FINAL REPORT FOR 2015

ON THE CHANGES MEASURED ON THE OCEANFRONT BEACHES IN THE BOROUGH OF MANTOLOKING, OCEAN COUNTY, NEW JERSEY

View to the north at 1041 Ocean Ave (Mant-2) from the top of the NJDOT steel bulkhead (wall) on October 8, 2015 following a moderate (winds not exceeding 25 mph) three-day northeast storm. That event eroded the berm and exposed the wall to storm waves. This photo shows new home construction adjacent to the low-elevation and narrow beach as well as the lack of a significant dune system. This places Mantoloking in a vulnerable state with respect to future coastal storms.

PREPARED FOR: **THE BOROUGH OF MANTOLOKING**
202 DOWNER AVENUE
MANTOLOKING, NJ 08738

PREPARED BY: **STOCKTON UNIVERSTIY COASTAL RESEARCH CENTER**
30 WILSON AVENUE
PORT REPUBLIC, NEW JERSEY 08241
March 25, 2016

TABLE OF CONTENTS

Annual Report for 2015
To
The Borough of Mantoloking
On the
Oceanfront Municipal Shoreline

Executive Summary:

The Stockton University Coastal Research Center (CRC) has monitored shoreline position (0.0 ft NAVD88) and beach, dune, and nearshore volume changes for the Borough of Mantoloking since 1993. This annual report provides the results and analyses from the fall 2014 to fall 2015 survey datasets.

The Borough awaits the commencement of the federal storm damage reduction project that would create an engineered dune and berm from Point Pleasant Beach to Island Beach State Park. Obtaining the real estate easements from homeowner's outside of the Borough limits has remained a challenge and has slowed the project's progress.

Since the steel bulkhead was installed throughout Mantoloking in the fall of 2014 it has been subjected to minor to moderate storm events (the year's most memorable was the October 2-5, 2015 northeast storm) that have exposed portions of the bulkhead allowing waves to erode berm sands at its base. When sand deposits were sufficient, the Borough continued its shoreline management practice of pushing sand from the berm to the seaward dune slope using bulldozers.

In general, there have been consistent volume losses of the municipal beaches and dunes since the passage of Hurricane Sandy as natural recovery has not been sufficient in moving sand from the nearshore to the berm, then to the dune. The October 2015 storm compounded the erosion problem and net municipal volume losses totaled -171,459 cubic yards (September 20, 2012 to December 16, 2015).

The periodic exposure of the vertical steel wall continued as a result of two early 2016 northeast storms. At this time, there is insufficient sand on the berm that can be moved to protect the wall. While there was no damage to the wall, excavation of sand reached 22 feet of vertical steel exposed just south of Herbert Street. Reaching the lowest rung of escape ladders welded to the seaward face of the wall was in some cases out of the question.

2015 Storm Activity:

In early 2015 a winter storm brought snow, tidal flooding, and beach erosion and exposed sections of the vertical steel bulkhead that was installed in late 2014. The spring season was free of any significant storm events but there were periods of northeast wind conditions that moved sand along the shoreline. On October 2, 2015 a three-day northeast episode commenced that never exceeded a 25 MPH wind speed, but remained constant until the 5th. Erosion of the berm into the dune toe resulted in the wave energy reaching the steel wall by the 4th of October. Following the storm the vertical relief was between 6 and 12 feet on the wall extending south into Brick Township. No other storm events were recorded for the remainder of 2015. In fact, December was the warmest December on record with over 70 degree temperature days.

Beach Monitoring Program Methodology:

In 1993 the Borough of Mantoloking requested that the CRC design and establish a beach-monitoring program to provide information on coastal zone management issues within the municipality. Five sites were selected based on a variety of criteria including accessibility, prior history of data collection, uniformity in spacing between sites and providing a typical representation of the surrounding dune and beach conditions. These same five sites have been monitored by the CRC on a quarterly schedule over the last 23 years, ensuring a continuous and coherent data set, which provides the Borough with a valuable resource tool when determining coastal management issues. The following is a list of the selected sites and locations:

- Mant-1: Beach access path at Carrigan Place
- Mant-2: Beach access path at 1041 Ocean Avenue
- Mant-3: 1117 Ocean Avenue (NJBPN site #153)*
- Mant-4: Princeton Avenue street end
- Mant-51: Beach access path at 1543 Ocean Avenue**

* 1117 Ocean Avenue was established on private land in 1986 for the New Jersey Beach Profile Network
* * Replaced Mant-5 formerly located on private property at 1547 Ocean Ave.

This monitoring program is intended to provide municipal officials with a periodic review of shoreline stability, beach/dune erosion or accretion and changes to the vegetation and sand collecting systems installed by individual property owners. The CRC completed the quarterly surveys for 2015 on the following dates:

Winter	Survey #91	March 25, 2015
Spring	Survey #92	June 18, 2015
Summer	Survey #93	September 18, 2015
Fall	Survey #95	December 16, 2015

An emergency survey was conducted on October 8, 2015 (Survey #94) following a weekend northeast storm event. Results from that survey were presented in the CRC's November 23, 2015 quarterly summary to the Mayor and Council Members. The storm event created a vertical loss of berm sand with most sand transported offshore or downdrift to Brick Township. Beach access was hindered by this large loss of sand from the municipal beaches generating a vertical drop from the 16-foot elevation wall structure.

Table 1 below shows the shoreline and sand volume changes at the five monitoring locations during the last quarter of 2015 (comparing surveys #93 and #95). Shoreline changes are measured in feet while sand volume changes are in cubic yards per foot (yds^3/ft). Individual profile changes are averaged with adjacent sites and multiplied by the distance between sites to determine a net cell volume change. Total volume change for the Borough is determined by summing the net cell volume changes.

Table 1
Fall 2015 Shoreline & Sand Volumes Changes
September 18, 2015 to December 16, 2015

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Distance Between (feet)	Net Volume Change (yds^3)
Northern Municipal Boundary					
			-23.037	294	-6,773
Mant-1	-33	-23.04			
			-14.880	3,033	-45,131
Mant-2	-52	-6.72			
			0.666	2,584	1,720
Mant-3	-38	8.05			
			5.615	2,789	15,660
Mant-4	-40	3.18			
			1.069	2,164	2,313
Mant-51	-62	-1.04			
			-1.038	495	-514
Southern Municipal Boundary					
			Total Volume Change =		**-32,725**

During the last quarter of 2015, all of the Mantoloking profile locations experienced significant shoreline retreat due to the October 2-5 (2015) northeast storm that generated modest (25 mph) winds and higher than normal water levels that moved the shoreline (0.0 ft. NAVD88 datum) landward. Beach and dune volume losses were most prevalent in the northern section of the Borough. The Mant-3 site, normally problematic, had an overall gain in sand volume, predominantly below the datum as berm sands were transferred to the nearshore.

Table 2 shows shoreline and sand volume changes that occurred between December 29, 2014 (Survey #90) and December 16, 2015 (Survey #95). Municipal beach volume losses continued for another year (-43,036 cubic yards) and are comparable to the volume losses incurred during 2014. Multiple minor strong wind

events occurred in early 2015 within the first quarter but volume losses occurred predominantly in the northern section of the Borough (Table 3). Volume and shoreline position gains occurred at 1117 Ocean Avenue (Mant-3) and shoreline gains at Princeton Avenue (Mant-4).

Table 2
2015 Annual Shoreline & Sand Volumes Changes
4th Quarter 2014 to 4th Quarter 2015
December 29, 2014 to December 16, 2015

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Distance Between (feet)	Net Volume Change (yds^3)
Northern Municipal Boundary					
			-27.991	294	-8,229
Mant-1	-27	-27.99			
			-20.567	3,033	-62,378
Mant-2	-0.15	-13.14			
			2.074	2,584	5,359
Mant-3	22	17.29			
			8.162	2,789	22,764
Mant-4	40	-0.97			
			-0.327	2,164	-707
Mant-51	-15	0.31			
			0.313	495	155
Southern Municipal Boundary					
			Total Volume Change =		**-43,036**

Mantoloking Quarterly Volume Changes:

Table 3 provides individual profile site sand volume changes for each of the four quarters of 2015. Each volume calculation compares the indicated survey with the previous one and sums the areas of accumulation and erosion across the entire profile line in cubic yards of sand per foot of beachfront. Net volume changes are presented in cubic yards.

