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Natural Resource Stewardship and Science

Coastal Adaptation Strategies: Case Studies

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On this Page
The historic Peale Island Cabin in Yellowstone National Park is threatened by shoreline change that may be accelerated by tectonic uplift, tree death, and longer ice-free periods. Photograph courtesy of Yellowstone National Park.

On the Cover
Investment in repairs to Fort Jefferson, at Dry Tortugas National Park, should consider historical integrity and long-term sustainability of the structure and the island, which are both vulnerable to climate change impacts.
Photograph courtesy of Marcy Rockman, National Park Service.

Coastal Adaptation Strategies: Case Studies

National Park Service Report 2015

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Abstract

Innovative and unique solutions are being devised throughout the national park system to adapt to climate change in coastal parks. This report includes 24 case studies of adaptation to coastal changes. The adaptation efforts described here include historic structure preservation, archeological surveys, baseline data collection and documentation, habitat restoration, engineering solutions, redesign and relocation of infrastructure, and development of broad management plans that consider climate change. Each case study also includes a point of contact for park managers to request additional information.

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Introduction

The 24 case studies in this document describe efforts at national park units in a variety of settings to prepare for and respond to climate change impacts that can take the form of either an event or a trend. Examples of these impacts include increased storminess, sea level rise, shoreline erosion, melting sea ice and permafrost, ocean acidification, warming temperatures, groundwater inundation, precipitation, and drought. The adaptation efforts described here include historic structure preservation, archeological surveys, baseline data collection and documentation, habitat restoration, engineering solutions, redesign and relocation of infrastructure, and development of broad management plans that consider climate change. Each case study also includes a point of contact for park managers to request additional information and insight.

These case studies initially were developed by park managers as part of a NPS-led coastal adaptation to climate change training hosted by Western Carolina University in May 2012. The case studies format follows the format created for EcoAdapt's Climate Adaptation Knowledge Exchange (CAKE) database that identified a list of adaptation strategies. All case studies were updated and modified in September 2013 and March 2015 in response to a growing number of requests from coastal parks and other coastal management agencies looking for examples of climate change adaptation strategies for natural and cultural resources and assets along their ocean, lacustrine, and riverine coasts.

Case Study 1:
Reservoir Water Level Change Impacts on Cultural Resources, *Amistad National Recreation Area, Texas*

Contributing Authors: Jack G. Johnson (Amistad National Recreation Area) and Brenda K. Todd (Denver Service Center)

Panther Cave contains extensive pictographs, which are threatened by fluctuating water levels tied to storm events and (indirectly) to siltation. Reservoir level in the photo is about 332 m (1,089 ft) above mean sea level, with 2.4 m (8 ft) of water covering the silt bed. Image credit: Jack Johnson, NPS.

The reservoir level was 344 m (1,130 ft) above mean sea level in July of 2010, nearly reaching the base of the pictograph panel. By May of 2013 the reservoir had dropped to a record low of 322 m (1,055.9 ft) above mean sea level, leaving the canyon bottom completely dry. Image credit: Randy Rosales, Texas Parks and Wildlife Department.

Goals

Amistad National Recreation Area, Texas, protects many archeological sites in the Lower Pecos Canyonlands region of southwest Texas. Sites are affected by lake level fluctuations related to climate change impacts including precipitation, storms, and changes in agricultural water use. Park managers are documenting the impact of changing water levels on the cultural resources in the park.

Challenges and Needs

The reservoir that is the centerpiece of Amistad National Recreation Area was created when the Rio Grande, Pecos, and Devils Rivers were dammed in 1969. The reservoir provides flood control, water for agriculture, and recreational opportunities for visitors. In addition to having more than 129 km (80 mi) of international border with Mexico along the Rio Grande, the park is located at the intersection of several distinct physiographic, biological, and climatic regions and is characterized by variable and unpredictable weather. The park's location at the intersection of the arid west, the humid east, the seasonal latitudes to the north, and the tropical climates to the south contributes to exceptionally unpredictable precipitation patterns. The park is also periodically impacted by tropical storms and hurricanes coming off the Gulf of Mexico, resulting in massive flash flooding. As the climate changes, it is likely that weather patterns will become increasingly erratic, and that greater outputs from the reservoir will be required to satisfy agricultural water needs. Fluctuating water levels in the lake, caused by both variability in precipitation and by outflow from the dam, expose cultural resources to a variety of physical, human, and biological threats.

The park protects a variety of archeological sites that are exposed to weather. Most of these are open sites, rock-shelters, and pictograph panels created by nomadic hunter-gatherers and dating to the Archaic period. Besides both older and younger Native American sites, the park also contains sites relating to the American Indian Wars and railroad development of the late 19th century, and ranching and hydroelectric power in the early 20th century. When lake levels decrease, archeological sites on previously inundated land are exposed to severe erosion by wave action along the shoreline. Such erosion has taken place over varying timescales and has impacted several burial sites, resulting in inadvertent discoveries and damage under section 3 of the Native American Graves Protection and Repatriation Act.

Sites on denuded, recently exposed lakebed are often highly visible and susceptible to looting by park visitors. Unintentional damage to sites is caused by backcountry boating and camping activities, such as digging cat holes, clearing ground for tents, or making fire rings for ground fires (a prohibited but nonetheless recurring activity). Visitor campsite selection varies with changes in lake level and shorelines, leading to widespread and concentrated camping impacts. Good camping places today were often good camping places a thousand years ago, begging the question of how to mark no camping areas on a wide-open landscape without drawing unwanted attention to cultural resources.

The silting up of some of the upper reaches of the reservoir poses another physical threat to park cultural sites, especially around the confluence of the Pecos and Rio Grande Rivers. Because the silt effectively decreases the capacity of the lake, flash flood waters that are typically associated with tropical storms and hurricanes coming off of the Gulf of Mexico are reaching previously unseen levels and are threatening two of the park's most significant rock art sites (Panther Cave and Rattlesnake Canyon). These two panels are among the five most significant sites in a region that is becoming world-renowned for its elaborate 3,000–4,000 year-old Pecos River Style pictographs. Portions of the Rattlesnake Canyon site have already been inundated and damaged by storms resulting from Hurricane Alex in 2010.

Archeological sites also face biological threats that may be linked to changing lake levels. Photo-monitoring has shown that the number of mud-dauber wasp nests built on the walls of Panther Cave, which contains pictographs, has increased dramatically in the last decade, possibly due to the increased proximity of the reservoir edge (and associated mud source) to the rock shelter. Additionally, when lake levels change, a nonnative Asiatic clam *(Corbicula fluminea)* that lives in shoreline zones is able to invade new areas in large numbers and burrow into previously pristine archeological sites, increasing bioturbation.

The National Park Service (NPS) owns the land surrounding and underlying the Amistad Reservoir, but has limited authority in the management of the water in the reservoir. In this situation, relatively little can be done to prevent most of the physical and biological threats facing cultural resources from changes in lake levels. The primary tool utilized by the park to respond to climate change and manage cultural resources is scientific documentation, with additional efforts towards monitoring, salvage, and minimizing human impacts.

At this time, the park does not have a 100% inventory of archeological sites. In 1999, the Texas Archeological Society held their annual field school at the park, providing several hundred volunteers for the park to do surveys and test excavations, primarily at sites exposed by record-low lake levels. At that time, the lake was over 15 m (50 ft) below conservation pool. In July of 2010 the reservoir reached its second highest level ever, almost 4 m (13 ft) above conservation pool. In May of 2013 the lake reached its all-time low, approximately 18.5 m (61 ft) below conservation pool and nearly 22.5 m (74 ft) below where it had been three years before. These changing conditions result in a massively different shoreline, different exposed land area, and different sites to monitor. As of fiscal year 2015, the NPS Archeological Sites Management Information System indicated that there were 252 sites in the park, 111 of which were inundated. It should be noted that the unusual topography and ever-changing lake levels make "inundated" or "non-inundated" site status a moving target.

The extent of the 870 km (540 mi) shoreline in combination with the fluctuations in lake levels makes archeological monitoring efforts complex and labor intensive. At normal reservoir pool, some of the more remote sites in the park may only be accessible to park personnel by jet boat or overnight canoe trip. At lower lake levels, this becomes the case for an even larger area of the park. Because of security risks associated with illicit cross-border traffic, a law enforcement escort is needed when working in some remote areas of the park. Together, these factors make it difficult to monitor resources as extensively or as frequently as is desirable at low lake levels.

Responsive Actions

Park personnel are currently spending as much time in the field as possible to revisit known sites and to do condition assessments and improve documentation on recently exposed sites. Additionally, the park has recently completed a cutting-edge LiDAR and photo documentation project at Panther Cave in cooperation with the Texas Parks and Wildlife Department and local nonprofit rock art research and education center, Shumla.

The park is presently studying impacts to natural and cultural resources from illicit cross-border traffic and associated law enforcement activities—another human threat to cultural resources that is not yet well understood at the park. The fieldwork for this project allows park personnel to revisit sites and to complete more condition assessments and documentation than would be possible otherwise. Unsurprisingly, these assessments routinely show impacts to sites caused by threats associated with changing lake levels. One very successful measure the park has taken is that all new law enforcement rangers receive a three-day, intensive cultural resources orientation from the park archeologist. This increases their awareness of and enthusiasm for park resources and resource issues, and builds rapport between law enforcement and resources staff. Their informed observations while on patrol and timely communication with resources staff have proven very helpful.

The park also collaborates with Texas Parks and Wildlife Department and Shumla on outdoor experiential learning programs for local and area schools. These programs introduce elementary students to the cultural and natural resources of the area, and use these resources as a lens through which to teach and reinforce science and math concepts from the classroom that students will later be responsible for on standardized tests. Moreover, these programs work to instill an enjoyment of the natural and cultural landscape and appreciation of and respect for the resources, as well as to foster a sense of responsibility and stewardship.

This is an ongoing project. This case study is an example of the following adaptation strategies:

- Monitoring climate change impacts and adaptation efficacy
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies

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Case Study 2: Preparing for Impacts on Archeological Sites and Traditional Resources, *Olympic National Park, Washington*

Contributing Author: Dave Conca (Olympic National Park)

Tribal members share information about nearshore traditional resources at Crescent Bay in 2003. Image credit: Jacilee Wray, NPS.

Goals

Archeological sites and traditional resources of significance to indigenous groups along the Olympic Coast are being affected by climate change. The goals of this project can be split into three facets. The first is for the park to foster communication, data sharing, and cooperation between the eight federally listed tribes on the Olympic Peninsula and the National Park Service (NPS) to ensure proper alignment of resources and priorities for climate change adaptation. The second is to work cooperatively with all stakeholders to develop long-term, proactive plans for managing coastal archeological sites in the face of sea level change and increased coastal erosion, including surveys for additional sites that could be threatened. A final goal is for the park and the tribes to move forward with the clear understanding that tribal resource concerns are best understood at the landscape level and without a sharp distinction between "natural" and "cultural" resources; cross-discipline participation and communication is critical.

Challenges and Needs

The Olympic Coastal Strip, most of which is roadless and designated wilderness, includes a highly dynamic environment ranging from rocky headlands to broad sand beaches. Archeological sites and important traditional resources at Olympic National Park include terrestrial, intertidal, and submerged archeological resources as well as resources encompassed within offshore, nearshore, intertidal, and shoreline environments. These resources will be affected by sea level changes, inundation, and coastal erosion.

Coastal archeological sites, particularly shell middens, are actively eroding and will likely continue to do so. These sites are important to local tribes both for their traditional values and also for the cultural and scientific data they contain. Erosion of middens along the coast often exposes faunal remains, artifacts, and other sensitive materials that can be damaged or lost through wave action or inappropriate treatment by visitors. A worst-case scenario for exposed and highly visible coastal midden sites includes exposure of sensitive materials, increased unauthorized disturbances, and loss of data. A major challenge in this regard is to develop and implement long-term management actions for coastal archeological sites given that erosion prevention is infeasible in most cases.

A critical need to guide future planning and adaptation is acquisition of updated baseline data on archeological site condition and potential climate-related threats.

One way to effectively address climate-related changes to the large variety of resources is for the NPS to work with tribes to identify important traditional resources. This includes working to understand how the resources were and are collected, how they were and are managed, and how they are affected by climate change. The development of appropriate adaptation strategies for archeological sites and traditional resources will require dedicated resources and staff to complete condition assessments and tribal consultation.

Responsive Actions

Olympic National Park has identified and implemented several climate change adaptation actions on the Olympic Peninsula.

In 2008 the park and eight federally recognized tribes signed a Memorandum of Understanding (MOU) that guides consultation and data sharing among and between the participating groups. Required annual MOU meetings have been and will continue to be an excellent forum for climate change adaptation planning at the parkwide level and should be used to foster engagement for more detailed discussion and actions with individual tribes. The MOU agreement specifically provides for creation of workgroups to address issues like climate change in greater detail.

The park's cultural resources branch has submitted funding proposals to complete condition assessments and data collection for coastal archeological sites and to complete archeological surveys on raised beach terraces.

Park archeologists, in coordination with local tribes and park law enforcement staff, continue active monitoring of coastal archeological sites as staff time and resources permit.

This case study is an example of the following adaptation strategies:

- Conducting/gathering additional research, data, or products
- Communicating climate change or adaptation actions to the park and tribal partners

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Case Study 3:
Shell Mound Sites Threatened by Sea Level Rise and Erosion, *Canaveral National Seashore, Florida*

Contributing Author: Margo Schwadron (NPS Southeast Archeological Center)

Building a living shoreline with volunteers at Castle Windy mound site, Canaveral National Seashore. Image credit: Margo Schwadron, NPS.

Goals

Canaveral National Seashore contains several of the largest, most intact, and most significant prehistoric shell mounds in North America. Four of these mounds are threatened by erosion induced by sea level rise and increased storm activities. The goals of this project are to recover archeological, environmental, and paleoecological data that are threatened with irrevocable loss from erosion; to document the threatened mound sites with national historic landmark (NHL) level documentation; to work to stabilize and protect sites; and to offer effective communication and civic engagement with youth and volunteers.

