DAMAGE ASSESSMENT REPORT ON THE EFFECTS OF HURRICANE SANDY ON THE STATE OF NEW JERSEY'S NATURAL RESOURCES

FINAL REPORT

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NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

FOR:

HURRICANE SANDY

NATURAL & CULTURAL RESOURCE WORKGROUP

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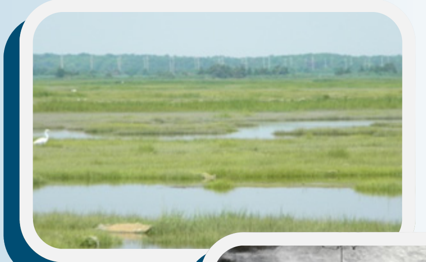

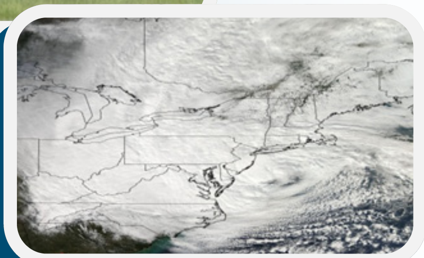

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IMAGE Credits:

Credit: NASA Goddard MODIS Rapid Response Team. NASA's Aqua satellite captured a visible image of Sandy's massive circulation on Oct. 29 at 2:20 p.m. EDT. Sandy covers 1.8 million square miles, from the Mid-Atlantic to the Ohio Valley, into Canada and New England.

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Executive Summary

Hurricane Sandy (October 28, 2012) was the most destructive hurricane of the 2012 Atlantic hurricane season, as well as the second-costliest hurricane in United States history, and the most destructive natural disaster ever to hit the State of New Jersey. Sandy's devastation included:

- 346,000 homes damaged;
- 1,400 vessels sunken or abandoned;
- 70 drinking water systems affected by power loss and damages;
- 80 wastewater treatment plants affected by power loss and damages;
- The entire coastline of beaches experienced significant erosion.

Persistent northeasterly winds over coastal waters, compounded by the astronomically high tidal cycles that coincided with and followed Sandy's landfall, caused water to accumulate and become trapped for a prolonged period along the coast in the bays, harbors, rivers, etc. (NOAA 2013). Coastal damage to human development and natural areas along tidally influenced waterways was immense immediately after landfall. Inland, the effects of strong sustained winds and unseasonably wet conditions caused tremendous tree damage and blow-down, generating widespread damage to infrastructure, buildings, and disruption of public services. Although the impacts to human communities were well documented, comprehensive assessment of damages to natural communities were not thoroughly evaluated.

In coordination with efforts to restore coastal and lowland communities, and to rebuild New Jersey's infrastructure following Hurricane Sandy, damage to specific natural resources was inventoried and rapidly assessed for degree of impact by the New Jersey Department of Environmental Protection (NJDEP). Feedback provided by the NJ State Park Service (SPS), Division of Fish and Wildlife Endangered and Nongame Species Program (DFWENSP), Division of Parks and Forestry - Office of Natural Lands Management (DPF- ONLM), New Jersey Forestry Service (NJFS), Land Use Regulation (LUR), and Bureau of Dam Safety & Flood Control indicated that although significant impacts were reported by field staff, the resources to conduct scientific site assessments, or to adequately evaluate the pre- vs. post-storm viability of these natural areas within the Park System were insufficient. In order to estimate the full extent of natural resource damages, the Department's Natural and Cultural Resources (NCR) Working Group assembled a Damage Assessment Team (DAT) to assess the qualitative and/or quantitative extent of damages to natural resources via surveys of riparian habitat, wetlands, forests and open waters.

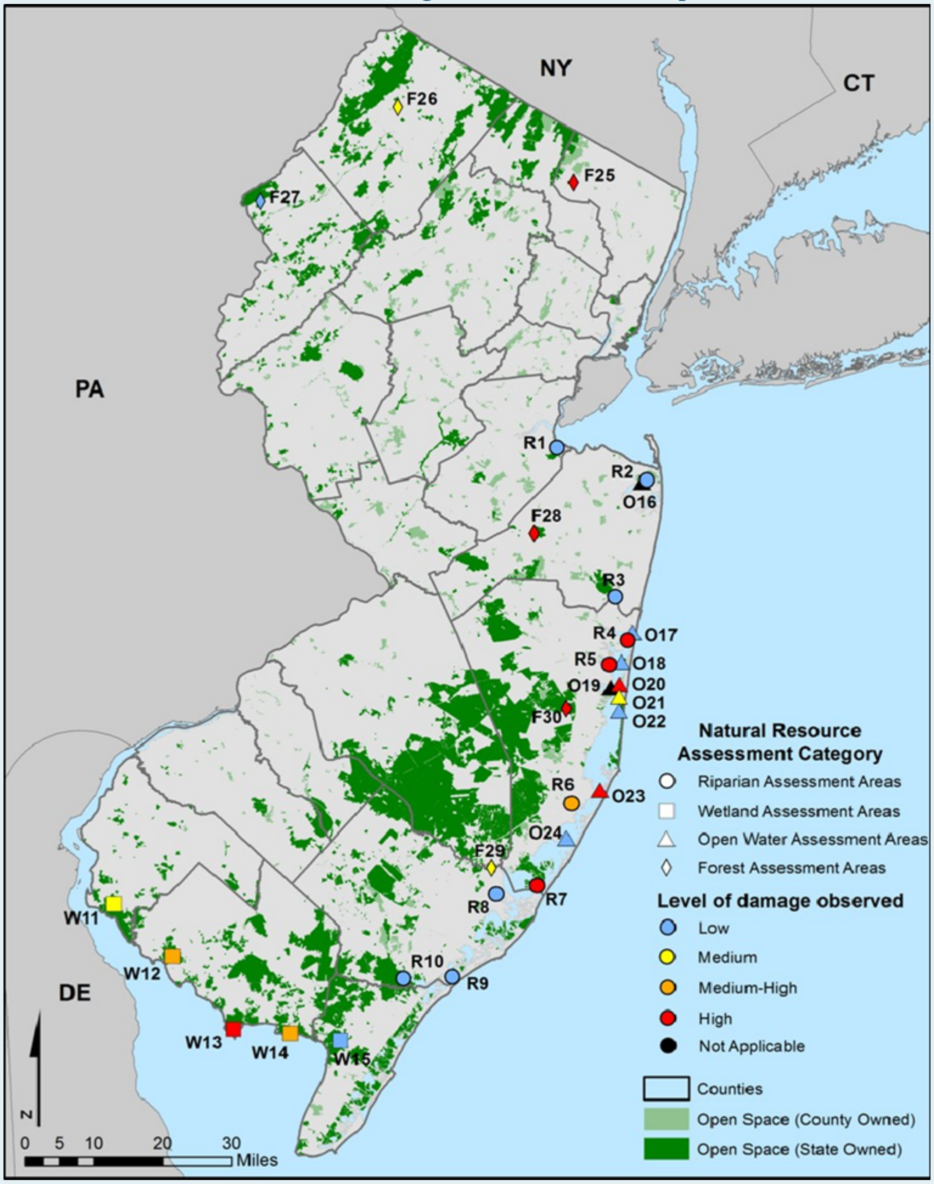
The objective of the natural resource damage assessment surveys as stated above was to investigate realized impacts to "natural areas", those that are undeveloped, maintained as County, State, and Federal lands or natural areas (managed and/or conserved), or otherwise considered environmentally sensitive areas. The DAT determined which resources and areas were the most heavily impacted, and provided recommendations to inform future research and investigation. Additionally, if warranted by the DAT findings, habitat restoration could be contemplated with measured consideration of the estimated cost of rehabilitation, overall benefit to habitat, and other environmental factors, as well as the simple fact that habitat lost for some species may represent additional habitat opportunities for others.

Desktop damage assessments were initiated in April 2013 as a precursor to field investigations and natural resources surveys. Using NOAA post-Sandy aerial photography, NJDEP 2007 aerial photography, NJDEP 2012 GIS land use/land cover data, and Pictometry® Connect for Hurricane Sandy, qualitative comparisons were made to determine areas that exhibited signs of impact.

Areas identified as having sustained natural resources damage (specifically New Jersey's coastal areas and Delaware Bay), were selected for further investigation via ground truthing and field assessment. Information (e.g. blow-down areas, impacted marsh, erosion, etc.) from the various NCR programs, county and local park officials, and partnerships were used to corroborate appropriate selection of field sites and survey locations.

Field investigations commenced in June 2013 and continued through September 2013. Four teams were deployed to survey areas reported as the most heavily impacted, with concerted efforts focused in riparian habitat/ floodplains (coastal), wetlands (coastal), forests, and open waters (bays and estuarine systems).[1]

Figure ES-1. Natural resource damage assessment field investigation locations and levels of damage observed: June – September 2013



Overall results from the field investigations indicate that riparian habitat and **wetland systems** performed well, with the most severe impacts (e.g. shoreline failure, erosion, and/or undercutting) observed in the central and northern coastal region (i.e. Barnegat Bay) and in southern Delaware Bay (Figure ES-1). These are consistent with damage inflicted on infrastructure and development observed in the vicinities of northern and central Barnegat Bay, and the Maurice River (Delaware Bay). Since baseline data immediately prior to the storm were unavailable for coastal wetland/ riparian habitats, accurate estimates of shoreline loss could not be quantified.

Based on field surveys, it is estimated that less than 1% of shoreline was eroded during Hurricane Sandy. However, impacts to **wetlands** (especially to coastal marshes) did occur, where impacts up to 5% were estimated. Accumulation of natural (e.g. wrack, trees, etc.) and manmade debris, prolonged periods of inundation, as well as loss of vegetation were all issues of concern and observed at numerous locations to

[1] It is important to note that surveys of NJ's barrier islands and coastal beaches were excluded from this assessment, since most of the information on these impacts was reported from other DEP programs and municipalities (see Appendix C for NJSPS information on the impacts to Liberty State Park and Island Beach State Park).

the farthest extent of the storm surge (although some recovery had occurred by the time the field investigations were initiated). Comparison of recent NOAA aerial photography for 2012 (post—Sandy) and State land use/land cover for 2007 show remarkable shoreline changes (both loss and gain) for bay and coastal estuarine/marsh shorelines. Caution must be taken in interpretation of the coverage review, since many of the changes observed from 2007 to present occurred due to multiple storm events prior to Hurricane Sandy's influence.

In **forests**, especially along the salt marsh/maritime forest interface, salt marsh – upland ecotone (e.g. Manahawkin WMA/Edwin B. Forsythe NWR), central Pinelands forests (e.g. Bass River State Forest), and in the northwestern ridge line forests (e.g. Stokes State Forest), blow-down and breakage of trees in isolated areas were observed in most state forests, however overall forest damage is estimated at no more than 5% of all state and natural lands.

Field investigation of **submerged aquatic vegetation (SAV)** beds in open water habitats revealed variable amounts of loss. Some locations in Lower Barnegat Bay and Little Egg Harbor (e.g. Loveladies to Beach Haven), appear to have lost significant seagrass beds.[2] Similarly, SAV losses were observed in the central section of the bay and a significant portion east of Conklin Island (Barnegat, NJ) as well.

All four habitats examined in this study sustained damage from Hurricane Sandy, with the level of damage ranging from minimal to moderate. The investigation highlighted the fact that tidal wetlands were especially impacted, with observed losses of forest and riparian habitat, as well as aquatic vegetation. However, the assessment was made more difficult by the limited baseline data available pre-storm for these important natural resources and some losses likely occurred pre-storm. It is recommended that monitoring be continued, which will provide for a baseline characterization and allow a much more concise assessment of damages sustained from storms in the future. Generally, the State's natural resources endured the effects of the storm better than the built environment (e.g., homes) and protected these areas from more severe damage. However, these results strongly imply that these habitats, especially coastal and tidal, and the valuable functions they provide will continue to be at risk from the effects of sea level rise and severe storms.

Table ES-1. Natural resource assessment areas surveyed by OS and the level of assessed damage associated with the effects of Hurricane Sandy. Map Code refers to the mapped area locations in Figure ES-1.

Map Code	Area Description	Damage Assessment
Riparian Assessment Areas		
R1	Cheesequake S. P.	Low
R2	Navesink/Shrewsbury Rivers	Low
R3	Manasquan River WMA	Low
R4	Mantaloking/Edwin B. Forsythe NWR	High
R5	Cattus Island	High
R6	Manahawkin WMA/Edwin B. Forsythe NWR	Medium-High
R7	Great Bay WMA	High
R8	Leeds Point/ Edwin B. Forsythe NWR	Low
R9	Pork Island WMA	Low
R10	Tuckahoe WMA	Low
Wetland Assessment Areas		
W11	Alloways Creek	Medium
W12	Cohansey River	Medium-High
W13	Maurice River	High
W14	Thompson's Beach	Medium-High
W15	Dennis Creek	Low
Open Water Assessment Areas		
O16	Navesink	Low
O17	Bay Head	Low
O18	Lavallette	Low
O19	Toms River	Low
O20	Seaside	High
O21	Seaside Park	Medium
O22	Island Beach SP	Low
O23	Manahawkin	High
O24	Long Beach TWP	Low
Forest Assessment Areas		
F25	Abraham Hewitt SF	High
F26	Stokes SF	Medium
F27	Worthington SF	Low
F28	Battlefield SP	High
F29	near Great Bay	Medium
F30	Double Trouble SP	High

[2] *It is important to note that the cause or causes of such divergent seagrass bed conditions and losses can be attributed to multiple factors. Therefore, these impacts cannot be solely attributed to the effects of Hurricane Sandy, since beach sand overwash and consequent buildup from other storm events, including Hurricane Irene, can negatively impact sea grass survival (Kennish 2012).*

Introduction

Hurricane Sandy was a late-season hurricane in the southwestern Caribbean Sea, first making landfall as a category 1 hurricane in Jamaica, and as a 100-knot (kt) category 3 hurricane in eastern Cuba before quickly weakening to a category 1 hurricane while moving through the central and northwestern Bahamas (Blake et al, 2013). After undergoing a complex transformation, the hurricane grew considerably in size while over the Bahamas, and continued to grow despite weakening into a tropical storm north of those islands. The system then intensified once again into a hurricane while moving northeast and parallel to the coast of the southeastern United States, and finally reached a secondary peak intensity of 85 kt while moving toward the mid-Atlantic states (Blake et al, 2013). Sandy came ashore near Brigantine, NJ around 7:30 p.m. on Monday October 29, 2012 with an estimated wind speed near 80 mph (70 kt) (NOAA, 2013b) and a minimum central pressure of 945 mb. At landfall, Sandy broke all-time low pressure records for Philadelphia, Harrisburg, and Baltimore. Tropical storm force winds extended across approximately 1,000 miles, making Sandy one of the largest Atlantic tropical storms ever recorded. Shortly after landfall, NOAA satellite imagery showed Sandy covering 1.8 million square miles.

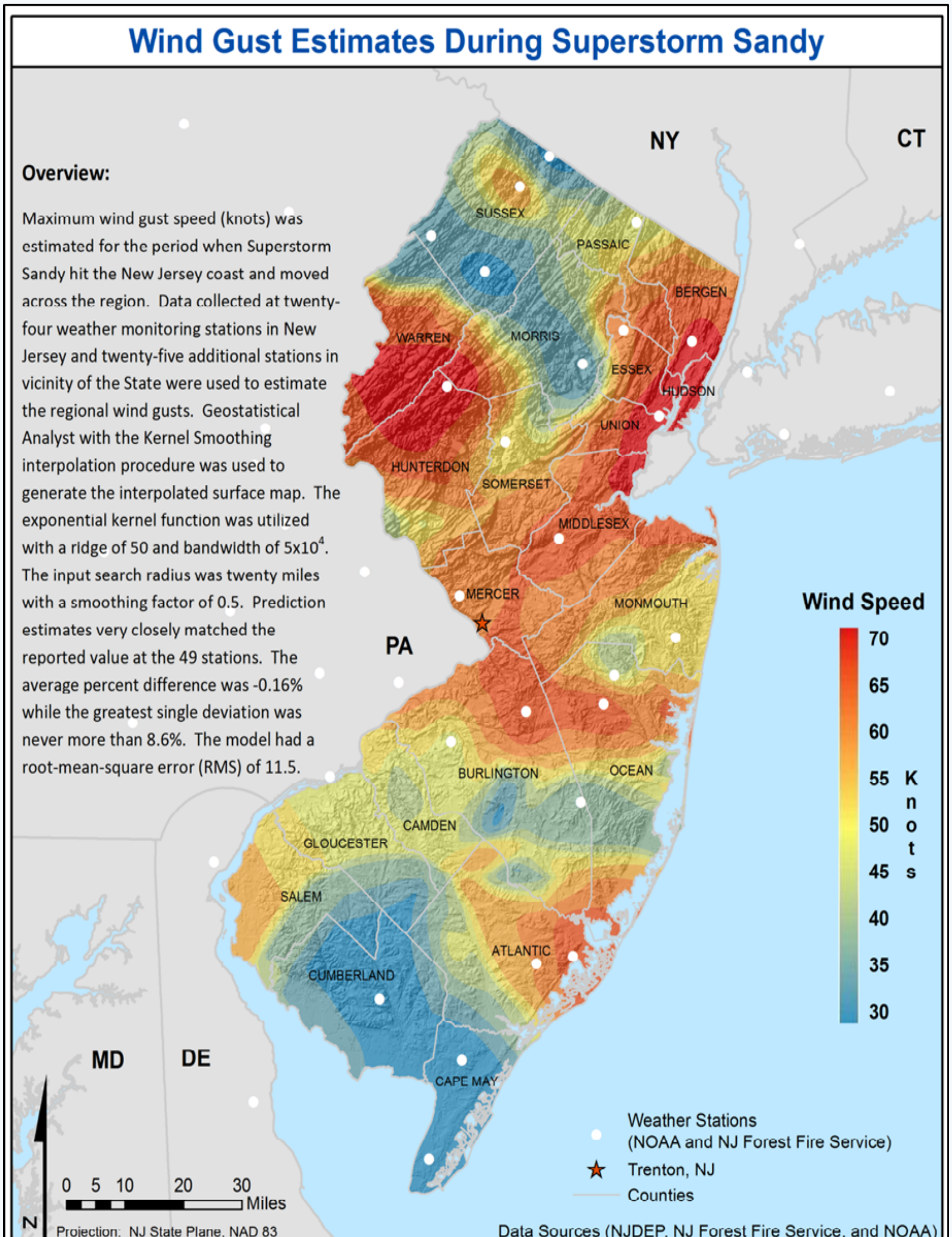


Figure 1-1. Maximum sustained wind gusts (kt) observed for New Jersey during Hurricane Sandy, October 29 – 30, 2012 (NJDEP-OS 2012).

