DUNES, BLUFFS AND PENEPLAINS ON NEW YORK'S OCEAN COAST

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Abstract

The nature protect features (NPFs) were identified using Light Detection and Ranging (LiDAR)-derived digital elevation data (DEMs) collected by NYDEC and National Oceanic and Atmospheric Administration (NOAA) in 2012. Analysis of these features was done by an R-tool and the total number of features is 750 along the East Hampton ocean shoreline. Both dune and bluff will protect the shoreline in a certain level. However, in the study area, the excavation of the bluff is likely to be the controlling factor.

Introduction

Persistent problems of coastal erosion and flooding on NY's ocean shoreline were only accentuated by the impact of "Superstorm" Sandy on 29 October, 2012. Long before that, however, NY, like other coastal states, managed its shoreline with long-standing policy and regulations. One of the mainstays of NY's program has been the preservation of natural protective features (NPFs). Alterations of NPF's might reduce the protection against erosion and coastal flooding, or they may lower the reserves of sand available to replenish storm losses through natural processes. New York State has a conservative policy that treats all NPF's with the same intrinsic value. As a practical matter, however, the characteristics of some features, or the combination of features, should provide different levels of protection to various events. The characteristics of particular NPFs result in a degree of natural protection that should not only differ depending on the combination of NPFs superimposed, but also allow the shoreline to respond differently to extreme events than it does to long-term sea level rise.

NPFs include beaches, bluffs, and dunes. The beach is defined as the zone of unconsolidated sediment that extends landward from the mean low water (MLW) line to the seaward toe of a dune or bluff, whichever is most seaward. (If there is no dune or bluff, it extends 100 feet landward from the place where there is a marked change in material or physiographic form or from the line of permanent vegetation, whichever is most seaward). Shorelines subject to seasonal or more frequent overwash or inundation are considered to be beaches. The bluff is a bank or cliff with a precipitous or steeply sloped face at the shoreline. As a practical matter, bluffs are often composed of compacted sands, silts and clay. The dune is defined as a ridge or hill of loose, windblown, or artificially placed sand.

During the 1980s, New York's Coastal Erosion Hazards Area Act (New York Environmental Conservation Law, 3-0301, 34-0108, Section 505.2) was enacted in order to establish a repeatable, defendable methodology for the delineation of NPFs. The original maps for this program were developed in 1983-84. For the section of ocean shoreline in East Hampton, the NPFs on these original maps had been determined from a set of aerial photographs. Eight-by-eight-inch stereo pairs were used to manually identify changes in topography associated with the landward toe of the dune. The bluff crest was usually easily identified on the aerials. Where bluffs were present, either the bluff edge or the landward toe of the bluff was delineated. Now after more than 30 years have passed, additional erosion had occurred in many areas. Perhaps more importantly, over the last 30 years, mapping technologies have greatly advanced.

For this study, the cross-sectional geometry of the eastern ocean shore of Long Island was re-examined using modern survey techniques to redefine the NPFs. The character of NPFs is now better resolved especially where features overlap. These characteristics result in a degree of natural protection that not only differs depending on the combination of NPFs superimposed, but also allow the shoreline to respond differently to extreme events than it does to long-term sea level rise.

Classically, the cross-sectional geometry of the coast has been used to examine how the shoreline responds to erosional stress. This type of study, in particular, seeks to evaluate the mode of the shore's response to rising sea level by examination of the coast's cross-sectional geometry. The technique is not new. As early as 1919, D.W. Johnson examined the development of the barrier island by looking at the altitude of the offshore slope with respect to the slope of the coastal peneplain (Johnson 1919) concluding that, if the landward extrapolation of the shelf slope intersected the sea level datum at or seaward of the marginal bays, barrier island formed as spits in response to longshore action, under the assumption that sea level was stable. If the intersection occurred landward of the bay, barrier formation occurred by increasing deposition offshore, in addition to longshore deposition. Since Johnson's seminal research, other investigators have conducted similar studies along the shoreline of the United States over the years (e.g. Bruun 1962; Schwartz 1967; Dubois 1977; Hands 1980; Rosen 1978; Fisher 1982; Weggel 1979; and Maurmeyer and Dean 1982). Although superseded by other quantitative methods, the "profile" technique is still useful in interpreting features along the ocean coast and characteristics of the shoreline response to rising sea level.

