Fire Island National Seashore: A breach in the barrier island at the Otis Pike Fire Island High Dune Wilderness

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On October 29, 2012, Hurricane Sandy created three breaches in the barrier island system off the south shore of Long Island, New York, including one within the Otis Pike Fire Island High Dune Wilderness (Fire Island Wilderness) at Fire Island National Seashore (FIIS). Two other breaches were also formed during Hurricane Sandy, one in the easternmost area of Smith Point County Park on Fire Island and the other on the east side of Moriches Inlet in Cupsogue County Park. These breaches were filled in within months of the storm. Just over a year ago, in July 2018, the National Park Service (NPS) approved the *Fire Island Wilderness Breach Management Plan and Environmental Impact Statement* (EIS). To date, NPS has been letting nature takes its course with the breach in the Fire Island Wilderness.

Breaches are channels connecting ocean to bay that form during powerful storms. These natural barrier island features can come and go over time. Hurricane Sandy created a breach within the Fire Island Wilderness, a federally designated wilderness area on the eastern end of FIIS. The wilderness breach occurred in a narrow, low-lying area that is historically prone to breaches (see Figure 1). This part of the barrier island is called "Old Inlet" because in the 1800s a breach occurred here that remained open for approximately 60 years before closing through natural sediment transport processes.

The barrier island system along the south shore of Long Island has developed over thousands of years in response to changes in sea level and the complex and dynamic interaction of waves, tides, storms, and sediment (Leatherman and Allen 1985; Williams and Meisburger 1987; Williams, Dodd, and Gohn 1995). Breaching and overwash are natural processes that transport sediment, which increases the elevation of the barrier system and provides for barrier island migration and the development of estuarine salt marsh and mud flats. Over the past century, human development of the barrier system has altered these natural processes and provided an additional driver of change (Williams and Foley 2007).

Within days of the October 2012 breach occurring, observing what was then a 25-foot-wide breach of the island, it was determined that there would need to be a plan for data collection in order to develop a document on how to manage this breach in a federally designated wilderness. Something like this had never happened in NPS-managed wilderness. The team that determined data needs, collected data, and developed the final approved *Fire Island Wilderness Breach Management Plan and EIS* included staff from two cooperating agencies, US Army Corps of Engineers and New York State Department of Environmental Conservation; FIIS; NPS's Washington Office Environmental Quality Division, Denver Service Center, Coastal Barrier Island Network, Northeast Regional Office Resource Stewardship and Compliance Program, Social Science Branch, Office of the Solicitor–Northeast Region, and Wilderness Stewardship Division; US Geological Survey (USGS); US Fish and Wildlife Service; and University of Rhode Island, State University of New York–Stony Brook, Syracuse University, and Rutgers University.

The *Wilderness Breach Management Plan* has several goals: ensuring the continued integrity of wilderness character, protecting the natural and cultural features of FIIS and its surrounding ecosystems, protecting human life, and managing the risk of economic and physical damage to the surrounding areas. The plan was created to address these management issues at this particular wilderness breach. A note of interest: the plan cannot be used as the management document for

