:NI (Bo4) BZ:NI (Or11) BZ-0.5 (T2) BZ:NI (W4) BZ:NI (Y3)	BZ:NI (Ba2) BZ:NI (Bo) BZ:NI (Y)	-2.5 (D) -6.0 (T2)	-2.0 (T) -1.0 (T)	BZ:NI (Or4) BZ:NI (Ba) BZ:NI (Bo) BZ:NI (Y2)	NI (Ba7) NI (H2) NI (Bo3) -1.0 (Or) NI (Or)
New house pile foundation			-6.0 (Ba) -4.5 (T)	-4.5 (Ba) -2.5 (T)		-2.5 (Ba)

PERMITTED ACTIVITY	***Bank***	***Beach***	***Dune***	***Barrier***	***Saltmarsh***	***LSCSF***
Addition solid foundation	BZ:NI (Ba14) BZ:NI (H3) BZ:NI (M) BZ:NI (Br4) NI (F) BZ:NI (F2) BZ:NI (H) BZ:NI (Or7) NI (Or) BZ:N (W2) BZ:NI (Y2) BZ:NI (C)	BZ:NI (Ba) -0.5 (F) BZ:NI (F) BZ:NI (W) BZ:NI (Y)	-2.5 (Ba) -2.0 (Ba) BZ-0.5(E) -1.0 (H) -6.0 (H) -0.5 (F) -1.0 (F) BZ:NI (F) -0.5 (E) -1.0 (S)	-4.0 (Ba) -2.5 (Ba) -1.5 (F2) BZ:NI (F) -1.0 (S)	BZ:NI (Ba2) BZ:-0.5 (Ba) BZ:NI (Bo) BZ:NI (E2) BZ:NI (F2) BZ:NI (H) BZ:NI (Or2) BZ:NI (Y)	BZ:NI (Ba2) NI (Ba4) -2.0 (Ba) -1.5 (Ba) NI (Bo) -0.5 (F2) -1.0 (Or)
Addition - pile foundation			-2.5 (Ba) NI (E) +4.5 (Sa) -2.0 (Sa) -1.0 (Sa) +3.0 (Sa)	-1.5 (Ba) +1.0 (Sa)		-1.0 (Ba)
Elevate existing house on piles	BZ:NI (E)		BZ:NI (E) -5.0 (Sa) +2.0 (Sa) +3.0 (Y)	-3.5 (Sa) +1.0 (Sa) +1.0 (Y)		
Rebuild building (no expansion)	BZ:NI (Ba4) BZ:NI (Br) BZ:NI (E2) BZ:NI (F) BZ:NI (H3) BZ:NI (M) BZ:NI (Or4) BZ:NI (W2) BZ:NI (Y2)	BZ:NI (Y)	-2.5 (Ba) NI (F) -5.0 (Sa)	-3.5 (Sa)	BZ:NI (Ba2) BZ:NI (Or2) BZ:NI (Y)	-0.5 (Ba3) NI (Ba) NI (Bo) NI (Or)
Relocate structure (e.g. house)	BZ:NI (E2) NI (Y)			-1.0 (T)	BZ:NI (Ba)	+1.0 (H)
New septic (subsurface)	BZ:NI (Ba6) BZ:NI (Bo2) BZ:NI (Or11) BZ:NI (W)	BZ:NI (Ba2) -2.0 (Bo)	-1.5 (Ba) -2.5 (D) NI (P) -2.0 (Sa) NI (T)	-2.0 (Sa) NI (T)	BZ:NI (Ba) BZ:NI (Bo) BZ:NI (Or3)	-0.5 (Ba) NI (Ba) BZ:NI (Ba) -1.0 (Bo) NI (Or)
Septic upgrade (subsurface)	BZ:NI (Ba) BZ:NI (E5) BZ:NI (H) BZ:NI (Or3) BZ:NI (Sa) BZ-0.5 (T) BZ:NI (T) BZ:NI (W)	BZ-1.0 (T)	-1.0 (D) NI (E3) BZ:NI(E2) NI (P) -3.0 (Sa) -1.0 (Sa)	-3.0(Sa) -1.0(T)	BZ:NI (H2) -2.0 (H) BZ:NI (Or2) BZ:NI (Sa)	-1.0 (H) -2.0 (Sa) -1.0 (Sa) NI (W)
Replace septic (subsurface)	BZ:NI (Bo) BZ:NI (Br) BZ:NI (E)	NI (P)	NI (E)	-3.5 (Sa)		NI (Bo)

ACTIVITY	*Bank*	*Beach*	*Dune*	*Barrier*	*saltmarsh*	*LSCSF*
New mounded septic system						NI (Bo)
Replace mounded septic system						NI (Bo2)
New elevated bank walkway	NI (Ba3) -0.5(T) NI (Bo) NI(Y) -1.0(C) -0.5(Y) +0.5(E2) -2.0(E) NI (M3) +0.5(W4)					
Reconst elevated bank walkway	NI (Ba4) NI(Or) -0.5 (Ba) NI(W) NI (F) +1.0 (H)					
New elevated walk over dune			-0.5 (Ba) -1.0 (Ba) -1.5 (M) -2.5 (Sa) -3.0 (Sa) -2.0 (Sa) +1.5 (W) NI (Y)	-2.0 (Sa)		
Dune walkway at grade			-2.0 (Ba) -3.5 (Ba) -2.0 (F) -2.5 (P)			
New elevated walk over beach (to pier)			-1.0 (Ba) -0.5 (Ba) NI (Ba2) NI (F) N (Or) -0.5 (Y)			NI (Ba)
Existing pier		NI (Bo)			NI (Bo)	NI (Bo)
Elevated marsh walkway/catwalk					-2.0 (Ba) -3.5 (Ba) -1.5 (Ba) -1.0 (Ba3) -1.5 (Ba) -1.0 (Bo) -0.5 (C) -1.0 (C) -2.5 (E) NI (H) -1.0 (Y)	-0.5 (Ba)
Marsh walkway at-grade						