Challenges and Needs

Turtle Mound, Ross Hammock, Castle Windy, and Seminole Rest shell mounds were key prehistoric/proto-historic monuments and settlements, and later served as important navigational landmarks along the east coast of Florida during the early European exploration and colonization of the Americas.

Turtle Mound is the tallest extant shell mound within the national park system, and is one of the tallest in North America, at 11 m (37 ft) high; it is composed of mostly oyster and clam shell formed into two main peaks, forming a saddle. Very limited archeological documentation of Turtle Mound, Castle Windy, and Ross Hammock has ever occurred, and all are threatened with severe erosion. Seminole Rest was listed in the National Register of Historic Places, and is also undergoing erosion from sea level rise and increased storm activities.

Climate change effects are already producing severe, measurable, and detrimental impacts to these mound sites, including erosion and loss of significant and unevaluated archeological, environmental, and paleoecological data. Impacts from sea level rise and increased storm activities are predicted to continue to accelerate erosion, loss of archeological data, destabilization of mounds, and eventual total loss of site integrity; the National Park Service (NPS) is addressing these threats through some of the following actions.

Responsive Actions

The NPS Southeast Archeological Center designed a project to address these threats in three ways: documenting the resource, offsetting stressors, and interpreting the change.

The center is working to thoroughly spatially map and document the current cultural landscape, and to recover important archeological, environmental, and paleoecological data before significant portions of the mounds are lost. The four mound sites were mapped to capture and document the contextual terrain and site details by using existing maps and generating new terrestrial LiDAR data. Additionally, airborne LiDAR and high-resolution aerial imagery were used to examine the larger environment, document the present state of erosion on sites, and examine possible related terrain features. Archeological testing included NHL-level documentation and archeological and scientific data recovery of the four threatened mound sites to support a national historic landmark eligibility study. NHL status would allow for more surveys to be completed and increase opportunities for education and outreach.

On-the-ground conservation and stabilization methods and techniques are being successfully employed to strengthen, protect, and stabilize eroding sites by combining soft armoring and living shoreline techniques. This hybrid approach involves planting of cordgrass (*Spartina alterniflora)* and mangroves in the intertidal zone, deploying bags of oyster shells seaward of the cordgrass, and placing oyster restoration mats seaward of the bags.

This project is intended to engage a wide spectrum of the public at all age levels. Volunteers, local school groups, and park visitors have multiple opportunities to gain hands-on experience with archeology, building oyster mats, and planting the living shorelines. Civic engagement with stakeholders and the public includes effective communication about the effects of climate change on cultural resources. The project has been successful and can therefore also serve as a model to other coastal parks with similar management challenges.

This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Developing/implementing an adaptation plan

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Case Study 4:
Cultural Resources Inventory and Vulnerability Assessment, *Bering Land Bridge National Preserve, Alaska* *Cape Krusenstern National Monument, Alaska*

Contributing Authors: Dael Devenport (Alaska Regional Office) and Frank Hays (Western Arctic National Parklands)

Bluffs along the coast eroded 78 m (256 ft) in only 54 years. Image credit: NPS I&M Program.

Goals

Climate change has increased the vulnerability of cultural resources in coastal locations at Bering Land Bridge National Preserve and Cape Krusenstern National Monument along the northwestern Alaska coast. The Alaska Regional Office is developing and testing a GIS model that is intended to predict locations and vulnerability of these cultural resources.

Challenges and Needs

The 1,600 km (1,000 mi) of coastline along the parks are experiencing increased storm impacts due to climate change effects including rising sea level, melting permafrost, increasing storminess, and the failure of shore ice to form its usual protective barrier against wave erosion during open water season, including storms in the late fall. The Alaskan Arctic has experienced average temperature rise at twice the rate of the rest of the world, and precipitation patterns are changing. Seasonal (winter) sea ice is not forming to its previous extent and thickness, and thick multi-year ice has mostly disappeared. Satellite data indicate that the extent of the sea ice is decreasing by 3% per decade, and submarine data show that the thickness has decreased by up to 1 m (3.3 ft). The ice plays a role in surface reflectivity, cloudiness, humidity, exchanges of heat and moisture at the ocean surface, and ocean currents. Summer ice is projected to disappear over most of the Arctic Ocean by 2020. Permafrost, which protects cultural resources by preserving organic materials, has warmed by up to 2°C (3.6°F) and is melting.

Both parks preserve some of the earliest most significant archeological sites in North America including ancestral villages of the Inupiat people. Some of these prehistoric sites are being lost due to destabilization of the coasts and the resulting erosion that can be up to 3.7 m (12 ft) per year. As the permafrost that encases the soil of the region melts, the stratigraphy, artifacts, and buried house remains that make up a typical site are exposed and then become victim to mechanical erosion from the waves and thermal degradation from the warmer temperatures that prevail on the bluff faces.

Already, recently exposed archeological sites litter the bluff faces that line the coastline of Bering Land Bridge National Preserve. Only a small percentage of the coastlines have been inventoried, and there is little information on the significance or condition of most of the vulnerable archeological sites. Through actions, as described below, the National Park Service (NPS) is documenting unknown and unprotected archeological sites in order to make informed decisions about management actions.

Responsive Actions

To build basic inventory knowledge and inform subsequent management actions, the Alaska Regional Office is creating a GIS-based vulnerability assessment to determine which areas of the park coasts are most vulnerable to erosion and which of those areas are most likely to contain archeological sites. The GIS-based model will combine predictive local climate scenarios produced by the Scenarios Network for Alaska and Arctic Planning, a coastal erosion model from the Arctic Network (NPS Inventory & Monitoring program), and a model to predict the presence of archeological sites based on physical site characteristics. The model will be tested first on its ability to predict the locations of known sites, and then on its ability to identify the high or low probability of sites occurring in particular areas. This study will give a more detailed overall picture of where erosion rates are greatest relative to the density of sensitive archeological zones, and will enable prioritization of future archeological inventories.

House pits are visible near Cape Krusenstern in this 2003 orthophotograph. Image credit: NPS I&M Program.

Lack of relevant baseline data (e.g., site locations and conditions) has impeded this project. Consultation with communities affiliated with both park coastal areas will help the parks incorporate traditional knowledge of climate impacts, record documented and undocumented archeological and ethnographic sites and features, and develop survey strategies and priorities. The project will also compile archeological inventory data, digital elevation models, soil maps, aerial imagery, and documentation including Bureau of Indian Affairs Alaska Native Claims Settlement Act (BIA ANCSA) files, toponym studies, and scholarly journal articles.

The initial phase of this project, identification of at-risk sites, was initiated in 2011 and was recently completed. Site treatment will be an ongoing process.

This case study is an example of the following adaptation strategies:

- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Creating/enhancing technological resources
- Developing/implementing an adaptation plan

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Case Study 5:
Strategic Planning and Responsible Investments for Threatened Historic Structures,
Dry Tortugas National Park, Florida

Contributing Authors: Dan Kimball (Everglades / Dry Tortugas National Parks, retired), Marcy Rockman (NPS Climate Change Response Program), and Kelly Clark (Dry Tortugas National Park)

Goals

Sea level rise and increased tropical storm intensity pose a serious risk to the long-term sustainability of historic Fort Jefferson at Dry Tortugas National Park, Florida. The park is trying to mitigate these effects over time through strategic planning, informed decision making, and responsible investments that consider historical integrity and long-term sustainability of the fort and island on which it was built.

Historic Fort Jefferson is a six-sided structure built on a landform that is impacted by coastal processes.
Image credit: Marcy Rockman, NPS.

Challenges and Needs

Located 110 km (70 mi) west of Key West, Florida, in the Gulf of Mexico, the seven small islands and historic Fort Jefferson of Dry Tortugas National Park sit on the front lines of the climate change discussion and decision-making process within the National Park Service. The most pressing climate change issues that could directly affect the resources and operations of Dry Tortugas National Park are sea level rise and increased tropical storm intensity. These two factors pose a serious risk to long-term sustainability of Fort Jefferson, the main cultural resource and the base of all park operations, as well as the other islands and accompanying natural resources of the park.

Fort Jefferson needs repairs to its front and moat wall.
Image credit: Kelly Clark, NPS.

For more than 165 years, Fort Jefferson on Garden Key has exhibited incredible resilience to storms and the marine environment of the Dry Tortugas. Still the structure is deteriorating. The fort is a mid-19th century Third System Coastal Defense. It is an unreinforced masonry structure composed of coral concrete faced with brick, with six sides and three tiers. It is surrounded by a 21 m (70 ft) wide wet moat that is separated from the open waters of the Gulf of Mexico by a masonry wall, formally called the counterscarp. The counterscarp sits approximately 2 m (6 ft) above the low water line and 1 m (3 ft) above high tide. The moat and counterscarp were designed to keep would-be attackers at bay and to provide a structural first line of defense for the fort against the sea.

Throughout the architecture of the fort, there are iron components embedded within the masonry that served various functions, including water collection, supports for catwalks, and, most importantly, protection against enemy fire. In this salt water environment, the wrought-iron has rusted and expanded, pushing the brick apart and causing serious structural damage to Fort Jefferson's exterior scarp walls; large sections of the fort walls have collapsed into the moat.

The moat wall surrounding the fort also needs repairs in many places. Because it is an integral part of the site design and protects the fort from wave forces, it also protects the investment in stabilization of the fronts.

Given projections for sea level rise and increased storm intensity, many questions exist as to the appropriate level and nature of investment in repairs and restoration of Fort Jefferson and other historically significant cultural resources at the park. Such spending decisions will incorporate considerations such as long-term feasibility of park operations within the fortification, sustainability of the fort and moat wall and the island on which it was built, historic preservation goals of the National Park Service in terms of both stewardship and visitor experience, and other repair needs within the National Park Service.

Responsive Actions

Through strategic planning, informed decision making, and responsible investments, the park is trying to mitigate the effects of the environment over time. This approach has resulted in removing the corroded iron shutter assembly components and stabilizing the exterior masonry walls. Preservation and stabilization work on the fort has occurred on an intermittent basis since the 1990s. The moat wall has been worked on intermittently since the 1960s. For both structures, the scope of work has been guided by the amount of available funding. At this point in time, all six sides of Fort Jefferson have received some form of stabilization, but the work is not complete. The main priority for the park is to complete the removal of the remaining iron shutter components embedded in the exterior scarp wall (fronts 3 and 2) and to stabilize as much of the brick work from the top of the parapet to the low water line with selective brick replacement and repointing. The estimated cost to finish these stabilizing measures by 2018 is just under $12 million.

Moving forward with preservation efforts, the park is following the National Park Service Climate Change Response Strategy to address the projected consequences of climate change. The park is also using the National Park Service Climate Change Action Plan as a framework for the development of mitigation and adaptation plans; consideration of alternatives for making decisions based on cost effective actions that deliver results; and development of long-term monitoring and documentation that will contribute valuable data to be considered in the future. This course of action should allow the National Park Service to maintain park operations on-site, comply with the park's enabling legislation by preserving important cultural resources, provide opportunities for visitor enjoyment, and simultaneously make the fort more resilient to the effects of projected climate change while allowing for future adaptation.

To help in prioritizing park needs and strategic investment planning, the park has looked towards scientific data being produced by groups such as the Intergovernmental Panel on Climate Change and the Southeast Atlantic Coastal Ocean Observing System. The US Geological Survey has completed coastal vulnerability studies of the park. The park also installed a sea level monitoring station at Garden Key in fiscal year 2014 using concessions franchise fee funds; this real-time, on-site sea level data will establish a monitoring baseline and will aid in climate change scenario planning and future decision making.

Preservation decisions must also consider long-term feasibility of park operations within Fort Jefferson and on Garden Key, historic preservation goals and mandates of the National Park Service, visitor experience, and the overall short- and long-term budgets of the National Park Service. Striving for constant improvement and long-term sustainability through the stabilization efforts, the cultural resources staff and stabilization project team have continued to review and improve specifications and contractor performance with increased project oversight and improved documentation of material performance.

Planning for future repairs to the fort and the moat wall require budget foresight, structural vulnerability analysis, careful historic preservation considerations, and continued incorporation of climate change projections, particularly with respect to local sea level rise and storm intensity. Such decisions must include all appropriate compliance and consultation, and participation by policy, preservation, documentation, interpretation, and other programs from across the National Park Service.

This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Conducting vulnerability assessments and studies
- Making infrastructure resistant or resilient to climate change
- Developing/implementing an adaptation plan
- Creating new or enhancing existing policy

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Case Study 6:
Eroding Shoreline Threatens Historic Peale Island Cabin, *Yellowstone National Park, Wyoming*

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Peale Island Cabin is located on a small spit of land on the northwest corner of Peale Island. Image credit: Yellowstone National Park.

Goals

Yellowstone National Park collaborated with the National Park Service Geologic Resources Division (NPS GRD) to examine the causes of shoreline erosion on Peale Island and to identify adaptation options for protecting the shoreline and a historic cabin on the island.

Challenges and Needs

Peale Island is located in a wilderness area in the South Arm of Yellowstone Lake. It is composed of glacial till and has no source of new coarse sediment but does receive a minor supply of erodible fine sediments. Several processes may be accelerating shoreline erosion, including a change in sediment transport processes, tectonic uplift, longer ice-free periods, tree death, and changes in wave and wind patterns. Climate change has already affected the park in ways such as reduced annual snowpack, declining streamflow, increased stream temperature, and more frequent wildfire events. Ongoing climate change has the potential to drive several process changes: increased precipitation may raise Yellowstone Lake water levels and increase shoreline submergence; higher summer temperatures may increase evaporation that lowers water levels; and warmer temperatures may increase the number of ice-free days on Yellowstone Lake and cause a corresponding increase in exposure of the Peale Island shoreline to wind-driven waves and coastal erosion.

The historic Peale Island Cabin is eligible for listing in the National Register of Historic Places and is used regularly by park staff including backcountry patrols. It is located on a narrow spit on the eroding north end of the island. As of 2013, the shoreline had moved closer than 2 m (6 ft) from the cabin porch, and the number of live trees along the shoreline continued to decrease.

The park needed to know how the shoreline would continue to change, how it would threaten the preservation and functionality of the historic cabin, what options were available to protect the shoreline and cabin, and the impacts of implementing alternative management options.