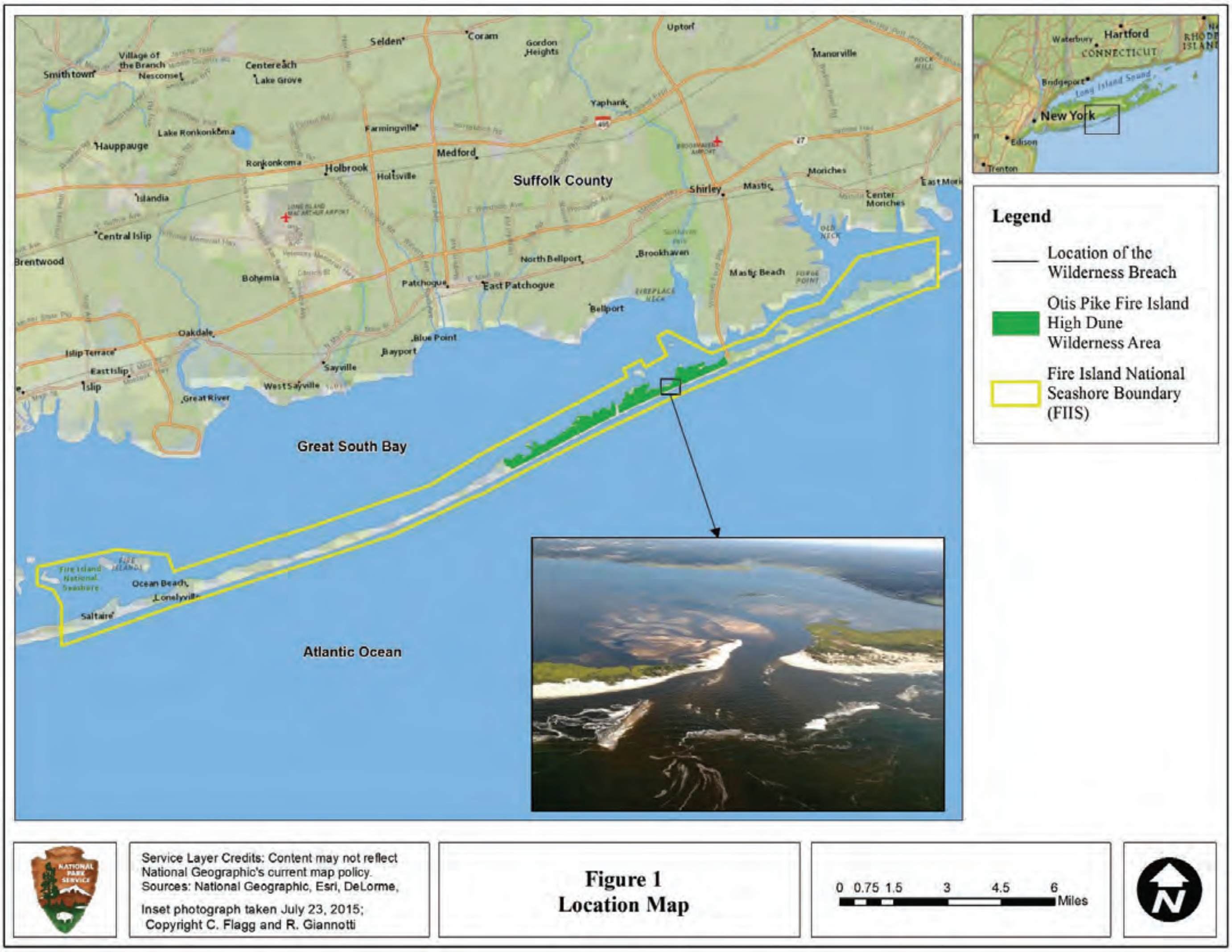


FIGURE 1. Location of the breach within the Otis Pike Fire Island High Dune Wilderness, Fire Island National Seashore. Source: Fire Island Wilderness Breach Management Plan Environmental Impact Statement.

future breaches, but may be used to help inform the National Environmental Policy Act (NEPA) process if future breaches occur within the boundaries of FIIS.

When it opened, the breach displaced sand from the barrier island into Great South Bay. Waves reworked the sand into flood and ebb shoals, accumulations of sand that occur on the bay side (flood) and ocean side (ebb) of the breach. Over time, these shoals will serve to widen the island, provide platforms for the growth of new salt marsh or other habitats, and enhance the resilience of the barrier island to future storms and sea-level rise. The breach has caused localized erosion immediately to the west. However, the ebb shoal that formed on the ocean side has remained relatively small and stable, indicating that the breach is not interrupting the sediment transport system. Sediment continues to move west along the ocean shoreline with littoral drift.

The breach will continue to change. Storms since Sandy and future storms will cause further changes to the shape. Scientists cannot be sure how the breach will change; sediment cores taken to the east and west of the breach reveal a layer of clay deposits that should limit the breach's migration east and west.