General information on the impact of the storm

New Jersey's natural resources were affected by multiple aspects of the storm. Sustained and gusting winds caused significant damage to widespread areas of the state (Figures 1-1 and 1-2). In addition to the more than 100,000 downed trees in urban, suburban and rural communities of the state (48,000 trees cut/removed in the PSEG service area - PSEG, 2013; 65,000 trees cut/removed in JCPL service area, First Energy Corp., 2013), the winds damaged forests along the coast and well inland. Areas impacted included state parks, wildlife management areas and state forests.

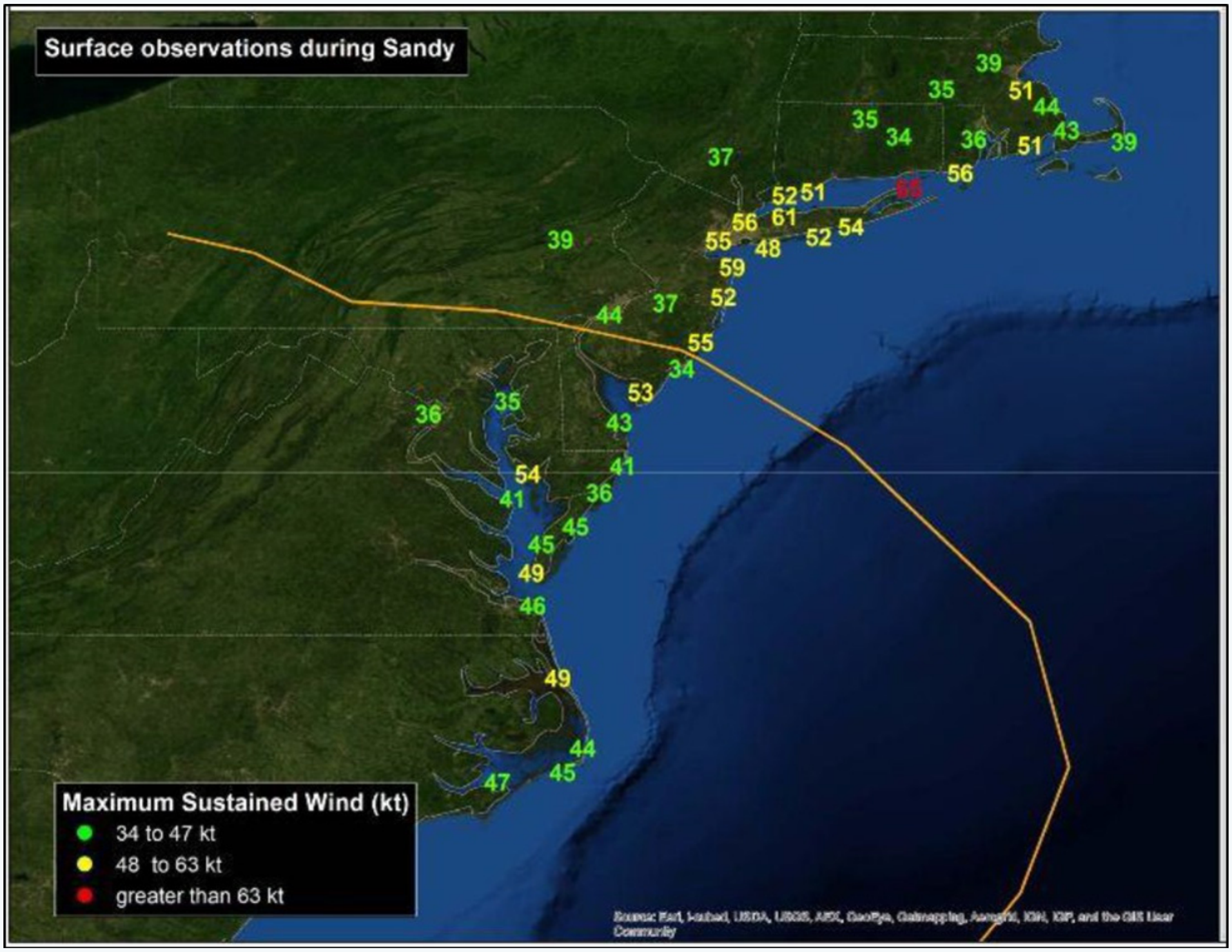
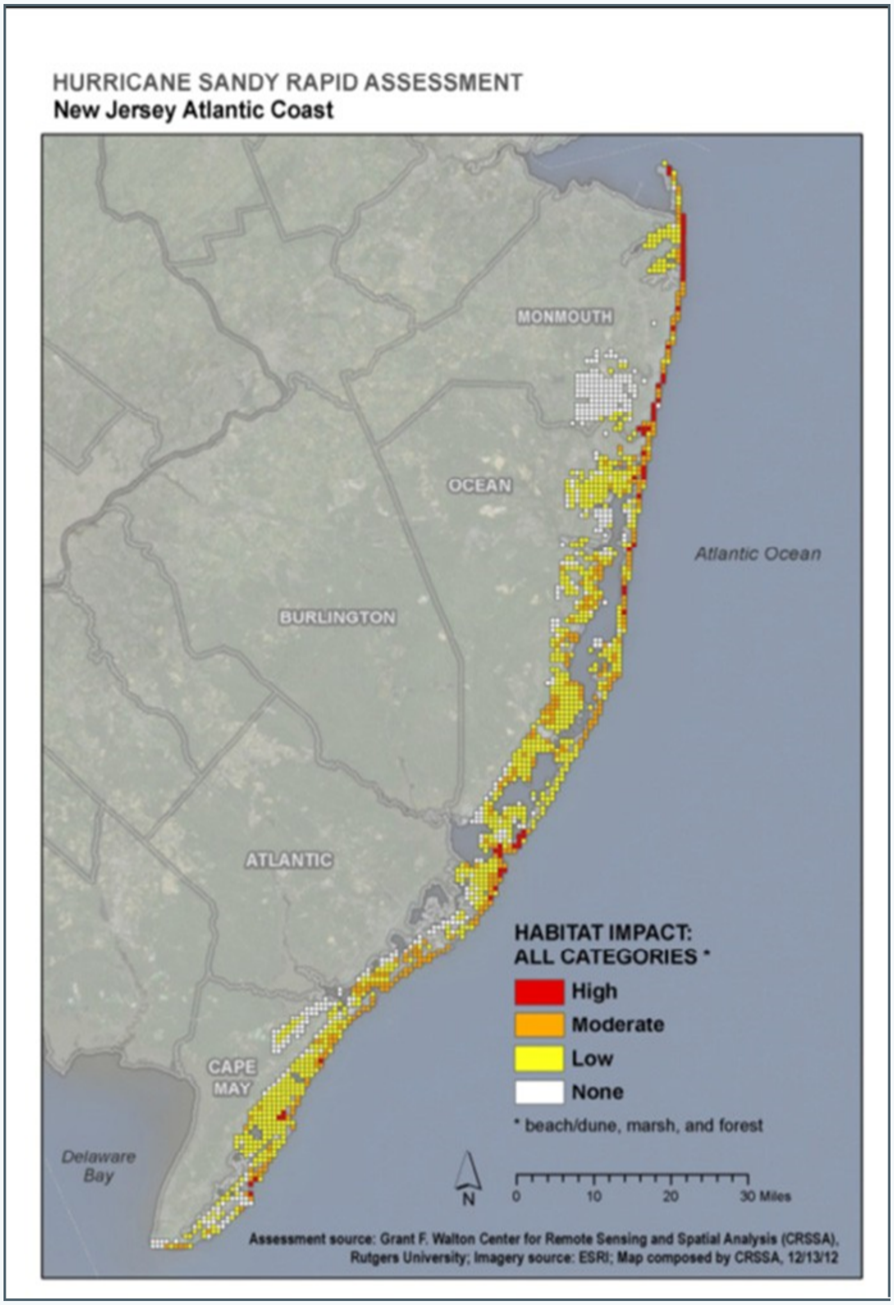


Figure 1-2. Maximum Sustained Wind Observations (34 knots; 38 mph or greater) along the Mid-Atlantic and New England coasts associated with Hurricane Sandy. Storm track is the orange line. (Source: NOAA, 2013a).

Prior to the Department's comprehensive efforts in evaluating the full impacts of Hurricane Sandy on its natural resources, federal agencies (e.g. FEMA, USGS, NFWF, NOAA) coordinated efforts to rapidly and qualitatively assess damage and its scope. The American Littoral Society (ALS) was tasked by the National Fish and Wildlife Foundation (NFWF) with coordinating a regional assessment to rapidly evaluate the quantitative and qualitative environmental impacts associated with Hurricane Sandy. The project was presented in two parts: an Interim Assessment Report (November 21, 2012) and the Final Assessment Report was submitted on December 17, 2012 (ALS 2012). The initial qualitative rapid assessment conducted by ALS concluded that the most severe impacts to natural resources occurred to the barrier islands, and to a lesser extent coastal marshes of Barnegat, Raritan and Delaware Bays (Figure 1-3). The report also stresses that secondary and tertiary impacts associated with storm surge[1] and wind damage would include disruptions in species breeding and foraging, wetland function, changes in species distribution, vegetation composition, etc.

Storm surge affected large areas of the coast and inland areas via tidal bays and rivers including freshwater marshes and salt marshes (Figures 1-4 and 1-5). The worst flooding occurred over Staten Island and to the south along the New Jersey shore (Middlesex, Monmouth, and Ocean Counties). In coastal Monmouth and Ocean Counties, post-storm surveys confirmed entire communities were flooded, with houses washed off foundations, and cars and boats carried well inland by the surge. The storm surge caused significant flooding in parts of the Hudson River Valley, with record flooding at Poughkeepsie, and minor flooding as far north as Albany (NOAA 2013). Damages included deposition ofdebris, inundation of vegetation and trees leading to physical damage, as well as erosion, changes in water and soil chemistry (e.g., fresh to saline).

Figure 1-3: Initial rapid damage assessment of natural resources impacts following Hurricane Sandy (Source: ALS, 2012).



A major example of the ancillary effects of storm surge occurred following Hurricane Sandy's landfall on October 29, 2012, where approximately 255,180 gallons of low sulfur diesel fuel was released from the Sewaren, NJ, Motiva Facility into Woodbridge Creek (a tributary of the Arthur Kill) (NOAA and NJDEP, 2013). Although localized, oil was distributed into the tidal headwaters of Woodbridge and Smith Creeks, and along both banks of the Arthur Kill. Following the spill response and subsequent cleanup efforts, field investigations revealed minimal impacts to wildlife short

[1]Storm surge is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Since storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. Storm tide is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, e.g. the North American Vertical Datum of 1988 (NAVD88) or Mean Lower Low Water (MLLW). Inundation is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW). (Source: NOAA, 2013a)

term, however impacts to habitat and vegetation due to varying degrees of oiling would necessitate the need for limited wetland restoration (1.23 acres) and continued environmental monitoring.

As noted in the ALS (2012) report assessment, storm surge also deposited large volumes of sand, sediment and debris in open waters in bay and tidal rivers. This deposition resulted in the burying of ecological habitat including submerged aquatic vegetation, filled in deeper waters (e.g., channels, open marsh water management areas [OMWMs], depressions/seeps, etc.) and impacted marsh surfaces by blocking channels and/or covering large areas of marsh vegetation.

The following is a summary from NOAA (2013a) on the Sandy storm surge in New Jersey (see Figure 1 -4 and Table 1-1):

> *The highest storm surge measured by an NOS tide gauge in New Jersey was 8.57 ft. above normal tide levels at the northern end of Sandy Hook in the Gateway National Recreation Area. Since the station failed and stopped reporting during the storm, it is likely that the actual storm surge was higher. Farther south, the NOS tide gauges in Atlantic City and Cape May measured storm surges of 5.82 ft. and 5.16 ft., respectively.*
>
> *The deepest water occurred in areas that border Lower New York Bay, Raritan Bay, and the Raritan River. The highest high-water mark measured by the USGS was 8.9 ft. above ground level at the U.S. Coast Guard Station on Sandy Hook. This high-water mark agrees well with data from the nearby NOS tide gauge, which reported 8.01 ft. above MHHW before it failed. Elsewhere, a high-water mark of 7.9 ft. above ground level was measured in Keyport on the southern side of Raritan Bay and a mark of 7.7 ft. was measured in Sayreville near the Raritan River.*
>
> *As storm surge from Sandy was pushed into New York and Raritan Bays, sea water piled up within the Hudson River and the coastal waterways and wetlands of northeastern New Jersey, including Newark Bay, the Passaic and Hackensack Rivers, Kill Van Kull, and Arthur Kill. Significant inundations occurred along the Hudson River in Weehawken, Hoboken, and Jersey City, where many high-water marks indicated that inundations were between 4 and 6.5 ft. above ground level. Inundations of 4 to 6 ft. were also measured across Newark Bay in Elizabeth and the area around Newark Liberty International Airport.*
>
> *Water levels were highest along the northern portion of the Jersey Shore in Monmouth and Ocean Counties, north of where Sandy made landfall. Barrier islands were almost completely inundated in some areas, and breached in some cases, due to storm surge and large waves from the Atlantic Ocean meeting up with rising waters from back bays such as Barnegat Bay and Little Egg Harbor. The USGS surveyed high- water marks as high as 4 to 5 ft. above ground level in locations such as Sea Bright in Monmouth County and Tuckerton, Seaside Park, and Long Beach Island in Ocean County. Farther south, measured inundations were as high as 2 to 4 ft. in areas near Atlantic City and Cape May.*

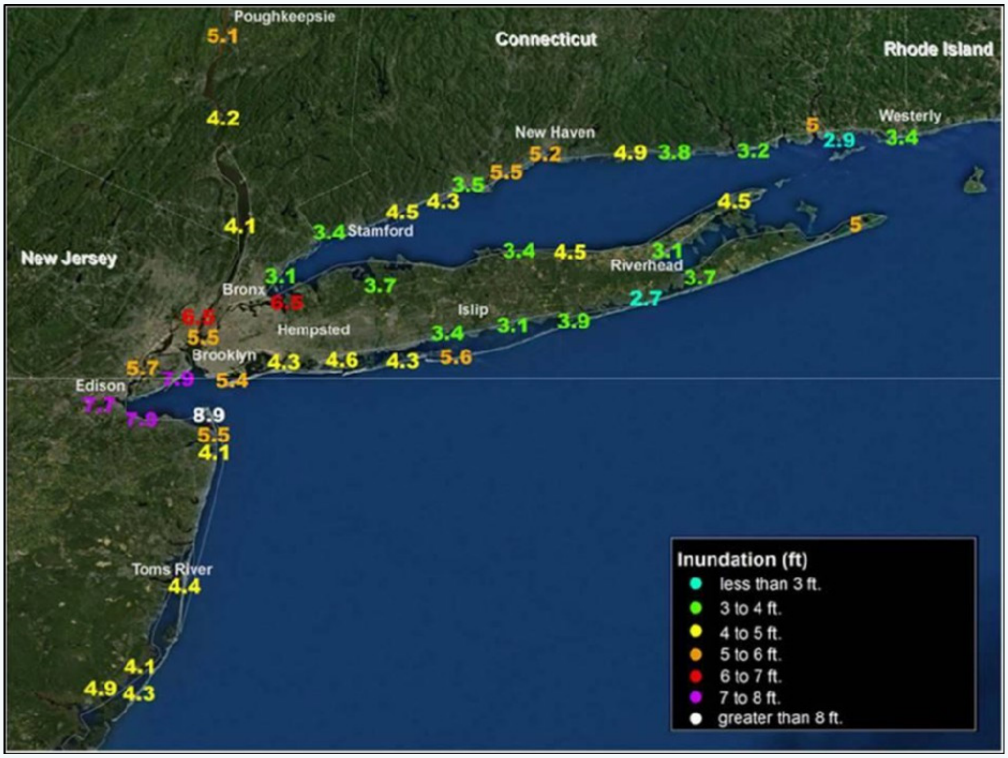


Figure 1-4. Estimated Sandy storm inundation (feet, above ground level; AGL) calculated from USGS high-water marks and National Ocean Survey tide gages in Connecticut, NewYork, and northern New Jersey, (Source: NOAA, 2013a)

As indicated by NOAA, large sections of the New Jersey coast were impacted by Sandy's storm surge (Figure 1-5). This qualitative assessment examined key areas in more detail to help define the actual impacts to natural resources.

Figure 1-5. Affected coastal and wetland areas of New Jersey following storm surge inundation due to Hurricane Sandy (NJDEP, OS 2014).

Response by federal agencies

A preliminary assessment has been conducted by the National Oceanic and Atmospheric Administration (NOAA) and other federal agencies for the 'NJ Natural Areas Impact Assessment'. The assessment identified natural resources potentially impacted by using the FEMA Interim High Resolution Surge Area data and by reviewing/comparing to state and federal agency data sets. In August (2013), FEMA released the "Superstorm Sandy (FEMA-4086-DR-NJ) Federal Recovery Support Strategy" report (RSS) in collaboration with the Recovery Support Functions (RSF), the Hurricane Sandy Rebuilding Task Force (HSRTF), the Governor's Office of Recovery and Rebuilding (GORR), and various state departments and agencies. The goal was to identify state priorities and initiatives within particular recovery areas, as well as to identify Federal support strategies for those initiatives, thereby assisting local recovery efforts within each identified programmatic area. The intent of the Federal RSS for New Jersey is to provide guidance for engaging recovery partners across all sectors and jurisdictions, while describing the various priorities as the State continues developing and implementing its recovery initiatives (FEMA 2013).

With respect to natural resource damages, the RSS (specifically the Natural and Cultural Resources RSF) has focused on assisting interested and affected parties with protecting natural and cultural resources and historic properties through numerous response and recovery actions. Particular areas of concern identified by State agencies include: beaches and dunes; wetlands; coastal lakes; residual debris; cultural and recreational resources; and natural habitats and wildlife, including marine life (FEMA 2013).

Federal agencies have contributed assessment data to the State, including pre- and post-Sandy light detection and ranging (LiDAR) survey information, as well as information about safe cleanup methods. Federal and State agencies continue to work together to provide information, environmental assessments, and other resources for beach restoration. Map projections of storm surge overlays (FEMA and NOAA data) and other information are available via the New Jersey Office of GIS - Hurricane Sandy GIS Resources website (http://njgin.state.nj.us/oit/gis/sandy/). USGS Hurricane Sandy Storm Tide mapper is also available at: http://water.usgs.gov/floods/events/2012/sandy/sandymapper.html, showing storm surge projections using tide gauge data. Additional information and resources, response information, and Federal agency links are available at: http://www.state.nj.us/dep/special/hurricane-sandy/.

