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C. Scott Hardaway Jr.
Virginia Institute of Marine Science

Donna A. Milligan
Virginia Institute of Marine Science

Travis R. Comer
Virginia Institute of Marine Science

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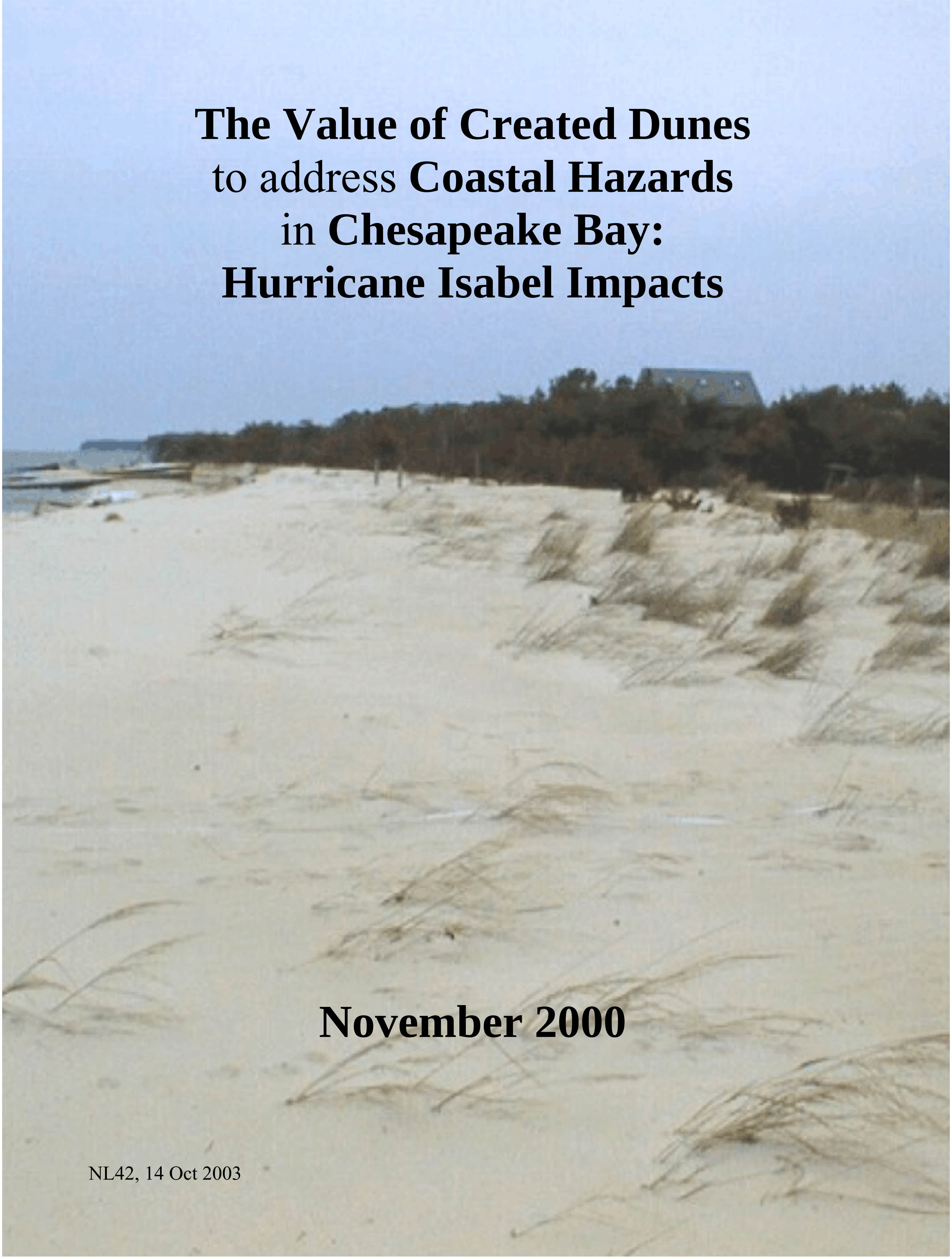

November 2000

NL42, 14 Oct 2003

The Value of Created Dunes to address **Coastal Hazards** in **Chesapeake Bay: Hurricane Isabel Impacts**

Data Report

C. Scott Hardaway, Jr.
Donna A. Milligan
Travis R. Comer

Shoreline Studies Program
Department of Physical Studies
College of William & Mary
Gloucester Point, Virginia

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The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its subagencies or DEQ.

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I. INTRODUCTION

A. Background and Purpose

Creating dunes as part of a shoreline management plan can be an effective way to augment and enhance the "coastal profile" along the tidal shorelines of the Commonwealth. One obvious but vital component to creating a dune is to provide added shore protection along a stable beach. Through various research efforts (Hardaway *et al.,* 2001; Hardaway *et al*., 2002a; Hardaway *et al*., 2002b; and Hardaway *et al*., 2003), we have shown that the ability of a dune to grow and withstand time and tide requires three parameters: 1) stable geomorphic setting, 2) sufficient supply of sand and 3) exposure to an active wind/wave climate.

Perhaps the most important function of a created dune, from some perspectives, is coastal protection. Since the initiation of this subtask within the overall Chesapeake Bay Dune Monitoring and Management Analysis project, Hurricane Isabel impacted the coastal plain of Virginia and significantly altered almost all Bay shorelines to one degree or another. This is particularly true of shorelines facing north, east, and south since the winds shifted as the storm passed. The original task scope has changed slightly as a result of Isabel's passage since it was such a significant storm event and provided an opportunity to show how dunes created under different conditions responded to the storm.

Isabel impacted several of our monitoring sites, part of our ongoing dune research since 2000 (Figure 1). Three of those sites (MA3, NL42, and NL59) have "created dunes" resulting from different anthropogenic activities. The purpose of this data report is to evaluate these sites from a coastal hazard perspective and determine how they performed during Hurricane Isabel and how they have recovered.

B. Hurricane Isabel

Hurricane Isabel made landfall along the southeast coast of North Carolina on September 18, 2003. At one time, the storm was a Category 5 on the Safir-Simpson scale. It had been downgraded to a Category 2 before it made landfall. By the time it impacted the Chesapeake Bay, it was a minimal Category 1. However, in addition to being in the "right front" quadrant of the advancing hurricane, southeastern Virginia experienced east and east south east winds which have the greatest potential to transport water into Chesapeake Bay and its Virginia tributaries.

The extent of coastal flooding during a storm depends largely on both the background astronomical tide and the surge generated by the storm's high winds and low atmospheric pressure. Together, surge and astronomical tide combine to form a "storm tide." Storm-tide flooding is maximized when the storm surge and a rising tide reach their peak at the same time. The hurricane of 1933, widely known as the "storm of the century" for Chesapeake Bay, generated a storm surge in Hampton Roads of 5.84 feet, more than a foot higher than the 4.76 ft storm surge recorded for Hurricane Isabel. Yet many long-time Tidewater residents say that the high-water marks left by Isabel equaled or exceeded those of the 1933 storm (Boon, 2003).

