



Climate Change Hazards Summary Report for Facility Investment Planning

Everglades National Park January 2021

Prepared By
NPS Climate Change Response Program
NPS Sustainable Operations and Maintenance Branch

Executive Summary

Changing climatic conditions can adversely affect the construction and usefulness of the built environment. Foresight into potential, even likely, future conditions over the anticipated lifetime of an investment can enable an asset to maintain its maximum usefulness over time.

Future conditions in Everglades National Park will be warmer. These higher temperatures will be warmer overall, and the hottest days will be hotter. The increased heat will be accompanied by stronger storms and higher winds but may also be accompanied by either more precipitation overall, or a decrease in overall precipitation throughout the year.

Higher temperatures may make the park inhospitable to individuals seeking outdoor experiences, change drought conditions (frequency, severity, duration) that will affect infrastructure and operations in the NPS (e.g., water supply and wastewater systems), impair water quality (Mosley 2015), affect soil heaves and shrinkages (Fernandes et al. 2015), and enhance other related risks such as wildfire (Halofsky et al. 2020).

Flooding threatens 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 and insect attack; mold and mildew; and physical deterioration of wood, brick, tabby and coquina (sedimentary rocks formed from shell deposits), and stone building materials. Climate change can also favor pests like termites, ants, mosquitoes, ticks, forest pests, and invasive species.

Sea level rise and storm surge threaten the stability of the land on which Everglades infrastructure is based and will flood many of those structures during intense storm events. Hurricanes 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; they also can cause flooding and wash out sections of roads.

As projects are developed and Everglades National Park staff move forward with investments in the built environment, there is a desire to anticipate future risk. This report details the best available science about future climate change and illustrates some of the way this change could pose a hazard to projects. It is intended to serve as the beginning of a dialogue surrounding these hazards and provides information about how to get additional assistance.

Introduction

Climate change is increasing air and water temperatures, the extent and frequency of large storms and extreme weather events, flooding, erosion, intrusion of salt water, nonnative invasive species, and the rate of sea level rise at Everglades National Park. Much of the park's infrastructure was created in the

1950s and 1960s and is at risk from sea level rise and climate change, as well as deterioration due to facility age and the harsh South Florida climate. Climate change may also affect seasonal use patterns at the park and access for dispersed recreation.

With the deterioration of canal plugs, bulkheads, and other engineering structures meant to separate inland areas from the corrosive effects of salt water, the stresses on park assets and resources is increasing. More frequent nuisance “high tide” flooding of developed areas, sea level rise, saltwater intrusion, and powerful hurricanes will accelerate the loss of Everglades soils, marsh elevation (by erosion and biological processes), and the “filled” land on which much of Everglades infrastructure is sited. Visible effects on park infrastructure due to climate change include increases in flooding, saltwater intrusion, soil subsidence, and loss of natural protective berms. While some park assets have been upgraded following hurricane impacts and can withstand heavy rainfall and high winds, not all park infrastructure is built to hurricane standards.

The park has significant deferred maintenance. The future investment in Everglades assets must be made with an eye toward increasing climate impacts and pending changes for park access and infrastructure viability. By protecting natural areas from pollution and over-harvesting, restoring already damaged ecosystems, and modifying and improving park facilities, the park’s resources and assets will endure for some time despite the added threat of climate change (NPS 2010).

Purpose

Everglades National Park is developing a facility investment plan and associated projects for the funding through the Great American Outdoors Act and Legacy Restoration Fund. Information provided in this report is intended to help the park consider climate change related hazards when addressing Question 16 of the narrative template.

Future and Current Climate

Low greenhouse gas scenarios for this century (RCP 2.6) lead to projections of annual mean temperature increase of 1° C, and an increase of annual average precipitation by 4%. When higher concentrations of atmospheric greenhouse gas are modeled (RCP 8.5) projections show an increase of annual mean temperature of 3.1° C, and annual average precipitation decrease of 3% (Gonzalez et al. 2018).

When looking over the past century, the three most recent decades have been extremely warm, and there has been more precipitation compared to the past century. Both annual mean and maximum temperatures were higher in recent decades. The wettest parts of the year are experiencing more precipitation and higher temperatures, and the hottest part of the year is experiencing more precipitation (Monahan and Fisichelli 2014).

Climate-Driven Risks to the Built Environment

Air Temperatures: Hotter average days and more very hot days

It's possible heat 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.

