



Climate Change Hazards Summary Report for Facility Investment Planning

Sleeping Bear Dunes National Lakeshore February 2021

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Executive Summary

Trends toward warmer, wetter, and more humid conditions provide challenges for park operations and assets, increase disease and pest pressure, and alter habitats. Infrastructure currently designed for historical climate conditions is more vulnerable to future weather extremes and climate change. High water levels threaten infrastructure at Sleeping Bear Dunes National Lakeshore designed for lower lake levels. From an historic lighthouse at South Manitou Island to docks and boat launches that support park operations and visitor access, the relationship with the changing water level of Lake Michigan will continue to affect park natural and cultural resources and assets at Sleeping Bear Dunes National Lakeshore. During the Geologic Resources Scoping Meeting (KellerLynn 2010), the main geohazards identified were mass wasting and landslides; flooding; cave and karst features; and potential earthquakes. The massive Sleeping Bear Point landslides in 1941, 1971, and 1995 occurred during times of above-average lake levels and “unseasonably warm” winter months (Jaffe et al. 1998, Barnhardt et al. 2004; summary in KellerLynn 2010).

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?

Step 1: Review summary information for known or potential hazards identified for Sleeping Bear Dunes National Lakeshore

- Review the list of potential hazards below and decide whether or not they apply to your specific GFIP project. NPS Climate Change Response Program (CCRP) staff attempted to identify potential hazards for the park; however, park staff and project planners have more information about hazards that are likely to be applicable to a specific project.
- The hazards below were selected from a longer list included in Appendix 1, which also indicates CCRP’s ‘best professional judgement’ about the relevance of the hazard for this park. Note both lists serve as a “coarse filter” screening tool to help identify potential climate-related hazards for facility and asset planning.

Hotter average days and more very hot days

Climate change is driving observable increases in average and extreme temperatures, and this trend is projected to continue, with record setting years becoming more common in the future (USGCRP 2017). The annual average temperature in the United States is expected to increase by 2.3 to 11°F by the end of the century depending on greenhouse gas emissions, relative to 1986-2015 (USGCRP 2017). 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.

By the end of the century, low greenhouse gas scenarios lead to projections of annual mean temperature increase of 2° C. Higher concentrations of greenhouse gas in the atmosphere projects an increase of annual mean temperature of 5.8° C (Gonzalez et al. 2018). During the three most recent decades, the hottest part of the year is getting hotter (Monahan and Fisichelli 2014). Across the national park system, parks varied widely in the historical relationship between long-term average monthly visitation and temperature, however the visitation-temperature relationship at SLBE was strong (Fisichelli et al. 2015) and will likely result in more visitation during spring/fall shoulder seasons and during very hot summer days. Hotter temperatures may increase risk of landslides, especially at Sleeping Bear Point where massive slides in 1914, 1971, and 1995 all occurred during “unseasonably warm” winter months (Jaffe et al. 1998, Barnhardt et al. 2004, summary in KellerLynn 2010).

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, wood decay, increase fire risk, and intensify drought conditions, depending on the pattern of change. 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, erosion of supporting ground around structures, among many other effects.

Models of future climate indicate that precipitation could either increase by 11% under high emission concentrations, or, if greenhouse gas emissions stay low, precipitation could increase by 6% (Gonzalez et al. 2018). In coming decades, the driest quarter of the year is likely to experience more precipitation (Monahan and Fisichelli 2014). The effects of additional precipitation, especially at certain times of the year may have unexpected and cascading consequences. For example, some slopes may be more susceptible to failure with increased rainfall, so steep slopes that are prone to failure and slumping should be evaluated following intense rainfall events. Pore pressure in ground water appears to be a trigger for each of the massive landslides at Sleeping Bear Point in 1914, 1971, and 1995 (Jaffe et al. 1998, Barnhardt et al. 2004, summary in KellerLynn 2010).

