



THE RICHARD STOCKTON COLLEGE OF NEW JERSEY

**An Assessment of Cape May County Beaches
at the
New Jersey Beach Profile Network (NJBPN) Sites
After Hurricane Sandy
Related to
(DR-NJ 4086)**

Introduction:

The Richard Stockton College of NJ Coastal Research Center (CRC) has initiated a post-storm survey and assessment of the New Jersey shoreline in response to severe beach erosion resulting from the impact and landfall of Hurricane Sandy October 29, 2012. Declared a Federal Disaster by President Obama on October 31, 2012, this information is being prepared to show the general trend of beach/dune loss between the Delaware Bay on the west shore of Cape May County around the Point, and up the coast to Ocean City. The analysis for the 31 survey sites starting at Reeds Beach, moving around Cape May Point and up the oceanfront to Ocean City, NJ was completed November 26, 2012. Beachfront clean up work was all but complete in most locations because all of Cape May County was south of the point of landfall for the storm. The consequence was that the second high tide was opposed by the southwest wind on the back side of the storm; therefore the surge was up to 10 feet lower than documented in Long Branch. This initial report is focused on the impact to municipal dunes and beaches from Hurricane Sandy. All of the Cape May NJBPN sites were surveyed earlier in the fall, so site was re-surveyed to wading depth to get as much information as fast as possible. In the spring of 2013, the normal long profiles will be run to see longer term comparisons with the spring of 2012 conditions.

Beach/Dune Damage Assessment by Municipal and Island Segment:

To measure the erosion, pre-existing New Jersey Beach Profile Network (NJBPN) monitoring sites were used to provide an accurate comparison and assessment of storm related shoreline and beach volume changes. Using the data from the fall 2012 NJBPN survey, completed in Cape May County by October 19, 2012, provides a good baseline for damages that occurred during the hurricane. Data collected at the 31 beach profile locations was done between November 12 and 26, 2012 using RTK GPS and extended from the reference location, across the dunes, beach and into the surf to wader depth. By Nov. 12th, it was clear that sand recovery was well under way as a berm had been deposited on the erosional surface generated by Sandy with a substantial offshore bar present in water less than 5 feet deep offshore. Very little sand in the oceanfront locations had been washed inland beyond the dunes. Exceptions were found in Ocean City, Sea Isle City, and at the Reeds Beach site. A gap in the dunes at the point where Cape May City borders the Nature Conservancy lands also saw wave damage to a few structures.

Profile Locations: The following sites were surveyed during September and October 2012 and post-Sandy by November 26, 2012 (Figure 1).

- | | | | |
|------------------|------------------------------|------------------|------------------------------|
| NJBPN 100 | Reeds Beach, Middle Township | NJBPN 115 | 35 th St., Avalon |
| NJBPN 201 | Pacific Ave. Villas | NJBPN 116 | 23 rd St., Avalon |
| NJBPN 102 | Whitter Ave. No. Cape May | NJBPN 216 | 9 th St., Avalon |

NJBPN 103	Higbee Beach State Park	NJBPN 117	80 th St., Sea Isle City
NJBPN 104	Lake Dr. Cape May Point	NJBPN 118	57 th St., Sea Isle City
NJBPN 105	Nature Conservancy, Cape May	NJBPN 119	25 th St., Sea Isle City
NJBPN 206	Broadway Ave. Cape May	NJBPN 120	1 st St., Sea Isle City
NJBPN 107	Baltimore Ave. Cape May	NJBPN 121	Williams Road, Strathmere
NJBPN 108	Cape May Beach Club	NJBPN 221	Corson's Inlet Park, Ocean City
NJBPN 208	USCG Base, Lower Township	NJBPN 222	59 th St., Ocean City
NJBPN 109	Raleigh Ave., Lower Township	NJBPN 122	56 th St., Ocean City
NJBPN 110	Cresse Ave., Wildwood	NJBPN 223	34 th St., Ocean City
NJBPN 111	15 th Ave., North Wildwood	NJBPN 124	20 th St., Ocean City
NJBPN 212	121 st St., Stone Harbor	NJBPN 125	6 th St., Ocean City
NJBPN 113	90 th St., Stone Harbor	NJBPN 225	Gardens Road, Ocean City
NJBPN 114	70 th St., Avalon		

*Below is a map showing the location of each profile.

Western Delaware Bay Shoreline of Cape May County;

Between Reeds Beach and Cape May Point, the western shoreline of Cape May County suffered from the back-side of Hurricane Sandy after the storm made landfall on the New Jersey shoreline. The wind direction reversed and came across the storm-surge flooded Delaware Bay with 4-foot waves with very short periods. Due to the high water levels these waves pounded dunes and made low-lying areas subject to inundation, wave damage and loss of some structures.

Reeds Beach was hit hard because there was no bluff, and a minimal dune system. The region is basically a narrow sand beach, low dune all as a barrier on and seaward of the salt marshes. Sand was pushed across the service road to Bidwell Creek and the majority of the dredge material pumped from the creek project two years ago was moved inland onto the salt marsh lying between Reeds Beach homes and the Cape May County mainland.

To the south, the bluff of the county uplands is mantled with dune sand and made a better barrier. Erosion took some dune and moved the zero elevation position toward the bay because the beach/dune slope was reduced in gradient allowing sand to deposit on the terrace that extends over 1,000 feet into the Delaware Bay from Villas and North Cape May. This wide terrace is the geological result of long, slow erosion of the bluff by bay waves.

Higbee Beach, a natural area, suffered bluff erosion and beach retreat, but on a minimal scale. Cape May Point had sand moved up onto the highest parts of the dry beach and suffered minimal dune losses from the bay side around to the oceanfront beach.

Cape May City;

The approach direction of the ocean waves, deflected somewhat by Cold Springs Inlet jetties and the south, southwest orientation of the shoreline acted to pile sand from the beachface landward onto the backshore beach into the dune vegetation. The Cape May beaches all gained berm sand at the expense of beachface retreat. Only the short segment between the Third Avenue groin and the Nature Conservancy suffered inundation largely because building a decent sized dune was resisted by the adjacent property owners.

The Wildwoods;

The same process appeared to be working at 3 of 4 cross sections between the natural area and North Wildwood, with the 15th Street site not performing as did the Wildwood site at Cresse Avenue. The Cresse

berm became 2 feet higher with a ridge over 100 feet wide created from beachface sand pushed up on top of the back berm region of the beach. At the 15th Avenue site in North Wildwood another signature result from Sandy appeared with the deposition of a sand ramp deposited up the seaward slope of the primary dune. It appears that when the dry beach is deeply flooded by a storm surge, the waves break on the submerged beachface slope, excavating abundant sand that the broken wave bores transport across the berm, and deposit it where they run up the dune slope. If the waves do not breach the dunes, they deposit beach sand as a ramp at the seaward toe of the dune. Where a hard structure presents an effective wave barrier, this ramp was likewise deposited and in some cases effectively enabled the waves to run-up and over the hard structure. The example of this was seen at the Sea Bright seawall in Monmouth County.

Avalon & Stone Harbor;

These two communities have been leaders in shore protection by having successfully managed to have Federal shore protection projects constructed and have for years, promoted wider, higher dunes with coordinated development of pedestrian access pathways that do not make a breach easier at street end access points. No instance of dune breaching occurred in either Borough; no waves washed sand into streets or under homes. Dune erosion did occur, but in some cases, the extraordinary width of the dune area allowed Sandy's wave energy to be absorbed within the swales and vegetation of the foredunes arrayed along the mid-section of the barrier island. Elsewhere a wide, relatively high primary dune blocked wave over-topping by just enough to be successful. A major hard structure improvement to the Townsend's Inlet shoreline in Avalon paid dividends by reducing the damage from Sandy to considerably less that was incurred during the December 1992 northeast storm. The worst wave damage occurred to the highway leading to the Townsend's Inlet draw bridge to Sea Isle City.

Sea Isle City & Strathmere;

A 2009 NJ State and locally sponsored shore protection project saved these two communities substantial damage expense as well. Previous storms of far less intensity had made a shambles out of the Commonwealth Avenue highway leading through northern Sea Isle City into Strathmere. Sandy produced minor breaching and over-topping, but not nearly the extent of overwash seen previously (1998 for example). There were instances of dune breaching in Sea Isle City, extensive tidal flooding, but no catastrophic structural damage. The project protected Strathmere only allowing a couple of minor instances of waves cresting the dunes. The Corson's Inlet shoreline, a crisis situation in 2008, was un-damaged in spite of being flooded by tidal surge.

Ocean City;

The shore protection was a Federal project (Great Egg Inlet to 34th Street) and a local/State partnership (34th Street to the Corson's Inlet State Park). Two decades of sand redistribution produced results ranging from fantastic through fair to poor. The mid-section of the island had vegetation covering 450 feet of dunes before reaching the dry beach. These areas saw absolutely no wave damage with the storm's energy totally absorbed within the foredune region lying seaward of the primary dune. This was a welcome change from the October 1991 northeast storm where just the boardwalk suffered \$4 million in damage in the 15th to 20th Street region. There has been no damage to this structure since (the initial fill was completed in the summer of 1992 and resulted in no damage in December of 1992 when a worse event than 1991 hit Ocean City).

To the north the recently maintained Federal project had a narrow beach between a dune system and the direct frontal assault of the northeast waves during Sandy. With little or no beach to break on, and roll across, the waves pounded with full fury on the dunes immediately. Eroding at rates up to 12 feet horizontally per hour, many sections lost the protection the dune afforded. Sand was washed into the streets; storm surge flooding was made worse by every wave crossing into the city. Structural damage occurred, but not at catastrophic levels. At the southern end of development, the beach had not been maintained as frequently and there was

only one fairly narrow line of dunes protecting property. Sandy crossed this line easily and waves flowed against, around and beneath 10 blocks of homes. Damage was considerable with early clean-up focused on moving thousands of cubic yards of sand back to the beach in early November.

The Corson's Inlet State Park shoreline south of development in Ocean City suffered dune loss of considerable magnitude. These losses were major increases in loss that had commenced in 2011 with the series of modest northeast storms that commenced in November 2009. The beach had been narrow with spring high tides reaching the near-vertical scarp in the dunes. This slow rate of retreat was greatly accelerated during Hurricane Sandy.

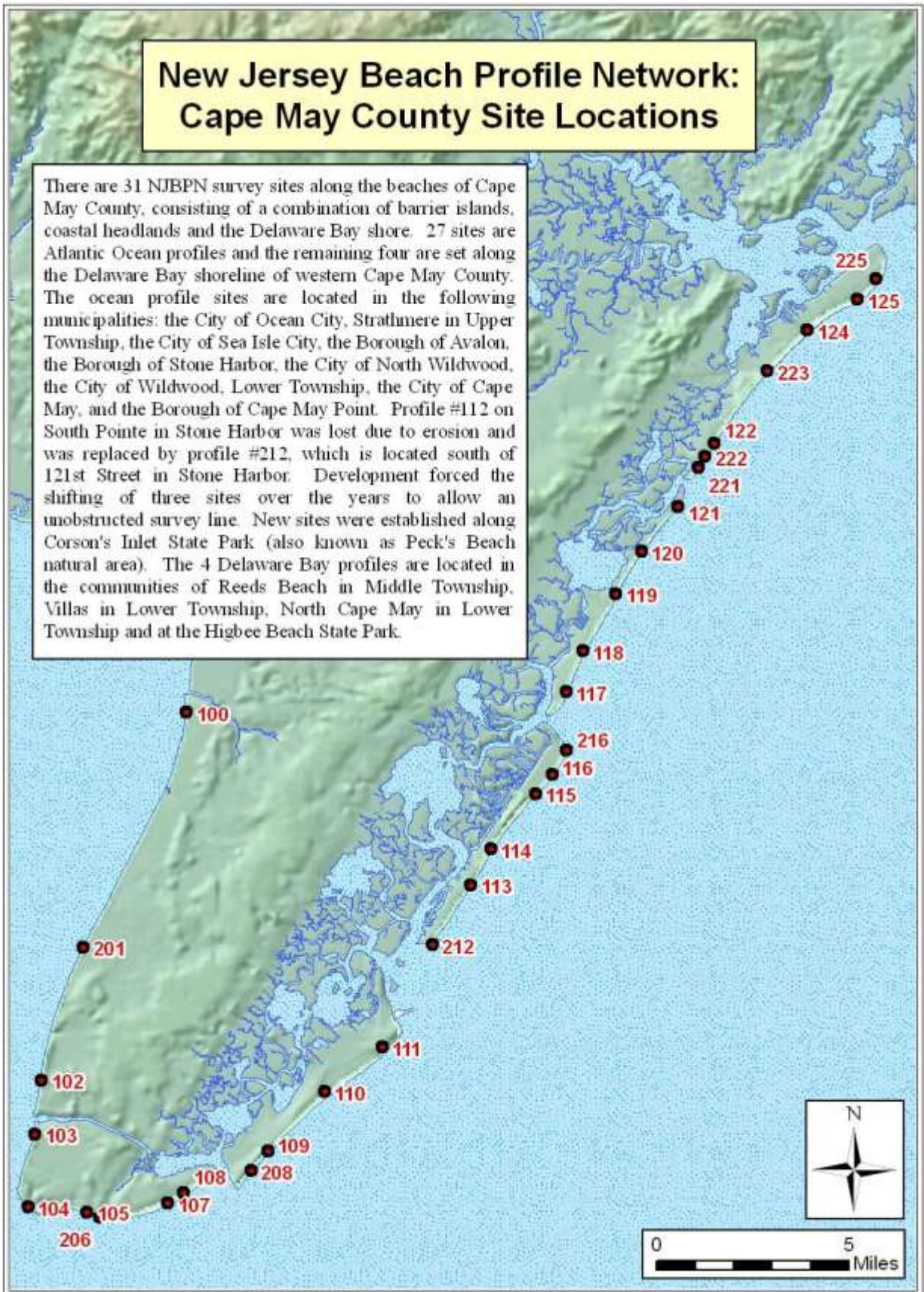


Figure 1. Map of Cape May County showing the locations of the 31 profile sites in the county.

Individual Site Descriptions:

Each site will display a photograph from the earlier fall 2012 survey several weeks prior to Sandy. The second picture was taken during the survey at each site to show the extent and nature of storm damages. The profile cross section displays the longer, early fall survey and the post-Sandy assessment to illustrate where and the magnitude of storm erosion. Since the natural areas in the wildlife refuge, Corson's Inlet State Park and Higbee Beach State Park were left un-surveyed until after Sandy, those cross sections will be of normal length. The Cape May County natural areas performed quite well except for the Corson's Inlet Park shoreline on the Peck's beach side of the inlet.

Reeds Beach, Cape May County, Site #100;



The left photograph was taken March 5, 2012 looking south. The dune was vegetated and the beach was higher in elevation compared to the post-Sandy picture on the right taken November 9, 2012. The sand in the center of the right photo has been transferred from the roadway back to the beach as a series of piles.

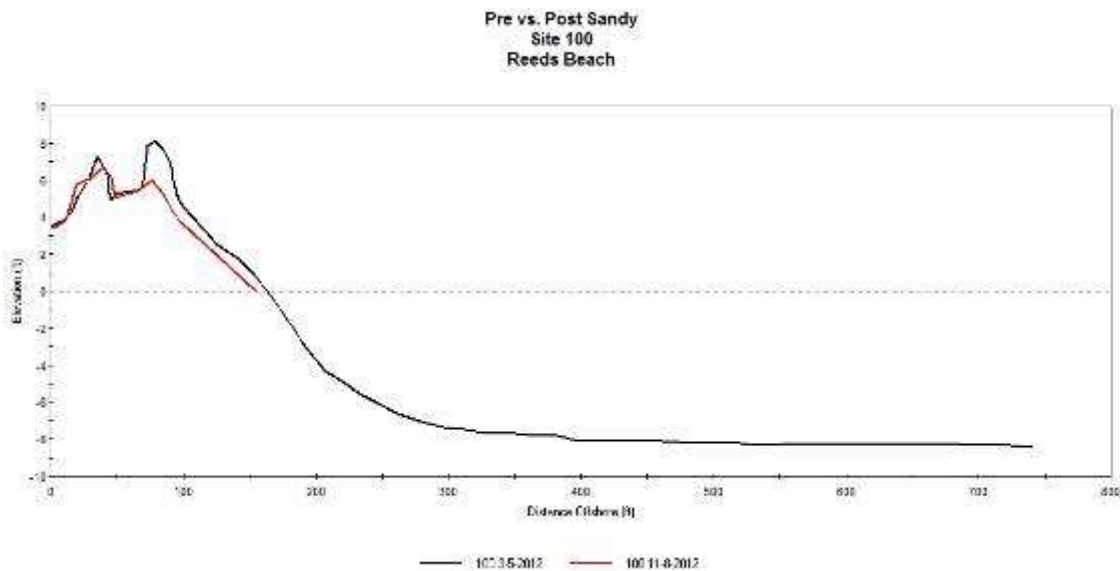


Figure 2. Reeds Beach, Cape May County is located on the western shoreline facing into Delaware Bay. This beach was nourished using dredge material from Bidwell Creek to the north in 2010. The “dune” between the road and the bay was removed and the sand pushed across the road into the salt marsh. The shoreline retreated 8 feet as well. The lost material will not return to the beach except for the material excavated from the roadway.

Pacific Avenue, Villas, Cape May County, Site #201;



The left view was taken March 7, 2012 looking south along the beachfront. By November 9th the storm impact was found to have eroded the beach into the toe of the dune reducing the beach elevation and creating a minor scarp. The height of the uplands bluff prevented local wave or tidal flooding.