By the end of the century, low greenhouse gas scenarios (RCP 2.6) lead to projections of annual mean temperature increase of 1° C, higher concentrations of greenhouse gas (RCP 8.5) in the atmosphere projects to an increase of annual mean temperature of 3.1° C (Gonzalez et al. 2018). For this past century, In the three most recent decades, the hottest part of the year is getting hotter (Monahan and Fisichelli 2014).

Hotter temperatures may affect seasonal use patterns at the park and access for dispersed recreation. 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 Everglades National Park was strong when statistically modeled and explained 73% of the variation (Fisichelli et al. 2015).

Drought: Increased frequency, intensity, magnitude, and duration; and Karst Geology

Changing drought conditions (frequency, severity, duration) can challenge a variety of infrastructure and operations in the NPS (e.g., water supply and wastewater systems), impair water quality (Mosley 2015), affect soil heaves and shrinkages (Fernandes et al. 2015), and will enhance other related risks such as wildfire (Halofsky et al. 2020).

Everglades National Park is home to some peatlands which require a surplus of inflow of precipitation over evapotranspiration loss, without which, drought will ensue. Some modeling indicates a threshold of a temperature increase of 1.5 ° C and a 10% rainfall reduction could lead to drought (Nungesser et al. retrieved 2021). Beneath the surface at Everglades National Park, is a karst landscape characterized by solution holes, sinkholes, disappearing streams, springs, and incredible water storage capacity. The storage capacity of the rocks underlying Everglades National Park is the reason the unique ecosystems have flourished there through drought seasons, fire danger, and seasonal hurricanes. Aquifers at various stratigraphic levels including the Biscayne unconfined surficial aquifer support the habitats at Everglades (Thornberry-Ehrlich 2008).

Wildfire: Increased frequency, intensity, magnitude, and duration

Wildfire can threaten people and infrastructure. The park environment is a fire-adapted and -dependent landscape. The unique combination of climate and vegetation of the Southern Florida region creates a fragmented and highly flammable landscape next to one of the nation's largest metropolitan areas. A critical challenge to reestablishing and maintaining native ecosystems and habitats is maintaining an effective fire management program in the modern Everglades landscape. In the future,

rising temperatures and increases in the duration and intensity of drought are expected to intensify the heat that drives wildfire (Jolly et al. 2015); and increase wildfire occurrence and reduce the effectiveness of prescribed fire (Addington et al. 2015).

Precipitation: Altered patterns 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. Models of future climate indicate that precipitation could either decrease by 3% (RCP 8.5), or, if greenhouse gas emissions stay low (RCP 2.6), precipitation could increase by 4% (Gonzalez et al. 2018). In recent decades, the wettest and hottest parts of the year are both experiencing more (Monahan and Fisichelli 2014).

Precipitation: Increased extreme events

The growing number of extreme rainfall events is stressing the deteriorating infrastructure in the Southeast. Many transportation and storm water systems have not been designed to withstand these events. The combined effects of rising numbers of high tide flooding and extreme rainfall events, along with deteriorating storm water infrastructure, are increasing the frequency and magnitude of coastal and lowland flood events (USGCRP 2018). 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.

The intensity of extreme precipitation events increases with increasing temperatures. Extreme rainfall events have increased in frequency and intensity in the Southeast, and there is *high confidence* they will continue to increase in the future (Easterling et al. 2017). The region, as a whole, has experienced increases in the number of days with more than 3 inches of precipitation, and a 16% increase in observed 5-year maximum daily precipitation (the amount falling in an event expected to occur only once every 5 years) (Easterling et al. 2017). Both the frequency and severity of extreme precipitation events are projected to continue increasing in the region under both medium and higher scenarios (RCP4.5 and RCP8.5). By the end of the century under a higher scenario (RCP8.5), projections indicate approximately double the number of heavy rainfall events (2-day precipitation events with a 5-year return period) and a 21% increase in the amount of rain falling on the heaviest precipitation days (days with a 20-year return period) (Easterling et al. 2017).

Flooding

Flooding threatens 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 and insect attack, mold and mildew, and physical deterioration of wood, brick and stone building materials.

In the wetlands of South Florida, drastic measures that included canals, ditches, dams, and levees were implemented to drain swamps for agricultural and urban development. The altered hydrologic condition of the “River of Grass” is the focus of a large, multiagency effort to restore the Everglades (Thornberry-Ehrlich 2008). A variety of complex projects that are ongoing or planned to restore water delivery to the park through the East Everglades and Shark River Slough will mitigate some, not all, of the environmental impacts due to disruptions in the timing, duration, distribution, quantity, and quality of water deliveries into the park. With a highly altered, complex ecosystem, the effects of extreme precipitation events will increase the risk of flooding with a changing climate (Tabari 2020).