In the study area, dunes crest typically at elevations above six meters although the crests of some dunes are above 12 meters. The late geomorphologist, Rhodes Fairbridge, suggested that, because of their size, the largest dunes along Long Island's ocean shoreline were relict features, built at a time of lower sea level when a greater expanse of beach sand was available (H. Bokuniewicz personal communication). As early as 1914, Myron L. Fuller identified many of the large ridges on Long Island as dune sand resting on terraces. Some were "conspicuous hills from 50 to 100 feet high" and "of relatively recent origin" (Fuller 1914). As part of my research I hope to show that the elevation of dune crests along the headland section can be attributed to the growth of dune structure upon a pre-existing terrace. The East Hampton terrace, at an elevation of about 6 m grows to become the dominant bluffs at Montauk Point.

Study Area

The ocean shore of Long Island, NY is divided into two physiographic provinces, the headland section along the eastern shore and the barrier beach in the west (Taney 1961; Figure 1). The headlands section extends 53 kilometers westward from the extreme southeast tip of the island, Montauk Point. The East Hampton (EH in Figure 1) ocean shoreline in southeastern Long Island is in the headlands section, with the ocean beach cut directly into sands of the coastal peneplain. To the east, high, unconsolidated bluffs are found, whereas, barrier beaches and barrier islands dominate to the west. While high, unconsolidated bluffs are found in the easternmost part of the headlands, the western part of headlands shoreline is cut into a thick layer of unconsolidated, glacial outwash sand three or four kilometers south of the Wisconsin-aged, Ronkonkoma Terminal Moraine. This section of the coast is characterized by a gradually sloping outwash plain. In this area, the slope of the outwash surface decreases slightly from about 0.0035 in the east to 0.0032 in the west (Zimmerman 1983).

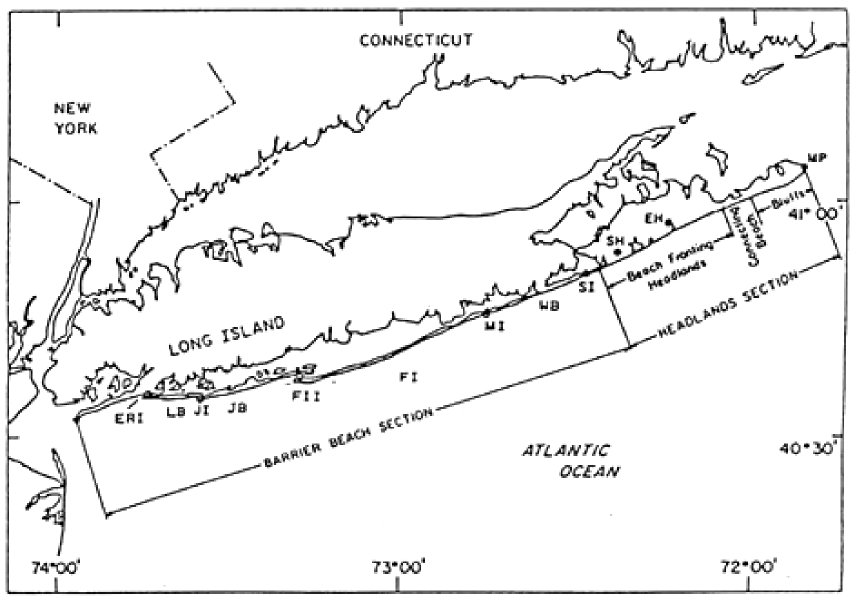

Figure 1. Physiographic provinces of New York's ocean shoreline (Taney 1961). "ERI" East Rockaway Inlet, "LB" Long Beach, "JI" Jones Inlet, "JB" Jones Beach, "FII" Fire Island Inlet, "FI" Fire Island, "MI" Moriches Inlet, "WB" Westhampton Beach, "SI" Shinnecock Inlet, "SH" Southampton Beach, "EH" East Hampton Beach, "MP" Montauk Point.

