Resource Brief

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
Northeast Region

Hurricane Sandy Resilience and Recovery Efforts

Using Critical Elevation Data to Protect Park Resources

On October 29, 2012, Hurricane Sandy hit the east coast of the United States, battering coastal towns with heavy winds and a storm surge of up to 14 feet in some areas. More than 23,000 people were displaced from their homes, and critical infrastructure, such as transportation and electricity, was permanently damaged. With over $68 billion in damage, only Hurricane Katrina was more costly in U.S. history.[1]

Three National Parks were particularly affected by Hurricane Sandy: Assateague Island National Seashore, Gateway National Recreation Area, and Fire Island National Seashore. These coastal parks are exceptionally vulnerable to the effects of storms and sea level rise because of their low elevation, the frequency of Atlantic hurricanes, the adjacent shallow continental shelf, and because they are located in an observed "hot spot" of sea level rise in the mid-Atlantic region.[2,3]

Given these vulnerabilities, scientists and managers from the National Park Service (NPS) and other government and academic organizations are working to integrate scientific data into planning for future effects of climate change, including storms like Hurricane Sandy, and to develop comprehensive coastal storm response strategies that will help to protect public safety, property, and natural environments. To accomplish this, NPS staff must have a basic understanding of the techniques and uses for collecting and analyzing elevation data.

Elevation Data and Maps

Elevation data and maps are critical research and management tools that illustrate and can help to predict changes to natural landscape features. Elevation data are three-dimensional points that scientists use to create digital elevation models (DEMs) or surfaces that can then be shown on maps as simple contour lines (three-dimensional renderings of a site) or be used to create thematic maps (Figure 1).

Elevation models can be used to track and predict areas most vulnerable to changes in sea level, identify potential areas of water inundation during storms, and inform land use modeling, landscape planning, and engineering. Inundation maps, which are created using elevation data, can help managers understand which park resources are lowest on the landscape and therefore most vulnerable to storm surge and the effects of climate change like rising sea levels.