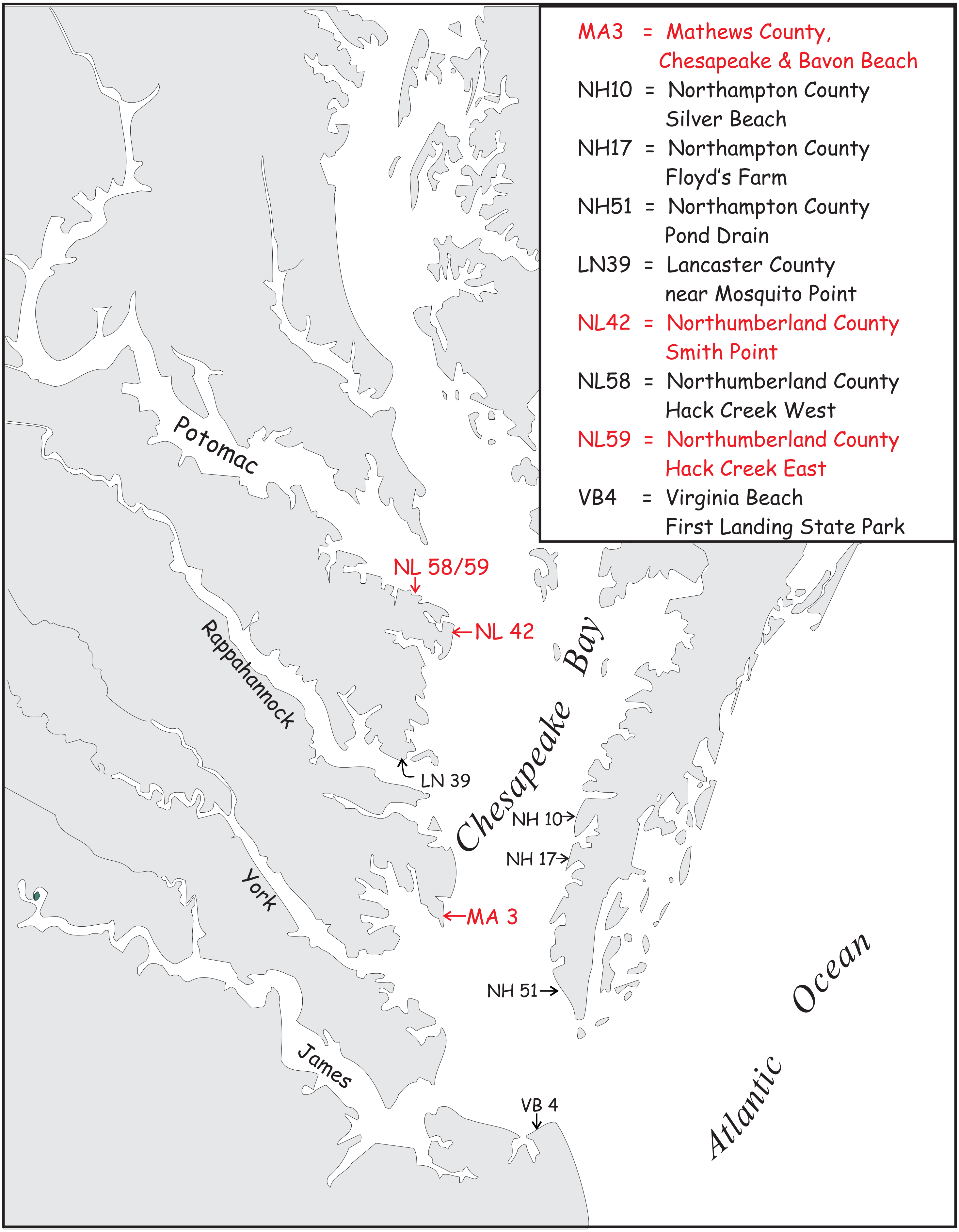


Figure 1. Location of dune monitoring sites. Red indicates the sites used in this report.

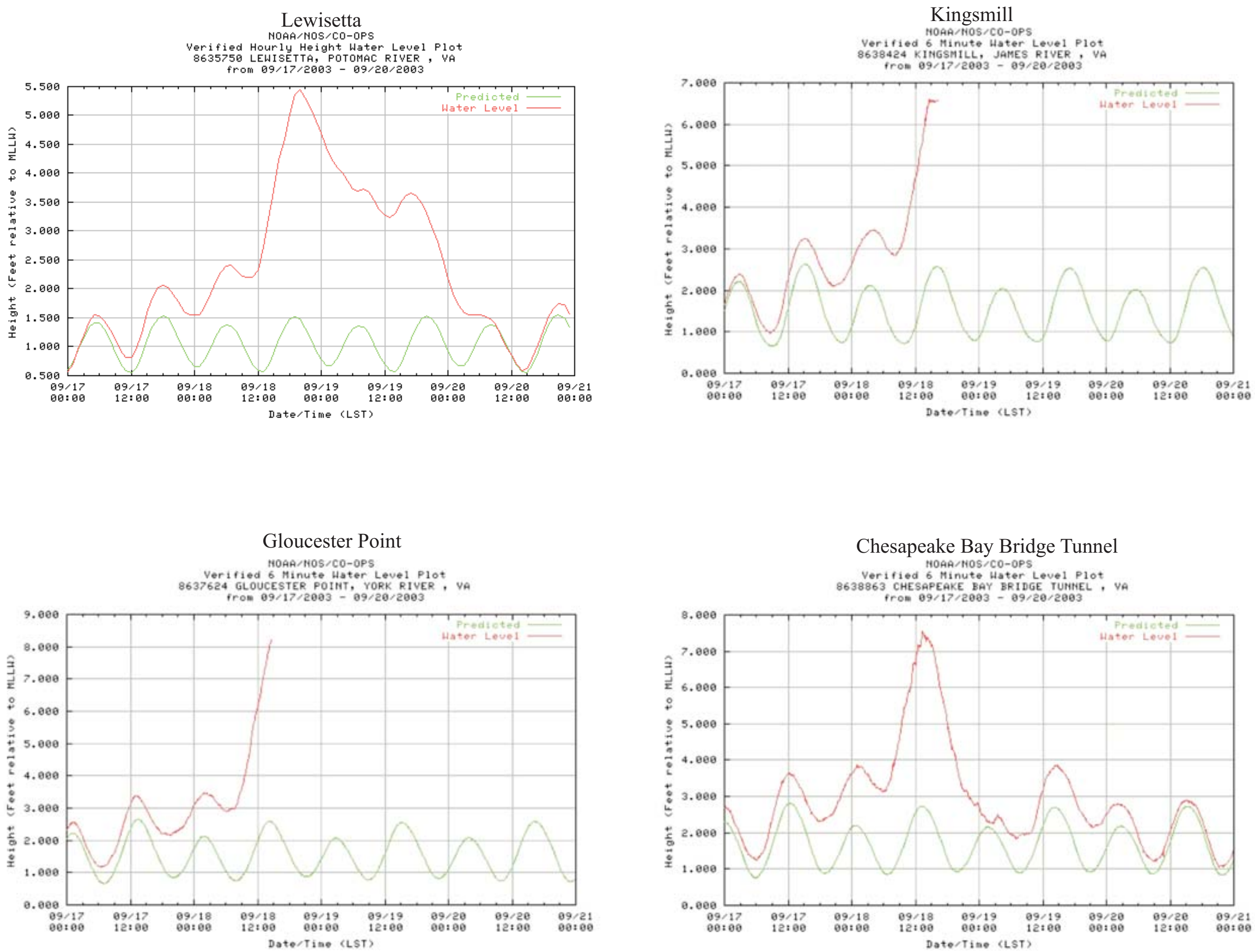
An analysis of sea-level records shows that Isabel's coastal flooding matched that of the August 1933 storm due to the long-term increase in sea level in Hampton Roads (Boon, 2003). Data from a tide monitoring station at Sewells Point show that sea level in tidewater Virginia rose 1.35 feet between August 1933 and September 2003. Based on storm surge and astronomical tide, the 1933 hurricane storm surge exceeded Isabel's by more than a foot. Its surge also occurred at the beginning of spring tides while Isabel's surge occurred in the middle of a neap tide. However, the increase in sea level at Hampton Roads in the seventy years between the two storms was enough to boost Isabel's storm tide to within an inch and a half of the level experienced during the 1933 storm (Boon, 2003).

Additional storm data was obtained by an Acoustic Doppler Current Profiler (ADCP) was deployed in 28 ft of water offshore of VIMS at Gloucester Point. The instrument provided a quantitative record of the hurricane's impact on lower Chesapeake Bay. Data from the ADCP show that Isabel created a 7-foot storm tide topped by 6-foot waves. At the height of the storm, wave crests were passing over the instrument once every 5 seconds, and the storm was forcing the entire depth of the York River upstream at a rate of 2 knots. Because Isabel was so large, its winds, waves, and surge affected the Bay for an abnormally long time. The ADCP data showed that storm conditions persisted in the Bay for nearly 12 hours and that wave-driven currents were strong enough to mobilize bottom sediments even at this depth, increasing water turbidity by a factor of two to three compared to fair-weather conditions (VIMS, 2003).

Weather data provided by instruments atop VIMS' Byrd Hall show that maximum sustained winds on the campus reached 65 mph, with 90-mph gusts. The barometer bottomed out at 29.2 inches, with a rainfall accumulation of about 2.2 inches (VIMS, 2003).

Around the Bay, similar impacts were recorded by wave gages (Figure 2). The location and records of five wave gages indicate the widespread flooding that occurred due to the storm. In the lower Bay, the Sewells Point and Chesapeake Bay Bridge Tunnel gages survived the storm and indicated a total water level of 8 ft and 7.5 ft above MLLW at the peak of the storm. This is about 5 ft above normal. Also of note was that tide was running higher than normal for the day before the storm and the two days after at both locaitons. In fact, on the day after the storm at Sewells Point, the lowest tide was higher than predicted high tide of 2.5 ft.

Two of the the other three wave gages were destroyed during the storm before the peak water level. At Gloucester Point on the York River, the tide gage stopped recording at 8.5 ft MLLW during the storm. Maximum measured stillwater level across the river at Yorktown was 8.6 ft MLLW with the trash line indicating the water plus waves was at 12.5 ft MLLW. That is a surge above the mean range (2.4 ft) of 6 ft with additional 4 ft waves. Kingsmill on the James River stopped recording at 6.5 ft MLLW. Measured trash lines indicate that the maximum surge and wave level was about 12 ft MLLW or about 8 ft above the mean tide range. Lewisetta, on the Potomac River, remained intact probably owing to it's slightly more sheltered location. It measured a maximum storm surge of 5.5 ft MLLW.



