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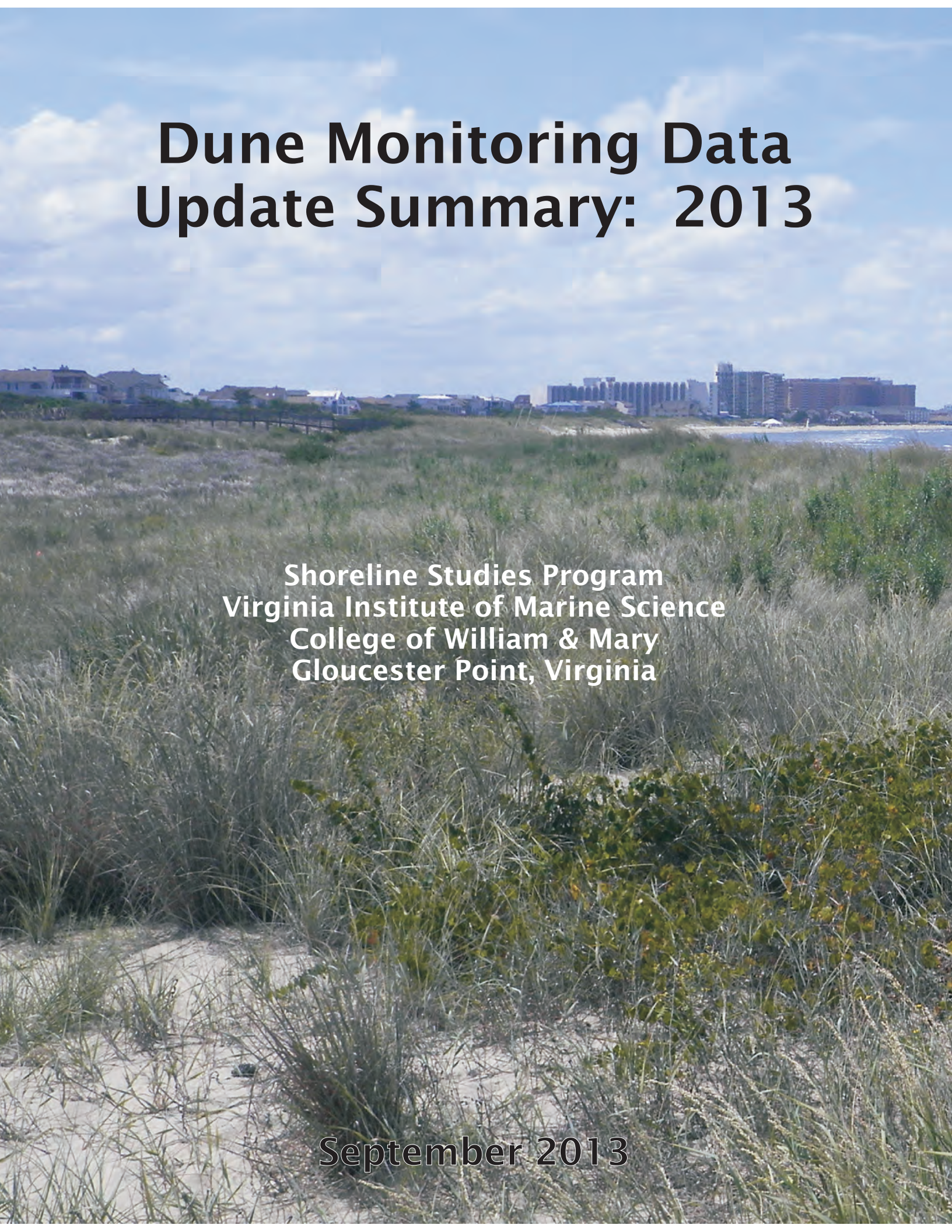
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Dune Monitoring Data Update Summary: 2013



Shoreline Studies Program
Virginia Institute of Marine Science
College of William & Mary
Gloucester Point, Virginia

September 2013

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September 2013

Introduction

The Shoreline Studies Program at VIMS established a beach and dune monitoring program for nine sites around the Virginia portion of Chesapeake Bay (Milligan *et al*., 2005). These sites were monitored twice yearly for four years (2001-2004). In addition to three years of relatively calm conditions, these data included the impact of Hurricane Isabel, a nearly 100-yr event, on the Bay's shorelines. The shoreline's change due to the storm and their subsequent short-term recovery was documented by this data. Since the end of the monitoring program other events have impacted Chesapeake Bay shorelines. In order to document the longer-term recovery of these systems, additional monitoring occurred. Several of these sites are man-influenced and have upland development behind the dune. Understanding storm impacts and shoreline recovery is critical knowledge when determining the suitability of living shoreline options (i.e. beach/dune) in higher energy environments. In addition, the overall stability of these sites and their response to physical forcing can provide important information when developing guidelines for beach and dune encroachment. Six of these sites were resurveyed in the spring of 2009 (O'Brien *et al*., 2009).

In November 2009, the Veteran's Day Northeaster impacted Chesapeake Bay. The storm originated with the remnants of Hurricane Ida which made landfall as a tropical storm along the U.S. Gulf Coast on November 10, 2009. Tropical Storm Ida weakened quickly after landfall and was soon absorbed by a frontal boundary advancing toward the southeast U.S. Coast. By the morning of November 12, 2009, the remnant low was located near the North Carolina. The storm developed strong northeast winds and its movement was blocked such that it impacted over several tidal cycles. At Sewells Point in Norfolk (Figure 1), the tide gauge peaked at 7.73 ft above mean lower low water (MLLW) at 624 pm EST, November 12. This was more than 5 feet higher than the astronomical high tide (NOAA Tides and Currents, 2009). This value ranks as the 5th highest water level on record since 1930, and is just 0.2 feet below the level



Figure 1. Location of surveyed dunes sites within the Chesapeake Bay estuarine system. Tide gauge locations also are shown.

recorded during Hurricane Isabel. The highest level on record occurred with the 1933 Hurricane (8.9 ft MLLW) (U.S. Army Corps, 2009). Peak wind gusts varied around the Bay. At Norfolk International Airport, the wind peaked at 74 mph while closer to Mathews at the Yorktown Coast Guard facility, it peaked at 58 mph. Gwynns Island in Mathews received 3.52 in of rainfall in 36 hours between 8 p.m. November 10 and 8 a.m. November 12. Over the three day storm period, the Norfolk International Airport received 7.40 in of rainfall which is nearly triple the average value it receives in the entire month (U.S. Army Corps, 2009). In order to document change, MA3 was surveyed after the storm.

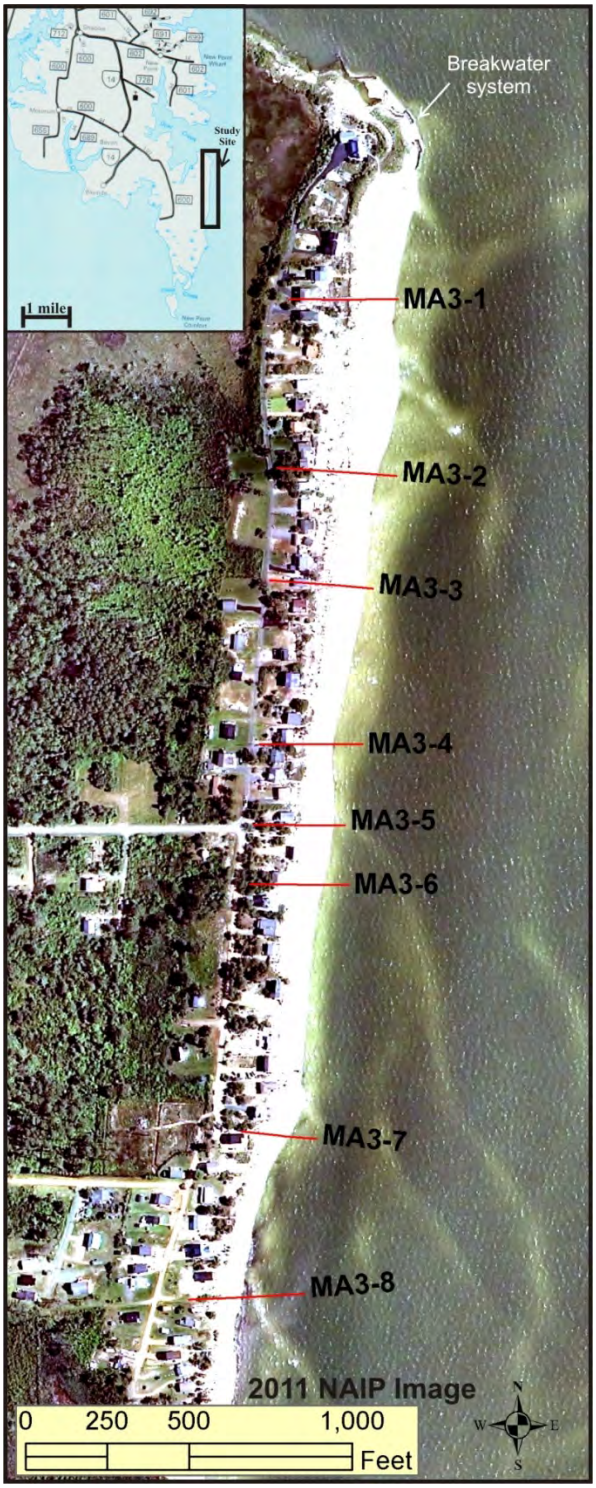


Figure 2. Location of cross-sectional profile lines at site MA3.

The present effort re-occupied the monitoring site profiles at two sites and provided new data on the long-term evolution of these sites. Two sites were surveyed:

Site MA3

Site MA3 is Bavon/Chesapeake Beach in Mathews County. This site represents a linear dune field that has faced developmental pressures for the past 20 years (Figure 2). MA3 is a secondary dune site with a low upland that is controlled by a breakwater system in the north, a marsh headland in the south, and nearshore attached bars (Milligan *et al.*, 2005). The source of sand for dune development at this site is from these nearshore bars. This abundance of sand has elevated the toe of the beach such that sand is available for aeolian transport to the backshore and dune area. The residents of the local communities have enhanced this process by installing dune fencing and planting dune grasses.

When Hurricane Isabel impacted the shore in September 2003, a wide beach was left as sand was eroded from the dunes and deposited nearby (Milligan

et al., 2005). The residents reinstalled dune fencing to help the dunes recover, and many of the dunes rebuilt at the same location. Before the storm, most of the beach was accretionary as only the southern end was eroding, and the dunes were stable overall (Milligan *et al.*, 2005). Profile MA3-7 was completely eroded during the storm.

The site was surveyed on July 26, 2007 and March 23, 2009, and these surveys reveal accretion for most of the primary dunes on the site (O'Brien *et al.*, 2009). With the exceptions of MA3-6 and MA3-8, the profiles along the rest of the beach were showing growth and stability including the primary dune on MA3-7 which had started to grow back. MA3-6 eroded along the beach face and upper beach while MA3-8 eroded along both the beach and dune (O'Brien *et al.*, 2009).