Table 3
2015 Quarterly Municipal
Profile Volume Change

Profile Number	Winter 12/29/14-3/25/15 (yds^3/ft)	Spring 3/25/15-6/18/15 (yds^3/ft)	Summer 6/18/15-9/18/15 (yds^3/ft)	Fall 9/18/15-12/16/15 (yds^3/ft)
Northern Municipal Boundary				
Mant-1	-4.25	-0.50	-0.28	-23.04
Mant-2	-13.33	9.95	-4.36	-6.72
Mant-3	1.45	5.87	2.02	8.05
Mant-4	9.92	-9.20	-1.62	3.18
Mant-51	6.46	-7.70	1.94	-1.04
Southern Municipal Boundary				
Net Volume Change (yds3)	-6,492	7,881	-8,278	-32,725

The sum of the four seasonal volume changes across the municipal beachfront was a net loss of **-39,614** cubic yards. This value agrees within 8% of the annual loss generated by direct comparison of the two fall cross sections (Survey #90 to Survey #95) in Table 2. All volume changes were relatively minor with all less than 24 cubic yards per foot and only 2 of 20 values over ±10 cy/ft.

Table 4 below notes the shoreline position and net volume changes from September 20, 2012 (a month before Hurricane Sandy) to December 29, 2015. Shoreline changes are given in feet while individual volume changes are expressed in cubic yards per foot of linear shoreline. Individual volume changes are averaged with adjacent volume changes then multiplied by the distance between sites to determine a net cell volume change in cubic yards. A summation of the net cell volumes provides a total volume change for the Borough's oceanfront shoreline.

Table 4
Shoreline & Sand Volumes Changes
Pre- Hurricane Sandy to 4th Quarter 2015
September 20, 2012 to December 16, 2015

Profile Number	Shoreline Change (feet)	Volume Change (yds^3/ft)	Avg.Volume Change (yds^3/ft)	Distance Between (feet)	Net Volume Change (yds^3)
Northern Municipal Boundary					
			-37.056	294	-10,894
Mant-1	-50	-37.06			
			-32.491	3,033	-98,544
Mant-2	-26	-27.93			
			-3.477	2,584	-8,985
Mant-3	-30	20.97			
			-1.991	2,789	-5,552
Mant-4	-20	-24.95			
			-18.972	2,164	-41,054
Mant-51	-39	-12.99			
			-12.991	495	-6,431
Southern Municipal Boundary					
			Total Volume Change =		**-171,459**

Between 2012 (pre-Sandy) and 2015, the overall net profile volume loss of sand continued (-171,459 cubic yards) across all of the municipal locations with the greatest losses occurring in the northern two locations. Only site Mant-3, which is located within a few hundred feet of the barrier breach opened by Hurricane Sandy shows volume gains, but these gains were recorded below the 0.0 ft datum. It appears that much of the sand that was transported below the datum following the storm has not been moved landward via cross-shore processes. In addition, even moderate northeast storm events continue to erode the Borough's beaches (note total volume loss from Table 1= -32,725).

Mantoloking Trend Analysis since 2002;

Since 2002, the CRC has included figures that show the quarterly shoreline and volume trends for each of the Mantoloking locations and show how each profile responded to past storm events including Hurricane Sandy. The purpose is to provide a continuous view of accumulative changes and plot these changes versus time. These plots are included as figure (e) in each profile site description.

Important Information from Before Hurricane Sandy to 2015;

- Each of the five profiles shows an uptrend in volume beginning at various times between 2003 (Mant-4) and as late as 2010 (Mant-5).
- Each trend line had a pronounced "up-sweep" in sand volume in 2010 that more than doubled the sand volume than was present between 2002 and 2010.

- The CRC believes this result stems from when the Borough of Mantoloking assumed the role of general contractor for the beach bulldozing that provided consistent volume, slope and timing of the work.
- Hurricane Sandy (October 2012) cut deeply into the accumulated sand volume, reducing 3 of 5 sites to zero or below.
    - Sand volumes at site Mant-1 were just cut by half largely because sand was moved into Mantoloking from Bay Head.
    - Site Mant-2 was reduced from +35 yds^3/ft to -12 yds^3/ft
    - Site Mant-3 (at the breach location) went from +7 yds^3/ft to -38 yds^3/ft, but saw large volumes of sand restored from recovery of overwashed sands providing a pronounced increase in volume.
    - Mant-4 lost the least sand volume dropping from 75 to 48yds^3/ft without much recovery.
    - The southernmost site (Mant-51)lost all 50 cubic yards of added material with about 20 recovered since Sandy. This lower recovery is largely due to no need to mechanically move overwash sand back to the beach since these dunes did not fail.
- Borough beach bulldozing had a demonstrable positive impact prior to Hurricane Sandy as sand was pushed into the dunes where ordinary winter storms do not pull it off the beach every winter.
- Comparison of pre-Sandy and 2015 profiles indicate volumetric losses (-171,459 cubic yards) of sand within the municipal beaches.

Profile Site Descriptions:

Each site was surveyed four times in 2015. Cross section plots with each of the four surveys are presented in the figures for each site. Photos from each site provide a visual record of changes during the year. A sand volume change trend chart is also included for each site to show the seasonal and annual trends from 2002 through 2015.

- **Mant-1 Carrigan Place**

Mant-1 is located at the seaward end of Carrigan Place, along the municipal beach access path between the private residential properties at #911 and #915 East Avenue. Carrigan Place is located about 500 feet south of the Bay Head – Mantoloking boundary. The profile reference location is a fire hydrant located along the west curb of East Avenue. The cross-section includes the road and beach access path on the landward dune toe between the oceanfront homes.

This location has shown fairly good recovery in the two years that followed Hurricane Sandy, but during 2015, total volume losses were recorded. The most significant losses occurred in the last quarter (-23.04 yd^3/ft) along with landward movement of the shoreline (-33 ft.) to its approximate location in March 2015. Trends in sand volumes are presented in Figure 1e and show the volume losses and landward movement of the 0.0 ft. datum over the past year. Hopefully this volume loss does not represent a reverse in the trend that has been consistent since late 2006.

1a. March 25, 2015

1c. December 16, 2015

1b. September 18, 2015

Mant-1 Photographs 1a, 1b, and 1c show views to the north from the beach berm.

Photograph 1a shows the view from the beach berm following a landward movement of the shoreline (-24 feet) from its December 2014 position.

Photograph 1b shows the berm and shoreline in relatively the same position as measured in March 2015. Minimal sand volume losses occurred between Survey 91 and Survey 93 (less than -1.0 yds^3/ft.

Photograph 1c shows the high water marks on the berm. The shoreline moved considerably landward since the September survey (-33 feet) in part due to the October 2-5, 2015 northeast storm.