The Federal government has also been developing strategies for assessing impacts to and restoring beach dunes, wetlands, coastal lakes, natural habitat and wildlife, and debris removal (DOI-USGS 2013). Strategies include:

- beneficial reuse of dredge material to create living shorelines and buffering wetlands for habitat and shore protection
- assisting the State in continuing to monitor water quality of impacted fresh and coastal water bodies

- assessing the impacts of changes to fish habitat in relation to sustainability of commercial and recreational fisheries
- collecting and periodically updating state-wide information for land as well as for water depth
- assisting with a targeted assessment of the impacts to wetlands, including edge loss and overall health
- assessing and enhancing ongoing monitoring and observation for storm events
- assisting the State in assessing the protective services provided by natural systems (e.g., beach dunes, salt marshes, and tidal wetlands) and hard structures (e.g., groins, jetties, and riprap)
- evaluating the suitability, costs, and benefits (socio-economic and ecological) of both hard structures and natural coastal systems
- establishing pilot natural sites that can be studied and monitored to improve our understanding of baseline conditions

Response by New Jersey

New Jersey's state Natural and Cultural Resources (NCR) Working Group was established to provide overall technical direction and oversight of the distribution of federal funding, established in a manner which corresponds to the overall Federal Recovery Framework in the aftermath of Sandy. The NCR serves as the focal point for projects and federal funding opportunities for those resources that have been impacted, as well as subject matter experts regarding all projects in New Jersey potentially impacting natural, cultural and historic resources. Natural features including coastal wetlands, beaches, aquatic and terrestrial habitats, farmland, marine fisheries and aquaculture, and urban rivers and streams were greatly impacted by the storm. Additionally, many public institutions, state forests and places of historic significance were also impacted. The mission of the NCR Working Group is to help restore, reestablish, and reconstruct these resources in an environmentally sound manner that is consistent with State and Federal policies and goals. In addition, the NCR will provide technical assistance to all of New Jersey's State agencies as part of the Sandy Recovery and Rebuilding Federal assistance process.

The NCR team consists of subject matter experts within New Jersey's Department of Environmental Protection, Department of Community Affairs, and the Department of Agriculture. In addition, a multi-disciplinary approach is being utilized in project implementation, and includes members of the Governor's office, the Attorney General's office, and team members possessing information technology (IT), communications and federal grant funding and processing expertise. The Department's Natural and Cultural Resources programs have been actively assessing impacts to natural resources immediately following Hurricane Sandy's landfall, and interpreting the continued effects to and recovery of these resources. For example, efforts to monitor observed impacts to nesting and breeding habitat for numerous species, both inland and coastal along various habitat types, have been exhaustive and ongoing.

The following is a brief summary of the statewide approximate acreage impacted by the storm by category based on a preliminary assessment conducted by the National Oceanic and Atmospheric Administration (NOAA) and other federal agencies for the 'NJ Natural Areas Impact Assessment' shortly after Hurricane Sandy (note some categories may overlap):

Natural Resources Preliminary Assessment – Acreage Inundated by Storm Surge:

642,000 acres of shellfish harvesting waters (adjacent to areas inundated)
380,000 acres of habitat inundated
292,000 acres contain state-endangered species
23,000 acres contain federally-listed endangered/threatened species
21,500 acres of Natural Heritage Priority Sites inundated

Specific Planning, Management or Federal Areas Impacted:

132,000 acres of Coastal Environmentally Sensitive Planning Areas
129,000 acres in NJ Pinelands Management Areas
36,000 acres of US Fish & Wildlife Service National Wildlife Refuges
12,000 acres of Critical Environmental and Historic Sites
1,600 acres of National Park Service land (Gateway National Recreation Area)

Land Use/Land Cover – Acreage Inundated by Storm Surge

Wetlands: 260,000 acres
Water: 81,000 acres
Urban: 74,000 acres
Forest: 16,000 acres
Agriculture: 8,000 acres
Barren Land: 3,300 acres

Shoreline Type- Total Length Impacted by Hurricane Sandy within the CAFRA Zone section covering from Keyport (Monmouth County) to Heislerville (Cape May County)

Marsh/Wetland: 678 miles
Beach: 194 miles
Bulkhead: 194 miles
Erodible shoreline: 70 miles
Earthen dike: 5.6 miles

Table 1-1. Storm Surge Levels in New Jersey Counties (Source: NOAA, 2103a

County	Storm Surge (feet above ground level)
Monmouth and Middlesex Counties	4 – 9 ft.
Union and Hudson Counties	3 – 7 ft.
Essex and Bergen Counties	2 – 4 ft.
Ocean County	3 – 5 ft.
Atlantic, Burlington, and Cape May Counties	2 – 4 ft.

Damage Assessment Team

The NCR Working Group assembled a team to examine and assess the damages from the storm with the NJDEP's Office of Science leading the effort. Multiple programs were involved in compiling information on impacts to state parks, wildlife management areas, beaches, estuaries, and ecologically sensitive habitats. Four primary assessment themes were selected for additional damage screening. These themes included wetlands, forests, riparian/floodplains and open waters. These habitats were identified as priorities and as having a nexus to ongoing research in affected areas (e.g. Barnegat Bay, Delaware Bayshore, etc.). NJDEP Programs providing support to the team included:

Division of Fish & Wildlife (ENSP)

State Park Service

State Forestry Service (DPF, NHP)

Green Acres & Ecological Restoration

Office of Science

Themes (Results & Discussion)

Wetlands

New Jersey's tidal wetlands are one of the State's most dynamic features providing a multitude of ecological and economic benefits. Fringing the perimeter of the state, these areas have been subject to natural and human induced perturbations and change. These include tidal inundation, subsidence, sea level rise, sediment supply, ditching, diking, filling, water withdrawal and the stressors of adjacent development.

As documented in the NJDEP Coastal Management Program's 2011-2015 Section 309 Assessment and Strategy, New Jersey has (according to the 2007 Land Use/Land Cover GDS Dataset) 198,773 acres of tidal wetlands in the CAFRA zone. This amount corresponds to a loss/change of approximately 9,997 acres of coastal/emergent wetland vegetation or conversion to open water from the 2002 Land Use/Land Cover data. It is important to note that this acreage does not include the tidal wetlands outside the CAFRA area in the Raritan Bay, Meadowlands and northern coast, or on the tidal Delaware River, and part of the loss may be attributed to differences in classification methodology as well as the physical changes that occurred between 2002 and 2007.

Regardless of the present distribution of tidal wetlands, these areas provide unquestionable ecological and economic values that New Jersey residents have come to rely upon. Hurricane Sandy demonstrated that these wetlands serve as a 'first line of defense', providing vital flood and storm surge protection to human assets and infrastructure. After Hurricane Sandy, it became evident that those communities buffered by coastal wetlands sustained less physical damage, and consequently less economic losses. Hurricane Sandy produced a record level of storm surge due to its wind strength, angle of approach and time of landfall coinciding with a lunar high tide. However, the tidal wetlands withstood this assault and proved to be resilient to Sandy's powerful effects.

Hurricane Sandy made landfall on the eastern coast of New Jersey, however, the wind strength and circulation pattern impacted all of New Jersey's coastal wetland areas. While it was to be expected that the tidal wetlands on the east coast of New Jersey (i.e. ocean-side) would sustain damage, the tidal wetlands fringing the Delaware Bay (not buffered by barrier islands) suffered severe damage. The vast area of the Bay and the extended periods of sustained wind speeds contributed to the impacts and to the severity of these effects.

It has been documented that the Delaware River Estuary has lost 2% of its wetlands between 1996 and 2006 (PDE 2012). This loss is attributed to increase in tidal water levels, subsidence, and to the lack of sediment enabling the wetlands to keep pace with sea level rise. It is estimated that an additional 25 – 75% loss of wetlands will occur with one meter of sea level rise (PDE 2012 – Application of the SLAMM6 Model). The decline in the integrity of the tidal wetland system of the Delaware Bayshore has resulted in decreased resiliency of these wetlands to storm impacts associated with severe storm events including Hurricane Sandy, Hurricane Irene, and seasonal Nor'easters.

Immediately following Hurricane Sandy (October and November 2012), aerial and field assessments of the State's built and natural resources were conducted by federal, state and non-governmental organizations (NGOs). There were numerous reports of adverse impacts inflicted by the storm on the state's wetlands. The Office of Science (OS) reviewed the various reports of impacts and followed with a qualitative survey of the State's tidal wetlands.

The qualitative damage assessment was intended to identify and estimate the 'observed' impacts of Hurricane Sandy on wetland and shoreline vegetation, substrate, integrity, and observed function. The following procedure was employed:

Step 1: Determine current knowledge and assessment information

- Contact DEP programs and determine:
    - ◊ Damage Assessment (DA) information specific to the resources they manage; Have the programs completed DA information summaries requested by OS.
    - ◊ What DA information did the program need or want checked and/or confirmed in the field.
    - ◊ Was the Program conducting any DA at the time (in the field, desk top); was any planned; where, when?
    - ◊ Had the Program reviewed and confirmed DA information provided by other sources (federal, state, NGO, etc.)?

Step 2: Desktop Damage Assessment – Remote sensing review and interpretation (aerial photography, reports)

- The Office of Science utilized the NJDEP Hurricane Sandy Waterway Debris Management Zone map (OIRM-BGIS 2012) as the basis to assign assessment areas for desktop and future field review. The Wetlands Damage Assessment areas included the entire tidal (salt marsh and freshwater) wetland area of the state and overlapped with the Damage Assessment being conducted for Floodplain and Riparian Habitats.

  The sources of information utilized for the desktop aerial review included:

  - ◊ 2012 NJDEP aerial photography (flown in March/April 2012 – Pre Sandy)
  - ◊ 2012 NOAA/USGS post-Sandy aerial photography – October/November (limited to coastal zone); east of the Garden State Pkwy; no coverage of the Delaware Bay or River
  - ◊ 2007 NJDEP aerial photography
  - ◊ County Road Maps
  - ◊ USGS Hurricane Sandy Storm Surge Line
  - ◊ LiDAR data sets
  - ◊ Pictometry® Connect for Hurricane Sandy– aerial photography with various dates pre- and post-Hurricane Sandy
  - ◊ Aerial and marsh-level photographs provided by NGO and academic sources

The objective of the Wetlands Damage Assessment was to identify areas showing changes to marshes/wetlands post Hurricane Sandy which includes (see Figures W-1 – W-5):

Figure W-1. Marsh edge – collapse, sloughing off, undercutting, erosion (Edwin B. Forsythe NWR, Mantoloking Ocean County).

Figure W-2. Marsh scouring (Edwin B. Forsythe NWR, Mantoloking, Ocean County).

Figure W-3. Marsh edge overwash (Great Bay WMA, Ocean County) .

Figures W-4 and W-5. Marsh ponding, drowned (excessive water retention) (Great Bay WMA, Ocean County).

- Matting – areas where the marsh and underlying substrate have been lifted and rolled back on itself (i.e.: sod)
- Rafts of debris and marsh vegetation
- Marsh scour or deposition – areas where the marsh vegetation and substrate was scoured away and sediment /sand was deposited
- General assessment of the marsh – did it appear to sustain damage or remained relatively intact (as compared to the 2012 pre-Hurricane Sandy photography)
- High Marsh/Upland Edge – condition of the high marsh vegetation and along the upland edge
- Extent of the debris/rack line (vegetation) and associated ponding
- Condition of trees on upland edge of marsh – was there evidence of salt water stress/dieback (note: this might not be observed until next growing season), and uprooting of vegetation
- Development adjacent to marsh – observations of condition of bulkheads, docks, piers and condition of adjacent marsh
- Observed damage to residential and commercial development upland of marsh
- Stream Channel modifications – changes in width, sediment deposits, erosion, bank scouring, changes in meanders

Step 3: Prioritize Areas for Field Reconnaissance

- Based on the desktop assessment identify areas for ground-truthing and field assessment:
    - Identify which areas had the most damage
    - Identify areas having sensitive habitat – areal extent of impact, condition of habitat (inundated, scoured)
    - Investigate areas where there were data gaps, limited data and /or conflicting observations between sources

Step 4: Refining Desktop Assessment for Field Reconnaissance:

- The desktop assessment revealed several factors that required consideration and refinement prior to making determinations on impacts. These included discrepancies in the scale and stage of tide between the various aerial overflights. The timing of the NOAA/USGS October/November 2012 overflight immediately following the storm captured immediate impacts, but also captured standing water on the marsh and did not account for potential 'natural adjustment' that might occur between photo documentation and field assessment. In comparing the NJDEP aerial photography flown in 2007 to those for same area flown in 2012 there appeared to be considerable change to wetland areas that were being attributed to Hurricane Sandy but were in fact evident pre-storm. In some areas the storm exacerbated or highlighted the changes but was not responsible for the erosion/loss of wetland area. Additionally, there were significant data gaps depending on the region being observed, and the potential for exaggeration of impacts due to low resolution and report discrepancies.

Field Assessment

The OS Field Assessments were conducted in the spring and summer of 2013. These field reconnaissance investigations were conducted during the 2013 growing season, and after Hurricane Sandy and other winter storms. The individual desktop Wetlands Assessment Reports coinciding with the NJDEP Waterway Debris Management Zones are available on the Office of Science computer network (available upon request). These reports identify the aerial photographs viewed, observations, and areas identified for field observation. The field investigations for the Northern and Eastern coastal areas were conducted in coordination with the field investigation for Floodplain and Riparian Habitats. The summary of the findings and place specific photographs documenting field observations can be found in this report's Floodplain and Riparian Habitat section.

General Observations

The earliest aerial photographs taken post Hurricane Sandy revealed extensive flooding of tidal wetlands, debris from destroyed developments, areas of sediment deposit (sand wash-over) from barrier islands, broken dikes, edge loss and altered channel meanders. Details of the field assessments for each geographic region are presented below.

Atlantic Coast and northern coastal waterfront – The post-Sandy aerial photography showed large areas of standing water and some wetland edge loss.

- Areas of edge loss were not extensive or contiguous. As noted previously a comparison of 2007 and 2012 pre-Sandy aerial photography (same scale and orientation) showed significant changes in shoreline configuration and areas of loss. Hurricane Sandy may have contributed to under-cutting and additional loss to already compromised shorelines.
- Field investigations of areas identified on aerial photography as being flooded or having extensive areas of standing water showed that standing water had receded. However, there were areas where vegetation had not recovered leaving areas of bare ground in the interior marsh.
- Field surveys of areas identified on aerial photography as being managed for mosquito control [open marsh water management – OMWM] showed evidence of retaining water (ponding) and vegetation loss

with reduced recovery (Figure W-6). Edge loss was greatest in areas where OMWMs were constructed in lower marsh areas (closer to open water). In areas where OMWM ponds were present in greater abundance, the marsh also appeared slower to recover (e.g. greater prevalence of ponding/retention). There has been concern that the OMWM areas will not be as resilient (i.e. due to their influence on the diminished integrity of marsh vegetation composition and original surface structure) to future assaults from storm surge or wind damage.

Figure W-6. Open Marsh Water Management areas showing evidence of water retention (Cape May County).

- Wetlands areas previously compromised by ditching, OMWM, and diking appear to have sustained more damage and were slower to recover than other less impacted marsh areas.
- The communities that were upgradient of wetlands were buffered from storm surge and winds. These communities appeared to have sustained less damage. However, there was evidence of damage to docks, piers, and bulkheads, but these features were directly impacted by the storm's intensity.
- Based on the USGS mapping of the storm surge line, it was evident that the upland vegetation/ tree line bordering tidal wetlands was impacted by saltwater intrusion. These areas retained water and debris for longer periods of time than the open marsh. There is concern that this ponded water and debris would create or enhance breeding habitat for mosquitoes, insects and vermin. The impact of saltwater intrusion on the long-term viability of the trees and understory vegetation may require surveys during additional growing seasons to fully estimate long term effects.
- The field investigations conducted post storm documented that the tidal wetlands (with few exceptions) recovered from the assault of Hurricane Sandy as they would from other coastal storms. Unfortunately, post storm assessments are not conducted on a routine bases. As noted previously, there appears to be a significant change in wetland acreage and integrity (vegetation vs. mud flats) when comparing the 2007 and pre-Sandy 2012 aerial photography.
- The impact of ongoing recreational activities including boat traffic, wakes, and landings in the marsh, have had a greater adverse impact on shoreline stability, vegetation, and wildlife habitat than the impacts attributed to the storm in a number of areas where wetland vegetation recovered.

The following two photos (Figures W-7 and W-8) were taken on the same day (7/24/13) and illustrate how various marshes responded to the impacts of Hurricane Sandy

Figure W-7. Atlantic Coast Wetlands - Tuckahoe 1: Example of ponding post inundation (Atlantic and Cape May Counties).

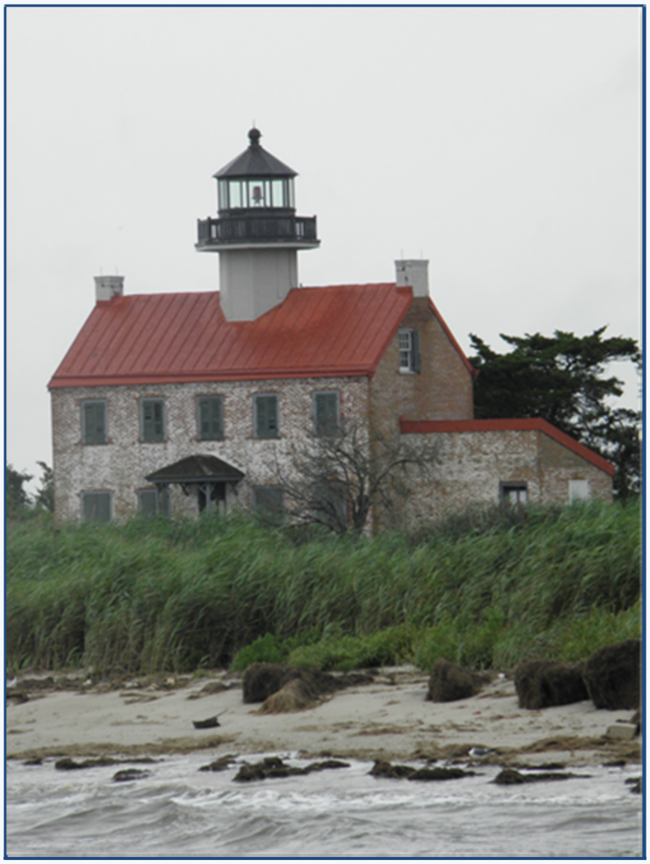
Figure W-8. Dennis Creek 1: No lasting impacts (Cape May County).

Delaware Bayshore Wetlands

A majority of the post Hurricane Sandy media reports indicated that Delaware Bayshore communities did not sustain significant economic damage to their residential and commercial businesses as compared to Atlantic coast communities. These reports failed to address any potential impact to natural communities (e.g. wetlands, forests, or sandy shorelines). In the absence of post Sandy aerial photography for the Delaware Bayshore and want of natural resource impact assessments, the OS conducted a qualitative review and assessment of storm impacts for this region. Areas potentially impacted by the storm were selected for field investigation utilizing 2007, 2010 and 2012 aerial photography, LiDAR, local NGO post storm reports and prior (2011) NJDEP Coastal Program Coastal Hazard Project information. The Delaware Bayshore wetlands investigated (Cape May, Cumberland County and Salem counties) showed significant storm impacts to tidal wetlands. Impacts to wetland edges (land water interface) appeared to be more significant than those on the Atlantic coast. Larger, contiguous areas of shoreline were compromised by erosion, undercuts, and sloughing. Furthermore, the storm surge extended further inland to the tree line, dikes were blown out, wetlands inundated, and a significant loss of wetland area was observed at the confluence of the Bay and rivers (i.e. Maurice and Cumberland Rivers). There were also forested areas showing downed trees. Another observation revealed that storm winds contributed to sand and sediment deposition along shorelines creating shallow embayments water ward of former wetland edges on the Delaware Bayshore. In discussion with property owners, it was confirmed that moorings and piers were unusable because of the additional sediment.