Shoreline position data, aerial photography, and measurements of water depth, collected as part of monitoring efforts, show that the breach is dynamic but has been relatively stable since 2013. Figures 2 and 3 are examples of how the park has been monitoring the breach over the last six years. Figure 2 utilizes a June 2019 base National Oceanic and Atmospheric Admin-

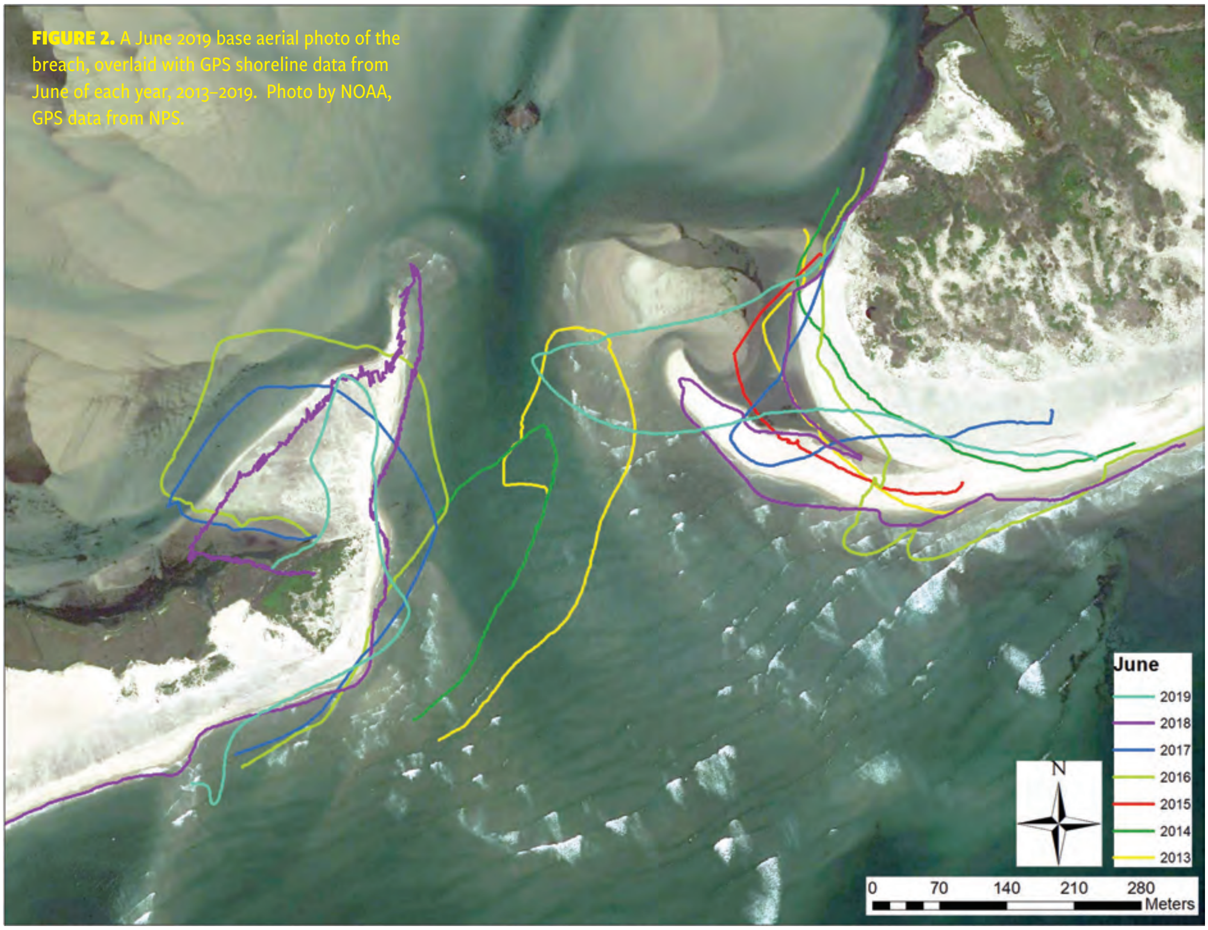


FIGURE 2. A June 2019 base aerial photo of the breach, overlaid with GPS shoreline data from June of each year, 2013–2019. Photo by NOAA, GPS data from NPS.