Responsive Actions

The park asked the NPS GRD to develop information about shoreline change on Peale Island and to clarify the options for the Peale Island Cabin and shoreline. The resulting natural resources report (Beavers et al. 2014) presented and described 10 coastal adaptation options:

- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Monitor, learn, and interpret the change: Continue current management practices
- Record, then let go: Deconstruct cabin
- Improve structure resiliency: Elevate cabin
- Indirect/offsite action: Nourish shoreline with compatible sediment
- Indirect/offsite action: Armor shoreline with rocks, logs, or other materials
- Relocate cabin to Peale Island interior
- Relocate cabin to outer shore of Yellowstone Lake
- Replace cabin function and structure

Many of the adaptation options suggest similar "no-regrets" actions, including monitoring shoreline position and lake water level; documenting the historic resource and cultural landscape; and monitoring the condition of the historic structure.

Several datasets would improve estimates of how long each option would protect Peale Island resources: historic wave and wind conditions; detailed erosion rates for the Peale Island shoreline; and tree stand chronology data.

As of September 2014, the park intends to initiate a planning process for an alternative management option. The process will include screening of the potential project, discussions with the Wyoming State Historic Preservation Office and engagement in appropriate National Historic Preservation Act and National Environmental Policy Act processes to evaluate the project and make a final decision (Dave Hallac, Chief, Yellowstone Center for Resources, email, 21 October 2014). In summer 2015, alternate sites along the shores of the South Arm of Yellowstone Lake were evaluated to define suitable sites for potential relocation of the cabin.

This is an ongoing project. This case study is an example of the following adaptation strategies:

- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Developing/implementing an adaptation plan
- Incorporating climate change into policies, plans, and regulations
- Managed retreat of built infrastructure

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Case Study 7:
Lighthouse Stabilization Design Incorporates Sea Level Rise, *Fort Pulaski National Monument, Georgia*

Contributing Author: Mike Eissenberg (NPS Denver Service Center)

The Cockspur Lighthouse at Fort Pulaski National Monument needs to be stabilized. Image credit: Mike Eissenberg, NPS.

Goals

The goal of this project was to develop a plan to stabilize a historic lighthouse at Fort Pulaski National Monument in a way that considered expected sea level rise and related impacts.

Challenges and Needs

The historic revetment around the Cockspur Lighthouse has eroded away in the past 30 years, and a portion of the original wooden foundation has been exposed to shipworm damage. Ongoing erosion around the revetment has led to concern about the possibility of severe structural damage in the next few years.

To stabilize the lighthouse, the park needed to design a structure that can withstand sea level rise over the next 20 years and related impacts such as increased wave heights.

Responsive Actions

The revetment will be modified to protect against sea level rise over the next 20 years assuming that the current rate of rise will continue. The modification will be constructed to allow for future adaptation to accommodate faster rates of rise. Project design would be improved by development of a reproducible process that could estimate local sea level rise qualitatively or quantitatively, incorporating contemporary science and evaluating risks.

This and other projects would benefit from identifying appropriate climate change issues that should be addressed as part of the project development process. A predictable and transparent process for addressing climate-related impacts would minimize surprises and modifications to project design, and would improve the effectiveness of dialogue among stakeholders.

To improve understanding of current and future sea level rise, the park has identified global sea level rise projections from the Intergovernmental Panel on Climate Change, historic rates calculated by National Oceanic and Atmospheric Association, and trends in local water level monitoring data collected at the park.

This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Conducting/gathering additional research, data, or products
- Making infrastructure resistant or resilient to climate change
- Developing/implementing an adaptation plan
- Short-term adaptation coupled with watchful waiting

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Case Study 8:
Relocating the Lighthouse,
Cape Hatteras National Seashore, North Carolina

Contributing Author: John Kowlok (Cape Hatteras National Seashore)

The Cape Hatteras lighthouse was moved inland using a railway in 1999. Image credit: NPS.

Goals

Ongoing erosion threatened the base of a historic lighthouse at Cape Hatteras National Seashore, despite multiple hard stabilization protection efforts. The park needed to obtain funding and public support to relocate the lighthouse away from the eroding shoreline.

Challenges and Needs

The Cape Hatteras lighthouse is one of the most popular visitor attractions at the park. This historic structure was built on the barrier island in 1803 and is a culturally significant asset.

By the 1930s, shoreline retreat threatened the base of the lighthouse with an estimated erosion rate of 3.7 m (12 ft) per year, independent of beach nourishment and protection efforts. Hurricanes and associated storm surges exacerbated this erosion.

Over the following decades, the park attempted to protect the lighthouse from erosion using a number of hard stabilization techniques including sheet pile groins (1930s), beach nourishment (1966, 1971, 1973), nylon sand-filled bags (1967), reinforced concrete groins (1967), a sand bag wall (1971), piled rubble (1980), and artificial "seascapes" (1981). The park also considered moving the lighthouse, but after receiving oppositional feedback at a public workshop in 1982, a seawall revetment with artificial seaweed was installed instead, followed by installation of a sand bag revetment in the 1990s.

None of the mitigation techniques seemed to provide any long-term protection. Relocation seemed to be the most promising way to protect the lighthouse, but public support and funding was needed to accomplish this.

Responsive Actions

Following so many unsuccessful attempts to protect the lighthouse with hard structures, the "Move the Lighthouse Committee" was formed in 1986 and became strong proponents of relocating the lighthouse inland. In 1988 the National Academy of Science also recommended that the lighthouse be moved. The National Park Service (NPS) released a statement in December 1989 formally announcing the decision to move it.

Securing funding and gaining public support were two significant challenges to implementing the relocation plan. Planning the move required several years of litigation, planning meetings, and public outreach. Public response was mixed. In particular, it was difficult to persuade stakeholders that the high cost of relocation was more cost-effective in the long term.

The lighthouse was moved in June 1999 at a cost of $11.8 million. The new location is 0.9 km (0.55 mi) from its previous position and approximately 0.5 km (0.3 mi) from the shoreline. The Lighthouse Society placed a ring of granite stones, each engraved with the name of a lighthouse keeper, to mark the former position of the lighthouse. Although the original plan called for the stones to be left in place, continued overwash and burial of the stones led to negotiations between the Lighthouse society, a Congressional Representative, and NPS to uncover and move the stones. Cape Hatteras National Seashore funded the new Keepers of the Light Amphitheater, which was built in 2015 by placing the stones in arcs in front of the lighthouse's new location.

Climate change impacts such as sea level rise and increased storm surge frequency may present future threats to the lighthouse in its new location.

The project took 11 years to complete. This case study is an example of the following adaptation strategies:

- Increasing/improving public awareness, education, and outreach efforts
- Making infrastructure resistant or resilient to climate change
- Managed retreat of built infrastructure

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Case Study 9: Collecting Baseline Biological and Geologic Data to Understand Coastal Change, *Bering Land Bridge National Preserve, Alaska* *Cape Krusenstern National Monument, Alaska*

Contributing Author: Tahzay Jones (Alaska Regional Office)

Coastal bluffs are eroding as a result of permafrost thawing and coastal storm erosion. Image credit: Tahzay Jones, NPS.

Goals

Climate change impacts, including coastal erosion, reduction in sea ice, and thawing of permafrost, are impacting Bering Land Bridge National Preserve (BELA) and Cape Krusenstern National Monument (CAKR) along the northwestern Alaska coast. The parks need baseline information and an updated evaluation of coastal resource vulnerabilities in order to make prudent management decisions related to increased marine traffic, sensitive areas, and natural and cultural resource protection.

Challenges and Needs

Climate change impacts are affecting park resources in several ways. Increasing ocean temperatures are causing a reduction in the summer sea ice extent in the Chukchi Sea. This in turn delays the winter return of the ice and the coastal protection that it provides the northwest Alaska coastline. The resulting increase in storm erosion, combined with the thawing of permafrost, has accelerated the erosion of BELA and CAKR coastal natural resources and cultural sites. The barrier islands supporting the village of Shishmaref and Kivalina are also eroding, and residents are considering relocation to inland sites: Shishmaref to interior Shishmaref Inlet, within the lagoon system that is hydrodynamically connected to the BELA lagoons; and Kivalina to the mainland with a road connection to the CAKR Red Dog Mine port site.

The reduction in ice along the Arctic coastline also has allowed oil development and marine traffic to increase, raising the potential for marine incidents with associated environmental ramifications. Marine traffic has significantly increased because the only connection between the Pacific and Arctic Oceans is the Bering Strait adjacent to BELA and just south of CAKR. This transit point is of high value because the northern sea routes significantly reduce the travel distance between Europe and Asia, creating significant cost savings. The US Coast Guard and US Army Corps of Engineers are currently evaluating sites for a deep water port in the Arctic, and the current preferred site is Port of Nome on the southern side of the Bering Strait, a short distance south ofBELA.

Loss of sea ice will likely increase the ocean exchange with lagoons, a process that will likely be accelerated by sea level rise. Changes in chemical and physical characteristics of lagoon water, such as salinity and hydrodynamics, will alter biological components of the ecosystem in unknown ways. These systems currently provide habitat for globally important bird populations, threatened and endangered bird species, and are home to the northernmost extent of eelgrass in North America.

Adaptation will require understanding, preparing for, and responding to these changes.

Responsive Actions

National Park Service (NPS) climate change scenario planning has been done for both parks. The NPS Arctic Network Inventory and Monitoring Program is developing long-term monitoring protocols for coastal erosion and lagoon biology, and is already engaged in climate monitoring. Datasets continue to be developed that will enhance understanding of climate change vulnerability in these parks. Datasets include coastal erosion (using satellite and aerial imagery from 1954–2003 and satellite imagery including 2013 data), LiDAR (topographic) coverage of both parks (2003), and improved accuracy of coastal maps (2013). A one-year ShoreZone mapping project was conducted that included coastal orthophotography and maps of intertidal biotic components, geomorphology, and coastal hazard areas along the BELA and CAKR coastlines (2012 and 2013). Projects supported by the park and the Alaska regional office have included post-breeding bird surveys in BELA (2013) and CAKR (2014), lagoon water mass budgets in BELA (2013), permanent marine debris monitoring sites in BELA (2013) and CAKR (2014), and a coastal survey of at risk cultural sites (2012 and 2013).

To accomplish these results, all projects work synergistically to share and utilize logistical resources to the maximum extent possible. Additional projects planned include ecological classifications of the BELA and CAKR coasts; an interdisciplinary biophysical baseline assessment of BELA and CAKR lagoons and estuaries; and updating environmental coastal sensitivity indices. Current park proposals include post-breeding surveys of water birds; understanding whitefish ecology and seasonal dynamics (a primary subsistence fish in both parks); seasonal marine mammal presence, distribution, and coastal use; lower trophic level biophysical surveys; gathering of local community traditional ecological knowledge; engaging with local communities to identify new areas of concern; and working with partners to model ship traffic.

Significant outstanding data needs include lagoonal water quality, hydrodynamics, and bathymetry; lower trophic level seasonality, distributions, and densities; further surveys to identify locations of cultural sites at risk; subsistence needs and restrictions; and political and jurisdictional boundaries. Additional challenges are presented by the difficulty in obtaining funding to conduct work along this coastal region; the extensive land area needing study; and the logistics of reaching these remote parks.

This case study is an example of the following adaptation strategies:

- Monitoring climate change impacts and adaptation efficacy
- Conducting/gathering additional research, data, or products

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Case Study 10:
Recognizing Coral Adaptations to Environmental Stressors, *National Park of American Samoa*

Contributing Author: Tim Clark (National Park of American Samoa)

The coral reef in Ofu Lagoon is threatened by warming waters and ocean acidification, but is proving to be surprisingly resilient in comparison to nearby reefs. Image credit: NPS.

Goals

Ofu Lagoon, part of the National Park of American Samoa, contains a healthy coral reef habitat that supports a diversity of species. The park is working with university partners towards the goal of understanding the unique adaptations of the coral in Ofu Lagoon to multiple environmental stressors associated with climate change.

Challenges and Needs

The coral reefs in and around the park support more than 975 fish species and 250 coral species, and a high diversity of invertebrates. Disturbances such as cyclones are expected to increase with climate change, but the principal threat to coral reefs is global warming, which increases nearshore water temperatures and, in turn, increases coral disease and coral bleaching events. Coral reefs within the park and worldwide are expected to experience substantial mortality, up to 90% loss by the end of the century. Ocean acidification, which is caused by increased levels of carbon dioxide in the atmosphere, prevents corals from absorbing the calcium carbonate they need to maintain their skeletons, and dissolves the stony skeletons that support corals and reefs.

The corals in Ofu Lagoon are remarkably resilient to the multiple environmental stressors affecting them, such as high daily temperatures (regularly exceeding 31°C/88°F) and large fluctuations in temperature (range of 4.4°C/8°F), pH (varying by more than 0.5 units of pH), and dissolved oxygen (from 50% to 200%). In 2002 and 2003, increased water temperatures caused extensive coral bleaching, an event in which the heat-stressed coral polyps expel their symbiotic zooxanthellae, which are tan colored, causing coral to look white or "bleached." Surprisingly, the corals in Ofu Lagoon experienced less bleaching than other nearby reefs. Although the Ofu Lagoon corals are better adapted to the lagoon environment than corals transplanted from other reefs in American Samoa, they do not fare as well when they are transplanted to areas outside the lagoon.

More research would help the National Park Service (NPS) to understand this unique tolerance to high temperatures and other stressors, and the implications of this resilience for the health of corals worldwide; to identify areas of reefs in Samoa that would benefit most from protection and conservation; and perhaps to use these corals to reseed areas where corals have been lost to climate change impacts.

Responsive Actions

The park works closely with territorial government agencies and advisory groups to develop solutions to concerns related to coral reef health and expected impacts of climate change. This is not only an effective collaboration but it is also necessary, because the park leases rather than owns the lands and waters within its boundaries, and so must negotiate management plans and actions with traditional landowners and village councils in addition to American Samoa government agencies.

To study and support research on this unique coral reef system, the park operates a laboratory facility on the island of Ofu. This facility supports park and university researchers, and includes an experimental coral tank system that the park designed and built to study the effect of temperature shifts on living coral. Local Samoan interns provide field assistance and monitor experiments while researchers are away.