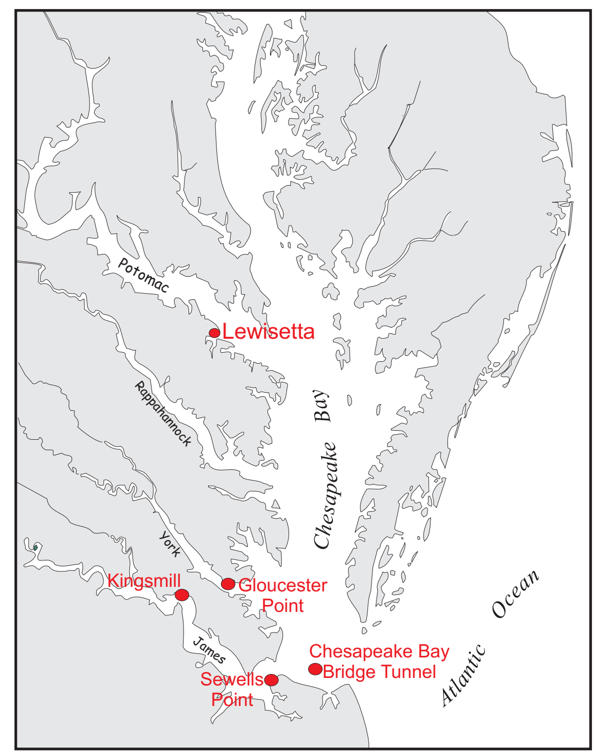


Figure 2. Verified water levels at wave gages around Chesapeake Bay during the storm and approximate gage location. From the NOAA website (http://www.co-ops.nos.noaa.gov/).

II. METHODS

A. Site Selection and Characteristics

Three monitoring sites typify several degrees of dune creation by man's actions that either was 1) inadvertent, where a coastal structure was built, sand accumulated, and a dune formed; 2) a coastal structure, such as groins, were built to create a beach and a dune developed as well; and 3) dune creation through dune fencing and/or grass plantings. Numerous examples exist of each category; however the focus was on three monitoring sites where profile data and ground photos were available pre- and post-Isabel to describe the site.

1. Large Coastal Structure

Smith Point is located at the confluence of the Potomac River and Chesapeake Bay in Northumberland County (Figure 3). The Point is defined by two long stone jetties that were initially built in 1937 and have been repaired several times since. The structures were built to maintain the navigation channel into the Little Wicomico River. Since construction, sand has accumulated on either side of the channel jetties. Beaches formed then dunes. The dune fields on the Chesapeake Bay side is designated NL 42.

The dune site was partially sheltered from northerly wind-driven waves, but as Hurricane Isabel passed northward, the winds shifted to the east, then southeast, and finally south which impacted the entire dune field.

2. Groin Field

Thousands of groins exist along the shores of Chesapeake Bay. They were built for the express purpose of collecting sand to maintain or create a beach. Two such shore reaches occur on either side of Hack Creek in Northumberland County. These are sites NL 58 and NL59 that have developed only because of the groin field installation. In particular, NL 59, a monitoring site has developed a significant primary dune over time in front of a previously eroding upland bank (Figure 4). The groins were installed over the years beginning in the 1960s. It took 20 to 30 years for a wide enough backshore to be created for a primary dune to become established. Adjacent to the shoreline is a residential community along the upriver half of the site and a coastal freshwater pond along the downriver half. The groin field and associated beach and dunes protect the upland from erosion and keeps the pond from breaching.

Hurricane Isabel impacts were generated by a storm surge of at least 5.5 ft MLLW, as measured at Lewisetta (Figure 2), and wind-driven waves originated from the north and east. Wave height estimates onshore from measured wrack lines were 3 to 4 ft.

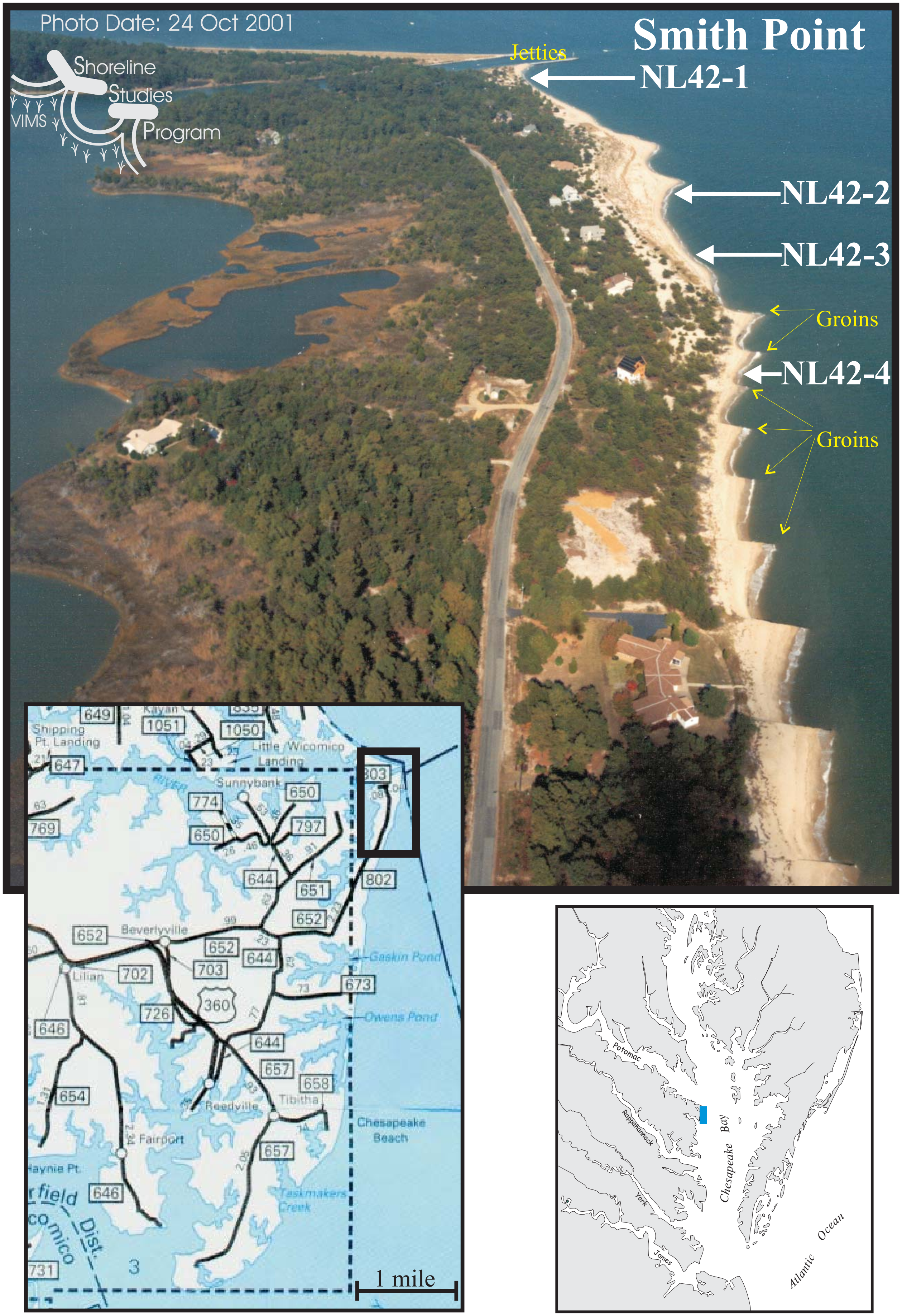


Figure 3.Location of site NL42 in Northumberland County with approx imate position of cross- shore beach profiles.

