



Climate Change Hazards Summary Report for Facility Investment Planning

Golden Gate National Recreation Area March 2021

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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 Golden Gate National Recreation Area

- 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 temperatures

Greenhouse gas emissions from human activities have increased temperatures globally (IPCC 2013), across the U.S. (USGCRP 2017), and in U.S. national parks (Gonzalez et al. 2018). Annual average temperature of the area within the boundaries of Golden Gate National Recreation Area increased at the statistically significant rate of $1.2 \pm 0.1^{\circ}\text{C}$ ($2.2 \pm 0.2^{\circ}\text{F.}$) per century from 1895 to 2017 (Gonzalez et al. 2018). Under the highest greenhouse gas emissions scenario, climate models project additional heating of Golden Gate National Recreation Area of $3.7 \pm 0.8^{\circ}\text{C}$ ($6.7 \pm 1.4^{\circ}\text{F.}$) by 2100. The temperature increase could be kept to $1.4 \pm 0.6^{\circ}\text{C}$ ($2.5 \pm 1.1^{\circ}\text{F.}$) under a scenario of reduced emissions (Gonzalez et al. 2018). Under the highest emissions scenario, models project up to 10 more days per year with a maximum temperature $>32^{\circ}\text{C}$ (90°F.) and an increase of $2\text{--}4^{\circ}\text{C}$ ($4\text{--}8^{\circ}\text{F.}$) in the hottest temperature of the year, from 1990 to 2050, in the San Francisco Bay Area (Vose et al. 2017). Extreme temperatures can increase weathering and stress on infrastructure and people.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
☐ No

Altered rainfall

Total annual precipitation of the area within the boundaries of Golden Gate National Recreation Area decreased slightly from 1895 to 2017, but the rate was not statistically significant (Gonzalez et al. 2018). For projections under continued climate change, approximately two-thirds of the climate models project increases and the other third project decreases (Gonzalez et al. 2018). This lack of agreement exists for monthly, seasonal, and annual projections. Even if precipitation were to increase, higher temperatures would tend to increase aridity through an increase in evapotranspiration (Byrne and O’Gorman 2015). The number of dry days per year and the number of extreme rainfall days could increase, leading to intense droughts alternating with intense wet periods (Polade et al. 2014, 2017; Swain et al. 2018). Changing rainfall affects drought, water scarcity, street flooding, mold growth, and wood decay.

Climate change has contributed to a 10% increase in 100-year storms (a day with more precipitation than any other day, on average, in 100 years) for the southwestern U.S. as a whole from 1958 to 2016 (Easterling et al. 2017). In the San Francisco Bay Area, continued climate change under the highest emissions scenario, could, by 2100, increase by 50% the frequency of extreme storms comparable to the storms that generated the 2016-2017 floods (Swain et al. 2018). Under the highest emissions scenario, climate change could increase the frequency and intensity of atmospheric rivers, narrow bands of highly concentrated storms that move from the Pacific Ocean into California, increasing rainfall in severe storms in the San Francisco Bay Area up to 40% by 2100 (Hagos et al. 2016, Huang et al. 2020). Extreme storms can cause flooding, damaging roads, buildings, drainage systems, and other infrastructure.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Drought

Drought is an extended period of low precipitation, surface water, or soil moisture below a long-term average. A severe drought struck most of California from 2012 to 2016, with the hottest annual average temperatures and lowest 12-month precipitation total since 1895 (Diffenbaugh et al. 2015). From 2012 to 2015, soil moisture for California as a whole dropped to its driest level in the past 1200 years (Robeson 2015). For California as a whole, the high temperatures of human-caused climate change accounted for one-tenth to one-fifth of the 2012-2014 period of the drought (Williams et al. 2015). From 2000 to 2018, the increased heat of human-caused climate change has caused half the severity of the most severe drought for the southwestern U.S. as a whole since the 1500s (Williams et al. 2020).