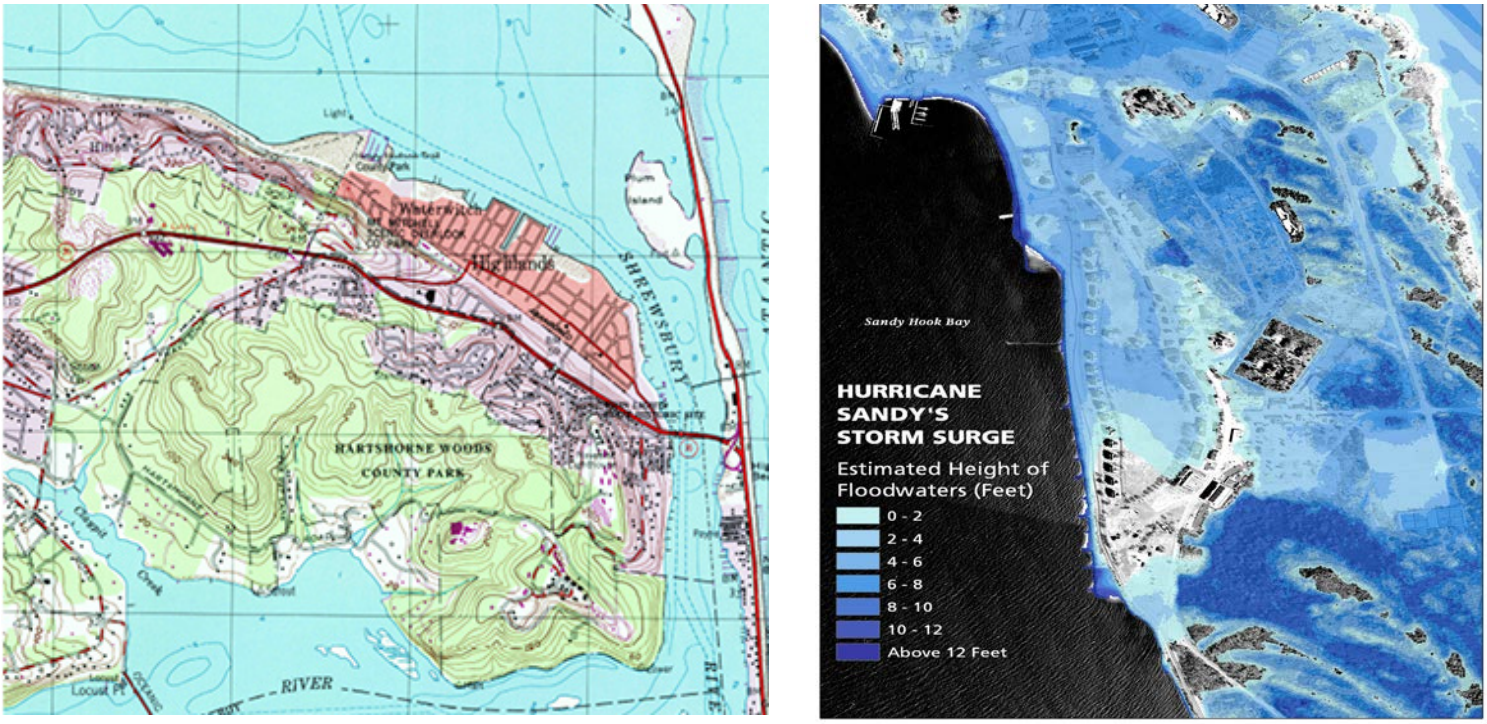

Figure 1. A. Contour map of southern Sandy Hook Bay. The curved lines indicate different elevations. Map courtesy of USGS. B. Inundation of the Fort Hancock area at Gateway National Recreation Area (GATE), NJ, as a result of Hurricane Sandy storm surge. The powerful storm resulted in several feet of flooding and damage across the Sandy Hook peninsula. Map courtesy of GATE GIS.

Techniques used for elevation mapping		
	RTK-GPS	LiDAR
Full name	Real Time Kinematic and Global Positioning System[4]	Light Detection and Ranging
Collection techniques / equipment	Two mobile GPS receivers, one serving as a base station and the other as a 'rover' for collecting data (Figure 3)	Laser attached to an airplane or helicopter points toward a land feature to measure the amount of time it takes for the light pulses to return to the source
Data output	Height data used to create profiles of coastal areas	Based on return time, the relative distance or elevation of the feature or point can be measured
Accuracy	Vertical: 2-5 cm Horizontal: 1-3 cm	Up to 1 m
Benefits	"Real-time" results More accurate than LiDAR Useful when collecting elevation data over a small area	Covers a wide area in a short amount of time
Limitations	Difficult to access rocky terrain with handheld or vehicle-mounted GPS receivers	Inaccuracies require correctional techniques Expensive

Elevation data are collected using a number of different methods and equipment including Real Time Kinematic Global Positioning System (RTK-GPS) technology (Figure 2), laser sensors attached to planes (a system called Light Detection and Ranging and referred to as LiDAR), or aerial photography.

Scientists must also use land-based reference points, referred to as benchmarks to collect elevation data. These marks allow scientists and surveyors to test the accuracy of elevation data through a process called differential correction. Since a benchmark's elevational position is known, scientists can detect slight errors in elevation measurements obtained by GPS. The amount of error measured in the ground surveys can be extrapolated to unmeasured sites. Benchmarks are critical because they help define the accuracy or error of field measurements (Figure 3).

Figure 2. RTK-GPS in use in the field. Photo by Karen Anderson, NPS.

In the wake of Hurricane Sandy, the NPS is assessing the need to replace benchmarks destroyed during the storm. These benchmarks are necessary to assure high accuracy elevation measurements for facilities and landscapes. Replacing these benchmarks, as well as installing additional marks in key park areas, will allow researchers to continue their study of the effects of future big storms and sea level rise on critical natural and cultural resources.

Figure 3. A park ranger uses a survey monument (beneath the center tripod leg) to position an RTK-GPS instrument. These monuments serve as stable reference points when collecting elevation data. Inset: Example of an embedded NPS survey monument, several inches in diameter. Photos by Michael Bradley, URI EDC.

How is the National Park Service using elevation data and maps?

Following Hurricane Sandy, scientists from the NPS Northeast Region determined a greater need for detailed elevation data collection and modeling for key park areas affected by the storm and future storms. Funding has been provided by Congress to assure that scientifically credible and accurate information is gathered and incorporated into future park planning efforts.

From 2013-2014, in collaboration with university scientists, students and interns, the NPS will be assessing the need to replace and install additional survey benchmarks in Northeast coastal parks, collect on-the-ground high-resolution elevation data in key areas, and develop data products that are available to researchers, park managers and planners.

Tidal Data

Creating elevation maps and modeling complex processes is made more difficult by the rise and fall of the tides. Tides are a critical component in the ever-changing coastal environment. They must be considered when creating inundation maps because, when coupled with sea level rise or storm surges, tides can significantly amplify coastal inundation. To be even more specific, and meet the needs of NPS managers, local tide data associated with each park is critical. The combination of local tide data and park elevation data will increase the spatial and temporal accuracy of predictive, site-specific models for management. Scientists at the National Oceanic and Atmospheric Administration have been using long-term tide gauge records to monitor sea levels since the 1800s. Hurricane Sandy damaged or destroyed 73 tide gauges on the U.S. east coast, which has hindered the progress of NPS researchers attempting to evaluate and assess post-Sandy change and future needs. Replacement of these tide gauges and installation of new gauges in areas where there are gaps in tide data is imperative for accurate measurement of inundation, erosion, and vulnerability of park resources.