Results from recent research indicate that heat tolerance derives from both the coral polyps and also from their symbiotic photosynthesizing zooxanthellae. The gene expression of heat-sensitive corals can change in response to heat stress, but the most resilient corals in the Ofu Lagoons already have those thermal tolerance genes "turned on." Additionally, the zooxanthellae in Ofu corals are of four different genotypes, or clades; the corals with clade D were found to be more resilient to heat stress but less tolerant of cooler waters in comparison to coral with other clades. Over time, selection for the thermal tolerance gene expression and the clade D zooxanthellae may allow coral reefs to adapt to higher temperatures and fluctuations. This appears to already have occurred in Pool 300 in the park's section of the Ofu reef lagoon, making these corals some of the most heat tolerant known.

Related studies conducted near the park found that discharging cooler water onto heat-stressed reefs could speed and sustain recovery from coral bleaching events. Furthermore, ultraviolet protection from shade cloth improved coral health. The park is conducting baseline studies of corals within park waters; data will allow comparison with future coral cover. The NPS Pacific Islands Network Inventory and Monitoring Program also provides water quality data and natural resources inventories for the park.

Results of these studies help the park in planning long-term management efforts, such as identifying new candidates for marine protected areas. It would be most effective to target areas that are expected to have higher resiliency to climate change provided that other locally controlled stressors (such as destructive fishing practices) are reduced; examples include shaded areas at the base of cliffs, and reef edges that experience cold-water upwelling events. Although actions such as shading and cool-water discharge would not allow coral to adapt to changing conditions or slow climate change, these strategies could be implemented for short-term solutions, such as briefly protecting small areas of reef, while longer-term management decisions are resolved.

In addition to working with agencies and community groups on broad efforts to protect island reefs and other natural and cultural resources, the park has also developed educational outreach programs focusing on how to minimize individual contributions to climate change.

This project is ongoing and is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Reducing non-climate stressors (e.g., destructive fishing practices)
- Coordinating planning and management across institutional boundaries
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products

The park laboratory on the island of Ofu supports coral reef research. Graduate student Lupita Ruiz-Jones lifts a crate of coral samples from Ofu Lagoon. Image credit: Carlo Caruso, NPS.

Local NPS interns Sui Fautua and Vano Alosio take water samples while assisting visiting researchers. Image credit: Carlo Caruso, NPS.

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Case Study 11: Restoring the Jamaica Bay Wetlands, *Gateway National Recreation Area, New York*

Contributing Authors: Patricia Rafferty (NPS Northeast Region) and Amanda Babson (NPS Northeast Region)

Goals

Gateway National Recreation Area partnered with other state and federal agencies to restore wetlands in Jamaica Bay, a eutrophic urban estuary, through sediment addition and plantings. While the project was not driven by climate change concerns, addressing marsh elevation loss is consistent with methods to address sea level rise. The monitoring program strives to determine factors contributing to project performance; to test several experimental techniques; to develop and justify adaptive management actions; and to better understand factors contributing to marsh loss throughout Jamaica Bay.

Challenges and Needs

Historically, Jamaica Bay's extensive marsh islands, tidal creeks, and mud flats served as important nursery and feeding grounds for fish. The quantity and quality of bay habitat has declined due to urban development, shoreline hardening, channel dredging, sewage treatment plant operations, and causeway and jetty construction. Emergent salt marsh islands have converted to intertidal and subtidal mudflats. The current (2003–2008) annual average rate of salt marsh island loss is 7.7 ha (19 ac) per year, a rate that is high in terms of both annual loss and percentage by area. That loss is likely to be further exacerbated by sea level rise.

In response to public recognition and concern about the loss of salt marsh habitat and functions within the Jamaica Bay ecosystem, an interagency wetland restoration project was developed. Compliance and design work were completed by a contractor for the first restoration site in 2006 and by the US Army Corps of Engineers (USACE) and an interagency team for subsequent sites under special use permits. USACE performed the National Environmental Policy Act (NEPA) planning, which the National Park Service (NPS) adopted to issue a Finding of No Significant Impact.

Restoration methods were based on ecological expertise, NPS policies, bio-benchmarks (elevation requirements for vegetation), and engineering guidance from the USACE. Using a variety of experimental techniques, sediment was added to the marsh surface to increase elevation, and vegetation was planted or relocated. A comprehensive monitoring and adaptive management program has been implemented at each restoration site; data are collected prior to restoration and will continue for five years following restoration. Monitoring results and practical experience gained at each restoration site are used to improve planning and execution at subsequent sites. Research efforts focus on mechanisms of salt marsh loss, including regional sea level rise, hydrologic modifications, and eutrophication.

Responsive Actions

The project faced several challenges. Development of a functional interagency team was not smooth at first but has become one of the project's successes. When construction funding could not be secured, the project was repackaged as a beneficial use project for sediment dredged by a harbor deepening project. Because USACE policies limit monitoring to 1% of project costs, NPS funding and in-kind cost sharing were used to maximize limited resources. Initially, partners did not support the NPS preference for higher-elevation marsh, which supports a different species assemblage and which builds in resilience under sea level rise; fortunately restoration at each successive site has included increasingly more high marsh.

The park obtained fiscal year 2014 funding through the NPS servicewide combined call to support research that will focus on marsh response to sea level rise and that will populate published models with project monitoring data.

Future restoration efforts may be inhibited by the availability of a cost-effective clean source of sediment. NPS and park standards for sediment quality that exceed Environmental Protection Agency and New York Department of Environmental Conservation standards were met with resistance from funding partners. Fund transfer mechanisms among state and federal partners will likely be a recurring challenge. Another challenge is the inability of restoration fund sources to support basic research that would improve restoration by optimizing techniques or identifying the causes of marsh loss. For example, this project would have benefitted from a better understanding of the tidal range, and the elevation range for saltmarsh cordgrass (*Spartina alterniflora)* growth within Jamaica Bay, in order to restore marshes to the maximum elevation at which the desired habitat could establish. Site-specific data relating to shallow subsidence and compaction would have improved estimates for the fill volume required to achieve design elevations.

Salt marsh restoration in Jamaica Bay has tried a variety of experimental techniques to increase marsh elevation, including spraying the marsh surface using a swing-ladder dredge. Image credit: USACE New York District.

This project is ongoing. This case study is an example of the following adaptation strategies:

- Reducing local climate or related change
- Coordinating planning and management across institutional boundaries
- Conducting/gathering additional research, data, or products

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Case Study 12:
Restoring the Giacomini Wetlands from Agricultural Lands, *Point Reyes National Seashore, California*

Contributing Author: Lorraine Parsons (Point Reyes National Seashore) and Sarah Allen (NPS Pacific West Region)

A new channel forms on East Pasture marshplain, part of the restoration of agricultural lands to wetlands. Image credit: Lorraine Parsons, NPS.

The wetlands during a king tide. Image credit: Sarah Allen, NPS.

Goals

Point Reyes National Seashore developed the Giacomini Wetland Restoration Project to restore tidal wetlands from diked agricultural lands. Restoration efforts were accomplished through sub-goals to engage the public, manage public access, protect pre- and post-project habitats for multiple listed species, build in resilience to accommodate for potential climate change effects, and adaptively monitor effectiveness of management actions.

Challenges and Needs

The Giacomini Wetlands originally comprised tidal salt marsh, intertidal mudflats, and subtidal areas in the southern portion of the Tomales Bay watershed just north of San Francisco Bay. They were altered by human influence beginning in the 1860s, when logging and agriculture practices increased sedimentation. Later, in 1946, a large dairy ranch implemented agricultural practices and built infrastructure including tidegates and 4 km (2.5 mi) of levees that greatly reduced the condition and functionality of the wetlands. These changes converted the marsh to freshwater habitats, and channeled Lagunitas Creek. The channeling caused the river flow to bypass the wetlands, which previously served to reduce flood levels and to filter pollutants and sediment from stormwater flow. After purchasing the ranch in 2000, the National Park Service restored more than 248 ha (613 ac) of agricultural land to wetland habitat in 2007 and 2008, representing 12% of central California's outer coastal wetlands.

The ranch was purchased for several reasons: the site was identified within the park boundary, the restoration of the valuable coastal wetland would serve as mitigation for previously lost coastal habitat in the park, and the previous owner was interested in selling the land. The restoration of the wetlands was achieved through a number of measures including the removal of levees, the construction of channels and a flood spill area, the planting of native plants, the removal of nonnative plants, and the installation of mitigation ponds for the California red-legged frog (*Rana draytonii*). Computer modeling was undertaken prior to the restoration to ensure that the restored wetland would not result in any unintended changes in salinity, particularly salt water intrusion in the nearby fresh drinking water supply. These models also looked at how changes in sea level under multiple scenarios might alter the wetlands.

The project's environmental impact statement included inventories of threatened, endangered, and keystone species and habitats, and hydrologic and hydrodynamic modeling of saltwater intrusion and flooding under several scenarios. As the project developed, climate change issues including sea level rise, salt water intrusion, habitat migration into upland areas, species diversity, invasive species, and residential floods were addressed. Based on sea level rise models, restoration design took into account habitat migration and retention of rare high marsh habitat. Because multiple listed species were present in the project area prior to restoration, it was difficult to maximize habitat for new target species while minimizing impacts on the species flourishing under pre-project conditions.

The restored wetland is vulnerable to sea level rise and impacts of increased salinization of waters, which would impact several listed species that are adapted to freshwater or brackish conditions. The resiliency of the restored area to storm surge and flooding has not yet been tested by a 100-year storm, but flooding of homes did not occur during the past few years of large winter storms. Restoration of the wetland has resulted in significant positive response by waterbirds and other wildlife with increases in number and biodiversity documented in monitoring data. Outstanding needs include assessment and analysis of field data and hindcasting to verify model accuracy. Acquiring funding for this project was challenging, particularly for post-project monitoring, despite wide recognition of this valuable component.

Responsive Actions

To address the many concerns raised by the environmental impact statement, the planning process included an engaged discussion with the local community, particularly about public access issues. The final project plan also incorporated a pre- and post-restoration monitoring program for hydrology, topography, sedimentation, water quality, zooplankton, benthic invertebrates, fisheries, vegetation, and birds. Although the National Park Service provided some support for this project, funding had to be obtained from multiple non-park sources.

This project is ongoing. This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Enhancing connectivity, migration corridors, and areas under protection external to the park unit
- Reducing flood risk for adjacent private lands/homes by removing channeling of river and enhancing wetland habitats
- Monitoring climate change impacts and adaptation efficacy
- Reducing non-climate stressors (e.g., river channeling, sediment management)
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Developing/implementing an adaptation plan
- Increasing biodiversity by creating restored wetland habitat

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http://www.nps.gov/pore/parkmgmt/planning_giacomini_wrp.htm

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Case Study 13:
Consideration of Shackleford Banks Renourishment, *Cape Lookout National Seashore, North Carolina*

Contributing Authors: Mark Kinzer (NPS Southeast Region) and Patrick Kenney (Cape Lookout National Seashore)

Shoreline erosion along the western portion of Shackleford Banks is accelerating due to adjacent channel dredging. Image credit: NPS.

Goals

Cape Lookout National Seashore had to evaluate whether it was appropriate to pursue opportunities to mitigate shoreline erosion along Shackleford Banks, a proposed wilderness area.

Challenges and Needs

Navigational channel dredging along the North Carolina coast has contributed to erosion along Shackleford Banks, an undeveloped barrier island that is part of the proposed wilderness area within the park. This island supports important habitat for shorebirds and protected species of birds, sea turtles, and plants; provides recreation; and is home to an iconic feral horse population. It also serves as a natural laboratory and control site for multiple research efforts.

In early 2013, the US Army Corps of Engineers released its draft 20-year dredge material management plan for the adjacent Beaufort Inlet, and requested to deposit the sediment spoils on Shackleford Banks. The park expressed interest in future opportunities for beach renourishment and nearshore placement along Shackleford Banks to mitigate erosion on its western tip and related impacts on island ecosystems. The local communities objected, desiring that the entirety of the sediment be committed to beach renourishment along the adjacent developed Bogue Banks instead. Through the environmental impact statement process the National Park Service (NPS) analyzed the impacts of the actions of depositing sand on the island as a means of mitigating the dredging-caused erosion as well as restoring wilderness.

To improve long-term decision making related to erosion mitigation, the park needed additional information about local sea level rise, ongoing inlet maintenance, and future impacts on Shackleford Banks such as size reduction and ecosystem degradation. The park also recognized the need to engage in a public dialogue about regional sand management strategies, acknowledging that competition for dredged sediments may intensify with increased recognition of climate change impacts.

Responsive Actions

In June 2014, after receiving feedback from the public and consulting with additional scientists, the park withdrew its request for sediment. The park recognized that it needed additional data to determine the rate of sediment loss, the proportion of erosion that could be attributed to channel maintenance rather than natural processes, and the intention to intervene in proposed wilderness areas to mitigate the impacts of human actions.

This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Coordinating planning and management across institutional boundaries
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Developing/implementing an adaptation plan

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Case Study 14:
Large-Scale Restoration of Barrier Island Systems and Cultural Resource Protection through Sediment Placement, *Gulf Islands National Seashore, Mississippi*

Contributing Author: Larissa Read (NPS Denver Service Center)

Several Gulf Islands National Seashore barrier islands along the Mississippi coast will be restored as part of the Mississippi Coastal Improvements Program. Image credit: NPS.

Goals

The large-scale project known as the Mississippi Coastal Improvements Program (MsCIP) is intended to restore multiple barrier islands and protect cultural resources within Gulf Islands National Seashore by recreating sediment transport processes and replacing a portion of sediment lost to dredging and storm impacts.

Challenges and Needs

In 2005, Hurricane Katrina caused significant erosion of park barrier islands along the Mississippi Gulf Coast. These islands were already vulnerable due to impacts of regional dredging and earlier hurricanes. Since the late 1880s, navigation channels have been constructed and maintained in the area, disrupting sediment transport and availability to barrier islands that are now part of the park. Park barrier islands have lost 24–64% of their land mass since 1848 according to surveys, with the greatest losses on East and West Ship Islands. Ship Island was breached in 1969 by Hurricane Camille, creating Camille Cut and separating East Ship Island from West Ship Island. Hurricane Katrina expanded Camille Cut to 5 km (3 mi) in width and caused significant shoreline erosion around Fort Massachusetts on West Ship Island. To restore the geomorphic integrity of the islands, sediment is needed.