Pre vs. Post Sandy
Site 201
Pacific Ave., Villas

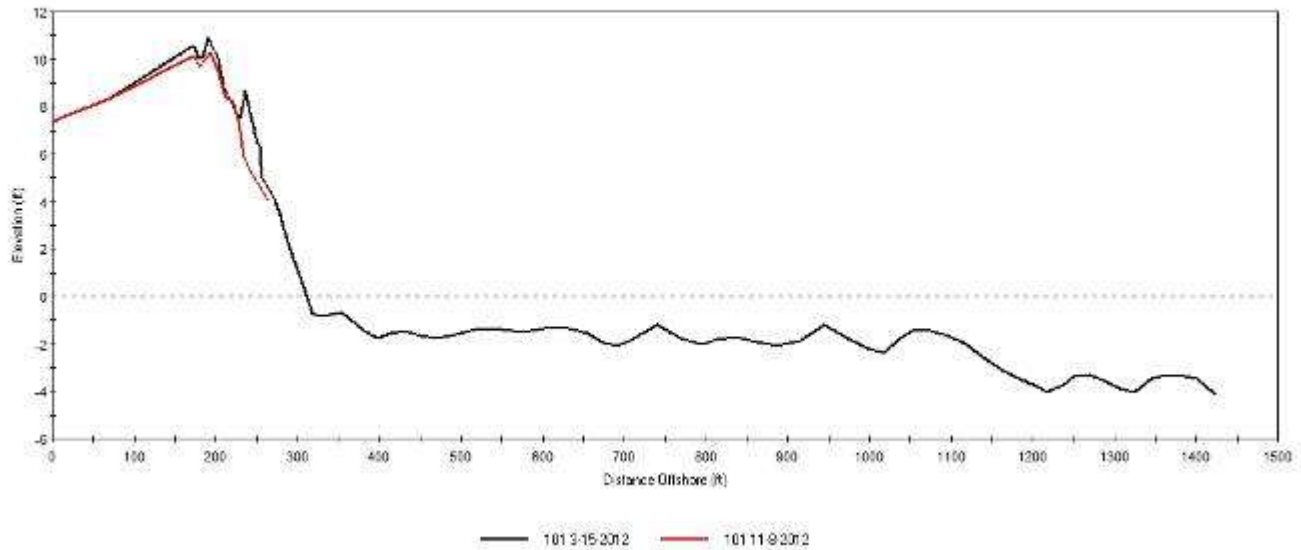


Figure 3. The wide shelf terrace likely saw sediment shifted around, but little erosion vertically appeared to have drastically changed the situation. The small foredune was removed and waves lowered the beach elevation, likely moving sand onto the nearshore terrace segment.

Whittier Avenue, North Cape May, Cape May County, Site #102;



At Whittier Avenue the drainage line shows the extent of beach erosion between March 15, 2012 and after Sandy on November 9th. Sand was moved offshore onto the terrace, but the dune withstood the majority of the Delaware Bay wave assault on this shoreline.

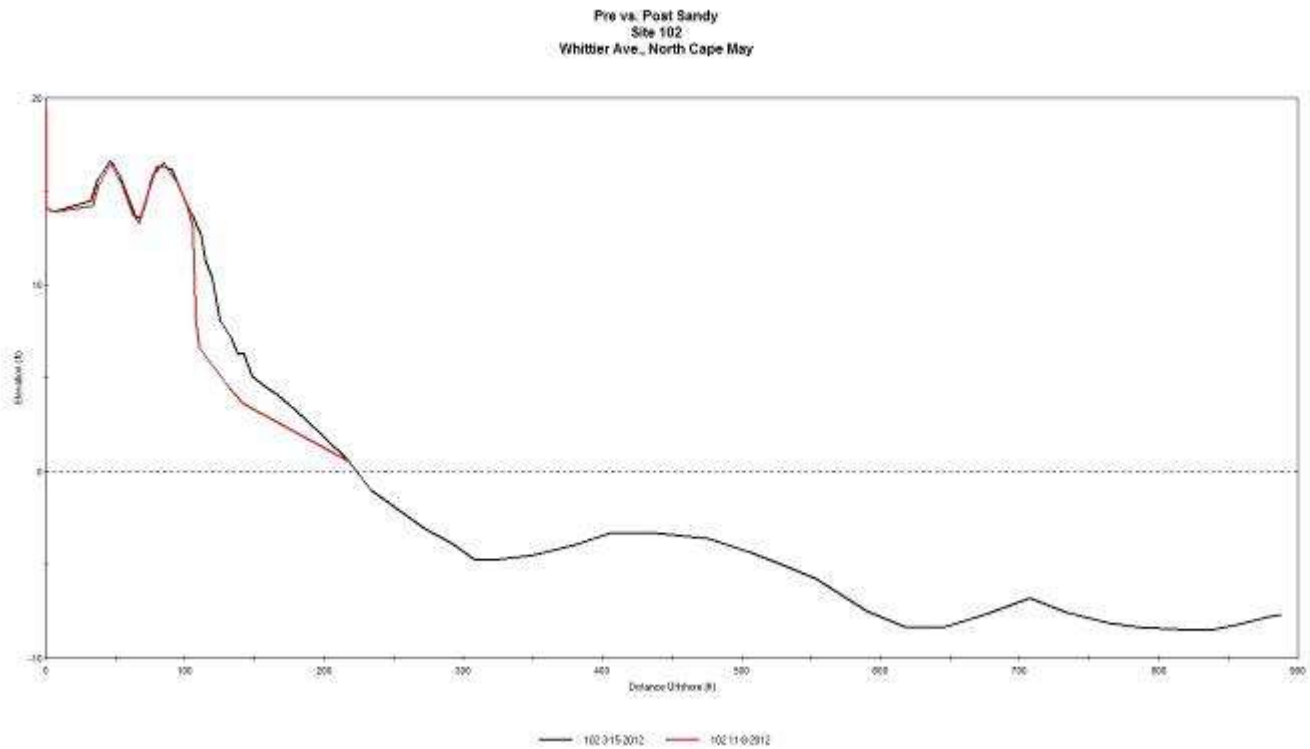


Figure 4. The cross section shows the erosion into the seaward toe of the dune with the post-storm beach slope meeting the pre-storm line at a much lower slope angle. Sand was transported offshore at the expense of the existing beach and dune.

Higbee Beach State Park, Cape May County, Site #103;



The left picture was taken March 5, 2012 while the post-storm picture on the right was taken November 20, 2012. The shoreline at the State Park, south of the Cape May Canal suffered bluff erosion into the mantle of wind-deposited sand that mantles the scarp. The incipient grasses were stripped away between the high tide line and the base of the bluff during Sandy. The beach was lower but wider with some sand moved into the bay.

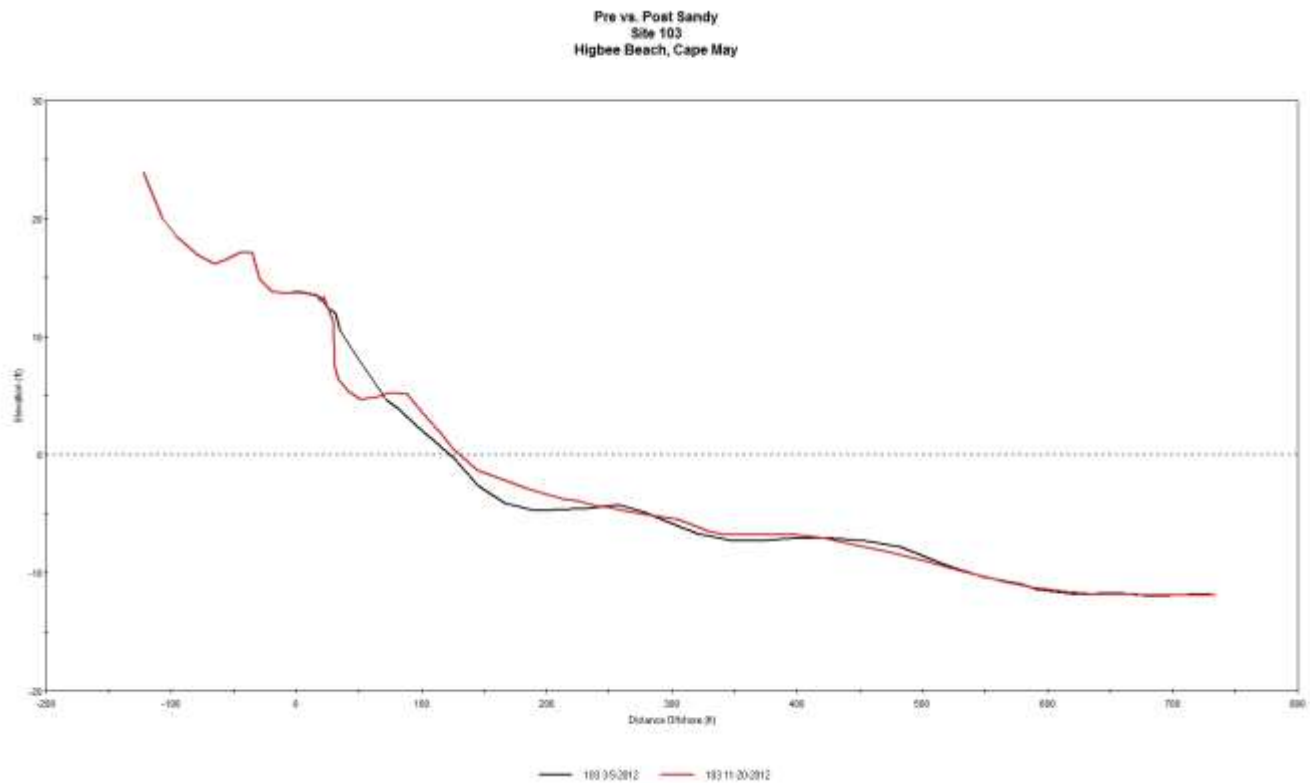


Figure 5. The bluff was cut into a more vertical slope to the beach with sand deposited offshore. Note that little change occurred further into the bay below the 5.0-foot depth. While the waves were large by Delaware Bay standards, they were of short period and therefore unable to impact the bay floor below the 5-foot depths. Surge elevations made the depths greater by 4-5 feet as well, so when the waves were active the bay floor beyond the 250-foot distance was between 10 and 12 feet of water depth.

Lake Drive Cape May Point, Cape May County, Site #104;



The left picture was taken March 15, 2012 while the post-storm photograph was taken November 20th looking across the dunes to the bay. The beach was reduced in width somewhat, but no erosion occurred in the dunes. This location was essentially untouched by the storm.

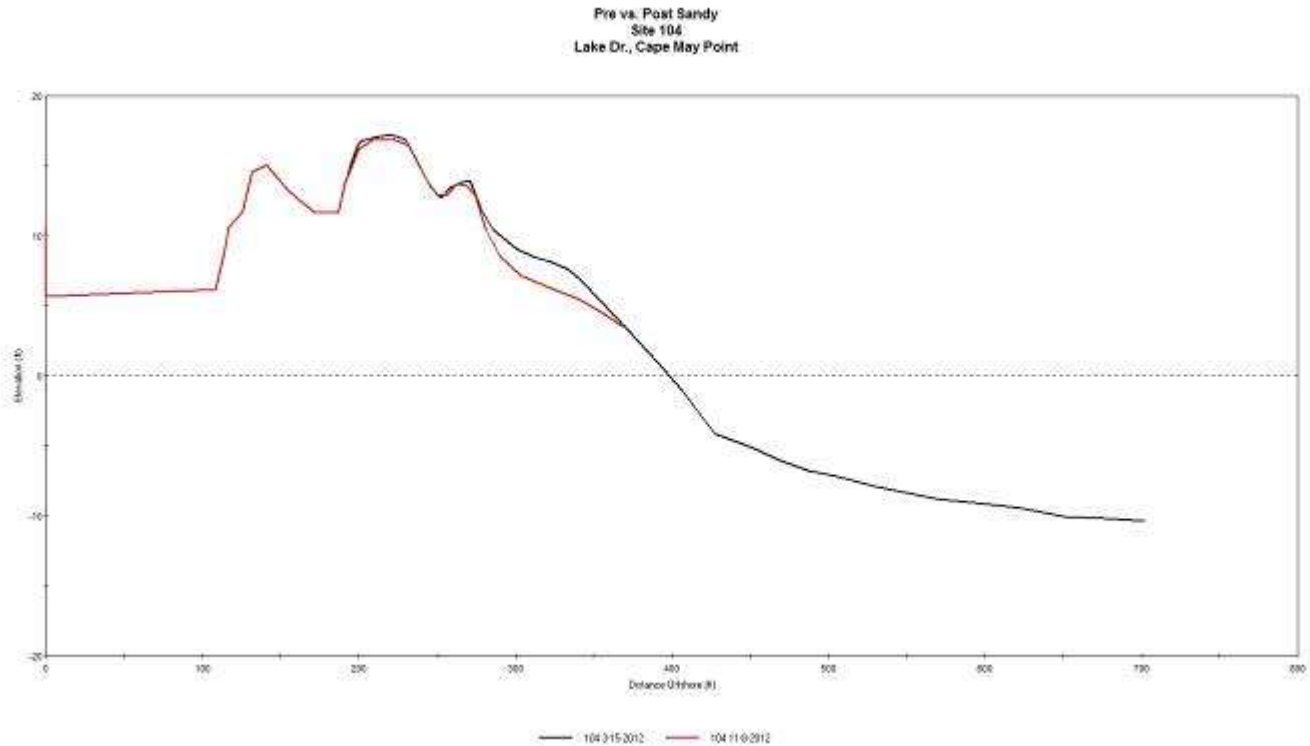


Figure 6. The Lake Drive location faced in a direction where very little direct storm impact was seen. The northeast winds early in the Sandy storm had no impact, while the southwest waves from Delaware Bay reached to the toe of the dunes and acted solely on the upper beach surface to lower its elevation somewhat.

Nature Conservancy, Cape May County, Site #105;



The left picture was taken March 5, 2012 looking toward the terminal groin in Cape May City. The left shot was done November 9th showing the dune erosion and overwash into the newer dune development that has occurred over the past 22 years since the initial beach restoration took place in Cape May City in 1990.

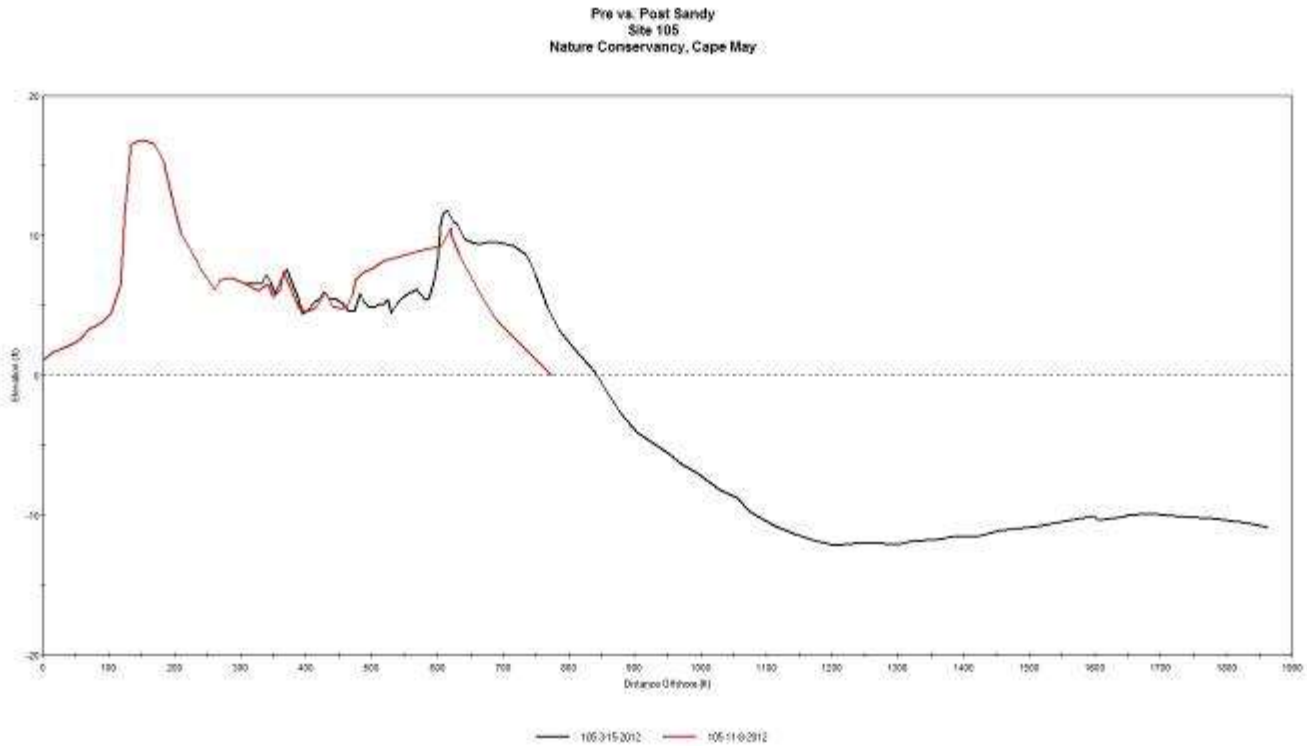


Figure 7. The very south section of Cape May City was exposed to storm damage because almost no dune or hard structure protection existed immediately south of the Third Avenue rock groin. A few buildings, several owners of which had opposed the building of an extension of the dune system found in the Nature Conservancy lands suffered wave surge flooding as a result. The storm surge did invade the naturally extended dunes depositing substantial quantities of the beach and seaward dune material.

Broadway Avenue, Cape May City, Cape May County, Site #206;



The June 5, 2012 picture shows the popular bathing beach at the beginning of the last summer season. The right side shows the post-storm view on November 9th. The elevation increase shown below can be seen in the smaller slice of ocean in the right-hand view as compared to the left side. The seaward stair railings in both pictures have the same relative relationship to the horizon indicating that the view from the camera is almost the same elevation in both pictures.