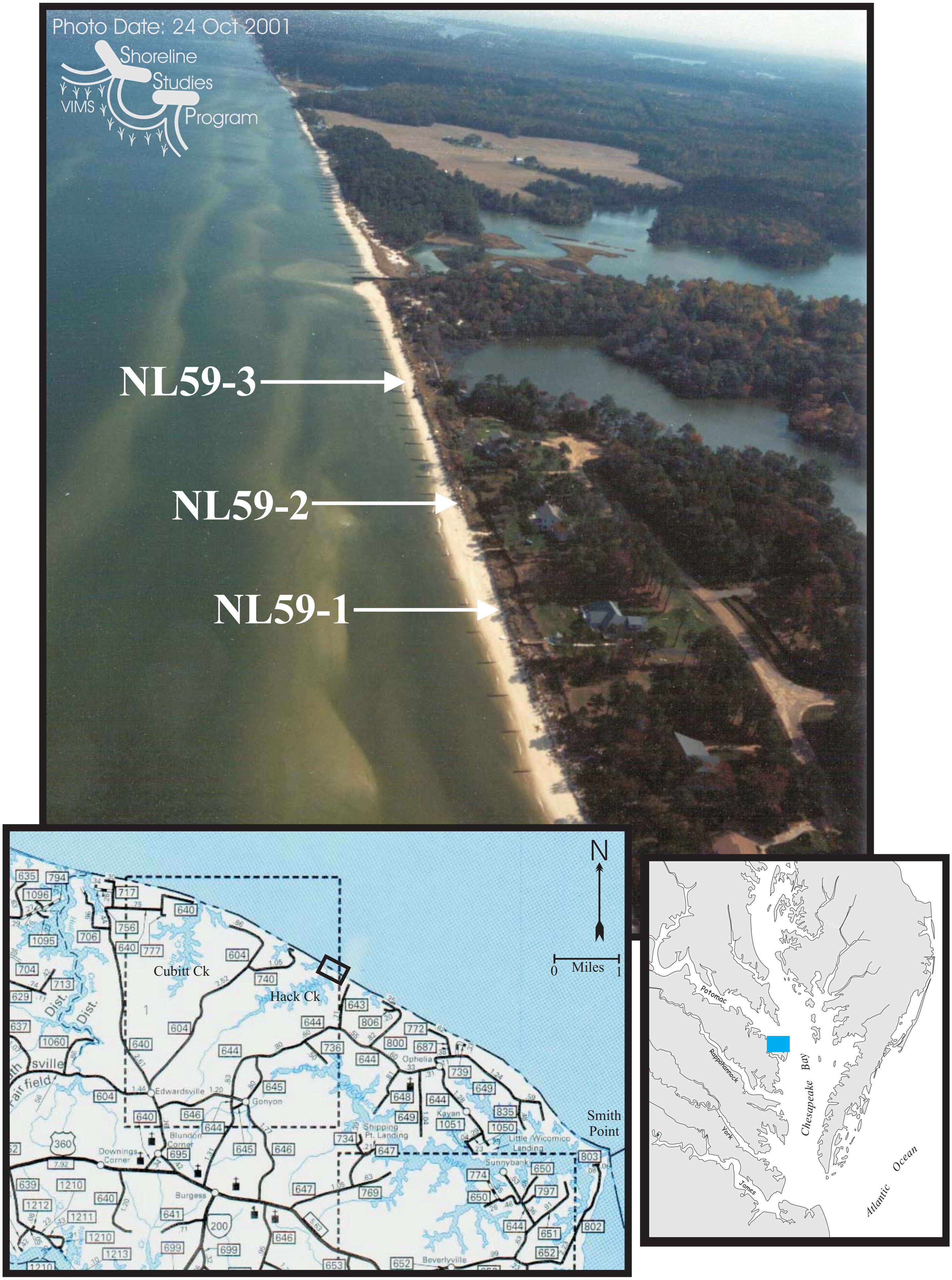


Figure 4. L ocation of site NL 59 in Northumberl and County with approximate positionof cross- shore beach profiles.

3. Dunes as part of Shore Management

The cottage community at Chesapeake Shores/Bavon (MA3) is located on the Chesapeake Bay in southeastern Mathews County (Figure 5). It has had a large sandy beach areas for many years. Cottage construction began in earnest in 1970s. Over the years and after many storms, the residents have used sand fencing and intermittent dune grass plantings to help maintain a protective dune feature.

Hurricane Isabel impacts were significant. Storm surge readings at Sewells Point and Gloucester Point were +8 ft MLLW. Maximum wrack line meaurements at the site were about 9 ft. Wind-generated wave action at the site ranged the whole spectrum from northeast to southeast and south as the storm progressed across the Virginia coastal plain.

B. Man's Influence

Whether on purpose or unintentional, man's influence on beach and dune creation is significant. Through a series of queries, the Chesapeake Bay Dune Database was searched to determine the relative influence of various shoreline activities on primary dune development. There are six categories to describe man's influence: 1) groins, 2) revetments/bulkheads 3) breakwaters 4) jetties 5) beach nourishment and 6) miscellaneous.

Of the six categories listed, groins are by far the most extensive in Chesapeake Bay and are placed to collect sand to capture a beach. The structure captures and holds littoral sands to create a beach. With a sufficient supply of sand and time, a dune may develop along the effected reach. Revetments and bulkheads are not conducive for sand accumulation due to their tendency to reflect wave action and reduce the adjacent sand beach. However, they often act as boundary structures that pin a beach/dune shore on one or both ends sometimes acting like a groin or breakwater to prevent sand movement in a particular alongshore direction. Breakwaters are more effective at holding a stable beach planform on which a dune can develop or become established. Jetties are similar to large groins and can extend far into the nearshore and trap a significant amount of littoral sands. Beach nourishment can provide sand material to a reach that might not have enough naturally to form a protective beach dune system. The miscellaneous category includes beach raking.

C. Survey Methods

A baseline with several cross-shore profiles was established at each site. Each surveyed transect used the crest of the primary dune as the horizontal control and mean low water (MLW) as the vertical control. The MLW line is indirectly obtained from water level measurements. The water level position and elevation are checked in the lab against measured tidal elevations (at the nearest NOAA tide station) and time of day to establish MLW on the profile.

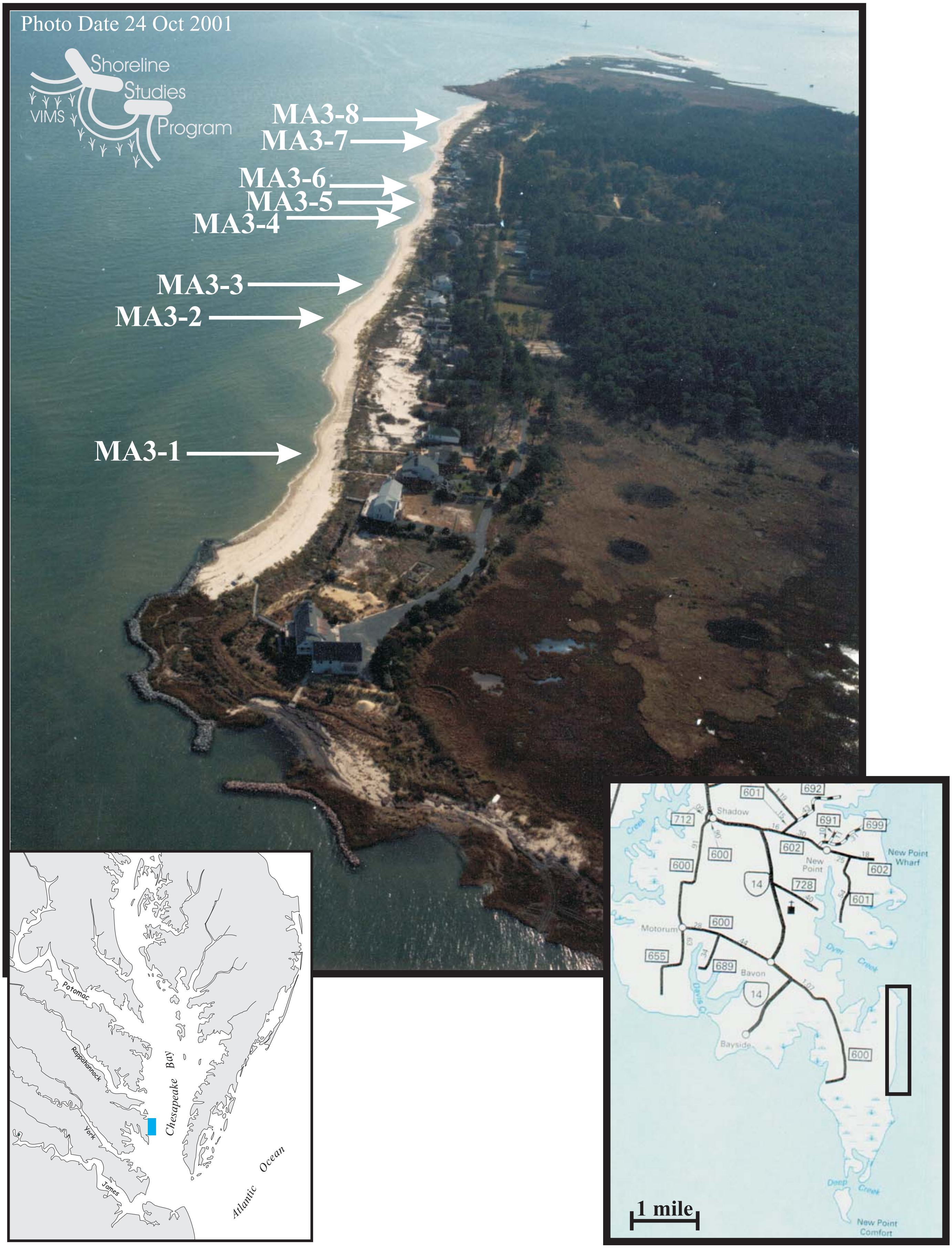


Figure 5. Location of site Ma3 in Mathews County with approximate position of cross-shore beach profiles.

