Analysis of the Coastal Protection Experience in Three Towns on Cape Cod, Massachusetts

A thesis

Submitted by

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ABSTRACT

Coastal protection permitting data from 780 Notice of Intent submissions is presented from three towns on Cape Cod, Massachusetts to analyze the coastal protection permitting experience since the creation of the Massachusetts Wetlands Protection Act in 1978. Notice of Intent records serve as a measure of demand for coastal protection and indicate that demand is rising in the towns of Truro, Wellfleet and Eastham and there appears to a trend towards soft coastal protection alternatives. A number of potential anthropogenic and natural variables are discussed that could influence demand for coastal protection permits but no clear trends are identified. Municipal decision-making processes should to be refined to plan for upward trends in coastal protection permitting to take advantage of wide regional expertise in the field.

ACKNOWLEDGEMENTS

This study would not have been possible without the assistance of the conservations agents and staff in Truro, Wellfleet and Eastham. Special thanks go to Arozana Davis, Town of Truro, Hillary Greenberg and Andrew Petty, Town of Wellfleet, Amy Usowski, Town of Eastham.

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INTRODUCTION

Coastal erosion and shoreline change is a natural process of terrestrial and ocean interaction that is often unacceptable to humans when property and infrastructure is adversely impacted. While it is almost impossible to accurately determine the impacts of erosion in the future, a solid understanding of past actions can guide a range of prudent response mechanisms. Federal, state, and local environmental regulations in Massachusetts manage coastal protection policy in response to erosion. Given the inevitable nature of erosion and shoreline change on the Massachusetts coastline, there has been and continues to be significant interest in protecting coastal areas from adverse effects. This study addresses a question relevant to coastal communities: with the inevitable nature of erosion on Cape Cod, what has the coastal protection permitting experience been for individual municipalities; and how can past coastal protection decisions influence future decision-making?

The goal of this study is analyze historic data on the coastal protection permitting experience in three municipalities on Cape Cod, Massachusetts in order to guide future decision-making. This topic integrates multiple research interests in coastal zone management: environmental policymaking at local levels of government and adaptation to changes in coastal dynamics. A number of variables that may influence the demand for coastal protection permits include rising sea level, increasing frequency and intensity of storm events, land use changes and socioeconomic changes; all of which may influence erosion rates and in turn, demand for coastal protection. With these possible influences it is important for municipalities to analyze historic permitting data in order to have the tools to address future needs in a consistent fashion that benefits both environmental protection and property protection needs.

SCOPE

An initial goal of this study was to conduct a quantitative analysis to the measure relationships between demand for coastal protection permits and a number of natural and anthropogenic variables. As Haddad and Pilkey (1998) note, the shortcomings in coastal protection records like beach nourishment records are prevalent and that small state and locally funded projects are often underestimated or not reported. Finkl (2002) also notes that coastal protection data is not always available from federal and local government and that analysis of poor data can be suspect at best and meaningless at worst. Finding and organizing historic records from various government agencies can be challenging and can lead to poor analysis of past coastal protection decisions. The challenge of analyzing multiple data sets under multiple jurisdictions led to the decision to measure demand for coastal protection solely at the local level to ensure a consistent data collection process. Given the time frame of this study, an effort to develop a dataset of sufficient size to test quantitative hypotheses would be a significant undertaking. It would be a good area of research for a more extensive project.

Additionally, an assessment of the environmental impacts and effectiveness of coastal protection alternatives will not be addressed in this study. While both are important questions in coastal research, it is also important to quantify the existing coastal protection permitting experience before addressing questions of impact and effectiveness. Therefore, this study pursues a qualitative analysis of the coastal protection permitting experience in three towns on Cape Cod: Truro, Wellfleet and Eastham. This is conducted in the following steps:

1. A review of existing coastal protection policies in the study area;

2. A qualitative assessment of municipal Notice of Intent (NOI) records in the study area from 1975-2010;

3. A discussion of a number of potential natural and anthropogenic indicators that may influence demand for coastal protection permits;

4. Policy recommendations for municipalities to consider to help manage future demand for coastal protection permits.

CHAPTER ONE:
RELEVANT MASSACHUSETTS REGULATIONS

Coastal protection activities are regulated by Massachusetts wetlands regulations because coastal protection structures and activities can affect sediment flow and prevent the migration and preservation of wetlands (U.S. Environmental Protection Agency [EPA], 2009). Wetlands migrate in response to sea level changes and are maintained by sediment transport from other coastal features (Orson, Panageotou, Leatherman, 1985). When sediment transport is diminished or stopped, it can lead to wetlands losses, which lead to other impacts like habitat loss, loss of storm protection benefits, and loss of public trust lands (Moorhead & Brinson, 1995; EPA, 2009). Coastal protection projects in the study area may be required to comply with a number of local, state, and federal environmental laws before they can be built. This study only addresses environmental permitting at the local level and not the additional permitting that may be required to satisfy state and federal regulations[1]. Typically, projects begin the permitting process at the local level before state and federal review, if applicable; making the local level a useful point to look at projects before they become subject to addition environmental regulations.

Under Massachusetts General Law Chapter 91, (The Massachusetts Waterfront Act), the Commonwealth has the authority to regulate activity in

[1] (Massachusetts Office of Coastal Zone Management [CZM], 2005) provides a comprehensive guide to environmental permitting in Massachusetts including relevant state and federal regulations that may part of a permitting process.

tidelands including submerged lands up to the mean high water line in order to protect and promote public trust interests that include navigation, fishing, hunting and environmental protection; this is known as the public trust doctrine[2]. Coastal banks, coastal dunes, coastal beaches, barrier beaches, salt marshes and land subject to coastal storm flowage influence public trust lands and are regulated by the Massachusetts Wetlands Protection Act (MGL 131, section 40); and the Wetlands Protection Act Regulations, (310 CMR 10.00). Massachusetts Department of Environmental Protection (MassDEP) oversees the program and handles an appeals process that can supersede local permitting decisions (CZM, 2005).

O'Connell (2000) provides an explanation of MGL 131; section 40 and 310 CMR 10.00:

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[2] CZM (2005) defines MGL c. 91 as the following:

Jurisdiction: Dredging, placement of structures, change in use of existing structures, placement of fill, and alteration of existing structures in any of the following coastal areas (recognizing that MGL Ch. 91 applies more broadly than to coastal areas):

- Flowed tidelands - projects in, on, over, or under tidal areas between the mean high water (MHW) line and the limit of state territorial waters (generally 3 miles from shore).
- Filled tidelands outside Designated Port Areas (DPAs) - projects up to the first public way or 250 feet from MHW, whichever extends farther inland.
- Filled tidelands inside DPAs - projects between the present and historic MHW (i.e. all filled areas inside DPAs).

Regulatory Summary: The Division of Wetlands and Waterways in MassDEP administers the Chapter 91 Waterways Program. Chapter 91 is the Massachusetts public trust statute and, as such, protects the public's rights to fish, fowl, and navigate below the current or historic high water line, as well as in great ponds and navigable rivers and streams in Massachusetts, the so-called public trust lands. Waterways regulations promote the preservation of tidelands for water-dependent uses that require direct access to the water. In addition, the regulations seek to ensure that areas in jurisdiction are maintained for public use and enjoyment when privately developed.

> The wetlands protection regulations (WPR) protect the critical characteristics of wetlands, including in part, coastal bans, beaches, dunes, barrier beaches, salt marshes, 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. (p. 9)

MGL 131, section 40 and 310 CMR 10.00 regulate all proposed projects within 100 feet of a wetland resource area that involve any excavation, construction activity and vegetation alteration; and require that the project is approved by municipal conservation commissions. This study only reviews NOI submissions for projects adjacent to estuarine wetlands and not palustrine wetlands. An important note is that the effective date of MGL 131, section 40 and 310 CMR 10.00 was August 10, 1978. Buildings and hard coastal erosion structures (CES) built or permitted before this date were considered preexisting non-conforming uses and were vested from wetlands regulations. Only those two exceptions are allowed to seek new permits for hard CES on coastal banks. Projects outside of these categories are only permitted to construct alternatives like soft CES or managed land use. This has inevitably influenced coastal protection choices for properties that were not vested from MGL 131, section 40 and 310 CMR 10.00.

Although the Commonwealth of Massachusetts has public trust responsibilities, MassDEP grants municipalities the authority to administer MGL

131, section 40 and 310 CMR 10.00. The process for a proposed project subject to MGL 131, section 40 and 310 CMR 10.00 is that an applicant requests a Request for Determination from municipal conservation commissions to determine if the project will affect the wetland buffer. This request requires a site plan, description of the project and notification of abutters. If the commission determines the work will affect a wetland it issues a Positive Determination and requires the filing of a Notice of Intent (Town of Orleans, 2003). A Notice of Intent demonstrates an applicant's interest in a project within a wetland or a buffer zone and is subject to conservation commission review. At this point, the applicant has a demonstrated interest in a project under jurisdiction of MGL 131; section 40 and 310 CMR 10.00. The project may be approved and an Order of Conditions is issued; it may be rejected because it did not meet MGL 131, section 40 and 310 CMR 10.00 and/or additional local bylaws; or it may be continued for the purposes of seeking additional information. Below are descriptions of coastal landforms that are regulated in MGL 131, section 40 and 310 CMR 10.00 because each is essential components of a coastal system. O'Connell (2000) defines these landforms as:

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 ban subject to vigorous wave activity. This type of coastal ban 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.

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 over wash. Coastal dune also means sediment deposited by artificial mean 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 lie landward to the dune line, coastal ban lie, or seaward edge of existing man-made structures, when the structures replace one of the above lies, 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 over wash sediment transport, and all other critical characteristics of beaches and dunes.

Salt marshes (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 sale soils. Dominant plants with salt marshes are salt meadow cord grass *Spartina patens* and/ or salt marsh cord grass *Spartina alter flora.* 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.
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 line 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), erodibilty, 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. [p. 11]

LOCAL CONSERVATION BYLAWS

In addition to MGL 131, section 40 and 310 CMR 10.00; municipalities can create additional bylaws to provide further protection under MGL c. 43B: the Massachusetts Home Rule Procedures Act[3]. While Massachusetts is an unplanned state that does not require the creation of a municipal comprehensive land use plans; municipalities are allowed under MGL c. 43B to regulate almost any concern they choose in order to protect health, safety and welfare as long as the bylaw meets two criteria: the bylaw cannot preempt state law and the bylaw has to

[3] MGL c. 43B, section 13: Any city or town may, by the adoption, amendment or repeal of local ordinances or by-laws, exercise any power or function which the general court has power to confer upon it, which is not inconsistent with the constitution or laws enacted by the general court in conformity with powers reserved to the general court by section 8 of Article LXXXIX of the Amendments to the Constitution and which is not denied, either expressly or by clear implication, to the city or town by its charter.

be implemented on a rational basis and be consistently applied to all projects. However, the study area on Cape Cod has a regional planning authority called the Cape Cod Commission that was created by the Cape Cod Commission Act of 1990. The Act requires municipalities to adopt local comprehensive plans that are consistent with a regional policy plan for Cape Cod (Cape Cod Commission, 2011). Therefore, local bylaws must be consistent with both Massachusetts statutes as well as the Cape Cod Commission Act. (National Research Council [NRC]. 2007) notes that local governments have some advantages over states in addressing coastal protection because of their familiarity with local problems and capabilities. This gives towns the ability to address erosion and protection needs in a dynamic way that may be more nimble than regional or state capabilities.