Most recently, a revetment has been built along the southern reach to protect eroding property. In addition, the residents have conducted meetings with the National Fish and Wildlife Foundation to discuss the possibility of building a breakwater system to provide additional erosion protection.

Site VB4

First Landing State Park is located along the southern shore of Chesapeake Bay at its mouth. This Bay site is part of a large, accreting, natural dune field that also has an oceanic influence including sea swell and northeast storm waves (Figure 3). Site VB4 is located within the larger shore reach defined by Cape Henry to the east and Lynnhaven Inlet to the west. Adjacent properties are Fort Story to the east and residential private properties to the west. Site VB4 is the only natural reach of shoreline left between two developed coasts.

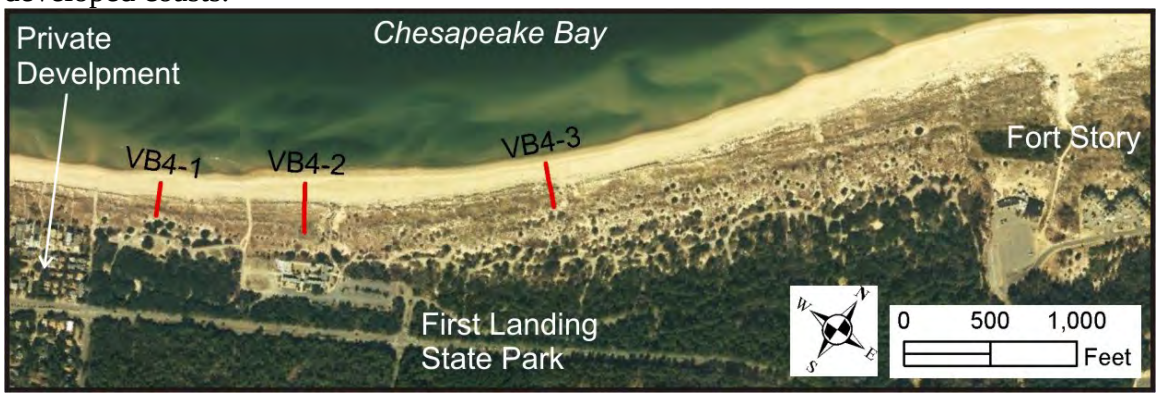


Figure 3. Location of cross-sectional profile lines at site VB4.

Overall, the beach and dunes at this site are accreting. Large amounts of sand move from east to west in the nearshore sand bars. Like the Mathews site, extensive sand dunes provide material that can be transported by wind to the beach and dune. This sand likely comes from two sources; sand is transported into Chesapeake Bay from oceanic swell. In addition, ongoing beach nourishment at the City's Resort Strip on the ocean coast may have been transported northward around Cape Henry and onto the Bay beaches (Milligan *et al.*, 2005).

Milligan *et al.* (2005) documented the effect of Hurricane Isabel on this site during its passage in 2003. While many sites around the Bay were severely affected by the storm, the storm had little effect on the long-term accretionary trend at the site.

Methods

Several cross-shore profiles with benchmarks were established at each site (Milligan *et al.*, 2005). 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 for the profile. At each survey, cross-sectional profiles and ground photos were taken. These data were used to determine the changes at each site.

In order to document the beach and nearshore change due to the Veteran's Day storm, Site MA3 was photographed during the course of the storm and surveyed on November 16 and 17, 2009. No other sites were surveyed. For the present effort, both sites were surveyed in September 2013 with a Zeiss Ni2 Level; elevations and distances were determined along the dune, beach and nearshore. Care was taken to measure the same dune and beach system components. Each site has a continuous sand feature that extends from the offshore landward that consists of a 1) near shore region seaward of MLW; 2) an intertidal beach, berm and backshore region, the latter of which may be vegetated, between MLW and base of primary dune; 3) a primary dune from bayside to landside including the crest and foredune where present; and 4) a secondary dune region where present. All profiles extended from beyond MLW (seaward) to the back of the primary dune (landward). If a secondary dune was present at the site, the back or landward extent of the secondary dune was not always reached, but the crest was always surveyed. The two-dimensional data are represented in an Excel spreadsheet. This data was analyzed using the Beach Morphology and Analysis Program (BMAP) (Veritech, 2004). Profile plots are located in Appendix A (MA3) and Appendix C (VB4).

Results and Discussion

Site MA3

MA3 was severely impacted by the Veteran's Day Northeaster in November 2009. The beach and dune changes in response to the storm varied along the site. The northern end of the site (profiles 3-1, 3-2, 3-3, and 3-4, Appendix A) generally had limited dune scarping and/or beach face erosion, and the sand was deposited on the beach face and nearshore (Figure 4). Conversely, the southern end of the beach was severely impacted by the storm (Figure 5). The entire dune was lost at profiles 3-5, 3-6, 3-7, and 3-8 (Appendix A). Some of the eroded sand was redistributed to the beach face, particularly at profile 3-7, but most was lost to the system. Additional photos taken at MA3 during this storm and are shown in Appendix B.

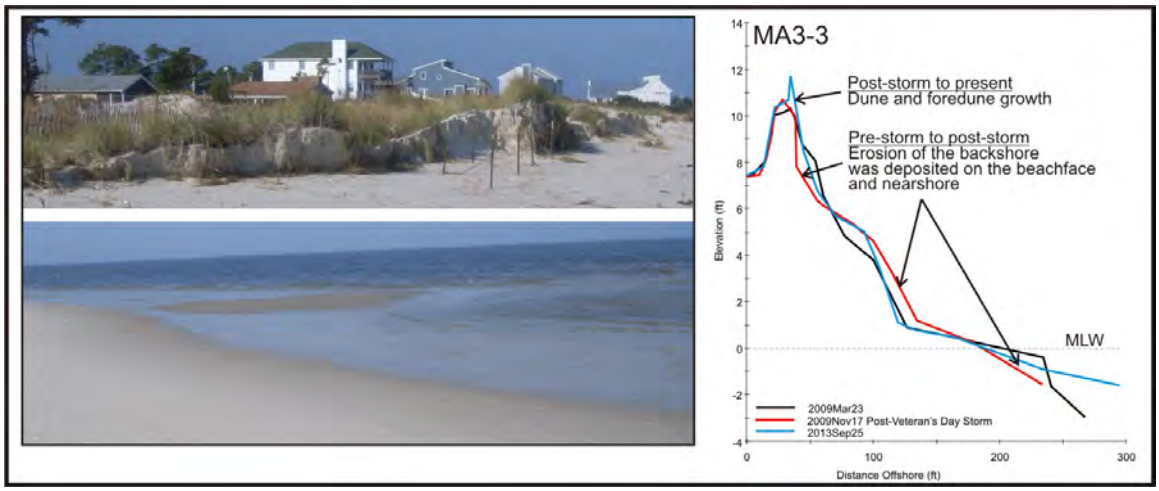


Figure 4. Dune scarping and nearshore flats along profile MA3-2 on 16 Nov 2009 after the Veteran's Day Northeaster and a across-sectional profile (MA3-3) showing the changes to the beach and dune since 2009.

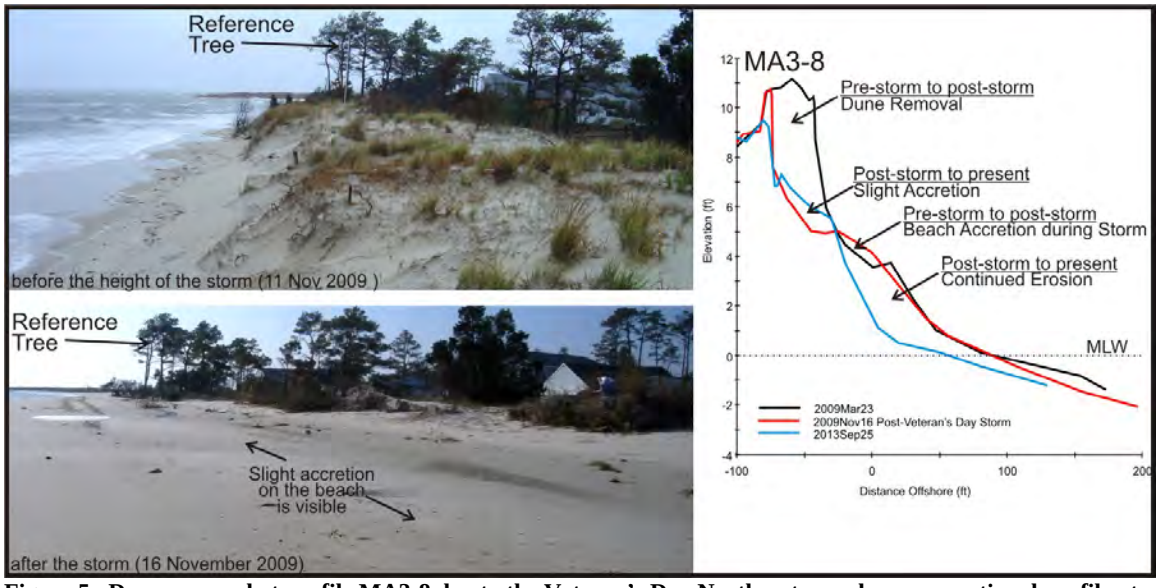


Figure 5. Dune removal at profile MA3-8 due to the Veteran's Day Northeaster and a cross-sectional profile at the same location showing the changes to the beach and dune since 2009.

Since the storm, profiles 3-2, 3-3, and 3-4 have accreted in the upper beach and dune, but overall, the system has moved slightly landward. Profiles 3-4, 3-5 and 3-6 have recovered some of the dunes that were lost during the storm, but their beach face also is landward of the post-storm profile. At profiles 3-4, 3-5, and 3-6 the houses are situated close to the shoreline, but these locations have the advantage of having a bar shore-attached. The location of profile 3-7 was lost because of construction of a house and revetment between 2009 and 2013. Profile 3-8 had modest positive elevation changes in the area of the dune, but the beach face is significantly landward of the post-storm position (Figure 5).

The distance to the position of mean high water (MHW) is often used to show the movement of the beach through time. At MA3, several trends are visible. Profile MA3-1

continues to accrete because of its location just south of the breakwater shore protection system at the northernmost tip of the Bavon/Chesapeake Beach (Figure 6). This system has held the headland feature and reduced loss of sand transported north. At the southern end of Bavon/Chesapeake Beach, the opposite is occurring. The position of MHW at profile MA3-8 has eroded such that it is now landward of where the primary dune crest (0 position on the graph) existed in 2001 (Figure 6). Along the rest of the shoreline, the general trend was accretion until 2009. Because of erosion of the dune face under the increased water levels, the position of MHW was actually farther seaward after the Veteran's Day storm. However, MHW is now moving landward. This corresponds to the dune growth at the northern end of the site.

