



Climate Change Hazards Summary Report for Facility Investment Planning

Cape Hatteras National Seashore January 2021

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Executive Summary

At CAHA, temperature can be used to predict visitation patterns with 98% accuracy, with peak visitation occurring in the summer (Fisichelli et al. 2015), coincident with peak visitation. For this past century, in the three most recent decades, both the temperature during the hottest part of the year and the annual average temperature are getting hotter (Monahan and Fisichelli 2014). By the end of the century, low greenhouse gas scenarios (RCP 2.6) project an annual mean temperature increase of 1.2° C, and scenarios of higher atmospheric concentrations of greenhouse gas (RCP 8.5) project an increase in annual mean temperature of 3.7° C (Gonzalez et al. 2018).

At this time, recent decades are not significantly different from the precipitation the park has experienced over the course of the previous century (Monahan and Fisichelli 2014); however, projections are that with a changing climate, annual average precipitation will increase by 5% (RCP2.6) to 6% (RCP 8.5) by the end of the century (Gonzalez et al. 2018).

The changing heat and precipitation could favor damaging pests and invasive species. It is unclear if the increased heat will lead to drying since precipitation is also increasing, however the park does have a fire management plan which can be found at: <http://obpa-nc.org/DOI-AdminRecord/0052773-0052924.pdf>

Between 1900 and 2000, sea level increased by about 0.3 m at Oregon Inlet (N.C. Coastal Resources Commission Science Panel 2016). CAHA is projected to experience .15 m more sea level rise by 2030 (RCP 2.6), and up to 0.79 m (RCP 8.5) by 2100, resulting in large areas of inundation (Caffrey et al. 2018). Sea level rise will enhance storm surge. Today, even a category 1 hurricane at high tide or a northeaster storm often leads to flooding from storm surge. A category 5 hurricane making landfall at high tide is a worst-case scenario, but still a possibility at CAHA.

A variety of steps can be taken to adapt to these hazards, such as shoreline stabilization, beach nourishment, the placement of natural and nature-based features for shoreline protection, redesign (including elevating structures) and relocation of facilities, use of portable structures, and use of new, sustainable, green infrastructure where appropriate. Historic structures have resilient design features, and often, if buildings are well maintained, they may have a better chance of surviving a major storm. Ultimately, storms are expected to happen; all damages cannot be anticipated or mitigated in advance; and so post-storm recovery is a critical opportunity to learn and adapt.

Introduction

Parks are required to complete a PARK Project Narrative Template for each proposed Great American Outdoors Act Facility Investment Plan (GFIP) project for Legacy Restoration Funding in fiscal years 2023-2025. Information provided in this report is intended to help parks consider climate change related hazards when addressing Question 16 of the narrative template.

Specifically: What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?

Summary information for known or potential hazards

Hotter average days and more very hot days

Extreme temperatures can increase weathering of structures, threaten park staff and visitor safety, and increase stresses for HVAC systems. If not addressed through building design or more efficient temperature control systems, the increased demand for complex air conditioning systems can add stress to building envelopes and can require significant alterations to a structure.

It is possible that heat, combined with humidity, can make the park inhospitable to individuals seeking outdoor experiences, and more climate controlled indoor environments may be needed to provide an escape from the elements for park staff and visitors. At CAHA, temperature can be used to predict visitation patterns with 98% accuracy, with peak heat coincident with peak visitation in the summer (Fischelli et al. 2015). For this past century, in the three most recent decades, both the temperature during the hottest part of the year, and the annual average temperature are getting hotter (Monahan and Fischelli 2014). By the end of the century, low greenhouse gas scenarios (RCP 2.6) project an annual mean temperature increase of 1.2° C, and scenarios of higher atmospheric concentrations of greenhouse gas (RCP 8.5) project an increase in annual mean temperature of 3.7° C (Gonzalez et al. 2018).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Altered precipitation patterns, increased extreme precipitation, and changing humidity

Changing precipitation and humidity conditions can result in local flooding, encourage mold growth, cause wood decay, increase fire risk, and intensify drought conditions. Extreme precipitation events present a variety of threats to infrastructure and operations including flooding of sites, sewage backup, accelerated decay of masonry, overcoming drainage systems, road wash out, cracks in building infrastructure, destabilization of buildings and pipes, and erosion of supporting ground around structures, among many other effects. At this time, recent decades are not significantly different from the precipitation the park has experienced over the course of the previous century (Monahan and Fischelli 2014); however, projections are that with a changing climate, annual average precipitation will increase by 5% (RCP2.6) to 6% (RCP 8.5) by the end of the century (Gonzalez et al. 2018). If sandy soils experience repeated wet/dry cycles, structures could settle, especially when the ground is saturated with higher water tables and repeated flooding.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Increased wildfire frequency, intensity, magnitude, and duration