Truro, Wellfleet and Eastham each have conservation bylaws that provide additional levels protection to lands regulated under MGL 131, section 40 and 310 CMR 10.00. A review of these differences is important because different bylaws may influence the types of projects that can be permitted in each town. This is why this study's data analysis only reviews NOI submissions because local bylaws can affect the permitting process after the NOI submission. Truro has two components of their bylaw that were adopted in 2010 that are unique in the study area. First, Section 8-6-4 allows the conservation commission to take "cumulative adverse effects from past, as well as foreseeable future activities into account" when reviewing an application and requires the applicant to prove that the activity will not have significant adverse environmental effects. Projects can be denied for failure to provide adequate evidence of this (Town of Truro, 2010). The second unique section is Section 9: Emergency Repair Exemption. Section 9 exempts projects from the normal NOI process if they are deemed "emergency repairs to protect health, safety and or property." This allows the conservation agent to permit immediate work to "ensure safety and prevent further damage" with 24 hours of the damage if a NOI is filed at that time or within 10 days (Town of Truro, 2011).

Wellfleet's Environmental Protection Regulations, updated in 2010 include a 100 foot buffer zone and 50 foot vegetated filter strip from any wetlands resource area and prohibits any "new structure or addition to existing structure to be closer to a wetland resource area than existing conditions" (Town of Wellfleet, 2010). Section 2.04, part 3 requires CES to be designed to "avoid, minimize, and mitigate scour effects on neighboring properties." If adjacent property is not also protected by a CES, the proposed CES "must be set back 15 feet from the property line." Additionally, a coastal bank/beach nourishment plan must be implemented for the life of the structure that includes "annual maintenance and monitoring to assess impacts of the CES and sediment needs" (Town of Wellfleet, 2010). In 1993, Eastham adopted a conservation bylaw that encourages the use of "soft solutions such as revegetation, snow fencing, and gabion boxes instead of hard CES" for protection or reinforcement projects (Town of Eastham, 2011).

It will be interesting to see in the data if the differences between the conservation bylaws in the three towns influence demand patterns for coastal protection permits. A particularly rigorous bylaw might prevent prospective projects from reaching the Request of Determination or NOI stages if the bylaw and the conservation commissions suggest that a project will not meet the designated thresholds.

CHAPTER TWO: EXISTING CONDITIONS

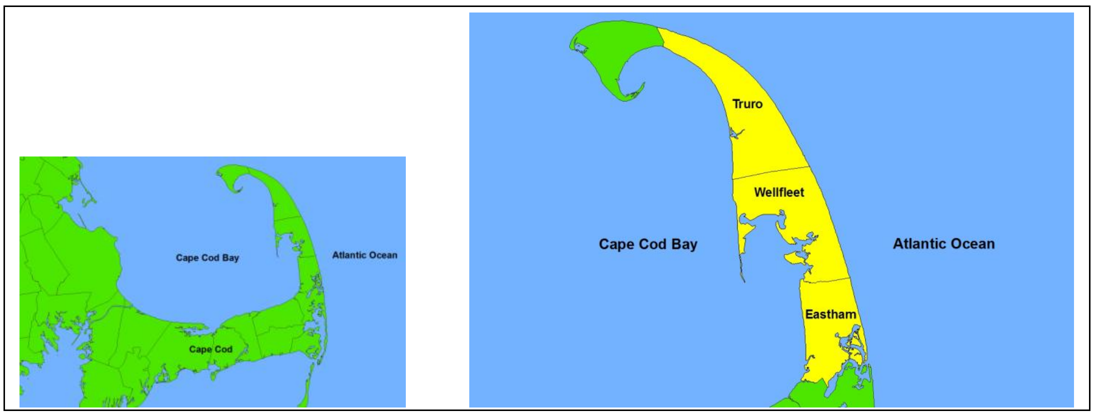

Figure 1: Cape Cod with study area in yellow: Truro, Wellfleet & Eastham, Massachusetts

This chapter describes the geomorphologic history of Cape Cod as well as the natural and human factors that affect coastal processes. Cape Cod is comprised of geologic deposits and is particularly prone to erosion unlike most landforms in New England that consist of exposed bedrock (Kelley, 2004). Cape Cod’s shoreline owes its existence to the legacy of the Laurentide Ice Sheet which reached it furthest extent south of Cape Cod at the islands of Nantucket and Marthas Vineyard around 17,000-18,000 b.p. (U.S. Geological Survey [USGS], 2011). When the Laurentide Ice Sheet began to retreat it left behind ridges called terminal moraines, which were made of glacial till, consisting of an unsorted mix of boulders, gravel, sand, silt, and clay picked up by the glacier as it advanced. Outwash plains, formed by sediments deposited by streams of melt water created a series of connected, broad, sandy plains and hilly terrains. Today, the outwash plain deposits comprise the major geologic features of the study area on Cape Cod (figure 2). Cape Cod's beaches are generally known as mainland beaches that are characterized by adjacent erodible bluffs that supply sediment that accumulate along the shoreline (National Research Council [NRC]. 1990). The beaches are defined by tall bluffs and narrow fronting beaches in the northern part of the study area that gradually turn into barrier beaches and spits in the southern part (USGS, 2011). Kelley (2004) notes that erosion rates in New England are highest and most persistent on the Atlantic shore of Cape Cod where persistent wave action undermines the sand bluffs.

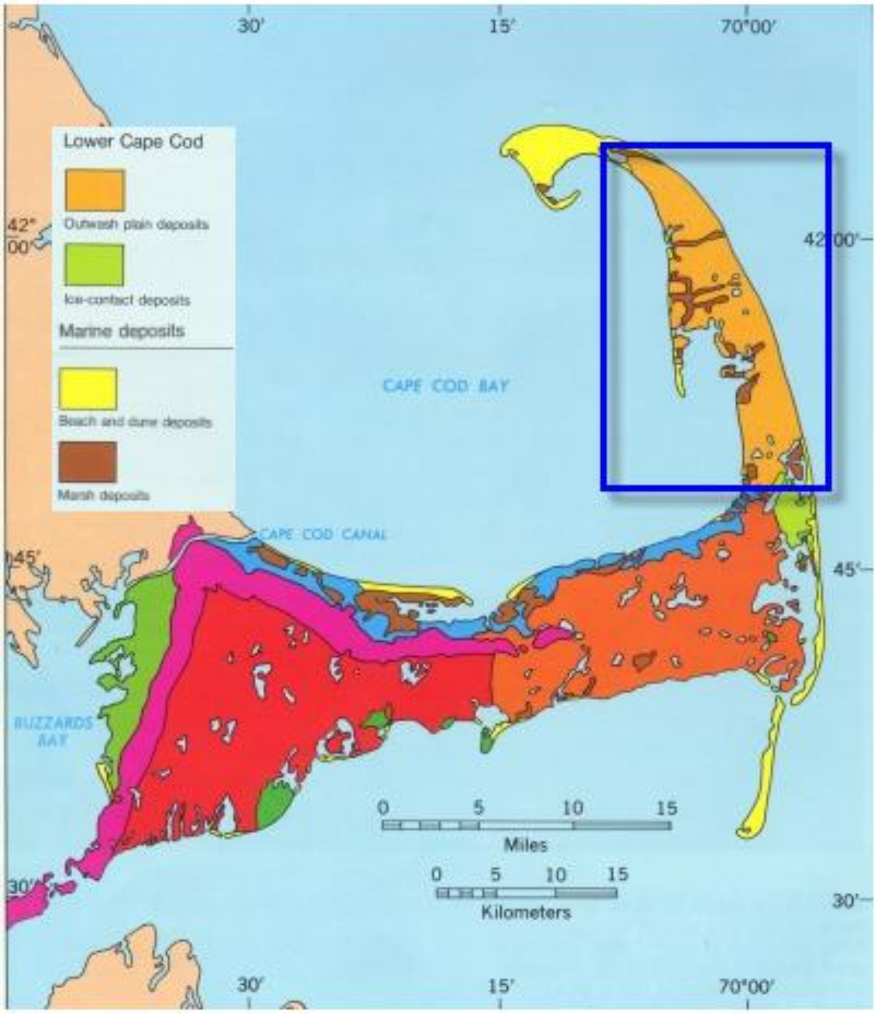

Figure 2: Distribution of the glacial deposits on Cape Cod with study area in blue. (USGS, 2001)

EROSION ON CAPE COD

Coastal erosion is defined in terms of the movement of shoreline contours caused by sea-level rise or movement of geologic material that composes the shore (National Research Council, [NRC 2007]. 2007). In the absence of human intervention, erosion is driven by winds, waves, currents and tides; all of which facilitate transport of shoreline sediment. These processes destabilize landforms like dunes and bluffs that provide sediment to replenish beaches (Kelley, 2004). Primary beach sand sources include the continental shelf and eroding cliffs that provide sand that was not previously in the surf zone; while long-shore currents supply material from adjacent beaches (Pilkey and Dixon, 1996). Sediment dislodged from cliffs and bluffs by waves and currents are the major supplier of beach material on Cape Cod (Psuty and Ofiara, 2002). Sea level change also contributes to erosion by displacing the shoreline inland that can lead to the loss of wetlands (Orson, Panageotou, Leatherman, 1985). Beaches are essential for the protection of adjacent coastal features and when combined with dunes and other landforms, create a coastal equilibrium that provides sediment for beaches, which in turn provides a shoreline buffer from storm damage (O’Connell, 2000).

Factor	Effect	Time Scale	Comments
sediment supply	accretion/erosion	decades to millennia	Natural supply from inland or shoreface and inner shelf sources can contribute to shoreline stability or accretion
sea level rise	erosion	centuries to millennia	relative sea level rise, including effects of land subsidence is important
sea level change	erosion	months to years	causes poorly understood, interannual variations that may exceed 40 years of trends
storm surge	erosion	hours to days	very critical to erosion magnitude
large wave height	erosion	hours to months	individual storms or seasonal effects
short wave period	erosion	hours to months	individual storms or seasonal effects
waves of small steepness	accretion	hours to months	summer conditions
alongshore currents	accretion, no change or erosion	hours to millennia	discontinuities (uplift ? downdrift) and nodal points
rip currents	erosion	hours to months	narrow seaward-flowing currents that may transport significant quantities of sediment during coastal storms
underflow	erosion	hours to days	seaward flowing, near-bottom currents may transport significant quantities of sediment during coastal storms
inlet presence	net erosion; high instability	years to centuries	inlet-adjacent shorelines tend to be unstable because of fluctuations or migration of inlet position; net effects of inlets is erosional owing to sand storage in tidal shoals
overwash	erosional	hours to days	high tides and waves cause sand transport over barrier beaches
wind subsidence	erosional	hours to centuries	sand blown inland from beach
compaction	erosion	years to millennia	natural or human-induced withdrawal of subsurface fluids
tectonic	erosion/accretion	centuries to millennia	elevation or subsidence of plates

Table 1: Summary of Natural Factors Affecting Shoreline Change. Source: NRC 1990.

Table one notes the natural variables that influence erosion in general, and to some degree in the study area. Erosion occurs on two temporal scales: short-term erosion is caused by short-term events like storms or a series of storms in contrast to long-term erosion that is permanent and occurs over decades and is influenced by a number of variables (Maine Sea Grant, 2010).

Both CZM as well as USGS have produced shoreline erosion rates for the study area. The CZM *Shoreline Change Project* provides long and short-term statistical data on shoreline change caused by erosion and accretion including estimates of rates of change. CZM incorporated transects of shoreline change rates over time into MORIS, the publicly available *Massachusetts Ocean Resource Information System* (CZM, 2011). Three examples of long-term erosion rates in the study are noted at Corn Hill, Truro; Indian Neck, Wellfleet; and Campground Beach, Eastham (figure 3). These examples are representative of the shoreline change experience in each town and do not represent average erosion or accretion rates for the whole town. Moore (2000) notes that there are a number of coastal mapping techniques available to reduce errors; and factors like project size and resources should dictate the choice of mapping technique. For this study, CZM data provides a useful snapshot of erosion rates at historically vulnerable locations in each town. CZM (2011) notes that shoreline change rates in MORIS vary significantly on a local scale due to the influence of anthropogenic erosion control structures.