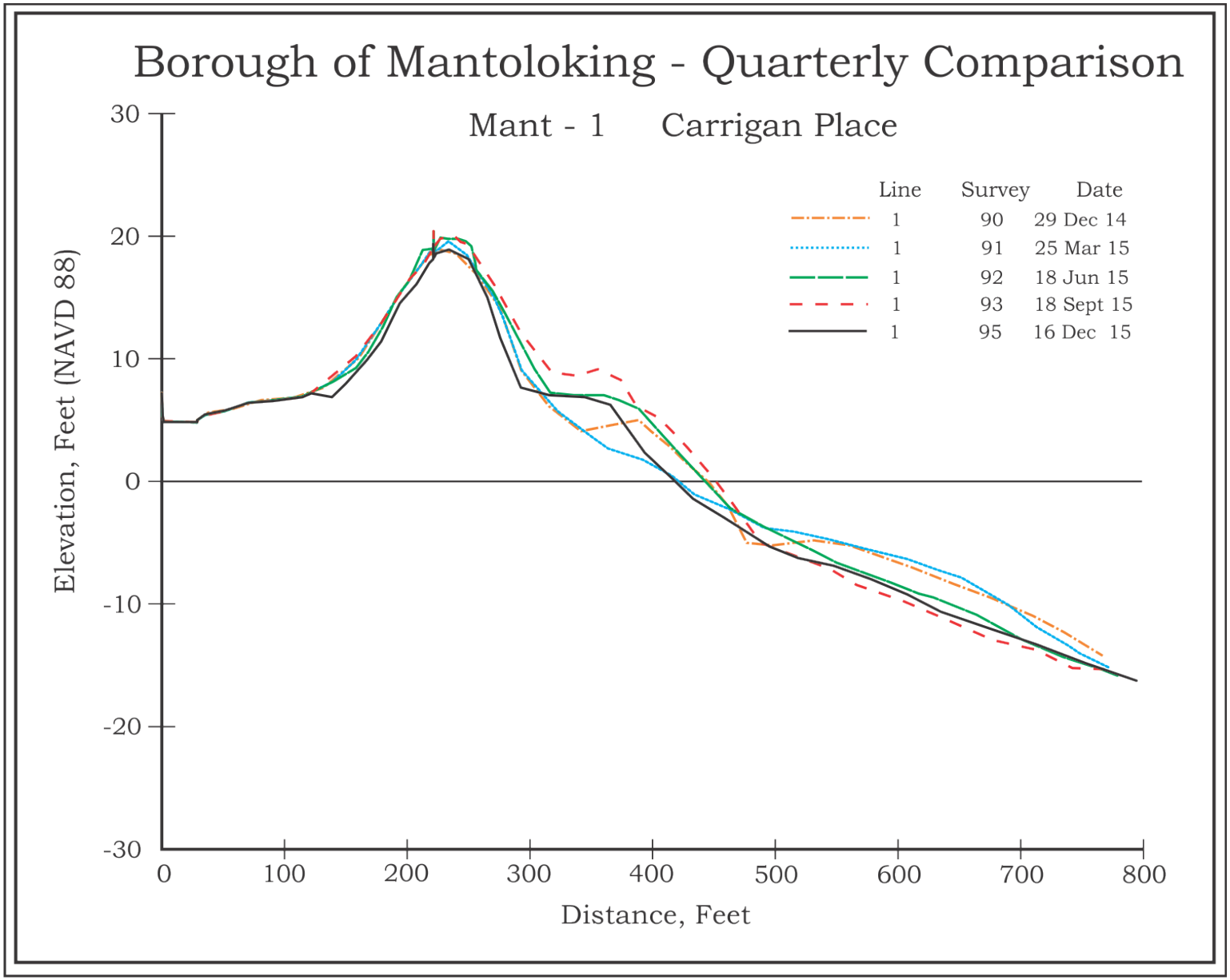

Figure 1d: The quarterly cross sections show the seaward progression of the inflated summer berm and seaward movement of the shoreline. Survey #95 shows the lowering of the dune and shoreline retreat that was the result of the October 2-5 northeast storm that created losses predominantly above the datum.

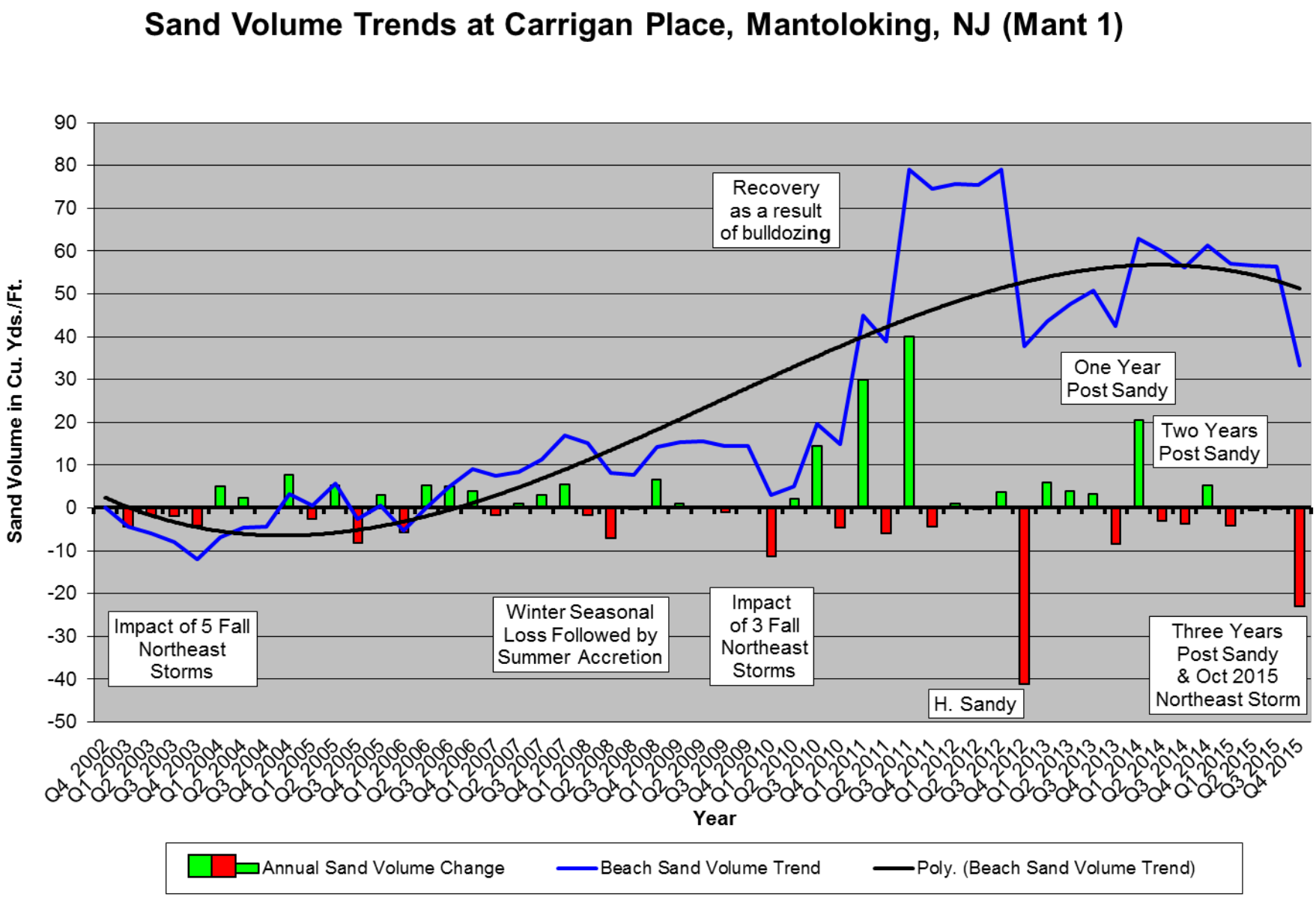

Figure 1e. The quarterly sand volume trends show early impact of storms in 2003, 2006, and 2009. Net increase in sand volumes were maintained over 5 quarters in 2011 and early 2012 in part due to both natural and bulldozing actions. Hurricane Sandy cut the gain by half. Though the profile has shown volume gains in the two years after Sandy, volume losses were recorded for each quarter in 2015 with the greatest amount recorded during the last quarter (Survey #93 to Survey #95).

- **Mant-2 #1041 Ocean Avenue**

Mant-2 is located along Ocean Avenue on the municipal beach access path between the private residences at #1039 and #1041 Ocean Avenue. The site location was selected because of its position approximately midway between Carrigan Place and the pre-existing New Jersey Beach Profile Network site located at #1117 Ocean Avenue and it has public accessibility. The profile starts at a reference location at a monument located midway along the access path.

The vertical steel wall was installed in September 2014 at approximately the location of the April 2014 dune crest. The seaward dune slope and crest elevation remained fairly consistent throughout 2015 through the Borough's efforts of bulldozing sand from the high water line to cover sections of the exposed wall. Annual shoreline change between December 2014 and December 2015 was less than one foot, but there were volume losses (-13.14 yds^3/ft), predominantly from below the 0.0 ft (NAVD88) datum.

The trend here reflects the very serious impact of Hurricane Sandy which removed all the sand that accumulated since 2002 and left the site deficit relative to 2002 conditions. The net volume change from pre-Sandy conditions to December 2015 show a sand deficit (-27.93 yds^3/ft).

2a. March 25, 2015

2c. December 16, 2015

2b. September 18, 2015

Mant-2 Photographs 2a to 2c. All views are to the north taken along the seaward dune crest (on top of the steel sheet wall).

Photograph 2a. shows the manmade dune that covers the steel wall. The dune crest remained at nearly the same 18.5 ft (NAVD88) elevation during 2015.

Photograph 2b. shows the inflated summer beach as a result of bulldozing sand from the lower berm to the dune. Note the lower elevation of the nearshore and summertime volume losses recorded for this site (see Table 3).

Photograph 2c. shows a steep, narrow beach and fencing on top of the steel wall in an effort to trap windblown sand. The dune at this site also benefitted from the Borough's bulldozing efforts.