Under the highest emissions scenario, climate change could increase the number of dry days in the Sierra Nevada, the source of drinking water for San Francisco, by five to ten days per year (Polade et al. 2014). Under the highest emissions scenario, climate change could increase aridity in northern California in the period 2050-2099 to the 1% driest conditions experienced in the period 1931-1990 (Cook et al. 2015), with a 5% probability (one-in-twenty years) of a drought as severe as the 2012-2014 period of the California drought (Diffenbaugh et al. 2015). This could cause more frequent water shortages in California (Pagán et al. 2016). Drought can cause extensive tree mortality (van Mantgem et al. 2009).

Drought can also affect and water and wastewater system operations, water quality (Mosley 2015), and soil stability (Fernandes et al. 2015).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Wildfire

Wildfire is a natural part of many forest, woodland, and grassland ecosystems. Climate change is intensifying the heat that drives wildfire above natural levels (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). Across the western U.S., including the San Francisco Bay Area, analyses of causal factors found that human-caused climate change doubled the area burned by wildfire from 1984 to 2015 above natural levels, mainly through drying of vegetation (Abatzoglou and Williams 2016). Continued climate change under a high emissions scenario could increase fire frequencies across much of California, although models do not project substantial increases about current levels in the San Francisco Bay Area (Westerling 2018). Infrastructure located under or near tree canopies are vulnerable to burning and destruction.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Sea level rise and coastal storm surge

Human-caused climate change has increased global sea level through runoff from the melting of glaciers and ice on land and the expansion of ocean water when it warms (IPCC 2013, Slangen et al. 2016, Frederikse et al. 2020), increasing sea level at San Francisco 33 cm (13 in.) since 1854 (https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9414290). The sea level (tide) gauge is currently on a wharf at Crissy Field. Under the highest emissions scenario, continued climate change could raise sea level 1.4 m (4 ½ ft.) [range of projection 0.7-2.4 m (2-8 ft.)] at San Francisco by 2100 (Pierce et al. 2018). A 100-year storm off the Pacific Coast could add a 1.5 m (5 ft.) water surge on top of the increased sea level (Ruckert et al. 2017).

Sea level rise could increase periodic flooding of coastal areas of Golden Gate National Recreation Area and permanently inundate some shoreline areas. Sea level rise could cause or exacerbate saltwater intrusion into the groundwater at Stinson Beach (Hoover et al. 2017). Sea level rise and coastal storm surge may increase coastal erosion at sections of the coast that are retreating. At coastal locations such as Ocean Beach and Fort Funston, increased coastal erosion would reduce the area of beach available for recreation and concentrate visitor use in certain areas. Coastal erosion and storm surge may also undercut and destabilize bluffs and associated infrastructure.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Stream and urban street flooding

In addition to flooding from sea level rise, increases in extreme rainstorms could increase flooding in streams (Dougherty et al. 2020) and in urban streets in San Francisco from the lack of green space to absorb stormwater runoff (Newcomer et al. 2014). Flood threats to infrastructure include erosion, structural damage from the force of floodwaters, and damage to electrical systems. Post-flooding effects include rot, fungus, insects, mold, and mildew and physical deterioration of building materials.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Insect pests

Warmer and moister conditions, which may increase under climate change, tend to favor numerous insect pests, including termites, ants, and hornets (Sims and Appel 2017). Continued climate change under low to high emissions could increase the number of invasive termite species in the San Francisco Bay Area (Buczkowski and Bertelsmeier 2017). Pests can directly infest buildings and other infrastructure and indirectly affect infrastructure by increasing risks of tree death and falling branches or trees.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Invasive species

Climate change can favor invasive alien plant species in temperate zone ecosystems due to increased warmth, humidity, vegetation disturbances, and atmospheric carbon dioxide (Davidson et al. 2011, Early et al. 2016, Hellmann et al. 2008, Liu et al. 2017). Invasive weeds can create a hazard of fires from accidental ignitions. Invasive rodents can damage buildings and electrical and water systems.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