Wildfire is a natural part of many forest, woodland, and grassland ecosystems. Excessive fire, however, can damage ecosystems, kill people, and damage infrastructure. Climate change is intensifying the heat that drives wildfire (Jolly et al. 2015) and altering the distribution and density of vegetation that comprises the fuel for wildfires (Gonzalez et al. 2010). These effects combine with the unnatural buildup of coarse woody debris and understory trees from decades of suppression of all fires, even natural ones (Agee and Skinner 2005). The effects of climate change on wildfire vary across landscapes. For areas where projected climate change increases fire risk, buildings, cultural landscapes, or other infrastructure located under or near tree canopies or dense grasslands are vulnerable to burning and destruction. It is unclear if the increased heat will lead to drying since precipitation is also increasing, however the park does have a fire management plan which can be found at: <http://obpa-nc.org/DOI-AdminRecord/0052773-0052924.pdf>

Park staff assessment – relevant to GFIP Project:

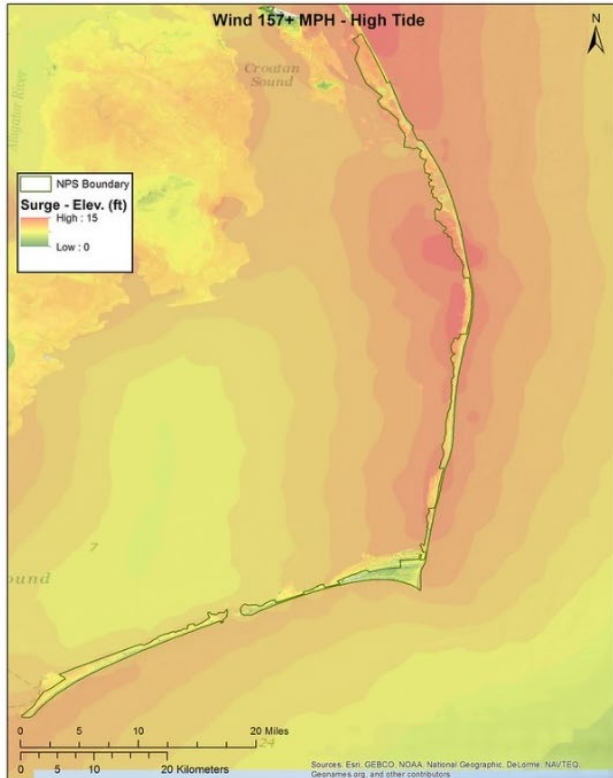
☐ Yes

☐ No

Sea level rise and coastal storm surge

Global sea level is rising and will continue to increase (Tebaldi et al. 2012), with local variability. Higher relative sea level causes accelerated coastal erosion, landward migration of shorelines, and saltwater intrusion and changes in groundwater, and amplifies flooding caused by higher storm surges (Field et al. 2007). Sea level rise poses considerable risks to infrastructure, lighthouses, forts, and other historic structures. Between 1900 and 2000, sea level increased by about 0.3 m at Oregon Inlet (N.C. Coastal Resources Commission Science Panel 2016). CAHA is projected to experience 0.15 m more sea level rise by 2030 (RCP 2.6), and up to 0.79 m (RCP 8.5) by 2100, resulting in large areas of inundation (Caffrey et al. 2018).

Sea level rise will enhance storm surge. Today, even a category 1 hurricane at high tide or a northeaster storm often leads to flooding from storm surge. A category 5 hurricane making landfall at high tide is a worst-case scenario, but still a possibility at CAHA. As sea level rises, storm surge will flood areas that previously remained dry in major storms. The maps below show places that will be flooded under category 1 and 5 hurricanes at high tide ([Sea Level Change - Climate Change \(U.S. National Park Service\) \(nps.gov\)](#)). The NPS also has a [Sea Level Rise Viewer](#) to visualize places expected to become inundated simply due to gradual sea level rise, and an online [Climate Vulnerabilities Map](#) for exploring the vulnerability of existing structures and infrastructure which ranges from minimal to high within the park. The challenge of maintaining access along Cape Hatteras National Seashore via NC Highway 12 will only become more problematic with increasing sea level and impacts of storm surge with each event.