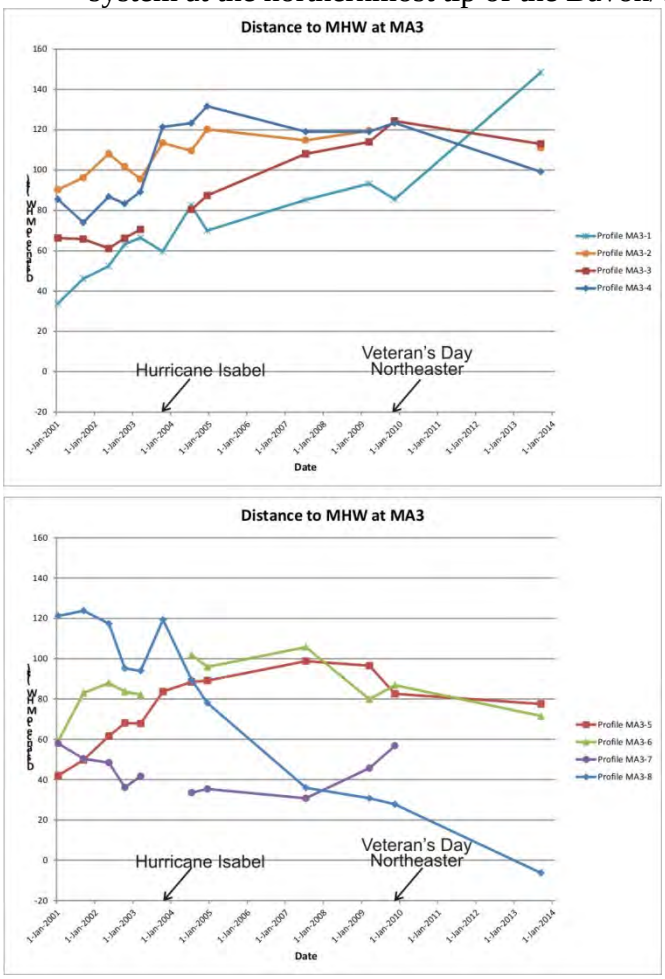


Figure 6. Distance to mean high water (MHW) in feet over time for profiles at site MA3.

Since the beginning of the beach and dune monitoring program in 2001, the net change at MA3 has varied between the north and south profiles. The northern profiles generally have accreted while the southern profiles have eroded (Figure 7). The measurements shown in Figure 7 are illustrated by photos in Appendix B. The full set of profile lines with selected dates between 2001 and 2013 are shown in Appendix A.

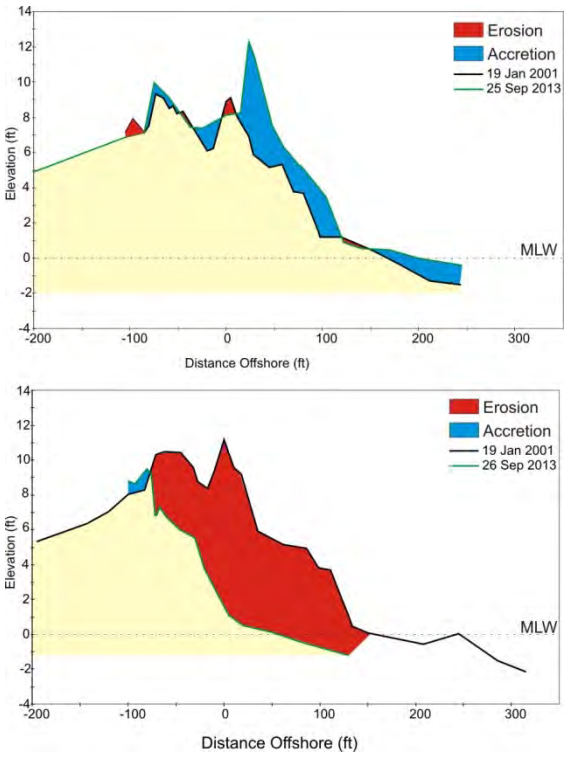


Figure 7. Depiction of the net change between 2001 and 2013 along the northern end (top) and southern end (bottom) of MA3.

Hurricane Sandy impacted the area in October 2012. No direct data exists for the storms impact on MA3; however, the continued erosion between 2009 and 2013 indicates that it did indeed impact this site. In 2011, the underlying marsh peat began to be exposed at the southern end of the site (Figure 8). This peat is a remnant from when this section of shore was part of back barrier lagoon (Appendix B). The peat outcrops along the intertidal beach.



Figure 8. A 2011 aerial photo of MA3 depicting morphologic features.

Because peat generally erodes slower than beach sand, it's possible that this section of shoreline, which has been eroding quickly, may be better able to maintain a beach width.

Site VB4

Overall, VB4 has been accretionary over the last 12 years of the monitoring program. The entire site has a wider, higher dune than in 2001 (Figure 9). The erosion shown in the nearshore indicates the migration of bars alongshore. It is not likely a true net loss. Additional profile plots are shown in Appendix C. The beach face has varied through time due to storm events and alongshore migrating sand bars but overall, it is wider today than it was in 2001 as depicted by the distance to MHW (Figure 10). No surveys were taken between 2004 and 2013. This large gap in data makes it difficult to show storm impacts. Likely VB4 was impacted by the Veteran's Day Northeaster in 2009 and Hurricane Sandy in 2012, but no data is available to quantify it. Photos taken after Hurricane Sandy indicate that sections of the dune were eroded and the trough along the beach indicates a high water event (Figure 11). However, the impacts were short-lived (Figure 12). After one year, the beach grass is recolonizing the foredune area and the dune scarp is no longer visible. Neither storm affected the sites long-term accretion. This is due to so much sand available to the system at this site.

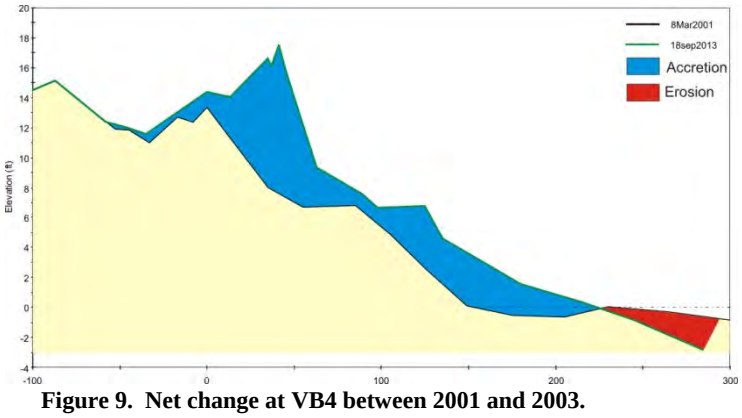


Figure 9. Net change at VB4 between 2001 and 2003.

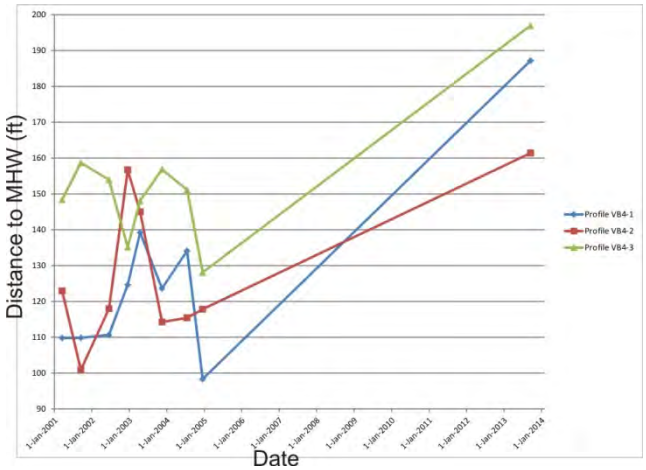


Figure 10. Distance to mean high water (MHW) in feet at site VB4 over time.



Figure 11. Photos taken at VB4 in November 2012 approximately one month after Hurricane Sandy.



Figure 12. Photos taken at VB4 in after Hurricane Sandy, November 2012 (top) and about one year after Hurricane Sandy, September 2013 (bottom).

Conclusion

Maintaining a monitoring site provides invaluable scientific data on the rates and patterns of change as well as how living shorelines perform in high energy environments. These particular sites were chosen for monitoring based on their variability of settings within Chesapeake Bay and storm impacts. These sites were monitored semiannually for four years, 2009 and 2013. Three large storms have occurred during this time period: Hurricane Isabel (Oct 2003), Veteran's Day Northeaster (Nov 2009), and Hurricane Sandy (Oct 2012). The Mathews site only was surveyed pre and post the Veteran's Day storm.

Along the northern half of MA3, the shoreline was only minimally affected by the storms. The section of beach on the north end nearest the breakwater system has been accretionary throughout the entire monitoring program. The rest of the northern reach has generally been accretionary in that the dunes are higher now than they were at the start of the monitoring program, but there have been changes in response to storm events. During storms, elevated water levels erode the dune face and sand can be deposited on the beach or nearshore bars. In these areas, the dune can readily be rebuilt with dune fencings to protect the upland structures from the next storm. The movement of sand from the beach face to the dune and the migration of nearshore bars can result in reduced beach width, but these changes do not necessarily indicate that a shoreline is erosional.

In areas where structures are close to the shoreline, it can be difficult for sand fencing to be effective. However, because the shoreline near profiles MA3-4, 3-5, and 3-6 are situated adjacent to a shore-attached bar, sand is available (Figure 13) and it may be



Figure 13. Photo looking north at Profile MA3-5 showing dune fencing collecting sand in the backshore (left). The 2009 VBMP aerial photo (right) shows two shore-attached bars in the vicinity of profiles 3-4, 3-5, and 3-6.

possible to rebuild some dune. This site underscores the impact that development and the underlying geology play in erosional patterns through time. The southern section of MA3, on the other hand, has been severely impacted by these storms. The southern reach of the site is erosional, and the beach and dunes were eroded during storms. At the most southern portion, all of the dune that was originally mapped in 2001 has been eroded and at profile 3-7, a revetment was built to protect the upland structure making it highly unlikely that a dune will exist in this site in the future (Figure 14).



Figure 14. Photo taken in September 2013 at Profile MA3-7. Because of erosion at this site, the dune no longer protected the shoreline. A revetment was installed to protect upland structures.

Site VB4 shows the resilience of dune systems when sand is plentiful and encroachment by structures is minimal. In addition, larger waves create higher dunes that require larger surges if they are going to be impacted by a storm. The net long-term change at this site has been overwhelmingly positive (Figure 15). Even in the face of these significant storm events, the beach and dune is higher and wider in 2013 than it was in 2001.



Figure 15. First Landing State Park in September 2013. A wide, natural dune system has thrived due to a constant flux of sand through the mouth of the Bay.