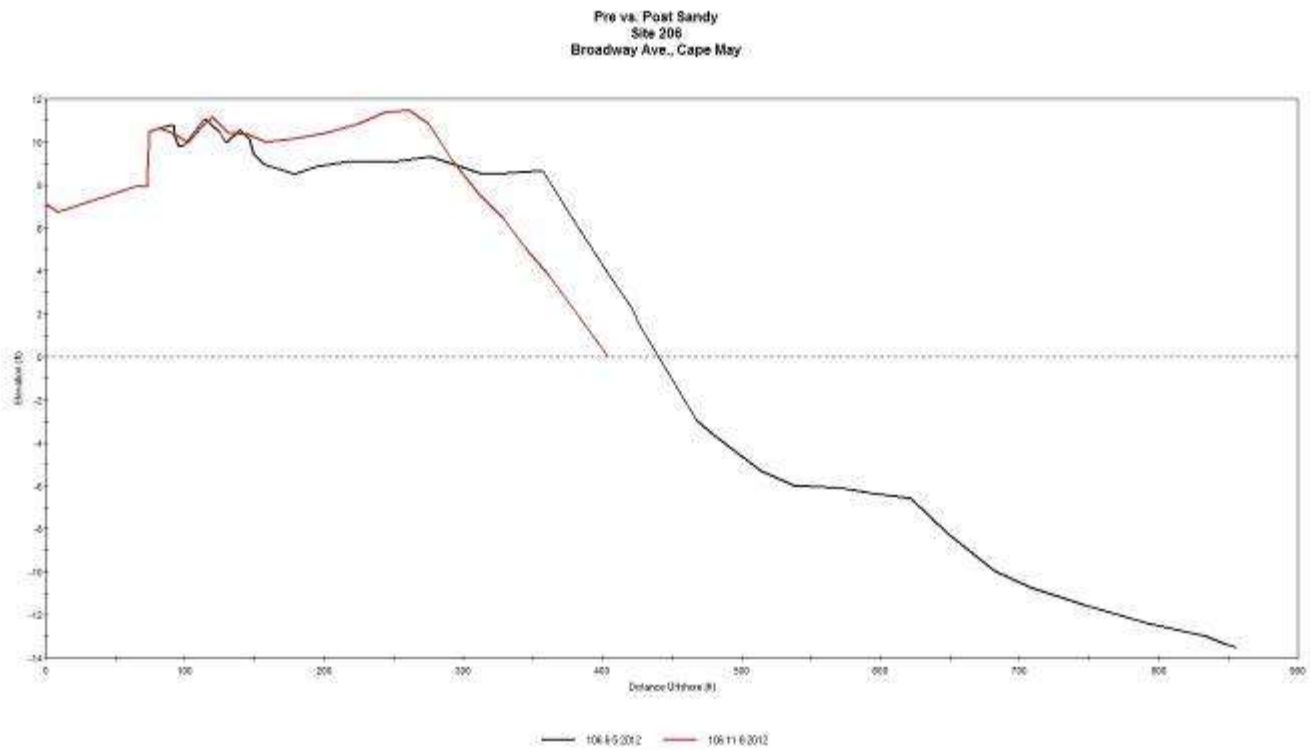


Figure 8. Located at the southwestern end of the Cape May City beach, this site saw substantial beach width loss, but the sand removed was pushed landward onto the remaining dry beach raising its elevation by up to 5 feet. Very little sand was transported into Ocean Avenue by the storm.

Baltimore Avenue, Cape May City, Cape May County, Site #107;



The left picture was taken in June 5, 2012 showing the beach toward the northeast. The post-storm shot on the right was taken November 9th in the same orientation. The sand can be seen deposited around the fencing leaving only two rows of wire above the sand while in June there were 5 rows of wire showing. Here the beach was also widened toward the zero elevation position.

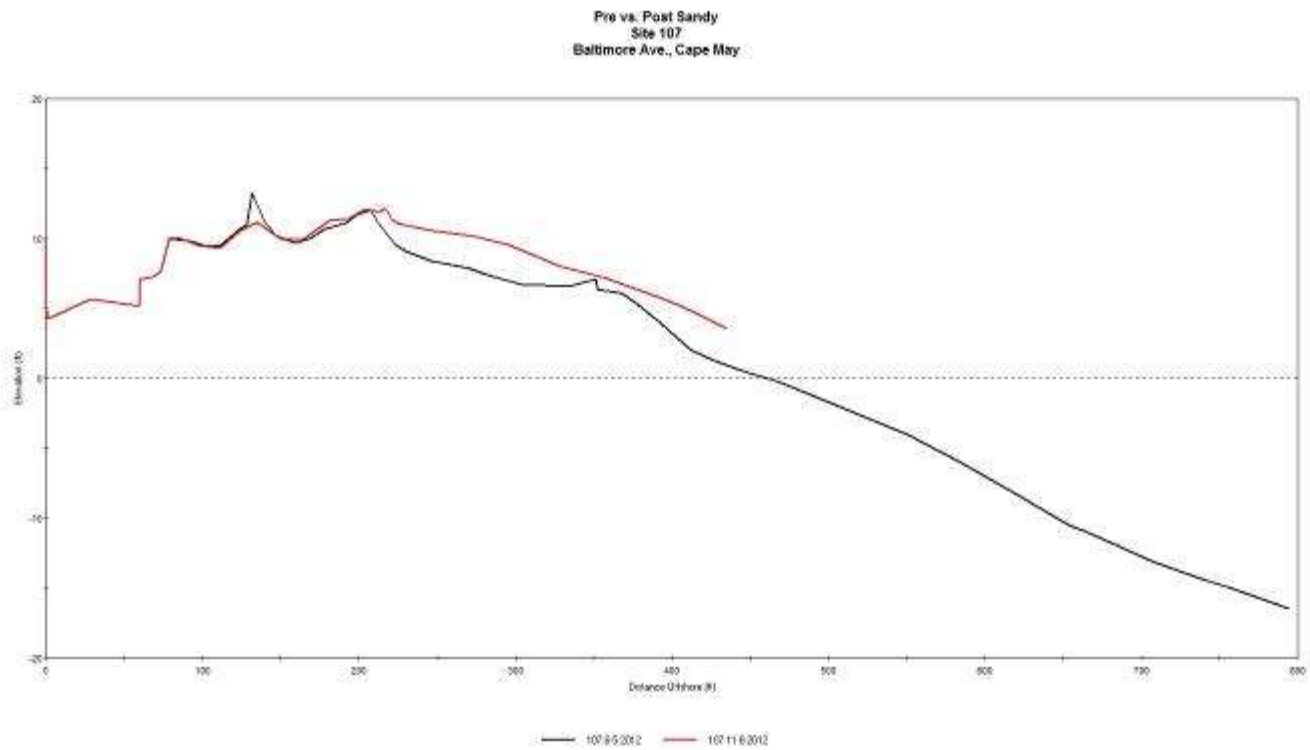


Figure 9. At Baltimore Avenue the beach was made wider and sand was pushed up onto the berm raising its elevation by 2-3 feet all the way landward to the fore dune slope. This beach segment had unusual responses to Hurricane Sandy.

Cape May Beach Club, Cape May City, Cape May County, Site #108;



On June 5, 2012, the beach was wide with the removable boardwalk ready for the summer. The post-storm picture on the right was taken November 9th at approximately the same spot looking southeast to the ocean. Assuming that the photographers are all about the same height and were standing when they took the shots, the berm elevation covers far more of the view of the ocean in November than it did in June. The cross section below shows why.

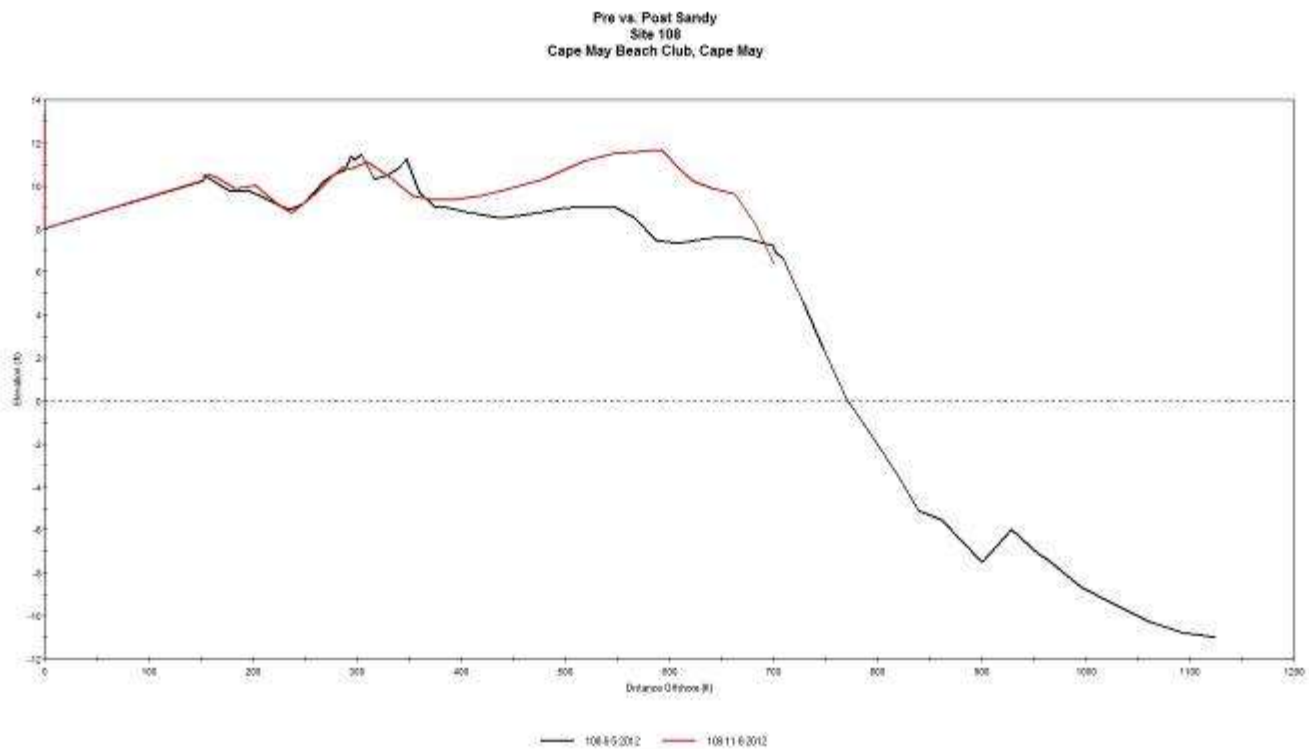


Figure 10. The northeastern most site in Cape May City is occupied by the Cape May Beach Club. Here the beach remained essentially the same width, but with up to 3 vertical feet of sand deposited on the dry sand between the berm crest and the small dunes landward. The deposit covers 300 feet horizontally and amounts to 22.63 yds³/ft. of sand from up drift or offshore deposited above high tide by the storm. The CRC staff captured NJ surf cam views of ocean waves on October 28th and 29th prior to the loss of electric power and the Cape May City camera recorded absolutely picture-perfect 8-10 foot breaking waves ideal for surfing. These waves came to the Cape May City shoreline suited for building up sand beaches, not eroding them. The data for sites #105, 206, 107 and 108 bear this out since all exhibit deposition on the upper dry beach accompanied by some erosion of the beachface.

US Coast Guard Base, Lower Township, Cape May County, Site #208;



The left picture was taken March 9, 2012 looking toward the sea. The natural areas were surveyed last and done with normal procedures, so the length of the surveys are equal and extend well off shore. The outfall line shows in both photographs (December 11th for the right side) and shows that little change in beach elevation occurred. The berm was eroded somewhat and transported toward the dunes. Water reached into the new foredune area directly landward of the vehicle and washed up into the second ridgeline. The new, white sand in the center of the right photo is not present on the left side.

Pre vs. Post Sandy
Site 208
Cape NWR, Lower Township

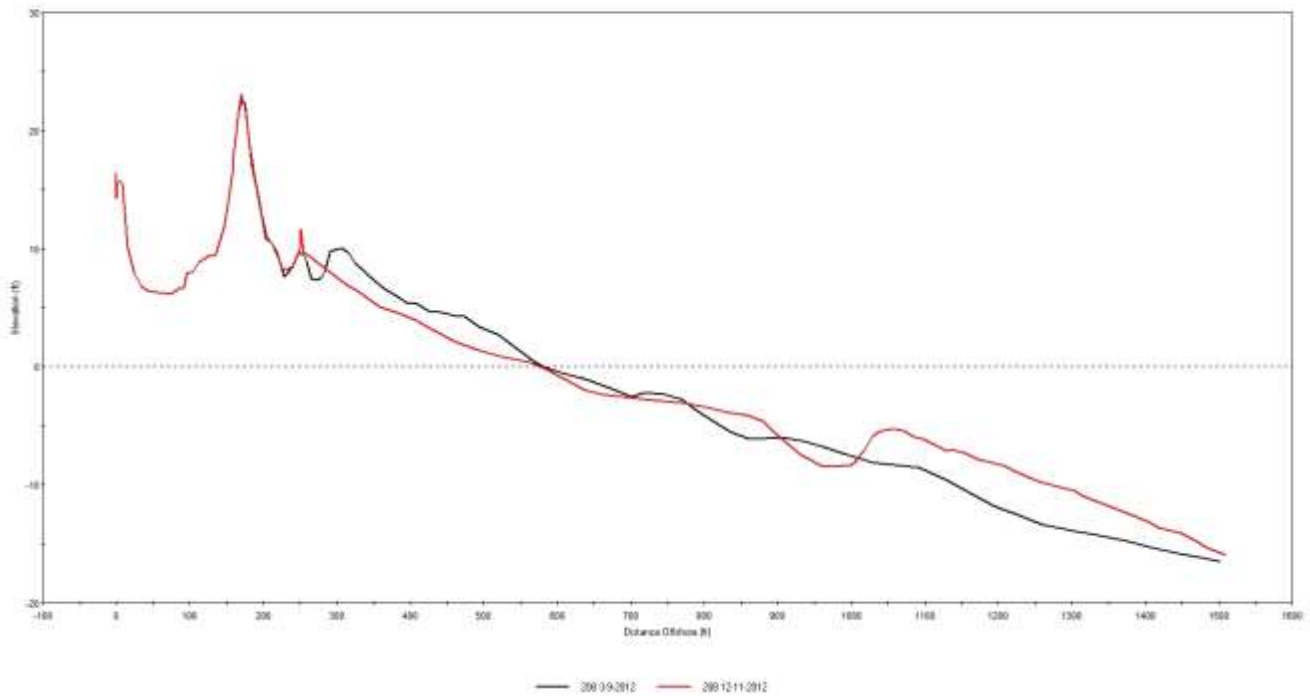


Figure 11. The small foredune was eroded away along with the upper berm on the beach. Bar material was becoming organized offshore by December 11, 2012 when this site was surveyed following Sandy.

Raleigh Avenue, Lower Township, Cape May County, Site #109;



The early spring photograph of the beach taken April 4, 2012 is shown on the left. The right-hand view was taken November 29th a month after the storm. Here sand was forced landward to the toe of the dunes where a deposit filled in a slightly lower part of the beach than the berm. The sand on the berm was likely the source of the deposit since the storm surge flooded the entire dry beach.

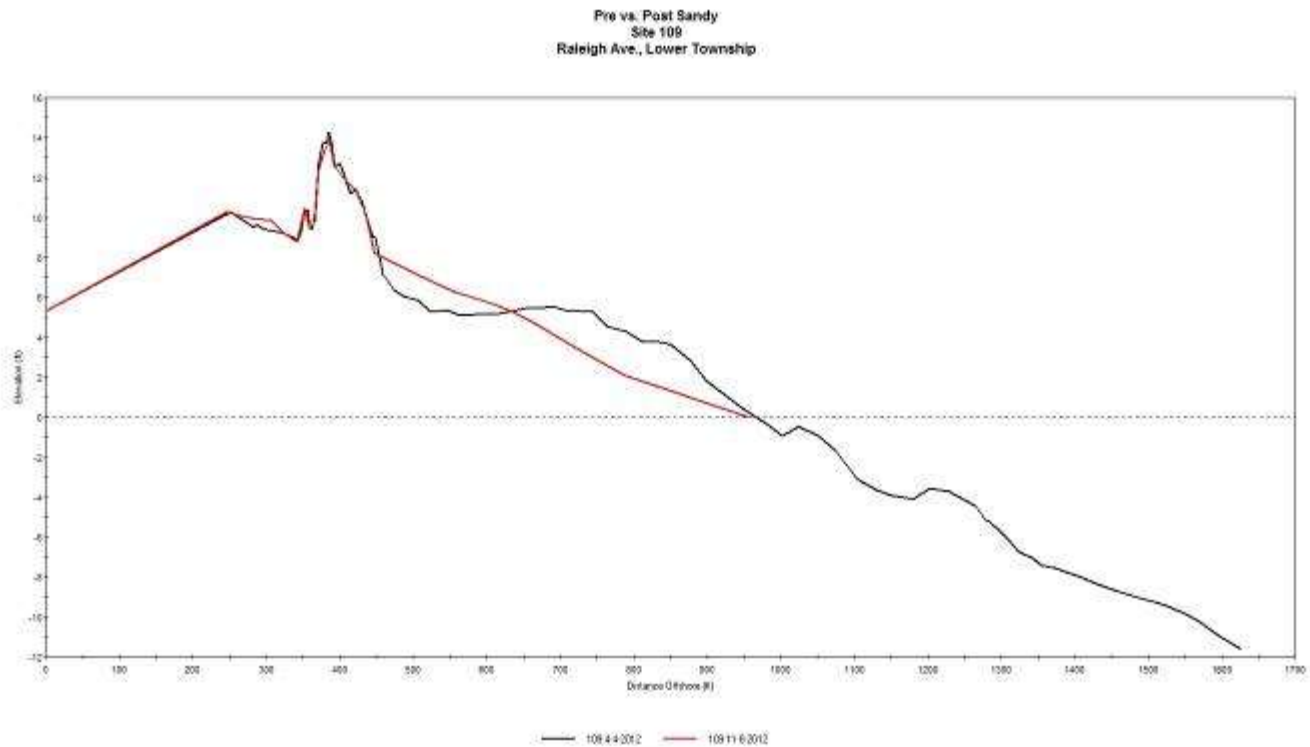


Figure 12. The storm's beach flattening power is evident here as the berm was planed off and sand pushed landward into the seaward dune slope. The losses slightly exceeded the gains above the zero elevation datum. One would expect that sand was also deposited offshore rearranging the offshore bars.