Expected climate change impacts, including relative sea level rise and increased storm frequency and intensity, will increase the vulnerability of the islands and associated natural and cultural resources (e.g., historic Fort Massachusetts and the French Warehouse archeological site). This will impair the island's ability to reduce the size of storm waves approaching the mainland, change the salinity regime that is currently favorable to oysters in the Mississippi Sound, and alter habitats that currently support migratory birds and endangered species such as sea turtles, Gulf sturgeon, and piping plovers.

Responsive Actions

The Mississippi Coastal Improvements Program, which began in 2007, is a large-scale project that will guide restoration of the barrier islands to reduce future storm and hurricane damage to the coastal area, minimize saltwater intrusion, protect fish and wildlife, and mitigate erosion. This project is led by the US Army Corps of Engineers (USACE) with the participation of numerous other agencies. The plan includes directly renourishing West Ship Island to protect Fort Massachusetts; renourishing East Ship Island and filling in Camille Cut to recreate a continuous Ship Island; and restoring the natural regional sediment transport processes by modifying future placement locations to better place material dredged from Horn Island Pass into the active littoral drift zone. Regional sediment transport processes will move sediment alongshore to renourish barrier islands to the west of the deposition site.

Project planning included science and modeling efforts, agency and political issues, and many opportunities for public input. The USACE has been very active in soliciting the assistance of partner agencies and team members with appropriate expertise. The project has progressed steadily, although it has, not unexpectedly, been slowed by the bureaucratic complexity of a multiagency and cross-jurisdictional project. Project implementation has also been delayed by the search for sediment sources that are of sufficient quality and quantity, including debate over whether it is appropriate to use an area known as Sand Island as a sediment source.

By 2011, approximately 0.4 million cubic m (0.5 million cubic yd) of sand had been pumped onto West Ship Island to complete the $6 million north shore portion of the project. The draft supplemental environmental impact statement for the barrier island restoration portion of the MsCIP project was released in March 2014; dredging and nourishing costs are estimated at $368 million. The southern (Gulf) shoreline of East Ship Island will be renourished with 4.2 million cubic m (5.5 million cubic yd) of sediment. Filling in Camille Cut to rejoin East and West Ship Islands will require approximately 10.3 million cubic m (13.5 million cubic yd) of sediment; this is intended to be a one-time effort with no additional placement planned as part of MsCIP if the cut breaches again after all of the fill has been placed.

Responsible management of the barrier island system requires additional data regarding the nearshore habitats and resources. The US Geological Survey mapped the nearshore seafloor between 2009 and 2013 to describe bathymetry, substrate, and underlying stratigraphy within the jurisdictional boundaries of the Gulf Islands National Seashore at East and West Ship, Horn, and Petit Bois Islands, Mississippi. The National Park Service (NPS) is monitoring the placement of sand on the eroded north shoreline of West Ship Island, where cultural resources are located. Other components of the project have not begun yet (such as the reintroduction of sand directly into the Camille Cut area) but monitoring, including sand tracer studies, will occur in those locations as well. The MsCIP monitoring and adaptive management plan (draft expected in September 2015) includes the use of monitoring results to guide future actions, such as changing the placement of sediment dredged from Pascagoula Pass and Horn Island Pass. In the long term, these areas will be monitored to understand whether the actions have been successful in accreting sand, recreating natural transport processes, and protecting cultural resources.

Project planning has taken more than seven years to complete. This case study is an example of the following adaptation strategies:

- Enhancing connectivity, migration corridors, and areas under protection external to the park
- Reducing non-climate stressors (e.g., sediment management)
- Coordinating planning and management across institutional boundaries
- Conducting/gathering additional research, data, or products
- Reintroducing and supporting natural processes (sediment transport and budget of the barrier island ecosystem)

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http://ngom.usgs.gov/gomsc/mscip/

http://www.sam.usace.army.mil/Missions/ProgramandProjectManagement/MsCIPProgram.aspx

Case Study 15:
Rehabilitating Stream Crossings on Historic Roads, *Acadia National Park, Maine*

Contributing Author: Rebecca Cole-Will (Acadia National Park)

Hurricane Irene produced storm surge at Thunder Hole viewing platform, a popular visitor facility. Image credit: Rebecca Cole-Will.

Headwall and culvert after rehabilitation at Sieur de Monts Spring site. Image credit: Rebecca Cole-Will.

Goals

Acadia National Park in Maine is working to rehabilitate historic road systems and culverts that have been damaged by increasingly frequent flooding and erosion events that were causing maintenance and visitor use closures.

Challenges and Needs

Acadia National Park contains three historic circulation systems listed in the National Register of Historic Places (200 km/120 mi of hiking trails, 90 km/56 mi of carriage roads, and 50 km/33 mi of paved motor roads, with associated bridges and drainage structures). The drainage features are undersized for current conditions, as average annual precipitation has increased by 11.9 cm (4.7 in) in the past 100 years.

Over the past 10 years, the park has experienced flooding and erosion events that appear to relate to storm events that are increasing in both number and severity. Erosion has damaged roads and trails and caused redeposition of gravel into adjacent wetlands, requiring increasingly frequent maintenance cycles and closure of popular visitor sites. Resource management staff also documented sedimentation into wetlands and impaired natural processes in stream systems restricting access for migratory fish and amphibians. Coastal storm surges have flooded and damaged historic sites and roads. With climate model scenarios generally anticipating increased frequency of intense rainfall events, we anticipate that these problems will worsen and substantially affect visitor access and use of the park. Information regarding probable future flood streamflows is needed to help the National Park Service (NPS) properly size new hydraulic structures to accommodate the expected increased flows under the projected range of climatic conditions.

Responsive Actions

The park began a multi-pronged effort of inventory, monitoring, mitigation, and rehabilitation along the historic road systems. Consulting engineers and hydrologists inventoried all culverts, headwalls, and bridges. Using hydro-geomorphic data, they re-engineered the structures to be suitable for projected stream hydrology changes while maintaining the character-defining features of the historic structures. Information used in planning includes climate change scenarios (US Geological Survey [USGS] climate data models for the northeast) and hydrologic modeling data (USGS). The rehabilitated crossings have the added benefit of restoring aquatic animal passages (primarily migratory fishes and amphibians), and restoring natural hydrological processes for impaired stream systems. Rehabilitated crossings are monitored for streamflow dynamics and erosion. Watersheds renovated for fish passage are monitored and inventoried by fisheries biologists.

To develop a better understanding of how climate change will impact future stream flood flows, the park has requested technical assistance for hydrological analyses. In order to address other anticipated climate impacts, the park has also submitted a number of NPS funding proposals that would allow the park to conduct climate change scenario planning, manage archeological sites, restore subalpine vegetation on Cadillac Mountain, replace stream culverts, model streamflow hydrology, and restore fish habitat in coastal streams.

This project is ongoing. This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Making infrastructure resistant or resilient to climate change

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Case Study 16:
Relocating Visitor Facilities Threatened by Erosion, *Assateague Island National Seashore, Maryland and Virginia*

Contributing Author: Ish Ennis (Assateague Island National Seashore)

The Virginia visitor parking lot is constructed with native materials including clay and clamshell that can be reused in post-storm repairs. Image credit: Ish Ennis, NPS.

Goals

Assateague Island National Seashore is responsible for maintaining and managing access to a recreational beach that is impacted by storms multiple times each year. Maintaining the recreational beach in its present location is unsustainable in the face of continued storms, shoreline erosion, and sea level rise. The park must develop cost-effective, sustainable ways to provide a recreational beach and beach access that are acceptable to local interests and visitors.

Challenges and Needs

The park manages a recreational beach within the US Fish and Wildlife Service's (USFWS) Chincoteague National Wildlife Refuge in Virginia. This beach is the primary economic driver for the local community of Chincoteague, Virginia, which caters to visitors with hotels, restaurants, and other amenities. The park committed to maintaining and managing the recreational beach through a 1967 agreement with the USFWS, which had an existing agreement with the citizen group Assateague Bridge and Beach Authority to have a recreational beach in exchange for construction of a bridge connecting the town with the refuge.

The recreational beach is in one of the island's most dynamic locations, and has experienced accelerated shoreline erosion, increased storm impacts, and frequent overwash since the 1980s. Annual repair and relocation of roads and visitor parking lots in this area continue to be high-maintenance, expensive, time-consuming, and stressful for staff who must rush to complete months-long repairs before each summer tourist season.

The park has implemented several solutions to improve sustainability. Infrastructure in this area has been replaced with portable substitutes that can be relocated off-island in advance of National Oceanic and Atmospheric Administration (NOAA)-forecasted storms and in response to erosion. The park now constructs roads and parking lots in this area from island-compatible materials, a clay base with clam shell for a road surface, which are dug up and reused when the lot is moved, and which also avoid introduction of foreign debris such as asphalt on post-storm beaches. The surface requires twice-weekly maintenance and additional clam shells need to be added every year or two. Parking lot repairs have been supported by Emergency Relief for Federally Owned Roads (ERFO) funding and existing park staff.

Although these efforts have improved the sustainability and lifespan of the recreational beach facilities, new solutions will need to be developed. Due to continued island narrowing in this location, the current parking lot is now at its inland limit because it is backed by a wetland, leaving no room for another move westward, based on US Army Corps of Engineers (USACE) wetland delineations.

The two solutions that have been discussed as part of the updates to the USFWS comprehensive conservation plan are alternative transportation (shuttle or bus) and relocation of recreational access to a more stable location. However, the Town of Chincoteague dislikes both strategies, believing they would discourage tourism. The town insists that the 1960s agreements require the government to maintain not only the beach but also visitor parking areas. Furthermore, shuttles are not financially self-supporting, and the town, the USFWS, and the park do not have the operational funds to support this expensive option.

Responsive Actions

In consideration of cost constraints and town interests, relocating the recreational beach is not only the most reasonable solution but also may be considered essential at this point. To determine suitable parking lot locations and configurations, the park has used shoreline monitoring data to forecast future shoreline erosion rates, and has worked with the USFWS to identify appropriate areas for relocation. The park and USFWS will also use forthcoming results of a US Geological Survey model indicating the impacts of sea level rise and storm intensity along the island.

Due to its ongoing success, the existing portable infrastructure would likely be used in the new location, along with the visitor center, which has been moved twice already. The clay base and clamshell surface might also be used in the new location. The biggest challenge in moving forward with relocation of the recreational beach will likely be opposition by the Town of Chincoteague. Education and outreach programs may help to strengthen the park's efforts.

The project is ongoing. This case study is an example of the following adaptation strategies

- Incorporating climate change into policies, plans, and regulations
- Coordinating planning and management across institutional boundaries
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Conducting adaptation training and planning meetings or workshops
- Making infrastructure resistant or resilient to climate change
- Managed retreat of built infrastructure

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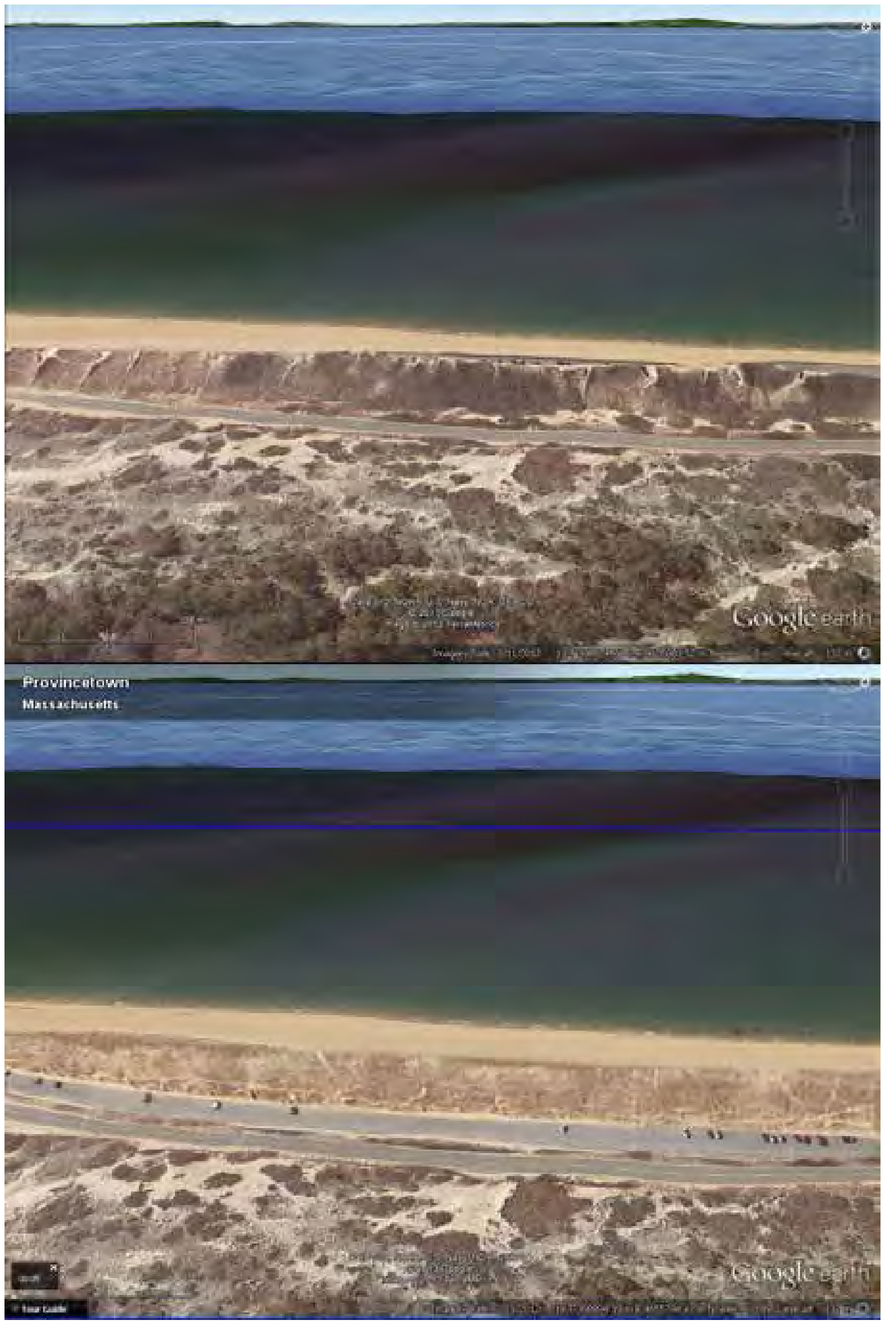
Case Study 17: Reducing Vulnerability of Coastal Visitor Facilities, *Cape Cod National Seashore, Massachusetts*

Contributing Authors: Mark Borrelli (Center for Coastal Studies)

Goals

Cape Cod National Seashore, Massachusetts, needs to replace visitor facilities along a popular beach vulnerable to coastal erosion and storm impacts. Redesigning this area required collaboration with visitors, town representatives, coastal engineers, and scientists to incorporate visitor use and needs with the realities of coastal change.