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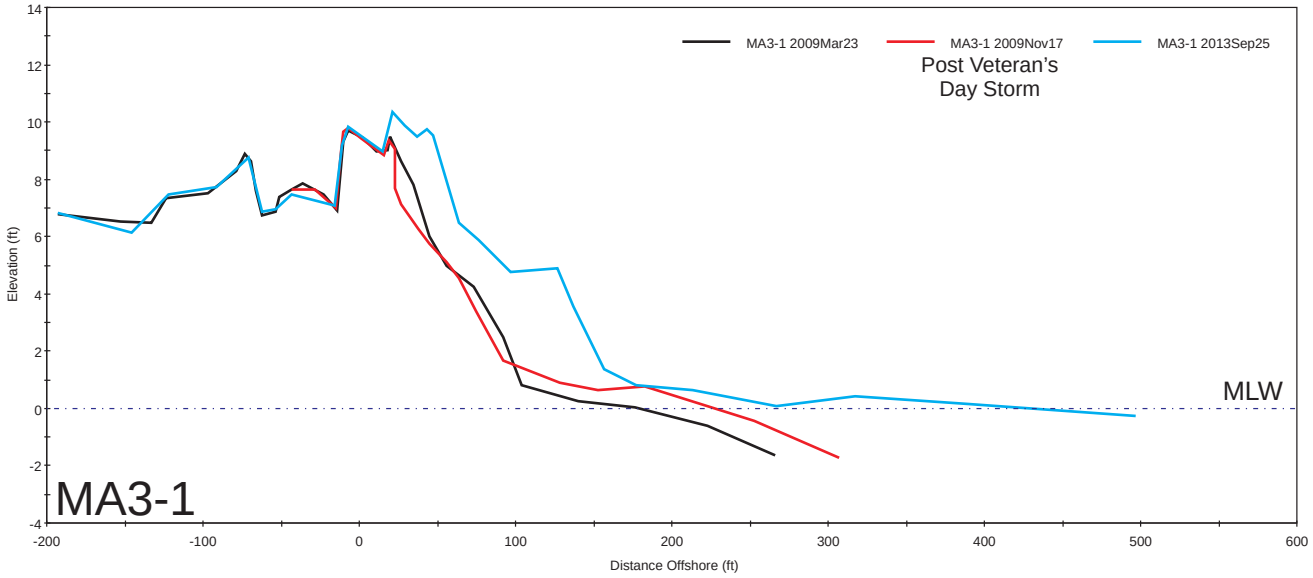
Appendix A

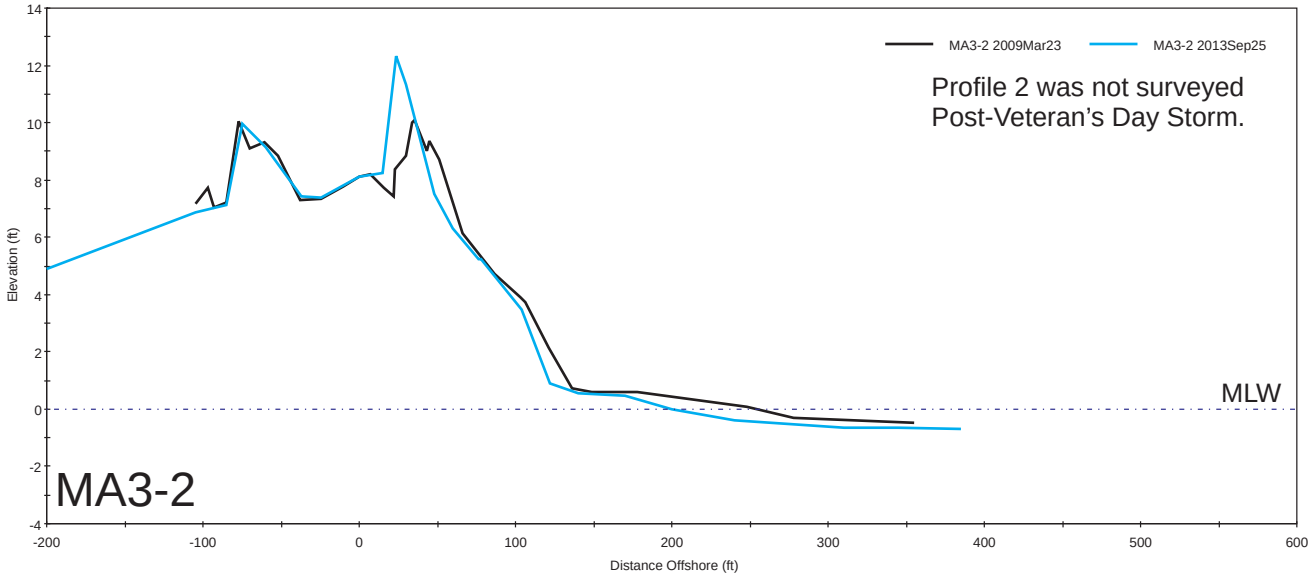
Site MA3 Profile Plots

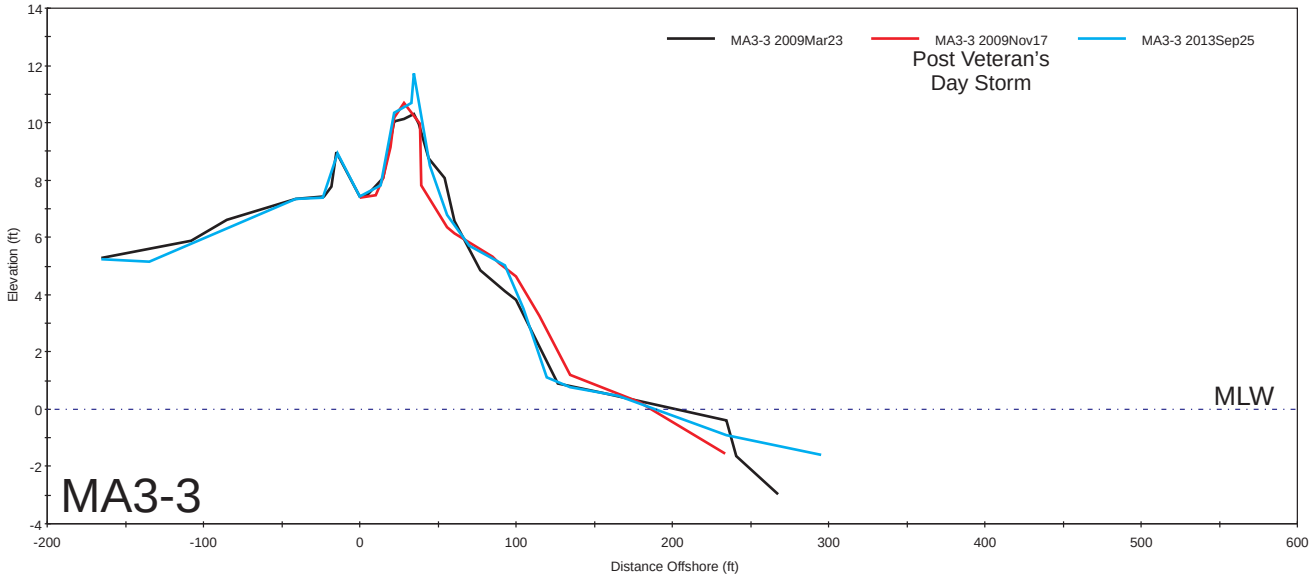
Two sets of profile plots are shown:

Set 1: The three most recent profile dates

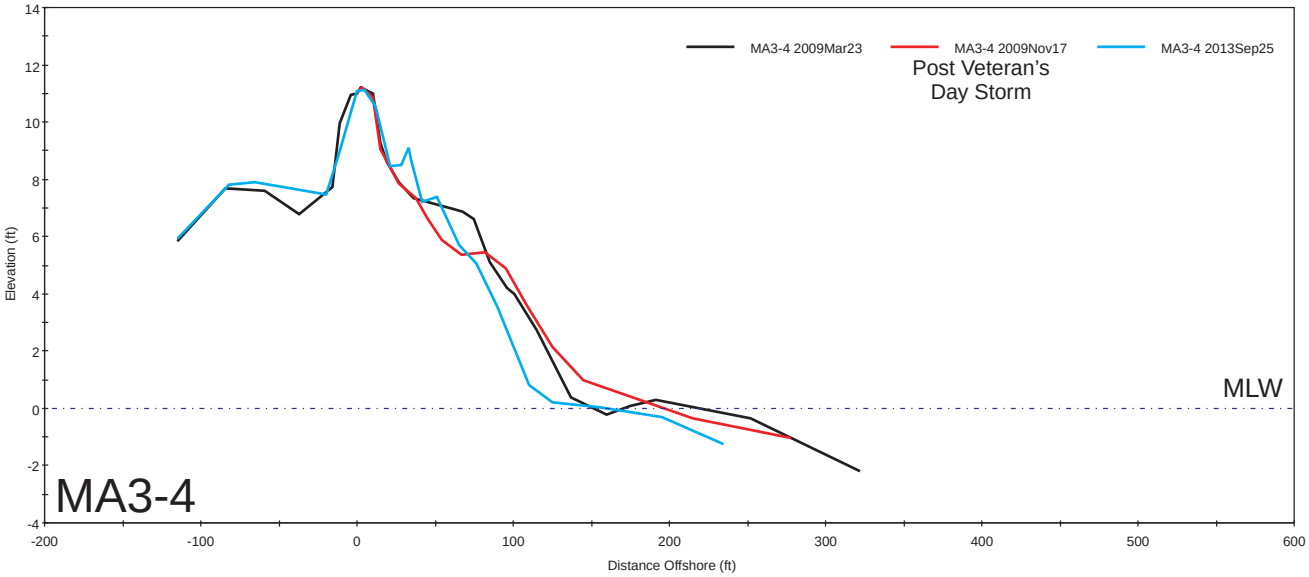
Set 2: Selected profiles since the start of the site monitoring including post-Hurricane Isabel and post-Veteran's Day Storm

