



Climate Change Hazards Summary Report for Facility Investment Planning

Yellowstone National Park January 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?

How to Use this Information for your GFIP Projects

Parks can use information in this report to answer Question 16 as well as to inform other related GFIP questions. The steps to incorporate this information are as follows:

1. Review Section 1.0, Table 1: *Climate-related Hazards Checklist* to identify potential hazards for your project. The checklist is a “coarse filter” screening tool to help identify potential climate-related hazards that need to be addressed at an early stage in facility and asset planning. 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. Additional detail describing ‘known’ or ‘potential’ hazards for the park is provided in Appendix 1.
2. Review Section 2.0, which defines adaptation and resiliency strategies and provides an example answer to Question 16 of the GFIP Project Narrative Template.
3. Develop an answer to Question 16 for your specific project and location, as well as strategies to address each hazard. Language can be adapted from Section 2.0 and Appendix 1 to assist with formulating your answer.
4. If additional assistance is desired, see Section 3.0 for contact information.
5. Appendix 2 provides a map to visualize how climate is changing for the park. The map portrays the present-day location that has a climate similar to that expected by the 2080s for (or near) **Yellowstone National Park (YELL)**.

Section 1.0 Using the Climate-Related Hazard Checklist

This report provides an initial evaluation of climate hazards for **Yellowstone 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. Park and planning staff **must use their knowledge of specific projects, locations, and local conditions** to determine the actual risk posed by a particular hazard, and whether/when to consult subject matter experts to conduct a more detailed assessment.

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.

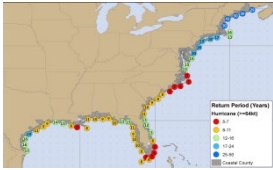
Not applicable: No evidence *was identified* showing this hazard is relevant to the park. Note this is a coarse filter evaluation; local knowledge of a hazard(s) should be used, when available.

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
1. 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
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	 • Global Permafrost Zonation Index Map	• Alaska CASC

Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
3. Increased drought 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)	• Drought Monitor • National Integrated Drought Information Center • National Climate Assessment • State Climate Summaries	• Drought Monitor • National Integrated Drought Information Center
4. 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	• NIFC • International Wildland-Urban Interface Code
5. Altered precipitation patterns and changing humidity	Known Hazard ☒ Potential Hazard ☐ Not applicable ☐	• Local flooding • Mold growth • Wood decay • Drought • Fire • Groundwater change	• 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
6. Increased extreme precipitation	Known Hazard ☐ Potential Hazard ☒ Not applicable ☐	• Surface erosion • Floods (see below) • Water damage to structures from driven rain • Unstable saturated soils	• National Climate Assessment • State climate summary	• Evaluations are mostly at regional scales
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	 • FEMA Flood map service	• FEMA Map Service Center • Floodplain maps for HUD projects • Van Dusen et al. 2020 • May require a special flood study
8. Sea/lake 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 • GRD SLR viewer • Specific Hazard Assessment: Coastal Storm Surge with Climate Change Effects • SLR reports • Great Lakes Dashboard Project

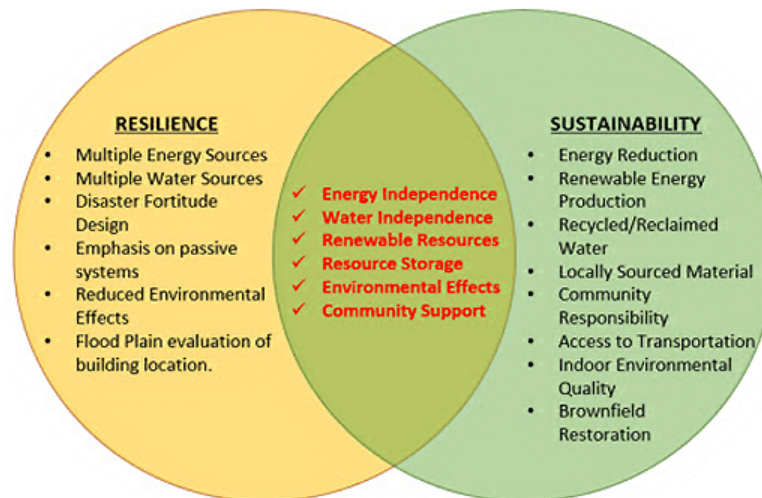
Potential Climate Hazard*	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
9. Hurricanes and tornados	Known Hazard ☐ Potential Hazard ☐ Not applicable ☒	• Building destruction • Flying debris • Storm Surge • Tree fall (see other categories for associated intense rainfall and floods)		• Wind Speed data – from local codes • International Building Code • FEMA Map Service Center • NPS Technical Support
10. 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	• Integrated Pest Management • Fisichelli et al. 2014 • USFS maps
11. 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	• Early Detection and Distribution Mapping System (current distribution) • Early Detection and Distribution Mapping System (projected distribution)

Section 2.0 Adaptation and Resiliency Strategies

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 generally refers to the ability of a 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.