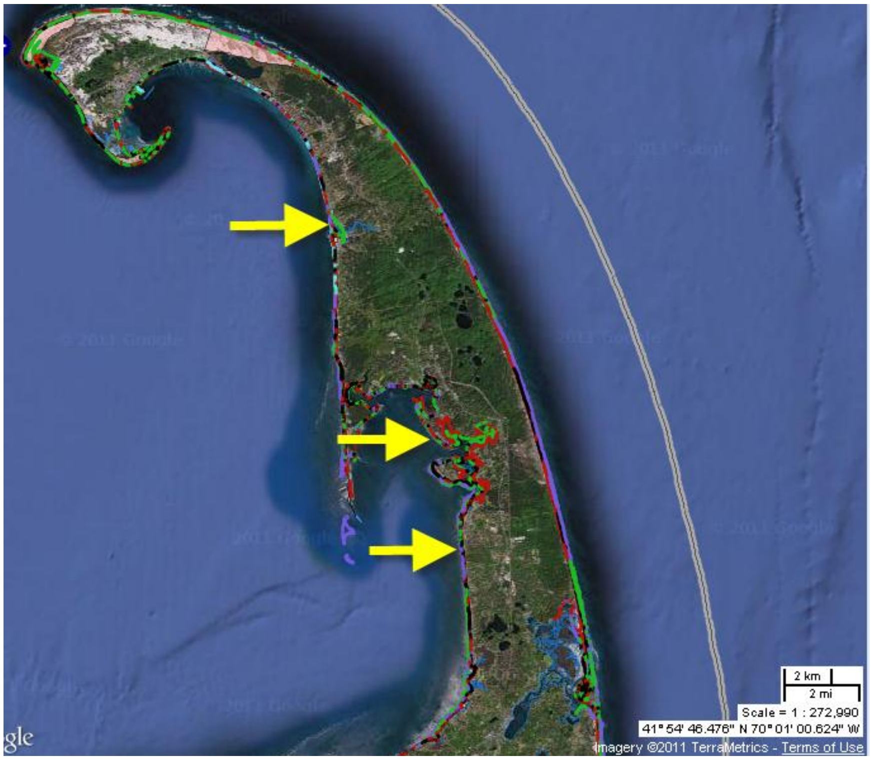

Figure 3: Shoreline rates of change examples, from top to bottom: Corn Hill, Truro; Indian Neck, Wellfleet; Campground Beach, Eastham. Source: CZM (2011)

The study area is generally affected by storms coming from the northwest to south. Since almost all of the properties in the study area except for the northern part of Wellfleet Harbor are westward facing, they are generally protected from the most severe impacts of nor'easters. Historically, nor'easters have caused the most damage on the Atlantic side of the study area; this is discussed further in the data analysis section.

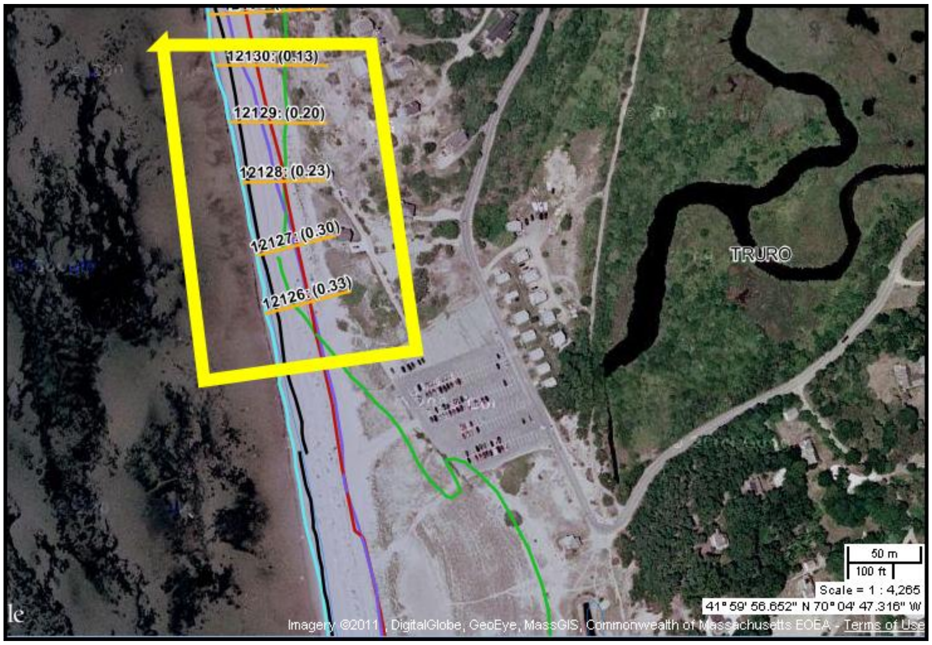

Figure 4: Current long-term rate of change at Corn Hill, Truro. Source: CZM (2011)

At Corn Hill in Truro, which is directly exposed to Cape Cod Bay to the west, the mean long-term erosion rate from [orange] transect 12126-12130, (the area inside the yellow box) is -6.2 feet (figure 4). The long-term erosion rate means that it could take years or decades to reach this level of erosion loss. Note the public beach parking lot to the south and homes to the right of the transects. At Indian Neck, which is in Wellfleet Harbor and has a little more protection from Cape Cod Bay to the southwest than Corn Hill and Campground Beach, the mean long term erosion rate from transect 11415-11419 is -1.85 feet (figure 5). At Campground Beach which is directly exposed to Cape Cod Bay to the west, much like Corn Hill, the mean long term erosion rate from transect 11060 to 11063 is -1.24 feet (figure 6).

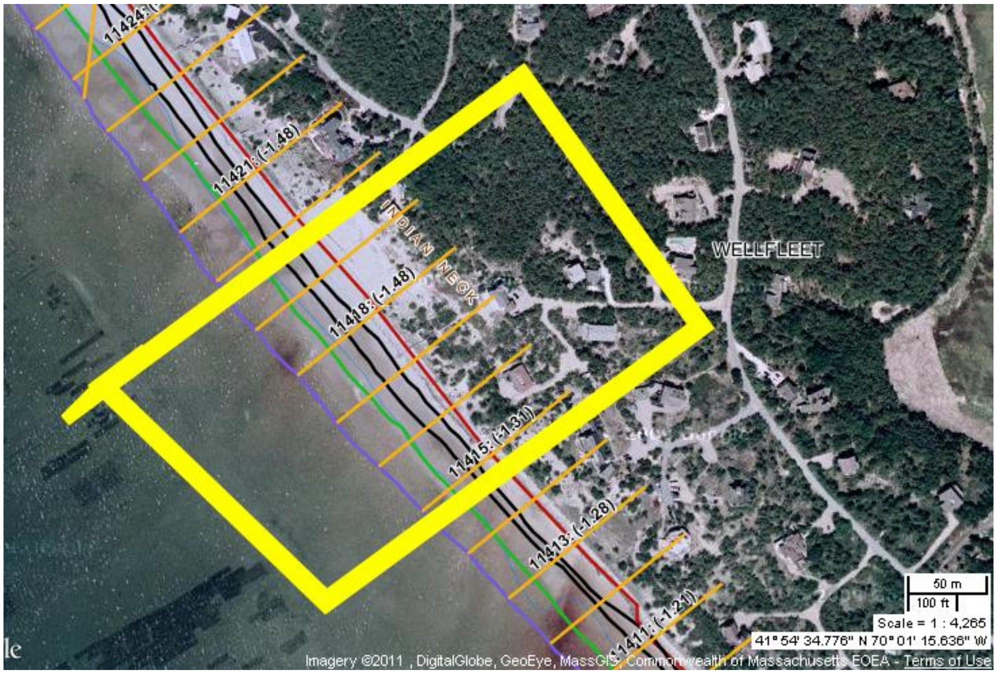

Figure 5: Current rate of change at Indian Neck, Wellfleet. Source: CZM (2011)

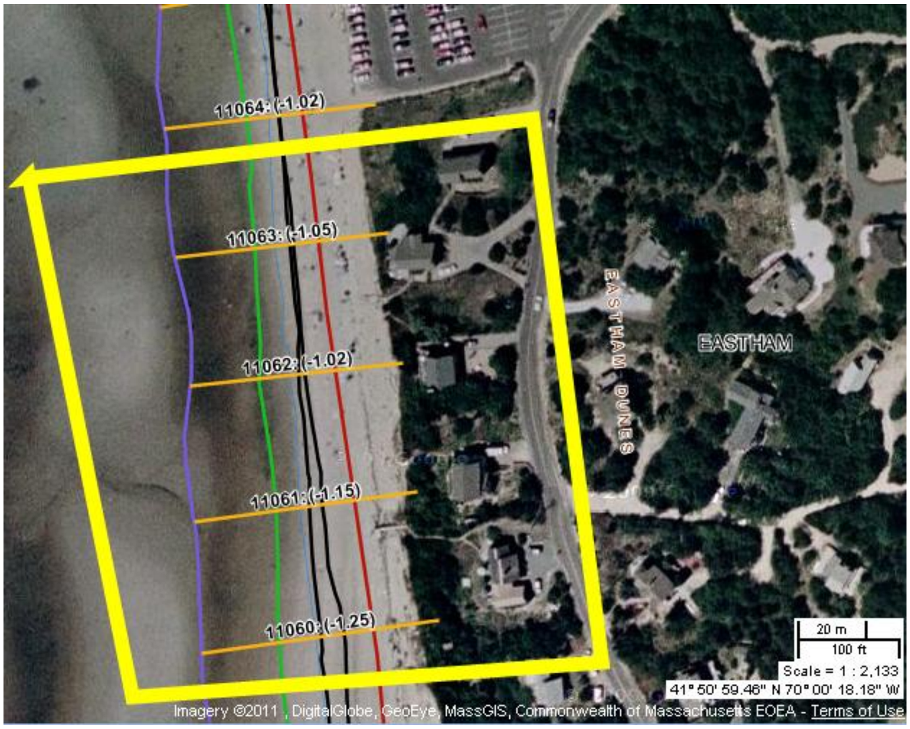

Figure 6: Current rate of change at Campground Beach, Eastham. Source: CZM (2011)

While the examples at these three locations only represent a sample of erosion rates in the study area, they demonstrate the dynamic nature of erosion rates and challenge of designing and maintaining a consistent regulatory response to the protection needs of impacted property owners and stakeholders. The variation of erosion rates in the three sample areas also suggests that the coastal protection experience may be different in each town.

In addition to the variables that drive natural erosion, a number of anthropogenic activities used to protect shorelines from erosion disrupt coastal systems and may contribute to increased erosion rates (Pilkey et al. 1998). These include constructed jetties, dredged channel and harbor entrances, piers, groins, seawalls and breakwaters; essentially anything that affects the supply of sediment to beaches and can both stop erosion as well as exacerbate it (Pilkey and Dixon, 1996). Certainly, coastal protection efforts by individual property owners can stop erosion, but the cumulative effects of shore hardening can alter the shore zone, causing loss of beach, reduced sediment supply and transport, and a deepening of the nearshore region (NRC, 2007).