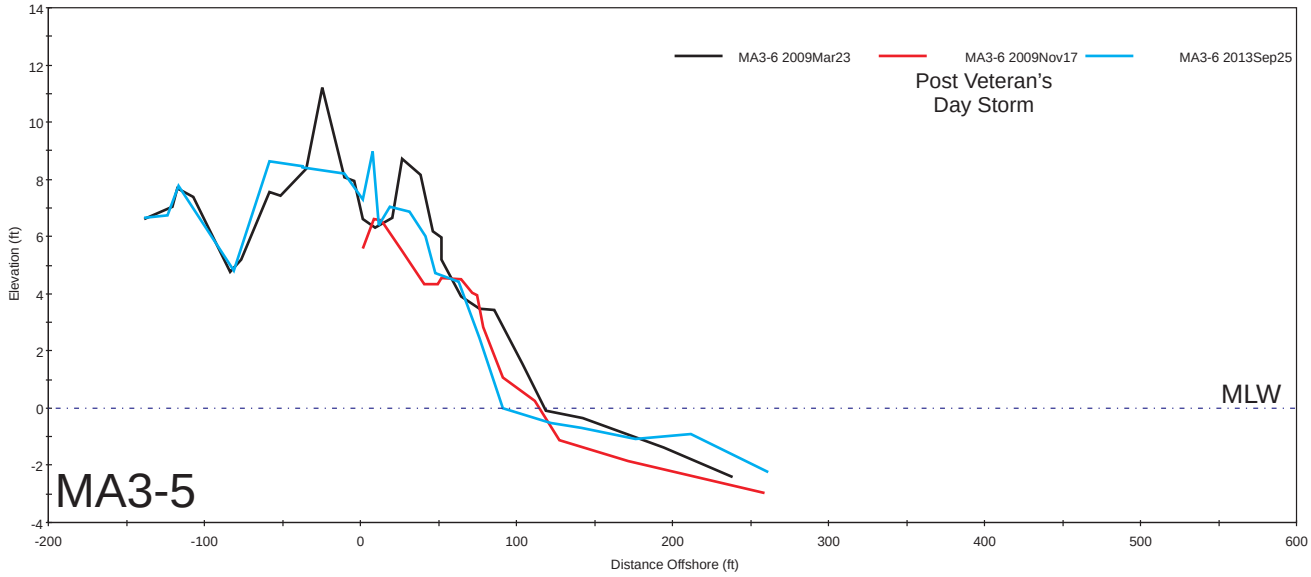


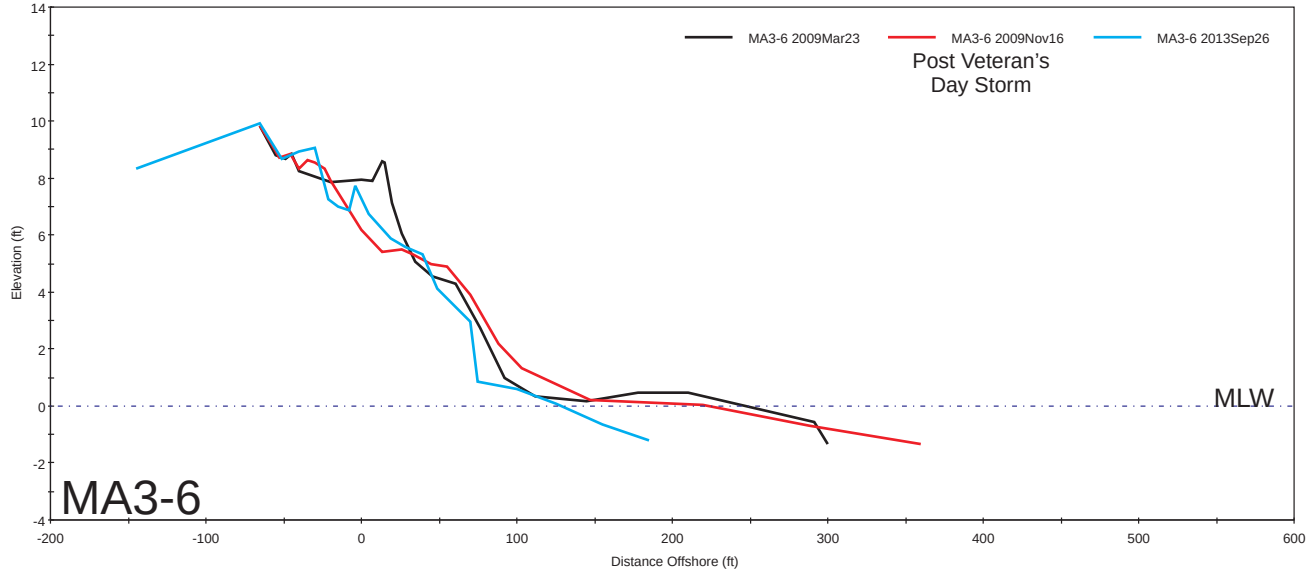




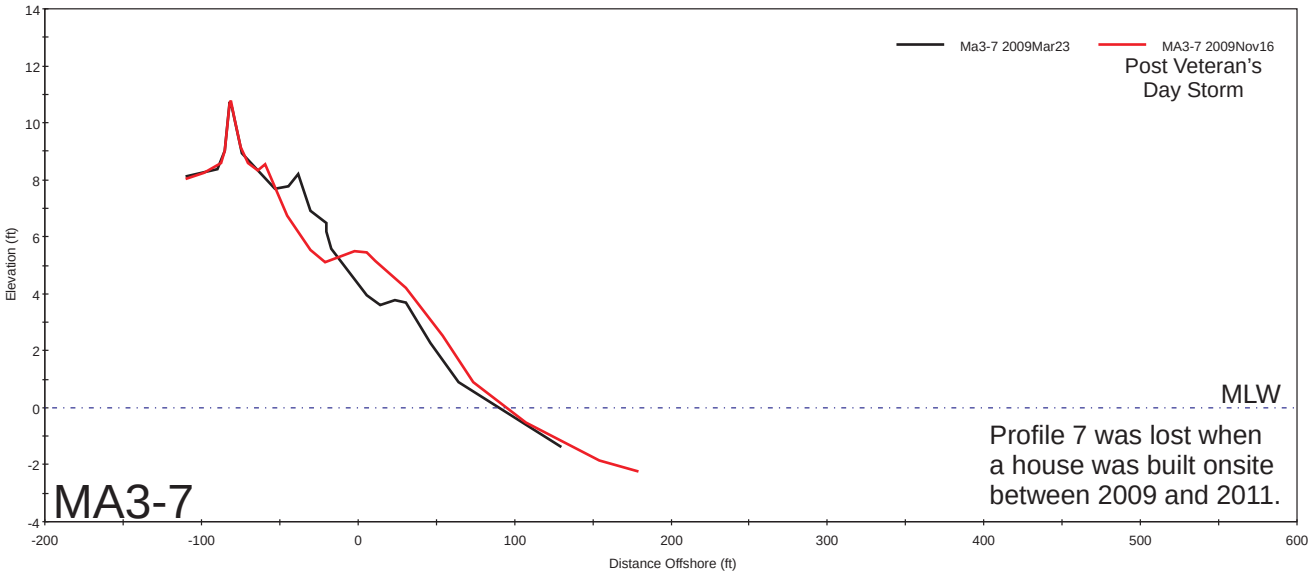
Set 1. Profiles pre-storm (March 2009), post-storm (November 2009), and present (September 2013).