Methods

Transects were created 50 meters apart perpendicular to a baseline, and buffered 30.48 meter (100 feet) seaward from the Mean High Water (MHW) line (Figure 2). The platform is an integrated GIS modeling system developed by Dewberry (8401 Arlington Boulevard Fairfax, VA 22031-4666) called "GeoCoastal". MHW lines come from the NOAA's VDatum software (v3.1) and they were referenced to NAVD88. This study contained 750 transects and it's along the south shore of Long Island, from the beginning of East Hampton to Montauk Point. The profile of each transects was delineated using orthoimagery and Light Detection and Ranging (LIDAR)-based data which had been collected in 2012. The horizontal accuracy was 1m and the vertical accuracy Root Mean Square Error was 0.05 m.

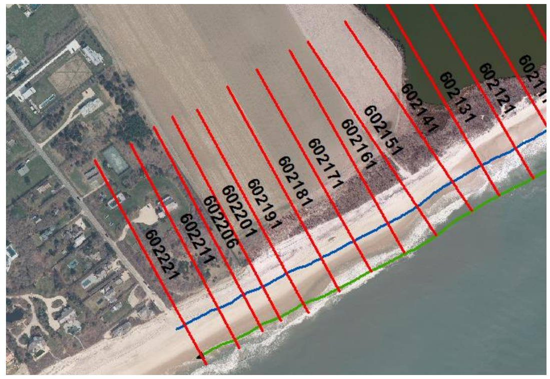

Figure 2. Example of the transects: red line, the transects; blue line, mean high water; green line, baseline

The identification of the NPFs was facilitated by a proprietary R statistical computing program developed by Dewberry (J. Plummer, 2014, personal communication) based on changes and inflections in the slope of each profile (e.g. Figure 3).

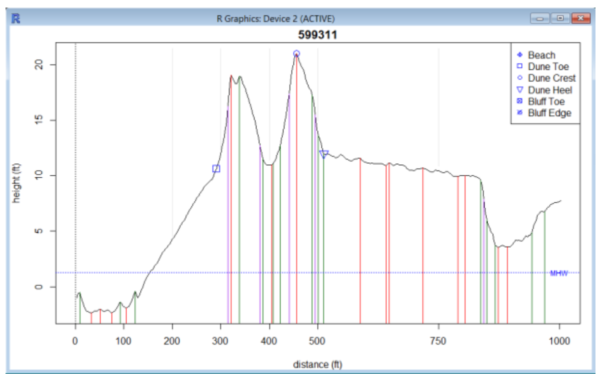

Figure 3. Proprietary R-tool analysis of a representative profile. Red lines indicate changes in the sign of the first derivative of the topographic profile; the purple line, the second derivative and the green line, the curvature of the profile.

Results

The study area contains 750 transects (50m distance), about 36.72 km, all the NPFs had been identified through the R tool. From west to east, the NPFs change from dune to bluff. The coast at Montauk Point ("MP" on Figure 1) is a well-defined bluff (Figure 4). The tableland is capped by the Ronkonkoma Moraine. The beaches before the bluff are coarse sediment, cobbles in some places, with little suitable sand to build dunes. Severe storms undercut the toe of the bluff and can cause collapse of the bluff face. Measures have been taken to armor the toe with rock or gabions in places and in some places terracing has been done to retard overland runoff.