Park staff assessment – relevant to GFIP Project:

- ☐ Yes
☐ No

Hurricanes and tornadoes

Under a changing climate, hurricanes are projected to increase in intensity and precipitation in a warmer world (USGCRP 2017). Northeast storms are also major storm events for the Outer Banks and can cause significant beach erosion and overwash. Climate change can also increase the frequency of severe thunderstorms, which generate tornadoes, analyses of historical records from 1954 to 2017 show increases in the southeastern U.S. (Agee et al. 2016, Brooks et al. 2014, Gensini and Brooks 2018). Moreover, tornado power, a function of wind speed, tornado path area, and air density, has increased $5\% \pm 1\%$ per year from 1994 to 2016 (Elsner et al. 2019).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
☐ No

Pest infestation

Increased temperatures and CO₂, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of pests (IPCC 2014). Rooting and burrowing mammals and termites have the potential to cause direct damage to power, water,

transportation, and building facilities (Vissichelli 2018). Facilities may be impacted indirectly through other mechanisms exacerbated by climate change such as forest insect pest invasions or fluctuating ground water levels leading to increased tree mortality, hazard trees, and treefall.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Invasive species

Increased temperatures and CO₂, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of invasive species (IPCC 2014). Weeds and aquatic mussels have the potential to cause direct damage to power, water, transportation, and building facilities (Vissichelli 2018). Non-native species that may not currently impact facilities may become harmful due to changes in local climates (NRC 2002, IPCC 2014).

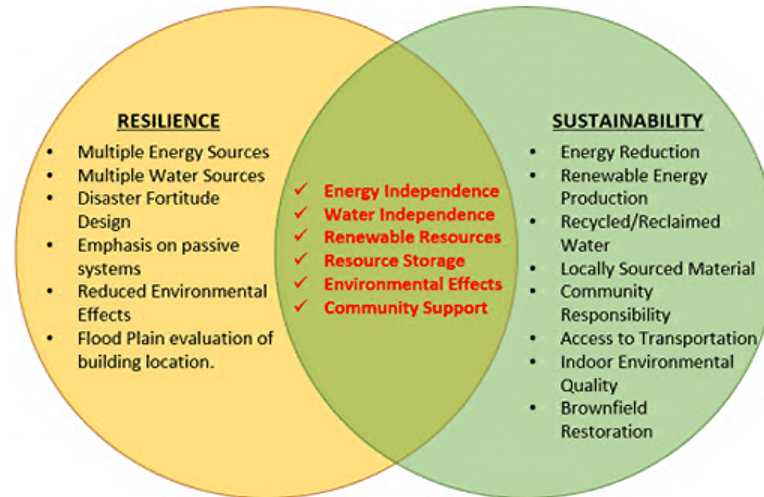
Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Adaptation and resiliency strategies

- Shoreline stabilization mechanisms can protect resources in place but are not long-term solutions and have tradeoffs, including disruption of natural processes. In certain circumstances, however, stabilization or shoreline hardening is unavoidable.
- Beach nourishment can be a costly short-term effort. There are ecological and physical consequences of dredging sand from other locations and placement of sediment on intertidal and nearshore habitats. Cape Hatteras National Seashore is developing a Sediment Management Plan through the NEPA process.
- The effectiveness of natural and nature-based features for shoreline protection is site-specific. Their suitability as a long-term alternative depends on ability to adapt to climate change, design, and compatibility with local conditions.
- Consider opportunities to redesign and relocate facilities, and to replace facilities with portable structures. Evaluate the maintenance costs and nonstandard costs associated with these alternatives.
- Historic structures have resilient design features. If buildings are well maintained, they may have a better chance of surviving a major storm.
- Storms are expected to happen; all damages cannot be anticipated or mitigated in advance; and post-storm recovery is a critical opportunity to learn and adapt to climate change.

- Resilient park operations can be supported with green infrastructure such as sustainable landscaping, as well as sustainable energy, water, and building envelope solutions. The figure below illustrates this relationship.



Lists of adaptation strategies for different types of infrastructure projects in response to different hazards can be found here: [Incorporating Climate Change Adaptation in Infrastructure Planning and Design](#) (see Chapter 4, Tables 25-34). If used, these adaptation strategies will need to be modified for proposed park projects. The NPS [Coastal Adaptation Strategies Handbook](#) (Beavers et al., 2016) provides guidance for policy, planning, cultural resources, and facility adaptation in the coastal zone.

Buildings and assets within national parks may include cultural resources (e.g., historic, and pre-historic buildings and structures). The adaptation and resiliency options for cultural resources often overlap with those defined for facilities; however, NPS has detailed specific strategies when dealing with cultural resources and climate change in national parks ([Cultural Resources Climate Change Strategy](#)). “Climate change poses an especially acute problem for managing cultural resources because they are unique and irreplaceable — once lost, they are lost forever” ([NPS Policy Memorandum 14-02](#)).