The following photos (Figures W-9 and W-10) were taken in June 2013 and illustrate the impacts to shoreline and coastal wetlands along the Delaware Bayshore .

Figure W-9. East Point Light House (Cumberland County).



Note: clumps of vegetation where substrate was scoured from root base. Vegetation appears free standing.

Scoured vegetation, wave run-up and undercutting of bulkhead are illustrated here (East Point Lighthouse)

Figure W-10a. View looking south to Thompson's Beach/Moore's Beach (Cumberland County).

Figure W-10b. East Point Lighthouse Beach.

Figure W-10c. Thompson's Beach - undercut vegetation

Figure W-10d. Heislerville WMA – Impoundment.

Figure W-10e. Mouth of the Maurice River Basket Flats.

Note: Historically, there was a vegetated oxbow where the remains of a railroad crossing are visible. With each storm the area erodes. Post Hurricane Sandy vegetation is no longer observable.

Riparian Habitats/Floodplains

Desktop damage assessments were initiated in April 2013 using NOAA Post-Sandy Aerial Photography at a resolution of 1:1000 and Pictometry® Connect for Hurricane Sandy for coastal riparian habitats and marshlands, and completed by June 2013. Special attention was given to Monmouth, Ocean (e.g. Barnegat Bay) and Atlantic Counties given the significant loss to human assets. Pre- and post- storm images and impact maps provided by the rapid damage assessment surveys conducted by the American Littoral Society (ALS, through the Rutgers University Grant F. Walton Center for Remote Sensing and Spatial Analysis - CRSSA project) (ALS 2012) were used as a background comparison for desktop survey observations. Based on the resolution of the NOAA aerial photography, few observable impacts could be ascertained from the review. Natural areas identified as having sustained some observable impact (e.g. change in shoreline, loss or gain, debris/wrack accumulation areas, blow-down areas, etc.) were noted and later investigated during field surveys (Table R-1).

Qualitative surveys were conducted for coastal riparian and riverine wetland habitats along the NJ Coast during the summer months of 2013 to assess impacts to natural areas (including Wildlife Management Areas [WMAs], State Parks, Municipal Parks, etc.) from Hurricane Sandy and post-Sandy storms. Natural resource damages were initially assessed by reviewing 2013 NOAA aerial photography compared to the Department's 2012 Land Use/Land Cover Imagery, 2007 GIS Land Use Data, and Pictometry® Connect for Hurricane Sandy imagery. Focus for the assessment centered on areas that were reported as sustaining the highest damage based on impacts to human habitation, and in natural areas managed by federal, state and/or local entities. Given information provided by various DEP programs including the Office of Natural Lands Management – Natural Heritage Program (ONLM – NHP), Division of Parks and Forestry (DPF), and Division of Fish and Wildlife – Endangered and Nongame Species Program (DFW – ENSP), coastal areas beginning north in the Raritan Bay region and south to Cape May were chosen as focal points for desktop review and field investigation; the Delaware Bay region is covered in the Wetlands Assessment section of this report. Damage assessments within State lands along the coast, as reported by other programs within the Department (see Niles et al. 2012 and NJDEP – ENSP 2013), were solely focused on T&E species and associated habitats, active species management programs (NJDEP and CWFNJ 2013a, 2013b, and 2013c), shore bird nesting (Niles et al. 2012, and physical damage to forestry and park resources (NJDEP-DFW 2013), infrastructure, and other resources.

Information provided by other State programs with respect to riparian habitat and wetland areas is limited, however impacts to resources such as Atlantic white cedar (AWC) (*Chamaecyparis thyoides*) stands and other imperiled species (e.g. 10-year assessment of 6 rare beach species prior to Sandy, including federally-listed Seabeach amaranth [*Amaranthus pumilus*]), have and are being assessed in great detail. Richard Stockton State College in collaboration with the NJDEP Division of Parks and Forestry (G. Zimmermann, pers. Comm.) has been quantifying AWC damage along the Mullica river in Cape May County, and in other areas of the state. According to Zimmermann, and supported by aerial photography provided by DPF (credit: J. Dunn, L. Flemming), large stands or sections of AWC stands show visible signs of stress in areas inundated by the storm surge.

Figure R-1. Aerial photograph illustrating stressed and dying Atlantic white cedar due to storm surge from Hurricane Sandy along the Mullica River, Atlantic County, NJ (Courtesy of DPF).

During the spring of 2013, aerial photography and field surveys conducted by DPF showed significant areas of dying and dieback (Figure R-1) of AWC (and other woody vegetation) observed along Barnegat Bay along and within the salt marsh-upland ecotone, maritime forest, and inland along tributaries entering Barnegat Bay and south to the extent of the storm surge. Some areas, specifically those along mid- and upper Barnegat Bay, were more heavily impacted than other areas of the State. The most severe impacts to vegetation, especially AWC, were observed in areas where water was impounded and trapped by physical barriers such as roads and blocked culverts. Studies conducted by the United States Geological Survey (2005) on coastal bald cypress forests in central Louisiana following Hurricane Rita show that in many locales, bald cypress has been in decline due to apparent saltwater intrusion. Study sites, including those many miles inland of the storm surge, have shown that inundation can elevate salinity levels twofold to threefold with long residence times, which can lead to delayed tree species mortality (Doyle et al, 2007). Increase in the duration of salt water retention in the back bay and riparian habitats surveyed by DPF and the Office of Science confirm that these areas are experiencing varying degrees of stress and dieback apparently due to elevated salinity. Studies are presently underway by Richard Stockton State College and DPF to further investigate these observations (G. Zimmermann and James Dunn, pers. Comm.)

With respect to wildlife, a number of assessments have been conducted to date (as of January 2014) regarding impacts to habitats on state lands, or elsewhere, other than for Delaware Bayshore, Atlantic coastal beaches, and vernal pools in southern Cape May County (ENSP 2013, D. Jenkins, pers. Comm. and ENSP 2014, G. Fowles, pers. Comm., respectively). However, ENSP (2013) reported that initial assessments of the habitat impacts for specific species in the above areas were conducted immediately following the storm, and surveys have been ongoing, with focus being on species and population. The impacts noted were more or less similar to what has been reported by the American Littoral Society (see ALS 2012), although more detailed work has since been done for Delaware Bay beaches (Niles et al., 2012). The ENSP also indicated that additional work was needed to assess impacts to species that use the back bay islands and coastal marshes, specifically colonial waterbirds. The ENSP received federal funding (not Sandy related) to perform that assessment for colonial waterbird surveys; these were initiated in late May 2013 to assess impacts to both the bird populations themselves and to nesting habitats.

The ENSP proposed plan is to continue assessment of avian populations for the next three years in order to evaluate the consequences of habitat changes. The three year colonial waterbird survey has completed its first year and 2013 results are available (ENSP 2014, C. Davis, pers. Comm). The results indicate that present populations of long-legged wading birds and associated habitat were fairly recovered, whereas tern and gull habitat was most affected in areas where debris of anthropogenic origin (e.g. construction, household, trash, etc.) were still present. Surveys for other avian marsh species such as sparrows, bitterns, and rails has been and is presently being conducted by the University of Delaware, with conclusions yet to be determined. Surveys conducted for raptors in 2013 such as the peregrine falcon (*Falco peregrinus*), osprey (*Pandion haliaetus*), and bald eagle (*Haliaeetus leucocephalus*) concluded that all surveyed species were largely unaffected by Hurricane Sandy, although minor disruptions to nest sites did occur without long term detriment to the species (NJDEP and CWFNJ 2013a, 2013b, and 2013c, respectively). A more comprehensive set of population surveys are available for the above and other species of concern for 2013 (NJDEP – ENSP 2013). More general assessments with regard to broader wildlife resources or broader areas have not been completed.

Table R-1. Summary of qualitative impacts observed during June – September 2013. OS field survey assessments of natural resources impacts described by observations of damage type to habitat type.

Region (Debris Mngmt Zones)	Field Location	Habitat Type	Damage Category								
			P	ER	IN	DB	UND	COL	SD	VS	BD
Zones 1 - 3	Navesink & Shrews-bury Rivers	Wetlands/ Forest		x	x	x					x
Zones 4 - 9	Manasquan River	Wetlands		x	x						
	Stafford Ave/Turtle Cove (Manahawkin)	Forested edge of Marsh			x	x				x	
	Beach Ave (Manahawkin)	Forested edge of Marsh	x		x					x	
	Taylors Lane, EBF NWR (Manahawkin)	Forested Edge of Marsh	x		x					x	x
	Bay Side (Manahawkin)			x	x	x			x	x	
	Cattus Island	Wetlands/ Forest		x	x	x	x		x	x	x
	Mantaloking/Edwin B. Forsythe NWR	Wetlands		x	x	x	x	x	x	x	
	Turkey Swamp WMA	Forest									x
	Monmouth Battle-field State Park	Forest									x
	Allaire State Park	Forest								x	x
Zones 10 - 11	Great Bay North Side	Wetlands		x	x	x	x	x	x		
	Mystic Island	Wetlands		x	x			x		x	
Delaware Bay	Cumberland/Cape May Counties	Wetlands		x		x		x			

Zones:

Zones 1-3 – Bergen county south through Monmouth county

Zones 4-9 – Ocean County south to Atlantic county

Zones 10-11 – Atlantic County to Atlantic Ocean face of Cape May County

Delaware Bay – Delaware Bayshore from point of Cape May to Cumberland/Salem County Border

Impact Type:

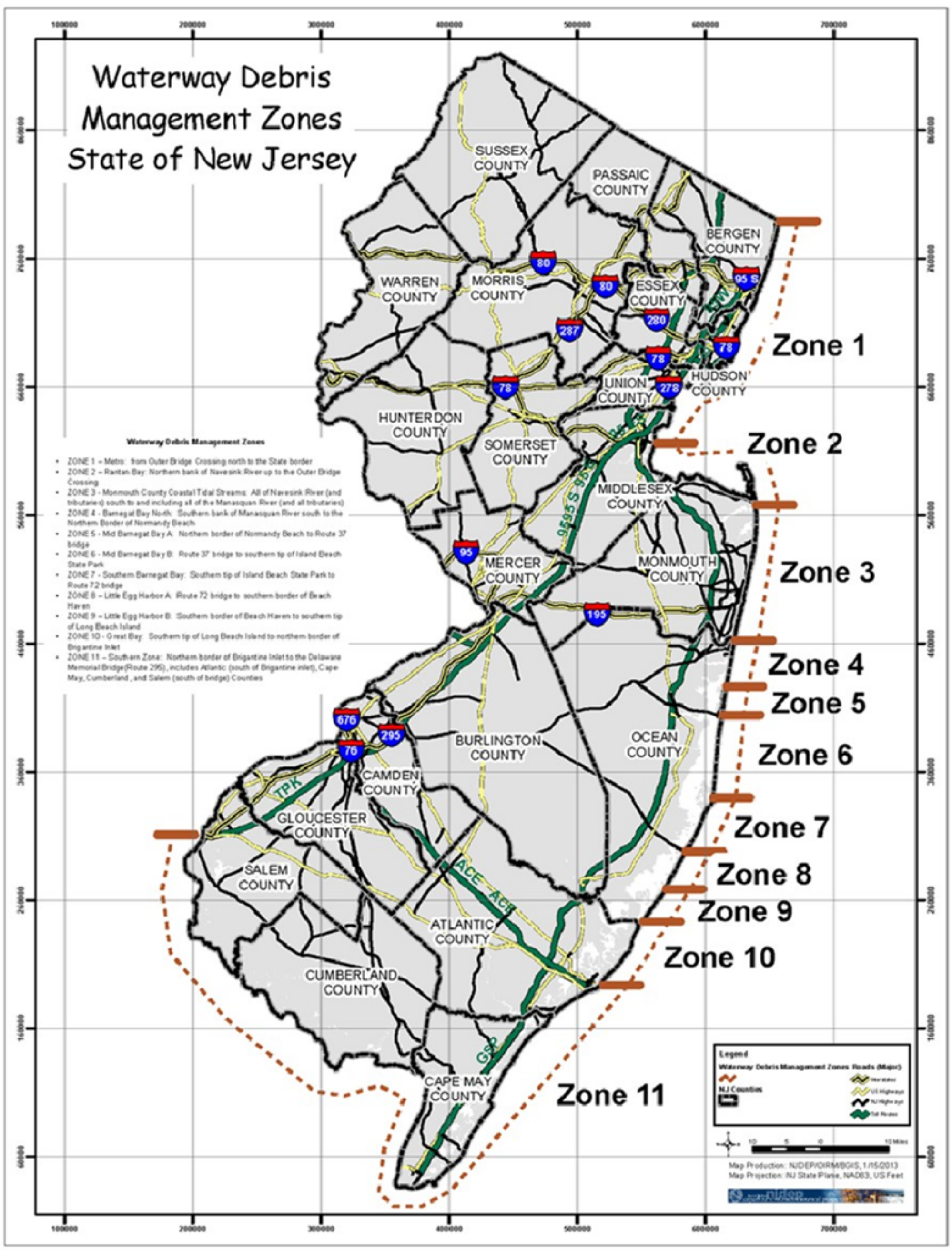
P = Ponding; ER = Erosion; IN= Inundation; DB = Debris; UND = Undercut; COL = Collapse; SD = Sediment Deposition; VS = Vegetation Stress; BD = Blow-down

Field surveys were conducted via ground-truthing reports by NHR and other sources, on foot and by boat, and visual estimations made of impacted vegetation, shoreline loss, and other impacts. Ten locations were chosen starting from the north and continuing south: Cheesequake State Park, Navesink River, Manasquan WMA, Mantoloking/Edwin B. Forsythe NWR, Cattus Island, Manahawkin WMA, Great Bay WMA, Pork Island WMA, Leeds Point, and Tuckahoe-Corbin City WMA (see Figure ES-1). Field assessments were conducted using qualitative observations, based on the Rapid Storm Assessment protocols developed by Washington State (Roberts et al. 2009). The following parameters were observed during the 2013 surveys including: shoreline erosion, undercut, bank collapse, wrack/construction debris, sediment/sand deposition, and vegetation impacts (dieback due to salinity, inundation, blow-down erosion, etc.).

Results

Field surveys along the Atlantic coast revealed that the greatest impacts to natural resources were sustained in areas consistent with those developed areas reporting the greatest damage (Zones 4 –9; see Figure R-2), from both wind and storm surge (i.e. Area roughly between the Metedeconk River and Great Bay. Results are presented below separated geographically (Northern, Central, and Southern Coast, respectively) and by waterway debris zones (Zones2 – 3; Zones 4 – 9; Zones 10 – 11).

Figure R-2: Waterway Debris Management Zone Map (Source: NJDEP-BGIS, 2013).



Northern Coast - Zones 2 – 3:

1.) **Cheesequake State Park (Zone 2)** - Field surveys of western and northern riparian/ wetland areas revealed no major impacts to these areas. In the northern wetlands (near Blue Bell Is- land), some shoreline erosion was observed along creek channels in the north (above the Garden State Parkway), although adverse impacts appeared to be sparse compared with the total area surveyed. Major slope erosion was seen on the northeast side of Arrowsmith peninsula (area about 75' in length) facing Stump Creek, an area already identified by the Park Service as having experienced erosion in past. Very limited dieback of vegetation was observed (along Sandpit Picnic Area parking lot and surrounding area); most marsh vegetation was remarkably lush and well intact in all wetland areas and riparian edges. No major debris were observed along the wetland boundary (wrack line of reeds & limbs evident at 6' +/- above wetland at upland edges), although an overturned boardwalk was still visible near the crabbing bridge area (i.e. Hooks Creek). According to the NJSPS, Hooks Creek Lake sustained major impacts due to salt water intrusion and retention (NJSPS, pers. Comm. 2014). Evidence of salinity effects on vegetation (i.e. stress, die-back of coniferous tree species) was visible in June 2013 at the time of the OS Survey. The majority of debris (natural and anthropogenic) were removed by park personnel and volunteers in November/December of 2012, however some natural debris was still evident at the high water mark in most areas of the park.

2.) **Navesink River area (Hubbards Bridge to Shrewsbury River – Zone 3)** - Field surveys of the northern & southern banks of the Navesink River, and main riparian and wetland areas:

- Bank erosion, some increasingly significant on the steeper slopes, was observed on the northern banks of the Navesink River. The most significant bank failures observed could be seen along Rocky Point in Hartshorne Woods Park out to Shrewsbury River. Impacted areas are most obvious from Huber Woods (near Oceanic Bridge) east to Shrewsbury River on the north side. Large areas of downed trees were observed on these steep slopes as well, distributed from water level up to top of slope; areas of woody debris and some construction material were seen on both sides of river. Comparison to previous conditions will be necessary to determine the extent of damage due to the storm; some areas appear to have had historic bank stability issues. Significant damage was still noticeable to private docks along the entire area surveyed. Additionally, some impacts were observed along the banks of the Swimming River, especially along the wetland southeast of Hubbards Bridge (W Front St. – Red Bank). These include bank failure and sections of torn vegetation mats (estimated percent damage minimal, less than 5%). No major impacts to wetlands or concentrated debris areas were observed. Communication with marina personnel (Chris' River Plaza Marina) suggests that significant mud deposition had occurred in the channel due to the storm, which was estimated to be as much as 4' in depth (however, they suggested this may still be due in part to a dam failure that occurred a few years prior).

• **South side of Navesink R. -** No major impacts to wetlands detected, although human property damage appears to have been significant in low lying areas in the Rumson area (e.g. Barley Point). Debris (vegetation and construction) were still present in the wetlands and at the vertical limit of the storm surge from Barley Point and toward the south and east.

3.) **Manasquan River WMA (Zone 3)** - No major impacts noted to either riverine wetland vegetation or shoreline. Some shoreline erosion was evident, especially in the area of the public boat access (Northern area) and along the southwest shoreline. However, stretches of eroded banks were not more than 100' in length in the few sections observed (note that it was difficult to ascertain whether the erosion present occurred prior to Sandy or occurred due to/exacerbated by past storm events and changes in land use). Some debris were observed, albeit limited, and consisted mostly of vegetation/wrack, although some construction material was also present.