Park staff assessment – relevant to GFIP Project:

☐ Yes

☐ No

Increased drought frequency, intensity, magnitude, and duration

Rising air temperatures and changing precipitation patterns are exacerbating drought risk in many parts of the United States (Wehner et al. 2017). Changing drought conditions (frequency, severity, duration) can challenge a variety of infrastructure and operations (Department of Homeland Security 2015) in the NPS (e.g., water supply and wastewater systems), impair water quality (Mosley 2015), affect soil heaves and shrinkages (Fernandes et al. 2015), affect karst geology in unique ways, and will enhance other related risks such as wildfire.

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.

Park staff assessment – relevant to GFIP Project:

☐ Yes

☐ No

Diminished lake ice

Lake ice onset and breakup are highly correlated with air temperature, and thus, ice formation is already later and loss is earlier throughout the US. Climate projections indicate rapid declines in ice duration throughout the continental US at least through 2050 (Sharma et al. 2020). Lake ice cover and duration have declined throughout the northern midwest region and will continue to do so. Ice cover of the Great Lakes declined an average of 71% from 1973-2010 (range 37-88%; <http://glisa.umich.edu/climate/great-lakes-ice-coverage>). Increased exposure of the water surface of the Great Lakes can lead to increased lake-effect precipitation and increased wind (Desai et al. 2009). Ice cover affects water-based transportation and recreation, access to NPS sites and facilities, fish and other lake biota, ecological dynamics, water quality, and the safety and timing of park visitation and activities. Areas that host winter sports are especially vulnerable to warming winters. For example, ice fishing was limited due to

mild temperatures in the winters of 2015–2016 and 2016–2017 (U.S. Global Change Research Program 2017).

Park staff assessment – relevant to GFIP Project:

☐ Yes

☐ No

Coastal storms, storm surge, and coastal erosion

Higher lake levels cause accelerated coastal erosion, landward migration of shorelines, and changes in groundwater, and amplifies flooding caused by higher storm surges (Field et al. 2007). High lake levels pose considerable risks to infrastructure, lighthouses, forts, and other historic structures. Diminished lake ice will expose more sections of coast with unconsolidated sediments to increased erosion. Slope failures may also result from increased coastal erosion.

Park staff assessment – relevant to GFIP Project:

☐ Yes

☐ No

Lake level change

Water levels at Lake Michigan are impacted by changes in precipitation, which may result in low lake levels during dry periods due to diminished inputs and increased evaporation, or high water levels due to intense storms or consistent precipitation over a prolonged period. Reservoirs and lakes with controls on inlet and outlet flows are able to manage surface water levels; however, climate change may result in extremes that limit the ability to meet water level requirements for user needs or overwhelm control systems resulting in flooding. The dynamic nature of water level can affect the safe use and exposure of park assets at various water levels. Park planning must address the variable nature of lake water levels and design infrastructure for flexible operations. The massive Sleeping Bear Point landslides in 1941, 1971, and 1995 occurred during times of above-average lake levels (Barnhardt et al. 2004; summary in KellerLynn 2010).

Park staff assessment – relevant to GFIP Project:

☐ Yes

☐ No

Riverine flood/Flash flood

Extreme precipitation events and the risk of flooding are expected to regionally intensify with a changing climate (Dethier et al. 2020, Tabari 2020). Floods threaten infrastructure and operations through a variety of mechanisms, including inundation of structures, enhanced erosional forces, road wash out, structural collapse from force of floodwaters, sewage backup, and damage to utilities, generators, and electrical systems. Post-flooding effects include increased rot, fungal/insect attack, mold and mildew,

and physical deterioration of wood, brick, and stone building materials. Flood may affect the timing and volume of material that may be dredged from the Platte River.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Intense storms and tornadoes

Storm surge can cause flooding and road wash outs. The combination of higher lake levels and increased storm surge will flood structures that previously were outside of the floodplain. Flood and storm surge depths may be deeper than in previous storms. Flooding may occur in areas that had no flooding during past storms. Building standard guidance is based on base flood elevations of 2-3 ft above FEMA flood zones of 100-year (1%-annual chance) storms, depending on the building criticality. For existing buildings that are not above base flood elevation, adaptation measures to reduce flood impacts should be considered. Intense storms also threaten structures via damage from wind, wind-blown rain and debris; their large temperature swings stress buildings through sudden thermal expansion and can crack pipes.