Besides hard-engineered structures, changes to soil and vegetation caused by pedestrian or off road vehicles can cause erosion on components of a coastal system. In the study area, most pedestrian traffic occurs at public landings and beaches but also may occur at properties along the shore by residents and visitors who often use stairs to get down the dune or bank. Indiscriminate parking and pedestrian traffic can lead to destruction of dune vegetation and incision of gullies on slopes of bluffs, (Nordstrom, 2000). While most of the study area is already protected by some coastal protection structure, erosion can also be caused by vehicle traffic. Godfrey and Godfrey (1981) found that 50 passes of a vehicle could stop seaward growth of dunes on Cape Cod. Each town in the study area allows vehicle traffic on beaches for different reasons. Truro allows it for fishing access, Wellfleet for access to commercial aquaculture grants, and Eastham for access to aquaculture grants. Nordstrom (2000) notes that vehicle and pedestrian impacts decrease away from access points; so well defined legal access points at public beaches and landings can control adverse effects. Godfrey and Godfrey (1981) also add that a few well-managed access points are better than many lightly used access points. In sum, many variables influence shoreline rates of change and some may drive demand for coastal protection. Some of these variables are discussed further in chapter five.

CHAPTER THREE: CATEGORIES OF PROTECTION IN THE STUDY AREA

Responses to erosion and shoreline change have predictably changed over time with new technology, resources and interest in protection. In the past, communities threatened by erosion were often abandoned and the residents migrated inland and rebuilt (Paskoff, 1987). An example of the limits of human intervention in the study area is Billingsgate Island, located in the middle of Wellfleet Harbor on the border with Eastham (figure 7).

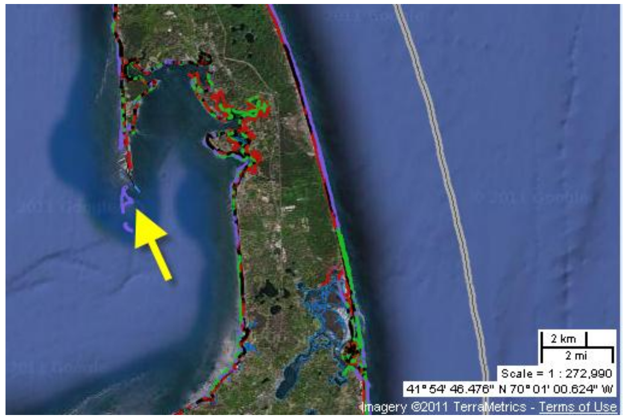

Figure 7: Location of Billingsgate Island. Source: CZM (2011)

Once a thriving fishing and whaling community in the eighteenth and nineteenth centuries; sea level rise and coastal erosion eventually subsumed the community and all residents had to retreat inland to present-day Wellfleet (New England Lighthouses: A virtual guide. [NEL] 2010). Predictably, with increasing wealth and technical ability, larger protection projects became common in the early twentieth century with the development of heavy machinery and increased value of coastal property. This experience has evolved into the coastal protection alternatives available today.

In this study, there are three coastal protection alternatives documented:

1. hard coastal erosion structures (CES): including engineered stabilization such as stone revetments, bulkheads and seawalls;
2. soft coastal erosion structures (SCES): including sand drift fencing, revegetation and beach nourishment;

3. managed land use: which includes relocation of threatened structures.

Method	Physical Description	Approx. costs per linear foot	Life expectancy (years)
shore parallel approaches			
Revetment	Interlocking concrete blocks or rip-rap build on a slope	$1000-1500	30
Bulkheads	Vertical walls constructed of steel, concrete sheet piling, lumber, aluminum, plastic or timber	$600-1000	30
shore perpendicular approaches			
Groins	Concrete blocks or stones built to varying lengths with a range of profile shapes	$1000-2000	30-40
Beach Nourishment	process of bringing quantities of sand from an outside source onto an eroding beach area	$4-8/cubic yard	4 to 7
Dune Stabilization	Creation and stabilization of dunes with natural vegetation, fill or sand fencing	Per square yard: $2 (vegetation). Per linear foot: $6-120 (fill); $1 (sand fencing)	5 to 10
Geo-tubes or other geotextiles	Large bags or tubes filled with sand to create a dune-like ridge	$60-70	5 to 10

Table 2: Comparison of Stabilization Techniques. Psuty and Ofiara (2002)

In the study area, NOI permitting records indicate that 50% of the protection alternatives were hard CES; 45% were soft CES and 5% were categorized as managed land uses (figure 13). Projects built parallel to the shore are known as shoreline parallel projects and are often built above the mean high water line because they do not require as many state or federal permits (Nordstrom, 2000). NRC (2007) defines bulkheads as shore anchored vertical barriers made of a variety of materials to block shoreline erosion. Psuty and Ofiara (2002) note that bulkheads are not generally designed to be subject to direct wave action except during astronomically high tides and storm tides because constant wave action undermines them. Bulkheads are often built landward of protective beaches while seawalls and revetments are often built once the protective benefits of a beach is gone and the shoreline is exposed

(Nordstrom, 2000). A seawall is generally built stronger than a bulkhead and is designed for more exposed shorelines. Both bulkheads and seawalls comprise 27% of the CES in the study area.

Figure 8: Stone revetment and timber bulkhead in Wellfleet. (Town of Wellfleet, 2011)

Revetments comprise 22% of the CES in the study area and are typically made of granite riprap. They armor shoreline slopes and are often used to replace failing bulkheads (NRC, 2007) Groins are built perpendicular to the shore and prevent littoral drift of sediment by stopping sediment transport. Pilkey et al. (1998) notes that groins work effectively to trap sand if a sufficient sediment supply exists, but stopping littoral drift starves adjacent beaches of sediment. There was only one NOI submitted for a groin in the study area although there are a number of groins in Wellfleet Harbor that were constructed at some point before the 1970s (figure 9). Another type of alternative are geotextiles that are sometimes called gabion bags. Shin and Oh (2007) note that they function like revetments and are made of woven fabric bags filled with sediment that form protective barriers that can adjust with shoreline change. Geotextiles are meant to be a softer alternative to harder CES. They can protect areas of modest erosion but can be undermined and torn apart in areas of high erosion (Psuty and Ofiara, 2002).

Figure 9: stone groins in Wellfleet Harbor. Source: CZM (2011).

Beach nourishment is the most popular coastal protection alternative in the U.S. and projects have been increasing over time (Valverde, Trembanis, and Pilkey, 1999). In the study area, beach nourishment is often used as part of dune stabilization projects and to maintain sediment lost near hardened CES. As noted in Chapter 1, the Town of Wellfleet requires beach nourishment as part of a CES maintenance plan. Nourishment projects in the study area comprise 17% of CES. Nourishment simply consists of putting quantities of sand to supplement beach losses, which may afford additional protection from storm and flooding damage (NRC, 1995). Psuty and Ofiara (2002) note that it is important to choose sand grain size that matches native material. Dune stabilization is another soft CES alternative. It can include re-vegetation with native species like American Beach

Grass, *Ammophilia breviligulata* or other native species; and installation of snow fencing which induces the settlement of wind blown sand (Nordstrom, 2007). In the study area, 24% of all NOI submissions were for dune stabilization, making it the most popular alternative.

Finally, managed land use (MLU) is any policy that promotes building away from the shoreline (Pilkey et al. 1998). In this study, it is defined as NOI submissions to demolish a structure or move a structure away from the shore. Managed land use can also include coastal realignment, which is the deliberate breaching of coastal erosion structures, and managed retreat of homes away from shore to allow the shoreline to migrate naturally (Turner, Hadley, Burgess, Coombes, Jackson, 2007).

CHAPTER FOUR: DATA ANALYSIS

This Chapter reviews the coastal protection permitting experience in the towns of Truro, Wellfleet, and Eastham. Each town has two exposed coastlines and only the western shoreline along Cape Cod Bay is included in the study area. The Cape Cod National Seashore instituted a "no protection policy" in 1972 and does not permit any coastal protection structures. Pilkey and Dixon (1996) note that the National Park Service (NPS) which administers the Seashore instituted the policy which remains intact today and maintains the Outer Cape’s backside beach free of CES. USGS (2011) notes that the lack of CES on the Atlantic facing shore of Cape Cod is the only system in New England and Mid-Atlantic region that is a natural system. Although the Atlantic coastline was not included in the analysis because of the NPS policy; Truro, Wellfleet and Eastham are in a unique position in coastal areas because they have two coastlines, while many coastal areas only have one exposed shoreline.

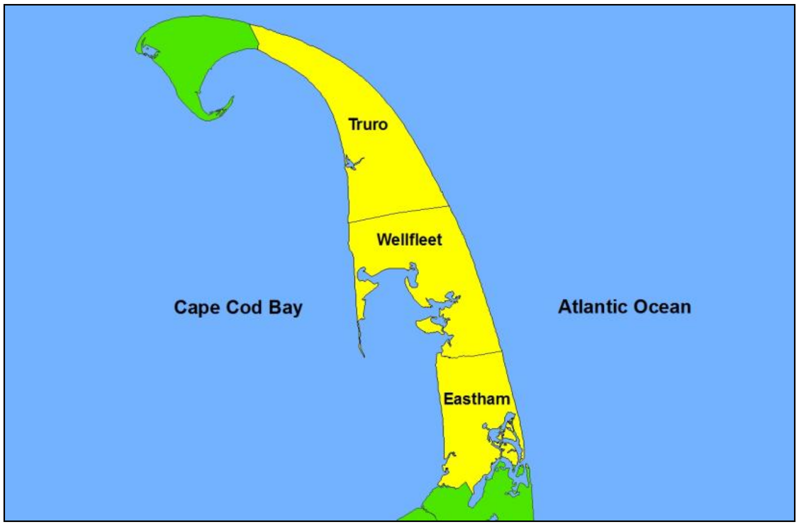

Figure 10: Towns in study area.

Similar analyses of this style have been done by Haddad and Pilkey (1998) to document the beach nourishment experience in New England from 1935-1996; and by O'Connell (2000) analyzing Order of Conditions for coastal protection on Cape Cod in addition to impacts on coastal landforms. This analysis is intended to fill the knowledge gap at the local level so municipalities can compare coastal protection permitting experiences and policies and to see what types of records they keep. The results of this analysis indicate that record keeping appears to be strong in the study area, with comprehensive data preceding the implementation of MGL 131, section 40 and 310 CMR 10.00 in 1978.

METHODS

Notices of Intent Records serve as the variable to measure the demand for coastal protection permits. As mentioned previously, NOI permitting records measure intent to construct a coastal protection project and do not represent projects that complete the permitting process and receive Orders of Conditions. NOI permit records are a uniform measure of demand across the study area before the submissions can be impacted by local bylaws or state and federal permitting requirements. Contact was made with town conservation departments and conservation agents in Truro, Wellfleet and Eastham and in person visits were made to each office. Truro and Wellfleet had digital secondary and paper primary NOI submission records dating to the 1970s. Eastham had limited digital records but complete primary records. Secondary records in Truro and Wellfleet, and primary source records in Eastham were reviewed and two variables were recorded: year of the NOI submission and project type.

FINDINGS

From 1975-2010, 780 NOI submissions were filed for coastal protection projects in the study area (figure 11). In general, NOI submissions have exhibited an upward trend since 1975, but there is annual fluctuation in number of submissions. These are characterized into three alternatives: hard CES, soft CES, and managed land use. Organization of the data was made as follows:

- Dune stabilization was organized under soft CES. Stabilization includes snow fencing, revegetation or other soft structures;

- Nourishment is included as a soft CES. Nourishment includes putting new sediment on a beach or to protect a hard erosion structure.