FIGURE 3. A November 2012 base aerial photo of the breach, overlaid with GPS shoreline data from June of each year, 2013–2019. Photo by NOAA, GPS data from NPS.

istration (NOAA) aerial photo of the breach with GPS shoreline data from June of each year starting in 2013. Figure 3 utilizes a November 2012 base NOAA aerial photo with the same GPS shoreline data.

Breach monitoring has been ongoing since early November 2012 in order to evaluate how the open breach has changed the geomorphology, hydrology, and ecology of the barrier island and estuarine systems. These monitoring programs and the data they produce represent the best available information on the wilderness breach, but there are limitations based on funding, technology, and research questions (which drive research methodology). Monitoring data and the professional judgment of physical scientists studying the breach was used to determine that the three criteria described below are the most logical indicators to alert FIIS staff to changes in the breach that could elevate the risk of severe storm damage in the form of loss of life, flooding, and other severe economic and physical damage, which could lead to a decision to close the breach.

NPS solicited data and input from a group of researchers studying the breach, culminating in the development of the technical synthesis report. As part of this effort, NPS asked the experts to help develop specific criteria for breach closure. This question was discussed throughout a three-day workshop on the wilderness breach in January 2016. The consensus of the group of researchers and other experts was that the evolution and migration of the breach is not sufficiently understood to develop criteria using specific physical measurements (e.g., breach width and depth). However, as long as the wilderness breach remains in the relatively same location and size that have been studied over the past seven years, scientists believe flood risks would remain the same. Points of consensus from the workshop:

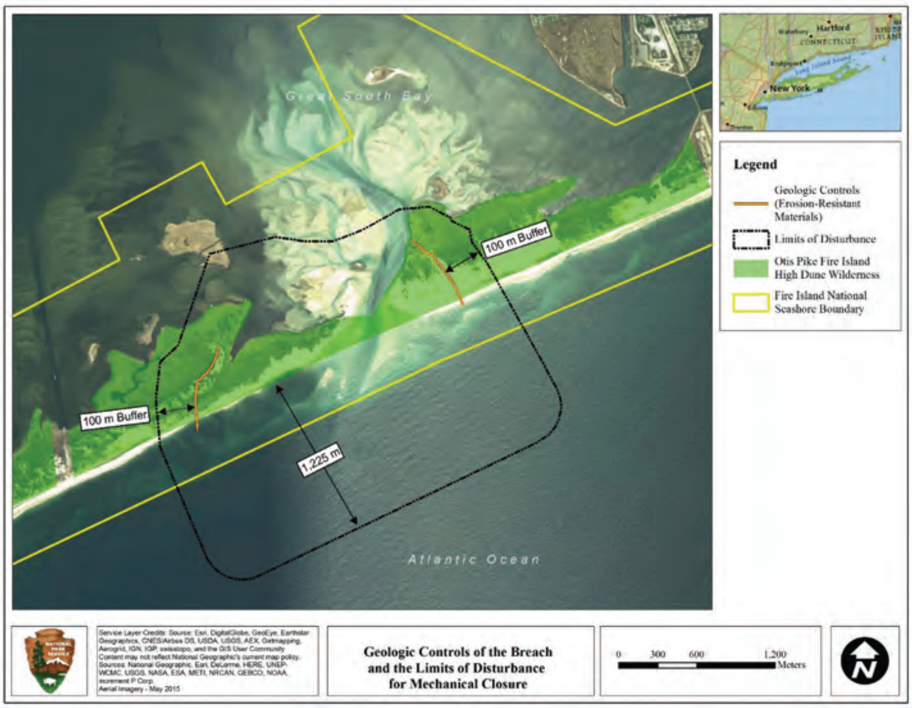
1. Storms since Hurricane Sandy have not resulted in major floods.
2. If the breach remains in its current form the experts would not expect major floods.
3. If the breach changes size or exceeds the geologic controls, there is uncertainty as to how that would affect flooding.

Based on the above points of consensus, the experts recommended continued monitoring with the same methods and annual review of the data to understand the wilderness breach evolution.