Climate change can increase the frequency of severe thunderstorms, which generate tornadoes, although analyses of historical records from 1954 to 2017 show mixed trends in the total number of tornadoes, with decreases in the southern Great Plains, increases in the southeastern U.S., and shown no statistically significant trend for the U.S. as a whole (Agee et al. 2016, Brooks et al. 2014, Gensini and Brooks 2018). For the U.S. as a whole, the number of days with over 30 tornadoes (Brooks et al. 2014, Elsner et al. 2015) and the number of tornadoes per tornado outbreak have increased (Moore 2017, Tippet and Cohen 2016). 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).

Under continued climate change, the potential for severe thunderstorms that provide conditions for tornadoes may increase substantially across the central and eastern U.S. (Diffenbaugh et al. 2013, Gensini and Mote 2015). Increasing urban and suburban development in tornado-prone areas increases the exposure to damage for the U.S. as a whole (Strader et al. 2017). Tornadoes can result in catastrophic damage to infrastructure from high winds, and associated debris, hail, and flash flooding. Other high wind events such as derechos may become more common.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Pest infestation and algal blooms

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.

Tourism and outdoor recreation are major economic activities that may be affected by climate change, particularly in coastal areas that are at risk from algal bloom impacts during periods of hotter water temperatures (U.S. Global Change Research Program, 2017).

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

Geologic features and processes

Geologic features and processes are affected by increased temperatures, changes in precipitation, and disturbance due to extreme climate events. During the Geologic Resources Scoping Meeting (KellerLynn 2010), the main geohazards identified were mass wasting and landslides; flooding; cave and karst features; and potential earthquakes. Other related resource management issues include: disturbed lands and restoration (pig farm, fish cleaning station, trucker dump); shoreline features and processes; hillslope features and processes; climate change impacts; impacts from wind erosion; dune disturbance; Platte River dredging; karst; oil and gas development; paleontological resources; and seismic features and processes (KellerLynn 2010).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

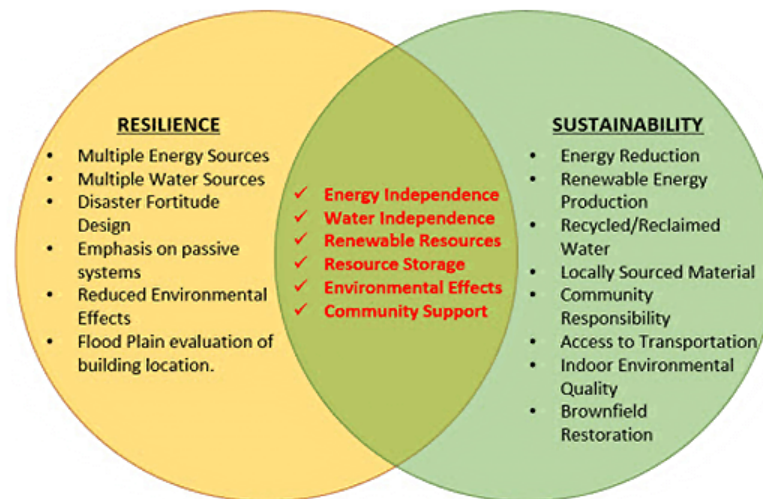
Step 2: Consider adaptation and resiliency strategies

- Review definitions of resiliency and adaptation strategies.
- Identify adaptation strategies that will help park resources respond to the hazards identified in Step 1.

Question 16 requires a screening for climate hazards followed by a review of adaptation and resiliency strategies that would be put in place to respond to these hazards. For the purposes of this report and investment planning, resilience is a property of a system or asset and generally refers to the ability of the system or asset to maintain its intended purpose following a temporary disturbance.

Adaptation strategies, in the context of built infrastructure, refers to the intentional management decision to identify, prepare for, and respond to observed or expected sustained changes in hazards, including climate change, to adjust to a sustained change in conditions.

It is important to note that resilient park operations can be supported through the use of 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.

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](#)).