Top: Before the Herring Cove redesign, visitors parked between the beach and an artificial dune. Image credit: Google Earth. **Bottom:** Following the redesign, the parking lot will be adjacent to the road, and the artificial dune will be reshaped to mimic adjacent natural topography. Image credit: Mark Adams (NPS) conceptual visualization using photographs from Google Earth.

Challenges and Needs

Visitor facilities at the park's most popular life-guarded beach, Herring Cove, were built in the 1950s and included an asphalt parking lot atop the beach and a concrete block bathhouse and concession stand. An artificially high dune was maintained and expanded over several decades through the maintenance practice of pushing windblown sand from the parking lot's surface to its landward edge.

The north parking area at this beach is popular not only for beachgoers in the summer, but also for winter visitors who sit in their parked cars to enjoy the viewshed and the opportunity to see North Atlantic right whales (*Eubalaena glacialis*) in Cape Cod Bay, where 200 of the 450 known individuals in the world have been counted.

In December 2011, the Herring Cove visitor facilities were impacted by a storm that undermined both parking lots and damaged an asphalt revetment protecting the bathhouse and north parking lot. The park needed to design replacement facilities that would continue to serve visitor needs, avoid placement of permanent infrastructure in highly vulnerable areas, and consider shoreline change and coastal policy.

Responsive Actions

To address stakeholder interests and needs, multiple public meetings were held by a park advisory commission subcommittee to discuss various redesign options. The park recognized public interest in continuing the beach's historic use, which included being able to park cars in a location with an ocean view and direct beach access, and the resistance to taking a shuttle bus from a remote parking lot to the beach.

To ensure the engineering and geophysical integrity of the new design, the park enlisted the services of a coastal engineer and of scientists from the Center for Coastal Studies, a Cape Cod-based research and education organization that provided expertise on marine and coastal geology and biology.

The bathhouse was removed in July 2013 and replaced with moveable structures that have a 0.6 m (2 ft) freeboard above base flood elevation and that are placed approximately 30 m (100 ft) landward of the former bathhouse position. The complex incorporates multiple green design techniques, including being built on pilings that reduce its vulnerability to sea level rise and wave impact. It can be moved in the future to a less vulnerable location as necessary to keep pace with erosion and sea level rise. Funding for a move has been incorporated into project requests for future park budgets.

To mitigate impacts of the 1950s construction, the asphalt from the parking lots will also be replaced when Line Item funds become available. In the meantime, as of summer 2015, the park continues to use Massachusetts Wetlands Protection Act and US Army Corps of Engineers notifications to remove asphalt and repair the parking lot. The artificial dune, which prevented natural beach processes from occurring, will be reshaped to replicate the topography of natural adjacent beaches. This will have the added benefit of allowing visitors to view the ocean from the new parking lot location. The north parking lot will be rebuilt on higher-elevation land (0.3–0.6 m [1–2 ft] above the base 100-year floodplain) located 38 m (125 ft) landward of the prior location, a distance that accounts for ongoing and expected shoreline erosion over the next 50 years due to sea level rise, continental subsidence and major coastal flood events. These calculations were possible in part due to the long-term shoreline monitoring datasets and local expertise available for this coastline.

This case study is an example of the following adaptation strategies:

- Incorporating climate change into plans
- Reducing local climate or related change (e.g., incorporating low-energy fixtures, sustainably-harvested wood, and natural ventilation)
- Reducing non-climate stressors (e.g., installing low-flow faucets, eliminating on-site septic waste)
- Increasing/improving public awareness, education, and outreach efforts
- Conducting vulnerability assessments and studies
- Making infrastructure resistant or resilient to climate change
- Developing/implementing an adaptation plan

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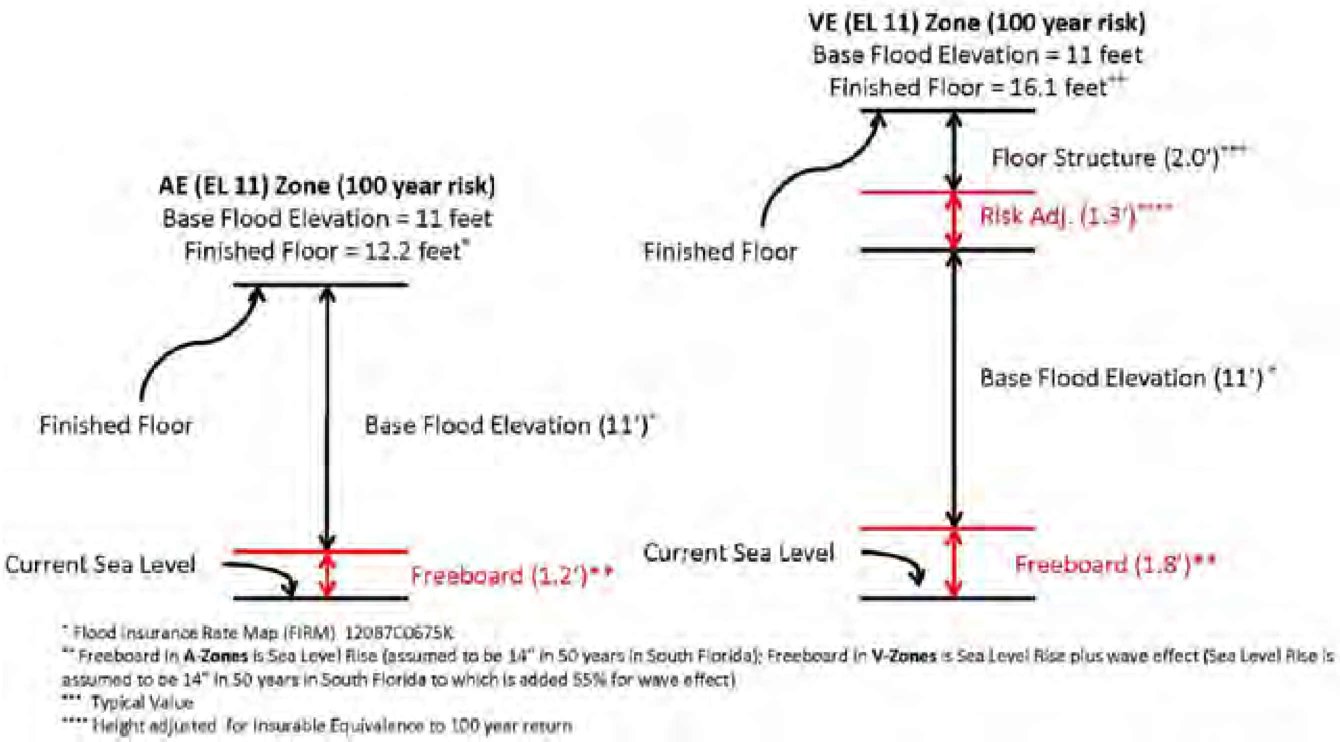
Case Study 18: Developing Sustainable Visitor Facilities, *Everglades National Park, Florida*

Contributing Author: Fred Herling (Everglades National Park)



Everglades National Park is redeveloping the Flamingo area, including proposals to mitigate risk by elevating structures. Heights include the incorporation of sea level and storm surge scenarios. Image credit: Everglades National Park.

Goals

Visitor facilities in the Flamingo area of Everglades National Park in Florida were destroyed by two hurricanes in 2005. Incorporating climate change sustainability into the redevelopment plan has required extensive data gathering efforts and public engagement.

Challenges and Needs

Until 2005 the Flamingo area of Everglades National Park was the park's primary destination and the only location offering overnight accommodations and providing direct access to the park's vast wilderness. Hurricanes Katrina and Wilma in 2005 caused severe impacts to Flamingo facilities including National Park Service (NPS) visitor facilities and concessions, including all lodging units. Due to the resulting damage, Flamingo has been relegated to a day-use/camping area. The NPS has been working with the public and key stakeholders to determine and implement a sustainable rebuilding effort. With overwhelming public support, plans were completed to define the new, sustainable Flamingo vision for the 21st century, including consideration of sea level and coastal storm threats. Then, in 2011, Director Jarvis expressed concerns about the project due to its cost and threats from climate change. Due to its coastal location on Florida Bay, a few feet above sea level, Flamingo is susceptible to storm surge, sea level rise, and hurricane-force winds. The Flamingo project needed to be revised with consideration of the location's vulnerability.

Responsive Actions

In 2011 the Flamingo project was revised to address these climate vulnerability concerns and to focus more on sustainable redevelopment strategies consistent with park goals and ensuring that the park's future concessions partner is provided a strong business opportunity. With the Director's support, the planning and decision making now underway is occurring as part of the concessions prospectus process and is incorporated into the park's long-term vision as described in the new general management plan, completed in 2015. The result will be a refined Flamingo vision that is sustainable for the next 50 years using the best available climate change data together with appropriate laws and policies for protecting Flamingo's unique resources and enhancing its visitor experiences.

This process has faced several setbacks in the concessions prospectus and contracting process that will result in substantial additional work effort and likely cause a one-and-a-half year delay in issuing a new concessions contract. A key contributor to this setback arose from policy guidance on concessions contract length. Though the standard 10-year contract length was shown to be feasible in the prospectus financial analysis, the analysis also demonstrated that having a longer contract period substantially improved the future concessioner's business opportunity. In a project like this, with a large capital investment requirement and/or risks associated with site conditions and vulnerabilities, NPS managers should encourage and facilitate opportunities that have the best chance of success while being consistent with applicable laws and policies. Having less-favorable terms likely led to not attracting any bidders. The prospectus is currently being modified with appropriate contract length and other modifications to be sent out for bids. Policies that allow local or regional flexibility, such as longer contract lengths where allowed by law due to site-specific conditions, would likely have improved the efficiency and timeliness of this project.

Sustainable improvements to park facilities have been funded by various sources: emergency hurricane repair funds, franchise and recreational fee programs, line-item construction, Federal Lands Highway, private sector support, and others. Key references and data sources for enhancing sustainability include Intergovernmental Panel on Climate Change (IPCC) reports, Federal Emergency Management Agency (FEMA) flood insurance data and maps, natural resource and vegetation data and maps, cultural resource assessments, visitor use data, past and projected visitor use and demand data for financial analysis purposes, asset condition assessments, sustainable architecture and designs for coastal areas, cost estimating and lifecycle cost assessments for facilities and assets, and NPS guidance and policy on how to evaluate and make decisions about development in vulnerable coastal areas.

Metrics to evaluate the success of project implementation will be related to natural and cultural resource protection, quality of visitor experiences, success of the NPS-concessioner partnership, and site viability in terms of future climate-change related events and knowledge. Short-term metrics will be associated with the successful approval of the project within the agency (achieved in November 2012) given the scrutiny it has received for a new development in a coastal high-hazard zone, and completion of a successful concessions contract process in 2015.

There are several lessons to be learned from this project. When high-profile projects require public engagement to succeed, the NPS needs to communicate and manage project timelines and expectations effectively. To improve project success, it is important to identify all parties in the project review and decision-making process and to ensure that they are kept aware of key activities, with frequent communication early on and throughout the project so there are no surprises at the end. Additional NPS products that would improve future projects include the following:

- Guidance on how to develop and manage projects with potential climate-change considerations, and how to locate relevant data sources
- Direction from Washington Support Office (WASO) Directorates on expectations for evaluating complex (and sometimes competing) information in a world of diminishing public resources (money and staff)
- Guidance for managing agency and public expectations regarding the level and pace of progress that can be expected
- Ecosystem-, landscape-, or threat-based models for addressing resource management, visitor experience and investment decisions that consider climate-change factors
- Bibliographies, references, and sources of information that can help get project teams thinking about and organizing project scope requirements comprehensively
- Project management tools that facilitate projects occurring efficiently and result in good decisions (e.g., sample work plans, interdisciplinary teams, project/task agreements, and schedules that take into account all key steps)
- Development of national policies and guidance documents that recognize the need for, and incorporate, local or regional flexibility to consider site- or project-specific conditions (e.g., fulfilling Americans with Disabilities Act (ADA) requirements; using optimal, not necessarily minimum contract length)

This project is expected to take 5–10 years to complete. This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Monitoring climate change impacts and adaptation efficacy
- Increasing/improving public awareness, education, and outreach efforts
- Making infrastructure resistant or resilient to climate change
- Creating new or enhance existing policy

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http://www.nps.gov/ever/naturescience/sfnrcpublications.htm (Fact Sheets, Technical Reports)

Case Study 19: Establishing Alternative Transportation to Fort Pickens to Supplement Vulnerable Road Access, *Gulf Islands National Seashore, Florida*

Contributing Author: Dan Brown (Gulf Islands National Seashore)

Storms regularly damage the Fort Pickens Road, resulting in extended road closures and high repair costs. Image credit: Federal Highway Administration.

Goals

In Florida, the Fort Pickens Road within Gulf Islands National Seashore is regularly destroyed by storms, and repairs are expensive and time consuming. The park continues to reevaluate the local conditions and implement cost-effective, sustainable modes of visitor access to Fort Pickens beaches and the historic fort.