Criterion 1: Geologic controls. As previously described, erosion-resistant clay to the east and west serve as geologic controls for the breach (Methratta et al. 2017). The monitoring that has been done to date—monthly GPS mapping of the breach shoreline by FIIS staff—provides a foundation for understanding the movement and evolution of the breach. There are no known erosion-resistant materials to control breach migration beyond those that have been investigated by the USGS on both the east and west sides of the breach (see Figure 4). If the breach migrates beyond these geologic controls, its growth would be less predictable.

Criterion 2: Cross-sectional area. The cross-sectional area of the breach has also been monitored since it formed (e.g., Figure 5, from June 2016). This monitoring is important as the cross-sectional area of the breach affects the volume of water moving in and out of the bay. Initially, USGS and Dr. Charles Flagg (Stony Brook University, an expert in continental shelf dynamics) monitored the cross-sectional area of the breach quarterly; researchers have reduced the frequency of this monitoring and, moving forward, the monitoring will be completed annually unless conditions indicate

FIGURE 4. The boundary of clay layers (in orange), which are the geologic controls that could stop a widening breach/inlet, and the overall boundary line (in yellow) within which mechanical closure would be considered. Source: Fire Island Wilderness Breach Management Plan Environmental Impact Statement.



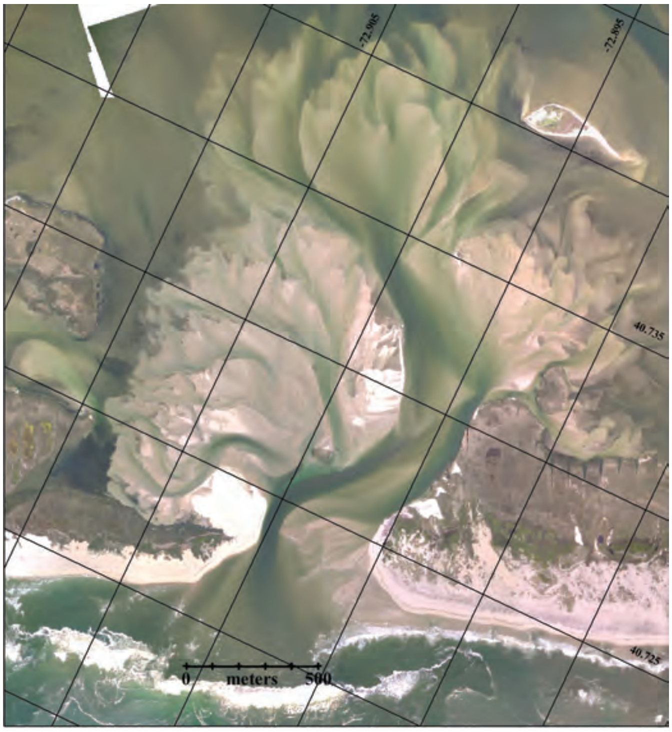


FIGURE 5. Aerial photography overlaid with a mosaic grid is used to monitor the cross-sectional area of the breach. Photo by R. Giannotti and C. Flagg June 2016.

more frequent monitoring is needed. Originally, the cross-sectional area increased rapidly; however, the breach has reached a dynamic equilibrium in which the cross-sectional area has fluctuated between 300 and 600 m^2. A cross-sectional area within or below this range represents a condition in which the effects of the breach are understood. An increase in cross-sectional area above this range will indicate breach growth and a condition in which the evolution of the breach is less predictable and impacts to the surrounding areas may change.

Criterion 3: Water level as measured by tide gauges. Data from tide gauges in Great South Bay will be reviewed to identify changes in the tidal prism (the amount of water that flows into and out of a bay or estuary with the flood and ebb of tide, excluding freshwater inflows), which could indicate a change in the breach conditions. Tide gauge data are made available to FIIS and the public through various websites. USGS and Stony Brook University help compile the data and informs FIIS of water-level trends. Tide gauge data, such as water level, are affected by many factors, such as storm-generated winds, seasonal tides, or sea-level rise and, by themselves, would not indicate a change in the cross-sectional area or an increase in flood risk. NPS will look for changes in the patterns of water-level heights, seasonal changes, and changes in variability at Bellport, New York, compared with the rest of the Great South Bay; specifically, an increase in the water level. This comparison will serve as an indicator that something in the system is changing, alerting NPS to a potential change in the conditions of the breach that is affecting the surrounding areas.