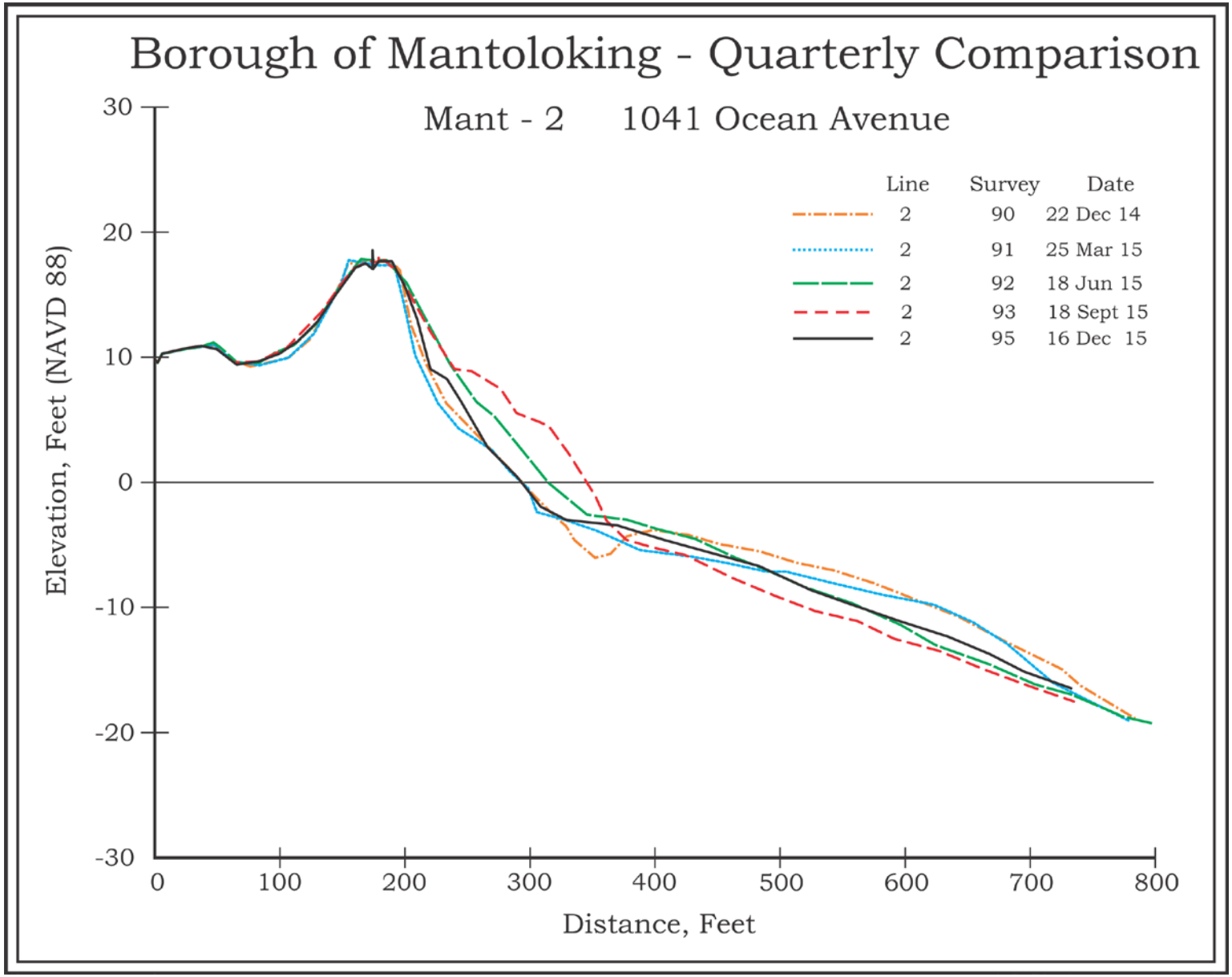

Figure 2a: The quarterly cross sections at 1041 Ocean Avenue show that the shoreline moved seaward from its December 2014 and March 2015 positions and follow summer inflated beach patterns and bulldozing efforts until Survey #95 which displays more of a resemblance to the March 2015 profile. Volume losses were recorded for 2015 except in the second quarter where there were gains in excess of 15 yds^3/ft above the datum.

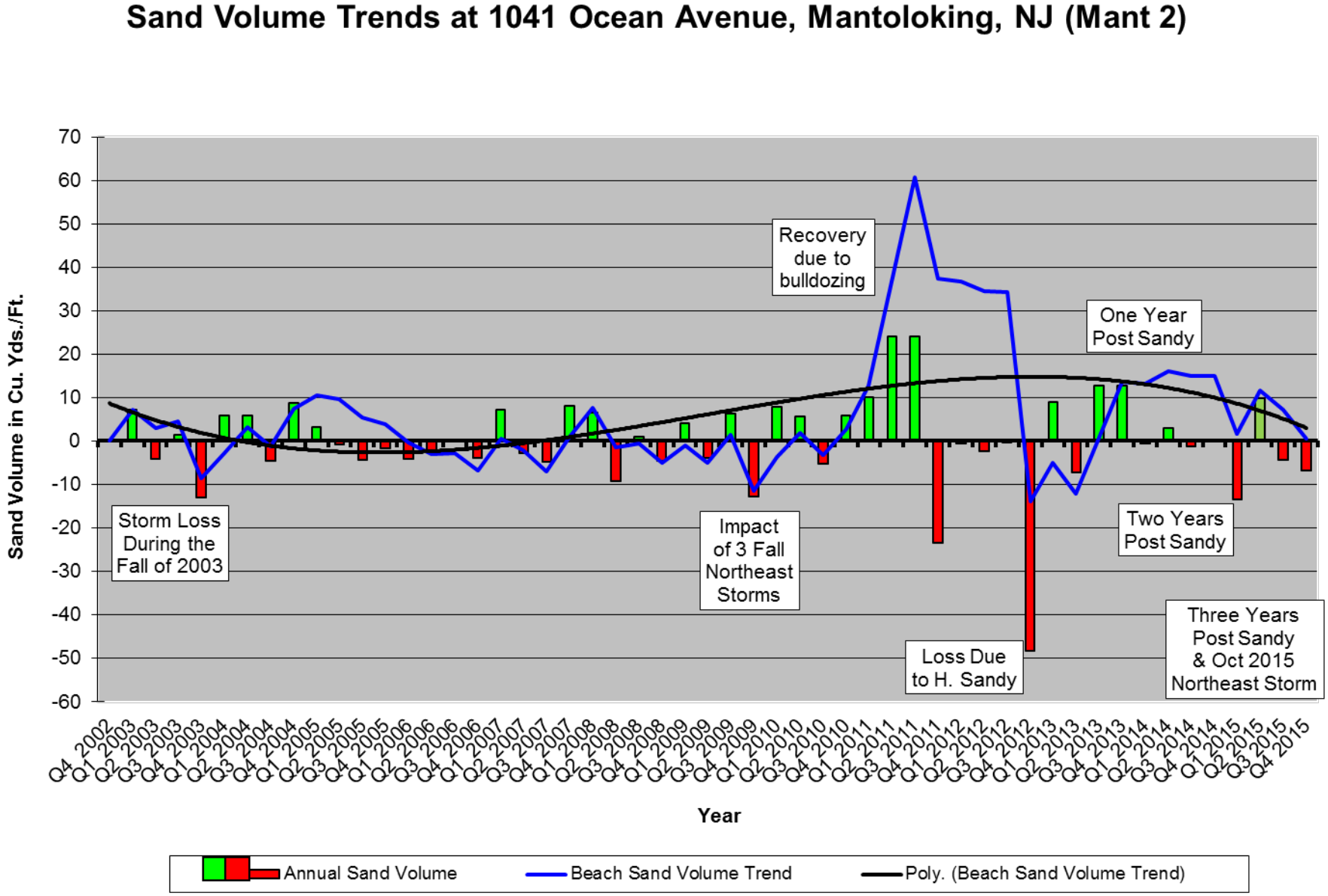

Figure 2. Quarterly sand volume changes since 2002 show modest annual or quarterly changes until 2011 when sand accretion commenced leading to a net increase of 60 yds^3/ft. The volume loss late in 2011 was doubled by the impact of Hurricane Sandy and recovery in 2013 was less than half of that removed by the storm. 2014 saw negligible changes to the sand volumes and 2015 continued net volume losses (see Tables).

- **Mant-3 #1117 Ocean Avenue**

The #1117 Ocean Avenue monitoring site is located on private property. This site originally established in 1986 is part of the State of New Jersey's coastal monitoring program (NJBPN). The site was later included in the beach-monitoring program in Mantoloking because of the pre-existing data collected for the State at this location. The profile line was set along the home's dune walkover to minimize damage to the dune vegetation. Positioned nearly in the center of the municipal shoreline, this site has shown to be vulnerable to dune erosion over the years.