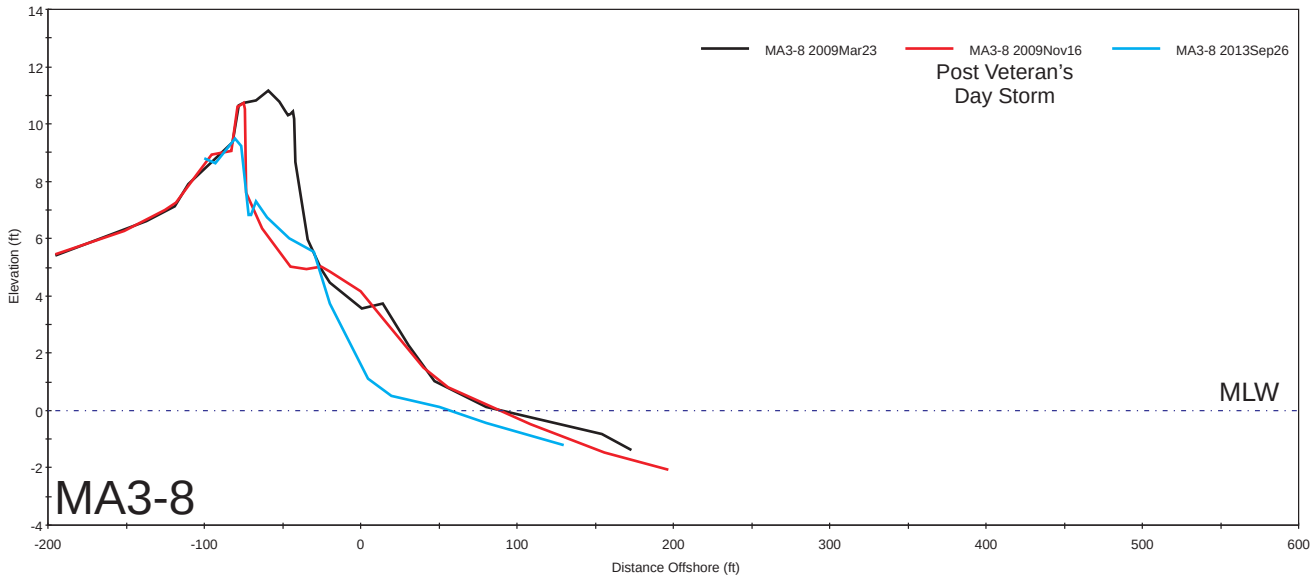




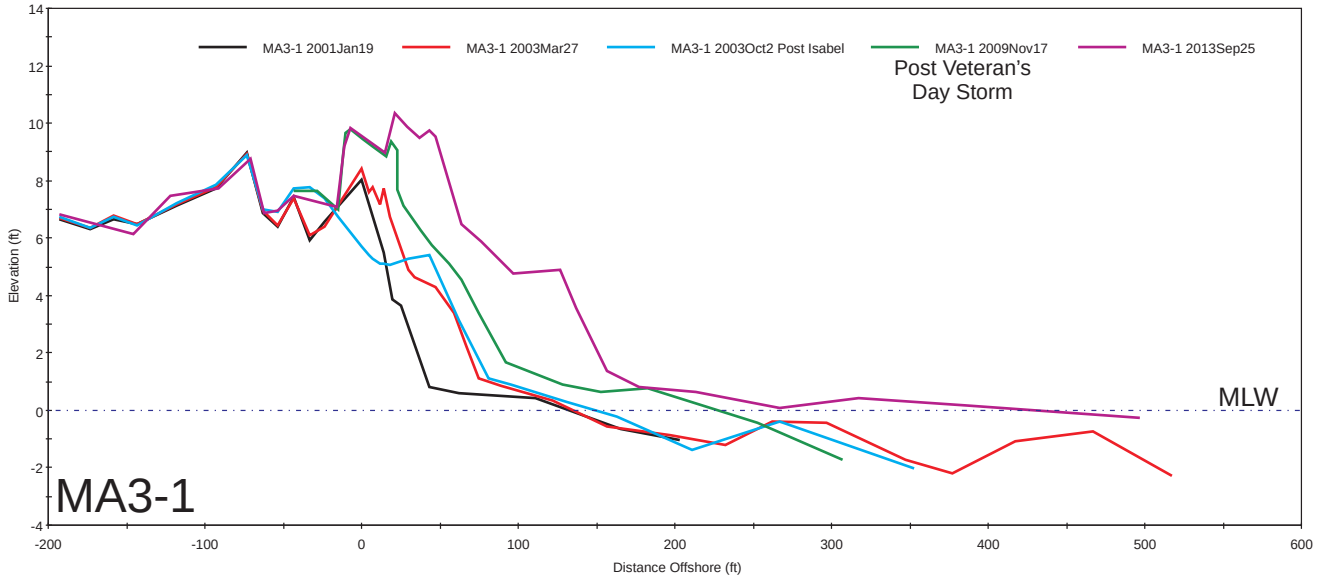


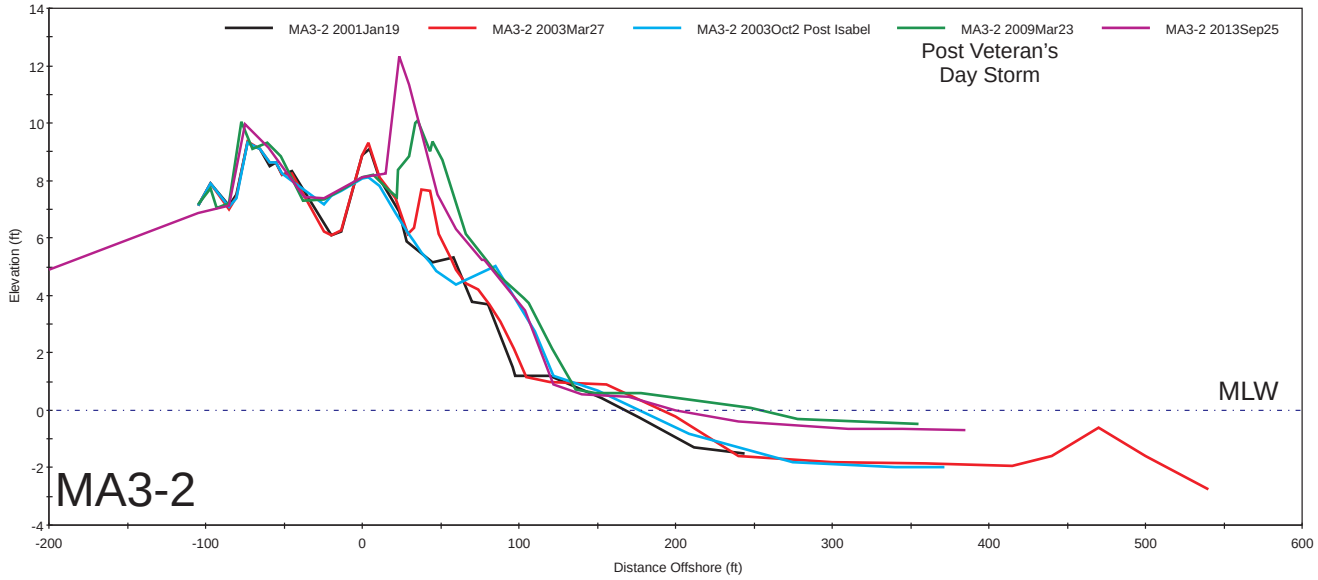
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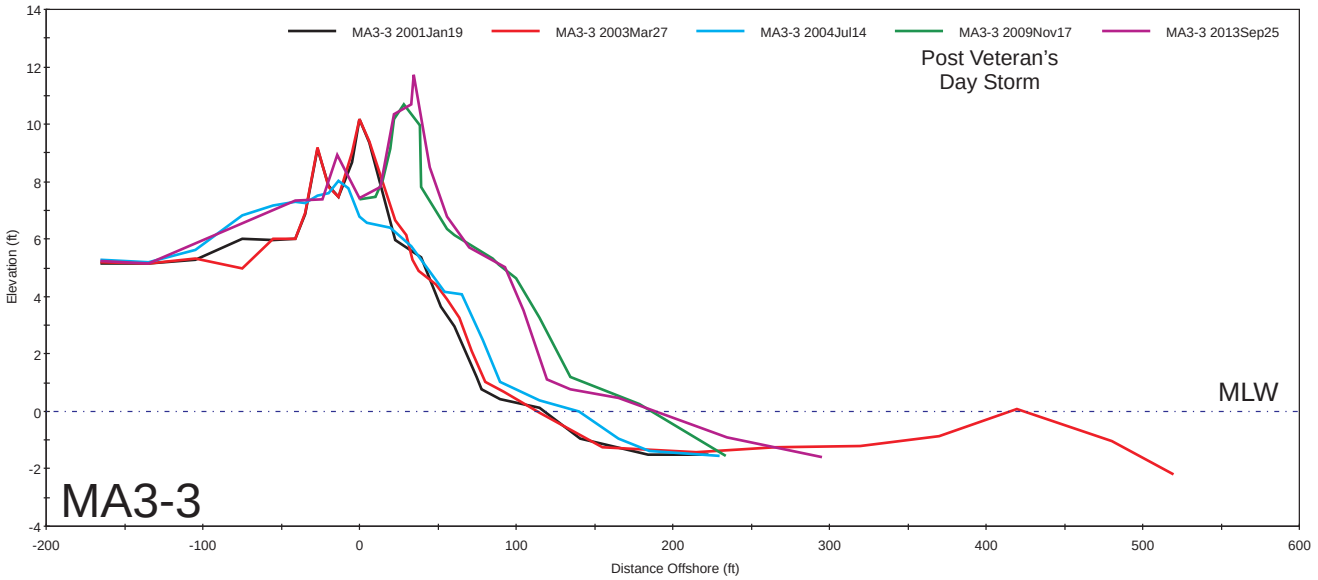




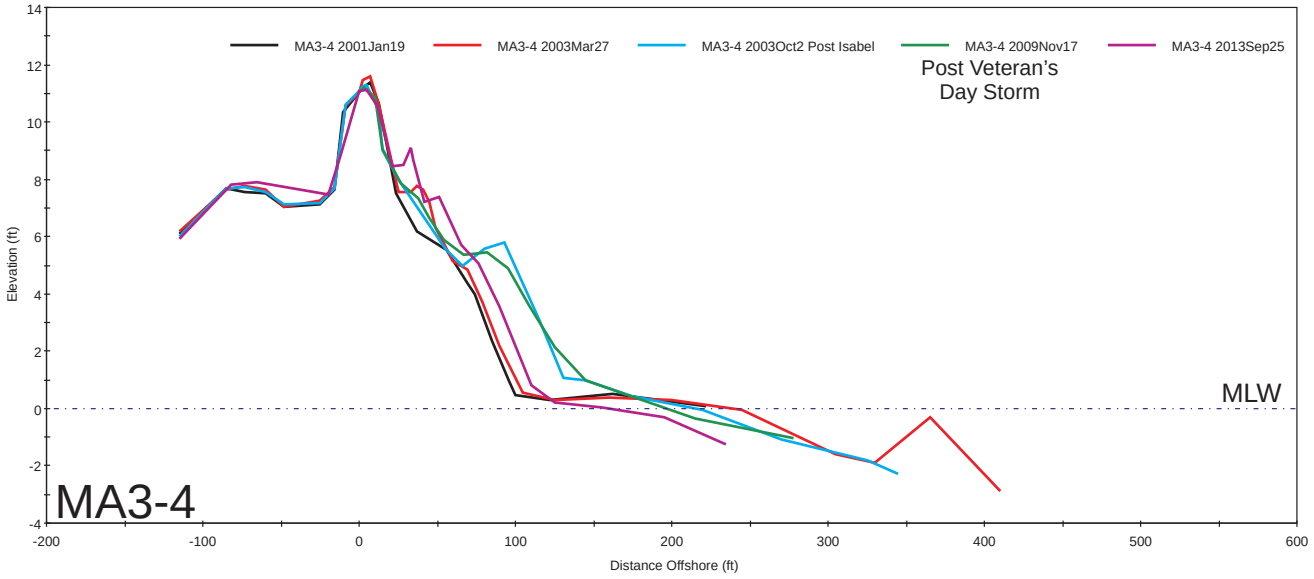
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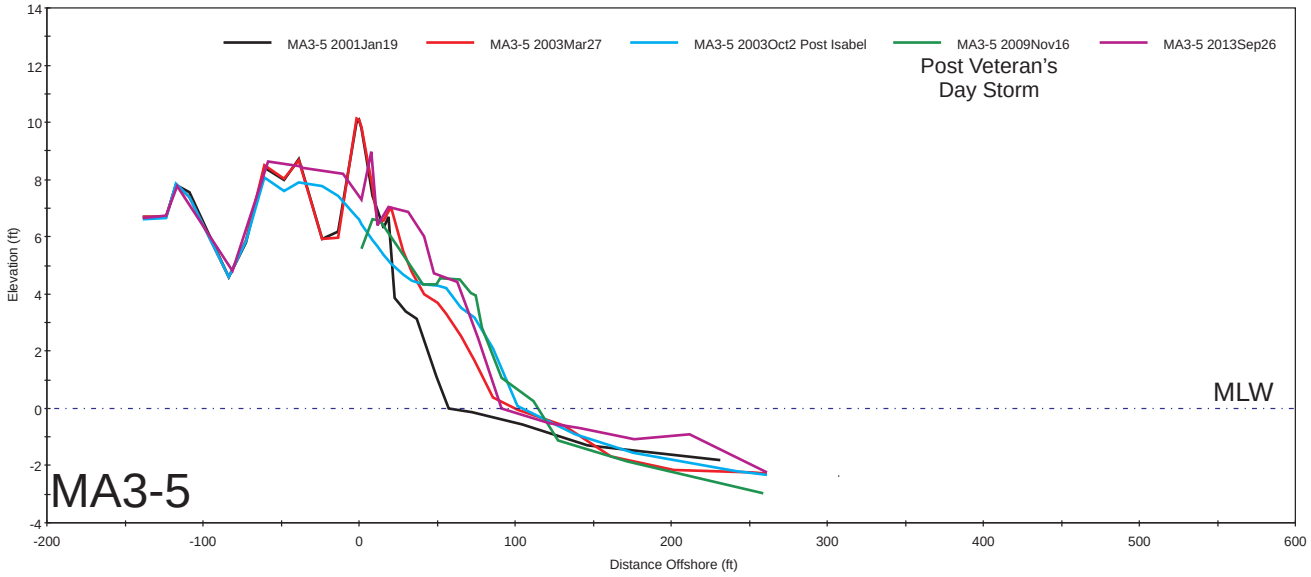