Central Coast – Zones 4 – 9:

1.) **Mantoloking area/Edwin B. Forsythe** - North (Zone 4): Edwin B. Forsythe NWR (EBF NWR) South of Mantoloking Bridge/Barnegat Bay shoreline/marsh: Surveys were conducted from canoe along and within the marshland south of the Mantoloking bridge. Significant impacts were observed along the entire shoreline interfacing with Barnegat Bay, with severe erosion spotted throughout (Figures R-4 and R-5). Depth of erosion/shoreline loss (perpendicular from shoreline/marsh edge) is estimated at 5' – 15' along the marsh/bay edge from Mantoloking bridge south to Reedy Creek, and about 2' from bank to water on either side of major channels moving inland. Mosquito ditches also show signs of significant mud and sand deposition. General shoreline impacts include collapse, undercutting, and scouring with areas of complete breakthrough/washout, with impacts extended to the OMWMs (e.g. filling in with mud/debris, or complete scouring). However, the marsh surface vegetation was largely intact, with herbaceous vegetation and wildlife abundant. Debris, mostly wrack, were observed along the marsh/forest interface and along the roadway; some debris was also

Figure R-3: Mantoloking/Edwin B. Forsythe NWR (July 2013). Severe shoreline erosion along marsh edge and inner channel.

Figure R-4: Mantoloking/Edwin B. Forsythe NWR (July 2013). Example of both marsh/shoreline loss and sand deposition along marsh edges.

still present on the marsh surface. Some construction debris were seen in the water along the outer marsh, where large areas of debris were observed from the desktop assessment (i.e. aerial photography) performed in March 2013. This debris was also observed inland along the forest edges and along Reedy Creek as far as Delmar Drive. Some stressed vegetation was detected along the forest margin of the EBF NWR.

Edwin B. Forsythe NWR North of Mantoloking Bridge/Barnegat Bay shoreline/marsh: Same as above; severe bank erosion was observed along the inland shore of the Bay, especially at F-Cove. Various types of debris, mostly anthropogenic, were still evident on and along the marsh with the greatest concentration along the wooded margin. Large amounts of debris remained in the water along the shoreline between the Metedeconk River and Herbert Island.

2.) **Cattus Island** (Ocean County; Zone 5) - As identified by park personnel (Chris Claus, Chief Naturalist Ocean County Parks Dept., Cattus Island), significant impacts were observed along the north-northeast shorelines and west shoreline of Scout Island. Impacts noted included: 1) severe bank erosion and under-cutting (NE portion of park on Silver Bay and OC boat launch area, sporadic stretches of marsh beginning in Crossway Creek and moving toward point of Scout Island/ Barnegat Bay proper); 2) inundation occurred throughout most of the park (to estimated depth of +/- 5 feet); 3) impacts to vegetation (browning and dieback), observed along Crossway Creek (estimated 40% of visible shoreline, coniferous tree spp.), around/on Scout Island (estimated 50% + coniferous tree spp.), areas of Applegate Cove, and American white cedar (AWC) stand in NE near Mizzen Road; 4) Tree blow-down, oriented to the WSW, seen especially along the south shores of Crossway Creek, Applegate Cove, and Barnegat Bay (observed to within 150' from shoreline); 5) and sand build up in two areas of Scout Island on the south side (area of 40' length, 25' width, and approx. 2' depth). Debris removal, comprised of both construction and natural debris in significant amounts, was almost complete as of June of 2013 due to the efforts of volunteers and contractors, as well as park personnel.

Figure R-5: Manahawkin WMA/Edwin B. Forsythe NWR – Tree blow-down within outer boundary and inner areas of maritime forest. Orientation of trees lying towards south and southeast.

3.) **Manahawkin WMA Area Field Survey** (Stafford Ave/Turtle Cove, Beach Ave, Taylors Lane/ Edwin B. Forsythe NWR – Barnegat; Zone 7):

Stafford Ave/Turtle Cove: Surveys were conducted along several points following Stafford

Ave. Significant impacts were observed along the entire forested edge of the marsh (inundation effects; debris line up to 6' + above water level), looking both south to Rt. 72 and north toward Barnegat. Stressed and dying vegetation (especially understory coniferous species, e.g. American holly – *Ilex opaca* and AWC) were observed, with an estimated 50% of damage/loss or greater consisting of large tree blow- down (mostly red maple – *Acer rubrum*, silver maple – *A. saccharinum*, and sweet gum – *Liquidamber styraciflua*) in some sections of the upland/marsh ecotone, and extending inland as much as 500' + (Figure R-5). Very little, if any, bank erosion was observed in the marsh channels, although some was observed along Cedar Creek on the western banks moving south toward Barnegat Bay. Debris, mostly wrack, was observed along the marsh/forest interface and along the roadway; some on the marsh surface as well.

Figure R-6: Manahawkin WMA/Edwin B. Forsythe NWR – Browning understory along outer edge of marsh/forest boundary. Stressed overstory (e.g. sparse and stunted foliage visible throughout).

<u>Beach Ave</u>: Stressed vegetation was observed along the forest margin (both tree and shrub species alike), estimated to reach in to the forest about 250'. Marsh surface vegetation and features appear largely intact, some wrack visible, although not in significant amounts.

<u>Taylors Lane, EBF NWR</u>: Severe impacts to forested edge of marsh observed, with impacts inward up to about ¼ mi. or greater. As stated above, extensive areas of blow-down was noted in the forested interior (Red maple - *A. rubrum* and *A. saccharinum*, especially) and dying understory, with effects observed out to outer 250' + of trees along the forest/marsh interface (Figure R-7). Atlantic white cedar and other conifer species (pitch pine – *Pinus rigida*, *I. opaca*, etc.) appear to be the most affected, although deciduous tree species such as black gum (*Nyssa sylvatica*) were intact in most areas surveyed.

<u>Bay Side:</u> Impacts evident to human structures, with evidence of heavy inundation in the immediate and surrounding area; some buildings still have not been removed or remediated. In addition, ponding effects were observed along the access roads and some erosion of shoreline; standing water was observed on and along all access roads. The forested margin along Rt. 72 and the surrounding wetland were observed to be showing significant vegetation dieback and stand blow-down, especially impacts to the understory as noted in the Manahawkin WMA and EBF NWR surveys. The estimated extent of damage appears to extend inland to about ¼ mile.

4.) **Great Bay Area Field Survey** (Great Bay WMA, Tuckerton Green Street Beach, Mystic Island, and Leeds Point area; Zones 9-10): Surveys were conducted at the above locations (at or near high tide), with significant impacts visible to dwellings and infrastructure due to inundation and wind shear from the northeast. Tuckerton Green Street Park appears to have

Figure R-7: Great Bay WMA – Severe marsh erosion along northeast- ern shoreline of peninsula. Various impacts visible, including erosion, overwash and separation of large mat areas visible.

significant shoreline erosion, with up to 5' + visibly missing or partially collapsed/submerged banks in some areas, as well as some severe undercutting. Sand and shell deposition was evident with wrack distributed throughout. Great Bay WMA: Observations were made along Seven Bridges Road, with no major impacts detected to interior channels on the peninsula proper, although wrack and other debris were visible throughout. The south side of Great Bay Blvd. appeared to be in good condition, although the north side was showing storm impacts, increasing SE toward RUMFS and the tip of peninsula. Severe impacts to the shoreline were observed on the SE and eastern shoreline of Great Bay WMA peninsula (Figures R-7 and R-8). The SE shoreline appeared severely eroded or collapsed along its entire length beginning from RUMFS and continuing NE to Point Creek. Sedge mat erosion/loss was estimated at as much as 30' from the water edge, with large areas collapsed, torn out, and/or submerged, with severe undercuts and subsidence evident. Mystic Island: Significant shoreline erosion was observed (estimated at 5' – 10') as above; wrack line measured at about 6'above water line. Uprooted and dying vegetation (mostly trees) were observed from the shoreline and inland along Radio Rd. Severe blow-down was seen in the forested parcel (Osborn Island), with the most visible blow-down oriented toward the NE and East. Leeds Point area (E Motts Creek and Oyster Creek Roads): No major impacts were observed at either location. Evidence of inundation was seen with wrack and other debris sporadically distributed. The shoreline and interior marsh areas appear to be healthy and in good shape. No large areas of vegetation impacts were observed.

Figure R-8: Great Bay WMA – Marshland looking Northwest. Erosion and large areas of collapse due to undercutting and wave action visible along northern and eastern shorelines.

Southern Coast – Zones 10 – 11:

Pork Island WMA, Great Egg Harbor Area Field Survey (Tuckahoe WMA).

Pork Island WMA/Scull Bay/Somers Point: No significant impacts observed. Large areas of wrack were seen along the north side of Rt. 152 (Somers Point); however no discernible erosion was evident. Some erosion was detected along the marsh shoreline at the terminus of Poplar road (Scull Bay), in addition to sporadic collapse of sedge mats (1' – 3' wide x 6' – 12' long in spots). However, at the time of this survey, it was difficult to ascertain whether these impacts were due to Hurricane Sandy or an ongoing issue. Shoreline damage was estimated at 2% along the western shoreline, and wrack was observed along all of the highest points along the roads and upland edges.

Great Egg/Jobs Point – Jeffries Landing: No significant impacts to wetlands observed. Evidence of inundation was measured up to 5'+ above the marsh surface, and various types of damage were observed to dwellings and structures at various points along the access roads to Jobs Point. Debris was still present and sporadically distributed, and some debris including stranded watercraft, construction material, and wrack were observed on the marsh. Additionally, stressed Atlantic white cedar individuals and/or stands were observed on the upland peninsulas/high marsh areas near Jeffries Landing.

2.) **Tuckahoe – Corbin City WMA**: No significant impacts were observed at the time of this survey. Severe damage to impoundments did occur during the storm and were reported, however these were repaired/replaced prior to the OS damage assessments. Evidence of inundation was seen along the tributaries and marshland, with sporadic areas of wrack piles and wrack lines observed. Major impacts to vegetation following inundation were not observed. However, some tree blow-down was detected in the forested areas due to high winds, and these effects appear to have been widespread, albeit sparsely distributed.

Forests

In summary, Hurricane Sandy caused mainly two types of effects on forested natural areas in New Jersey, tree blow-downs and toxicity to trees due to saltwater inundation. A qualitative examination of affected areas indicates that the overall effect of this storm is that less than 5 percent of trees were downed on State lands. Damage from seawater inundation supplied the most extensive effect of Hurricane Sandy, and has killed and/or stressed many stands of Atlantic white cedar.

Ground survey, aerial photography, and storm models have historically been used for forest damage assessments. Since the 1990s, remote sensing where satellite detection of light from forests can estimate chlorophyll content, leaf water content, and structural changes in a damaged forest have also been applied to damage assessment (Wang 2010). Damage classes as described by USDA have been categorized as follows: little to none (0 to 11%), moderate (11 to 25%), and severe (greater than 25%) (Nielsen 2006). These studies show that the less than 10% tree damage from Hurricane Sandy as being in the "little to none" classification for natural resource damage.

While the overall statewide extent of downed trees in natural areas is small, some areas covering tens of acres did experience almost complete tree toppling due to wind. This information is gleaned primarily from three sources: an overflight by the New Jersey State Forestry Services during late 2012, analysis of Pictometry® Connect images of state forests, and site visits to areas of known tree damage by the Damage Assessment Team.

Figure F-1 shows the results of a flight conducted on December 13, 2012 by the NJ State Forestry Service. The damage recorded is primarily in the northern part of the state along mountain ridgelines where there was exposure to hurricane force/high winds. Damage was observed at seven parks and consisted of 8% of the total area. Table F-1 shows these Parks and the number of damaged acres.

Table F-1. New Jersey State Parks and number of damaged acres (2012-2013). Please note that not all State forests reporting damages are included below (Source: NJSFS 2012).

State Park	Total Acres	Damaged Acres	Percent Damaged
Abram S. Hewitt State Forest	3,622	532	15
High Point State Park	13,866	450	3
Norvin Green State Forest	5,271	847	16
Stokes State Forest	15,453	1,139	7
Washington Crossing State Park	2,600	135	5
Wawayanda State Park	9,163	1,066	12
Worthington State Forest	5,075	337	7
Total Survey Area	55,050	4,506	8

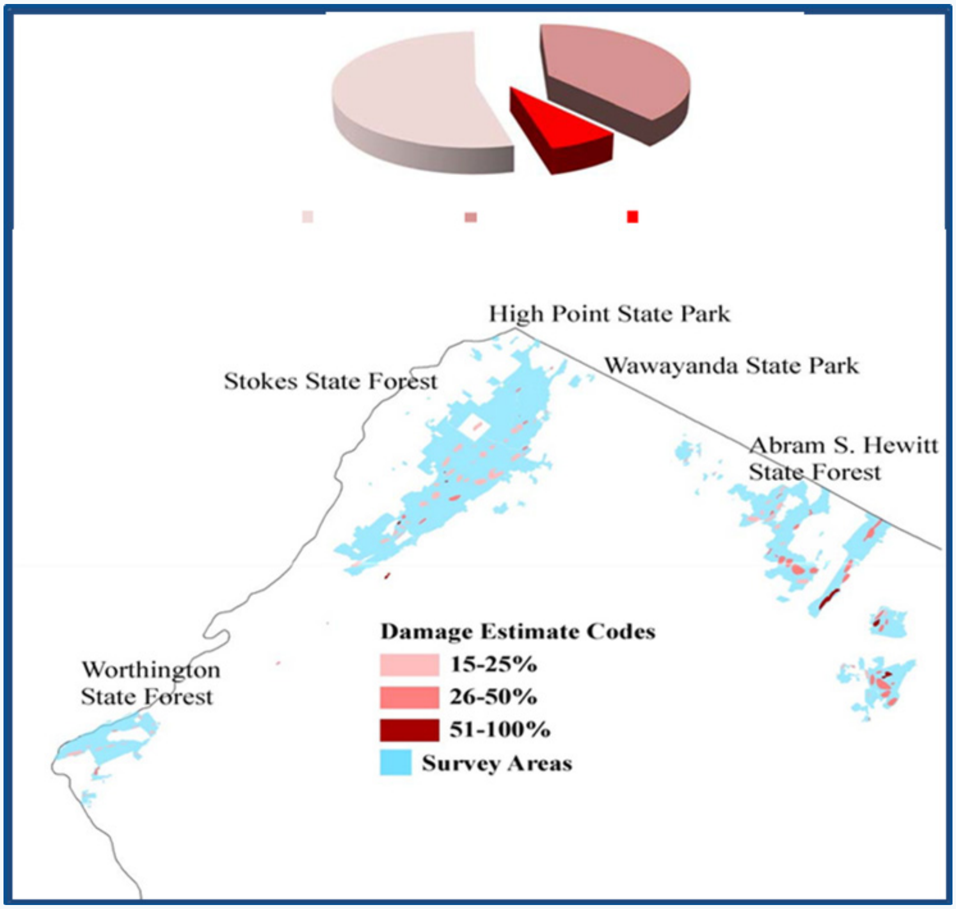
Aerial photography (Figure F-2) obtained from Pictometry® Connect shows conifer dieback at Double Trouble State Park probably caused by salt water inundation. The brownish areas are evidence of the dead and/or dying trees. This is an example of the type of damage responsible for damaging large areas of Atlantic white cedar.

Numerous parks were visited in June 2013 where there had been reports of blow-downs. Only portions of the parks were evaluated as the survey was from roadside and limited walks into the affected areas. Areas were chosen which had the most evidence of damage with the results of the survey shown in Table F-2.

Table F-2. Evidence of damage and results (acres) following field survey assessment.

Location	Acres Examined	Acres Damaged	Percent Damaged
Allaire State Park	20	5	25
Monmouth Battlefield State Park	40	8	20
Colliers Mills Wildlife Management Area	20	2	10
Turkey Swamp Wildlife Management Area	30	2	7

Figure F-1. Estimated forest damage in northern New Jersey Forests (NJSFS 2012).



On June 5, 2013 a field trip was conducted in the area inundated by the storm surge in the vicinity of Great Bay. Roadside observations on Hay Road and Lower Bank Road showed areas of Atlantic white cedar damage due to salt water toxicity. This was indicated by brown needles throughout the canopy. This location is about seven miles from the open water of Great Bay on the Mullica River. Observations in the Edwin B. Forsythe National Wildlife Refuge surrounding Great Bay showed blow-downs of Atlantic white cedar and pitch pine.

Figure F-2. Conifer dieback at Double Trouble State Park (Cedar Creek) probably caused by salt water inundation (Pictometry® International 2013).

SUMMARY OF FEBRUARY 14, 2013 NJ PARK SERVICE REPORT

The New Jersey State Park Service (NJSPS) of the Division of Parks and Forestry produced a report entitled "Hurricane Sandy Storm Impact on Natural Resources" (NJSPS, 2013). This report documents storm effects on approximately 40,000 acres of 12 state parks. Topics such as infrastructure damage, beach erosion, bird habitat, salt water intrusion and tree damage are covered. Salt water intrusion and tree damage data are the most relevant for this section of the report.

Stokes State Forest, Hacklebarney, Round Valley Recreation Area, and Cheesequake, Allamuchy, Voorhees, Wawayanda State Parks are noted as having significant damage to forest due to blow-downs with Tillman's Ravine, and the School of Conservation being particularly hard hit in Stokes State Forest. In Hunterdon County, the New Jersey State Forestry Service (NJSFS) also reported heavy tree damage to the Bull's Island and Cook Natural Areas (NJSFS, pers. Comm., 2014). Salt water inundation and resulting damage to Atlantic white cedar was documented for Bass River State Forest and Cheesequake State Park. Additionally, severe white pine (*Pinus alba*) and mixed hardwood damage in Washington Crossing State Parks was observed (D. Swaysland, NJSFS, pers. Comm., 2014).

Other programs within the Department focused on forest damage associated with park resources, infrastructure, and threatened and endangered species habitat.

SUMMARY OF SITE VISITS WHERE TREE PLOTS WERE COUNTED FOR BLOW-DOWNS

One quarter acre plots of visually damaged tree stands were examined on site for the number and diameter of downed trees. A total of 6 plots at three parks were counted. All trees over 3 inches in diameter were enumerated. After normalization to units of trees per acre (tpa) the plots ranged from 0 to 273 tpa with a mean of 53 tpa. The greatest damage of 273 tpa was recorded at Monmouth Battlefield State Park.

Open Water

Introduction

Damage assessment of open waters involved examination of multiple tidal waters along the coast for the presence/absence of submerged aquatic vegetation (SAV), critical habitat for a number of aquatic biota.

Since early 2013, several Department programs were contacted to provide information on what Hurricane Sandy damage assessments have already been conducted, are underway, and/or are being proposed to meet their specific program needs. Key personnel have been contacted and team members established with representatives of the Division of Fish and Wildlife (DFW), Bureau of Marine Fisheries, Bureau of Shellfisheries, and the Division of Water Monitoring & Standards (DWM&S). Currently, very little information is available to determine the degree to which marine fish or shellfish, as well as SAV habitat, have been impacted by or following Hurricane Sandy.