The primary dune profile has several components (Figure 6). A continuous sand feature generally exists from the offshore landward consisting of a 1) nearshore region, bayward of MLW, 2) an intertidal beach, berm and backshore region, sometimes vegetated, between MLW and base of primary dune, 3) a primary dune from bayside to landside including the crest and where present 4) a secondary dune region. All profiles extended beyond MLW bayward and to the back of the primary dune landward. The back or landward extent of the secondary dune was not always reached but the crest was. The dimensions, including lateral position and elevation of various profile components were measured.

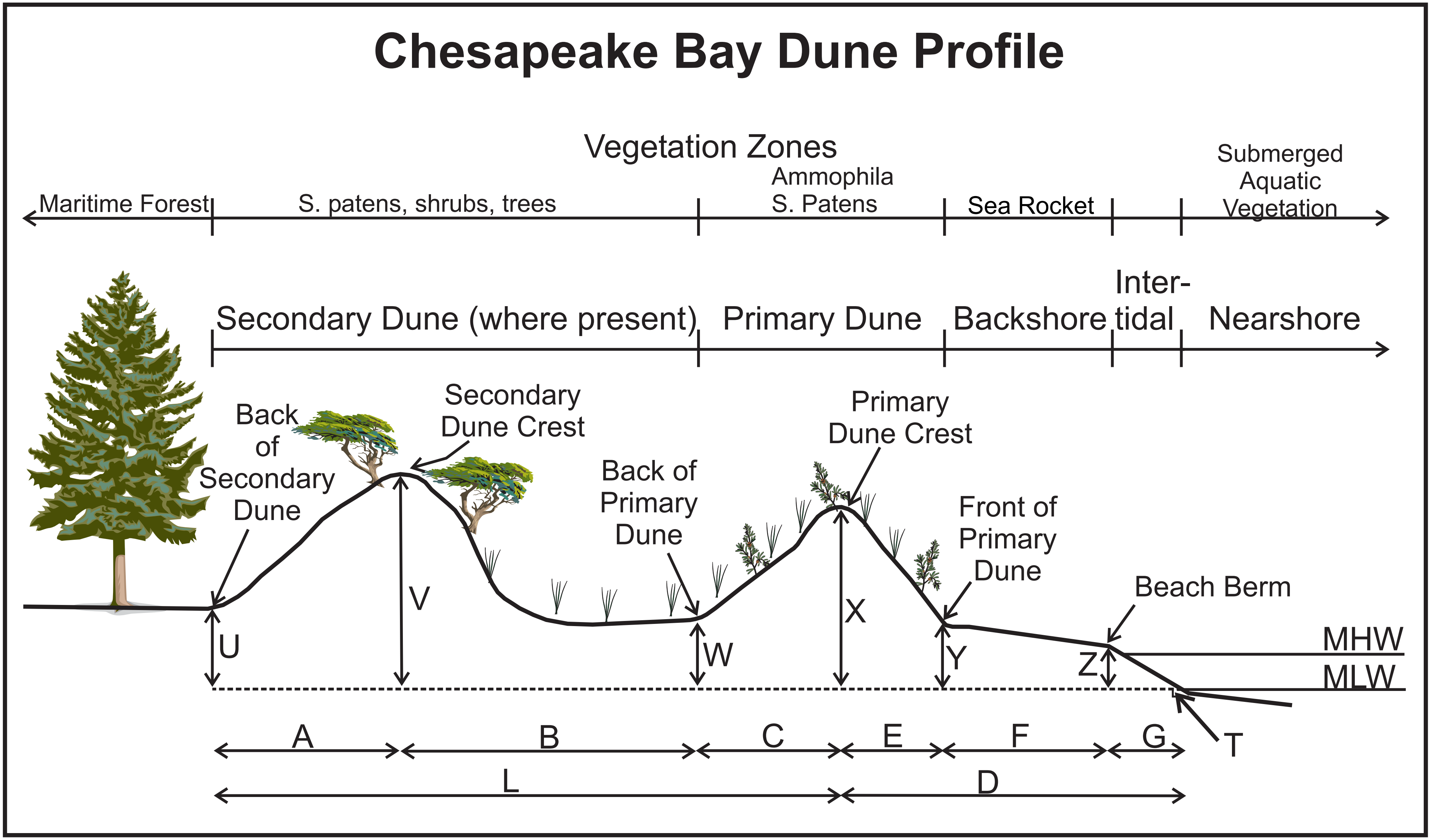


Figure 6 . Typical profile of a C hesapeake B ay dune system with measured parameters indicated.

III. RESULTS

A. Monitoring Sites

1. Large Coastal Structures (NL 42)

Survey data along the site shows that Isabel over-topped the primary dune and moved the beach face landward. The position of the primary dune shifted landward on all profiles along the dune field coast where it has remained through the recovery period (Figure 7). Landward shifts where about 50 ft, 35 ft, 10 ft, and 40 ft for NL42-1, NL42-2, NL42-3, and NL42-4, respectively. MHW shifted landward as well. Shore change on NL42-4 is interesting in that all the updrift groins were detached from the shoreline during the storm, and the large pre-storm sand fillet against the adjacent groins were eroded and carried landward (Figure 8).

2. Groin Field (NL 59)

Survey data show the loss of the bayward half of the primary dune face dune on NL59-1 and NL59-2 and the loss of the entire primary dune on NL59-3 due to Isabel (Figure 9). Much of this sand shifted to the beach and backshore. The following recovery period has been slow to develop a pre-Isabel profile on any transect. The pre- post and recovery is seen in the ground imagery (Figure 10)

3. Dunes as part of Shore Management (MA 3)

Five profiles have all three periods of pre- post- and recovery: MA3-1, MA3-2, MA3-4, MA3-5 and MA3-8. Impacts of Isabel varied along the length of the project site. The northern section, MA3-1 and MA3-2, had the primary dune material carried landward to fill the tough and bayward to widen the upper beach (Figure 11). Recovery has the primary dune redeveloping at about the same location as the pre- storm dunes with a wider beach/backshore and fore dune development. The sequence of events are seen clearly in ground photos. The residents had installed new fence and did some intermittent dune grass plantings after the storm.

The middle section, MA3-4 and MA3-5 had different impacts (Figure 11 and Figure 12). The primary dune at MA3-4 was impacted to the extent that the dune face was scarped and the foredune eroded. A wide beach was left after the storm. The "hot spot" of the site is typified by MA3-5 where the primary dune was flattened to fill the adjacent trough and widen the beach. Recovery shows the beach/berm positions to have remained fairly constant since the post-storm shift. A new primary dune appears to be developing very near the pre-storm position at MA3-5. A widened backshore has provided the opportunity for foredune development on both profiles. The seqeunce of pre- post and recovery are illustrated in (Figure 13 and Figure 14)

The southern part of the project shore is MA3-8. It had a large foredune pre-Isabel which was eroded out with a consequent increase in beach width (Figure 12). The recovery period shows a significant foredune re-vegetation (Figure 15).