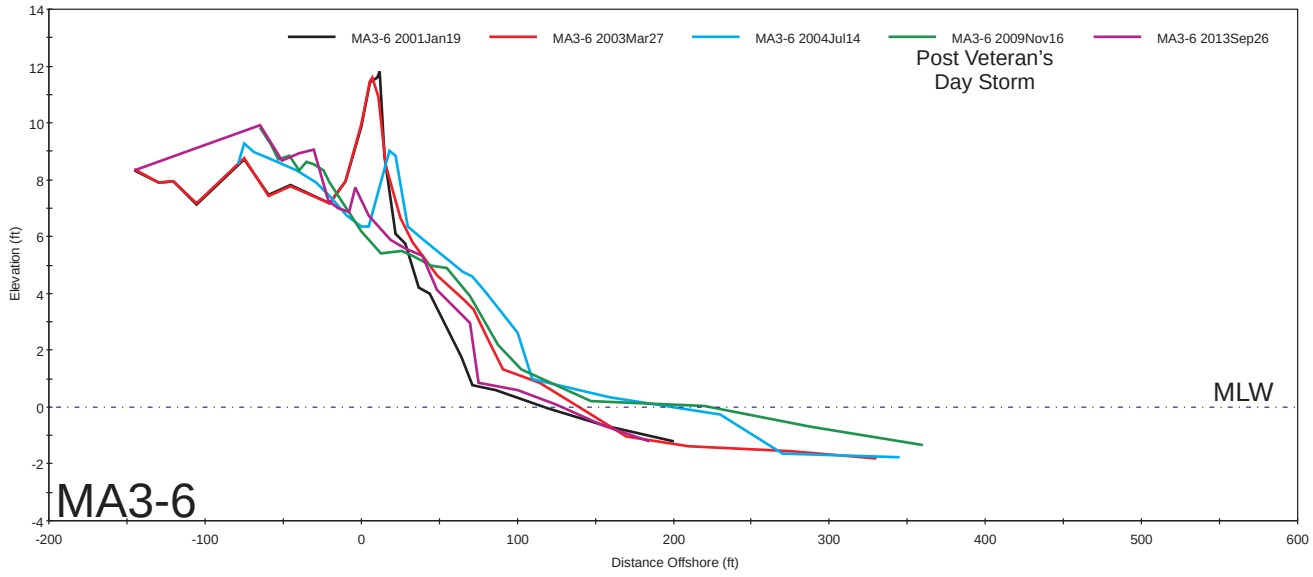




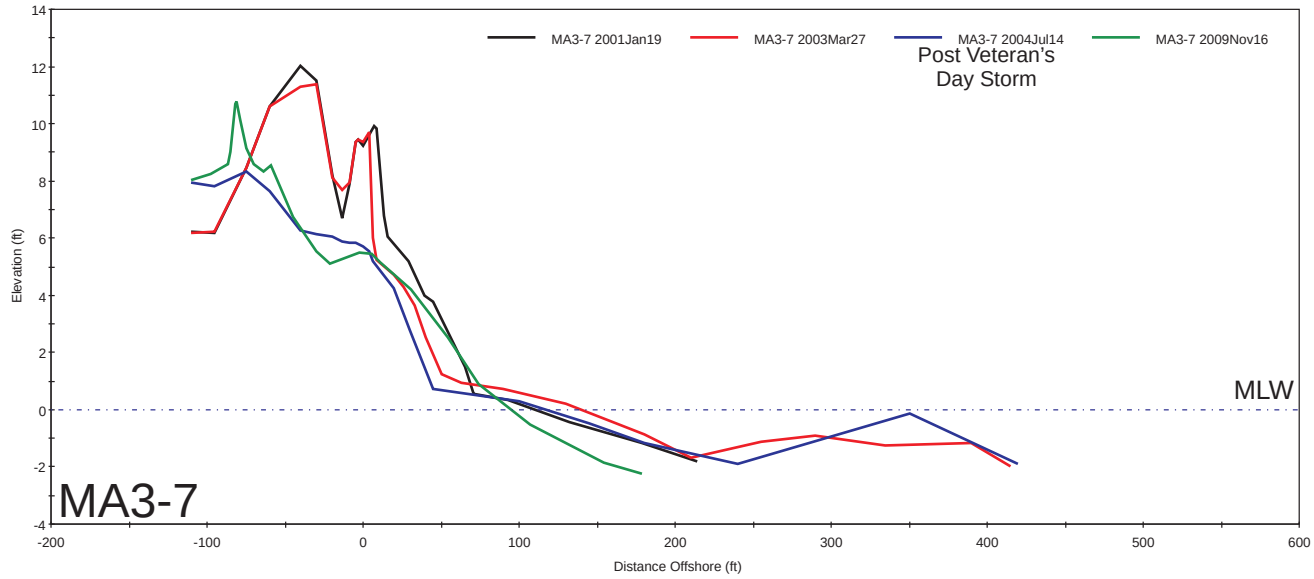
Set 2. Profiles selected dates throughout the monitoring program. The first profile (January 2001), pre-Hurricane Isabel (March 2003), post-Hurricane Isabel (October 2003 or July 2004), post-Veteran's Day storm (November 2009), and present (September 2013).

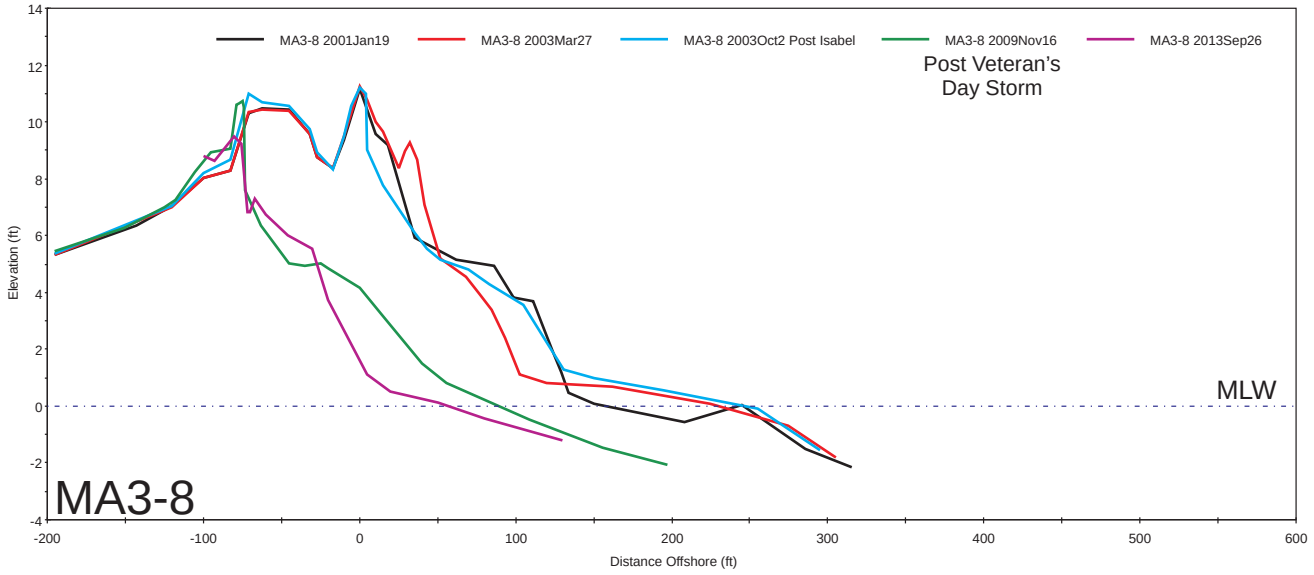






Set 2. Profiles selected dates throughout the monitoring program. The first profile (January 2001), pre-Hurricane Isabel (March 2003), post-Hurricane Isabel (October 2003 or July 2004), post-Veteran's Day storm (November 2009), and present (September 2013).





Set 2. Profiles selected dates throughout the monitoring program. The first profile (January 2001), pre-Hurricane Isabel (March 2003), post-Hurricane Isabel (October 2003 or July 2004), post-Veteran's Day storm (November 2009), and present (September 2013).

Appendix B

Site MA3 Photos

- Photos taken during the Veteran's Day Northeaster at profiles MA3-1, MA3-5, and MA3-7

- Historical and recent orthorectified map and images of the southern end of Bavon/Chesapeake Beach







Photos taken at Profile MA3-1 during the Veteran's Day Northeaster November 2009







Photos taken at Profile MA3-5 during the Veteran's Day Northeaster November 2009

Photos taken at Profile MA3-7 during the Veteran's Day Northeaster November 2009













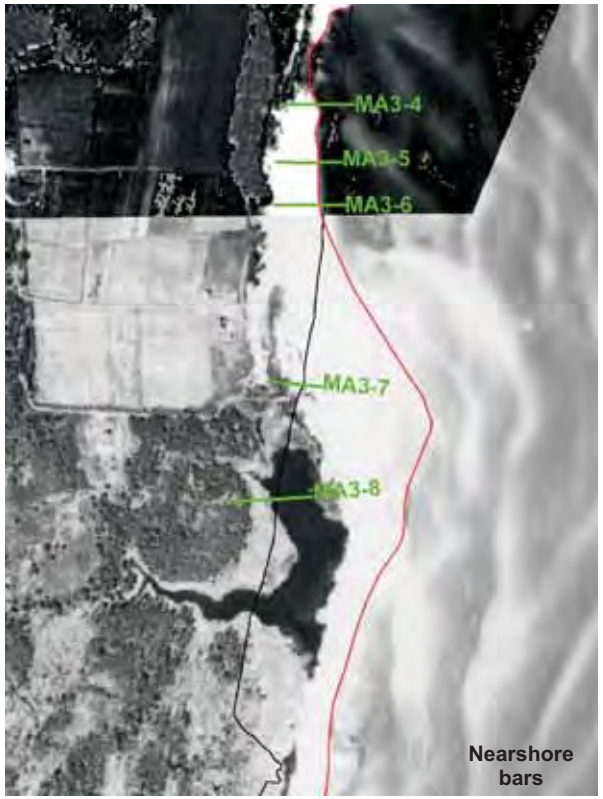


Net change at MA3 between 2003 and 2013 in photos.

Historical and Recent Orthorectified Images
Shoreline Studies Program Shoreline Evolution Database
With Dune Monitoring Profiles Shown



Marsh islands offshore in 1853



By 1937, the marsh islands have eroded and sand has migrated onshore trapping the back barrier lagoon behind the beach.



In the years between 1937 and 2011, the beach eroded and sand migrated landward filling in the lagoon. Continued erosion has exposed the underlying peat from the previous marsh and lagoon. Also evident in the 2011 photo is that the nearshore bars are migrating as well making the offshore deeper. Nearshore bars can attenuate waves reducing impacts to a site.