Managing a breach in designated wilderness is different from managing them elsewhere, as NPS must manage federal wilderness to preserve wilderness character. Management of the Fire Island Wilderness must comply with the Wilderness Act of 1964 (Public Law 88-577); the Otis Pike Fire Island High Dune Wilderness Act (Public Law 96-585), the legislation that established the Fire Island Wilderness; and the *2016 Wilderness Stewardship Plan and Backcountry Camping Policy, Otis Pike Fire Island High Dune Wilderness* (NPS 2016a).

The Fire Island Wilderness is the only federally designated wilderness area in New York state. Federal wilderness areas are wild, undeveloped federal lands that have been designated and protected by Congress. The Fire Island Wilderness is managed such that "the earth and its community of life are untrammeled by man," and "to preserve its natural conditions," as directed by the Wilderness Act of 1964. The preservation of wilderness character and values includes providing "outstanding opportunities for solitude or a primitive and unconfined type of recreation," with "the imprint of man's work substantially unnoticeable" (Wilderness Act of 1964). The Otis Pike Fire Island High Dune Wilderness Act directs NPS to manage this area to preserve its wilderness character and to refrain from interfering with natural processes that would typically occur on a barrier island. However, this legislation also states that a wilderness breach may be closed if the action is taken "to prevent loss of life, flooding, and other severe economic and physical damage to the Great South Bay and surrounding areas."

This directive is reinforced both by NPS *Management Policies 2006* (section 4.8.1.1, "Shorelines and Barrier Islands"), which states that "natural shoreline processes (such as erosion, deposition, dune formation, overwash, inlet formation, and shoreline migration) will be allowed to continue without interference," and by the overarching Wilderness Act, which calls for federal wilderness to be both wild (untrammeled or un-manipulated) and natural, thus allowing natural phenomena or processes to proceed unimpeded. Neither NPS *Management Policies 2006* nor the Otis Pike Fire Island High Dune Wilderness Act precludes closing a breach in the Fire Island Wilderness if there is a need to do so; however, the *Wilderness Stewardship Plan and Backcoun-*

try Camping Policy (NPS 2016a) stipulates that an appropriate level of NEPA compliance must be conducted before such a decision would be made.

In 1996 the US Army Corps of Engineers (ACOE) created the Breach Contingency Plan (BCP). At the time of Hurricane Sandy, the BCP was the only guidance in effect to address breaches along coastal Long Island from Fire Island Inlet east to Montauk Point. At the time of the wilderness breach the BCP was outdated and did not adequately address management of breaches in the Fire Island Wilderness.

As a result of the wilderness breach, and in accordance with the BCP, NPS, USGS, and other agencies and research institutions initiated numerous studies to better understand the dynamics of the breach and its effects on various elements of the Great South Bay ecosystem. The wilderness breach has offered researchers a rare opportunity to study the dynamics of the breach following its formation and the effects of the open breach on the bay ecosystem. Because the wilderness breach had existed for less than three years at the initiation of the final *Wilderness Breach Management Plan and EIS*, much of the research relating to the breach was still underway. In order to access the most current scientific information and to reach consensus among researchers on resource issues, NPS elected to prepare a technical synthesis report to compile and document the best available data and describe the current state of the science for the physical and natural resource issues, as identified by NPS. The information in the technical synthesis report provided the scientific foundation for the final *Wilderness Breach Management Plan and EIS*.

The plan looked at three alternatives. They were developed by soliciting input from FIIS staff, other government agencies, and the public on key issues, including protection of life and property, and conditions desired for the Fire Island Wilderness.

- Alternative 1 would carry out mechanical closure of the wilderness breach as soon as possible.
- Alternative 2 (no action) would allow the status of the wilderness breach to be determined by natural processes, with no human intervention.
- Alternative 3 (the proposed action and NPS preferred alternative) would allow the status of the wilderness breach to be determined by natural processes, with no human intervention, unless the condition of the breach exceeds established criteria, which would then trigger mechanical closure of the breach.