Hurricane Sandy's surge and storm waves caused massive damage in this region as the beach/dune system failed and a full breach occurred within a few hundred feet to the profile's south. The beach and dune were flattened and overwash carried sand across the highway into the bay. At Herbert Street, just south of this site, storm waves and surge obliterated the beach and dune opening a temporary inlet. Efforts by the USACE and NJDOT closed the inlet by early November that allowed beach and dune system restoration activity, debris clean up and reconstruction to begin. The net sand volume losses attributed to Sandy was 131.97 yds^3/ft of sand at this site. By December 12, 2012 a small dune ridge was reestablished as the beach began to recover both naturally and through restoration activities. Sand was returned from the streets, from the properties inland and from suitable sands pumped out of Barnegat Bay at the breach channel pathways. Since the installation of the steel wall in late 2014, the dune crest remained near 22 ft (NAVD88) throughout 2015 due to the bulldozing efforts by the Borough. Dry beach widths ranged from 75 to 125 feet.

The October 2-5, 2015 northeast storm event eroded the beach and dune slope that removed sand and exposed over 10 vertical feet of the wall impacting public access to the beach. Over 31.1 yds^3/ft of sand was eroded from the dry beach and dune and 15.45 yds^3/ft was deposited in the nearshore bar, indicating that the remaining sands were transported to the south by the littoral current or farther offshore.

3a. March 25, 2015

3c. December 16, 2015

3b. September 18, 2015

Mant-3 Photographs 3a to 3c show the view to the south from the top of the steel wall/dune crest.

Photograph 3a shows the steep, narrow beach. Over the winter, there was a net loss of sand (-16.02 yds^3/ft) below the 0.0 ft NAVD88 datum as the nearshore bar became less pronounced and was located in deeper water than its December 2014 position. Quarry sand was brought in to add elevation to the dune crest.

Photograph 3b shows remnant bulldozer tracks on the seaward dune slope. The September 2015 profile displays a typical summertime wide dry beach (100 ft) though no nearshore bar was recorded.

Photograph 3c. The October 2-5, 2015 northeast storm waves eroded the berm and dune sands and exposed over 10 vertical feet of the wall. This hindered public access as beach goers had to climb up & down the wall to reach the water. Photo shows recent bulldozed sand up the dune slope.

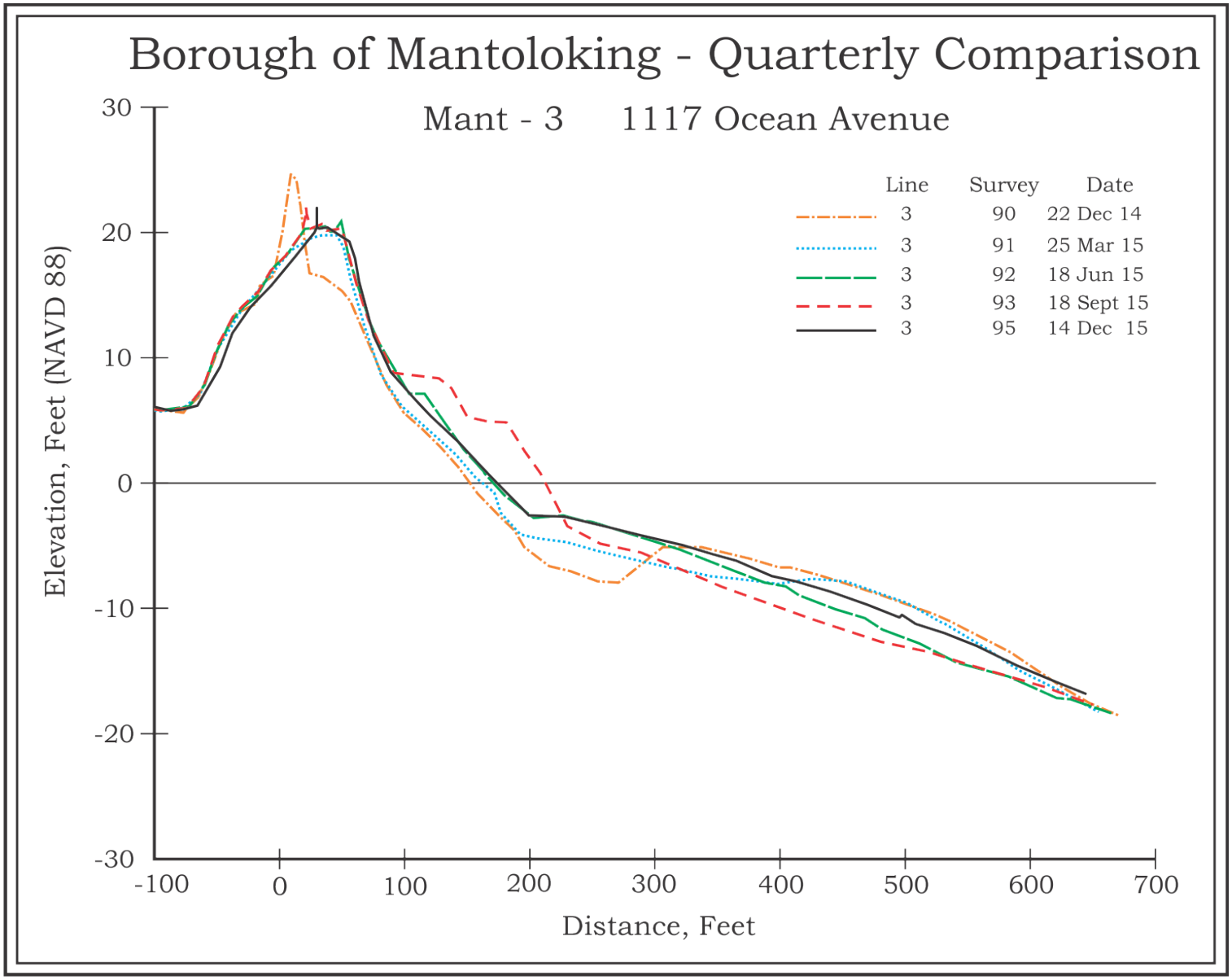

Figure 3a: The cross section shows the quarterly shoreline changes at 1117 Ocean Avenue. The dune elevation and position was mostly consistent throughout 2015 due to the Borough's bulldozing efforts. The shoreline position moved seaward 60 feet from the winter December 22, 2014 deflated beach profile to the summer September 18, 2015 inflated beach profile. Annual December 2014 to December 2015 volume change was 17.29 yds^3/ft across the profile.