Sea Level Rise and Coastal Storm Surge

Cumulative impacts of sea level rise and storm surge on Everglades ecosystems threaten the stability of the land on which Everglades infrastructure is based and will flood many of those structures during intense storm events. Specific actions to address these hazards are included in the following report section on addressing hazards. Additional tools for these topics include the [NPS Sea Level Rise Viewer](#), and for parks with and exposure or vulnerability assessment by asset, see the [Coastal Vulnerability Data Viewer](#).

Sea level rise is affecting South Florida. Historical tide gauge data from the Miami Beach, FL tide gauge show that sea level around Everglades National Park (EVER) is rising. Everglades National Park has an elevation lower than 3 feet in most places, and topography is among the controlling factors in ecosystem development at Everglades National Park. With an estimated 2.26’ of sea level rise predicted by 2100 under the high emission scenario (RCP8.5) (Caffrey and Beavers 2016), many of these low-lying areas will be permanently inundated. Because of the low elevation and small topographic relief, a small change in sea level can affect millions of acres of Everglades. Already, saline water is inundating low-lying areas, especially during storm events. The freshwater marshes and brackish estuaries are under constant threat of permanent inundation by the sea. Given the low topographic relief of the park, continued sea level rise will destroy mangrove zones, mud ridges, and other coastal features which normally buffer the freshwater wetlands from marine inundation (Thornberry-Ehrlich 2008). Since coastal terrestrial and freshwater ecosystems are highly sensitive to increases in inundation and salinity, sea level rise will result in the rapid conversion of these systems to tidal saline habitats.

Historically, coastal ecosystems in the region have adjusted to sea level rise by vertical and horizontal movement across the landscape (Doyle et al. 2015). As sea levels rise in the future, some coastal ecosystems will be submerged and converted to open water, and saltwater intrusion will allow salt-tolerant coastal ecosystems to move inland at the expense of upslope and upriver ecosystems (Howard et al. 2017). Where barriers are present (for example, levees and other coastal infrastructure), the potential for landward migration of natural systems will be reduced and certain coastal habitats will be lost. Mangroves – which stabilize sediments – might be able to keep pace with slowly rising sea levels by accumulating soil and effectively raising ground elevation. These habitats are also natural buffers for park infrastructure and help stabilize soils; restoring degraded areas and mitigating additional impacts to these “natural defenses” for park infrastructure must be a component of any park asset management plan.

The increase in high tide or “nuisance” flooding frequency is directly tied to sea level rise (USGCRP 2018). Recent analyses of historical water levels at many NOAA tide gauges has shown an increase in the number of times that these warming thresholds were exceeded compared to the past. Annual occurrences of high tide coastal flooding have increased 5- to 10-fold since the 1960s in several low-lying coastal cities in the Southeast. Higher sea levels will cause the storm surges from tropical storms to travel farther inland than in the past. More intense storm surges and higher sea-levels potentially overtop the marl ridge and threatening Cape Sable wetlands. Increases in peat collapse due to saltwater intrusion results in decreasing wetland elevation and accelerating the conversion of wetlands to open water estuaries as sea-level rises. More intense storm surges and higher sea-levels result in increased coastal wetland erosion, yielding wetland loss and water quality problems in adjacent coastal waters.

Hurricanes and tornados

Hurricanes 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; they also can cause flooding and road wash outs. With higher sea levels and increasing saltwater intrusion, the high winds, high precipitation rates, storm surges, and salts that accompany hurricanes will have large ecological impacts to terrestrial and freshwater ecosystems.

North Atlantic hurricane intensity and rainfall rates are projected to increase under continued climate change, although projections of the total number of North Atlantic hurricanes under climate change vary (IPCC 2013, USGCRP 2017). Under a medium greenhouse gas emissions scenario, the maximum intensity during the course of individual North Atlantic hurricanes could increase 4% and rainfall rates could increase 15% to 20% by 2100 (Knutson et al. 2015).

With continued climate change, the potential for severe thunderstorms that provide conditions for tornadoes may increase substantially (Abell et al. 2007, Diffenbaugh et al. 2013, Gensini and Mote 2015). Tornadoes can result in catastrophic damage to infrastructure from high winds, and associated debris, hail, and flash flooding. The number of days in spring in the eastern U.S. with severe thunderstorms that could produce tornadoes could increase 40% from 2000 to 2100 under the highest greenhouse gas emissions scenario (Diffenbaugh et al. 2013).