Cresse Avenue, Wildwood, Cape May County, Site #110;



On April 4, 2012 the view across the beach in Wildwood was taken from the tiny dune in front of the boardwalk. The November 29th view on the right was taken from the same location, but minus the sign. The beach gained sand at the berm 600 feet seaward of the boardwalk. The sand deposit probably was derived from the erosion of the spring survey's berm.

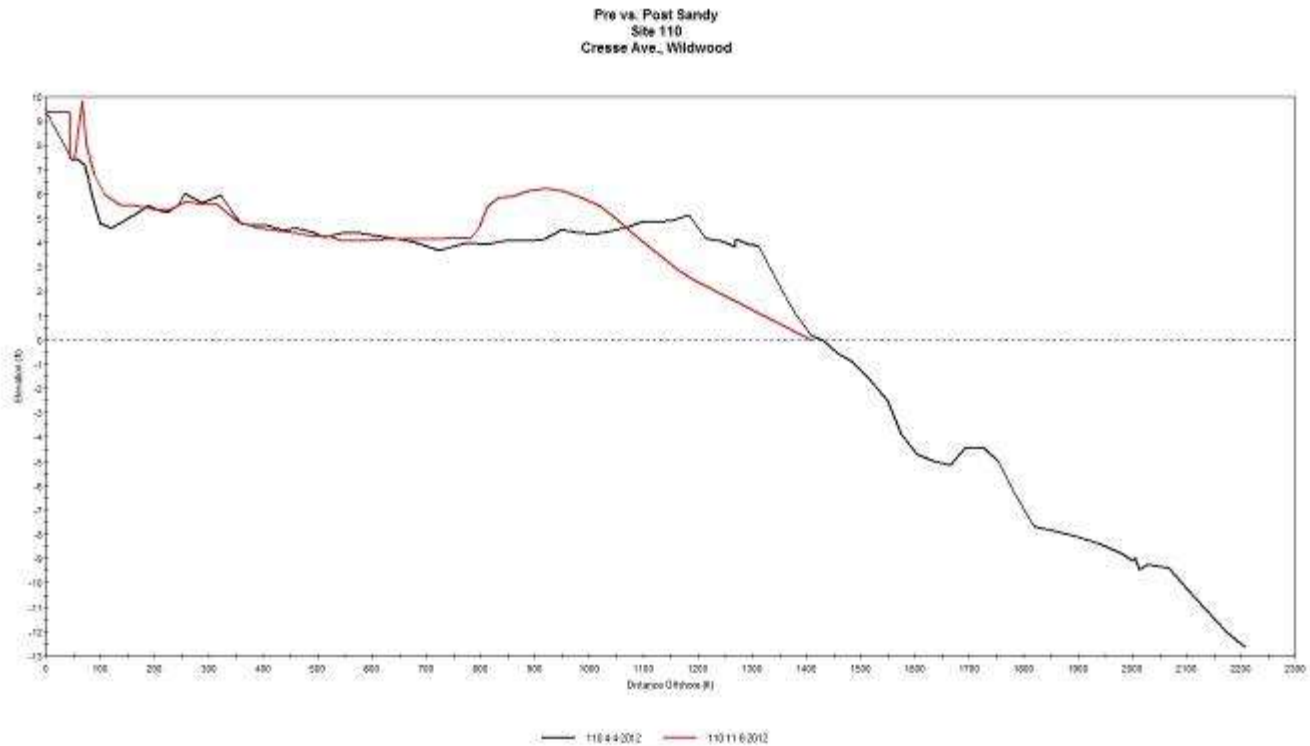


Figure 13. The beach in Wildwood responded differently by having the berm and upper beachface moved landward by 250 feet and deposited as a “super berm” well above sea level. One unanticipated consequence of this style of deposition is that future seawater over-topping of this deposit could cause serious flooding by trapping rain plus seawater between the berm and the City. The City has been plagued with repetitive “berm-top ponds” in the past and this looks like a potential issue.

15th Avenue, North Wildwood, Cape May County, Site #111;



The view to the southeast from 15th Avenue dune crossover was taken April 4, 2012. The picture following Sandy was taken on November 29th and is on the right. Summer dune grass growth shows in spite of the storm. The waves did flow across the entire dry beach (seen on TV, channel 10 Monday morning) and ramped up a deposit onto the seaward dune toe. No dune breach occurred near this location. Further south at the piers, the dune was erased because it was built to pass seaward of the pier ends and was far more exposed to wave action. Erosion at the very northeast corner of the City also removed the dune south to 4th Avenue and over-topped the bulkhead revetment there.

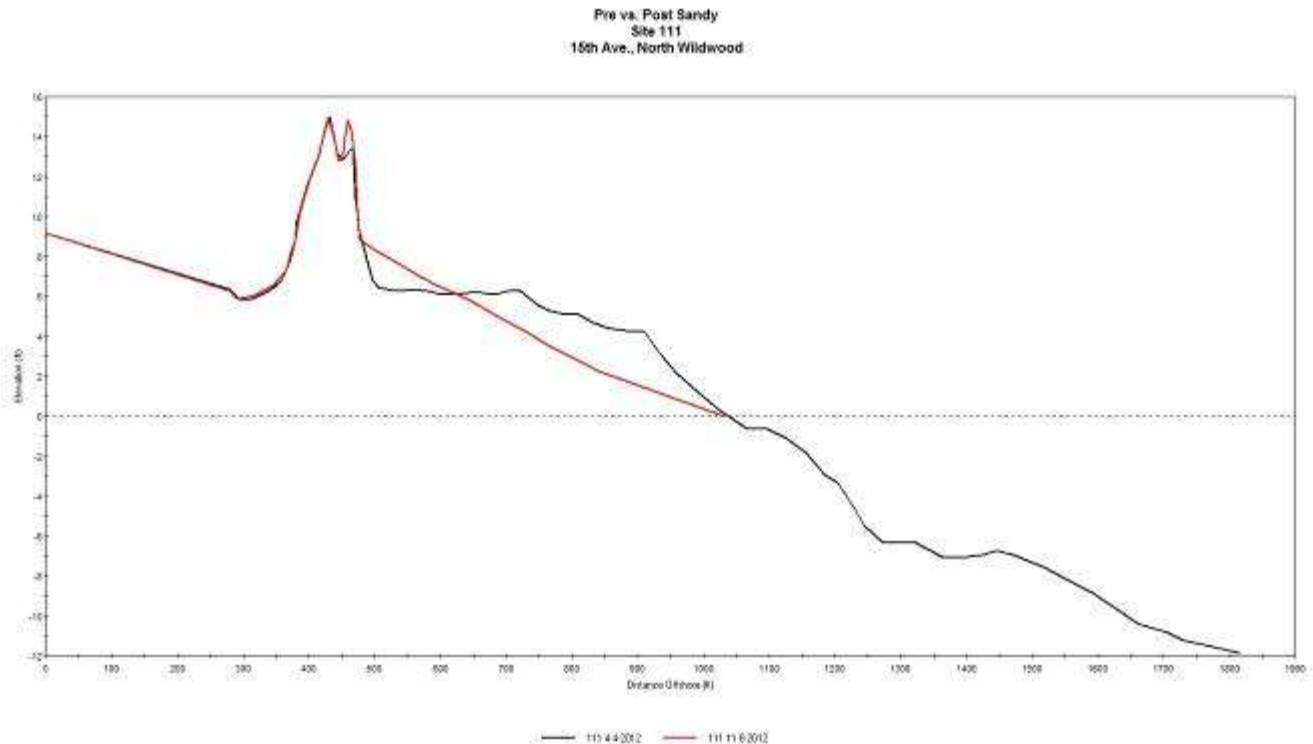


Figure 14. This North Wildwood site was included in the 2009 beach nourishment project conducted by the State and local funding. Damaged by three northeast storms between November 2009 and December 2010, a FEMA-coordinated repair was completed in late 2011 into 2012. During the spring of 2012 the municipality completed a 93,000 cubic yard sand backpass from the Borough of Wildwood Crest, placing the sand along the dune toe from 3rd Avenue south to 7th Avenue. The dry beach here was dramatically flattened by Sandy with sand pushed up to elevation 9.0 at the seaward dune toe, derived from the seaward berm and beachface. Sand further offshore may move landward to restore some of the lost material over time.

121st Street, Stone Harbor, Cape May County, Site #212;



The southern cross section in Stone Harbor was re-established just north of the terminal rock groin along the Borough oceanfront following the loss of South Point in 1990. The left picture shows the conditions in June 2012 where sand had deposited seaward of an older scarp cut into the dunes, building out to the sand fencing. Sandy eliminated all the newly-deposited material moving the beach landward uniformly by 50 feet. The catamarane pilings show a closer proximity to the surf after Sandy than prior to the storm (Nov. 8, 2012). The erosional cut in the dunes returned to approximately the location of the cut made in November 2009.

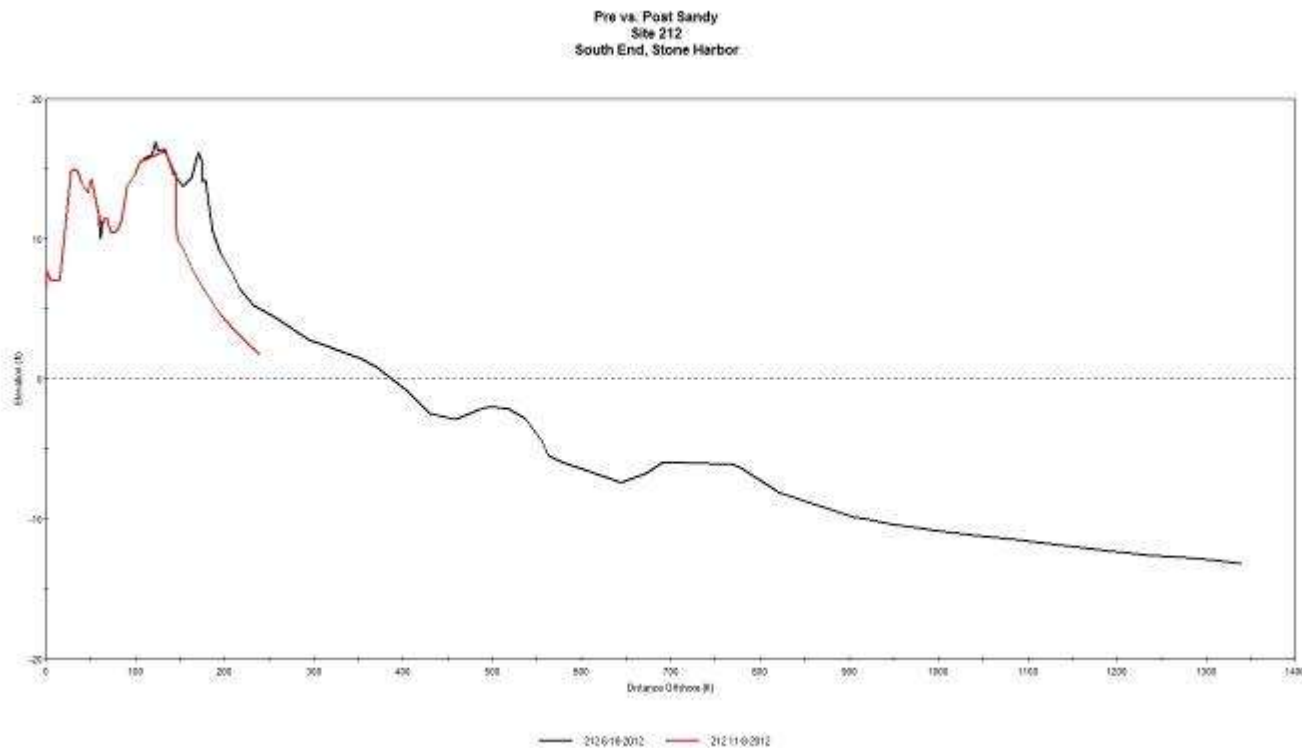


Figure 15. Sandy cut into both the dune and beachface pushing the shoreline position landward by 50+ feet. Sand was moved to the dune crest, likely by the wind, because other pictures show no grass damage above the scarp. The sand volume to produce dune recovery will likely need to come from mechanical transfer unless it is decided to allow nature to once again bring beach sand to the dune fencing when it is re-established.

90th Street, Stone Harbor, Cape May County, Site #113;



The left photograph was taken October 24, 2012 just prior to Sandy. The right picture was taken October 31, 2012 and shows the effects of lowering the berm elevation and some minor dune toe erosion. This site did not suffer significant erosion damage and no overwash beyond the dune toe area.

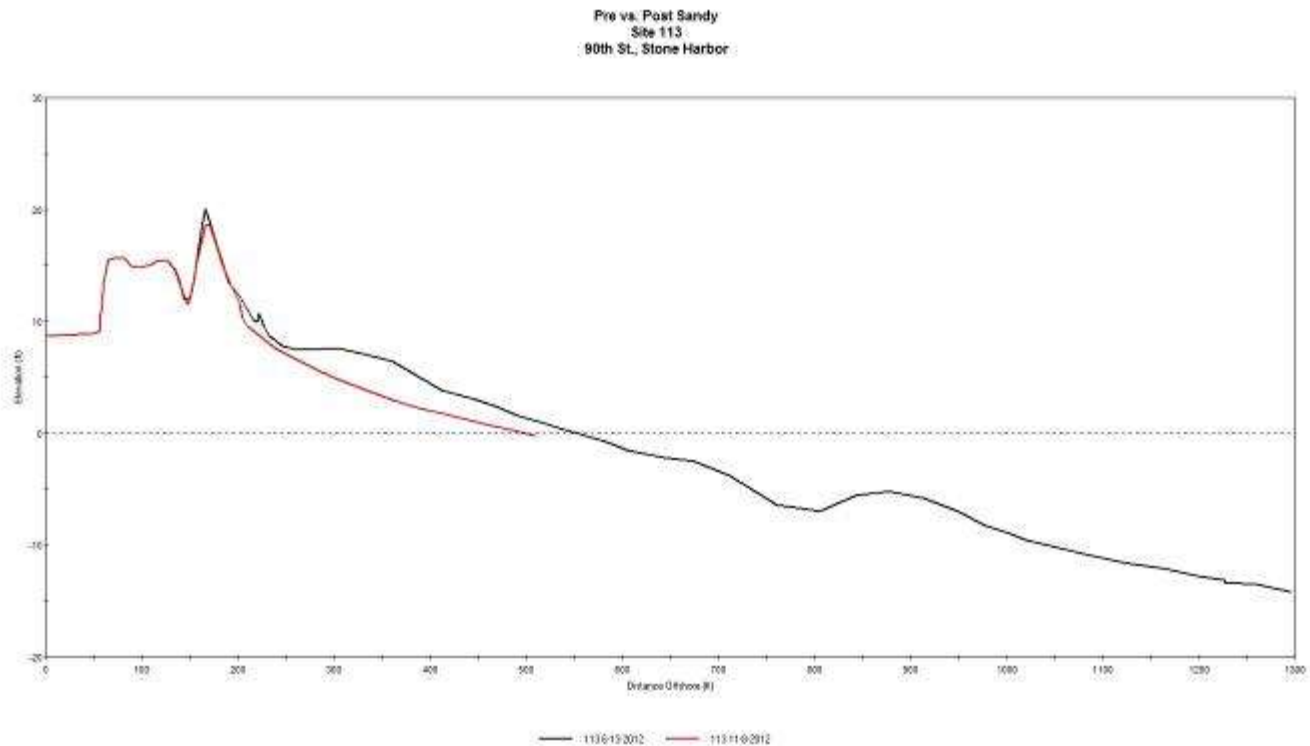


Figure 16. The two cross sections show modest berm loss as sand was likely transferred offshore and to the south by the strong littoral current flow. The dune toe damage should recover naturally.

70th Street, Avalon, Cape May County, Site #114;



The left picture was taken September 28, 2012 during the late summer survey, and the nearly identical view was obtained October 31st just after Sandy. Note that there are two pairs of closely spaced fence posts that have a small angle between them in their vertical positions. The two pairs of posts are present in both photographs and show the loss in seaward dune toe grass and sand. The berm along the ocean's edge was also reduced in elevation.