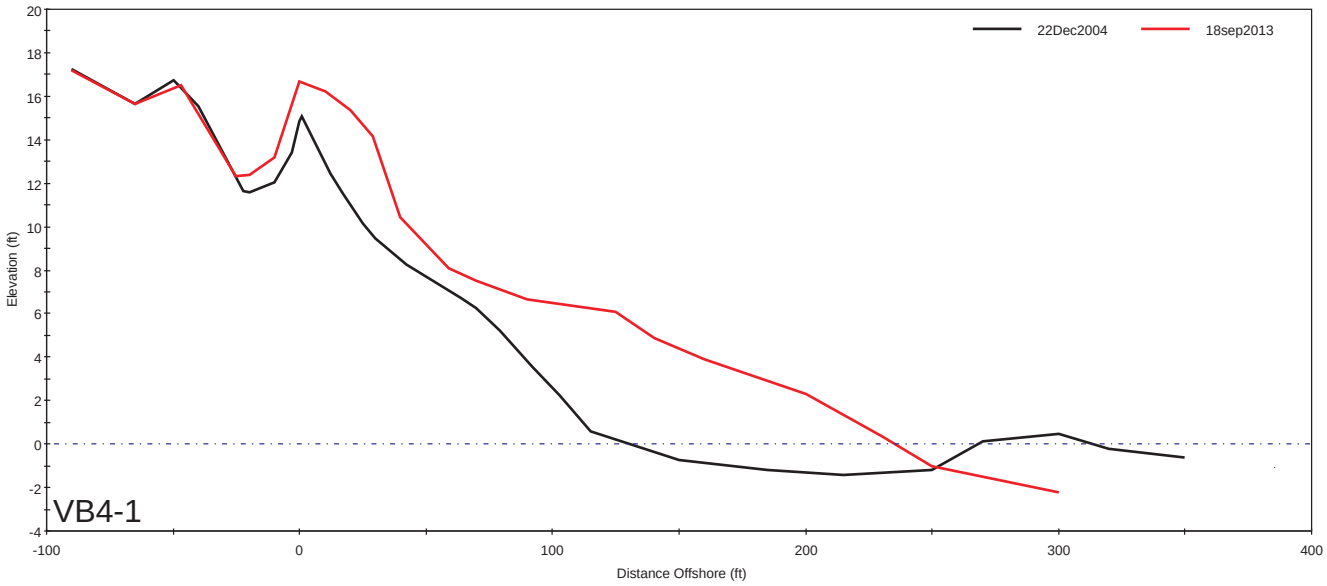
Appendix C

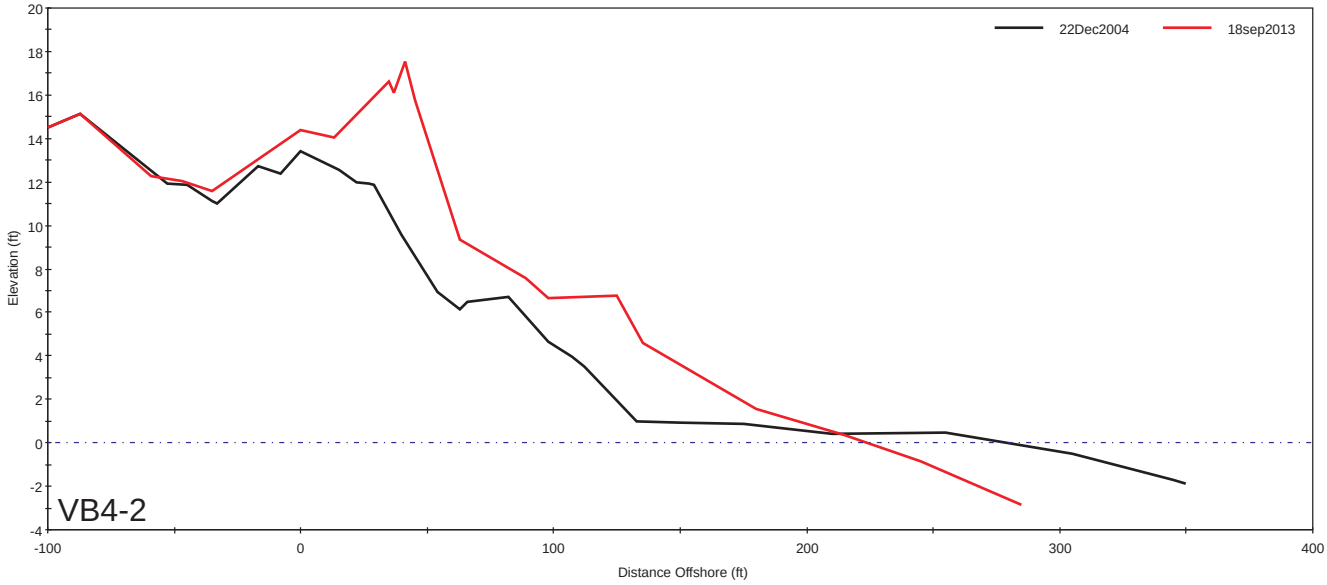
Site VB4 Profile Plots

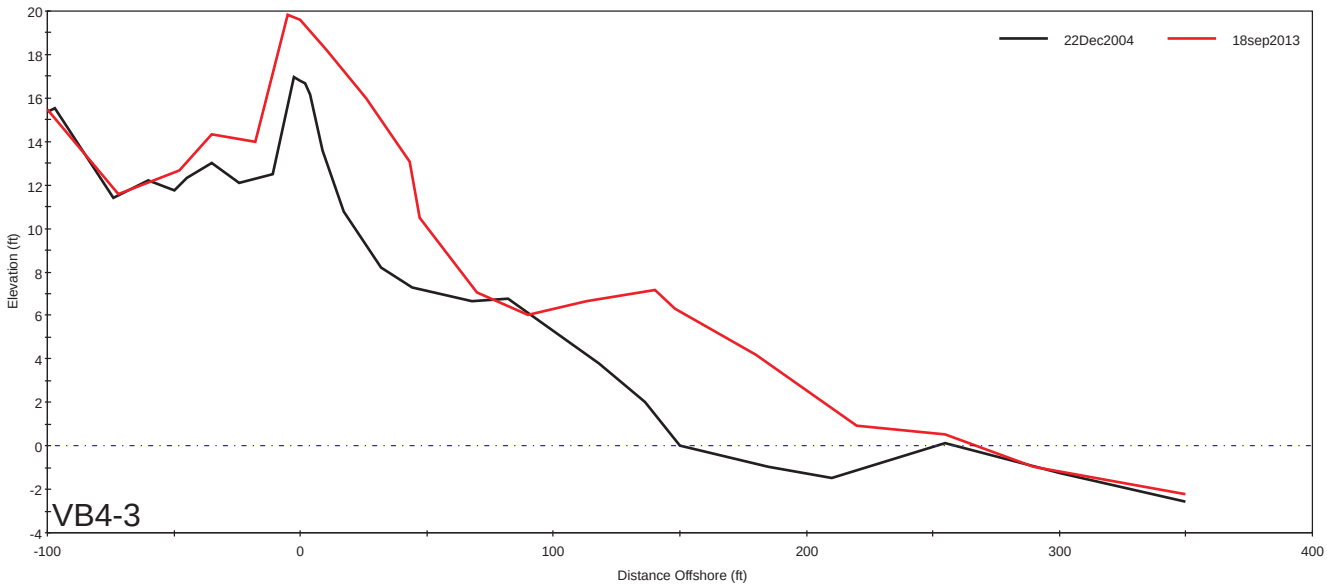
Two sets of profile plots are shown:

Set 1: The two most recent profile dates

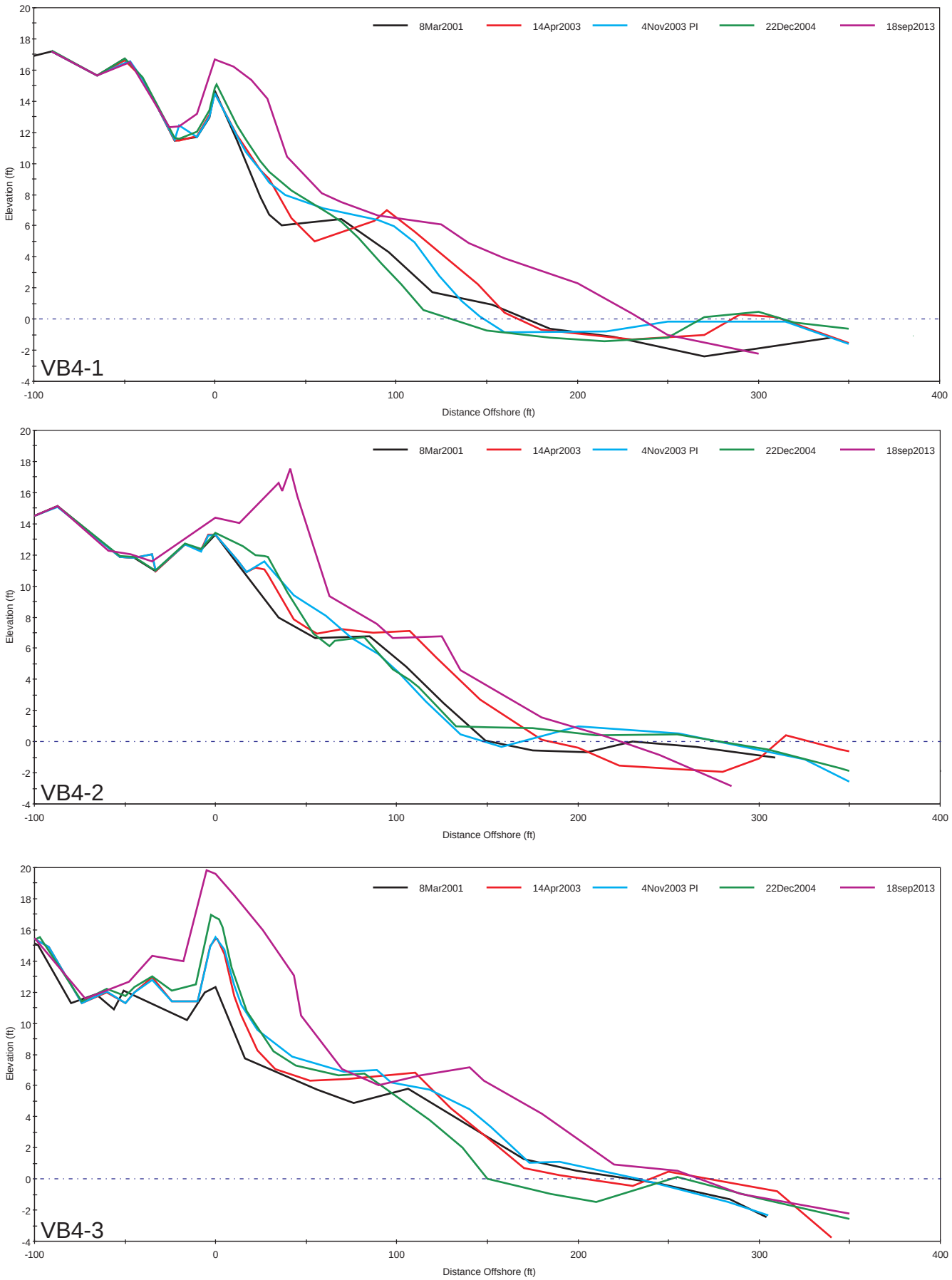
Set 2: Selected profiles since the start of the site monitoring including post-Hurricane Isabel







Set 1. Most recent profile comparison: December 2004 to present (September 2013).



Set 2. Profiles selected dates throughout the monitoring program. The first profile (March 2001), pre-Hurricane Isabel (April 2003), post-Hurricane Isabel (November 2003), December 2004, and present (September 2013).