- Hard CES includes bulkheads, seawalls, revetments and groins;

- Managed land use includes new foundations and moving buildings away from eroding shorelines;

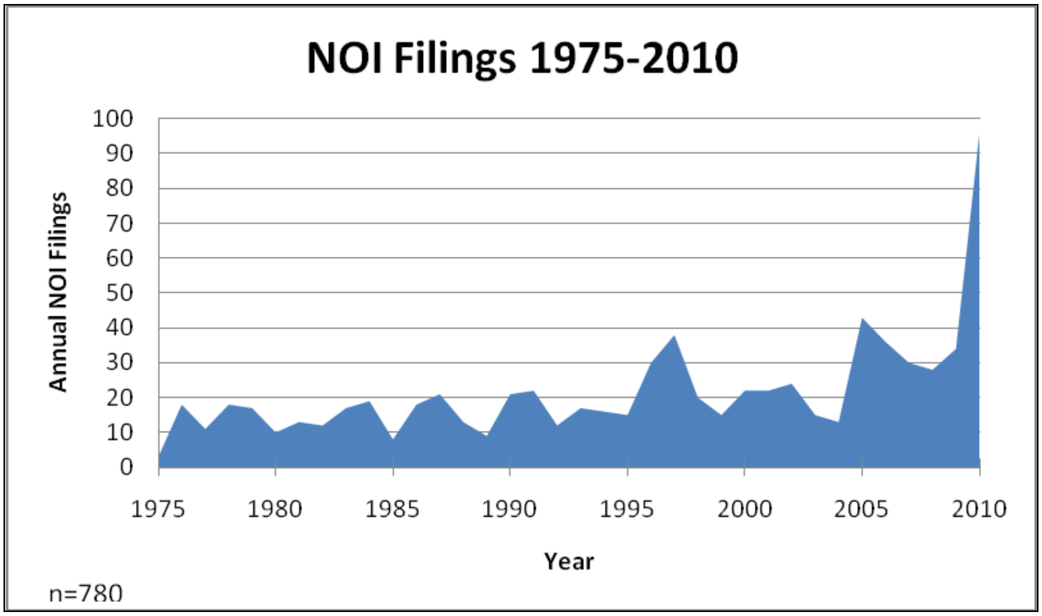

Figure 11: Cumulative NOI records in Truro, Wellfleet, Eastham (1975-2010).

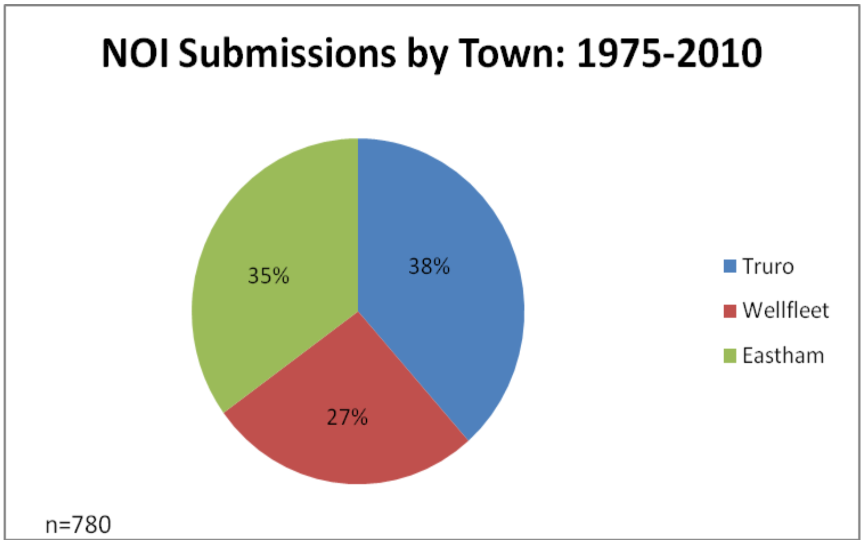

Figure 12: Percentage of NOI submissions by town (1975-2010).

Distribution of NOI submissions were similar between towns with Truro having 38% of all NOI submissions from 1975-2010; Eastham in second with 35%; and Wellfleet with 27% of all NOI submissions (Figure 12). One note is that Truro's NOI submissions increased significantly in 2010, so it could be possible that 2010 is an outlier for the dataset.

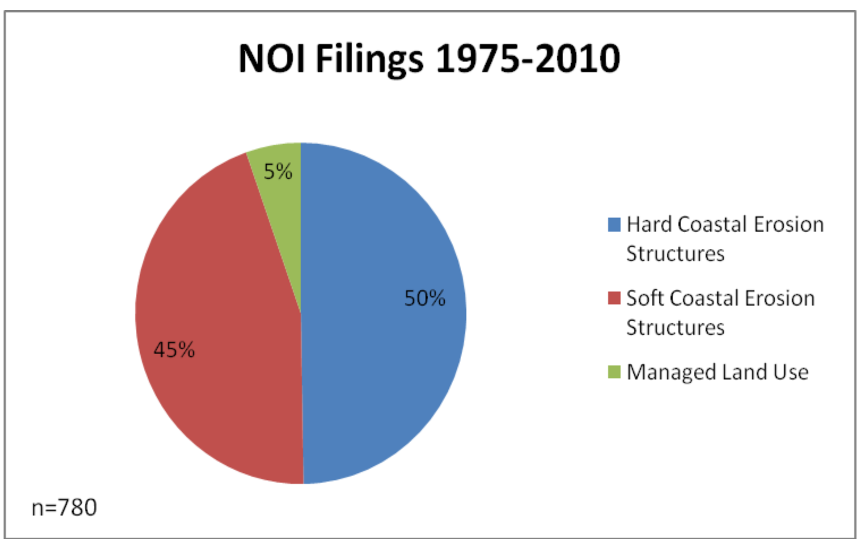

Figure 13: Type of coastal protection included in NOI

Hard and soft CES dominated the NOI records in aggregate, accounting for 95% of all NOI submissions. Only 5% of NOI submissions were for managed land use (Figure 13).

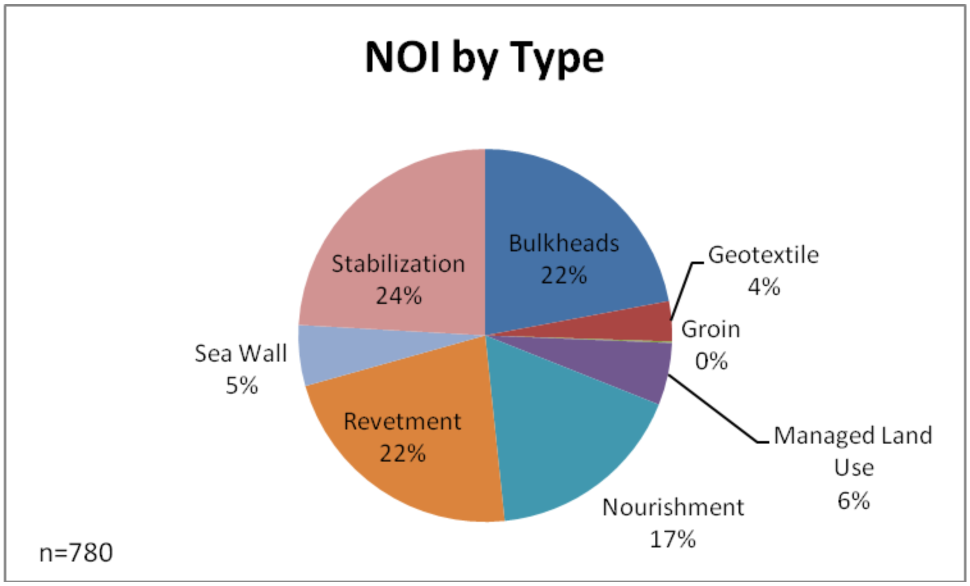

Figure 14: Type of protection included in NOI by type

Broken down further by type, the data indicates that bulkheads, stabilization and revetments all have similar percentages with nourishment close behind (figure 14). Geotexiles represent only 4% of all protection alternatives. Plotting the data over time, it appears that hard CES were the most popular permitting alternative until approximately 1998 when soft CES because increasingly popular (figure 15). Limited managed land use may indicate that property owners are choosing to protect their properties instead of moving structures at this time.

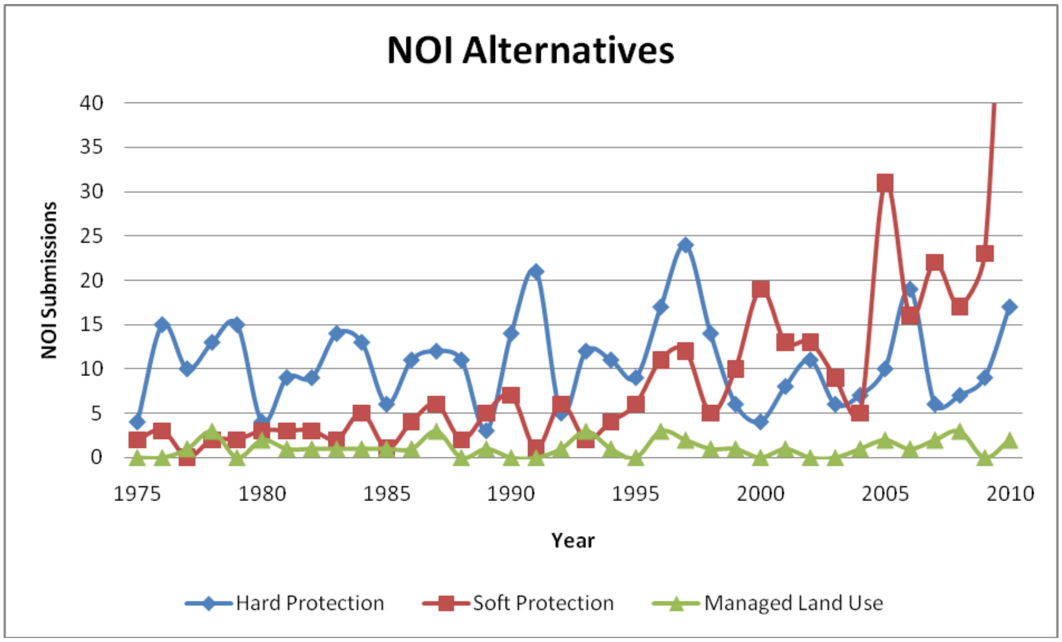

Figure 15: Types of protection over time (1975-2010)

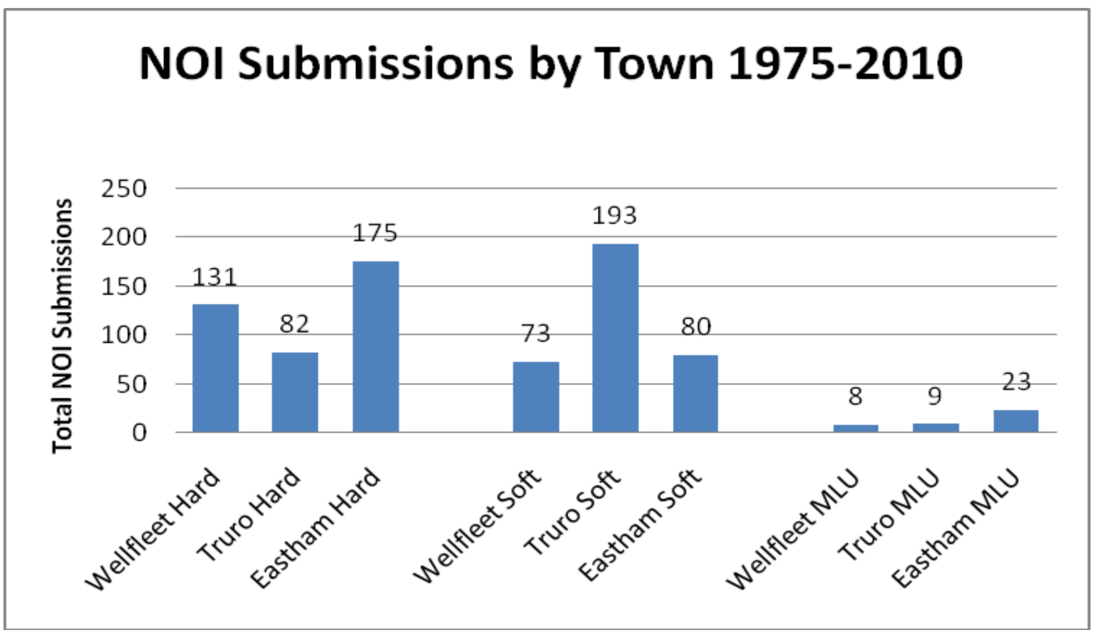

Figure 16: Types of protection by town (1975-2010)

Coastal protection choices vary by town. Eastham had the most NOI submissions for hard CES, while Truro dominated soft CES. All towns received very few NOI submissions for managed land use. Eastham had 60% more than either Wellfleet or Truro (Figure 16). The data demonstrates increasing demand for coastal protection permits across the study area, as well as in each town. The data indicates significant variablity in annual NOI submissions in total and between towns, but the data and trends suggest that it would be prudent for towns to prepare for increasing trends in NOI submissions in the future. The data also suggests an increasing trend in demand for permits for soft CES alternatives. This may follow the bylaws in each town that encourage the use of soft CES instead of hard CES. Given the results of the data, the next chapter discusses some of the variables that potentially influence the demand for coastal protection.