Bureau of Marine Fisheries:

According to the Bureau of Marine Fisheries, the fisheries resources themselves were not significantly impacted by Hurricane Sandy (BMF 2013, Pers. Comm., T. McCloy and B. Muffle). The distribution and movements of fish were likely changed right after the storm, but evidence is lacking of mass mortality or population level impacts. The Bureau believes that the greatest impact is likely to be habitat modifications - changes /covering/movement on the artificial reef network; sand impacts/covering hard bottom areas needed for winter flounder eggs to adhere; closing/opening of fish passage impediments; and impacts to nursery areas and SAV.

The only marine fisheries related assessments conducted to date have been directed at the various user groups (commercial and for-hire fishermen, bait and tackle shops, marinas, commercial docks, shell fishermen, shellfish hatcheries) that suffered physical (e.g., equipment and facility) and economic losses due to Hurricane Sandy.

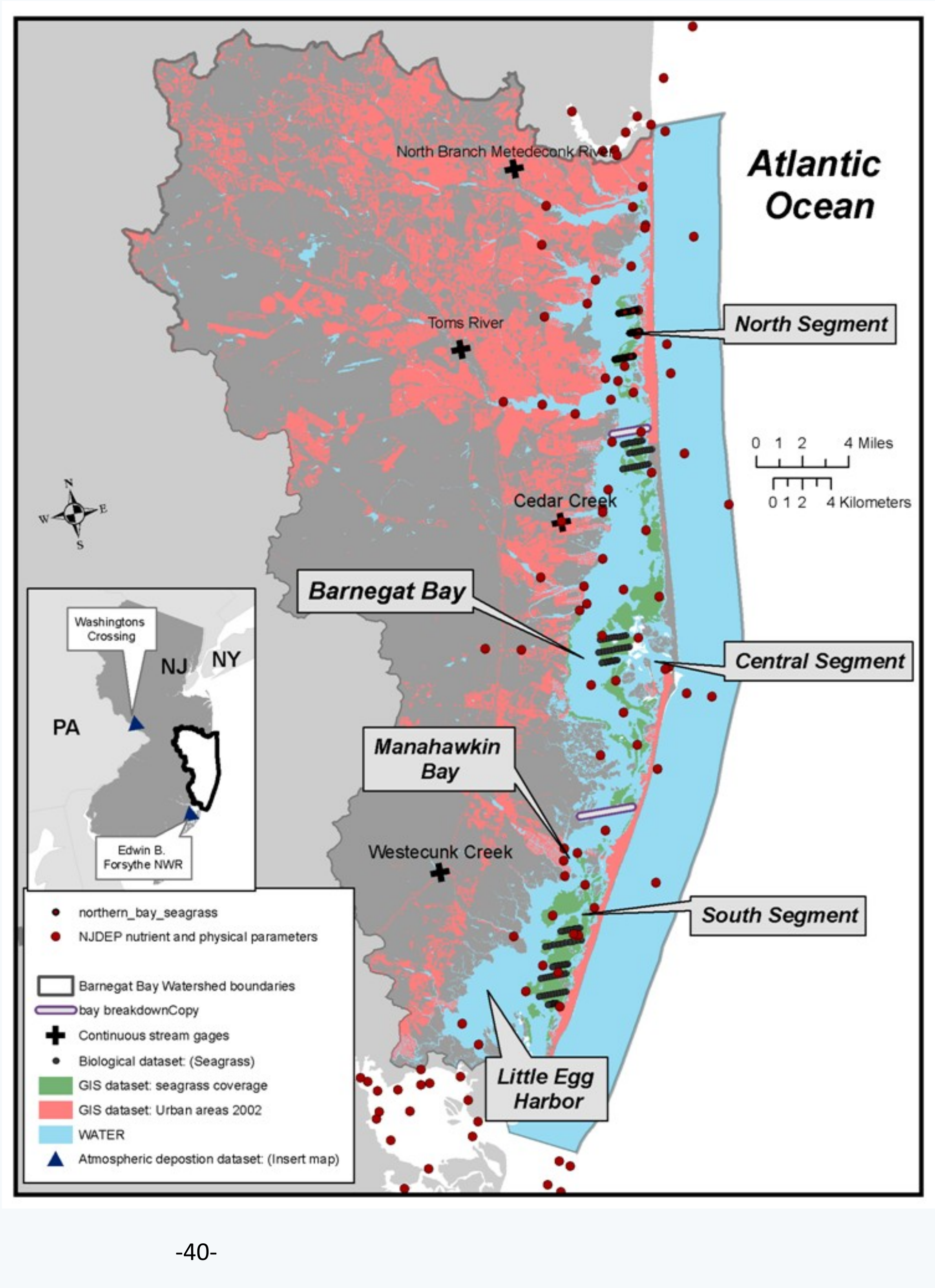
Bureau of Shellfisheries:

With respect to shellfish and SAV resources, the Bureau of Shellfisheries submitted a series of projects to the Aquatic Resources Workgroup for funding consideration in order to assess the present abundance of distribution of these resources in State waters (Personal Communication: Jeff Normant and Russell Babb). Beginning in 2011, the Bureau prioritized its comprehensive stock assessment program of shellfish and as a component of the program SAV throughout the State's waters. In 2011, an estuarine shellfish stock assessment was conducted in Little Egg Harbor, followed by an estuarine shellfish stock assessment survey of Barnegat Bay in 2012. The Little Egg Harbor survey was the first shellfish survey conducted since 2001 and the first for Barnegat Bay since 1985/1986. The presence or absence of SAV was also noted at each station sampled. These programs are essential for the management goals of the Bureau. Data obtained as part of this survey was instrumental in determining if any significant impacts from Hurricane Sandy could be ascertained.

In 2012, the Bureau sampled 356 stations using a hydraulic clam dredge and estimated the bay's standing stock and relative distribution of hard clams. Work was conducted between May 30, 2012 and October 25, 2012. The survey resampled stations that were sampled during the 1985/86 survey plus an additional 51 new stations to cover areas not previously sampled. The standing stock of hard clams in the bay for 2012 was estimated at 136.1 million clams. For the purpose of a direct comparison, the stock was also estimated using only those stations that were sampled during both surveys, which yielded an estimate of 134.6 million clams. That estimate represents an approximately 24% decrease in the standing stock compared with the 177.3 million clams estimated in 1985/86. Statistical analysis indicated a significant decrease in hard clam abundance when comparing stations sampled in 2012 to those same stations sampled in 1985/86.

Following Hurricane Sandy, the Bureau changed its survey schedule and revisited Barnegat and Little Egg Harbor bays in order to assess any population changes attributable to the storm event. Hurricane Superstorm Sandy officially made landfall on October 29, 2012 and survey work was conducted in the summer of 2013. Approximately 25% of all the stations in both bays were resampled. No significant difference was found in hard clam abundance or mortality when comparing stations sampled before and after the storm, and the survey showed little direct physical impact from Hurricane Sandy in the surveyed region. However, a significant decrease was found in the proportion of stations containing SAV that were sampled before and after the storm. Of the stations sampled prior to the storm, 60% contained SAV, whereas 45% of the same stations sampled after the storm contained SAV.

Figure O-1. Changes in Seagrass coverage for Barnegat Bay from2003 to 2009 (Lathrop 2011).



Methods: A desktop assessment of existing data and information gathered on SAV status and trends along the New Jersey Atlantic coast identified several studies that were used extensively in the field assessments and location determinations.

Lathrop (2011) employed high definition remote sensing overflights and spatial analysis to document the seagrass beds in Barnegat Bay for 2003 and

2009. According to Lathrop (2011), "The Barnegat Bay-Little Egg Harbor (BB-LEH) estuarine system contains about 75% of New Jersey's known seagrass habitat. Eelgrass (*Zostera marina*) is often the dominant species, while widgeongrass (*Ruppia maritima*) is also common in lower salinity and shallow regions of the BB-LEH. The remote sensing data generated for the 2003 and 2009 surveys of Barnegat Bay suggests that the area of mapped seagrass coverage was similar between the two time periods. While changes in seagrass locations and densities were evident at all locations surveyed, the overall assessment indicates that the seagrass beds for those areas surveyed were stable. The changes and direct impacts that were observed, were apparently enhanced by anthropogenic activities. Several direct impacts to seagrass habitat (including dredging, boat docks and scarring) were identified as contributors to diminishing seagrass habitat. However, these direct impacts overall have only contributed to a minor reduction in seagrass habitat (Lathrop, 2011).

Kennish (2013) conducted a comprehensive seagrass study in Barnegat Bay and Little Egg Harbor estuary in 2011 to determine seagrass demographics in the north segment of the estuary, and to document seagrass characteristics across the entire estuary in the same year as part of a separate study (Figure O-1) . The results of this study show that *R. maritima* dominates seagrass beds in the northern segment, while *Z. marina* dominates seagrass beds in the central and south segments of BB-LEH. Widgeongrass populations decreased between 2005 and 2010, and no *R. maritima* samples were found in the south segment during 2011. Total eelgrass biomass declined over the 2004-2006 and 2008-2010 periods, and more acutely during the 2004-2006 period. The 2010 eelgrass biomass values measured were the lowest levels ever recorded in the estuary.

Able (2013) examined how the macrofauna of Barnegat Bay respond to urbanization by comparing the temporal (annual, seasonal) and spatial (along the north-south gradient in urbanization) variation in the Bay. He found that seasonality dominated both abundance and diversity patterns in SAV habitat, as well as influenced the fishes associated with these habitats. Furthermore, a greater spatial effect was evident, specifically the relationship of sample site distance (i.e. SAV bed locations in relation to distance from the inlets). Able suggested "the effects of inlets on water quality, especially salinity and larval delivery, may also be substantial enough to mitigate urbanization effects for fishes in open bay SAV habitat, especially because these sites are along the eastern side of Barnegat Bay. Thus, they are not as closely tied to the land use patterns that define urbanization mostly through development of the western site of the bay".

Consequently, Able et al. (2013a) indicated:

> There are no clear negative responses to the hurricane (Sandy) in the fall of 2012, although the analysis of the data from 2013 is just beginning. The number of fish species collected in April (n = 18), June (n = 27) and August (n = 35) 2013 is similar to the number collected with the same otter trawl techniques and locations in April (n = 23), June (n =25) and August (n = 31) 2012 (Table 6). However, overall abundance (catch per unit effort, CPUE) is lower with number of individuals collected in April (n=322), June (n=1117) and August (n=2729) 2013 less than in April (n=1301), June (n=3103) and August (n=5175) 2012, prior to the storm.

> The number of blue crabs captured (2,301) in 2013 is very similar to the number captured over the same time period and sampling sites in 2012 (2,295), suggesting that there are no obvious negative effects of Hurricane Sandy on blue crab abundance.

Celestino (2013) (Bureau of Shellfisheries) conducted a hard clam *Mercenaria mercenaria* stock assessment of Little Egg Harbor Bay (LEH) in 2011. As part of this survey, the Bureau determined that the LEH contains an estimated 4,720 acres of SAV, a noted decrease of approximately 1,600 acres from 2001 (see Attachment 2). The SAV in Little Egg Harbor Bay declined approximately 25% in total estimated acreage from 2001 to 2011. Some of the more prominent changes in SAV distribution include additional fragmentation of the extensive beds located in the northern and central portions of Barnegat Bay. Some of the reported losses may be attributed to the fact some of the surveys were completed during different times of the year. Other losses may be due to impacts from other major storm events (e.g. Tropical Storm Lee, August 2011) impacting this region during this period. Other potential influential factors affecting the results include SAV phenology (seasonality), and concerns have been raised about the potential for habitat change.

Post Storm Impact:

The hurricane landfall information identified that the Barnegat Bay, from Mantoloking/Bay Head to Little Egg Harbor, was one of the most severely impacted sections along the New Jersey coast. As for other habitat examined in this report, aerial photography, Pictometry, and LIDAR were examined for areas to conduct ground truthing of reported damage and field reconnaissance. Based upon the data gathered from pre-Sandy SAV studies, the field assessment locations were concentrated mainly in the Barnegat Bay- Little Egg Harbor region. An initial field assessment conducted in the Navesink River Estuary was selected to identify the existence of seagrass beds in this estuary, and to determine if the macro-alga *Ulva lactuca* beds were in any way impacted.

One major consequence or potential impact of the storm not examined in the field (due to scope) includes loss of aquatic biota due to the storm surge. Freshwater ponds and lakes in the surge area were adversely affected by the penetration of saltwater during the storm. Carteret Pond in Carteret was found to be brackish following Hurricane Sandy, and both pumps and aerators were damaged by the storm (MyCentralJersey.com, 2013). It was reported that no fish were found in the pond, ostensibly from being dislodged by the storm surge[2]. Recovery has already been completed due to the addition of freshwater and stocking by the NJDEP's Division of Fish & Wildlife Hackettstown State Fish Hatchery.

Impacts to submerged aquatic vegetation (SAV) and shoaling leading to loss of habitat are a major concern. The greatest effect is suspected to be on fish/crab nursery areas in back bay areas, however the realized effects may not be evident for one or more years.

<u>Open Waters Field Assessments</u>

The OS Damage Assessment Team conducted a series of qualitative surveys along the backbay region of the Atlantic coast of New Jersey. These surveys targeted areas moderately to severely impacted by Hurricane Sandy. Survey site selection was based upon the availability of pre- hurricane data on the

[2] In this case recovery has already been completed due to equipment repair, lake drainage and addition of freshwater, as well as stocking by the NJDEP's Division of Fish & Wildlife Hackettstown State Fish Hatchery at the request of municipal officials (MyCentralJersey.com, 2013).

existence of seagrass beds as described in 2009 by Lathrop (2011). Sampling occurred in areas where seagrass beds had been previously identified and in areas where seagrass beds may have been established during post-hurricane conditions.

In all cases where seagrass beds were not established in 2009, no newly established (post-hurricane) beds were discovered. An assessment of seagrass beds in the Navesink River/Estuary identified little in the way of seagrasses and only macro-alga *Ulva* in the eastern portion of the estuary.

In areas where seagrass beds were identified in 2009, the presence or absence interpretation is not as obvious. For example, in 2009 a seagrass bed existed in and around Herring Island (Bay Head-Mantoloking). The assessment of the seagrass beds in this vicinity identified a markedly degraded bed with only a limited survival within the interior of the cove on the western side of Herring Island. By contrast, the surveys also identified areas of seagrass beds from Lavallette to Island Beach State Park that appear to be intact and thriving. However, even in this region, a large area (~ 200 acres) south of the Rt.35 bridge at Seaside Park did not contain a significant amount of seagrass as previously identified in 2009. This patch work survival pattern was not as evident farthest south along the eastern side of Barnegat Bay. From Seaside Park and into Island Beach State Park, the assessment survey found that the seagrass beds still appeared to be extensive and flourishing. Other locations in Lower Barnegat Bay and Little Egg Harbor such as Loveladies to Beach Haven, appear to have lost significant SAV in the central section of the bay and a portion of the seagrass bed east of Conklin Island (Barnegat, NJ) as well.

The cause or causes of such divergent seagrass bed conditions cannot be solely attributed to effects of Hurricane Sandy. While beach sand buildup in Barnegat Bay from Hurricane Sandy can have an impact on seagrass survival, from prior studies it is apparent that seagrass losses can be attributed to multiple factors. For example, Kennish (2012) states:

"Since 2004, eutrophication has generally worsened in BB-LEH, and the condition of the seagrass habitat has markedly degraded in the central and south segments. Eelgrass biomass declined consistently over the 2004-2006 and 2008-2010 periods, and overall from 2004-2010. The 2010 eelgrass biomass values were the lowest levels recorded in the estuary. Data collected on demographic trends indicate that eelgrass beds in 2011 had yet to recover from the marked decline of plant biomass and areal cover observed in 2009 and 2010. The trend of eelgrass decline over the years has not been isolated to one bed but has been observed over extensive areas of the estuary, signaling a response to a broad-scale stressor that adversely affects plant condition across the system."

In addition, Lathrop (2011) suggests that for the submerged aquatic vegetation (SAV) in Little Egg Harbor Bay there was:

"a decline of approximately 25% in the total estimated acreage from 2001 to 2011. Some of the more prominent changes in SAV distribution include further fragmentation of the extensive beds located in the northern and central portions of the Bay. He further suggested that the loss of SAV in the Barnegat Bay has been occurring for a long time and that there are probably many contributing factors (i.e. Hurricane Irene made landfall at Beach Haven, NJ 28 August 2011). Observed differences and other potential influential factors affecting our results (including SAV phenology) may be due to interpretation of the varying SAV databases during different times of the year (2001 survey conducted between 16 July 2001 & 31 August 2001, while the 2011 survey was conducted between 24 August 2011 & 18 October 2011). Concerns have been raised about the potential for habitat change."

It was decided that a series of qualitative field assessment surveys would be undertaken to determine the condition of SAV seagrass beds along coastal New Jersey. The field assessment site selections were primarily based on the results of the seagrass mapping project conducted by Lathrop (2011.) All qualitative field assessments were conducted by OS staff (Figures O-2a – O-2c).

Figure O-2a. Aqua-vu underwater camera

Figure O-2b. Horiba Model 4000 water quality data logger

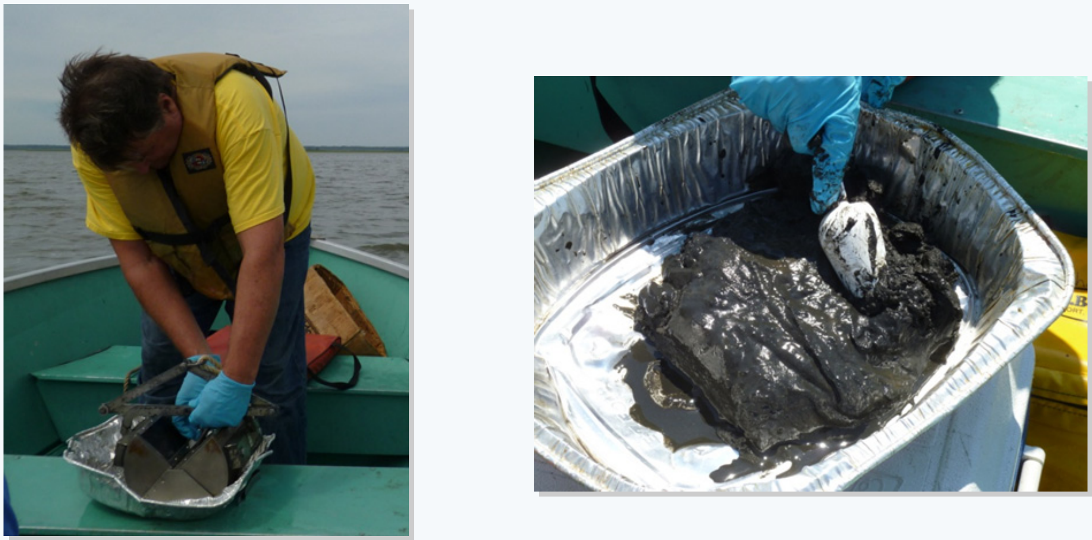


Figure O-2c. Ponar dredge sediment sampler

<u>Field Assessment Surveys</u>

1.) A field assessment was conducted on July 9, 2013 at the Navesink River from Red Bank to the Oceanic Bridge, Fair Haven. The qualitative assessment indicated very little presence of SAV at any of the 18 sites. Only the green alga *Ulva lactuca* was identified at two of 18 open water locations (Figure O-3). A previous shoreline survey identified *Ulva* at several near shore locations at water depth estimated less than one meter east of the Oceanic Bridge, Fair Haven, NJ.