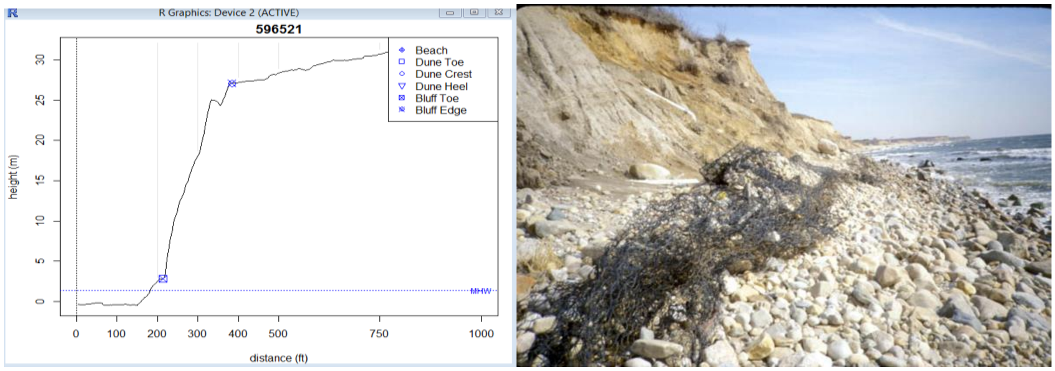

Figure 4. a. Profile across the bluffed coast at Montauk. b. Cobble beach near Montauk Point.

At one location from Montauk Point to the west, the elevation of the NPF crest decreases to about 7 m, because the dune crests have been constructed above this elevation the bluff face and crest are buried by dune sand, this is a case of combination of NPFs (Figure 5). While the primary NPF for extreme events is identified as dune, the underlying bluff face and terrace would control the retreat rate of the shoreline in the long-term due to sea-level rise.

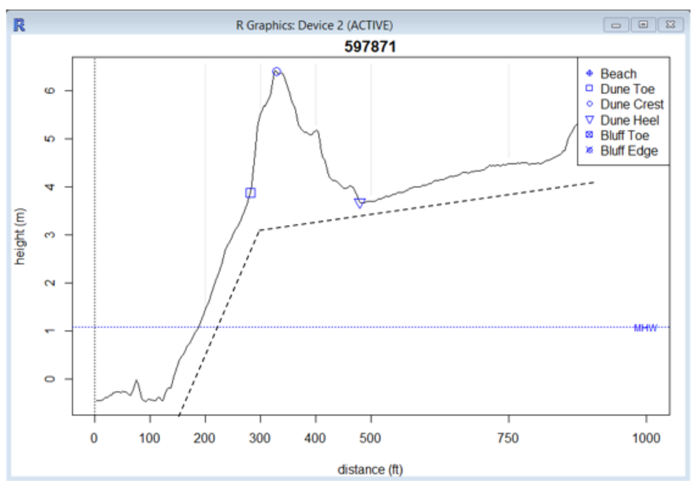

Figure 5. Profile of an aeolian dune burying the bluff crest.

Further west (Figure 6), sand beaches provide suitable sand for the aeolian construction of dunes. These tend to have dune crests at elevations below 7m and well below the bluff crest elevation of 9m. The dune does not cover the bluff crest but, in this case, it is the NPF against extreme events as the dune affords protection against undercutting and collapse of the bluff. If the dune is compromised, the bluff itself provides protection against flooding and resistance to landward migration of the shoreline. In the face of long-term response to sea-level rise, the dune is less important, it is the bluff that provides protection and controls the shoreline response.

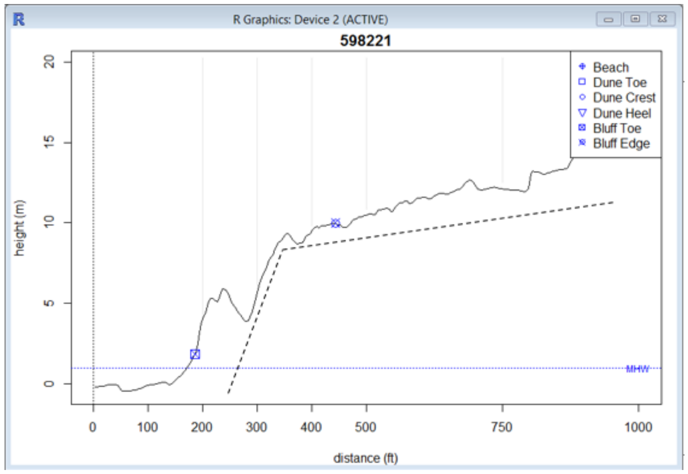

Figure 6. Profile showing an aeolian dune at the toe of a bluff.