Pest infestation

Pests like termites and ants can damage structures. Moths and beetles can damage museum specimens and archival materials. Mosquitoes and ticks can transmit disease. Forest pests can kill trees causing treefall hazards to structures. It’s possible that higher temperatures and humidity can make the environment more favorable to pests, however, the use of pesticides to combat expanding invasive species may also threaten the ability to use an affected structure.

Climatic conditions are currently suitable for adult mosquitoes of the species *Aedes aegypti*, which can spread dengue, chikungunya, and Zika viruses, across most of the Southeast from July through September, and cities in South Florida already have suitable conditions for year-round mosquito activity. The Southeast is the region of the country with the most favorable conditions for this mosquito and thus

faces the greatest threat from diseases the mosquito carries (Monaghan et al. 2016). Climate change is expected to make conditions more suitable for transmission of certain vector-borne diseases, including year-round transmission in southern Florida. Summer increases in dengue cases are expected across every state in the Southeast (USGCRP 2018)

Increased temperatures will result in redistribution of pests and intensification of pest outbreaks (Logan et al. 2003). Because temperature and other environmental conditions influence forest insect populations and outbreaks, climate change has and will continue to impact pest infestations (Pureswaran et al. 2018).

Invasive species

Invasive species can have direct and indirect effects on infrastructure and may require parks to develop updated integrated pest management plans to account for newly arriving species. The persistence of nonnative species can impact the ability to reuse fill material and introduce safety concerns for construction (e.g., pythons). Further, shifts in invasive species can affect recreational uses of the park (fishing, snorkeling, diving, etc.), park operations, and the need for facilities to access these recreation sites.

Many invasive species spread into new areas or become more abundant where they are currently established as a result of changing climate conditions (Essl et al. 2019). Damage from extreme weather events has been implicated in the introduction of numerous invasive species, thus additional introductions are possible given projections for increasing storm intensity. The park has been invaded by multiple nonnative species, and, once established, invasive nonnatives are very difficult to completely eradicate. Native reptiles and mammals are at greatest risk. Aerial surveys in the park indicate that 55,000 acres of canopy is covered in nonnative plant species, primarily Brazilian pepper, melaleuca, lygodium, and Australian pine. Animal species such as the Burmese python can survive in all park habitats and are found throughout the park (NPS 2017).

Warming ocean temperatures due to climate change are expected to have a large effect on marine and coastal ecosystems (Doney et al. 2012). Many species are sensitive to small changes in ocean temperature; hence, the distribution and abundance of marine organisms are expected to be greatly altered by increasing ocean temperatures. For example, the distribution of tropical herbivorous fish has been expanding in response to warmer waters, which has resulted in the tropicalization of some temperate marine ecosystems and decreases in the cover of valuable macroalgal plant communities.

What Climate Risks or Hazards are Likely to Affect Facilities at EVER?

Several climate change hazards have been identified that may affect a facilities project (Appendix 1), including hotter average days, more extreme heat days, increased hurricane impacts from wind and flooding, altered precipitation patterns, and increased extreme precipitation, and more risk from invasive species, and pests. Infrastructure related to drinking water treatment and wastewater treatment may be compromised by climate-related events (USGCRP 2018). Infrastructure, particularly

roads, bridges, coastal properties, and urban drainage, is vulnerable to climate change and climate-related events. (USGCRP 2018).

Overall considerations

- Park asset management plans and site-specific project plans should be evaluated to include elements of climate change vulnerability and coastal adaptation strategies.
- Shoreline stabilization mechanisms can protect resources in place but are not long-term solutions and have tradeoffs, including disruption of natural processes.
- 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.

Adaptation and resiliency strategies for the expected hazards should be consistent with SFRCC 2017 and Beavers et al. 2016 and are described below.

- Hotter average days and more extreme heat days will increase demand and requirements for appropriately sized air conditioning systems.
- Extreme heat and humidity can stress the building envelope and will require significant humidity control alterations for structures.
- 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 National Center for Preservation Technology and Training regarding alternatives and maintenance for historic structures.
- The facilities proposed should be capable, during their useful life, of coping with the projected effects of climate change. This includes potential sea level rise and greater storm surge associated with more frequent and intense hurricanes
- There is no suitable alternate location within Everglades National Park for replacing Flamingo facilities. Most of Everglades National Park is designated wilderness, where developed facilities are inappropriate and not permitted. Just as importantly, Flamingo's real attraction is its coastal location, with views of Florida Bay and access to the Park's more than 600,000 acres of marine and estuarine waters.
- As a historically disturbed (filled and elevated) area that has accommodated visitor and operational facilities for the past 50 or so years, it makes sense to continue historical uses of Flamingo for the next 50 years, albeit applying more sustainable, climate-change aware

practices. Fifty years from now, the question of whether facilities should remain at Flamingo will need to be reconsidered in the context of updated climate change projections and observed climate change effects like sea level rise, increased storm surge, and increased hurricane intensity.