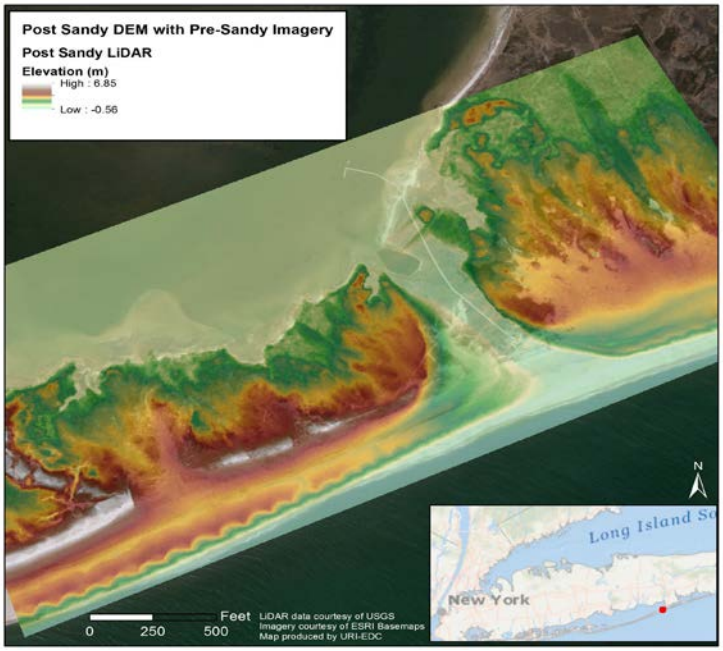

Figure 4. This elevation map shows a new breach that developed as a result of Hurricane Sandy at Fire Island National Seashore, NY. Map courtesy of Michael Bradley, URI EDC.

This information will be used to model both the changes that have occurred to park resources as a result of the storm and to predict the effects of future storms and sea level rise (e.g., Figure 4). The following are some examples of how these data have been used in the past:

• Modeling inundation scenarios (sea level rise and storm surge): Many models used by coastal managers incorporate elevation mapping to assess risk and damage from inundation at coastal sites. For example, the Coastal Vulnerability Index (CVI) was developed and used at the Cape Cod National Seashore to classify the vulnerability of shoreline segments to future sea level rise.[5] In addition to classifying vulnerability, elevation data can contribute to the formation of predictive inundation maps that forecast future storm damage and sea level rise. DEMs demonstrate how sea level rise will change coastal features and shoreline, such as along the coast of Assateague Island, MD (Figure 5). These models contribute critical information to the NPS for developing adaptive strategies in coastal parks.

• Monitoring shoreline change and beach profiles: Beaches are subject to rapid gains or losses in elevation during coastal storms. The barrier island beaches at Fire Island were severely altered by Hurricane Sandy; sand dunes were flattened and erosion was persistent along the beach coast.[6] The three-dimensional elevation maps can help researchers monitor and track changes to salt marshes, beaches, and dunes.

• Monitoring critical habitats (plovers and salt marshes): Changes in beach and dune systems due to elevation changes can affect important habitats for species such as the threatened piping plover by altering breeding and nesting sites.[7,8] Elevation data will also help scientists and managers understand the potential changes that may occur to salt marsh habitat. Knowing the elevation of marshes in relation to local tide information is key to understanding how they will respond to sea level rise and future storms.

Figure 5. DEMs show how sea level rise will translate to coastal inundation near Verrazano Bridge, Assateague Island, MD. A. With 0.6 meters of sea level rise, the bridge and other coastal features are still above sea level. B. Sea level rise up to one meter would partially cover the shoreline as well as a portion of road near the bridge, as indicated by the blue shading over the southern road segment. C. After two meters of sea level rise, most of the island would be inundated, including a significant portion of the road.

More Information

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http://science.nature.nps.gov/im/units/ncbn/

[1]http://www.fema.gov/hurricane-sandy
[2]http://www.nature.com/nclimate/journal/v2/n12/full/nclimate1597.html
[3]Murdukhayeva, A., P. August, M. Bradley, C. LaBash, and N. Shaw. 2013. Assessment of inundation risk from sea level rise and storm surge in northeastern coastal national parks. Journal of Coastal Research.
[4]http://www.channelcoast.org/southwest/survey_techniques/landbased/?link=rtk_gps.html
[5]Hammar-Klose, E.S., E.A. Pendleton, E.R. Thieler, and S.J. Williams. 2003. Coastal vulnerability assessment of Cape Cod National Seashore (CACO) to sea-level rise. Reston, Virginia: U.S. Geological Survey, Open-File Report 02-233, 23 pgs.
[6]http://www.nps.gov/fiis/parknews/post-storm-recovery-continues_2-7-2013.htm
[7]http://www.fws.gov/plover/facts/html
[8]http://www.nps.gov/fiis/naturescience/piping-plovers.htm