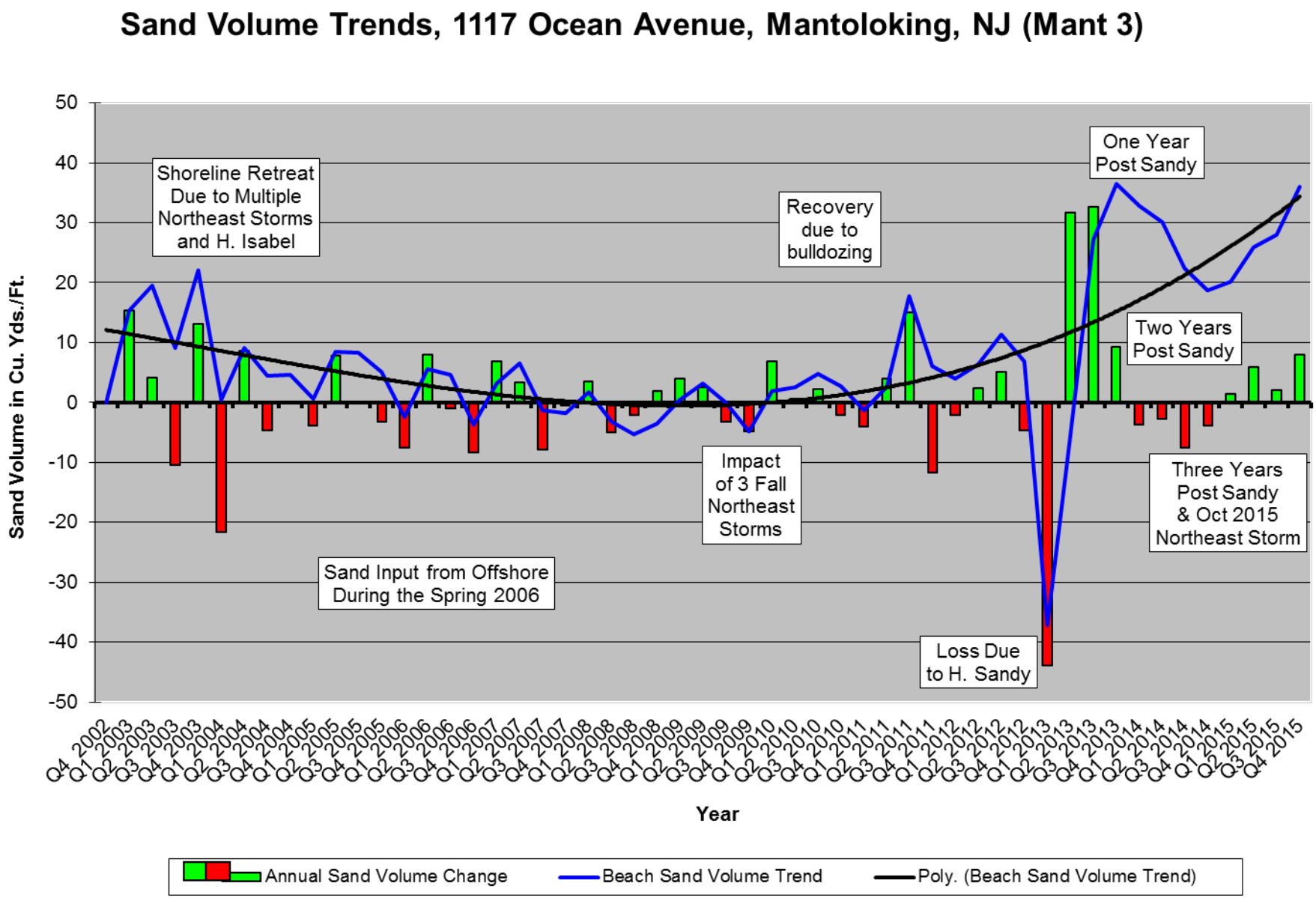

Figure 3. The Mant-3 site is located in the middle of the Borough and has been vulnerable to erosion. The dune is the narrowest of the five Borough sites but has a comparable crest elevation at 20 feet (NAVD88). Hurricane Irene eroded landward of the crest in 2011, and the sand volume that was pushed back to the shoreline by the Borough did replace the volume lost. This site is located within a few hundred feet of the breaches that were opened by Hurricane Sandy and the volume losses are shown. Since then, Borough and state efforts (through the installation of the steel wall) have stabilized the dune crest position. Bulldozing efforts to move sand from the high water line to the wall/dune slope have allowed positive volume changes above the 0.0 ft (NAVD88) datum. This shoreline management technique can help as long as sand is available to push.

- **Mant-4 Princeton Avenue**

The Mant-4 beach profile is located at the seaward end of Princeton Avenue along the municipal dune walkover. This site was selected for the beach monitoring program in the Borough due to its location approximately midway between the #1117 and #1543 Ocean Avenue sites, and for its easy accessibility. Of special interest is the history of erosional problems associated with the vertical access shaft for the Ocean County Utilities Authority (OCUA) sewage discharge line, located on the seaward dune slope, adjacent to the profile line. Following the 1992 northeast storm Mantoloking installed individual geo-textile bags filled with sand around the street end and the access shaft at the municipal utility line.

Hurricane Sandy completely removed the dune and severely eroded the beach so that the street pavement simply ended at a continuation of that elevation out onto the dune's position, then down to the beach. The dune breach caused significant overwash to cascade into the Borough at this street-end opening. A volume loss of 76.32 yds^3/ft of sand was attributed to Sandy at this location.

Since the storm, the restoration efforts have replaced a slightly lower and narrower dune with about the same width of beach. In fall 2014, the vertical steel sheet wall was installed with a top elevation of 14.8 ft (NAVD88) and covered with sand. As in the other monitored locations, the Borough bulldozes sand from the high water line to the dune to maintain sand coverage along the wall and this has enabled the top elevation of the dune to remain at 19 ft (NAVD88) throughout 2015.

4a. March 25, 2015

4c. December 16, 2015

4b. September 18, 2015

Mant-4 Photographs 4a to 4c. All views are to the north from the toe of the dune at Princeton Avenue.

Photograph 4a shows a narrow beach and bulldozed sand on the dune slope.

Photograph 4b from September 18, 2015 shows a more natural inflated summer beach as traces of bulldozing was not evident. The berm crest was at its lowest elevation for 2015.

Photograph 4c from December 16, 2015 shows the narrow beach and bulldozed sand to recover from the impacts of the October 2-5, 2015 northeast storm. The loss of sand from above the 0.0 ft datum was deposited in a bar that was 500 ft seaward from the top of the dune.

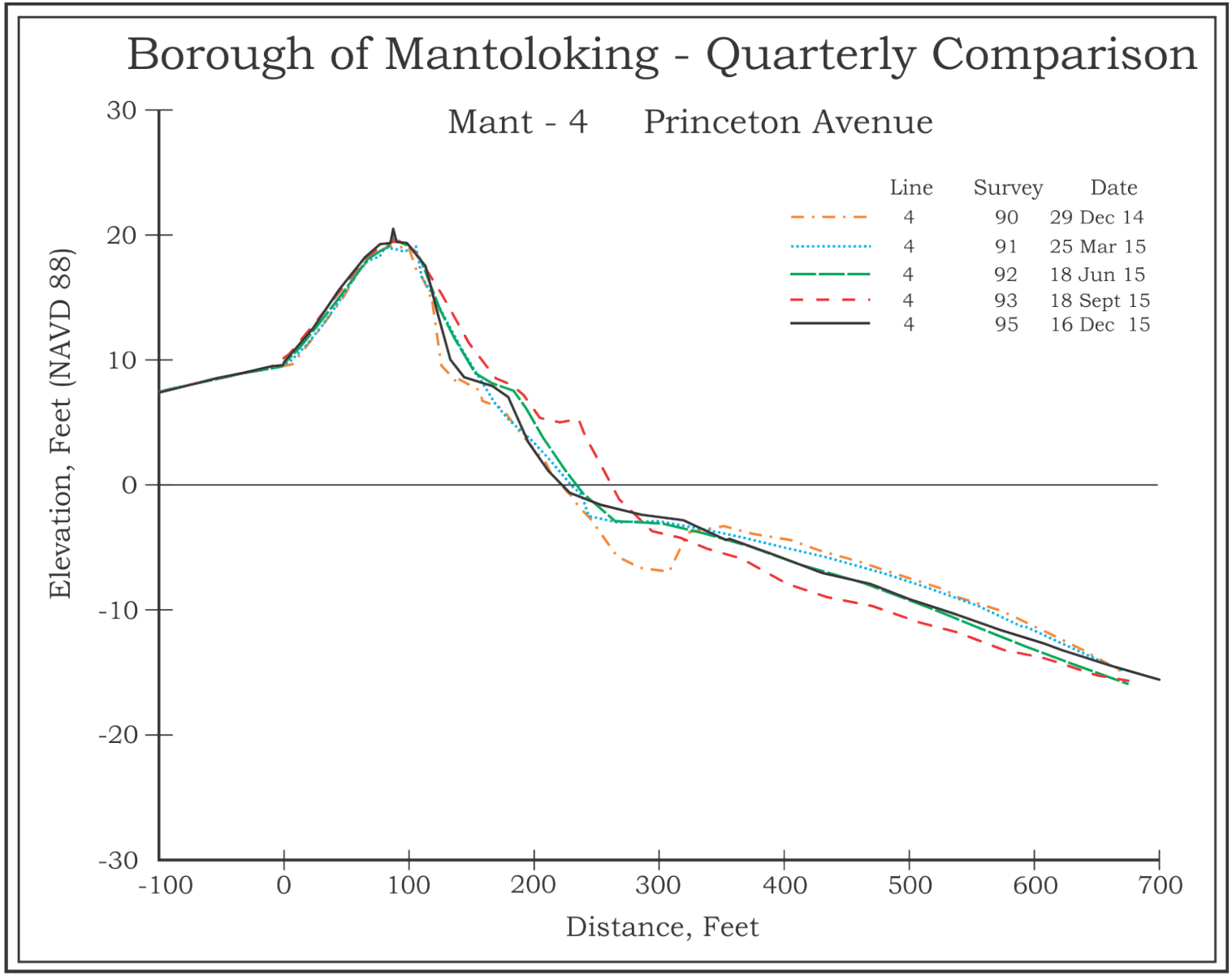

Figure 4a: The annual analysis of Princeton Avenue shows a consistent location of the seaward dune slope as a result of bulldozing efforts by the Borough, though summertime accumulations attributed to natural processes contributed. Between December 2014 and December 2015, cross-shore processes moved the nearshore bar landward to fill in the trough. These sands eventually made their way to the berm and dune slope either through natural or mechanical means as the profile gained in volume (2.1 yd^3/ft) with most accumulation above the 0.0 ft datum. The position of the shoreline remained relatively in the same position throughout the year except during the September survey where it expanded seaward about 40 feet from the December 2014 position.