Identification of Coastal Landform Affected by Permitted Activity & Rating

Cape Cod COASTAL LANDFORM SYSTEM SUSTAINBILITY PROJECT: 1999

	Affected Coastal Landforms						Summary rating based on project responses (NI = no impact) (BZ: buffer zone)		
ACTIVITY	*Bank*	*Beach*	*Dune*	*Barrier*	*Saltmarsh*	*LSCSF*	*Pos*	*Neg*	*Comment*
New coastal (hard) armoring of sediment source w/o nourishment	neg	neg				neg		Neg	
Reconstruct (hard) armoring of sediment source w/o nourishment	neg	neg		neg				Neg	
New armoring (hard) w/nourishment	neg	neg						Neg	
Reconstruct (hard) armoring w/nourishment: no nourishment previously	neg							Neg	
Reconstruct bulkhead	NI		NI						NI
New house solid foundation	BZ	BZ	neg	neg	BZ	NI		Neg	BZ:NI
New house pile foundation			neg	neg		neg		Neg	
Addition/expand house (motel,etc) solid foundation	BZ	BZ	neg	neg	BZ	neg		Neg	BZ:NI
Addition - pile foundation			**	**		neg			** + & -
Elevate existing house on piles	BZ		**	**					** + & -
Rebuild building (no exp.)	BZ	BZ	neg	neg	BZ	NI		Neg	BZ:NI
Relocate structure (e.g. house)	NI			neg	BZ	pos			Depends on direction
New septic (subsurface)	BZ	neg	neg	neg	BZ	- & NI		Neg	
Septic upgrade (subsurface)	BZ	neg	neg	neg	BZ & neg	neg		Neg	
Replace septic (subsurface)	BZ	NI	NI	neg		NI			NI
New mounded septic sys						NI (A-zone)			NI

ACTIVITY	*Bank*	*Beach*	*Dune*	*Barrier*	*Saltmarsh*	*LSCSF*	*Pos*	*Neg*	*Comment*
Replace mounded septic system						NI (A-zone)			NI
New elevated walkway down bank	**								** +/- & NI
Reconstruct elevated walkway down bank	**								** +/- & NI
New storm drainage		neg						Neg	
New elevated walk over dune			neg	neg				Neg	Pos if walking on dune
Dune walkway at grade			Neg					Neg	
New elevated walk over beach (to pier)		neg & NI				NI			neg & NI
Existing pier		NI			NI	NI			NI
Elevated marsh walkway/catwalk					neg			Neg	
Marsh walkway at-grade					**				+ & -
Dune nourishment w/ vegetation		BZ:-	pos	pos	BZ:NI	neg	Pos		
Bury intake pipe					neg			Neg	
Beach nourishment		pos	pos			neg	Pos		
Bank nourishment/vegetate	pos						Pos		
Water intake pipe			neg					Neg	
Bank stabilization (soft) e.g. bio-logs	neg	neg temp						Neg	
New dock on saltmarsh					neg			Neg	
Replace elevated walkway/ pier		NI				+/-/NI			+ & -
Jetty reconstruction		neg		+ & -					+ & -
Jetty extension		neg						Neg	
Groin construction/ reconstruction		neg						Neg	
Extend drainage pipe into inter-tidal area w/rip-rap		neg						Neg	

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16. Abstract (Limit: 200 words)

In their natural state, the coastal landform systems of Cape Cod are self-sustaining. However, recognition that humans have become intrinsic agents in the evolution of coastal landscapes is significant. There is a great need to understand how individual actions on a small scale (lot-by-lot) basis affect the sustainability of coastal landform systems, such as coastal dunes, beaches, coastal banks, barrier beaches, saltmarshes, and coastal floodplains. However, there are few investigations relative to this scale.

This study illustrates the vast extent of human alterations to coastal landforms on Cape Cod. As a result of analyzing 318 Orders of Conditions issued for activities permitted on and adjacent to coastal landforms in all 15 Cape Cod towns in 1999, it documents and quantifies the gains and losses to coastal landform system sustainability.

The study documents the types of activities presently taking place on and adjacent to our coastal landforms and their potential affects, and potential mitigation being required by local commissions to minimize these affects. It also documents the trade-offs and balances oftentimes necessary in the application of performance standard based regulations governing activities proposed on coastal landforms. Because our quantitative understanding of coastal landform function is still evolving, particularly on a small-scale lot-by-lot basis, many decisions are oftentimes made using best professional judgement (if available) without the predictive capability to know what the impact will be to the applicant's or neighboring property and resources.

It is hoped that the results of this study will assist local, state, and federal coastal resource managers and regulators, as well as the public, in gaining insight into the interactions of human activities and natural coastal landform system function leading towards improved coastal resource management. The project participants stated that during the course of this study the sharing of information among them was invaluable. It is hoped that the sharing of information in this study with a broader audience will also be utilized for improved coastal landform system management.

17. Document Analysis a. Descriptors

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Permits

b. Identifiers/Open-Ended Terms

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