Step 3: Develop an answer to Question 16 for your specific project and location, as well as strategies to address each hazard

- Example responses to Question 16 are provided below. THESE ARE GENERIC EXAMPLES FROM OTHER PARKS. You can view other examples here: [Example responses to Q16 on hazards Organized by Park](#).
- You will need to develop park specific answers based on the hazards identified in Step 1 and the adaptation strategies identified in Step 2 for your park and project. The park response should be as project-specific as possible.
- The NPS Climate Change Response Program (CCRP) and Sustainable Operations and Maintenance Branch (SOMB) are available to help evaluate climate change hazards and resiliency strategies for your specific projects. Requests should be sent to the NPS [GFIP Hazards and Risk Assistance email account](#); a member of the team will reply with support.

Question 16: 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?

Example from Minute Man National Historic Park: Restoring historic structures

Several climate change hazards may affect building-related projects at MIMA, including hotter average days, more extreme heat days, increased hurricane impacts from wind and flooding, altered precipitation patterns, and increased extreme precipitation. Adaptation and resiliency strategies for the expected hazards are described below:

- Hotter average days and more extreme heat days will increase demand and requirements for higher capacity air conditioning systems unless accommodated through modified building designs or other systems.
- Extreme heat and humidity can stress the building envelope and will require significant humidity control alterations for structures.
- Changes in building design or post-flooding dehumidification systems, in coordination with the NPS Historic Architecture, Conservation and Engineering Center or Historic Preservation Training Center, to avoid any increase in energy use.
- Hurricane force wind and wind-blown rain as well as damage from wind-blown debris or treefall will require wind resistant fortification of the structure. Addressing hazardous trees and retrofitting roof structures to be more wind resistant may also be required.
- Flooding from increased hurricane events, increased extreme precipitation, or in conjunction with altered precipitation patterns may require modifications to building infrastructure location and landscape drainage systems.

- Post-flooding effects may include increased rot, mold and mildew, and physical deterioration of wood, brick and stone building materials. Adaptation actions will include identifying appropriate dehumidification and air handling systems and coordinating with the NPS Historic Architecture, Conservation and Engineering Center or Historic Preservation Training Center regarding alternatives and maintenance for historic structures.

Example from Everglades National Park

Replace Water Distribution and Wastewater Collection Systems Parkwide.

- These systems have significant deficiencies that exposes them to routine ground water infiltration because of the heavy rainfall that the Park receives. This infiltration results in the treatment plants treating ground water infiltration as raw sewage thusly overtaxing the wastewater treatment plants and lagoons. Additionally, the routine tropical storms and occasional hurricane that hit the Park bring with them significant storm surge that renders the treatment plants and lift stations inoperable until the water levels have subsided. This project will address both the infiltration and storm surge by replacing the deteriorated wastewater collection lines with new HDPE pipe as well as by building more storm resilient treatment plants in a hurricane hardened facility that is elevated above the average storm surge levels of 15 feet.

Repave Roads and Parking Areas Parkwide.

- Roads and Parking areas in EVER were constructed lacking storm water management. This project will address storm water management in design and construction with proper storm water collection and containment in the form of containment ponds and swales to divert the storm water drainage where needed. Additionally, road culverts will be replaced or installed where needed. We are not initially planning on raising any road elevations; we will address this need or concern as we work through the design phase of this project.

Address Deferred Maintenance and Historic Preservation on Critical Buildings and Visitor Centers Parkwide.

- All buildings in EVER are subject to exposure to severe storms and hurricanes annually. This project will address building resiliency by incorporating Florida Building Code Standards for building construction in a high velocity hurricane zone. These standards are designed for wind gusts up to 170-190mph and may include standing seam metal roofs, tie downs on existing structures, impact resistant windows, etc. In incorporating the Florida Building Code Standards into this project, we will work to assure that historic buildings are more resilient to hurricanes in a manner that will preserve their historic character and that will meet the Secretary of the Interiors Standards for Treatment of Historic Structures.
- With sea level rise, it is expected that some structures will flood more often. Where structures are not elevated above the flood zone, building materials will be selected that resist mold and mildew (e.g., tile), and electrical panels will be elevated. HVAC systems will be designed to meet the temperatures and humidity level of south Florida; condensing units will be elevated and placed in more secure locations above ground level.