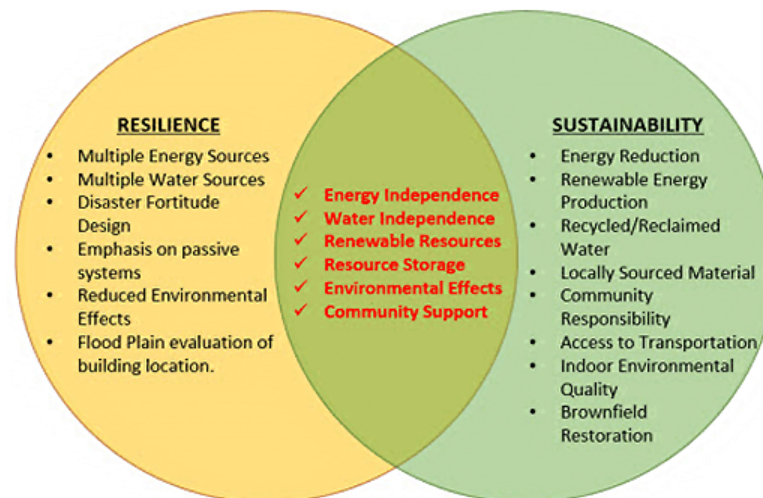
Step 2: Consider adaptation and resiliency strategies

- 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. See the NPS [Coastal Adaptation Strategies Handbook](#) (Beavers et al. 2016) for more NPS examples.

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](#)). Coastal parks can consult the Coastal Adaptation Strategies Handbook (Beavers et al. 2016) for information on coastal infrastructure, including piers and beach nourishment.

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

- An example response to Question 16 is provided below.
- You will need to identify the general type of project and modify the text below 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?

Several climate change hazards may affect a (historic building restoration, road repair, water system, other) project in Golden Gate National Recreation Area, 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:

- Sea level rise adaptation measures developed by Golden Gate National Recreation Area in a plan for Crissy Field (CMG Landscape Architecture 2016) and ongoing analyses at Stinson Beach.
- Natural shoreline features along the shore 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.
- Avoid new infrastructure in or near watercourses.
- Relocation of any infrastructure from an area where a hazard cannot be avoided.
- Install water conservation measures, including low-flow water fixtures, graywater recycling, and ground-coupled cooling systems.
- Clear any flammable vegetation away from buildings and follow the fire safety guidelines of the Firewise program <https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/Firewise-USA>
- Use site location, orientation, and design to take advantage of natural conditions such as breezes, shade, natural light, and sunshine for solar energy.
- Install energy conservation and renewable energy systems to reduce fossil fuel energy use.
- Incorporate building design features or systems to maintain appropriate temperatures and humidity without increasing energy use, which would increase greenhouse gas emissions and exacerbate climate change.
- Relocate any infrastructure from an area where a hazard cannot be avoided.
- Strengthen structures to prevent damage from extreme storms.
- Conduct early detection and removal of termites or other pests or hazards.

- Use weed and pest management control measures to prevent new introductions from construction equipment and materials.

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 Golden Gate National Recreation Area 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 Judgment' 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 ☐	• 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