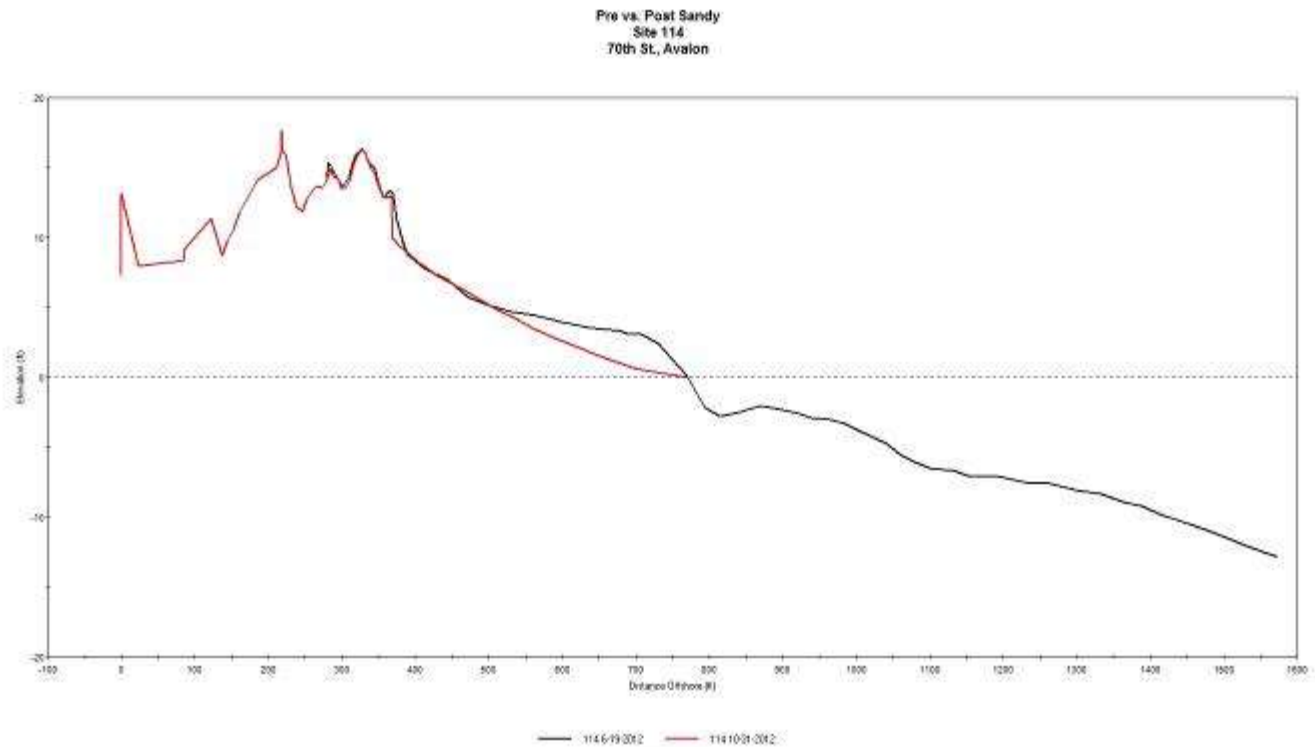


Figure 17. The loss in berm sand was nearly universal north of Wildwood, NJ as the more easterly orientation of the shoreline brought the waves more directly to bear on the coast. The minor loss in dune sand shows at the seaward toe. Storm surge washed among the foredunes, flooding the lower swales between ridges. This water was still draining across the beach when the surveys were done.

35th Street, Avalon, Cape May County, Site #115;



Between September 27th and October 31st, the beach at 35th Street suffered foredune flooding and minor erosion of the seaward toe. Sand was stripped from the berm and washed into the lower elevation dune field. The loss to individual plants can be determined by careful examination of the two photographs.

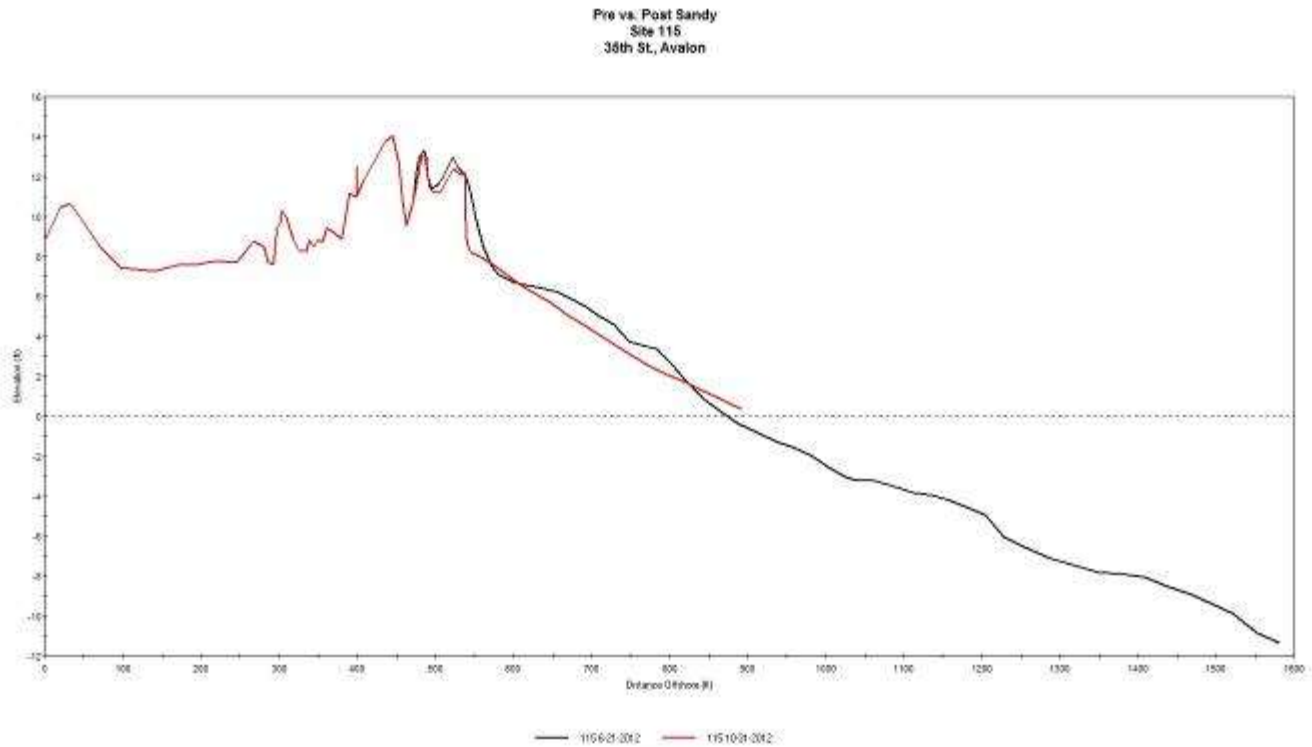


Figure 18. Erosion to the seaward dune toe was minor in nature and of no real significance to shore protection. The wide expanse of dunes allowed the storm waves to flood between or over the lower ridge of dunes at the rear of the beach and simply dissipate their energy over a 500-foot wide expanse of vegetation. The sand loss at the berm was likely transported seaward as the shorter post-Sandy cross section shows at the seaward end.

23rd Street, Avalon, Cape May County, Site #116;



The left picture was taken September 25, 2012 and shows the beach late in the summer with a generous post-sand fill berm present and a healthy season's growth in new dune plants. By October 31st, the beach was much lower in elevation as sand was carried offshore and the dune's seaward slope was cut and sand washed into the grasses. The entrance pathway was truncated at most Avalon street-end entrances.

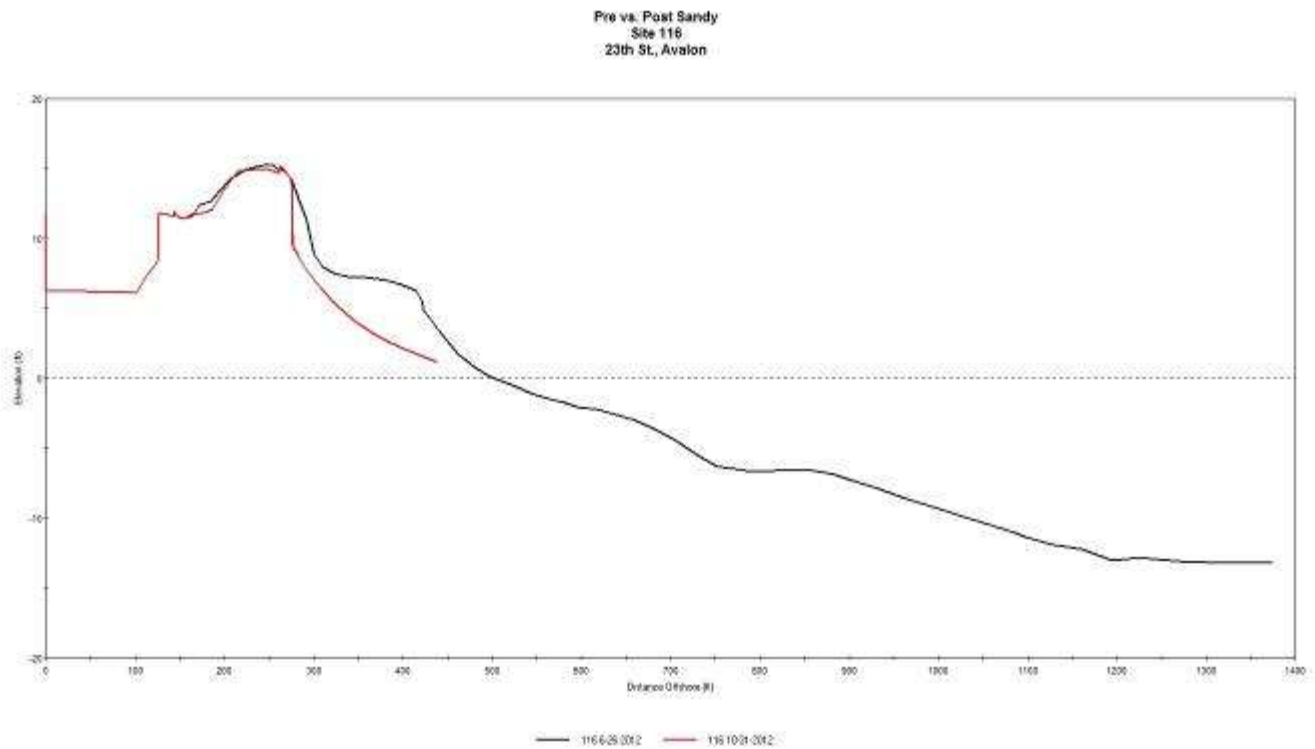


Figure 19. The degree of beach and dune erosion increased toward the north end of the island, with the worst losses seen between this site and the 9th Street position. The loss to the berm makes the dunes susceptible to future storm erosion.

9th Street, Avalon, Cape May County, Site #216;



The September 25th photograph shows the wide berm and seasonal plant growth at the 9th Street site. Following Sandy the fence was taken out as was the wide berm with erosion cutting into the seaward dune toe slope. The litter deposited on the dune slope shows the elevation to which the waves ran up the dunes (14.0 feet NAVD88 in Avalon).

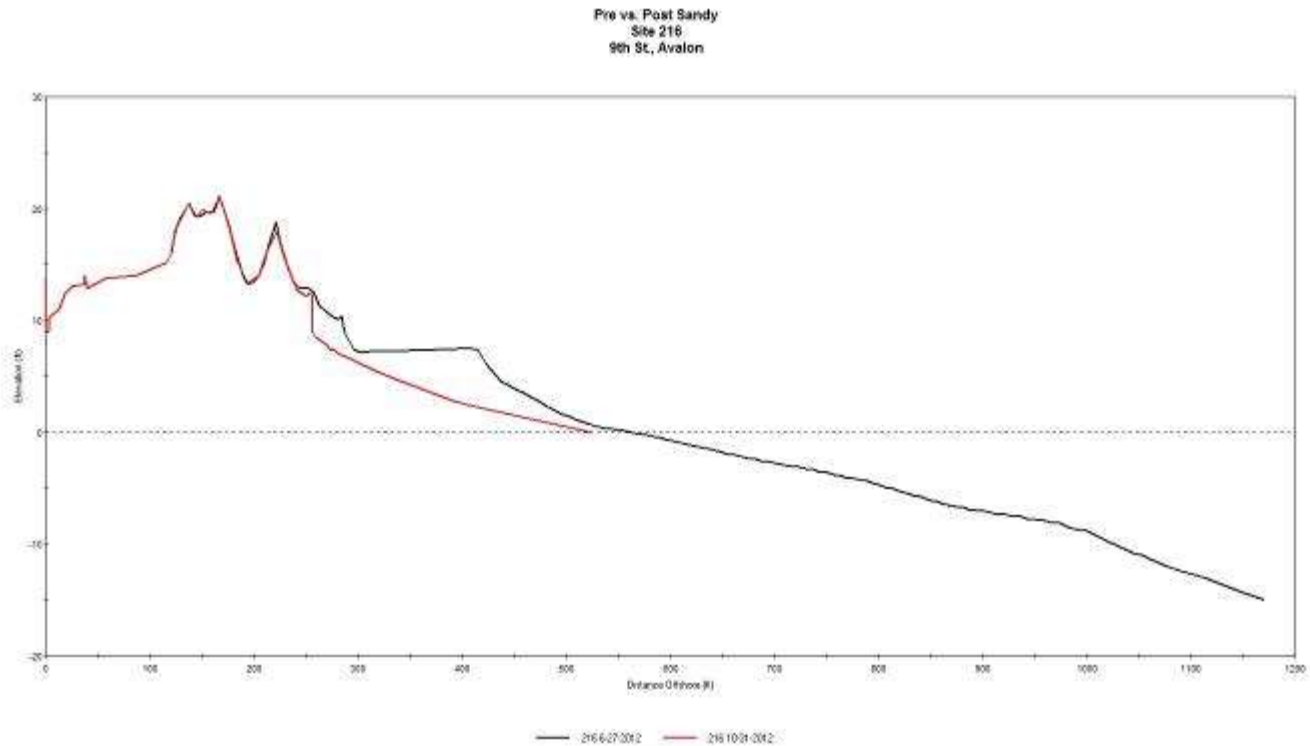


Figure 20, The erosion was significant between 23rd Street and 9th Street removing the wide berm deposited during the recent beach maintenance completed in 2011. The lost sand was carried offshore and to the south.

80th Street, Sea Isle City, Cape May County, Site #117;



On October 22, 2012 the beach possessed a recently deposited foredune developed at fencing installed in the past year. The beach was wider and higher than the scene following the storm. On the right, the post-Sandy clean-up was responsible for the deposition of sand, washed inland, having been hauled back to the beach to form a linear ridge to help with future storm protection.

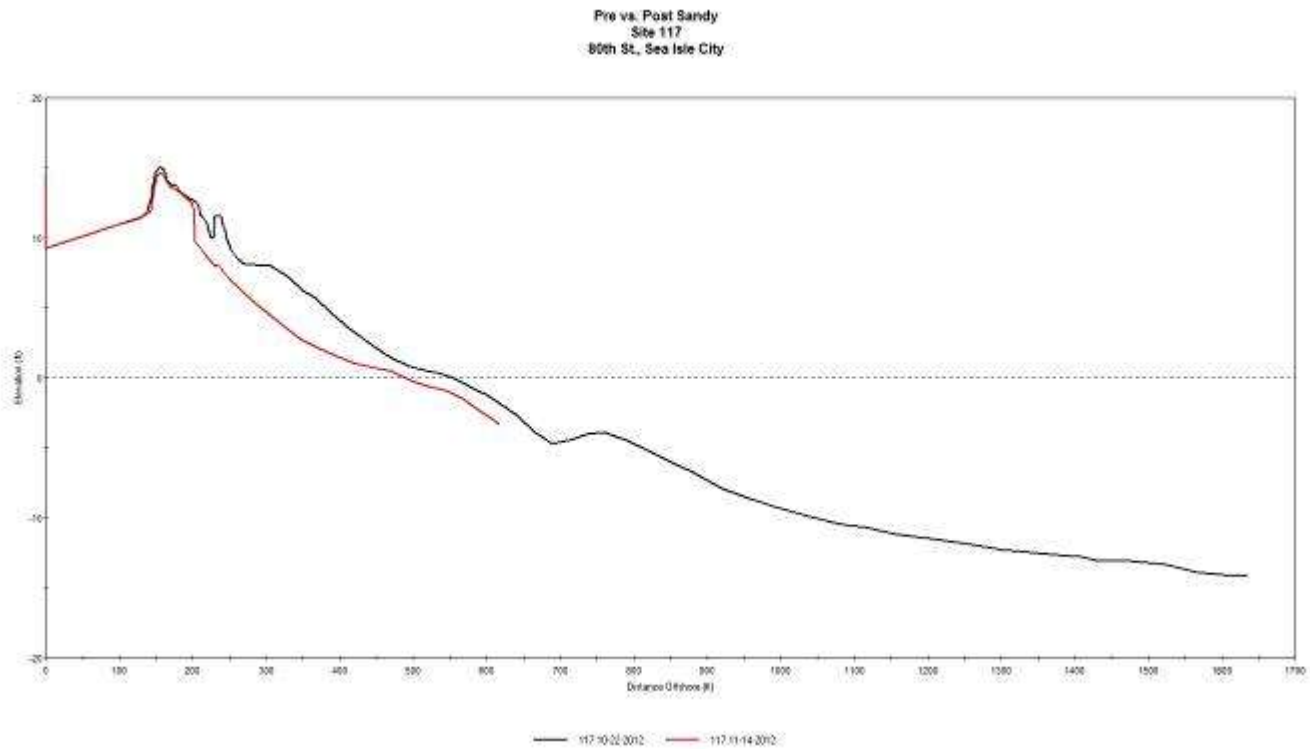


Figure 21. The dune was impacted by retreat and the total loss of the newer fore dune built around recent fencing. The berm was reduced in elevation and the shoreline retreated about 45 feet.

57th Street, Sea Isle City, Cape May County, Site #118;



The left picture was taken October 22, 2012 and shows the dune system landward of a wide, dry beach. Following Sandy on November 14, 2012, the beach was much lower in elevation and the dune was carved away nearly to the crest. The scarp had slumped two weeks later, but the impact can clearly be seen below.