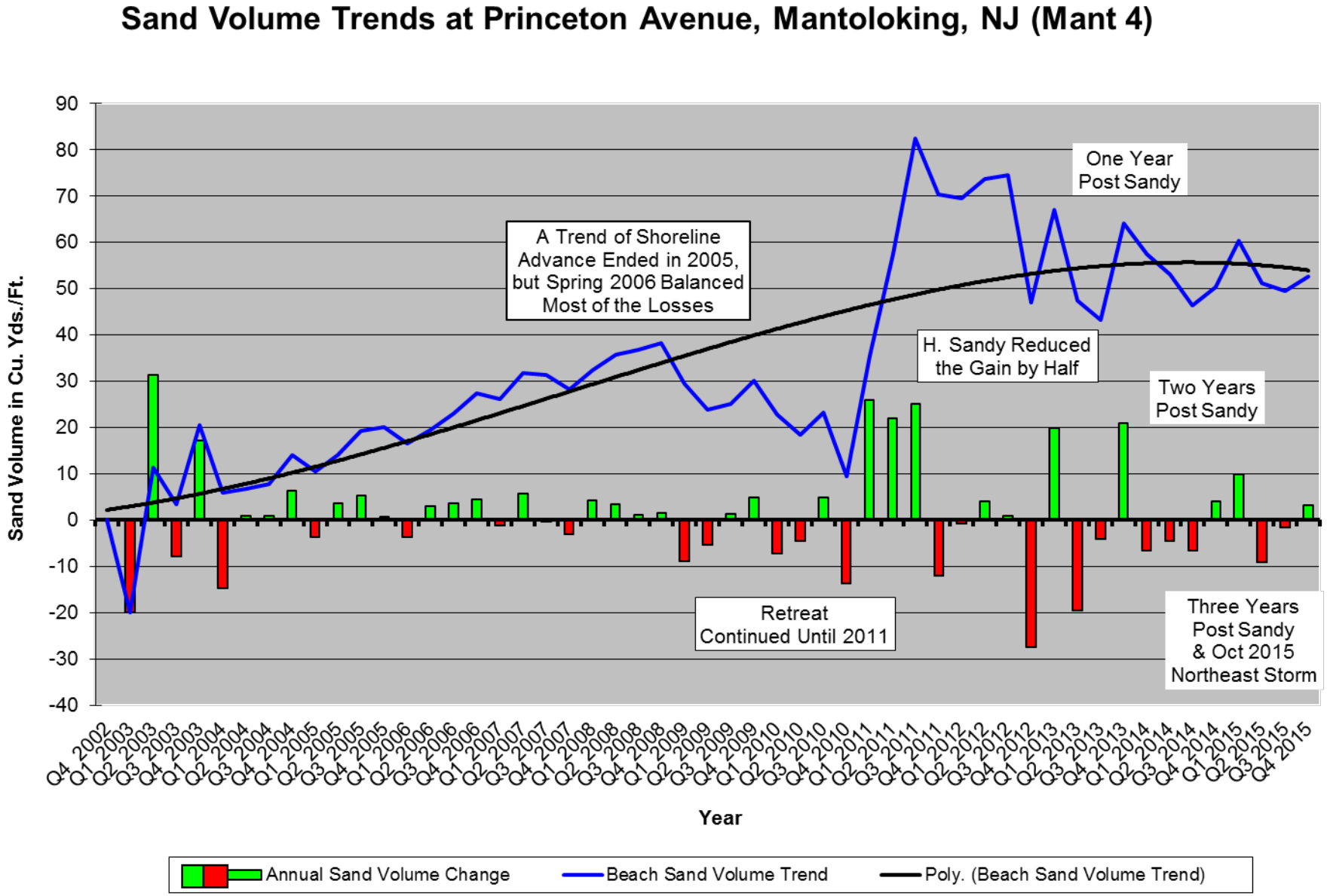

Figure 4. The trend in shoreline advance and volume gain at Mant 4 was influenced by multiple small sand fills to protect the MUA sewer line discharge pipeline that crosses the beach to the ocean. Hurricane Sandy reduced the volume gains by half. In 2014, sand volume losses occurred from the 1st through 3rd quarters, with modest recovery in the 4th quarter following the NJDOT bulkhead installation. The October 2015 northeast storm created a total volume gain (3.17 yd^3/ft) though the gains were below the datum as the dune and berm sands were deposited offshore.

- **Mant-51 #1543 Ocean Avenue**

This monitoring site was initially located on private property between the homes at #1547 and #1549 Ocean Avenue. Because of its proximity to the border with Brick Township, this location became the final site for the Borough monitoring program. A profile line was established along the southern property line of #1547 Ocean Avenue with a reference location at the landward dune toe. During 2005, the site was moved to the public access pathway between #1543 and #1539 Ocean Avenue because of accessibility issues on private property at the previous site location. The shift in the line's location was 202 feet to the north.

The dune system along the southern 1,500 feet of Mantoloking is the widest and highest in the municipality. Homes are set back to the natural toe of the back slope of the dune. In November 2010, the dune was 180 feet wide at the toe and 90 feet along the crest with an elevation of 23 feet NAVD 88. These dunes are among the best seen along the developed northern Ocean County shoreline outside of Island Beach State Park.

Hurricane Sandy's storm surge and fierce waves impacted the dune toe almost immediately as the ocean surge inundated the narrow beach rapidly allowing near continuous erosion throughout the storm. As a result over half the dune volume above the 10.0-foot elevation (NAVD88) was eroded away, but the dune elevation landward of the 24-foot crest elevation at the site remained above 20 feet in spite of the significant erosion and prevented overwash.

In recovery efforts following the storm, sand was bulldozed from the berm crest to the dune slope with the new dune crest at 24 feet (NAVD88) and approximately 100 feet landward of its pre-Sandy position. The dune elevation and position have been maintained throughout 2015.

5a. March 25, 2015

5c. December 16, 2015

5b. September 18, 2015

Mant-51 Photographs 5a to 5c. All views are to the north from 1543 Ocean Ave.

Photograph 5a shows the narrow winter beach and the location of the high water line. The profile of the seaward dune slope was a result of the Borough's bulldozing efforts.

View 5b shows the summertime accretion between the June and September surveys that resulted in an above datum volume gain of 8.92 yds^3/ft and the shoreline moved 39 feet seaward.

View 5c from December 2015 shows the steep dune-beach profile that was initiated by the October 2-5, 2015 northeast storm which generated above datum volume losses (-19.66 yds^3/ft) and shoreline retreat (-62.4 ft).