CHAPTER FIVE: POTENTIAL INFLUENCES

There are a variety of natural and anthropogenic factors that potentially influence demand for coastal protection permits in the study area. Some of the factors include population growth, land use change, property value change, sea level change and storm frequency and intensity. Statistical analyses to determine if different variables have statistically significant relationships with NOI submissions would be useful and could help decision-makers understand factors that influence demand for coastal protection. NOAA (2011) notes the potential relationships between population growth, housing growth, and demand for coastal protection. Population growth generally leads to additional voters who demand protected shorelines and maintained recreational opportunities in public trust lands (Nordstrom, 2008). Many current and future retirees with second homes plan to retire and live near the ocean; making their former season vacation homes primary residences and putting pressure on politicians to support coastal protection projects (NOAA, 2011).

POPULATION GROWTH

Truro, Wellfleet and Eastham are part of Barnstable County, all of which have seen population growth until the 2000s when both county and town populations leveled off and declined slightly (Figures 17 & 18). From 1980 to 1990, the population of Barnstable County grew by 26%; by 19% from 1990-2000; and declined by 2.9% from 2000-2010 (figure 18).

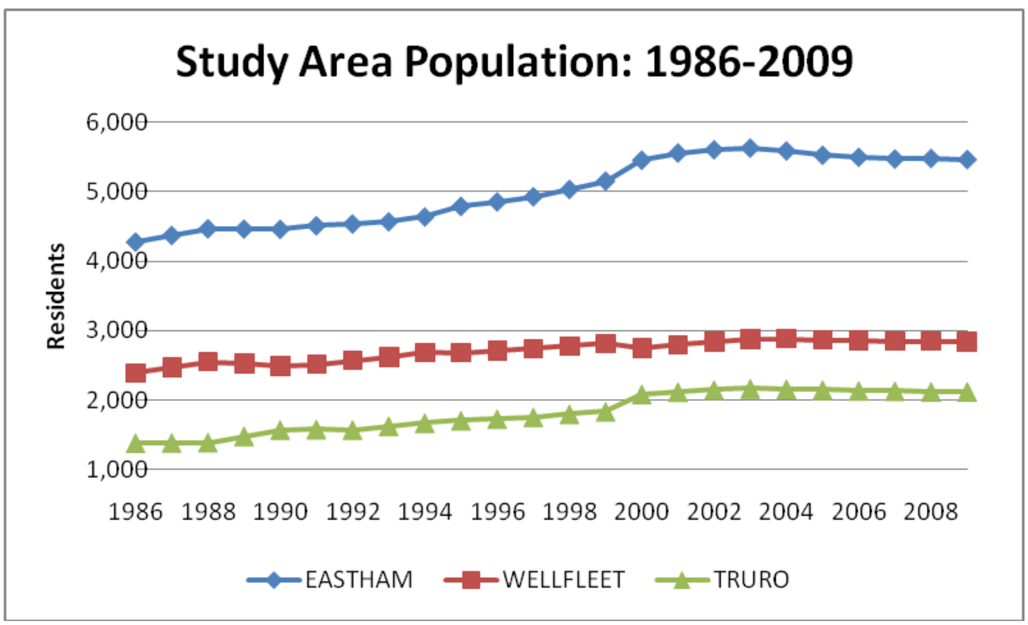

Figure 17: Residential Population (1986-2009). (U.S. Census, 2011)

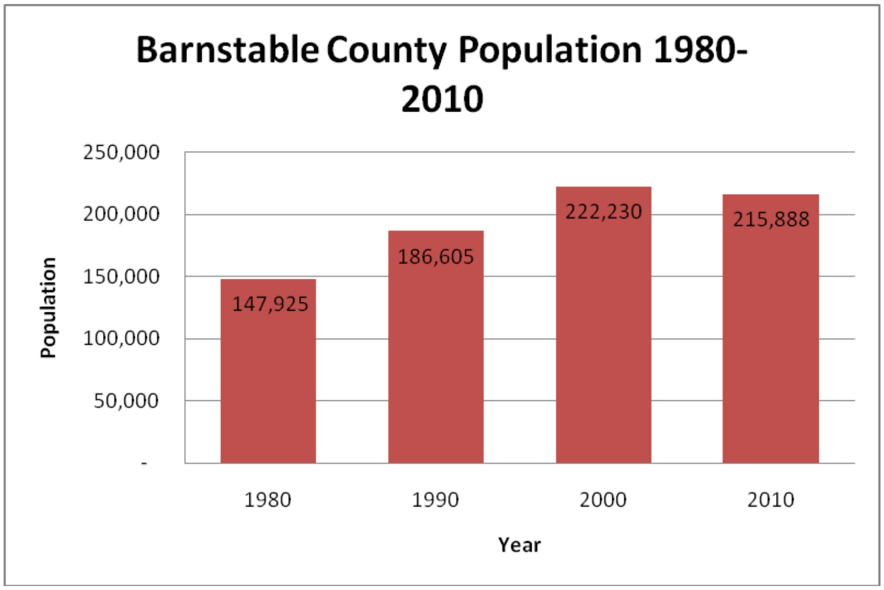

Figure 18: Barnstable County Population (1975-2010). (US Census, 2011)

Barnstable County's population grew by 19% from 1990-2000 exceeding that of Massachusetts as a whole, which only grew by only 5.5% during that period. However, the results of the 2010 census indicate that from 2000-2010, this trend reversed itself as Barnstable County's population declined by 2.9% while many Massachusetts counties' and the state as a whole population grew (figure 19). On Cape Cod, in addition to permanent residents, there is a major summer influx of visitors in July and August. The combination of summer visitors and permanent residents makes it difficult to gather accurate population data during peak vacation periods. The seasonal population influx requires a larger number of housing units to provide vacation lodging that would not be needed otherwise. The additional number of vacation homes may create demand for shoreline protection that might not otherwise exist if Cape Cod were not a tourism destination.

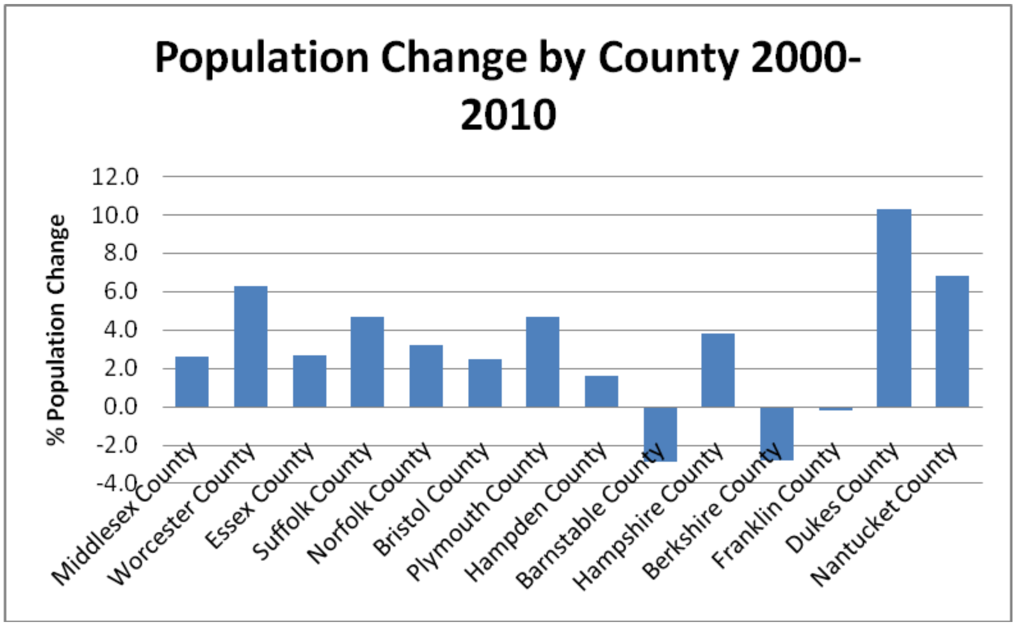

Figure 19: Massachusetts County Populations Change 2000-2010. (US Census, 2011)

Given the change in population growth rates and population decrease in the study area from 2000-2010, as well as seasonal fluctuations; it may be difficult to use population growth as a proxy for land use change. Particularly because of the study area's status as a tourism destination, population growth may not capture land use changes that may be reflected in the additional construction of vacation homes. There is a wide discrepancy between population change and growth in housing units in the study area. In each town, at least 50% of housing units are categorized as vacant, which are described more accurately as seasonal units (Figure 20).

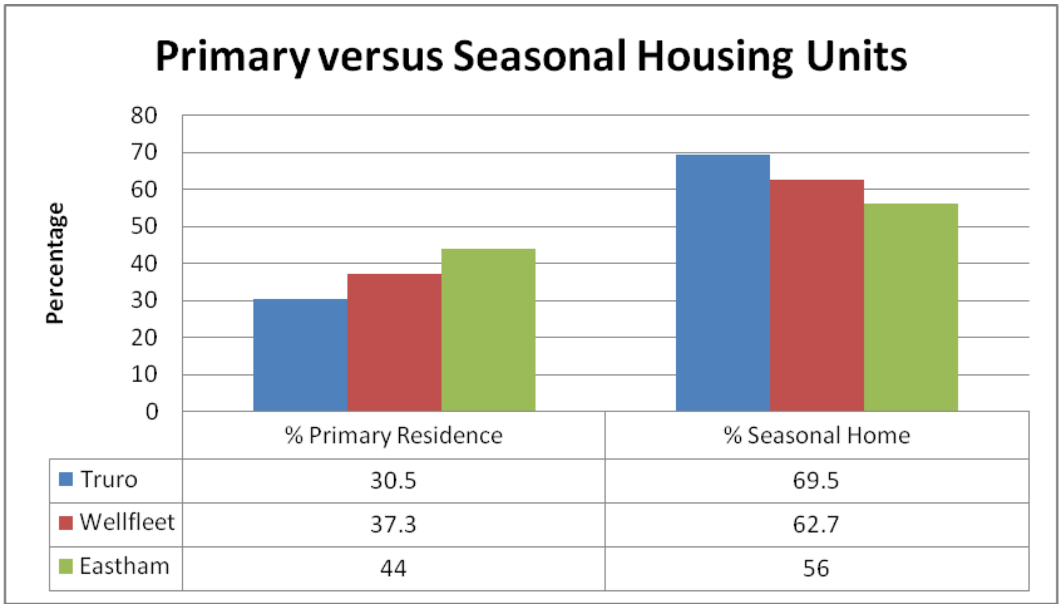

Figure 20: Primary versus seasonal housing units. (US Census, 2011)

LAND USE AND PROPERTY VALUES

Land use changes have altered the natural environment on Cape Cod for centuries in ways that may have exacerbated coastal erosion. Nordstrom (2000) notes that overgrazing and deforestation of drainage basins leads to increased amounts of sediment delivered to coastal areas. Motzkin, Eberhardt, Hall, Foster, and Harrod (2002) note the impact of land use changes in Cape Cod's history:

> Beginning in the mid-seventeenth century, rapid clearing for settlement and agriculture reduced the extent of woodlands across Cape Cod and altered the composition and structure of remaining woodlands through repeated grazing, burning, harvesting, and other activities. Frequently, these land-use practices resulted in local wood shortages and severe erosion, prompting passage of numerous acts of legislation during the

> seventeenth and eighteenth centuries aimed at restricting environmental degradation. Widespread farm abandonment in the nineteenth and early twentieth centuries allowed for an increase in forest area to 61% by 1951, through both natural re-forestation and extensive planting of native and non-native trees. By 1990, approximately 43% of forest remained because of growing residential and commercial development that fragmented the remaining land. (pg. 1442-1443).