Seek additional assistance if desired

- Additional resources for answering question 16 and related questions can be found in:
 - Appendix 1 below, which includes a full hazards checklist, providing additional links for supporting information related to each hazard.
 - Appendix 2 below, which provides a map to visualize how climate is changing for the park.

- The [GFIP Guidance and Logistics](#) folder under the [Resources to Assess Risks and Hazards tab](#) includes:
 - An Excel workbook labeled [T75 Parks GFIP NRSS Supporting Materials](#) that provides links to information for natural resources to be considered during project design and construction.
 - A [FAQs – Assessing Risks and Hazards](#) document that provides detailed guidance for answering Question 16.
 - A [Natural Hazard Assessment Webinar](#) recording that provides key information, definitions, and guidance for understanding natural hazards and related resources.
- The NPS Climate Change Response Program (CCRP) and Sustainable Operations and Maintenance Branch (SOMB) are also available for assistance in evaluation of climate change hazards and resiliency strategies as they relate to specific projects. Questions can be sent to the NPS [GFIP Hazards and Risk Assistance email account](#) and a member of that team will reply with support.

Appendix 1: The Climate-Related Hazard Checklist

The following checklist is an expert-opinion based screening tool that illustrates the hazards that were considered in the development of this report. Knowledge of how climate change will unfold is developing rapidly and new hazards may become evident in the future.

Potential Hazard	Best Professional Judgment	Potential Risk or Secondary Hazard
Air Temperature: Hotter Average Days and More Very Hot Days	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Inadequate HVAC • Road surface degradation • Lack of water due to increased water for irrigation • Increased humidity • Danger to staff and visitors
Melting Permafrost/ Declining Sea and Lake Ice	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Road and building foundations unstable • Landslides and unstable hillsides • Shoreline erosion
Drought: Increased Frequency, Intensity, Magnitude, and Duration	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Limited water supply for cooling, landscaping, other equipment • Increased competition for available water and water rights conflicts • Crack/heave damage in drier soils • Increased vulnerability to wildfire (below)
Wildfire:	Known Hazard	• Damage to facilities and contents

Increased Frequency, Intensity, Magnitude, and Duration	☐ Potential Hazard ☒ Not applicable ☐	• Smoke damage • Air quality dangerous to staff and visitors • Increased runoff • Increased erosion • Damage to water treatment plants
Precipitation: Altered Patterns and Changing Humidity	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Local flooding • Mold growth • Wood decay • Drought • Fire • Groundwater change
Precipitation: Increased Extreme Events	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Surface erosion • Floods (see below) • Water damage to structures from driven rain • Unstable saturated soils
Riverine Flood/ Flash Flood	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Damage or destruction of infrastructure • Stream channel migration • Stream bank erosion/extreme erosion • Safety • Water quality diminished

		• Damage to water source and delivery infrastructure • Changing requirements for culvert flow capacity
Sea Level Change and Coastal Storm Surge	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Rising sea and lake levels • Rising water – wind driven (e.g., hurricane, nor'easter) • Saltwater intrusion • Vegetation damage • Need to elevate or relocate coastal facilities
Hurricanes, Tornados, and Other High Wind Events	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Building destruction • Flying debris • Storm Surge • Tree fall (see other categories for associated intense rainfall, floods)
Pest Infestation	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Historic fabric and facility damage • Vegetation loss • Disease vectors may increase. • Termites and other woodboring pests are expanding range with warming and increased humidity.
Invasive Species	Known Hazard ☐	• Vegetation (e.g., kudzu, vines, Brazilian pepper) can damage buildings,

	Potential Hazard ☒ Not applicable ☐	kill trees, obstruct waterways. • Marine and aquatic invasive species
Subsurface Hazards Cave/Karst (Sinkholes)	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Surface collapse • Contamination • May affect freshwater availability, drainage, and drought potential • Abandoned Mineral Lands (AML) features
Shrink/ Swell Soils	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Damage to structure • “Heaving” of ground beneath structure • Increased landslide susceptibility
Landslide/ Rockfall/ Avalanche	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Rockfall • Mud or debris slides or flows onto structures • Mud or debris slides or flows from under structures • Snow avalanche
Tsunami	Known Hazard ☐	• Coastal area inundation associated with earthquakes or undersea landslides

	Potential Hazard ☐ Not applicable ☒	• May be triggered by mass wasting events
Volcanic Eruption	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Lava Flows • Fire • Toxic gas releases • Ash
Hydrothermal Activity (e.g., Geysers)	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Toxic gas release • Explosion • Boiling water • Steam • Surface collapse into void
Earthquake	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Falling objects • Collapsing structures • Inoperability of major building systems e.g. power, sewer, water • Liquefaction; loss of strength to foundations, silt deposition, standing water • Trigger to other hazards e.g. landslides, debris flows

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