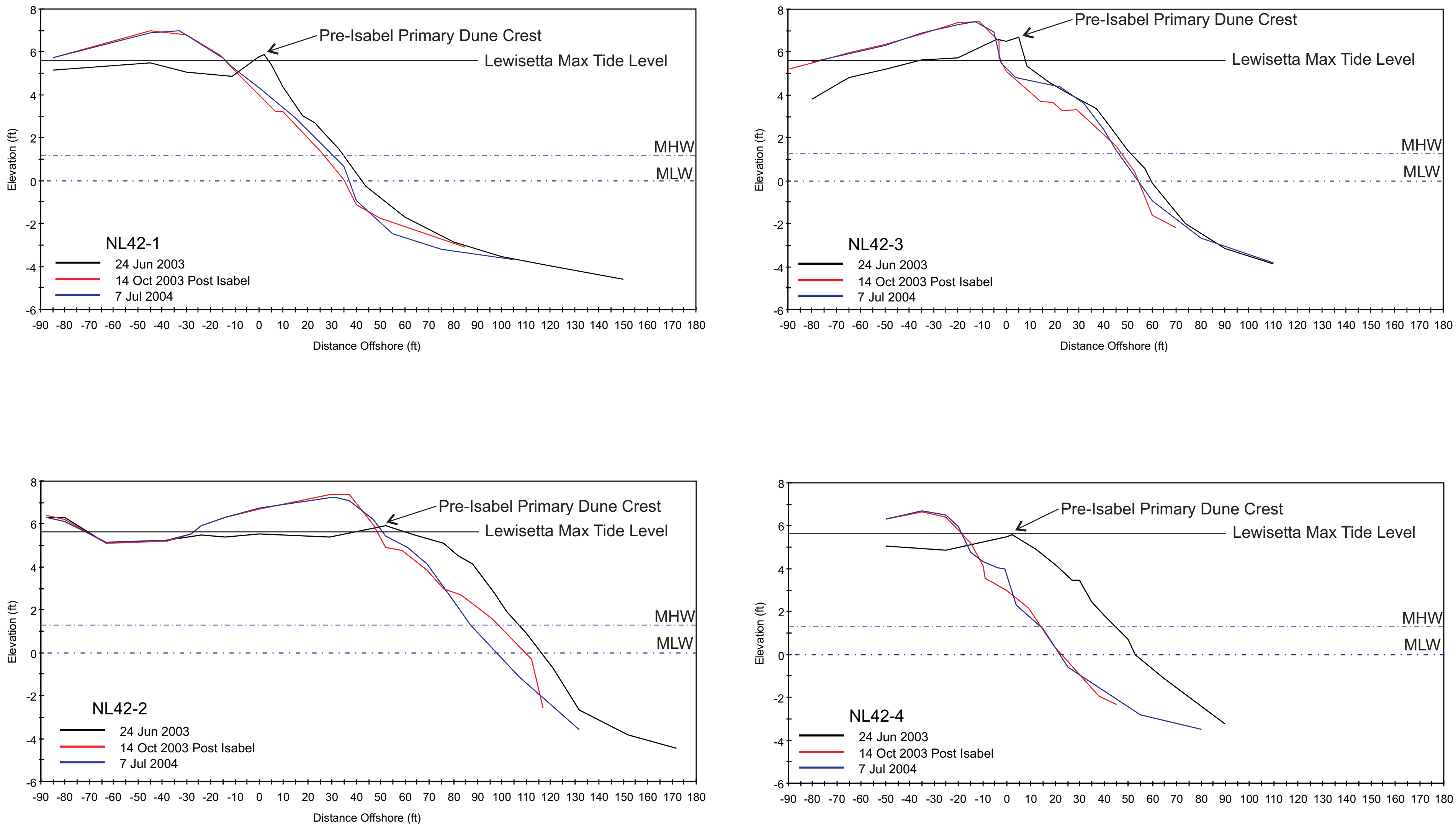


Figure 7. Beach profiles taken before Hurricane Isabel, after Isabel and 10 months after the storm at Nl42.

Smith Point NL 42

Figure 8. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at Nl42.

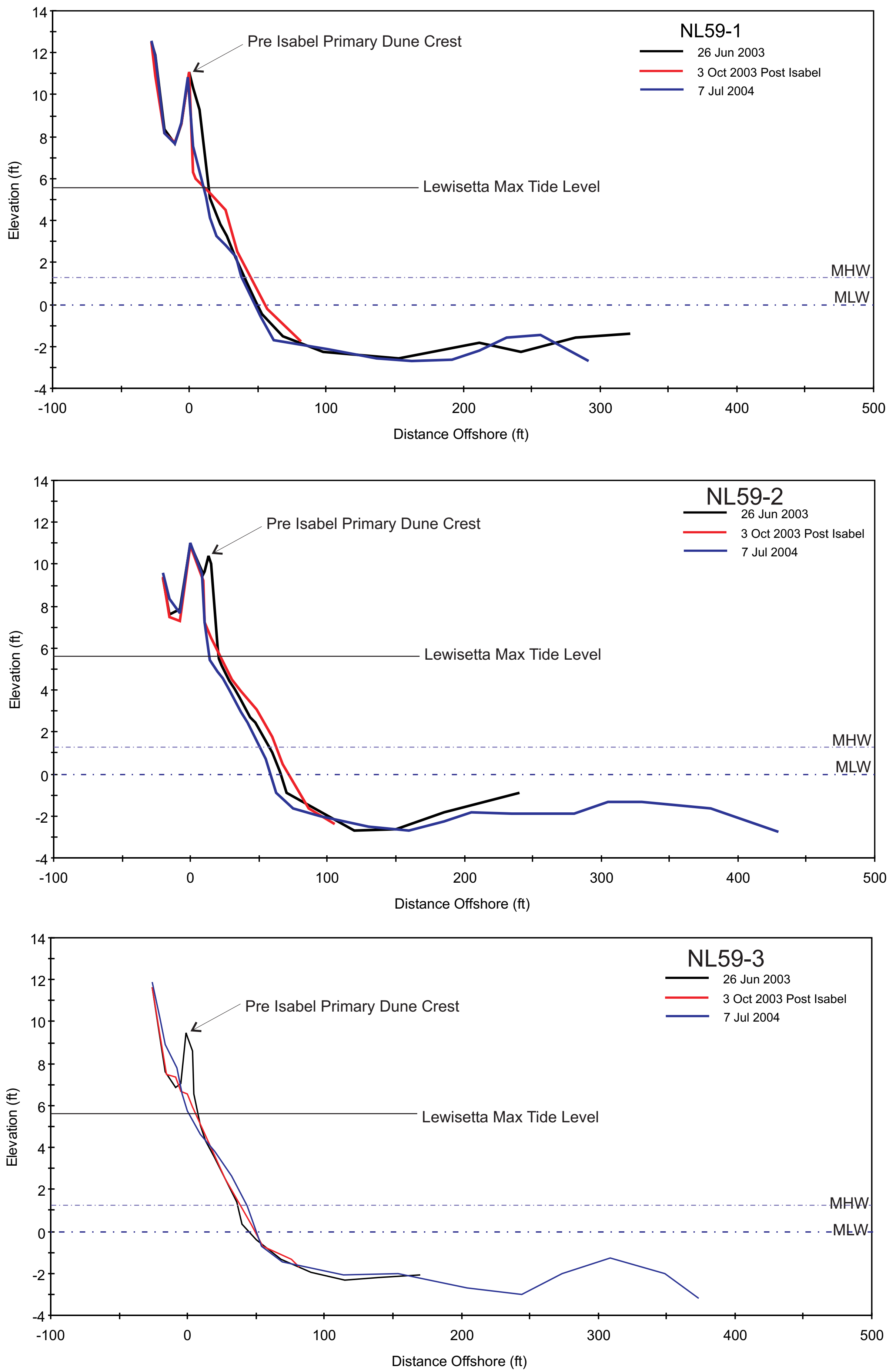


Figure 9. Beach profiles taken before Hurricane Isabel, after Isabel and 10 months after the storm at NL59.

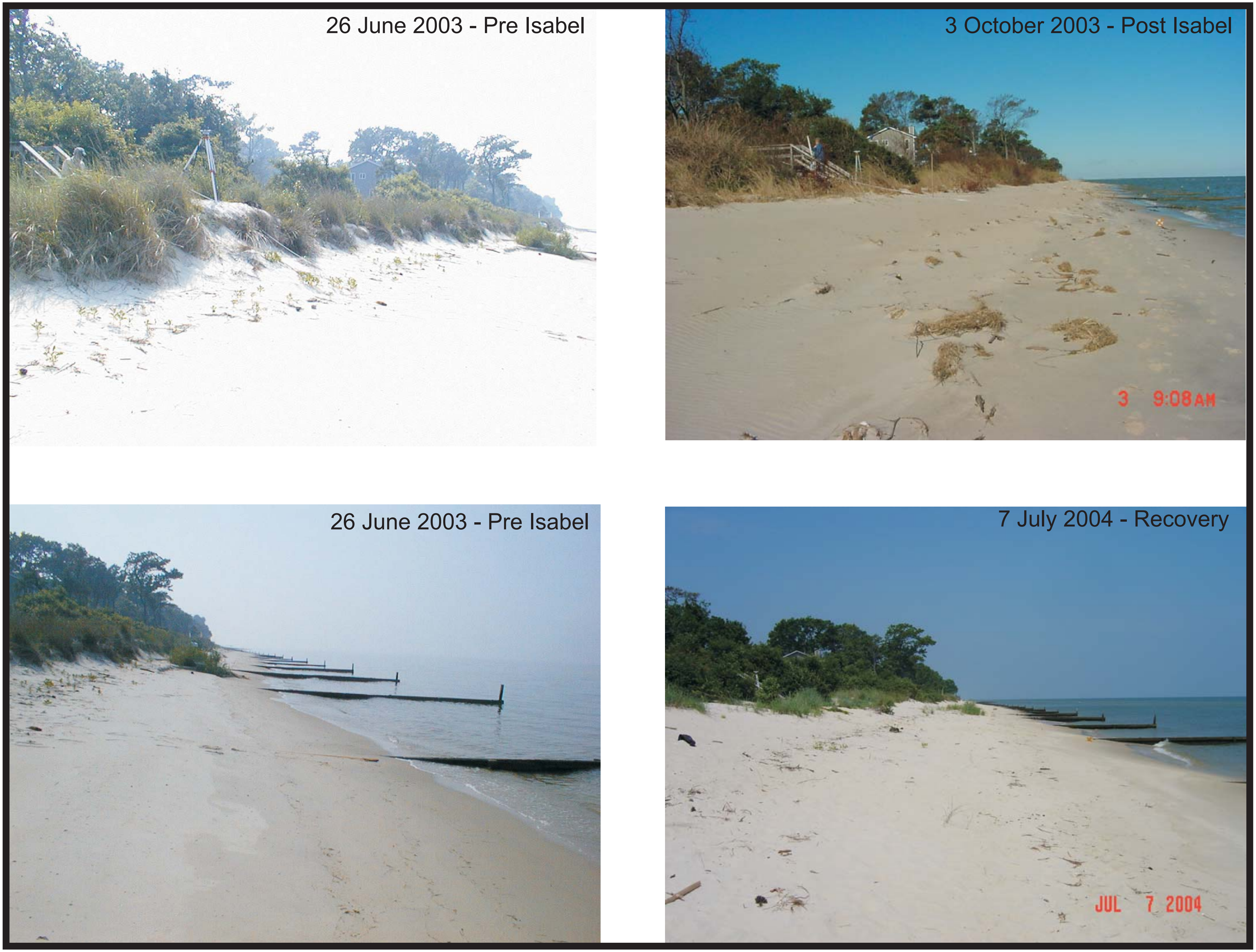


Figure 10. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at Nl59 .