“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](#)).

A significant amount of the infrastructure within national parks are 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 infrastructure, although NPS has detailed specific strategies when dealing with cultural resources and climate change in national parks. ([Cultural Resources Climate Change Strategy](#)).

Section 2.1 Example Answer to the PARK Project Narrative Template Question

A hypothetical response to Question 16 is provided below for a project at **Yellowstone National Park** that includes building assets.

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 have been identified that may affect projects in YELL, including hotter average days, more extreme heat days, increased drought frequency and intensity, altered precipitation and flooding patterns, increased wildfire, and increased invasive species abundance or distribution. Some example 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 appropriately sized air conditioning systems.
- Extreme heat can stress the building envelope and may require significant humidity control alterations for structures.
- Increased and more intense wildfires will require more planning in the wildland-urban interface, either by using fire-resistant building materials, reducing fuels near structures, or both.
- Increased drought and faster runoff can reduce the amount of water available for park use. New water sources might need to be identified and water conservation measures will need to be put in place.
- Heavy rains during the spring thaw can cause rapid melting of the snowpack resulting in severe flooding. Road construction may require larger culverts to accommodate heavy runoff. Buildings, infrastructure, and roads in existing flood zones may need additional mitigation.
- The potential for increased invasive species should be mitigated. Measures include mitigation during construction (e.g., using weed-free gravel and cleaning construction equipment) and increased weed treatment post construction.
- Termites are likely to arrive in YELL by mid-century. Early detection monitoring and eradication, if possible, will help protect historic structures and other buildings.

Section 3.0 Additional Assistance

The hypothetical response to Question 16 in Section 2.1 is provided as an example; 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 to the NPS [GFIP Hazards and Risk Assistance](#) email account and 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.

Appendix 1. Summary Information for Known or Potential Hazards Identified for Yellowstone National Park

Numbering relates to Potential Climate Hazard* presented in Table 1.

1. Hotter average days and more very hot days

Climate change is already 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 (U.S. Global Change Research Program et al. 2011). 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 (U.S. Global Change Research Program et al. 2018). Extreme temperatures can increase weathering of structures, threaten park staff and visitor safety, and increase stresses for HVAC systems. Demand for complex air conditioning systems can add stress to building envelopes and often requires significant alterations to a structure.

YELL has already experienced significant increases in temperature. Since 1948, annual temperatures across the Greater Yellowstone Area have averaged slightly above 39°F. Annual temperatures have increased by 0.31°F/decade (Chang and Hansen 2015). By mid-century, maximum temperature is projected to increase between 3.1 – 4.6 °F (moderate to high emissions scenario); by 2100, maximum average temperature is projected to increase between 4.4 to 9.7 °F (Gross et al. 2016).

Minimum (nighttime) temperatures are projected to increase even more intensely: up to 10.2 °F by 2100 under the high emissions scenario (Gross et al. 2016). The number of days with temperatures above 90 °F is projected to increase dramatically, especially at lower elevations, from ~ 5 days per year currently up to 34 days per year by end of century (Gross et al. 2016).

3. 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), and will enhance other related risks such as wildfire (Halofsky et al. 2020).

Wyoming is prone to droughts. From 1999 to 2008, large portions of Wyoming experienced drought conditions, followed by several years of above average precipitation. 2012 was Wyoming's driest year since historical records began in 1895. By October 2012 almost 90% of the state was in severe drought (Frankson et al. 2017). The intensity of future droughts is projected to increase, even as precipitation increases. Increasing temperature will increase evaporation rates, resulting in decreases in soil moisture during dry spells. Thus, future summer droughts, a natural part of the Wyoming climate, are likely to become more intense (Frankson et al. 2017).

Stream discharge has declined during 1950-2010 in 89% of streams analyzed in the Central Rocky Mountains, including those in the GYE (Leppi et al. 2012). Reduced flows were most pronounced during the summer months, especially in the Yellowstone River. This is reflective of declining amount of water in the snowpack (SWE) on April 1 of each year. Tercek et al. (2015) analyzed trends in April 1 SWE for 30 snow courses or SNOTEL sites across YELL and found that 70% (21/30) of the sites had significant declines during this 52-year period.

Snowpack declines will effect winter operations in YELL. The number of “driveable” days for oversnow vehicles during December—March is projected to decrease from in the West Yellowstone area from 77% during 1990–2010 to as low as 55% by mid-century and as low as 29% by late century. The south entrance road is projected to be the least affected by future climate change (Tercek and Rodman 2016).

4. Increased wildfire frequency, intensity, magnitude, and duration

Wildfire is a natural part of many forest, woodland, and grassland ecosystems but excessive fire 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 or other infrastructure located under or near tree canopies or dense grasslands are vulnerable to burning and destruction.