Example from San Francisco Maritime National Historic Park: pier repair, historic building restoration, road repair, or water system project

Several climate change hazards may affect a (pier repair, historic building restoration, road repair, or water system) project at San Francisco Maritime National Historical Park, including sea level rise, storm surge, more frequent storms, San Francisco Bay flooding, increased street stormwater runoff, hotter temperatures, and increased insect pests. Possible adaptation and resiliency strategies include:

- Adoption of sea-level rise adaptation measures developed by Golden Gate National Recreation Area in a plan for Crissy Field ([CMG Landscape Architecture 2016](#)) that covers an area up to the western boundary of San Francisco Maritime National Historical Park.
- Natural shoreline features along Aquatic Park Beach to handle some inundation from sea level rise.
- Vegetated catch basins for urban street stormwater runoff.
- Drainage systems and culverts that could handle greater water flows.
- Relocation of any infrastructure from an area where a hazard cannot be avoided.
- Water conservation measures to reduce water use during droughts.
- Strengthening structures to prevent damage from extreme storms or treefall.
- Changes in building design or post-flooding dehumidification systems, coordinating with the NPS Historic Preservation Training Center and avoiding any increase in energy use, which would increase greenhouse gas emissions and exacerbate climate change.
- Changes in building design or building systems to maintain appropriate temperatures and humidity without increasing energy use, which would increase greenhouse gas emissions and exacerbate climate change. Energy conservation and renewable energy systems to prevent any increase in fossil fuel energy use.
- Early detection and removal of termites or other pests or hazards.

Step 4: 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

This appendix provides an initial evaluation of climate hazards for **Sleeping Bear Dunes National Lakeshore** according to the hazard ratings identified below. The information used to identify hazards in the checklist is mostly from regional assessments. Park and project specific information was generally not available when assessing these hazards. NPS Climate Change Response Program (CCRP) staff made an initial attempt to identify potential hazards for the park broadly (see 'Best Professional Judgement' column); however, park staff and project planners have more information about hazards that are likely to be applicable to a specific project.

Explanation of Hazard Ratings

Known hazard: Conditions that cause the hazard are well documented in the area where the park occurs. If applicable to the project site, these hazards should always be addressed in the project plan.

Potential hazard: Conditions that cause or underlie the hazard are known to occur nearby or are likely to occur based on studies with conditions similar to the park. If applicable to the project site, these hazards should be considered for inclusion in the project plan.

Not applicable: No evidence *was identified* showing this hazard is relevant to the park. Note this is a coarse filter evaluation; local knowledge of a hazard(s) should be used, when available.

Table 1. Climate-related Hazards Checklist

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
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	• National Climate Assessment • State climate summary	• National Climatic Data Center • DAYMet gridded climate data • National park historical and projected climate change

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Increased drought frequency, intensity, magnitude, and duration	Known Hazard ☐ Potential Hazard ☒ Not Applicable ☐	- Limited water supply for cooling, landscaping, structural fire suppression, other equipment - Increased competition for available water and water rights conflicts - Crack/heave damage in drier soils - Increased vulnerability to wildfire (below)	Drought Monitor National Integrated Drought Information Center National Climate Assessment State climate summary	Drought Monitor National Integrated Drought Information Center
Increased wildfire frequency, intensity, magnitude, and duration	Known Hazard ☐ Potential Hazard ☒ Not Applicable ☐	- Damage to facilities and contents - Smoke damage - Air quality dangerous to staff and visitors - Increased runoff - Increased erosion - Damage to water treatment plants	Barbero et al. 2015 International Journal of Wildland Fire	NIFC International Wildland-Urban Interface Code
Altered precipitation patterns, increased extreme precipitation, and changing humidity	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	- Local flooding - Mold growth - Wood decay - Drought - Fire - Groundwater change - Surface erosion - Floods (see below) - Water damage to structures from driven rain - Unstable slopes	National Climate Assessment State climate summary	National Climatic Data Center DAYMet gridded climate data National Park historical and projected climate change - Evaluations are mostly at regional scales