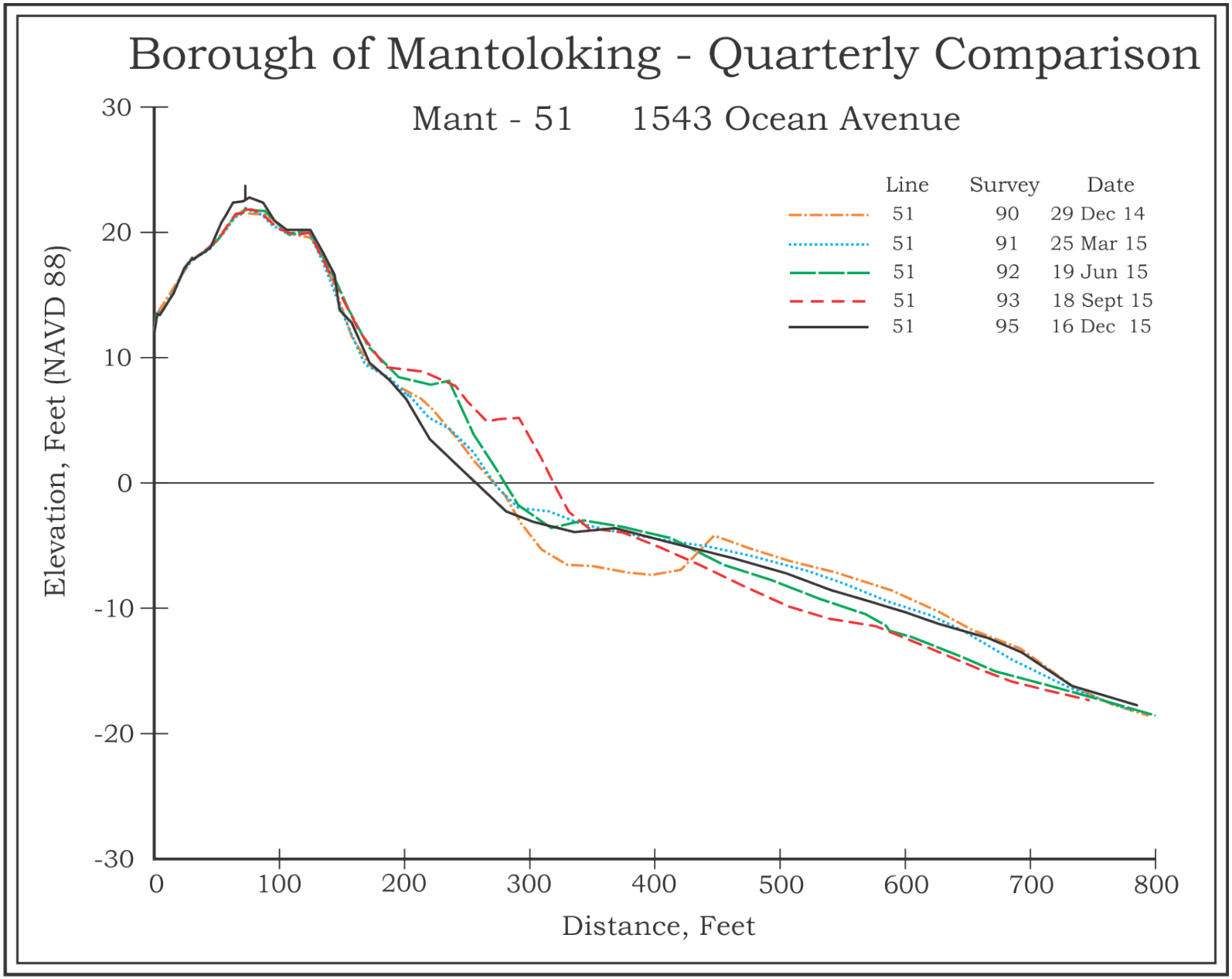

Figure 5a: In the 2014 to 2015 quarterly analysis of site 1543 Ocean Avenue, the dune position and elevation remained relatively stable. Shoreline position and quarterly volumetric changes were attributed to the cross-shore movement of sands from the nearshore bar to the berm and the annual volume change was less than 1 yds^3/ft. The impacts from the October 2015 northeast storm moved sand from the dune and berm to the nearshore in a sheet-like deposit and raised the bathymetry to former March and June 2015 elevations.

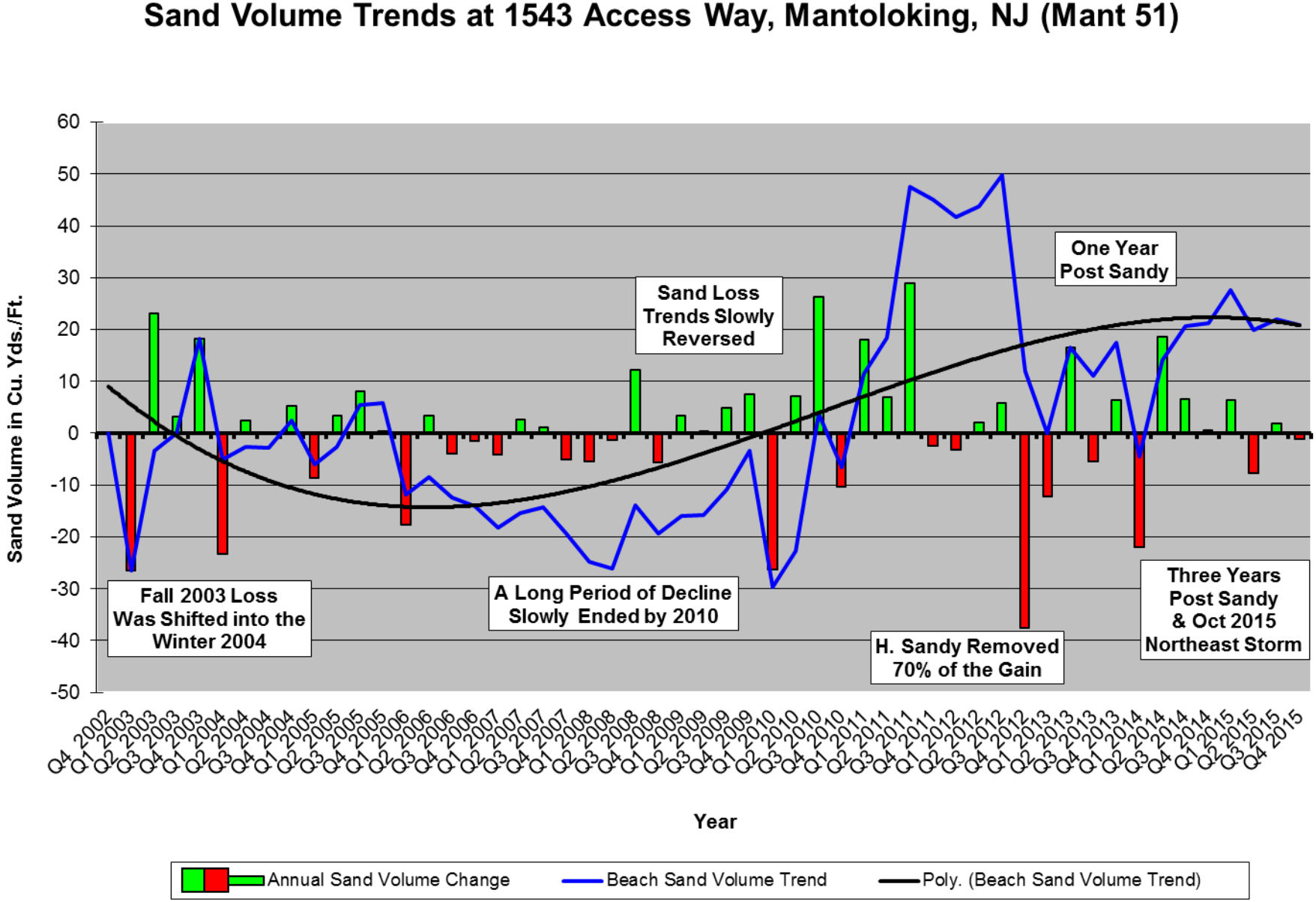

Figure 5. The highest and widest dune system in Mantoloking was located at the Mant 51 site. There was a long period of volume losses (2004 to 2009) but the trend changed in 2010 when the Borough began to more consistently bulldoze sand from the beach to the dune. Hurricane Sandy moved 70% of the volume gains to the nearshore, or, south into Brick Township. Since the 2nd quarter of 2014 there have been 4 of 6 consecutive quarters with recovery and the December 2014 to December 2015 volume change was 0.31 yds^3/ft where the losses were mostly from above the datum. The shoreline moved landward (-14.6 ft) during this time.

Conclusions:

Since the installation of the vertical steel wall in late 2014, the Borough's beaches have been subjected to minor and moderate storms that have eroded sand from the seaward dune slope and exposed sections of the wall. To fight the losses in 2015, the Borough of Mantoloking continued its shoreline management practice of pushing sand from the high water line to the seaward dune slope. This has allowed for general volume gains above the datum for the three central municipal locations (Mant-2, Mant-3, Mant-4) that ranged from 3.0 to 8.0 yds^3/ft and above datum losses at the north and south end locations (Mant-1, Mant-51) that ranged from -2.0 to -5.8 yds^3/ft.

Beach widths (measured from the shoreline to the seaward dune toe) ranged from approximately 75 feet to 125 feet during the December 2015 survey and approximately 100 to 135 feet during the September 2015 survey. These changes reflect the natural processes that occur during the winter (deflated beach) and summer (inflated beach). Though the elevations of the dune crests at all sites are approximately 20 feet (NAVD88), the narrow beach widths and lack of wide dunes puts the municipal beaches at risk from another Hurricane Sandy-like storm event. This is evident from the removal of sand from the seaward side of the vertical steel wall, touted as the last line of defense, by moderate northeast storms. The narrow beaches allow the waves to easily interact with the vertical wall which reflects wave energy and exacerbates erosion at the toe.

All of the municipal beaches remain at a sand deficit with respect to the conditions prior to Hurricane Sandy (Table 4). The net volume change between the September 2012 and December 2015 surveys is -171,459 cubic yards. While the bulldozing practices are effective at some locations for increasing the amounts of beach sand, overall the attempts appear futile for protection during moderate storms. A large shore protection project (engineered beach fill) will be needed to compensate the losses attributed to Hurricane Sandy. Restoring the beaches to pre-Sandy conditions would still leave the regional sand budget below what is needed to create a stable dune and beach system. Increasing the budget would provide long term benefits towards stabilizing the shoreline as the monitoring has shown cross-shore processes dominate absent of large scale storm events. This indicates any sand introduced would have a significant residence time within the Mantoloking beach system.