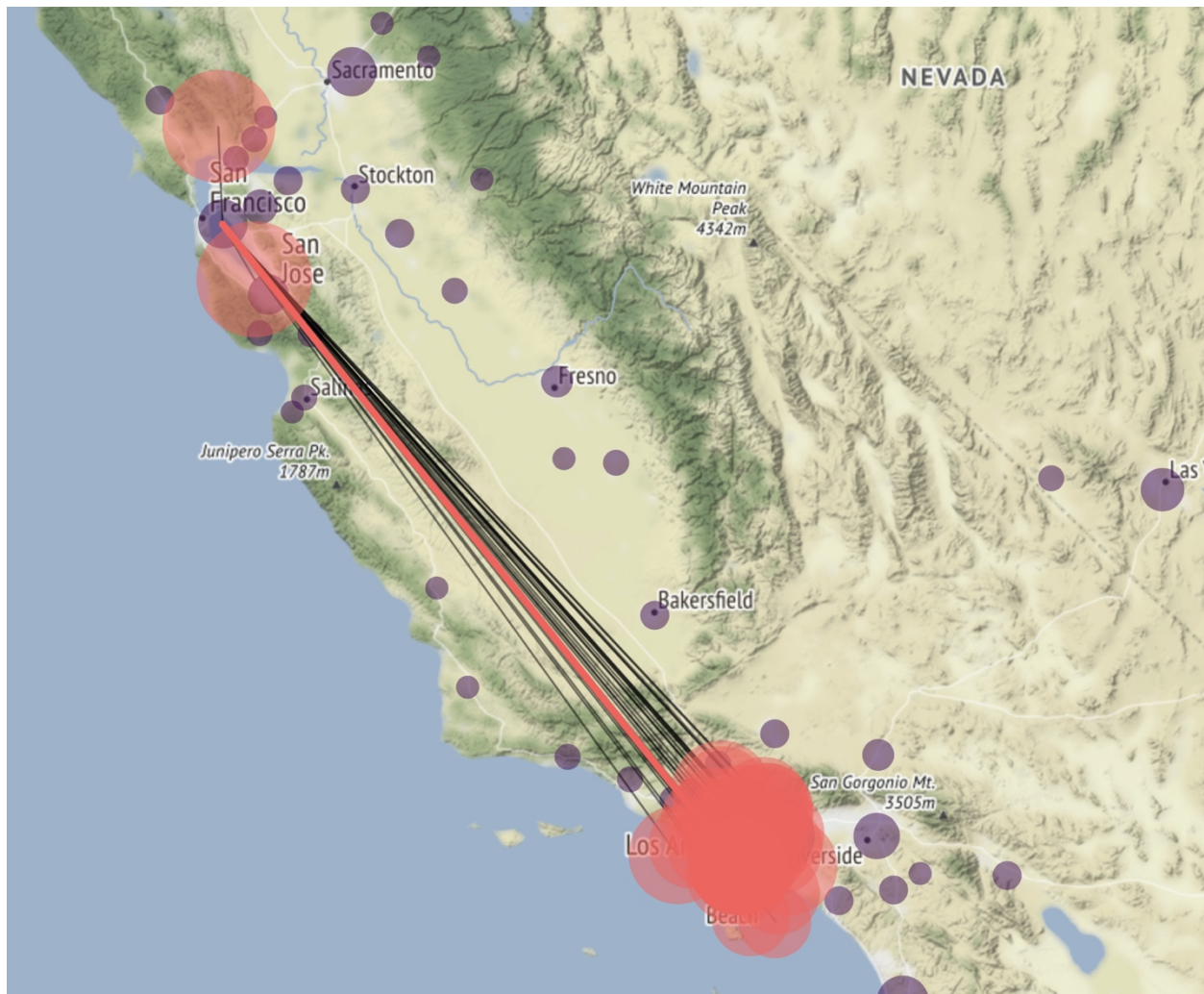
Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Altered precipitation patterns, increased extreme precipitation, and changing humidity	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Local flooding • Mold growth • Wood decay • Drought • Fire • Groundwater change • Surface erosion • Floods (see below) • Water damage to structures from driven rain • Unstable saturated soils	• National Climate Assessment • State climate summary	• National Climatic Data Center • DAYMet gridded climate data • National Park historical and projected climate change •
Street flooding	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 • Runoff projections (for select parks) • May require a special flood study

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
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	• NOAA SLR viewer • NOAA - Great Lakes Environmental Research Laboratory	• IRMA – Coastal reports • NPS SLR viewer • Specific Hazard Assessment: Coastal Storm Surge with Climate Change Effects (requires VPN connection) • SLR reports • Great Lakes Dashboard Project
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 Program	• NPS Pest and Invasive Species Management Contacts • Forest pests in eastern parks • 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)

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

The map below can help visualize how the climate at San Francisco could feel with continued climate change under high emissions by 2080, based on an analysis of climate model projections (Fitzpatrick and Dunn 2019). Under a high greenhouse gas emission scenario, San Francisco then could feel similar to Los Angeles today. The red line shows the average of the 27 climate models; the black lines show the 27 individual projections. Smaller circles indicating closer 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 at <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.