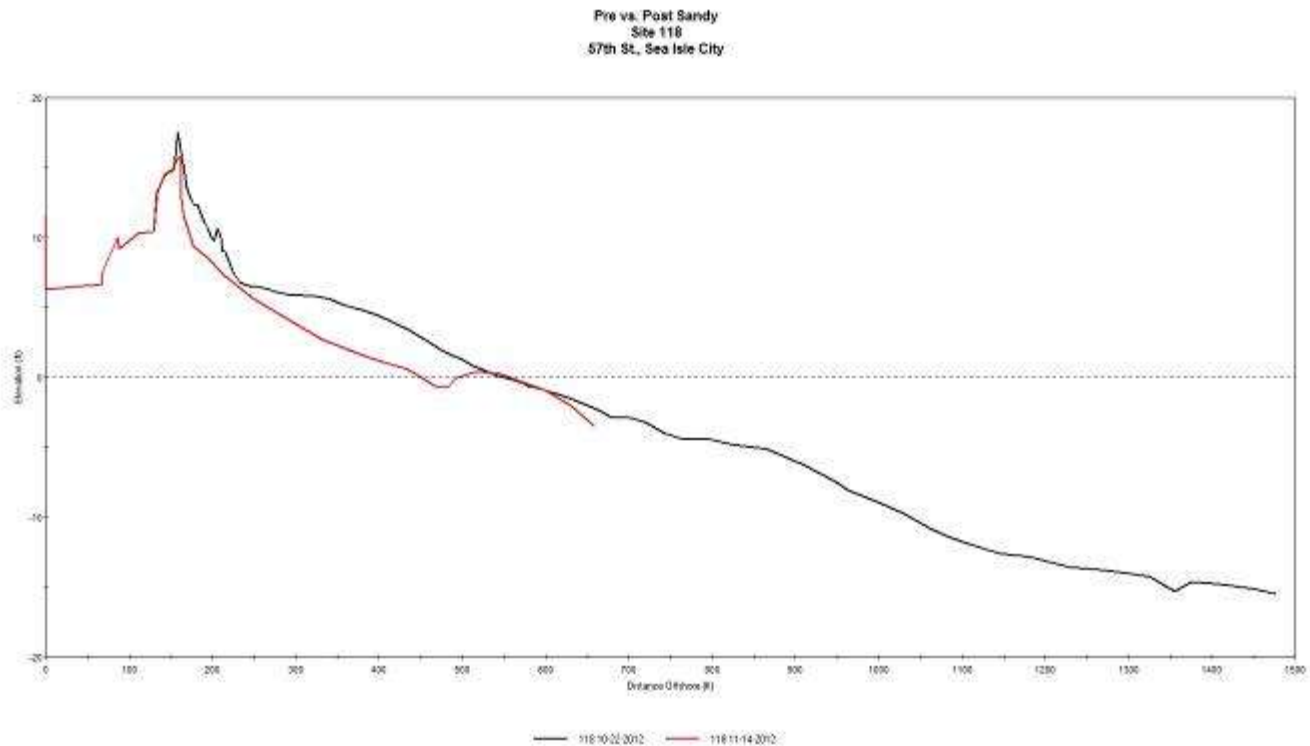


Figure 22. The loss to the dune was greater at 57th Street as the berm was scoured over three feet vertically in spots. The sand was likely transported seaward beyond the limits of the short post-Sandy surveys.

25th Street, Sea Isle City, Cape May County, Site #119;



On October 22, 2012, the beach was relatively wide and dry with a decent new deposit of sand along the recent fencing installed at the seaward toe of the dune system. After Sandy on November 14, 2012 the beach was lower in elevation, all the fencing was missing and sand was pushed back into the dunes, up the seaward slope.

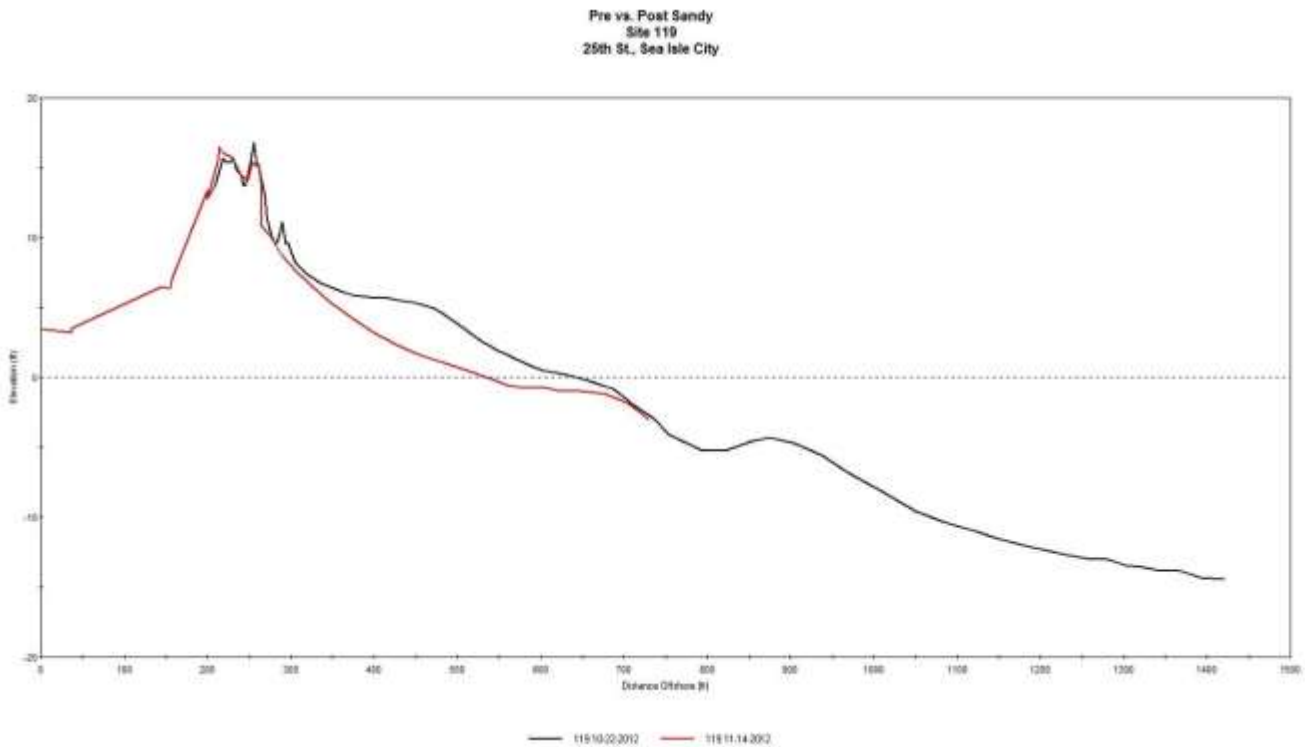


Figure 23. The sand volume loss was concentrated on the berm with the majority of the sand moved further seaward than the post-Sandy profile, or moved south along the shoreline. The dunes withstood the waves allowing overwash only at low elevation pedestrian access pathways.

1st Street, Sea Isle City, Cape May County, Site #120;



This location is on the boundary between Sea Isle City and Strathmere along the main (and only) road parallel to the ocean. The sand transported into the dune by October 17, 2012 was washed across by Sandy as seen on the left picture on November 14, 2012. Some minor breaching occurred along Commonwealth Avenue, but the dune remained relatively in tact.

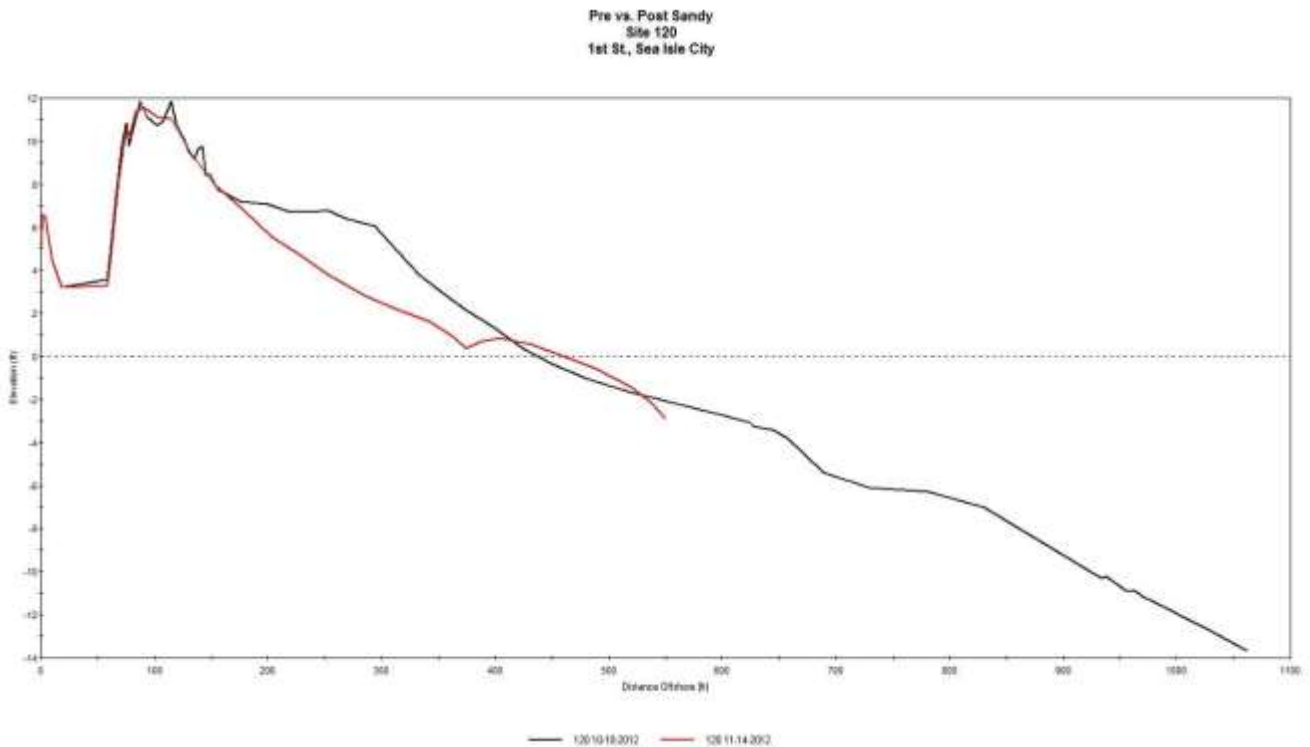


Figure 24. The beach was scoured, removing the berm and a large amount of sand that was transported offshore and carried south along the coast. The dunes were just high enough to withstand the wave onslaught without failure.

Williams Road, Strathmere, Cape May County, Site #121;



The left picture was taken October 17, 2012 looking across the wide dune zone area seaward of the primary feature. On November 5, 2012 the same view following Sandy shows that the area was flooded by waves that knocked down the highest primary dune, but did not flood the immediate landward area. The beach was flattened by the storm surge. The dune removed was only three feet higher than the post-storm feature however.

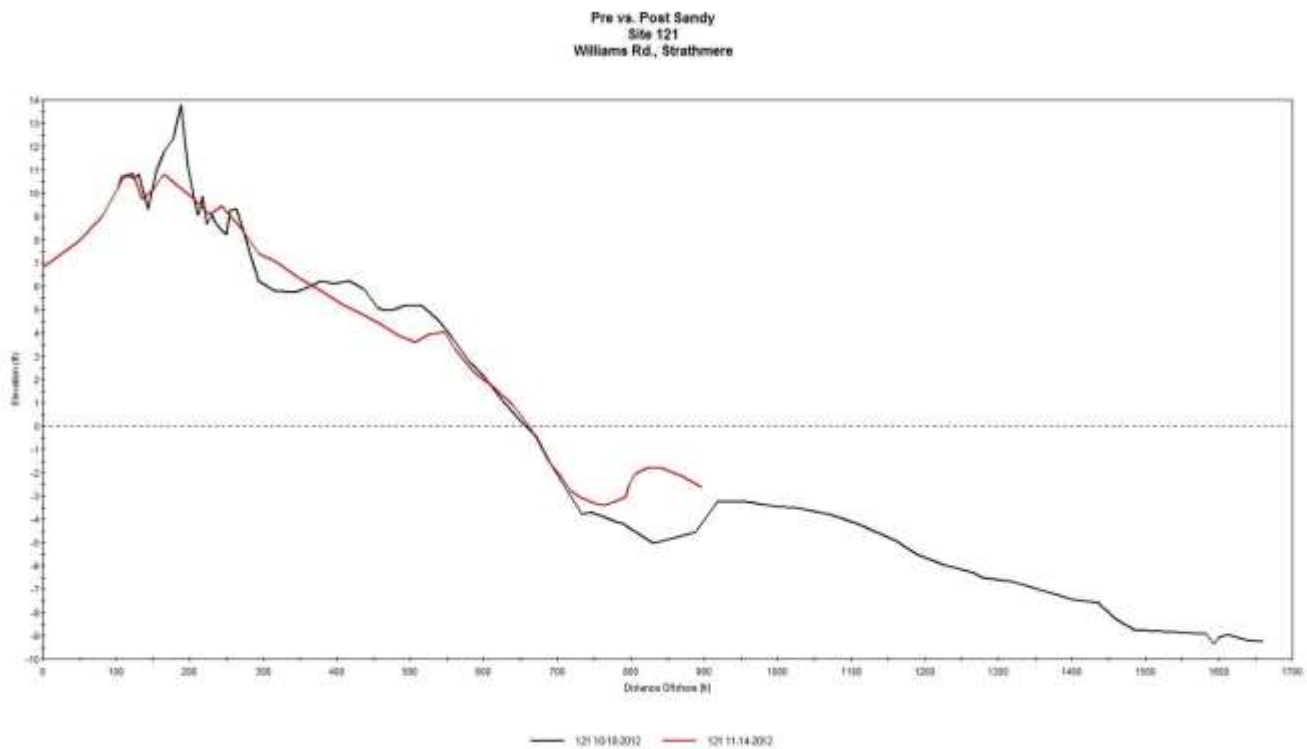


Figure 25. The cross sections do show the transport of sand offshore as well as the extensive flattening of the beach surface all the way into the dunes. The graph is extremely vertically exaggerated and the dune removed was only 3 feet higher than the surroundings.

59th Street, Ocean City, Cape May County, Site #222;



The left picture, taken March 9, 2012, shows an erosional scarp in the spring of 2012. This condition did not change during the summer and the waves during Sandy carved deeply into the remaining dunes. The erosion reflected up the beach into the southernmost development in Ocean City as well. The left picture was taken November 28, 2012 and shows large scale wash over and inundation of the lower sections of the dune system. The scarp was pushed landward a minimum of 155 feet with loss in elevation to the remaining dunes because the erosion passed the crest of the main dune ridge.

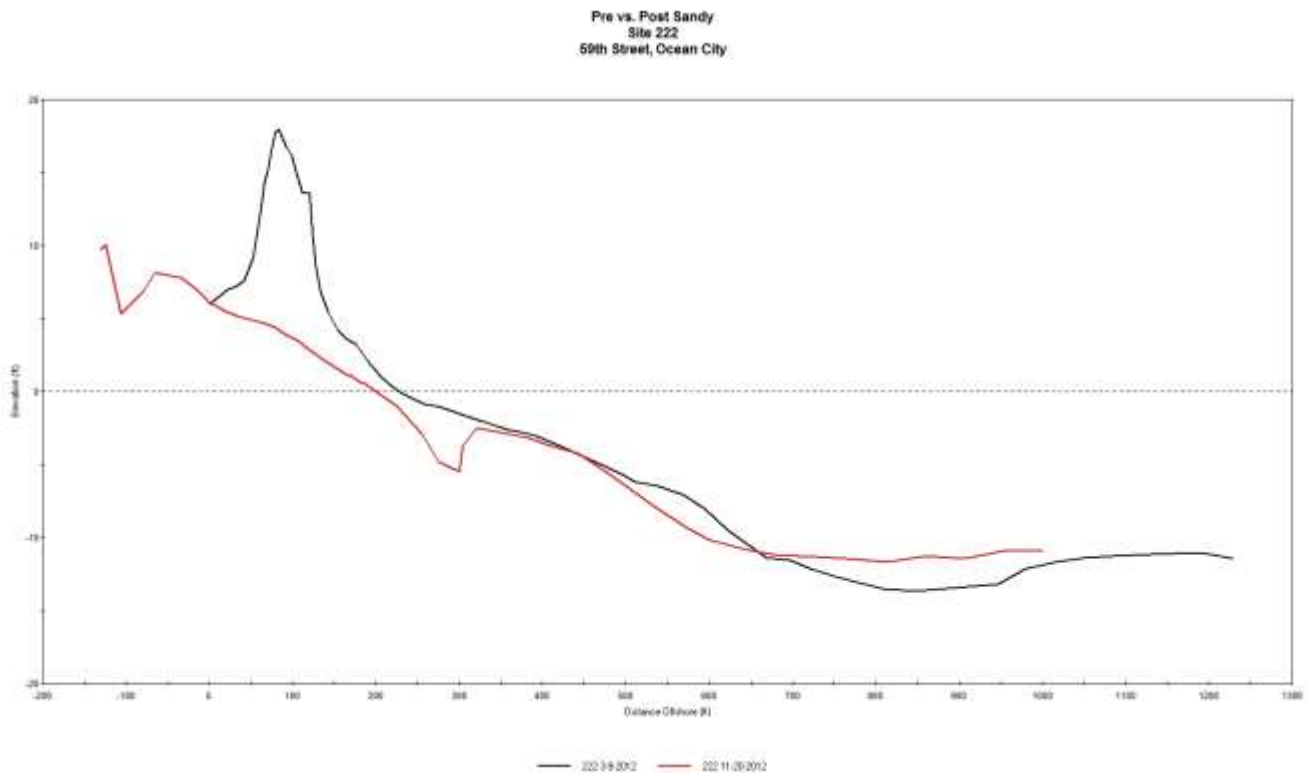


Figure 26. The primary dune was lost entirely as over 150 feet of landward migration occurred. Sand was deposited offshore, well outside the normal cycle of cross-shore movement possibilities in the future. Bar material was migrating back to the beach by November 20, 2012, almost a month after the storm.