It is possible that land use changes and forest fragmentation can influence coastal erosion and measuring relevant indicators is an initial first step before additional analysis can be conducted. NOAA's Coastal Change Analysis Program analyzed land use changes on Cape Cod from 1996-2006 and found that 3.84 square miles [2,457 acres] of development occurred in the period (figure 21). 0.23 square miles [147 acres] of wetlands were lost between 1996 and 2006 including 44 acres of estuarine wetlands (figure 22).

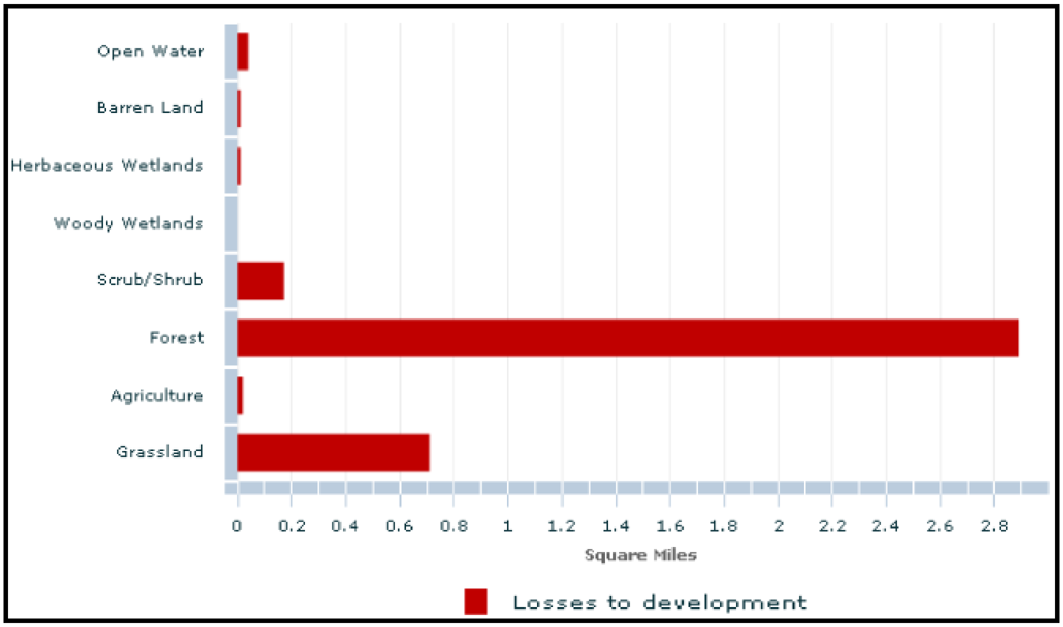

Figure 21: Development on Cape Cod, 1996-2006. (NOAA, 2011)

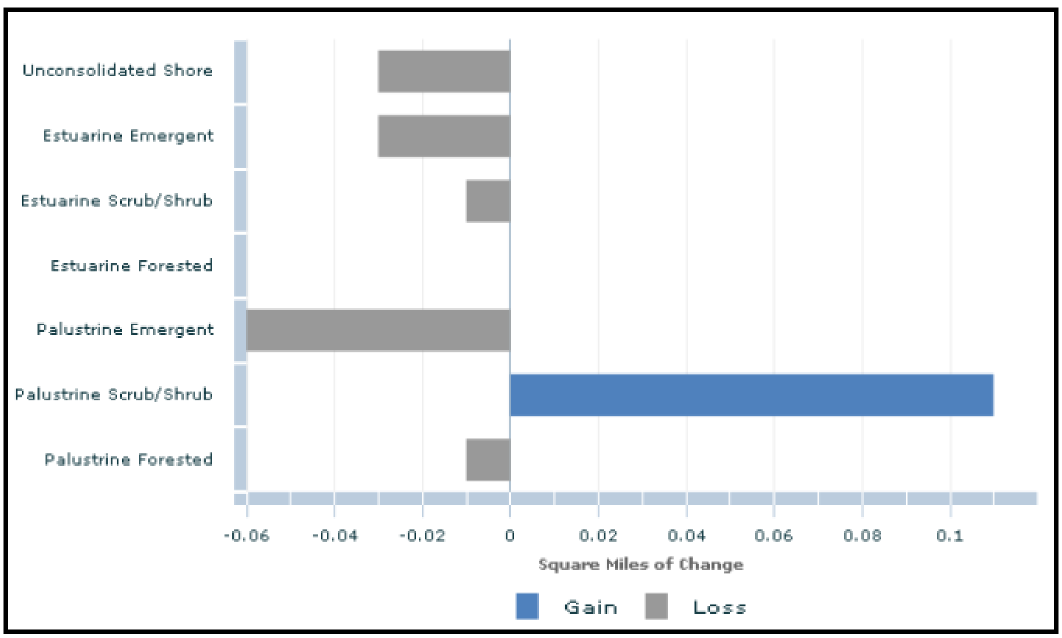

Figure 22: Wetlands change on Cape Cod, 1996-2006. (NOAA, 2011)

The data presented by Motzkin et al. (2002) and NOAA (2011) quantifies significant land use changes in the study area but it remains challenging to measure relationships between historic land use change, erosion rates and demand for coastal protection permits.

A variable that may exhibit a stronger relationship with demand for coastal protection is property values. Given the challenges of using population growth or land use changes to influence demand for coastal protection, it is possible that that property value change over time is a useful predictor of demand for coastal protection permits. A hypothesis would be that as property values rise, there is increased demand for coastal protection permits. This would be logical because properties values have risen in the study area and property owners are often willing to protect their properties from erosion-induced losses (Pompe and Rinehart 1995). To measure change in property values, the Commonwealth of Massachusetts produces equalized property valuations (EQV) each year from local assessor data, which are a measure of property values between towns.
The Massachusetts Department of Revenue defines EQVs as:

> An estimate of fair cash value of all taxable property in each city and town as of January 1 of each year. The EQV is a measure of the relative property wealth in each municipality. Its purpose is to allow for comparisons of municipal property values at one point in time, adjusting for differences in local assessing practices and revaluation schedules (Massachusetts Department of Revenue [DOR], 2011).

Estimated EQV adjusted for inflation were calculated in the study area and show that property values have risen significantly at least since the 1970s; the decade when MGL 131, section 40 and 310 CMR 10.00 was implemented (figure 23). Further analysis could measure the strength of any relationships between NOI submissions and property values since both real property values and NOI submissions have increased significantly since the 1970s.

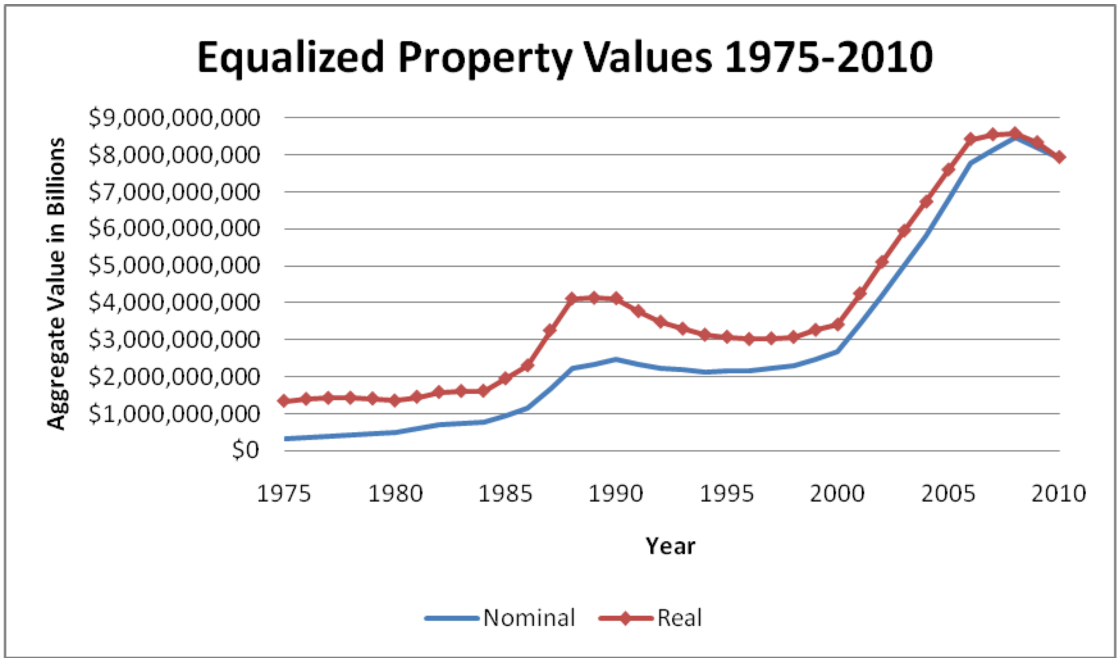

Figure 23: Equalized property valuations in Truro, Wellfleet and Eastham (1975-2010). (DOR, 2011)

Build out could be another factor that has lead to rising property values since the 1970s on Cape Cod. The study area may be approaching build out, which is the point in a municipality where all potential building lots have been developed and building lots have reached their maximum density pursuant to zoning. The Town of Wellfleet notes that it has between 200 and 400 developable residential lots left and could approach build out in the "not too distant future"

(Town of Wellfleet, 2007). Housing starts in the study area have been declining since the 1990s (figure 24).

