



Climate Change Hazards Summary Report for Facility Investment Planning

Yosemite National Park 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 Yosemite National Park

- 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 the Appendix, 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). For the area within the boundaries of Yosemite National Park, annual average temperature increased at the statistically significant rate of $1 \pm 0.2^{\circ}\text{C}$ ($1.8 \pm 0.4^{\circ}\text{F.}$) per century from 1895 to 2017 (Gonzalez et al. 2018). Under the highest greenhouse gas emissions scenario, climate models project additional heating of Yosemite National Park of $4.7 \pm 1^{\circ}\text{C}$ ($8.5 \pm 1.8^{\circ}\text{F.}$) by 2100. The temperature increase could be kept to $1.7 \pm 0.8^{\circ}\text{C}$ ($3.1 \pm 1.4^{\circ}\text{F.}$) under a scenario of reduced emissions (Gonzalez et al. 2018). Climate models also project more days in the Sierra Nevada of temperatures above current extreme temperatures (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 and snowfall

For the area within the boundaries of Yosemite National Park, total annual precipitation decreased slightly from 1895 to 2017, but the rate was not statistically significant (Gonzalez et al. 2018). For a network of snow courses in the northern Sierra Nevada, anthropogenic climate change reduced April snowpack one-tenth from 1950 to 1999 (Barnett et al. 2008).

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 increases, 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). Under the highest emissions scenario, climate change would tend to increase the elevation of the rainfall-to-snowfall transition in the winter in the Sierra Nevada (Klos et al. 2014) and increase the frequency of rain-on-snow events (Musselman et al. 2018). Changing rainfall and snowfall affect drought, wildfire, water scarcity, flooding, freezing and thawing, 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). 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 Sierra Nevada up to 40% by 2100 (Hagos et al. 2016, Huang et al. 2020). In the Sierra Nevada, continued climate change under the highest emissions scenario, could, by 2100, double the frequency of extreme storms comparable to the storms that generated the 2016-2017 floods (Swain et al. 2018). Extreme storms can cause flooding (see section below “River and stream floods”), 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 by five to ten days per year by 2090 (Polade et al. 2014). Under the highest emissions scenario, climate change could increase aridity in the Sierra Nevada 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 also affect and water and wastewater system operations, water quality (Mosley 2015), and soil stability (Fernandes et al. 2015).

Anthropogenic climate change doubled tree mortality in a network of plots across the western U.S., including plots in Yosemite National Park, from 1955 to 2007 from drought, wildfire, and bark beetles (van Mantgem et al. 2009). A network that included plots in the Sierra and Stanislas National Forests experienced 50% tree mortality after the 2012-2016 California drought (Fettig et al. 2019). Drought under continued climate change could increase tree mortality in the Sierra Nevada by 50% by 2100 (Goulden and Bales 2019). The falling of dead trees is a physical hazard to people and infrastructure and increases fuel for wildfires.

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 Sierra Nevada, 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 triple fire frequencies in the Sierra Nevada (Westerling 2018). Infrastructure located under or near tree canopies are vulnerable to burning and destruction.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

River and stream floods

Under continued climate change, projected increases in extreme storms (see section above “Altered rainfall and snowfall”) could increase flood risks along rivers and streams. Under the highest emissions scenario, continued climate change could increase January-March runoff 35% by 2030 in Yosemite National Park (Battaglin et al. 2020). Under high emissions, earlier snow melt due to climate change

could advance spring flow of the Tuolumne River up to a month by 2100 (Cristea et al. 2014). Continued climate change could substantially advance the timing of runoff, with the time at which half of water year runoff has occurred advancing two months in the Sierra Nevada, under the highest emissions scenario (Schwartz et al. 2017). So, floods could occur earlier than in the past. Nevertheless, the probability of a 1% flood (one in 100 years) would tend to decrease in the Merced River (Van Dusen et al. 2020). Flood threats to infrastructure include erosion, structural damage from the force of floodwaters, damage to roads, buildings, drainage systems, and other infrastructure, and post-flood physical deterioration of building materials.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Tornadoes

While tornadoes are uncommon in the Sierra Nevada, a tornado touched down in Sequoia National Park on July 7, 2004, in Rockwell Pass (Monteverdi et al. 2014). The state of California as a whole experienced approximately four tornadoes per year from 1950 to 2013 and a statistically significant increase of 0.3 tornadoes per decade (Guo et al. 2016). Historical tornado trends have not been attributed to climate change. Under continuing climate change, models project a slight increase in the number of severe thunderstorm days in the Sierra Nevada with conditions that generate tornadoes (Diffenbaugh et al. 2013). Tornadoes can result in catastrophic damage to infrastructure from high winds, debris, hail, and flash flooding.

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). Climate change also increases bark beetle infestations of conifers, causing tree mortality (see section above “drought”). Continued climate change under low to high emissions could increase the number of invasive termite species in the Central Valley and foothills of the Sierra Nevada (Buczowski 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, Hellmann et al. 2008, Liu et al. 2017). Yosemite National Park is in a zone of medium risk of invasive alien plant and animal species under climate change (Early et al. 2016). Invasive weeds can increase ground fuel for wildfires. Invasive rodents can damage buildings and electrical and water systems.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

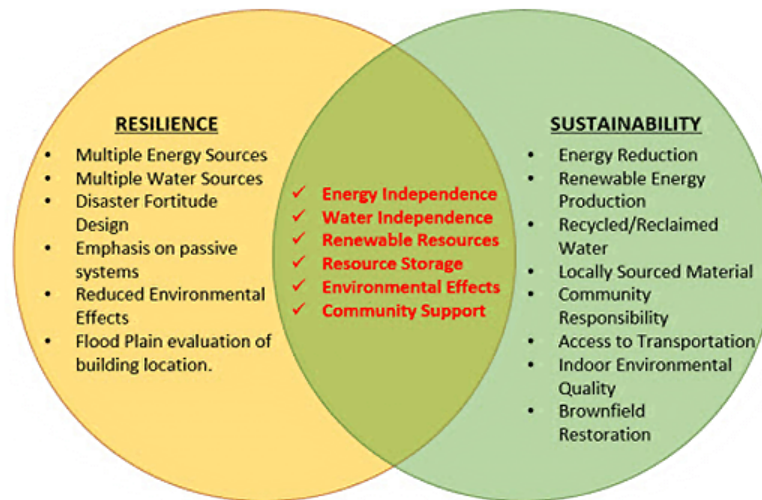
Step 2: Consider adaptation and resiliency strategies

- 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.

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

- 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 (new building, historic building restoration, road repair, water system, other) project in Yosemite National Park, including hotter temperatures, drought, and wildfire. Possible adaptation and resiliency strategies include:

- 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>
- Install water conservation measures, including low-flow water fixtures, graywater recycling, and ground-coupled cooling systems.
- Avoid new infrastructure in or near water courses.
- 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:

- The appendix below, which includes a full hazards checklist, providing additional links for supporting information related to each hazard.
- 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: The Climate-Related Hazard Checklist

This appendix provides an initial evaluation of climate hazards for Yosemite National Park 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 ☐	• 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 •
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 • 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)

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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.