Continue west and near transect 599821, (Figures 7), there is a section where the outwash peneplain is absent. Here, the shoreline spans a gap in the moraine that has been bridged by marine sands. Here dune fields crest at about 9m in front of low lying sandy terrain. It would seem that this section was built as a barrier beach between a headland island and Montauk and the terminal headland of the moraine segment further west. This barrier, Napeague Beach, is blanketed by dune sand over older beach ridges. The NPF are the dunes alone.

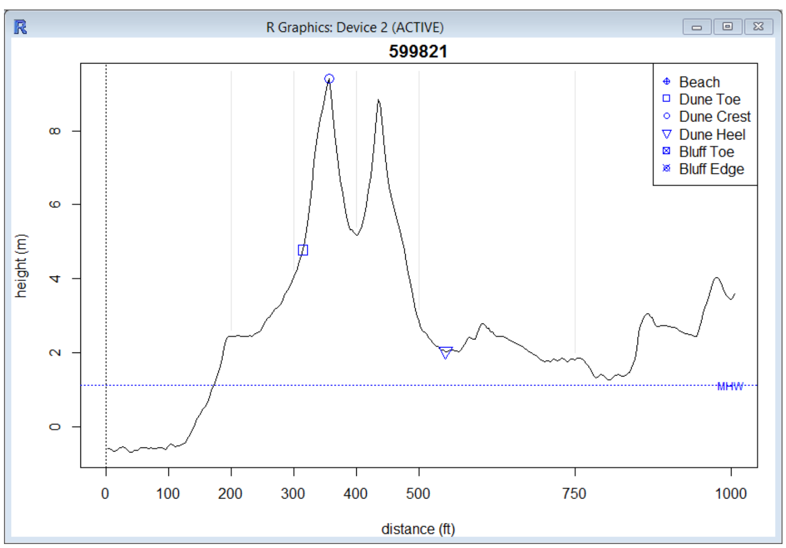

Figure 7. Transect across a dune field.

Discussions

FEMA sets an empirical minimum cross-sectional area for a dune expected to survive the 100-year storm. The area of the dune profile from the dune crest to the 100-year storm surge elevation must be greater than 540 square feet. In the study area the 100-year storm surge elevation ranged from 8.7 to 9.7 feet NGVD and between 1995 and 2002, 24% of the dunes in the study area exceeded these criteria (Batten 2003). Whether the natural protection is lost in sections of compromised dunes depends on the combination of features. In places where the dune has been formed in front of the bluff crest or built up over the bluff crest, the protective reservoir of dune sand could be removed without compromising the natural protection. In the former case, the bluff itself would become the first line of defense. In the latter, the bluff crest would be exposed and also take on the role of being the active NPF.

The dunes would play a smaller role in determining the shoreline response to long-term rise in sea level. In this case the bluff, whether exposed or buried under (transient) dune sand must be excavated for the shoreline to retreat. To maintain the coastal morphology as sea level rises at a rate of 3 mm/year, it had been estimated that a wedge of sediment with a volume of 14 m^3/meter of shoreline must be excavated and displaced from the fastland under the dune (Zimmerman 1983). The fine fraction of this sediment would be suspended and dispersed and the coarse fraction left in place as a lag pavement. The sand fraction would add to the active sand reservoir feeding the longshore transport. In this case, I would expect that a section of coast where the aeolian dune is at the toe of a bluff (Figure 6) might be transformed by a rise in sea level to a morphology in which the aeolian dune buries the bluff crest (Figure 5).

Conclusion

The southeastern ocean shoreline of Long Island is characterized by four types of NPFs: bluffs, dunes, dunes fronting bluffs and dunes covering bluffs. Where dunes are present they provide the first line of protect for storm events. However, in the face of a long-term rise in sea level, the excavation of the underlying bluff is likely to be the controlling factor.

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