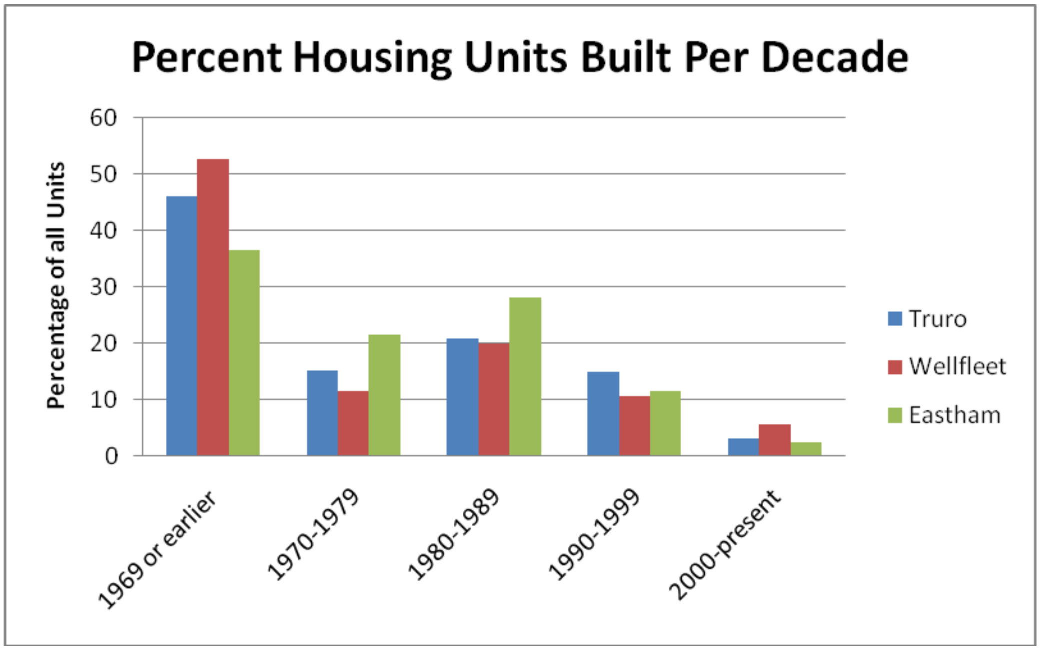

Figure 24: Percent housing units built per decade in Truro, Wellfleet and Eastham.(US Census, 2011)

If there is a relationship between housing starts and demand for coastal protection, it would an inverse relationship, because demand for coastal protection continues to increase while housing starts are declining over time. A complicating factor is that new housing starts may not be impacted by coastal protection policies because MGL 131, section 40 and 310 CMR 10.00 prohibit hard CES on land developed after 1978, and it is unlikely there are many new housing starts along the shoreline. If the current decline in housing starts continues, property values will continue to rise, reflecting limited supply. Additionally, personal observations suggest that all shorefront properties open to development have already been developed; and many are being redeveloped into larger homes, reflecting rising property values. This suggests that rising property values, not housing starts may influence coastal protection decisions.

NATURAL EVENTS

As noted in chapter two, coastal erosion is defined in terms of the movement of shoreline contours caused by a number of factors including sea-level rise. With concern that one of the impacts of climate change will be accelerated relative sea level change which could cause damage to coastal systems; measuring the relationship between sea level rise and number of NOI submissions would be useful. Zhang, Douglas, and Leatherman (2004) hold that while sea level rise acts as an enabler of erosion because higher water levels allow waves to act further; it does not directly cause long-term erosion because too little energy is associated with the rate of change. USGS (2011) notes that rates of sea level rise in New England vary spatially and temporally; and since the 1920s, mean sea level rise in New England has been on an upward trend equal to 2.63 milimeters per year, or 0.86 feet per 100 years (figure 25). It may be challenging to find a significant relationship between sea level change and demand for coastal protection given the small annual rate of change. However, if predictions of higher rates of sea level rise are accurate, it would be interesting to explore the extent of these relationships.

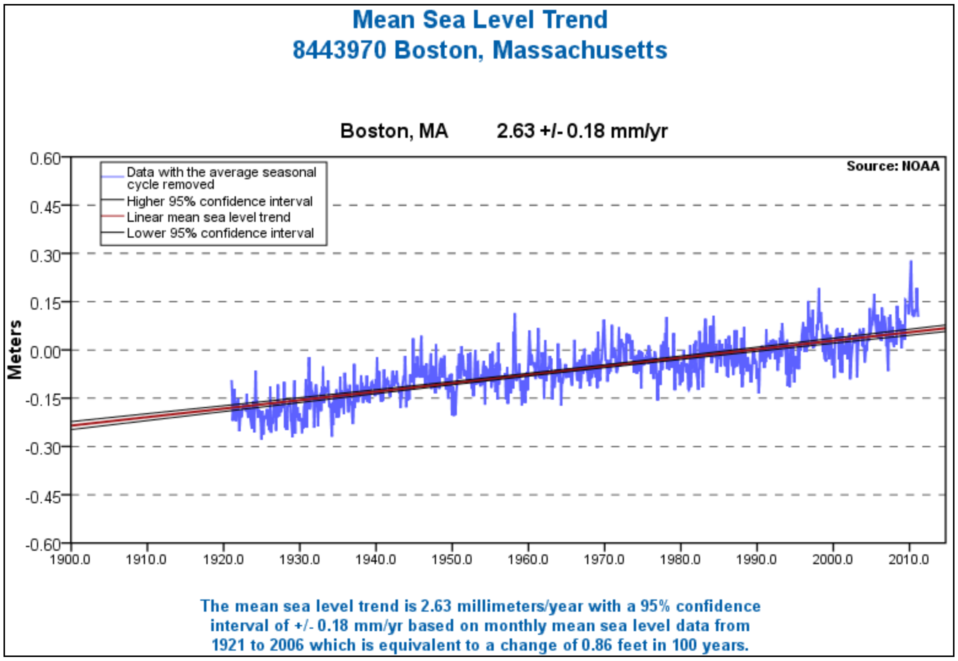

Figure 25: Mean Sea Level Trend at Boston, Mass 1920-2010. (NOAA, 2011)

HISTORIC STORM EVENTS

Storm events are major drivers of short term erosion (Maine Sea Grant, 2010; Zhang, Douglas, Leatherman, 2001). Local historic storm events are particularly relevant to this analysis because they provide a reference point marking major erosion events. Nor'easters are a major contributor to erosion on Cape Cod and have led to memorable short-term erosion events in the study area. Hurricanes also can create an enormous impacts but fewer have affected Cape Cod since 1975 than nor'easters; and Davis, Dolan and Demme (1993) note that nor'easters or coastal-extra tropical storms can often produce widespread damage over a wider area than most hurricanes. Hondula and Dolan (2010) note that between 20 and 30 wintertime extra tropical storms occur along the Atlantic Coast each year that produce beach erosion. While NRC (1990) suggests that storm surge heights, storm surge duration and wave steepness (ratio of wave heights to length) are the most important factors that cause erosion during nor'easters; Zhang, Douglas, and Leatherman (2001) suggest that the impacts of nor'easters are strongly dependent on astronomically high tides which influence storm tides and have a larger effect on storm erosion that do wave action or duration.

Tide gauge data recorded at Boston of the top 10 tide heights since 1975 suggest that almost all of the highest tides since 1975 have coincided with historic storm events on Cape Cod. These historic high tides almost all occurred during memorable nor'easters including: the Blizzard of 1978, the Halloween Storm of 1991, and the Patriots Day Storm of 2007, and most recently the post-Christmas blizzard in December 2010.

Zhang, Douglas, and Leatherman (2000) note:

> That an analysis of the hourly tide gauge records along the U.S, east coast shows a considerable interdecadal variation but no discernible long-term trend in the number and intensity of moderate and severe coastal storms during the twentieth century.

Rank	Height (feet)	Highest Date
1	18.62	February 7, 1978
2	17.72	January 2, 1987
3	17.66	October 30, 1991
4	17.56	January 25, 1979
5	17.55	December 12, 1992
6	17.32	April 18, 2007
7	17.3	May 25, 2005
8	17.22	December 27, 2010
9	17.19	May 26, 2005
10	17.1	January 31, 2006

Table 3: Top 10 highest tides 1975-2010 at Boston, MA. (NOAA, 2011)

Prolific damage from these storms occurred along the Atlantic shore of Truro, Wellfleet and Eastham and is well known the history of the communities. This damage includes the destruction of a 146 car parking lot built on the dune at Coast Guard Beach in Eastham during the Blizzard of 1978 (Lum, 2011); the first of two breaks in the barrier beach known as Nauset Beach in Chatham in 1987, resulting in the destruction of numerous homes; the break-through of the Pamet River in Truro from Cape Cod Bay to the Atlantic Ocean during the Halloween Storm of 1991; and the second break in Nauset Beach in Chatham during the Patriots Day Storm of 2007. It would be useful to measure the relationship between historic storm events and demand for coastal protection permits in the same year that the storm happened as well as the following year.

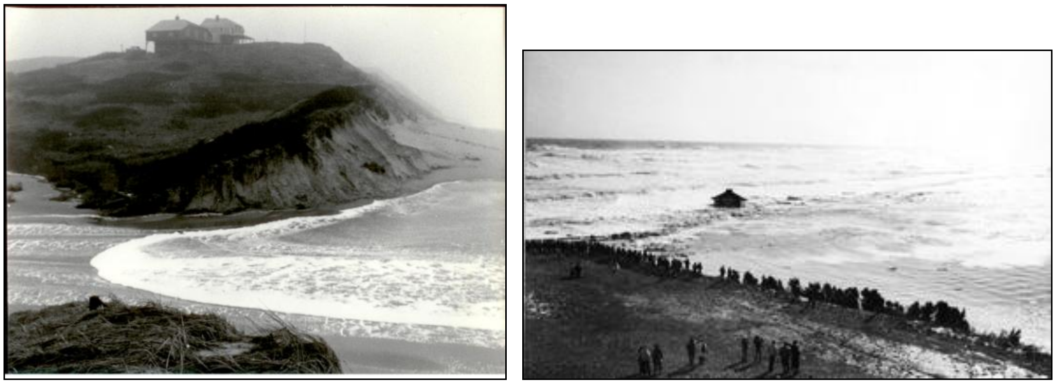

Figure 28: Pamet River breaking through dune at Ballston Beach, October 1991. Source: Town of Truro, MA Bathhouse being swept away at Coast Guard Beach in Eastham MA, February 7, 1978. Source: The Cape Codder

In sum, the discussion of variables is not meant to be exhaustive or cover all possible drivers of demand for coastal protection permits because there are numerous possibilities. The chapter points out variables that may influence demand and would be useful to conduct further research. It may be almost impossible to determine the exact drivers of the demand for coastal projection permits, but giving policymakers the data to understand that both natural and anthropogenic factors drive demand for coastal protection permits can help make prudent decisions.

CHAPTER SIX: CONCLUDING REMARKS

The qualitative assessment of municipal Notice of Intent records in the study area from 1975-2010 indicates that demand for coastal protection permits in Truro, Wellfleet and Eastham Massachusetts has been increasing since the 1970s. The data collection experience shows that the municipalities in the study area appear to have accurate coastal protection permitting records. NOI submissions fluctuate annually for reasons unknown but have exhibited an upward trend since records have been kept. Each town in the study area has received similar numbers of NOI submissions and those submissions are generally evenly divided between hard and soft coastal erosion structures. Possibly reflecting local bylaws and the intent of MGL 131, section 40 and 310 CMR 10.00, which encourage soft CES alternatives, there appears to be a trend towards NOI submissions for soft CES. While the data indicates that demand for coastal protection is rising over time in the study area; this research is not necessarily applicable to adjacent towns or in the Commonwealth overall. Speculation suggests that the experience in the study area is shared more broadly in the rest of the Commonwealth.

Municipalities in the study area can improve management in a number of ways. First, each town should reduce the ambiguity of some aspects of local wetlands bylaws to make the permitting process more transparent to both proponents and opponents of projects. Second, there is no need to reinvent the management wheel at the local level given perennial lack of resources. Organizations like the Massachusetts Association of Conservation Commissions and the Cape Cod Commission have created model bylaws to increase wetlands protection above MGL 131, section 40 and 310 CMR 10.00; and have resources to provide technical assistance at the local level. Wellfleet, Truro and Eastham, in additional to other communities on Cape Cod may consider requesting discretionary Cape Cod Commission reviews of hard CES as Developments of Regional Impacts (DRI). A DRI process may help to increase the consistency of the review process, create a higher regulatory threshold for hard CES, and allow a regional planning body to assess the "cumulative" impacts of projects mentioned in local bylaws, in a fashion that is often difficult for municipal conservation commissions.

Finally, it is the author's opinion that property owners have the right to protect their properties but not at the expense of public trust lands protected by MGL c. 91 and MGL 131, section 40 and 310 CMR 10.00. Given that demand is rising for coastal protection permits, municipalities as well as the Commonwealth of Massachusetts need to decide how they will manage future demand given vast uncertainty. Future research could determine empirical influences on demand for coastal protection, but until that research is conducted, stakeholders and decision-makers must plan for a variety of scenarios.

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