- Examples from the Flamingo Master Plan are current adaptation strategies that may be applicable in other areas of the park (NPS 2010):
 - Consolidate and minimize the developed footprint by building only what is truly needed and economically feasible, and by using spaces under elevated structures for other purposes (parking, shaded gathering areas, etc.) that would not be adversely impacted by flooding.
 - Keep infrastructure simple to reduce long-term maintenance needs and vulnerability to strong winds, storm surges, and saltwater corrosion.
 - Restore previously disturbed areas that are no longer needed for facilities.
 - Consider how development can best be sited, oriented, and designed to take maximum advantage of natural conditions such as breezes, natural light, energy from the sun, shade, etc.
 - Elevate and armor structures - especially overnight lodging and housing - to withstand storm surges and sea level rise impacts.
 - Build facilities to withstand Category 4 or greater hurricane force winds.
 - Adaptively reuse existing infrastructure where possible.
 - Use low-cost, mobile buildings that can be moved or removed when conditions warrant (e.g., eco-tents that are disassembled and stored during summer/fall, when visitor use is lower and hurricanes are likely).
 - Use native and/or local landscape plants and materials that ameliorate harsh environmental conditions, fit into the landscape, and require little special care.
 - Design and construct facilities that use the least amount of energy and water practicable. Use sustainable technologies such as solar power, graywater recycling, natural ventilation, ground-coupled cooling systems, and low-flow water fixtures to reduce energy and water consumption.
 - Use sustainable and conservation materials and practices during construction, operations, and maintenance.
 - Rebuild and restore in a way that encourages visitors and staff to walk, ride bicycles, or use shuttles instead of driving within Flamingo.

Additional Assistance

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 for assistance in evaluation of climate change hazards and resiliency strategies as they relate to specific infrastructure projects. Questions can be sent by typing GFIPHazardsandRiskAssistance into the [To:] line of an NPS email account; a member of that team will reply with support.

Additional resources can be found at the [NPS Facility Planning Branch Strategic Facility Investment Planning SharePoint site](#). This folder 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.

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Appendix 1: Climate-Related Natural Hazards 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
1. 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
2. Melting Permafrost/ Declining Sea and Lake Ice	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Road and building foundations unstable • Landslides and unstable hillsides • Shoreline erosion
3. 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)
4. Wildfire: Increased Frequency,	Known Hazard	• Damage to facilities and contents • Smoke damage • Air quality dangerous to staff and visitors

Intensity, Magnitude, and Duration	☒ Potential Hazard ☐ Not applicable ☐	• Increased runoff • Increased erosion • Damage to water treatment plants
5. Precipitation: Altered Patterns and Changing Humidity	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Local flooding • Mold growth • Wood decay • Drought • Fire • Groundwater change
6. 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
7. 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
8. Sea Level Change	Known Hazard	• Rising sea and lake levels

and Coastal Storm Surge	☒ Potential Hazard ☐ Not applicable ☐	• Rising water – wind driven (e.g., hurricane, nor'easter) • Saltwater intrusion • Vegetation damage • Need to elevate or relocate coastal facilities
9. Hurricanes, Tornadoes, 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)
10. 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.
11. Invasive Species	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Vegetation (e.g., kudzu, vines, Brazilian pepper) can damage buildings, kill trees, obstruct waterways. • Marine and aquatic invasive species
12. Subsurface Hazards	Known Hazard	• Surface collapse • Contamination

Cave/Karst (Sinkholes)	☒ Potential Hazard ☐ Not applicable ☐	• May affect freshwater availability, drainage, and drought potential • Abandoned Mineral Lands (AML) features
13. Shrink/ Swell Soils	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Damage to structure • “Heaving” of ground beneath structure • Increased landslide susceptibility
14. 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
15. Tsunami	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Coastal area inundation associated with earthquakes or undersea landslides • May be triggered by mass wasting events
16. Volcanic Eruption	Known Hazard	• Lava Flows • Fire

	☐ Potential Hazard ☐ Not applicable ☒	• Toxic gas releases • Ash
17. Hydrothermal Activity (e.g., Geysers)	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Toxic gas release • Explosion • Boiling water • Steam • Surface collapse into void
18. 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