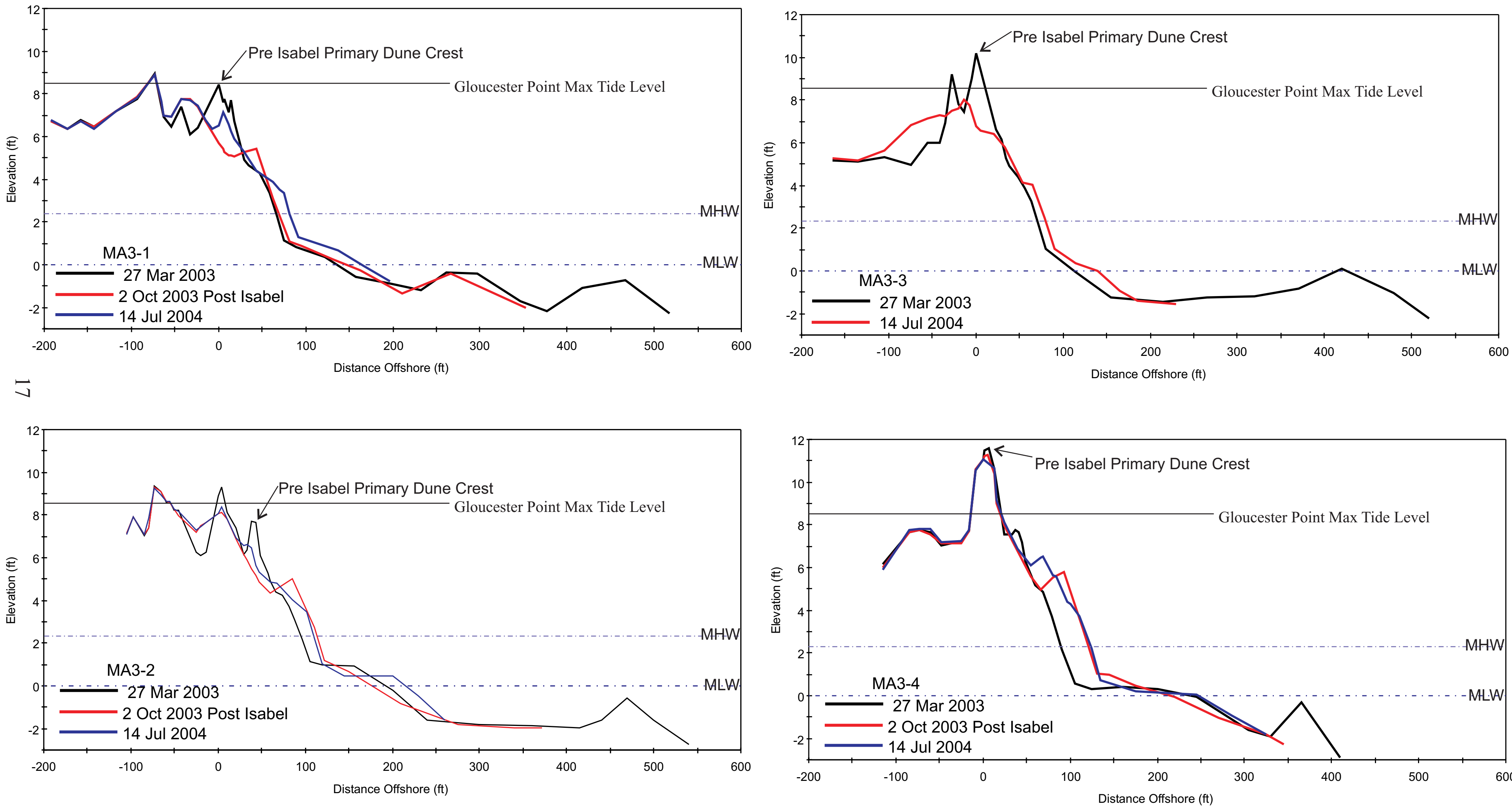


Figure 11. Beach profiles taken before Hurricane Isabel, after Isabel and 10 months after the storm at MA3, profiles 1-4.

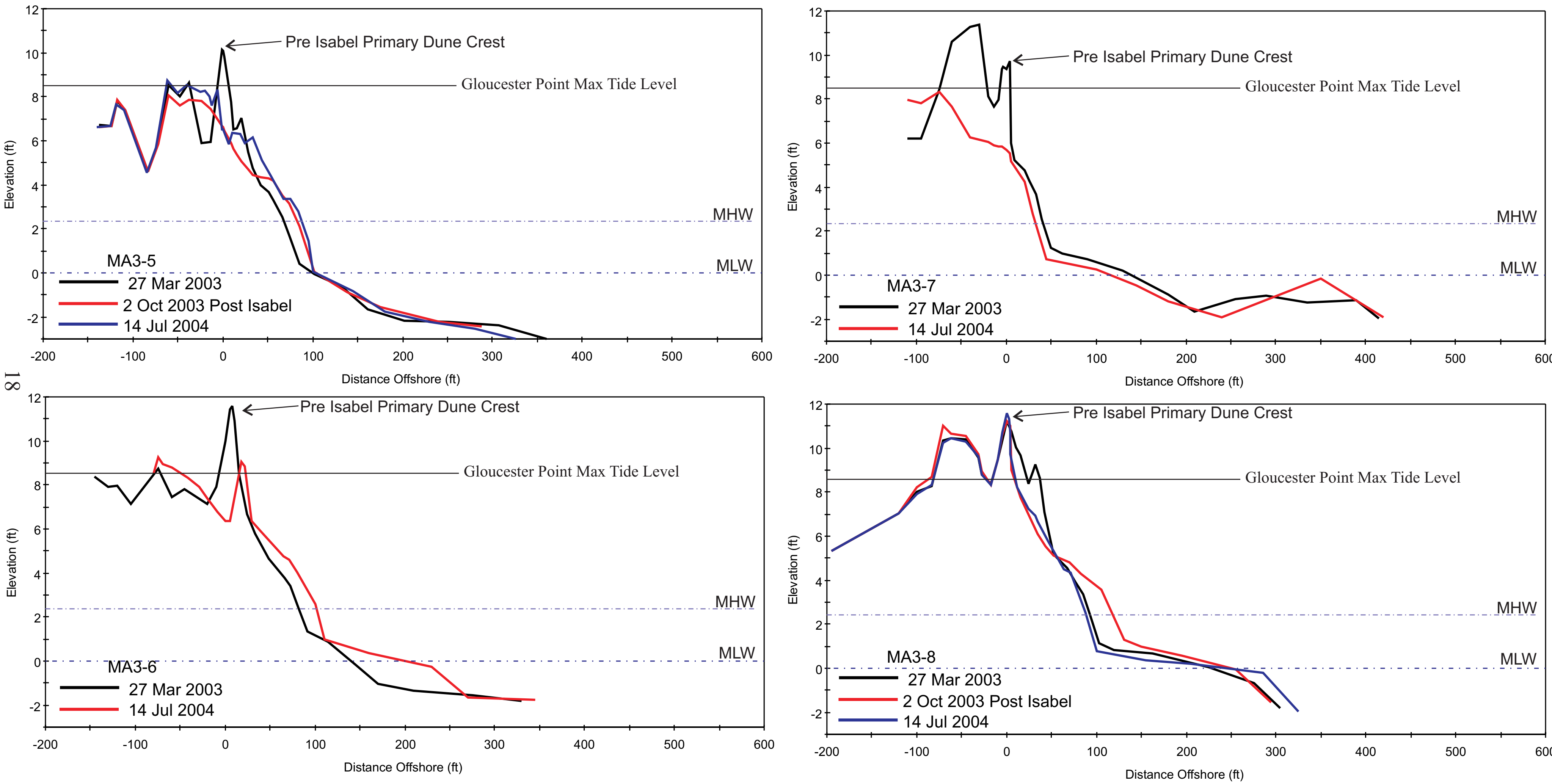


Figure 12. Beach profiles taken before Hurricane Isabel, after Isabel and 10 months after the storm at Ma3, profiles 5-8.