Corson's Inlet State Park, Ocean City, Cape May County, Site #221;



Positioned about a half-mile south of the development in Ocean City, the site has been one where the dune was repeatedly under erosion attack since the spring of 2012. Sandy hit this site pretty hard as a result of a narrow, low elevation beach. The November 28, 2012 picture on the right shows that the higher elevation dune was removed and the water pushed inland over lower elevation vegetation. There is an older, vegetated dune line over a hundred feet further landward that finally stopped the storm surge.

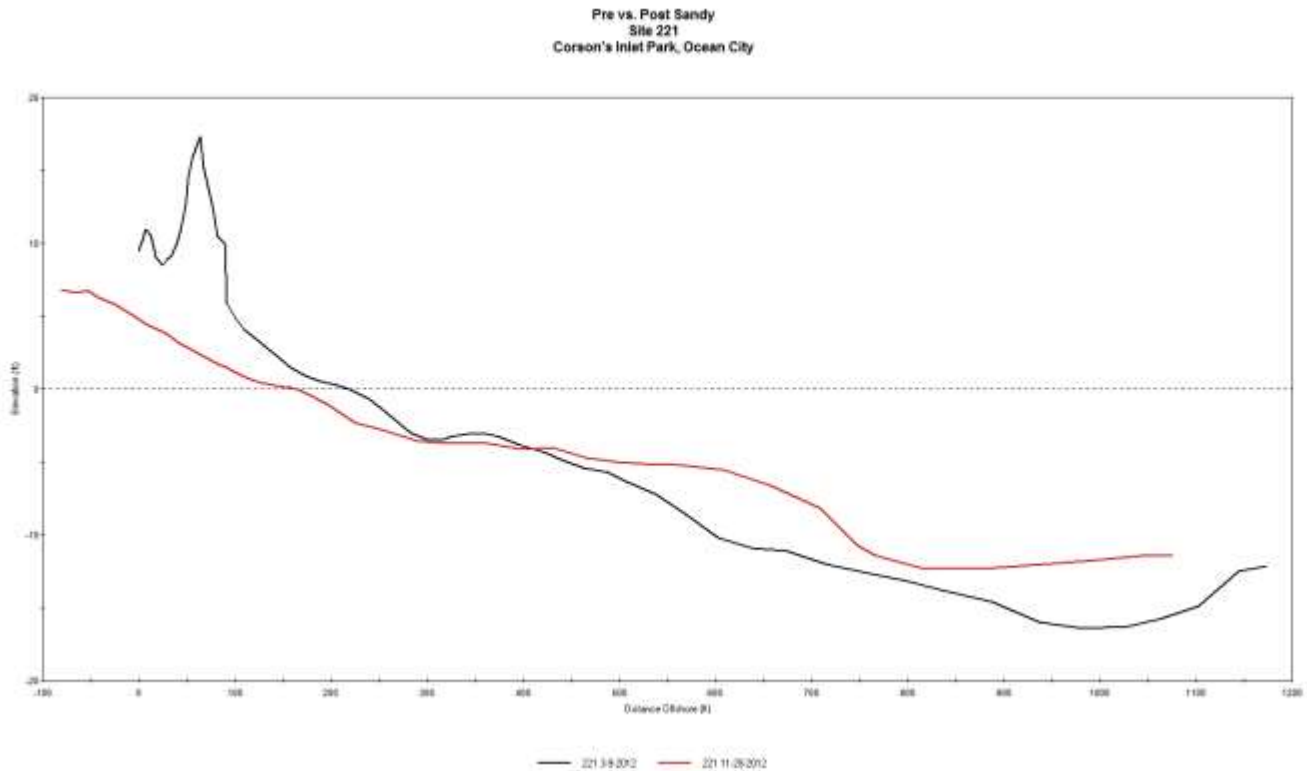


Figure 27. The landward retreat at the mid-point along the Park's Peck's Beach shoreline was about 160 feet with no significant dune remaining to block further retreat. Huge volumes of sand were deposited offshore due to littoral transport added to the volume carved from the local site's beach and dune. The zone of erosion came to 37.1 yds³/ft. while the gain offshore doubled that loss (63.2 yds³/ft.). This sand will most likely accumulate on the ebb-tidal delta shoals surrounding Corson's Inlet.

56th Street, Ocean City, Cape May County, Site #122;



The left photograph was taken October 26, as Sandy was approaching NJ. Machines were deployed pushing up a ridge of sand seaward of the existing dunes at this site. Sandy overwhelmed the shore protection, jumped the old bulkhead and washed well inland producing damage and flooding. The right picture was taken November 6th and shows recent bulldozing efforts to provide a small measure of protection for homes with nothing between them and the sea.

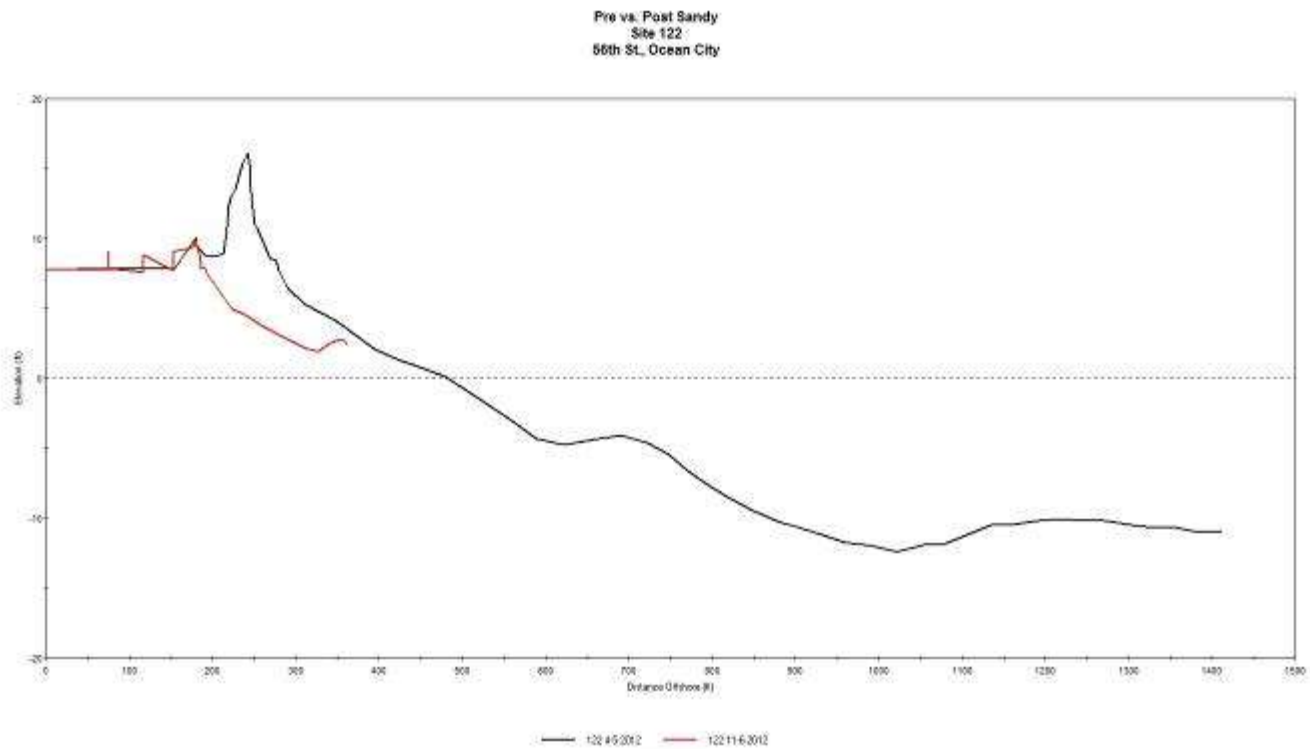


Figure 28. The southern 10 blocks of Ocean City had seen the 1995 beachfill deteriorate to the point where the dune was not protected by much beach width and the dune was not much over 50 feet in base width as well. The shoreline was pushed back toward the homes and the erosion was substantial.

34th Street, Ocean City, Cape May County, Site #223;



The 34th Street site has always possessed a low threshold dune that really is little more than a mound with a wide access path for both vehicles and pedestrians. The March 2, 2012 view shows the relatively wide dunes north of the site, but the storm barreled through the pathway into 34th Street landward. The piles of sand on the right picture were transported back to the beach as of November 28th. The beach berm was cut back, but since this site was surveyed a month following the storm a new berm was in the process of reconstruction.

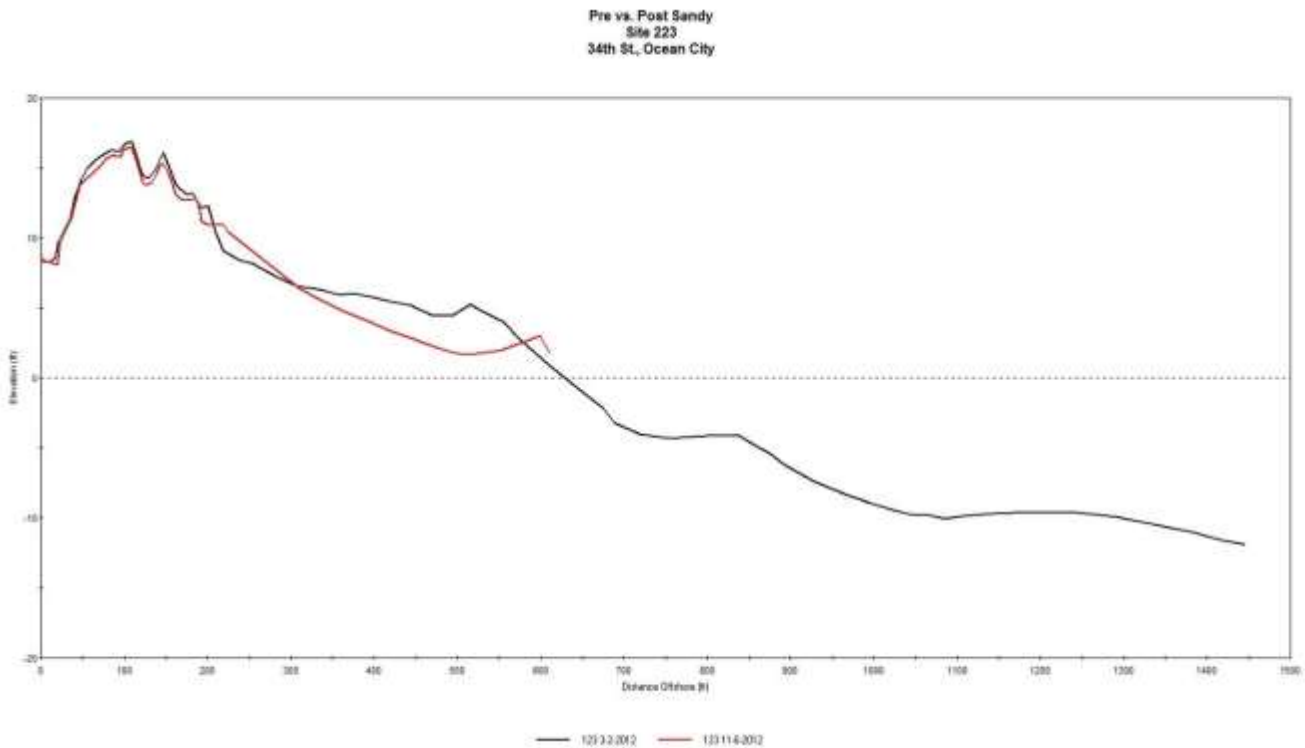


Figure 29. The sand was pushed up to the toe of the dune where the dune was developed to its regional elevation, but in the 34th Street pathway, the wide gap allowed water to flow into the city with considerable volume of sand transported. The month-after survey also shows the speed of sand recovery from offshore with a berm crest and beachface built on the erosional surface following the storm.

20th Street, Ocean City, Cape May County, Site #124;



The 20th Street site is at the maximum retention of beach restoration sand anywhere along the oceanfront. This site has seen the shoreline move seaward by 600 feet since the 1980's with 460 feet of dunes. The photograph on the right was taken March 2, 2012 showing the beach and gentle gradient into the seaward-most dune ridge. Following Sandy on November 6, 2012 the zone of about 150 feet in width had been inundated by the storm surge with sand pushed landward into the first major swale. The berm was lowered as would be expected without much shoreline retreat.

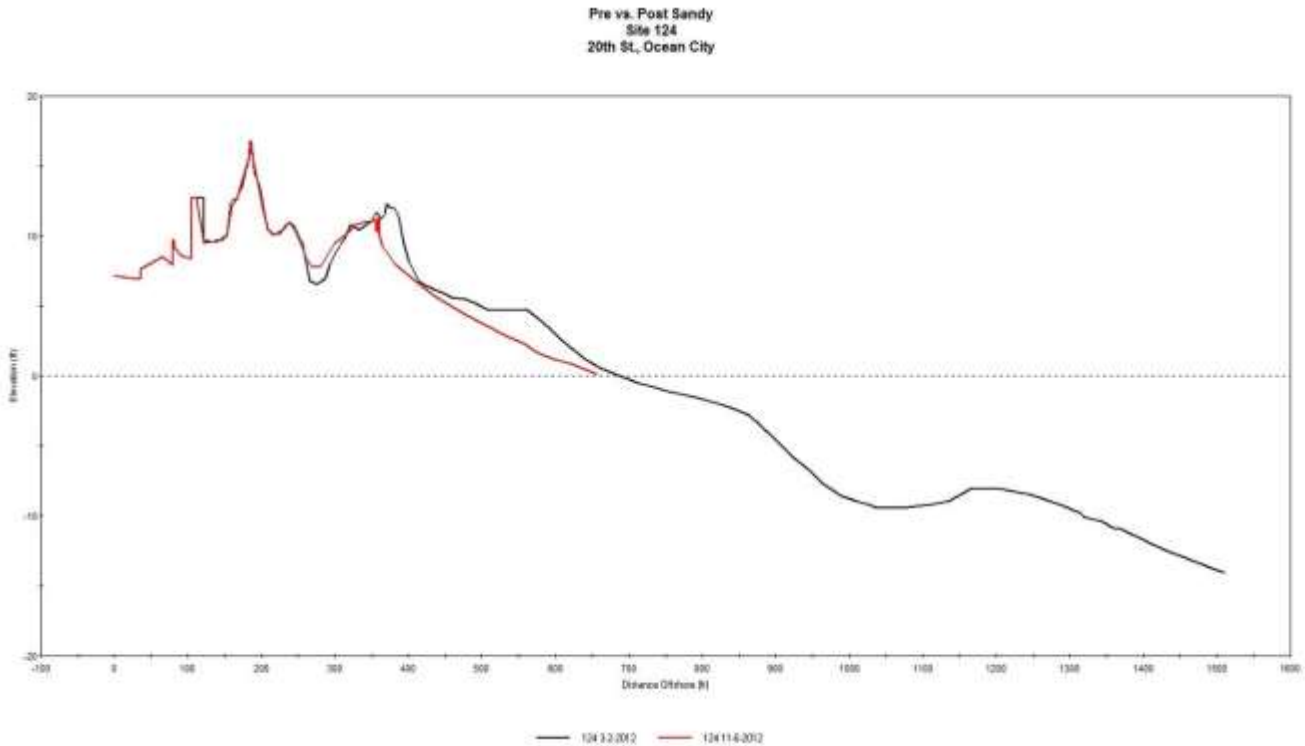


Figure 30. The boardwalk was once at the low tide line, now well removed from wave activity. The dune at the seaward limit of vegetation was truncated and washed into with berm sand deposited across the back slope and into the swale.

6th Street, Ocean City, Cape May County, Site #125;



The left photograph was taken October 26, 2012 just prior to the storm. The dune was in tact, but the beach was extremely narrow so the initial storm action was able to attack the dune. The right photograph was taken November 6, 2012 from the back shot position standing on the street end paving that had been excavated of sand, looking seaward to the boardwalk about 120 feet seaward. The sand had been deposited to the top of the timber by the storm surge. The wedge of sand was swept landward of the boardwalk.