Challenges and Needs

The Fort Pickens Road extends for 11 km (7 mi) along a very narrow, low-lying portion of the park on Santa Rosa Island, a Florida barrier island. It dead-ends at the historic Fort Pickens, and provides access to popular beaches and other park facilities that receive more than 700,000 annual visitors.

The local community has strong emotional ties to Fort Pickens, and considers vehicular access a mainstay for the local tourism economy. However, the road is regularly damaged by storm events; major hurricanes have destroyed the road three times since 1995, and the 2004–2005 storm season caused the road to be closed until 2009. Road maintenance and repairs are increasingly unsustainable and costly, and sea level rise and increased storm frequency and intensity increase the urgency of developing a sustainable alternative.

When storms cause significant road damage, the ensuing debate over whether or not to rebuild the road is highly political, and road design (e.g., whether to invest in a hardened structure designed to withstand storms) is controversial. After each event over the past two decades, the Federal Highway Administration has rebuilt this repeatedly damaged road, each time requiring development of road design scenarios and National Environmental Policy Act compliance. In the future, a decision not to rebuild likely would be tied to a lack of available funding for repeated road-building activity; to concerns about the cost and environmental impact of asphalt and road base removal from the beach environment; and to geomorphological changes, such as island narrowing or breaching, that reduce the land base available for construction.

Responsive Actions

The park's new general management plan, finalized in July 2014, establishes that Fort Pickens Road will be rebuilt only if feasible, as determined on a case-by-case basis. In late 2015, following an environmental assessment that was also finalized in July 2014, 4.5 km (2.8 mi) of the road will be repaved, and an additional 2.5 km (1.55 mi) of the road will be realigned and moved to a higher-elevation inland route, out of sea turtle nesting habitat to an area where it is less likely to be impacted by routine overwash. This 2.5-km (1.55-mi) section is within 15 m (50 ft) of the Gulf and is buried by sand and water during routine weather events between 6 and 12 times each year. The project is expected to cost $1,275,000 for the asphalt overlay and $2,425,000 for the realignment, and will be paid by the Federal Highways Administration. A proposed but currently unfunded addition of an entrance lane would cost an additional $1,000,000.

The park is working with local government (the City of Pensacola and Escambia County) to establish an alternative transportation system. The park's alternative transportation study was released in February 2009, and the final Pensacola Bay Ferry service feasibility study was completed in July 2014 and is awaiting Director Approval. The proposed passenger ferry service would connect Fort Pickens with Pensacola Beach and downtown Pensacola, providing an alternative means of accessing the park and maintaining island access when the road is rendered impassable by storm events or other unfavorable conditions. Ultimately, the ferry service could provide the only public access to Fort Pickens if the road is destroyed and not rebuilt. Two ferries will be purchased using $4,020,000 in Deepwater Horizon Oil Spill Phase III early restoration Natural Resource Damage Assessment funding.

In September 2014, the park began the environmental assessment process for the development of visitor facilities and shuttle service to support passenger ferry activities. The park is proposing to repurpose historic buildings and existing structures and pavement for ferry support services and to implement a landside shuttle service to the beaches, campground, and historic sites. Federal Highways Administration would pay $1.6 million for the visitor facilities and $513,000 for the five 27-passenger solar/electric trams, upgrades to Battery Langdon, which would house the shuttles when not in use, and a recharging station that would also be powered by a solar array with an inverter tied to the grid so that the park would earn financial credit when it is generating more power than it is using.

This case study is an example of the following adaptation strategies:

- Coordinating planning and management across institutional boundaries
- Increasing/improving public awareness, education, and outreach efforts
- Making infrastructure resistant or resilient to climate change
- Managed retreat of built infrastructure
- Developing/implementing an adaptation plan

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Case Study 20:
The Need for Storm Recovery Plans,
Cape Lookout National Seashore, North Carolina

Contributing Author: Patrick Kenney (Cape Lookout National Seashore)

Overwash during Hurricane Irene impacted infrastructure on Long Point. Image credit: Rebecca Beavers, NPS.

Goals

Cape Lookout National Seashore is regularly impacted by hurricanes and other storms. To improve park management, the park needed to develop a post-storm recovery plan to ensure wise fiscal decisions and management of public expectations for what facilities and services can be restored following these major events.

Challenges and Needs

In August 2011 Cape Lookout National Seashore was impacted by Hurricane Irene. The Long Point area of the park is a major hub of visitor and park operations on North Core Banks, one of three major islands in the park. Long Point serves as the primary access point for visitors arriving on the passenger/vehicle ferry to North Core Banks and for park operation vessels. Facilities at this site include 10 rustic rental cabins (20 rental units) for visitors, and additional buildings used for park operations including resource management, research, and law enforcement.

When Hurricane Irene made landfall at Cape Lookout National Seashore, storm waves and overwash flattened large dunes and damaged park facilities, particularly the harbor and infrastructure (e.g., septic tanks) at Long Point.

The current park planning documents provide no guidance on how post-storm recovery should be handled beyond an Incident Response and Recovery Framework. The National Park Service (NPS) response to prior storms has been to rebuild in-kind. In the hectic weeks following Hurricane Irene, as the park worked to restore the park in time for the peak visitor season, the park decided to dredge the shoaled-in harbor and to rebuild the visitor and operational facilities at Long Point.

This event has underscored the need for storm recovery planning and the associated public dialogue to manage expectations about the resource impacts, costs, and recovery time for park facilities. It is critical that this planning and dialogue occur well ahead of storm events to avoid decisions being made in the “reaction-mode” that occurs after storm events. Furthermore, the plans will allow for careful consideration of the fiscal impacts of rebuilding facilities in high risk areas. Increased storm intensity and frequency related to climate change are expected to heighten the urgency of these issues.

Responsive Actions

The park has identified several specific goals for the near future:

- Public dialogue on the future of these types of facilities and access to the park
- Further NPS guidance and policies related to storm damage and rebuilding in high-risk areas
- Development of post-storm recovery plans in order to avoid reactionary decision making
- Managing the public's high expectations for the park to rebuild facilities

This case study is an example of the following adaptation strategies:

- Making infrastructure resistant or resilient to climate change
- Managed retreat of built infrastructure
- Developing/implementing an adaptation plan

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Case Study 21: Incorporating Climate Change into Florida's State Wildlife Action Plan

Contributing Author: Doug Parsons (NPS Climate Change Response Program)

Dry Tortugas National Park protects submerged resources in south Florida. Image credit: NPS.

Goals

Although Florida habitats and species face significant threats related to sea level rise, Florida's first state wildlife action plan did not comprehensively consider climate change impacts. The Florida Fish and Wildlife Conservation Commission (FWC) worked with partners to assess species vulnerability using new models and approaches during the first revision of the state wildlife action plan.

Challenges and Needs

Florida has almost 1,930 km (1,200 mi) of coast, almost 3,700 km (2,300 mi) of tidal coastline, and a growing coastal population. Sea level rise and other climate change impacts, including increased temperatures and ocean acidification, threaten fish, wildlife, and natural ecosystems in Florida. Sea level rise will cause land loss, physical changes to coastal systems such as beaches and estuaries, and associated changes to habitat function and ecosystem services including degraded water quality and saltwater inundation of freshwater reserves.

Among other topics, Florida's first state wildlife action plan did not sufficiently address the impacts of climate change on wildlife, and needed to be updated. Vulnerability of individual species to sea level rise was unknown.

Responsive Actions

To update the action plan, FWC staff worked with Defenders of Wildlife and the Massachusetts Institute of Technology to explore two complementary approaches to assess species vulnerability. The first approach was a vulnerability index that generates relative vulnerability ranks across species and helps elucidate underlying factors contributing to vulnerability. The Climate Change Vulnerability Index, which was developed by NatureServ, was used to determine relative vulnerability of 25 species to climate change. Information for this approach was gathered from climate models and data available through The Nature Conservancy's Climate Wizard and input from species experts. In the second approach, spatially explicit vulnerability analyses were used to simulate a range of likely responses to sea level rise, public policy options, and financial conditions. These approaches differed in the degree to which they incorporated both human and species-level responses, as well as in the type and scale of the outputs that were produced.

Outputs from both approaches were brought into a workshop-based process involving managers and biologists and used to identify potential adaptation strategies for focal species. The FWC intends to build on the groundwork laid by this pilot study by exploring ways to apply vulnerability assessments more broadly and to determine how these results could be used to inform agency decisions such as species management, land acquisition, policy, and research and monitoring efforts.

The project took 1–3 years to complete. This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Coordinating planning and management across institutional boundaries
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Conducting adaptation training and planning meetings or workshops
- Creating/enhancing technological resources

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http://myfwc.com/

http://myfwc.com/media/2235922/ActionPlan.pdf

http://www.defenders.org/publications/integrating_climate_change_vulnerability_into_adaption_planning.pdf

http://myfwc.com/media/1770248/ConsideringClimateChange-WildlifeActionPlan.pdf

Case Study 22:
Developing a Multiagency Vision for an Urban Coastline, *Golden Gate National Recreation Area, California*

Contributing Author: Jodi Eshleman (NPS Geologic Resources Division) and Kristen Ward (Golden Gate National Recreation Area)

Left: The south end of Ocean Beach is eroding. Image credit: Steve Ortega, NPS. **Right:** Erosion below the Great Highway along Ocean Beach is believed to be exacerbated by development around San Francisco Bay. Image credit: NPS with photo from Google Earth 2013.

Goals

Golden Gate National Recreation Area is collaborating with local, state, and federal agencies to develop a long-term management strategy for Ocean Beach, where bluff erosion threatens natural and recreational resources, wastewater infrastructure, and a roadway (the Great Highway). Sea level rise and increased storminess are expected to increase the frequency of erosional events.

Challenges and Needs

Ocean Beach, located within the park, includes 5.6 km (3.5 mi) of beach that borders a significant portion of infrastructure along the western shoreline of San Francisco. Beach width varies, and the backbeach includes seawalls, constructed dunes, and parking areas. Ocean Beach is the park's most important resource for wintering and migrating shorebirds and supports two threatened bird species. It is also a popular destination for recreational activities including birdwatching, surfing, and dog-walking. The beach is located adjacent to a major tidal inlet and in the shadow of the ebb tidal delta at the mouth of San Francisco Bay.

Over the last century, a significant volume of sediment has been removed from San Francisco Bay through dredging and mining, which has reduced sand supply to the ebb-tidal delta and open coast beaches and has changed wave energy distribution along Ocean Beach. These factors have contributed to a persistent beach erosion hotspot along the southern reach of Ocean Beach that continues to threaten the Great Highway and city wastewater infrastructure that is located beneath the roadway. Episodic El Niño events over the last 20 years have caused significant bluff erosion, and various bluff protection efforts (i.e., rock revetment, sand bags, sand placement) have been emplaced in an attempt to protect city infrastructure. Extensive rock revetments placed in 1998 and 2010 have negatively impacted aesthetics, habitat value, and coastal processes. The National Park Service (NPS) and regulatory agencies urged the city to discontinue this practice and use "softer" engineering techniques, as it did in 2012, when approximately 58,100 cubic m (76,000 cubic yd) of sand was backpassed from the north end of Ocean Beach to the erosion hotspot at the south end.

Multiple federal, state, and local agencies share jurisdiction of Ocean Beach, but, until recently, lacked a shared management strategy. Because of the complex jurisdictional management, landowners and stakeholders sought assistance from the San Francisco Planning and Urban Research (SPUR) nonprofit organization to facilitate a planning process to develop a comprehensive management plan.

Responsive Actions

The resulting Ocean Beach Master Plan provides a management framework that incorporates recommendations for coastal adaptation including managed retreat, infrastructure relocation, beach nourishment, and dune restoration.

Although the Ocean Beach Master Plan is not a compliance document, the consensus-based plan will help to guide short- and long-term management actions (e.g., storm impact response) so that long-term feasibility and resource impacts are considered in a way that is compatible with the common vision developed for Ocean Beach. To be implemented, the proposals in the Ocean Beach Master Plan will be subject to environmental review including additional technical analysis, consideration of project alternatives, and public outreach. The timing of the plan's adaptive approach will be driven by how, and how quickly, erosion occurs.

Some of the recommendations in the Ocean Beach Master Plan are expected to be implemented in the near term whereas other actions may not be implemented for several decades. For example, a vulnerable section of the Great Highway will be narrowed and eventually closed over the next decade, with new coastal access parking and a trail to improve user access. The timing of beach nourishment alternatives described in the plan will vary depending on the scope and availability of funding. Although sand backpassing may continue to be implemented as a tested method with a clear compliance pathway, additional data are required to understand the feasibility of other beach nourishment alternatives described in the plan. Those alternatives will require a large volume of sand to develop dunes and a beach in areas that are currently subject to extreme erosion. The plan is based on the assumption that the US Army Corps of Engineers (USACE) will pump large volumes of sand onto the beach as a beneficial reuse of sediment dredged from the San Francisco Bay navigation channel. The expected persistence of material placed in this location is currently unknown; additional research, conceptual design, and regulatory compliance will be required to understand the feasibility and cost of implementing the plan. Project funding will likely require a phased approach, which has yet to be described.

Several data collection efforts will support development of the plan alternatives, and continued monitoring will be an important component of any alternative that is implemented through the plan. With funding from the NPS, San Francisco Public Utilities Commission, and California Coastal Conservancy, SPUR technical studies for design development are currently underway. The studies focus on understanding coastal dynamics as they relate to current and future protection of city utility infrastructure; transportation planning for rerouting the Great Highway to an inland location; and visitor amenities. The US Geological Survey (USGS) Coastal and Marine Geology Program monitors nearshore bathymetry and beach morphology, and has completed extensive bathymetric and sediment mapping offshore and inside San Francisco Bay. The USGS has also monitored dredge disposal sites to examine sediment transport patterns, and has developed numerical models to understand historic beach change and erosion mechanisms, and to predict future geomorphological changes. The USACE has funded significant portions of this research and also collects monitoring data related to dredging efforts. The park monitors two threatened bird species along Ocean Beach including the state-threatened bank swallow. The colony at Ocean Beach is one of only two known coastal bank swallow colony sites in California. The park has requested that monitoring of bluff conditions and protection of bank swallow habitat be considered in permits issued for short-term stabilization projects.