These alternatives represented a range of reasonable and feasible approaches that met the purpose and need for action.

NPS identified Alternative 3, the proposed action alternative, as its preferred alternative because it would allow natural processes to continue in the Fire Island Wilderness unless and until it became necessary to close the breach using mechanical processes. Alternative 3 was the only alternative that allows the management of the breach according to NPS resource management policies and wilderness directives while allowing closure if necessary to prevent "loss of life, flooding, and other severe economic and physical damage to the Great South Bay and surrounding areas," as allowed by the Otis Pike Fire Island High Dune Wilderness Act.

While the breach is allowed to function under natural processes, changes to the central and eastern Great South Bay ecosystem would persist. At the time the plan was approved, initial results (three years of data) indicated that the open breach had generally improved water quality by increasing circulation and reducing nutrients. These changes have benefited benthic communities and finfish, improved available fish nursery habitat, and produced a more robust and mature ecosystem. If the breach were to be closed using mechanical methods, the consensus among the experts consulted by NPS was that the bay would eventually revert to the conditions prior to the breach, eliminating the benefits to the ecosystem just described.

Breaches are not uncommon (take for instance the breaches created recently by Hurricane Dorian in the Outer Banks of North Carolina). They come and go on barrier islands over time, allowing the free flow of water between the ocean and bay. The breach created by Hurricane Sandy in the Fire Island Wilderness altered water circulation patterns in eastern and central parts of Great South Bay and caused higher salinity in eastern parts of the bay. Another factor to be considered is that Fire Island Inlet, which connects Great South Bay with the Atlantic Ocean, is regularly dredged. Using research and data from the past four years, scientists believe that changes to water levels, particularly in the western Great South Bay, are more likely due to Fire Island Inlet than the wilderness breach.

The breach also increased the exchange of organisms between ocean and bay waters. As a result, the ecosystem of Great South Bay has matured. There is an increase in species diversity, leading to a better, more complex food web. The breach also improved water quality in Bellport Bay and eastern Great South Bay in the immediate vicinity of the wilderness breach by increasing water clarity, diluting the bay's harmful nitrogen levels with ocean water, and prompting a decrease in brown tides.

The effects of climate change in New York state include increasing water and air temperatures, changing precipitation patterns, and accelerated sea-level rise (Rosenzweig et al. 2011). Sea-level rise intensified the impact of Hurricane Sandy and is predicted to increase coastal storm surge, making future coastal storms more damaging (Center for Climate and Energy Solutions n.d.).

Studies investigating Northern Hemisphere storm-track changes have not reached consensus on how storm activity will change with a warming climate. In the state of New York, precipitation is projected to increase by 5% every 30 years; however, it will not be distributed evenly over the course of the year—more is expected to fall in heavy downpours rather than in light rains (Rosenzweig et al. 2011). A number of studies show decreased nor'easter activity due to enhanced surface warming at higher latitudes and weaker surface warming at low latitudes, leading to a decreased temperature gradient (Catto, Shaffrey, and Hodges 2011). Other studies show no indication of more intense storms, but do show a decrease in weaker storms (Bengtsson and Hodges 2006). This uncertainty presents a substantial challenge for making future predictions about shoreline conditions; however, it should be noted that even if storm characteristics do not change, storm impacts will be greater at higher sea levels.

The Northeast region of the US Atlantic Coast (north of New York City) shows accelerated sea-level rise as compared with other Atlantic regions and with the estimated global rate of 1.8 mm/year (Church et al. 2011). While there is variability between years, rates of sea-level rise range from 2.5–3 mm/year in the North Atlantic region (Ezer 2013; Goddard et al. 2014). This acceleration of approximately double the global rate is attributed to circulation decreases, as described above. Additionally, the increasing sea-surface temperatures cause thermal expansion of water, which has shown to be responsible for 30–40% of sea-level rise since the 1970s (Yin 2012).

The breach is influenced by many factors, including wave action, sediment transport, and storm activity, complicating researchers' ability to predict future changes to the breach and its impact on flooding potential. Climate change adds to this uncertainty. As sea level rises, it will be difficult to determine if increased water levels are due to climate change or the presence of the breach.

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