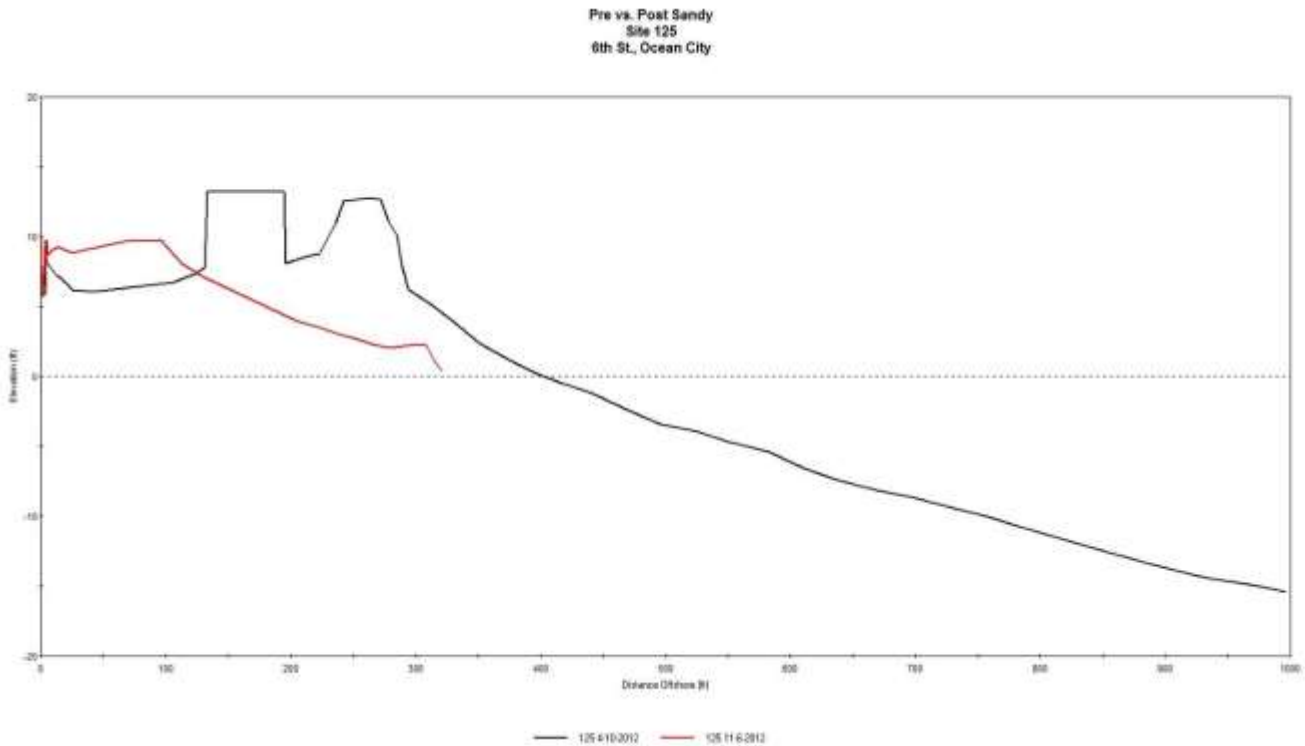


Figure 31. The cross section shows the setup leading to dune failure. The beach slope seaward begins immediately seaward of the dune toe and reaches zero elevation in about 100 feet. The retreat amounts to 200 feet placing 10-foot elevation sand landward of the boardwalk with a beachface slope under the structure after Sandy.

Gardens Road, Ocean City, Cape May County, Site #225;



Between October 26 and November 6, 2012 Hurricane Sandy removed 125 feet of dune vegetation at elevation 12.0 NAVD 88 or higher. The beach was not wide and occupied just 50 feet between the seaward dune toe and the zero elevation position. The home in both pictures was impacted with water inside due to wave surges, but could be repaired. The large pine trees actually helped save the home.

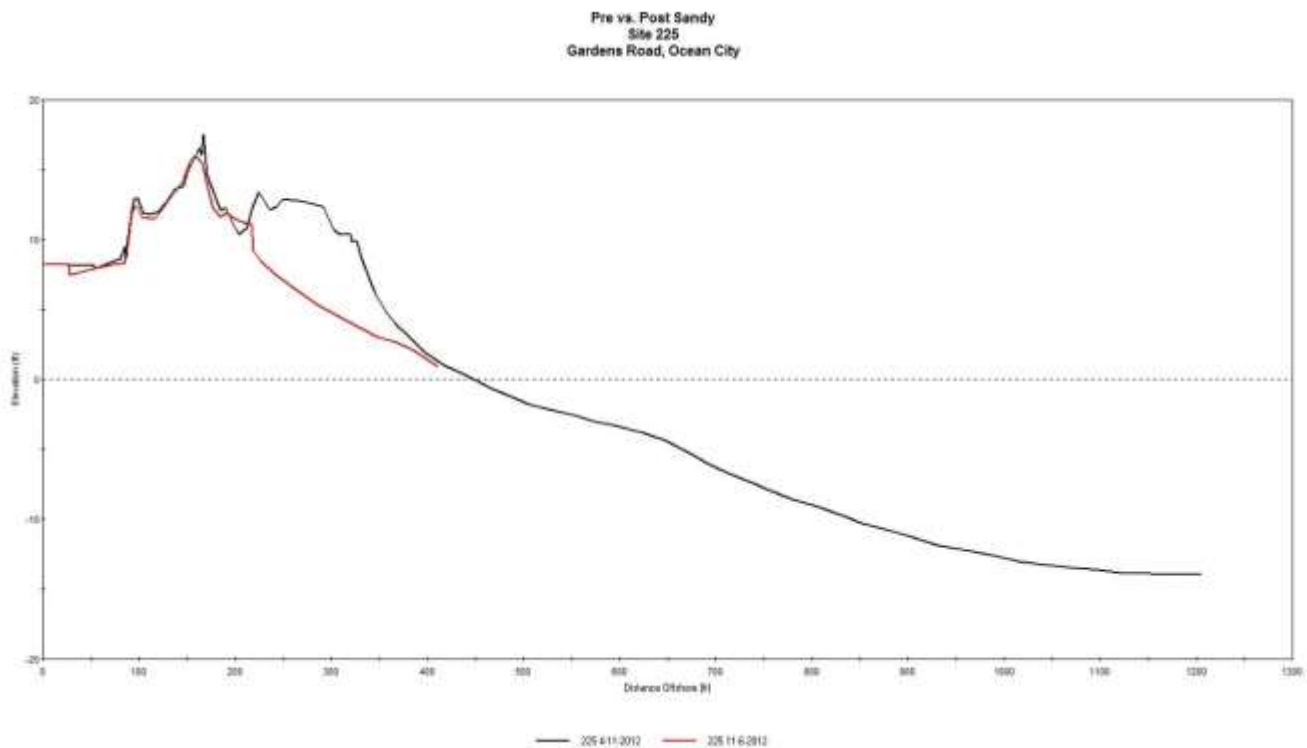


Figure 32. The dune was removed to the landward ridge at this location. The pedestrian pathway was a conduit for wave and water inundation. Sand was being hauled back to the beach at the time of the post-storm survey. The beach slope did closely match the April survey used as the pre-storm illustration.

Summary of Cape May County's Sandy impacts:

Cape May County's good fortune was greatly assisted by being located south of where the center of Sandy's rotation came ashore in New Jersey. The "eye" passed over northern Atlantic County about 9pm Monday night and produced a rapid change in the wind direction from the north-northeast to southwest. This acted to blunt the impact of the second high tide and reduce the wave height somewhat. Values of the elevation for wave run-

up on dunes were between 13.5 and 14.5 feet NAVD 88 elevation. This was ten feet lower than similar measurements made in Long Branch, Monmouth County. In addition, many of the Cape May communities had been participants in the Philadelphia Army Corps Shore Protection projects starting in 1989 in Cape May City. Wide beaches with in-depth dune protection provided all the storm-stopping power needed to prevent wave damage and the flooding of the oceanfront streets with sand. A few places suffered mostly due to narrow beaches unable to limit wave impacts on the dunes. The horizontal erosion rates during Sandy were sufficient to cut through and produce overwash into Ocean City in spots, Sea Isle City in a few places, and in Wildwood where there was no dune to stop the water in spite of having the widest municipal beach in New Jersey. In 2009 a dune was incorporated into a beach restoration design for a NJ State – locally sponsored project with the City of North Wildwood. This dune served to demonstrate the difference in wave damage dunes yield even for a community with an extremely wide natural beach.

The table below shows the sand volume change between either the earlier fall survey at each site or the spring 2012 survey (natural sites) and the post-Hurricane Sandy survey.

<i>Cape May County Post-Sandy Site Volume Changes</i>				
Site Location and Number	NJBPN Site #	Site Sand Volume Change (cu yds/ft)	Dune Failure (Y or N)	Date of Recent Beach Fill
Ocean City	225	-31.39	Y	2010
Ocean City	125	-37.19	Y	2010
Ocean City	124	-15.25	N	2010
Ocean City	223	-18.24	N	2010
Ocean City	122	-27.45	Y	1995
Ocean City	222	-40.81	Y	1995
Corson's Inlet S Park	221	26.11	Y-Partial	Never
Strathmere	121	5.70	N	2012
Sea Isle City	120	-16.46	N	2012
Sea Isle City	119	-29.57	N	2012
Sea Isle City	118	-31.43	Y-partial	2009
Sea Isle City	117	-33.99	N	2009
Avalon	216	-26.79	N	2011
Avalon	116	-21.38	N	2012
Avalon	115	-6.95	N	Never
Avalon	114	-15.26	N	2011
Stone Harbor	113	-24.37	N	2011
Stone Harbor	212	-17.41	N	2011
North Wildwood	111	-18.94	N	2011
Wildwood	110	-1.34	No Dune	Never
Lower Township	109	-10.83	N	Never
Lower Township	208	29.08	N	Never
Cape May City	108	22.47	N	2010
Cape May City	107	15.34	N	2010
Cape May City	206	-3.34	N	2010
Cape May Nature Con	105	-16.04	N	2011
Cape May Point	104	-5.08	N	2010
Higbee Beach S Park	103	3.91	N	Never
North Cape May	102	-8.74	N	Never
Villas	201	3.57	N	Never
Reeds Beach	100	-3.56	Y	2010

Cape May County Post Sandy Volume Changes

MUNICIPALITY	NJBPN Site#	Vol Change cu yds per ft	Average of Sand Loss Between Adjacent Sites (cy/ft)	Dune Failure	Recent Beach Fill	Distance Between Sites (FEET)	Vol Change - Cubic Yards Between Profiles (South to North)	Cumulative Volume Change - Cubic Yards (South to North)
Ocean City	225	-31.39	To Inlet	Y	2010	1,006	-31,578	-31,578
Ocean City	125	-37.19	-34.29	Y	2010	3,820	-130,997	-162,576
Ocean City	124	-15.25	-26.22	N	2010	8,108	-212,591	-375,166
Ocean City	223	-18.24	-16.74	N	2010	7,885	-132,027	-507,193
Ocean City	122	-27.45	-22.85	Y	1995	12,271	-280,328	-787,521
Ocean City	222	-40.81	-34.13	Y	1995	2,264	-77,287	-864,808
Corson's Inlet S Park	221	26.11	-7.35	Y-Partial	Never	1,739	-12,786	-877,593
Strathmere	121	5.70	15.90	N	2012	1,241	19,733	-857,861
Sea Isle City	120	-16.46	-5.38	N	2012	7,961	-42,834	-900,694
Sea Isle City	119	-29.57	-23.02	N	2012	6,824	-157,057	-1,057,752
Sea Isle City	118	-31.43	-30.50	Y-partial	2009	9,078	-276,889	-1,334,641
Sea Isle City	117	-33.99	-32.71	N	2009	6,087	-199,107	-1,533,747
Avalon	216	-26.79	-30.39	N	2011	500	-15,195	-1,548,942
Avalon	116	-21.38	-24.08	N	2012	3,921	-94,442	-1,643,385
Avalon	115	-6.95	-14.16	N	Never	3,482	-49,314	-1,692,699
Avalon	114	-15.26	-11.10	N	2011	9,780	-108,606	-1,801,305
Stone Harbor	113	-24.37	-19.81	N	2011	5,633	-111,605	-1,912,910
Stone Harbor	212	-17.41	-20.89	N	2011	9,833	-205,405	-2,118,315
North Wildwood	111	-18.94	-18.17	N	2011	3,582	-65,099	-2,183,414
Wildwood	110	-1.34	-10.14	No Dune	Never	9,987	-101,239	-2,284,653
Lower Township	109	-10.83	-6.08	N	Never	11,296	-68,718	-2,353,371
Lower Township	208	29.08	9.12	N	Never	3,638	33,198	-2,320,174
Cape May City	108	22.47	25.78	N	2010	5,757	148,387	-2,171,787
Cape May City	107	15.34	18.91	N	2010	2,667	50,424	-2,121,363
Cape May City	206	-3.34	6.00	N	2010	9,470	56,841	-2,064,522
Cape May Nature Con	105	-16.04	-9.69	N	2011	1,736	-16,819	-2,081,341
Cape May Point	104	-5.08	-10.56	N	2010	8,393	-88,616	-2,169,957
Higbee Beach S Park	103	3.91	-0.58	N	Never	9,934	-5,801	-2,175,758
North Cape May	102	-8.74	-2.41	N	Never	7,008	-16,914	-2,192,672
Villas	201	3.57	-2.58	N	Never	19,154	-49,484	-2,242,156
Reeds Beach	100	-3.56	0.01	Y	2010	35,265	282	-2,241,874

Figure 33. This table illustrates the changes in sand volume for the 31 Cape May County beach sites with the sand volume for the beach/dune part of the profile in cubic yards of sand per foot of shoreline at that site. The distance between sites (not counting inlets) allows an estimate of sand volume lost between profile locations that are compiled for the entire county in the right-hand column. Local site sand volumes in RED denote locations where Sandy added sand to the beaches and dunes.

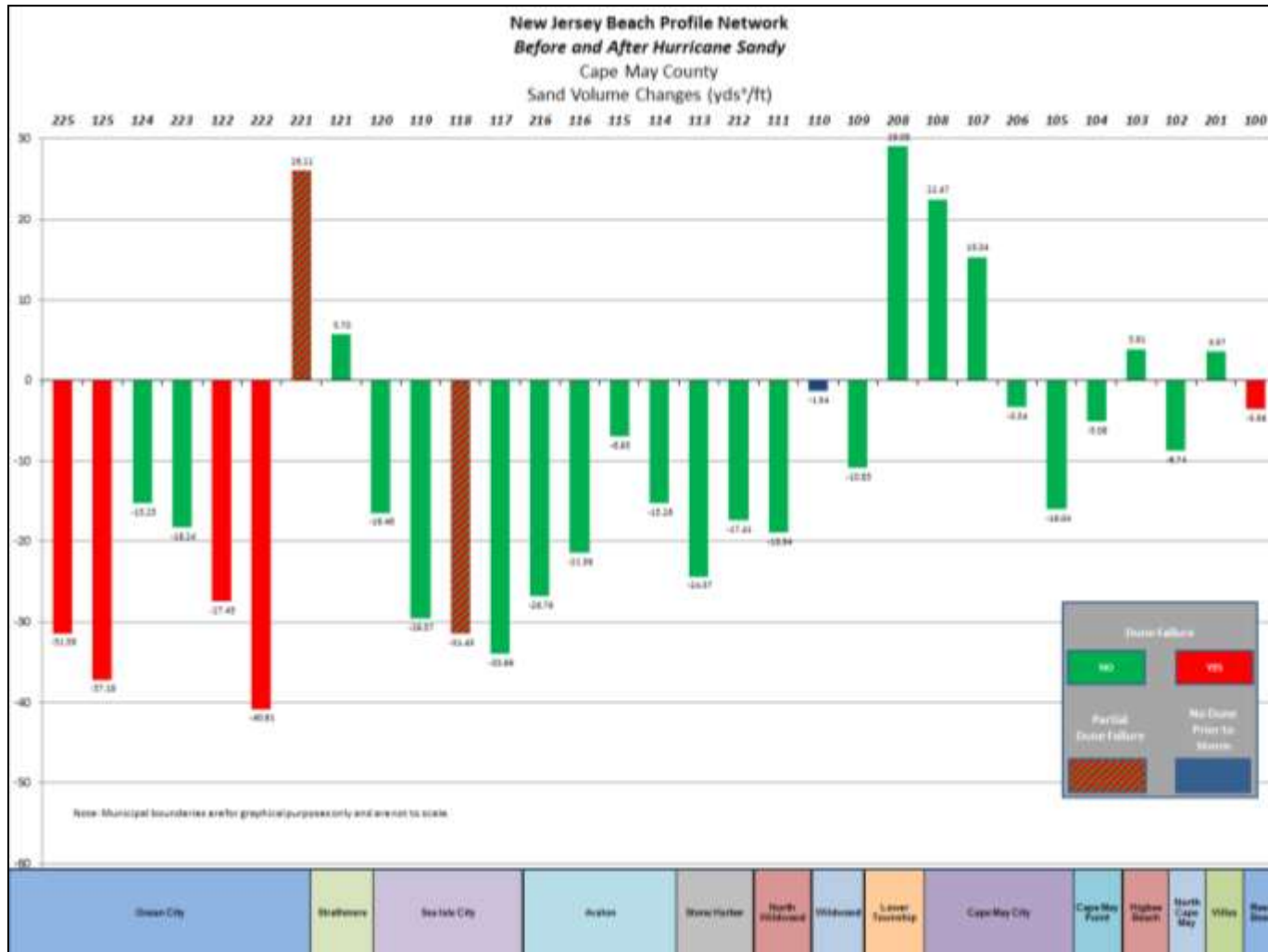


Figure 34. This graphic shows the sand volume loss figures for each of the communities within the developed sections of the Cape May County shoreline. Federal shore protection projects have occurred along this portion of the New Jersey shoreline in Ocean City, Strathmere, Sea Isle City, Avalon, Stone Harbor, North Wildwood, Cape May City, and Reeds Beach. The engineered beach and dune systems have been maintained by the USACE recently and withheld the storm generated waves from breaching the dunes. All sites experienced berm erosion and dune losses except for site 221 Corson’s Inlet State Park, which is undeveloped, site 121 in Strathmere, which recently completed a beach nourishment project, sites 208 Cape May National Wildlife Refuge, sites 108 and 107 in Cape May City, where the orientation of the storm and location of landfall actually created long period swell waves that built up the beach. There were also moderate gains at site 103 in Higbee Beach State Park and site 201 in the Villas, which is located in the Delaware Bay. True dune failures occurred in Ocean City, where the greatest sand volume losses also occurred and overwash of waves transported sand landward of the beach.