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
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	• FEMA Flood map service	• FEMA Map Service Center • Floodplain maps for HUD projects • Van Dusen et al. 2020 (for select parks) • May require a special flood study
Coastal storms, storm surge, and coastal erosion	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Changing lake levels • Rising water – wind driven (e.g. storms) • Vegetation damage	• NOAA - Great Lakes Environmental Research Laboratory	• IRMA – Coastal reports • Specific Hazard Assessment: Coastal Storm Surge with Climate Change Effects (requires VPN connection) • Great Lakes Dashboard Project
Lake level change	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Higher and lower lake levels • Groundwater change • Vegetation damage		

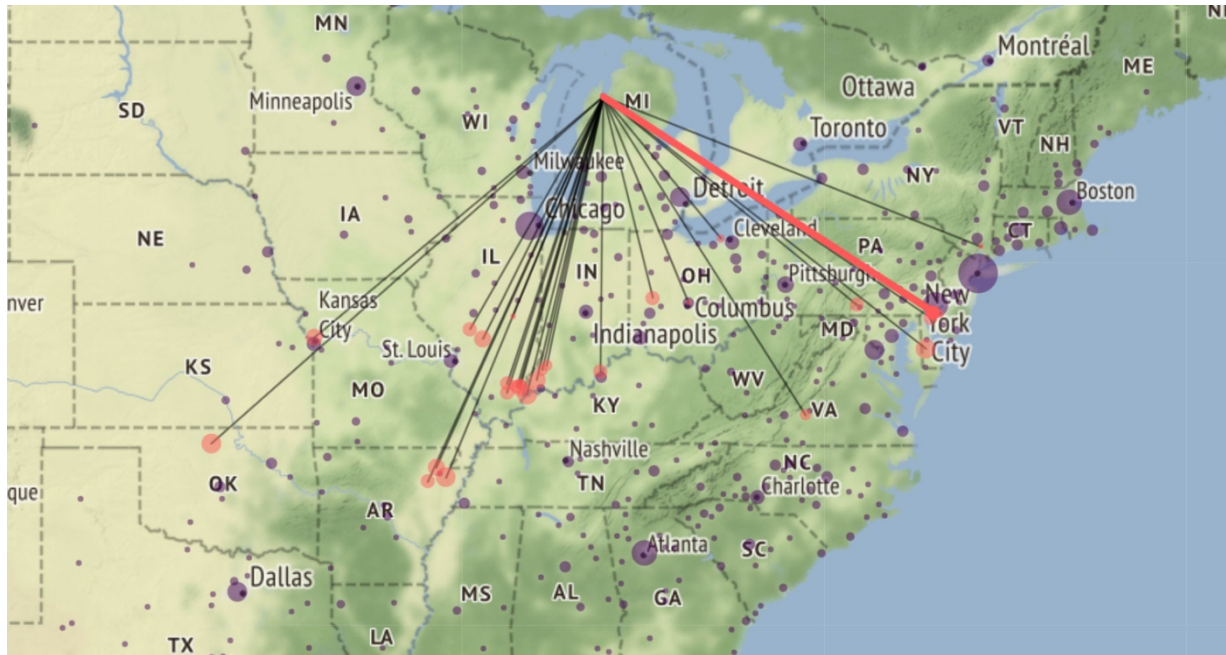
Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Diminished lake ice	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Increased coastal erosion • Ice Heave		
Intense storms and tornadoes	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Building destruction • Flying debris • Storm surge • Tree fall (see other categories for associated intense rainfall and floods)		• Wind speed data – from local codes • International Building Code • FEMA Map Service Center
Pest infestation	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Historic/facility fabric loss • Vegetation loss • Disease vectors may increase • Termites and other woodboring pests expanding range with warming and increased humidity	• USFS Forest Health Advisory System	• NPS Pest and Invasive Species Management Contacts • Fisichelli et al. forest pests • USFS maps