Improvements over the next three years will include removal of asphalt from the parking lots and roadway near the eroding bluff edge and the narrowing of the Great Highway as an initial step toward its future closure. Measures which may be used in the short term to address storm impacts may include additional sand backpassing, sandbag placement, and consolidation of existing rubble on the beach to stabilize the toe of the bluffs. Most recently, in October 2014, the 2012 renourishment strategy was repeated; approximately 22,900 cubic m (30,000 cubic yd) of sediment was backpassed from the accreting north end of Ocean Beach to the erosion hotspot at the south end of Ocean Beach. As the longer-term strategy of managed retreat is implemented, the artificial rock, rubble, and sandbags will be removed, allowing for the enhancement of beach and dune habitat.

The project is ongoing. This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Reducing non-climate stressors (e.g., sediment management)
- Coordinating planning and management across institutional boundaries
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Making infrastructure resistant or resilient to climate change
- Managed retreat of built infrastructure

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Case Study 23: Incorporating Climate Change Response into a General Management Plan, *Assateague Island National Seashore, Maryland and Virginia*

Contributing Author: Trish Kicklighter (Assateague Island National Seashore)

The low elevation of Assateague Island National Seashore increases park vulnerability to climate change impacts. Image credit: Jane Thomas, Integration and Application Network, University of Maryland Center for Environmental Science.

Goals

Assateague Island National Seashore is developing a general management plan that addresses projected climate change impacts on resources and infrastructure. The plan must include a range of management tools for improving resource resiliency and repairing facilities that will be impacted by climate change and storms.

Challenges and Needs

The park's current plan, which was signed in 1982, did not consider the impacts of a changing climate on the island's dynamic geomorphology. Park partners include local governments, area residents, and two other agencies (US Fish and Wildlife Service [USFWS] and Maryland State Park) that manage portions of the island. USFWS does not have strong policy statements concerning beach nourishment and shoreline armoring, increasing the difficulty of countering local interests in beach nourishment. Local government and residents in Chincoteague, Virginia, prefer current management practices to new policies that consider climate change, which is viewed skeptically despite the high vulnerability of this area to impacts from increased storm intensity. The state park system has not included climate change in its planning efforts, and current practices are impeding barrier island migration processes.

The park would benefit from a comprehensive plan directing its response to the expected landscape-level changes and the associated impacts to visitor services and resources. Outstanding questions include the following:

- How can the park improve sustainability of facilities?
- Should facilities be relocated or replaced as the island migrates westward and following storm damage?
- How should the park respond to a loss of vehicular access to the island?

- How should the park respond to an island breach?
- What is the best way to balance wilderness with off-road vehicle use?
- In what ways can the park cooperate with partner land management agencies?

Responsive Actions

The park has improved its understanding of climate change and park impacts through several efforts. By participating in the National Park Service Climate Change Scenario Planning process, the park was able to explore a range of possible future scenarios under different combinations of social and natural forces and to better identify the major drivers of change and the major issues that were common to all scenarios. The park also scaled the Intergovernmental Panel on Climate Change's sea level rise projections to a 30-year time span in order to identify an assumed local rate of sea level rise that is relevant both to the scope of the general management plan and to park neighbors and audiences.

Ongoing GPS and LiDAR monitoring of the island's shoreline and topography has allowed trend analysis of coastal change. Several new research and modeling projects will provide additional information over the next several years. The park is working with the US Geological Survey to develop a model for the projected impacts of sea level rise and increased storm intensity on the island's shoreline, and the predicted availability and distribution of shorebird nesting habitat under various sea level rise scenarios. The park and the US Geological Survey are also partnering to monitor salt marsh height, hydrology, and salt water intrusion on the shallow freshwater system.

The actions and alternatives described in the general management plan all consider and integrate the likely impacts of climate change identified through these scenario planning and research efforts. A consistent climate change message provides the base of a new educational outreach effort that targets park neighbors, an effort that also intends to garner support for the direction of the general management plan. The park has also communicated regularly with the adjacent Chincoteague National Wildlife Refuge, which has been developing its comprehensive conservation plan, the USFWS equivalent long-term planning effort with a similar public process. The results of the scenario planning, and the park's climate change message, have been shared with all employees. Meetings with land management partners have included presentations of the park's findings and concerns. The park has also held public meetings to discuss climate change and the projected impacts. The draft plan is expected to be released in fall 2015.

This project is ongoing. This case study is an example of the following adaptation strategies:

- Incorporating climate change into policies, plans, and regulations
- Coordinating planning and management across institutional boundaries
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Conducting adaptation training and planning meetings or workshops
- Making infrastructure resistant or resilient to climate change
- Managed retreat of built infrastructure
- Developing/implementing an adaptation plan
- Creating new or enhancing existing policy

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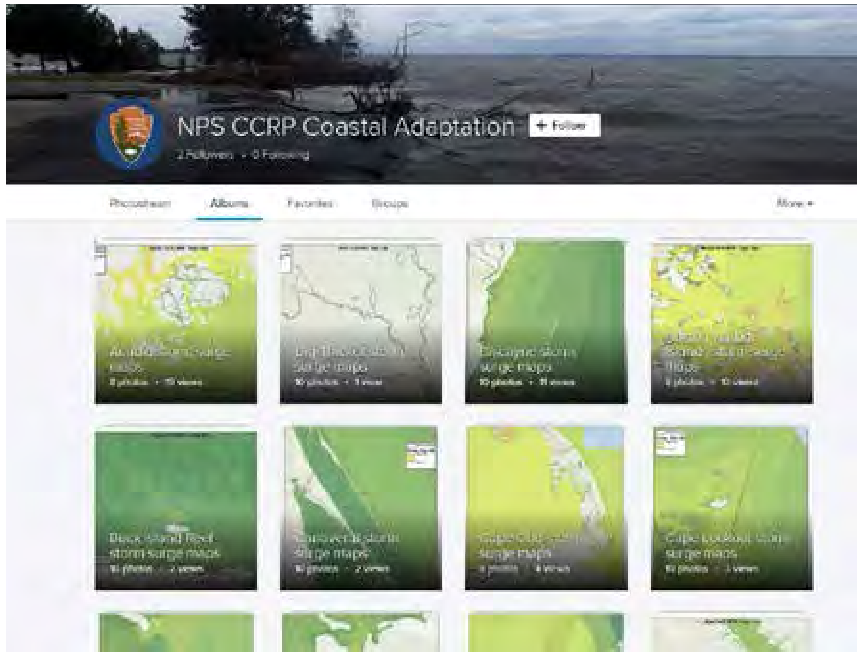
Case Study 24:
Storm Surge and Sea Level Change Data Support Planning, *NPS Geologic Resources Division, Colorado*

Contributing Authors: Rebecca Beavers (NPS Geologic Resources Division) and Maria Caffrey (University of Colorado Boulder)

Goals

The National Park Service Geologic Resources Division (NPS GRD) is working with the University of Colorado Boulder to develop sea level change and storm surge data that parks can use for planning purposes over multiple time horizons.



Storm surge maps completed for the parks (available at https://www.flickr.com/photos/125040673@N03/sets/). Image credit: NPS.

Challenges and Needs

Coastal parks frequently ask the division how individual parks will be impacted by sea level change. Parks need this information to prepare foundation documents and to calculate storm surge projections. Many park managers would prefer data for shorter time horizons (e.g., 2030, 2050) than is widely available in the academic literature. Although several National Oceanic and Atmospheric Administration (NOAA) models can simulate storm surge, most parks do not have tide gauges or other historical records of sea level to input into the models. The NPS GRD is using the latest Intergovernmental Panel on Climate Change (IPCC) data to “fill in the gaps” between tide gauges to give parks the latest sea level change data tailored specifically for their park.

Responsive Actions

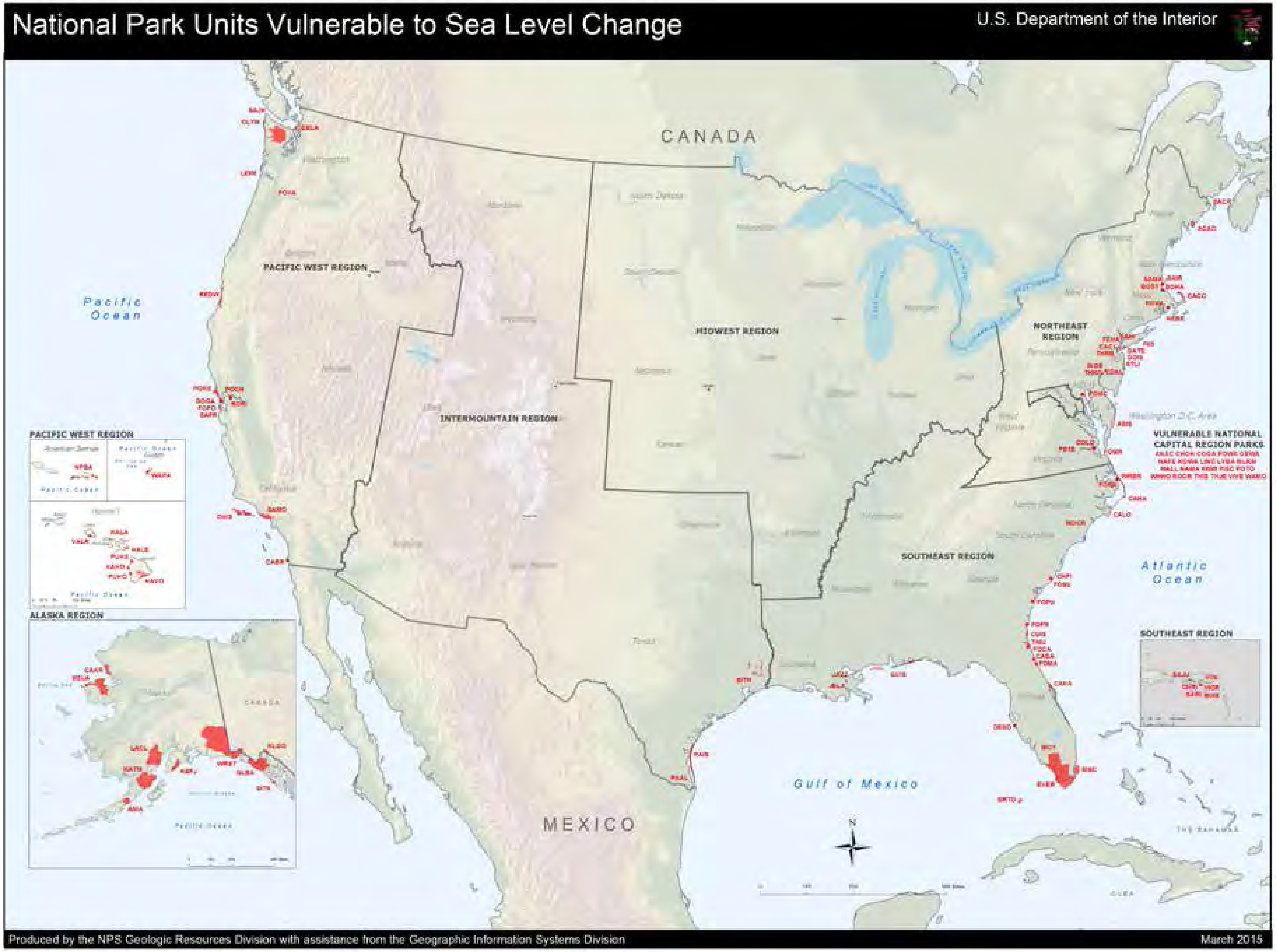
The NPS GRD is collecting the most recent data on sea level change and storms, primarily from the academic literature, in addition to projection data generated in-house and provided by other researchers. These data are used to assist with state of the parks reports, general management plans, and foundation documents at parks including, most recently, Santa Monica Mountains National Recreation Area, Cumberland Island National Seashore, Cape Lookout National Seashore, Timucuan Ecological and Historic Preserve, and San Juan National Historic Site.

The division uses IPCC and US Army Corps of Engineers data to generate new data that can be projected on multiple time horizons to help the parks. A three-year project began in fiscal year 2013 to analyze rates of sea level change coupled with potential storm surge in 118 of the coastal parks in order to project, for each park, the combined elevations of storm surge and sea level by 2030, 2050, and 2100.

NOAA Sea, Lake and Overland Surges from Hurricanes (SLOSH) model data have already been incorporated into 34 foundation documents, 9 state of the parks reports, and various assistance requests (e.g., Gulf Islands National Seashore, Acadia National Park, Assateague Island National Seashore, Boston Harbor Islands National Recreation Area, Colonial National Historical Park, Gateway National Recreation Area, Fire Island National Seashore, and Statue of Liberty National Monument). Individual sea level change and storm surge projections for each park will be released in a full report during the NPS Centennial Celebration in fiscal year 2016. Interim products that have been supplied to the parks as part of foundation documents or state of the parks reports can be found at https://irma.nps.gov. Sea level change and storm surge data will be featured in the park atlas and as a separate interactive website. In the meantime, storm surge maps are already available at https://www.flickr.com/photos/125040673@N03/sets/.

Three parks will also be selected for funding to install waysides highlighting the issue of sea level change. Gulf Islands National Seashore has been selected as the first park to receive funding, which they have used to install two waysides explaining the challenges of rising sea levels along the Gulf of Mexico coast.

A wayside explaining sea level rise. This wayside is one of two that were installed at Gulf Islands National Seashore in 2015. Image credit: NPS.



Parks included in the NPS sea level change study. Image credit: NPS.

This project is ongoing and will take three years to complete. This case study is an example of the following adaptation strategies:

- Monitoring climate change impacts and adaptation efficacy
- Coordinating planning and management across institutional boundaries
- Increasing/improving public awareness, education, and outreach efforts
- Conducting/gathering additional research, data, or products
- Conducting vulnerability assessments and studies
- Communicating climate change or adaptation actions to the parks

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On the Back Cover

Left: Peale Island Cabin, Yellowstone National Park. **Center**: Fort Jefferson, Dry Tortugas National Park. **Right**: Coral, National Park of American Samoa. Photographs courtesy of the National Park Service.

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