In the western U.S., analyses of causal factors have found that human-caused climate change has doubled the area burned by wildfire since 1984 above natural levels (Abatzoglou and Williams 2016). Under the highest emissions scenario, projected climate change could increase the frequency of large fires up to three times in the western U.S. by mid-century (Barbero et al. 2015).

Fire severity, frequency, and size are projected to increase in YELL in a warmer, drier climate. Westerling et al. (2011) projected changes in annual area burned and fire return intervals driven by climate scenarios by 2075 annual area burned was predicted to exceed 1988 levels, with years with no large fires becoming rare by 2050. Their findings projected a shift in the fire return interval to <30 years by 2050 for northern YELL and to <10 years by the end of the century. Clark et al. (2017) modeled future fire regimes on YELL’s Central Plateau. Annual area burned is projected to increase between 1.2 to 4.2 times more than historical. Fire return intervals are projected to decrease from the simulated historical rotation of 400 years to 336 years (low emissions) and 98 years (high emissions scenario), with shorter return intervals at lower elevations and longer return intervals at higher elevations.

5. Altered precipitation patterns and changing humidity

Changing precipitation patterns have been observed in many regions of the United States as result of climate change and changes are expected to continue. Depending on the region in the United States,

increases or decreases in precipitation have been experienced (U.S. Global Change Research Program et al. 2018). 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.

The amount, distribution, and variability of annual precipitation in the Northern Great Plains are anticipated to change, with 10 to 30% increases in winter and spring precipitation by the end of this century. The snow line (average lowest elevation at which snow falls) is also projected to move higher due to rising temperatures. It is likely that some precipitation that currently falls as snow will fall as rain instead (Easterling et al. 2017), reducing water storage in the snowpack, particularly at lower elevations. Higher spring temperatures will also result in earlier melting of the snowpack, further decreasing water availability during the drier summer months. In the mountains of western Wyoming and western Montana, the fraction of total water in precipitation that falls as snow is expected to decline by 25 to 40% by 2100 under a higher greenhouse gas emissions scenario (Pierce and Cayan 2013).

In the GYA, Chang and Hansen (2015) found a slight increase (0.4 in) in precipitation over the past century. Mean annual precipitation is projected to increase 2-4 inches by 2100. While temperature is projected to rise at similar rates across seasons, precipitation increases most rapidly in spring and decreases slightly in summer

6. Increased extreme precipitation

Increased frequency and intensity of extreme precipitation events has been attributed to climate change within some regions of the United States and such increases are projected to continue over the next century (U.S. Global Change Research Program et al. 2018). Furthermore, the intensity of extreme precipitation events increase with increasing temperatures (Easterling et al. 2017). 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.

In the northern Great Plains (which includes Montana and Wyoming), the frequency of heavy precipitation events is projected to increase, with an increase of about 50% in the frequency of two-day heavy rainfall events by 2050 under a high greenhouse gas emission scenario. Precipitation falling in single-day heavy events is projected to increase 8 to 10% by mid-century depending on emissions scenario (Easterling et al. 2017).

7. Riverine flood/Flash Flood

Extreme precipitation events and the risk of flooding are expected to regionally intensify with a changing climate (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.

In years with heavy snow cover, heavy rains during the spring thaw can cause severe flooding by causing rapid melting of the snowpack (Frankson et al. 2017). One study found that the magnitude of the 100 year flood (1% annual exceedance) generated from a high emissions scenario increased almost 30% for the Lamar River between the 1951–1979 and 2040–2069 periods (Van Dusen et al. 2020).

10. Pest infestation

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). This directly threatens the integrity of infrastructure (e.g., termite effects on wood structures) and indirectly affects structures through other mechanisms such as increased tree mortality leading to increased hazard trees or treefall.

As termite infestations are uncommon across the Northern US, termite prevention measures are not typically required in buildings or by building code (Peterson 2010). This is especially true of historic structures found in our national parks across northern climates. In the first global risk assessment of the expansion of termites, Buczkowski and Bertelsmeier (2017) found that the eastern subterranean termite, *Reticulitermes flavipes*, will likely expand to the Greater Yellowstone Ecosystem by 2050. The arrival of one of the most destructive termite species may prove catastrophic to the 695 historic properties in YELL.

11. Invasive species

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). 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 use of pesticides to combat expanding invasive species may also threaten structures.

Climate change may contribute to range expansion or contraction of invasive species. For example, Bradley (2009) and Bradley et al. (2009) have looked at invasive plants in the Western U.S. likely to expand their ranges, including yellow starthistle (*Centaurea solstitialis*) and tamarisk (*Tamarix spp.*); species likely to experience range expansion and contraction depending on local climatic variables, such as cheatgrass (*Bromus tectorum*) and spotted knapweed (*Centaurea biebersteinii*); and species predicted to contract in range, like leafy spurge (*Euphorbia esula*).

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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.