MA3-1
Pre Isabel
27 March 2003

MA3-1
Post Isabel
2 October 2003

MA3-1
Recovery
14 July 2004

Figure 13. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at Ma3-1.

MA3-4
Pre Isabel
27 March 2003

MA3-4
Post Isabel
2 October 2003

MA3-4
Recovery
14 July 2004

Figure 14. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at Ma3-4.

MA3-8
Pre Isabel
27 March 2003

MA3-8
Post Isabel
2 October 2003

MA3-8
Recovery
14 July 2004

Figure 15. Ground shots taken before Hurricane Isabel, after Isabel and 10 months after the storm at Ma3-8.

B. Man's Influence

Results of the first level of Chesapeake Bay Dune Database query is shown in Table 1. It provides the number of different site types (Natural, Man-Influenced and Man-Made), total shore length of each, average shore length of each and the average dune crest height of each shore type. As shown, there are 202 dune sites, 103 are Natural, 96 are Man-Influenced and 3 are Man-Made. The Man-Made is obviously a small category and included, Cape Charles on the Eastern Shore, Willoughby Spit on the Southern Shore, and Grand View Nature Preserve on the Western Shore of Chesapeake Bay where actions taken were sand fencing/planting, berm construction/planting, and grass plantings, respectively.

In the Man-Influenced category, where dunes were created by man's actions, most sites were influenced by groins (45) with revetments/bulkheads second at 22 sites. Groins also influenced the greatest length of coast at just over 27,000 ft, although the average site length was the lowest at about 600 ft/site. However, groins are often built by one or two property owners at a time specifically for beach creation/shore protection. If a dune develops, so much the better. Besides breakwaters, this is the only category that has this attribute. Notably, there are only four sites listed for breakwaters but the average length is large at about 1,400 ft/site. Breakwater systems are usually designed and built for longer reaches of coast.

A level two query of the dune database (Table 2) concerns the relative stability of the Man-Influenced sites. This is a fairly subjective classification subject to the assessment of the authors. Of the Man-Influenced sites (96), 51 are considered Stable, 39 Erosional and just 6 Accretionary. In reviewing groins, 29 sites are Stable, 2 are Accretionary and 14 are Erosional. This would tend to indicate that most of the groins that influenced dunes provide a stable coastal environment, conducive for dune development.

Table 1. Total dune site information and man influenced data.

Total Site Data	
Total Number of Sites	202
Total Number of Natural Sites	103
Total Number of Man-Induced Sites	96
Total Number of Man-Made Sites	3
Total Shore Length of Natural Sites	104,597
Total Shore Length of Man-Induced Sites	92,538
Total Shore Length of Man-Made Sites	4,113
Average Shore Length of Natural Sites	1,016
Average Shore Length of Man-Induced Sites	964
Average Shore Length of Man-Made Sites	1,371
Average Crest Height of Natural Sites	7.2
Average Crest Height of Man-Induced Sites	8.4
Average Crest Height of Man-Made Sites	12.4
Man-Induced Data	
Total Number of Sites Induced by 1	45
Total Number of Sites Induced by 2	22
Total Number of Sites Induced by 3	4
Total Number of Sites Induced by 4	11
Total Number of Sites Induced by 5	11
Total Number of Sites Induced by 6	3
Total Shore Length of Sites Induced by 1	27,024
Total Shore Length of Sites Induced by 2	14,459
Total Shore Length of Sites Induced by 3	5,650
Total Shore Length of Sites Induced by 4	12,835
Total Shore Length of Sites Induced by 5	18,110
Total Shore Length of Sites Induced by 6	14,460
Average Shore Length of Sites Induced by 1	601
Average Shore Length of Sites Induced by 2	657
Average Shore Length of Sites Induced by 3	1,413
Average Shore Length of Sites Induced by 4	1,167
Average Shore Length of Sites Induced by 5	1,646
Average Shore Length of Sites Induced by 6	4,820
Average Crest Height of Sites Induced by 1	8.2
Average Crest Height of Sites Induced by 2	7.4
Average Crest Height of Sites Induced by 3	9.7
Average Crest Height of Sites Induced by 4	6.6
Average Crest Height of Sites Induced by 5	10.6
Average Crest Height of Sites Induced by 6	15.1

1=Groin
2=Revetment/ Bulkhead
3=Breakwater
4=Jetty
5=Beach Fill
6=Miscellaneous

Table 2. Relative stability by site type.

Relative Stability Data	
Total Number of Sites Considered Stable	95
Total Number of Sites Considered Accretionary	21
Total Number of Sites Considered Erosional	86
Total Number of Natural Sites Considered Stable	43
Total Number of Natural Sites Considered Accretionary	14
Total Number of Natural Sites Considered Erosional	46
Total Number of Man-Induced Sites Considered Stable	51
Total Number of Man-Induced Sites Considered Accretionary	6
Total Number of Man-Induced Sites Considered Erosional	39
Total Number of Man-Made Sites Considered Stable	1
Total Number of Man-Made Sites Considered Accretionary	1
Total Number of Man-Made Sites Considered Erosional	1
Total Number of Man-Induced Sites Induced by 1 Considered Stable	29
Total Number of Man-Induced Sites Induced by 2 Considered Stable	5
Total Number of Man-Induced Sites Induced by 3 Considered Stable	3
Total Number of Man-Induced Sites Induced by 4 Considered Stable	8
Total Number of Man-Induced Sites Induced by 5 Considered Stable	3
Total Number of Man-Induced Sites Induced by 6 Considered Stable	3
Total Number of Man-Induced Sites Induced by 1 Considered Accretionary	2
Total Number of Man-Induced Sites Induced by 2 Considered Accretionary	1
Total Number of Man-Induced Sites Induced by 3 Considered Accretionary	0
Total Number of Man-Induced Sites Induced by 4 Considered Accretionary	1
Total Number of Man-Induced Sites Induced by 5 Considered Accretionary	2
Total Number of Man-Induced Sites Induced by 6 Considered Accretionary	0
Total Number of Man-Induced Sites Induced by 1 Considered Erosional	14
Total Number of Man-Induced Sites Induced by 2 Considered Erosional	16
Total Number of Man-Induced Sites Induced by 3 Considered Erosional	1
Total Number of Man-Induced Sites Induced by 4 Considered Erosional	2
Total Number of Man-Induced Sites Induced by 5 Considered Erosional	6
Total Number of Man-Induced Sites Induced by 6 Considered Erosional	0

1=Groin
2=Revetment/Bulkhead
3=Breakwater
4=Jetty
5=Beach Fill
6=Miscellaneous

IV. DISCUSSION

A. Monitoring sites

1. NL 42

The dune field at NL 42 is relatively low in elevation so that the combination of storm surge and wave action completely overwashed the entire site. The whole beach and dune system shifted landward during Isabel. During the recovery period the upper beach and backshore have stabilized or moved slightly bayward but not to the pre-storm profile position. The groin field to the south was stranded during Isabel allowing the position of MHW to move significantly landward. These groins have since been repaired.

2. NL 59

The groins along this reach have worked well to capture littoral sands, encapsulate a beach, and allow a significant primary dune to develop and grow. A sufficient supply of sand exists in the system for this approach to be successful over time. The distance that the beach can progress bayward is limited by the length of the groins. In addition, no area exists for the system to move landward because of the high bank “backstop”. The dune survives quite well in this restricted setting and serves as good shore protection. However, over time, if the supply of sand diminishes or becomes more restricted alongshore, then the material needed for the recovery may not be available for the next primary dune generation after each severe storm event.

3. MA 3

The primary dune and foredune was mostly flattened during Isabel but did attenuate waves during the storm thereby minimizing storm damage to adjacent cottages during Isabel. The primary dune sands moved landward and bayward widening the beach. The recovery shows the widened beach has remained near its post storm position except on the north end where it has moved back to its pre-storm position. New foredune development is significant on the north and south ends because of the new sand fencing efforts by residents.

B. Man’s Influence

Groins historically have been installed to create a beach, but the beach’s development is mostly a function of sand supply. We have documented that groins can provide a setting conducive to dune growth. However, future installations may require ongoing beach nourishment to provide the volume of material necessary to create a protective primary dune. Sand fencing and grass plantings should also be encouraged.

V. CONCLUSION

Shoreline management using dunes as part of the protection strategy is a very viable option for landowners around Chesapeake Bay. Much of the success of a particular influence by man's activities is a function of the geomorphic setting of a given site. The use of groins has been widespread around Bay, but if there is not a sufficient and constant supply of sand, no beach will exist and consequently, no dune. Geomorphic opportunities such as embayed coasts like Bavon should be taken advantage. Here only a modest investment in sand fencing and plants is required. However, caution is urged, so that after a storm there is not a rush to install defensive structures such as bulkheads and groins which tend to reduce the adjacent beach widths and make recovery more difficult by intercepting the coastal profile. Beach nourishment can always be used to enhance and/or create a protective beach/dune systems as long as there is a management plan for its use.

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