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Invasive species	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Aquatic mussels – water intakes clogged • Vegetation (kudzu, vines) – damage buildings, kill trees, obstruct waterways	• National Invasive Species Council	• NPS Pest and Invasive Species Management Contacts • Early Detection and Distribution Mapping System (current distribution) • Early Detection and Distribution Mapping System (projected distribution)
Landslide	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Rockfall • Mud or debris slides or flows onto structures • Mud or debris slides or flows from under structures	• USGS Natural Hazards • State geological surveys e.g.	
Subsurface Hazards Abandon Mineral Lands & Cave/Karst (sinkholes)	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Surface collapse • Contamination • Abandoned Mineral Lands (AML) features	• Abandoned Mineral Lands (AML) features Abandoned Mineral Lands • State geological hazards maps.	

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Seismic Features and Processes (Earthquakes)	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.	- International Building Code (IBC) - United States Geological Survey (USGS): Earthquake Probability Mapping	

Appendix 2. What Will the Park Climate Feel Like in 60 Years?

The map below is intended to help visualize how the present-day climate in the region of **Sleeping Bear Dunes National Lakeshore** is projected to change as a result of climate change (Fitzpatrick and Dunn 2019). Under a high greenhouse gas emission scenario, Traverse City, Michigan's climate in 2080 may feel like today's climate near Chester, Pennsylvania. The typical summer in Chester, Pennsylvania is 7.2°F (4°C) warmer and 29.8% wetter than summer in Traverse City, Michigan. The red line shows the average of the 27 climate models; the black lines show the 27 individual projections assuming continued high emissions, providing a sense of the plausible range of future climates. The size of a red circle gives a sense of how good of a match that location is, with smaller circles indicating better matches; all circles (red or purple) denote cities used in the analysis. The analysis is based on twelve climate metrics, including minimum and maximum temperature and precipitation by season (spring, summer, fall, winter). More details are available in the reference cited above and the website <https://fitzlab.shinyapps.io/cityapp/>.



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Disclaimer

Report Purpose and Scope:

Parks identified for Legacy Restoration Funding in fiscal years 2023-2025 are required to develop a Great American Outdoors Act Facility Investment Plan (GFIP). The intended use of this series of park-specific reports is to help parks address Question 16 of the narrative template: *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?*

Each report compiled and summarized published information on a suite of climate change hazards. Each report included an analysis of each hazard, for which the report author assigned a 'hazard rating' as follows:

Known hazard: Conditions that cause the hazard are well documented in the area where the park occurs. If applicable to the project site, these hazards should always be addressed in the project plan.

Potential hazard: Conditions that cause or underlie the hazard are known to occur nearby or are likely to occur based on studies with conditions similar to the park. If applicable to the project site, these hazards should be considered for inclusion in the project plan.

Not applicable: No evidence was identified showing this hazard is relevant to the park. Note this is a coarse filter evaluation; local knowledge of a hazard(s) should be used, when available.

As articulated within the report (in an appendix of the hazard ratings) those ratings constitute the author's 'best professional judgement' about the relevance of the hazard for that park based on the reviewed literature (cited in the narrative text for the hazard & provided in the report bibliography).

The intended use of each report is to inform decisions for facility investment planning related to (i) potential hazards that a suggested facility investment concept would need to appropriately consider and avoid or mitigate and (ii) identifying facilities possibly at greater relative vulnerability due to the identified hazards. The level of information quality in the report was calibrated to those purposes, i.e. to inform development of questions for a facility investment scoping process to further explore.

Peer Review Process:

Each report was based on a template, which heavily relied on boilerplate text for the non-park specific elements. The boilerplate text underwent multiple rounds of informal peer review by assorted CCRP staff, including members of the Climate Science and Adaptation Team, the Communications Team, the Regional Climate Change Liaisons, and the Climate Change Liaison to Facilities and Planning. Each report was peer-reviewed by a member of CCRP to check interpretation, consistency in hazard ratings, improve narrative coherence, and flag priority additions/modifications. In situations where revisions were required, the peer reviewer then re-reviewed the final revised report to assure adequate resolution of the identified issues.