2.) A Field Assessment was conducted on July 18, 2013 from Toms River to Seaside Park. The qualitative assessment indicated very little presence of SAV at any of the sites within the Toms River estuary; however, both Eel Grass and Widgeon Grass were identified only in a narrow strip of nearshore waters (< 3 ft.) at Seaside Heights and Seaside Park. A previously defined large grass bed south of the Rt. 35 bridge (~ 200 acres) was not located.

Figure O-3. Green macro-alga *Ulva lactuca* at Navesink River estuary

3.) A field assessment was conducted on July 25, 2013 from Lavallette, NJ to the Rt. 35 bridge at Seaside Heights. This qualitative assessment indicated the presence of SAV at 24 of the 30 sites examined. Both Eelgrass and Widgeon Grass were identified throughout this estuary section in waters < 3 ft. deep (Figures O-4 and O-5). Previously defined large grass beds (~ 588 acres) were located and appear to be thriving.

Figure O-4. A narrow strip of Eel Grass *Zostera marina* growing in Barnegat Bay at Seaside Park, NJ (Note: from underwater video capture).

Figure O-5. Ponar sediment sample and eel grass from Barnegat Bay at Lavallette, NJ

4.) A field assessment was conducted on Aug 1, 2013 from Seaside Heights to the IBSP. This qualitative assessment indicated the presence of SAV at 34 sites. Both Eelgrass and Widgeon Grass were identified throughout this estuary section in waters < 3 ft. deep (Figure O-6). Previously defined large grass beds (~ 950 acres) were located and appear to be thriving.

Figure O-6. Dense seagrass beds in Barnegat Bay at Seaside Park to Island Beach State Park, NJ (Note: from underwater video capture).

5.) A field assessment was conducted on Aug. 5, 2013 from Bay Head to Mantoloking. The qualitative assessment indicated very little presence of SAV at any of the sites within the Metedeconk River estuary; however, both Eel Grass and Widgeon Grass were identified in a narrow strip of waters (< 3 ft.) in the cove at Herring Island, Mantoloking, NJ (Figure O-7). The previously defined grass bed within this area (~ 30 acres) was not located.

Figure O-7. Seagrass bed in the cove at Herring Island, Bay Head, NJ

Figure O-8 Barnegat Bay at Conklin Island, seagrass beds are reduced in total acreage.

6.) A field assessment was conducted on Aug. 19, 2013 along the western side of Barnegat Bay (Conklin Island to Gulf Island) south of Barnegat, NJ (Figure O-8). This qualitative assessment indicated the presence of SAV at a limited number of sites along the northern side of the Edwin B. Forsythe NWR. Eelgrass and Widgeon Grass were identified along this section in waters approximately 3 ft. deep. A previously defined large grass bed (~408 acres) was not located.

7.) A field assessment was conducted on Aug. 27, 2013 along the central section of Barnegat Bay west of Loveladies-Harvey Cedars, NJ. This qualitative assessment indicated the presence of SAV at a very limited number of sites along the eastern side of the bay. Very little Eelgrass was identified along this section in waters approximately 3 ft. deep (Figure O-9). A previously defined large seagrass bed (~ 298 acres) was not located.

Figure O-9. Sediment sample from Barnegat Bay west of Loveladies-Harvey Cedars, NJ where large seagrass bed was located in 2009.

8.) A field assessment was conducted on Sept 12, 2013 along the southern section of Barnegat Bay west of Long Beach Township, NJ. This qualitative assessment indicated the presence of SAV at a very limited number of sites along the eastern side of the bay. Very little Eelgrass was identified along this section in waters approximately 3 ft. deep. Previously defined extensive seagrass beds (~ 950 acres) appear to be severely diminished (Figure O-10).

Figure O-10. Typical sediment conditions in Barnegat Bay at Long Beach Twp, NJ

Water-quality samples were collected at each regional area during the evaluation for the presence of submerged aquatic vegetation between July and September 2013. All samples were collected between the hours of 8:30 am and 2:00 pm (Table O-1). Water-quality parameters included temperature, dissolved oxygen, pH, turbidity, and oxidation-reduction potential. Parameter values were determined using a Horiba (model #4000) multi-probe meter. Plots of each parameter for each sample region are provided in Figures O-11 through O-15. Observed water temperatures were greatest during the July 18th survey run. Dissolved oxygen and pH varied the most at the Toms River survey sites. Median dissolved oxygen levels were above 4 mg/l at each regional area and above 5 mg/l at 7 of the 10 regions. Areas where median dissolved oxygen was less than 5 mg/l were the Navesink River, and the two Manahawkin areas. The lowest pH values were collected in the most inward parts of the Toms River estuary. The Toms River drains a portion of the Pinelands and natural pH values above the head of tide are typically less than 6.0[1]. Turbidity measures were relatively uniform with median values between 9.3 and 15.0 NTU at all of the regions except Long

Beach Township (LBT). The median value for this area was 31.9 NTU. Oxidation-reduction potential values were lowest at the northern most Navesink River sites and generally greatest at the Seaside Park and Island Beach State Park sites which were sampled on the same day.

Table O-1. Sample Locations, date, crew, times of the first and last samples, and the number of water-quality samples analyzed.

Regional Area	Code	Date	Field Crew	First Sample	Last Sample	N
Navesink	NAV	7/9/2013	GB, BR, LL	10:44:00 AM	1:22:00 PM	8
Toms River	TOMS	7/18/2013	GB, BR, NP	10:14:00 AM	12:34:00 PM	12
Seaside	BB	7/18/2013	GB, BR, NP	12:47:00 PM	2:03:00 PM	6
Lavallette	NBB	7/25/2013	GB, JB, LL	10:22:00 AM	1:42:00 PM	14
Bay Head	BYHD	8/1/2013	BR, JB, LL	8:42:00 AM	11:08:00 AM	15
Barnegat-Seaside Park	BBSP	8/7/2013	GB, JB, NP	9:38:00 AM	1:51:00 PM	6
Barnegat-Island Beach	IBSP	8/7/2013	GB, JB, NP	11:12:00 AM	1:37:00 PM	8
Barnegat-Manahawkin	BARN	8/19/2013	BR, LL, NP	9:10:00 AM	12:51:00 PM	24
Barnegat-Manahawkin II	BARN II	8/27/2013	BR, LL	9:51:00 AM	12:06:00 PM	13
Long Beach Township	LBT	9/12/2013	BR, LL	9:40:00 AM	12:28:00 PM	14

[1]Data from http://www.state.nj.us/dep/barnegatbay/plan-wqstandards.htm

Figures O-11 – O-15. Graphs of temperature (deg C), dissolved oxygen (mg/1), pH, turbidity (NTU), and oxidation-reduction potential (mv) showing the median and 10th, 25th, 75th, and 90th percentiles of data collected in each of the regions sampled for the presence of submerged aquatic vegetation. Regional codes on the y-axis match those in the Table O-1.

Figure O-11. Temperature (deg C)

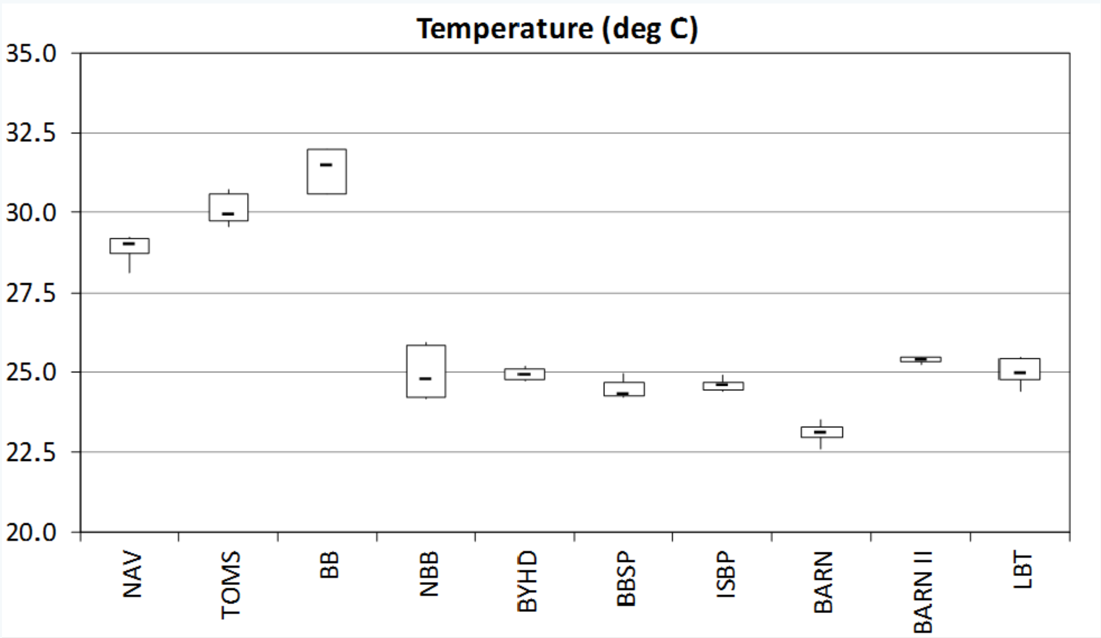


Figure O-12. Dissolved Oxygen (mg/L).

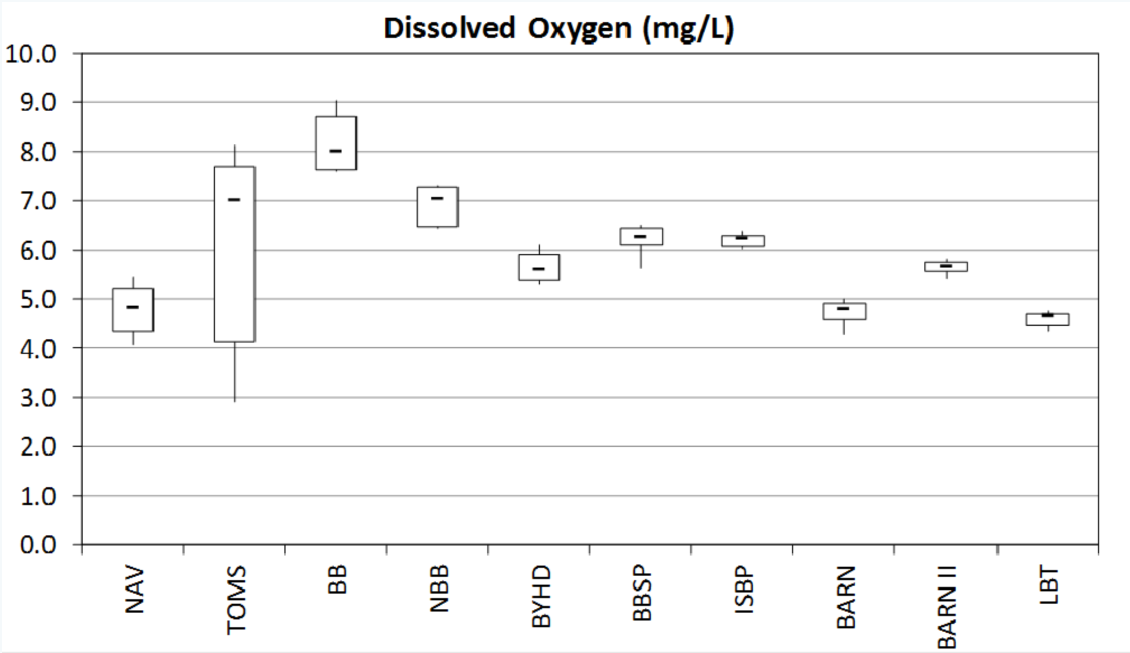


Figure O-13. pH

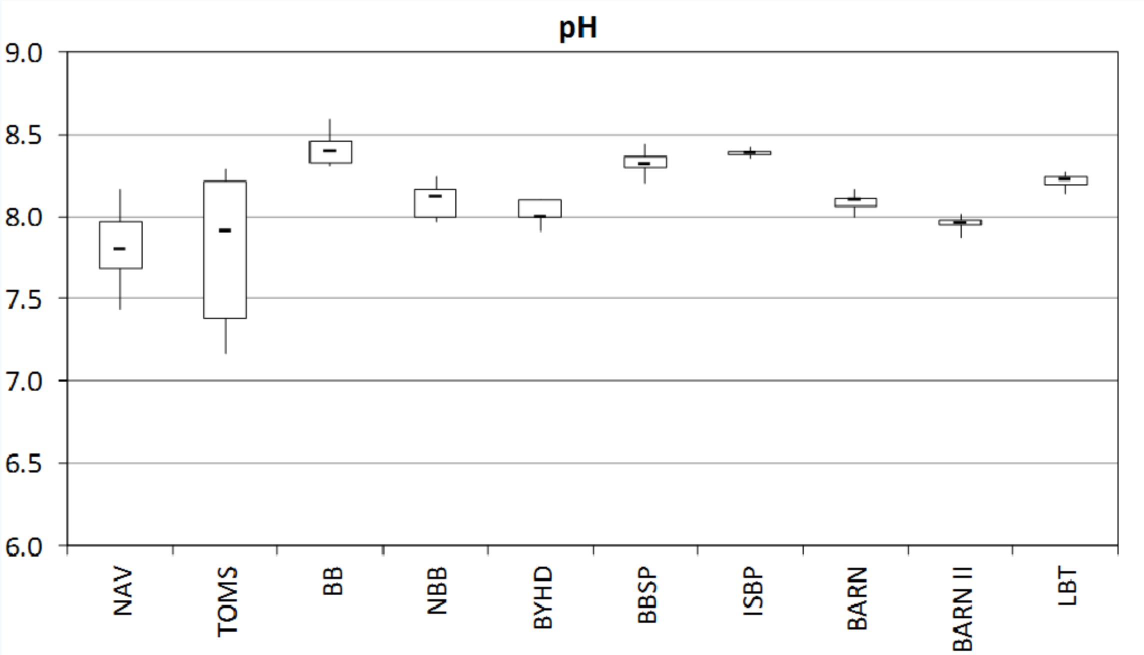


Figure O-14. Turbidity (NTU)

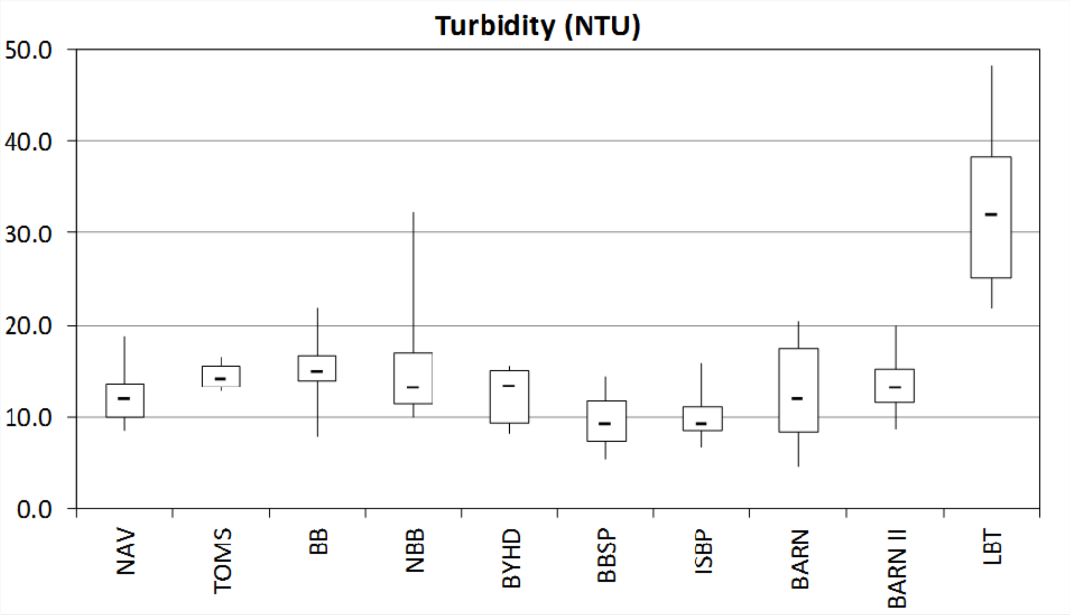
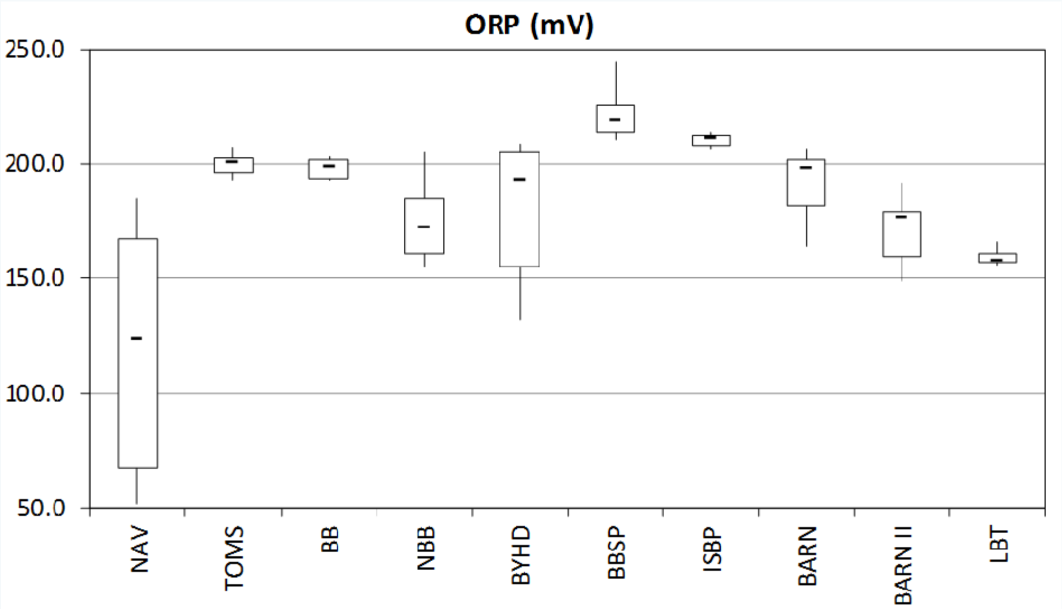


Figure O-15. ORP (mV)



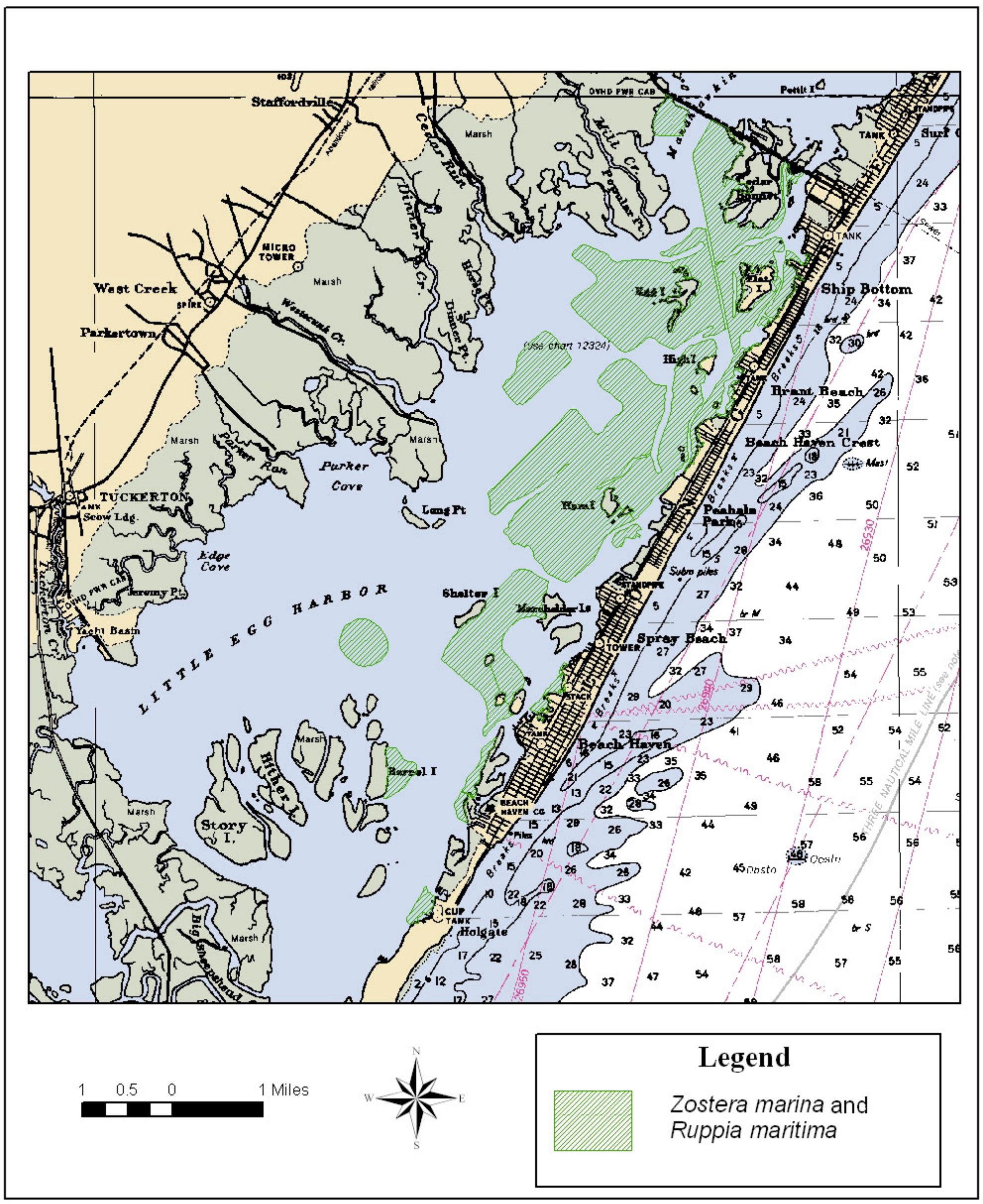
Future Assessments:

Due to the importance of SAV in the estuarine ecosystem, more comprehensive assessments (and continued monitoring) are recommended in order to characterize the current baseline extent and density of SAV. This will allow the impacts of future storms to be more effectively assessed as well as provide data for determining SAV trends. Funding for an assessment within Barnegat Bay for SAV, and other State shellfish waters for both SAV and shellfish, that includes an aerial survey of SAV during the shellfish growing season is recommended. It is also recommended that funding through the Department of Agriculture be pursued for a compilation of projects appropriate to shellfisheries. For example, an oyster shell planting project on the natural seed beds in Delaware Bay has been recommended. Funding for this project (and others related to this) had been proposed following and relative to oyster losses from previous storm events. The significance of this project has increased in the wake of recent hurricane and storm events and could generate useful resource management information.

Figure O-16— 2011 Little Egg Harbor Bay Shellfish Inventory: SAV distribution.

SHELLFISH STOCK ASSESSMENT OF LITTLE EGG HARBOR BAY (2011) REPORT

2011 Little Egg Harbor Bay Shellfish Inventory: SAV distribution.



Summary and Recommendations

Wetlands:

Hurricane Sandy's angle of approach, wind speeds and unfortunate timing (making landfall on a full moon high tide) produced record storm surges and devastating impacts to the built communities along New Jersey's coast. However, the wetlands that buffered these developments sustained comparatively less damage. Post-Sandy aerial photography and field assessments showed excessive ponding and the marsh being slow to drain where it was completely inundated by storm surge, areas of shoreline (marsh edge) erosion, and marsh vegetation disturbance. Wetland areas previously impacted by alteration appeared to have sustained more damage and were slower to recover than natural wetland areas. While tidal streams overflowed their banks and there was evidence of shoaling and creation of sand bars at the mouths of these streams, the watercourses themselves retained the same bank configuration. Only at the confluence of the Maurice River and Cohansey River and the Delaware Bay was there evidence of erosion to meanders. Field investigations documented greater adverse impacts to the wetlands on the Delaware Bayshore than on the Atlantic coast and back bay areas.

It was difficult to assess from presently available sources whether, or to what extent, the observed impacts would result in permanent alterations, or whether and how quickly the system would naturally adjust. Many of the questions generated from both the desktop and field assessments would require scientists to wait for one or more growing seasons to ascertain whether the saltwater surge permanently damaged trees on the upland/wetland edge; whether water would recede from ponded areas and vegetation would regrow where it had been scoured; and whether the tidal wetland system would recover from the release of chemicals and petroleum products spilled into the marsh from upland sources. The integrity of New Jersey's coastal wetlands was difficult to assess as is whether these wetlands could sustain additional assaults of the magnitude of Hurricane Sandy and perform as well.

The following recommendations are presented for consideration:

- It is suggested that in areas slow to recover, previously altered and/or showing impounded water be considered for restoration utilizing the 'thin layer disbursal of dredge material' (to elevate the marsh).
- Consider the regulatory review and application of an 'upland buffer' to tidal wetlands (as in the Freshwater Wetlands Protection Act) to limit upland impacts to tidal wetlands and to further protect development from storm surge.
- Consider the re-tabulation of wetland acreage (extent, coverage); new shoreline mapping (v-datum and mean high water line). There is not only a need for more accurate areal baseline data concerning wetlands and shoreline, but also data on health and condition and historic data to document wetland response and recovery over time and to formulate projections to future impacts.

Riparian Habitats/Floodplains:

1.) Based on desktop assessments/aerial photography/Pictometry®Connect, limited change was observed between 2012 and 2013 to the shoreline, however significant changes were observed between 2007 and 2012. There was some difficulty in assessing true impacts to shoreline from Sandy since the stage of tide for the aerial photographs was unknown. Other storms (e.g. Hurricane Irene) may have had an influence.

2.) Long-term monitoring – Baseline data for marsh shoreline/inner channel delineations are largely unavailable prior to Hurricane Sandy, thus quantification of shoreline loss/gain, marsh-sediment accretion, and vegetation loss are difficult to compare to prior conditions or measure full impacts. Establishment of permanent monitoring stations and vertical datum, as well as vegetation surveys/ inventories would effectively fill data gaps so that future impacts can be assessed with confidence.

3.) Restoration & Resilience - Living shoreline projects are highly recommended for shorelines exposed to direct wind and wave action, such as the Great Bay WMA peninsula, Cattus Island, and the north bank of the Navesink River (i.e. Hartshorne Woods Park). However, in order for public open space lands to benefit from these, regulatory coordination needs to occur.

4.) Protection or establishment of Green zones (e.g. forested buffers along Barnegat Bay, connectivity of parks and WMAs, no wake zones, etc.) could protect development located along the bay shorelines, as well as environmentally sensitive area and inland T&E species habitat.

Forests:

Forest natural resource damage was concentrated in areas where the storm surge inundated forested areas in coastal regions and salt water toxicity resulted in dieback of established tree stands. In particular Atlantic white cedar was affected as evidenced by brown needles in the canopy. These areas should be part of a continuing study into the extent of the damage and the potential for regeneration. Other areas inland and on the western edges will be monitored by the NJSFS for regeneration and/or invasive species colonization (D. Swaysland, pers. Comm.).

Open Water:

The assessment surveys presented here were not designed to determine whether there has been a change in seagrass viability and overall coverage due to Hurricane Sandy. However, the losses seen in this limited set of surveys suggests that the stressors on Barnegat Bay-Little Egg Harbor Bay are having an impact on the SAV at specific back bay locations.

It is recommended that data should be gathered in a comprehensive approach to determine the status and trends of seagrass throughout the Atlantic coastal region of New Jersey and the Delaware Bay/Estuary. A greater frequency in high definition remote sensing mapping is needed to more conclusively assess the status and trends in seagrass coverage and density in Barnegat Bay. High definition remote sensing mapping of seagrass beds is also needed throughout the coastal region of the state.

Furthermore, it is necessary to identify the causes of stressors that are having an impact on the health and viability of seagrass beds. Nutrient enrichment has been suggested as the primary driver of change in seagrass habitat of the BB-LEH. Long-term monitoring is essential to understand the impact nutrient enrichment has on seagrass populations and habitat over time. These data would provide the tools environmental managers need to protect and to enhance the natural areas that healthy seagrass beds rely upon.

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Appendix A

Questionnaire distributed to NJDEP programs for natural resource damage:

In order to prioritize and articulate the scope of natural resource damages resulting from Super Storm Sandy we would appreciate your consideration of the following questions as they pertain to your program. This information will help us identify what resources need to be assessed, coordinate data collection and assessment efforts, identify major data and resource gaps, help prioritize and articulate the Department's needs and project funding as we move forward.

1. DEP Program
2. Resource of Concern?
    a. Is there a specific geography?
    b. Is there a timing sensitivity?
3. Is there a pre-Sandy Assessment of this resource available?
    a. Date
    b. Status
    c. Type (written report, mapped, GIS)
    d. Scale
4. Is there a post-Sandy Assessment of this resource?
    a. Do you have people in the field?
    b. Status
    c. Type (field recon.; aerial/satellite photo; written report)
    d. Scale
    e. Where is this product located (program, GIS data layer, your computer...)?
5. Do you know of any ongoing assessments of this resource?
    a. Being conducted by whom?
    b. Type of Assessment?
    c. Scale?
6. To conduct an assessment (immediate) what are your needs (limiting factors)?
    a. Equipment
    b. Personnel
    c. Timing
7. Can you recommend a resource (academic institution, state, federal, NGO) to help complete this assessment?

Appendix B

Additional Information on Hurricane Sandy Impacts:

The following reports and data sets have been compiled post Sandy by various agencies. Many of these reports are in draft but may help you frame your data and assessment needs.

1. Natural and Cultural Resource Recovery Support Function: NCR_RSF_MSA_DR_4086_NJ v(3) - attached
2. NOAA Geospatial Resources: http://csc.noaa.gov/digitalcoast/geozone/hurricane- sandy-geospatial-resources
3. The following are NOAA links
   a. http://storms.ngs.noaa.gov/storms/sandy/

iPhone/mobile:

http://storms.ngs.noaa.gov/storms/sandy/mobile

The zip files of the entire flights and imagery is ready for download at:

http://storms.ngs.noaa.gov/storms/sandy/download/ WMTS (ArcGIS 10.1, QGIS 1.9)

http://storms.ngs.noaa.gov/storms/sandy/imagery/wmts?

ArcGIS users (9.3.1->10.1) with the ArcBruTile extension can access tiles as a web service with the following link:

http://storms.ngs.noaa.gov/storms/sandy/imagery/tms

4. Raritan Bay Project – NY/NJ Bay Keeper This map shows the extent of where the Bay Keeper Org. conducted the shoreline survey, but not all the data is uploaded yet for what was done this summer (anything with a green pin is not complete):

   http://www.arcgis.com/explorer/?open=d236435eec7c4a768627234957a95958

5. USGS data: USGS HDDS (http://hdds.usgs.gov/hdds/).

6. LiDAR Collections Attached above: Map showing pre and post Sandy LiDAR Collections– USGS

7. USGS has live links to oblique photo pairs (pre and post storm photos): http://coastal.er.usgs.gov/hurricanes/sandy/

8. Hurricane Sandy Data Sources: Geospatial Information and Remotely Sensed Imagery Products Attached above.

9. Several hundred aerial images of the New Jersey and NY shoreline are available at: https://picasaweb.google.com/psdspix. All images are georeferenced (i.e. you can see them on a Google Map) and grouped by town (or island)

10. Some layers have been added to DEPView (ArcGIS) and DEP Explorer (ArcGIS Explorer) that will help in hurricane Sandy damage assessment:

  a. DEPview updated to include following datasets—

    i. 2012 Imagery (Draft), 2012 Coastal Imagery Sandy. They can be found in the DEP Data-Imagery menu bar.

    ii. Statewide LIDAR, Hillshade and DEMs can be found in the DEP Data-Elevation menu bar.

  b. DEP Explorer updated to include 2012 Coastal Imagery Sandy (2012 Imagery Sandy)

  c. The NJ Office of GIS has posted information on their "Hurricane Sandy GIS Resources" page: http://njgin.state.nj.us/oit/gis/sandy/.

11. NOAA Natural Resource Assessment: ftp link for the zip file containing data (in geodatabase) and spreadsheets: ftp://ftp.csc.noaa.gov/temp/dbetenbaugh/NJ_JFO/ NJ_NaturalAreasImpactAssessment.zip

  a. Within the zip file you will find:

  - Natural Areas Impact Plan (post-analysis notes) - this is the original plan annotated with notes about which data sets were actually assessed and in which spreadsheets they are summarized. This is just included in case it is needed for reference.
  - Folder containing spreadsheets (FinalAnalysisSpreadsheets) - which contains:
    - o Data Dictionary for NJ Sandy Storm Surge Analysis
    - o Exacerbating Hazards Inundated by Hurricane Sandy Storm Surge in NJ
    - o Habitat Assets Inundated by Hurricane Sandy Storm Surge in NJ
    - o Land Use & Land Cover Inundated by Hurricane Sandy Storm Surge in NJ
    - o Managed Lands Inundated by Hurricane Sandy Storm Surge in NJ
    - o Marine and Shoreline Resources Adjacent to Areas Inundated by Hurricane Sandy in NJ
    - o Planning Areas Inundated by Hurricane Sandy Storm Surge in NJ

12. Post-Sandy assessment of the New Jersey Beach Profile Network (NJBPN) - Stockton University: Northern Ocean County Initial Report https://docs.google.com/open?id=0B77f6XPBgLKtYTZ4NVgxYXJSR2s

13. American Littoral Society: Assessing the Impacts of Sandy – Report http://www.littoralsociety.org/images/PDFS/Policy/alssandyassessmentreport.pdf

14. USGS: Hurricane Sandy Storm Tide mapper: http://water.usgs.gov/floods/events/2012/sandy/sandymapper.html.

Appendix C

New Jersey State Park Service Report (NJDEP)
March 11, 2014

Island Beach State Park (IBSP):

Destruction of the remaining portions of the former Army Corp of Engineer Dike which had restricted water flow from Barnegat Inlet into the Marine Conservation Zone in and around Island Beach State Park and the Sedge Island Wildlife Management Area.

The dike was constructed years ago to restrict water flow and control erosion. Over the last several years the dike and more specifically the synthetic geotube which contained the sediment to build the dike had been compromised in several locations. The tears resulted in water flow through the sedge. The flow may have been beneficial to the ecosystem. However as result of Hurricane Sandy the remaining sections of geotube were destroyed. The summer of 2013 saw a DRAMATIC increase in boat/vessel traffic. Use was high to points where floats or "raft-ups" of dozens of boats were using the area daily. The vessels may present significant hazard to the Marine Conservation zone by increasing erosion of coastal wetlands, propeller scarring of submerged aquatic vegetation (SAV) beds, disruption of shellfish beds, disruption of nesting bird colonies, and possibly disrupting diamondback terrapin nest activity.

Natural areas (two wetland/upland forested areas) within Island Beach State Park jurisdiction, specifically in northern Barnegat Bay, were both significantly impacted and have had little mitigation of loss. The Swan Point Natural area has very significant deposition of debris as it lies just southwest and across the bay from the area of Mantoloking breached during the storm. The upland section of the property essentially became a wrack line for debris. The area is very difficult to access and most debris remains. Upland sections also experience saltwater intrusion and vegetation has been compromised. A similar but less severe situation exists on Herring Island, just north of the Mantoloking Bridge. Both of these areas are managed by the SPS/IBSP but we lack resources to address the impacts to either.

Liberty State Park:

Hurricane Sandy impacted Liberty State Park with high velocity wind and a storm surge from the Upper New York Bay and Hudson River of up to 11 feet over the mean high water. The land that the park is situated on is mostly a man-made, built, environment. However, many natural features have been created or enhanced by the NJDEP over the last 40 years to provide for a healthier natural environment and wildlife habitat. Most of the park's damages from Sandy are with its buildings and infrastructure, notably, the Historic CRRNJ Terminal Building and Nature Center, but natural resources were impacted as well. Below is summary of those impacts.

Trees:

80 landscape and ornamental trees were severely damaged or destroyed by wind damage. A certified forester puts an appraised value of the 80 trees at $112,850. The estimated value to properly remove and dispose of these trees was $67,500. Approximately 20 additional trees were damaged from salt-water infiltration due to the storm surge.

Freshwater Wetlands Pond:

The storm surge flooded the 3-acre freshwater pond located near the Nature Center. The saltwater infiltration of the pond killed most fish populations. It took many months for the salt content to drop in the pond. The force of the flooding relocated 3 man-made floating habitat enhancement islands onto the uplands about 100 feet from the pond. The cost to restore the three islands is approximately $10,000. The pond's aerator was also destroyed. The estimated cost to replace the aerator is $13,000. Also, the storm surge transplanted tons of debris into and around the pond.

Richard Sullivan Natural Area and Caven Point Beach Area:

The storm surge transplanted tons of debris onto the beaches and natural areas. The debris included household, chemical, medical and industrial wastes. The total amount of debris removed from the park exceeded 1,000 tons. The estimated total cost of removal, and disposal of debris was over $200,000, including labor.

Jetties and shoreline:

The jetties are man-made, however, they serve a unique recreation opportunity for the public as well as shoreline habitat for certain marine species. The jetties and a properly established shoreline protect upland acres from wave attenuation and degradation. The storm surge and wave action from Sandy degraded the shoreline of the jetties and as a result causing the continual gradual loss of shoreline and upland acres. To date, approximately 0.75-mile of shoreline is still impaired. The estimated cost to restore the jetties is approximately $2,000,000.

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