



Climate Change Hazards Summary Report for Facility Investment Planning

Lake Roosevelt National Recreation Area February 2021

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

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 Lake Roosevelt 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.

Localized assessments of climate and weather influences on proposed GFIP projects will be especially necessary in the case of Lake Roosevelt National Recreation Area (LARO). LARO extends from the Grand Coulee Dam along 150 miles of the Columbia River corridor, with more than 630 miles of shoreline. In cooperation with the Bureau of Reclamation, the Confederated Tribes of the Colville Indian Reservation, the Spokane Tribe of Indians, and the Bureau of Indian Affairs, the National Park Service is responsible for managing about 312 miles of shoreline, 47,438 acres of the 81,389-acre water surface, and 12,936 acres of land (NPS 2000). Climate change effects will vary across the long, linear NPS management jurisdiction due to synergistic interactions of latitudinal, altitudinal, and topographical influences on climate variability; land use practices in the watershed that are out of the NPS jurisdiction and control; geological processes (such as shoreline slumping and erosion) impacted by fluctuations of reservoir water levels up to 80 feet annually; and the dynamic nature of reservoir water management and dam control practices. All of these factors contribute to the need for local expertise in assessing the potential impact of the following climate hazards on proposed GFIP projects.

Hotter average days and more very hot days

Temperatures in LARO are already increasing beyond the historical range of variability (Monahan and Fisichelli 2014). Areas within 30 km (18.6 mi) of the park's boundary experienced "extreme" annual mean temperatures, minimum temperatures of the coldest month, mean temperatures of the driest quarter, and mean temperature of the warmest quarter, with "extreme" defined as the past 10-30 years

of these temperature variables exceeding 95% of the historical range of conditions observed from 1901-2012 (Monahan and Fisichelli 2014). For LARO, annual average temperature increased at the statistically significant rate of $0.7 \pm 0.2^{\circ}\text{C}$ ($1.3 \pm 0.4^{\circ}\text{F}$) per century from 1895 to 2009, and $1.3 \pm 0.6^{\circ}\text{C}$ ($2.3 \pm 1.1^{\circ}\text{F}$) per century from 1950 to 2010 (Gonzalez et al. 2018). Under the highest greenhouse gas emissions scenario, climate models project additional heating of the area within park boundaries of $5.1 \pm 1.2^{\circ}\text{C}$ ($9.2 \pm 2.2^{\circ}\text{F}$) by 2100 (Gonzalez et al. 2018). The temperature increase could be kept to $1.9 \pm 0.8^{\circ}\text{C}$ ($3.4 \pm 1.4^{\circ}\text{F}$) under a scenario of reduced emissions (Gonzalez et al. 2018). Warming has been greatest near the Grand Coulee Dam and between Gifford and Barnaby Island (Gonzalez 2014).

Extreme temperatures can increase weathering of structures, threaten park staff and visitor safety, and increase stresses for HVAC systems. If not addressed through building design or more efficient temperature control systems, the increased demand for complex air conditioning systems can add stress to building envelopes and can require significant alterations to a structure. In addition to direct impacts of temperature, facilities and operations may experience additional strain associated with increased visitation. As temperatures increase at LARO, visitation is also expected to increase including during peak seasons, shoulder seasons, and low visitation seasons. Increased visitation is predicted by strong historic relationships between monthly temperature and visitation at LARO (Fisichelli et al. 2015).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Altered precipitation patterns, increased extreme precipitation, and changing humidity

Climate change has contributed to a 9% increase in 100-year storms (a day with more precipitation than any other day, on average, in 100 years) for the Pacific Northwest as a whole from 1958 to 2016 (Easterling et al. 2017). Under the highest emissions scenario, models project a doubling of 5-year storms (a two-day period with more precipitation than any other two-day period in five years) (Easterling et al. 2017).

Projected warming will raise the elevation of the snow line in the mountains of Washington state. This will increase the proportion of precipitation falling as rain instead of snow, leading to less snow accumulation during the winter. Rainfall is expected to be the dominant form of precipitation across the majority of Washington by the end of the 21st century (Frankson et al. 2017). Increasing spring temperatures will also result in earlier melting of the snowpack, with snowpack projected to decline by up to 70% by the end of the 21st century (Frankson et al. 2017). This will decrease water availability during the already dry summer months and increase the risk of spring flooding due to earlier peak flows (Frankson et al. 2017).

For LARO, historical trends and model projections of precipitation in this semi-arid region are inconsistent. Precipitation across LARO has decreased since 1950 but the rate was not statistically significant (Gonzalez et al. 2018). It appears precipitation decreases have been greatest between Plum Point and Keller Ferry and in the vicinity of Kettle Falls (Gonzalez 2014). Under the lowest emissions

scenario, the average of climate model projections is a total annual precipitation increase of $7 \pm 5\%$ by 2100 while under the highest emissions scenario, the average of climate model projections is a total annual precipitation increase of $12 \pm 6\%$ by 2100 (Gonzalez et al. 2018).

Extreme storms can cause flooding, and damage to water and wastewater systems, drainage systems, roads, buildings, and other infrastructure, and cause erosion. Changing precipitation and humidity conditions can result in local flooding, encourage mold growth, wood decay, increase fire risk, and intensify drought conditions, depending on the pattern of change. Extreme precipitation events present a variety of threats to infrastructure and operations including flooding of sites, sewage backup, accelerated decay of masonry, overcoming drainage systems, road wash out, cracks in building infrastructure, destabilization of buildings and pipes, erosion of supporting ground around structures, among many other effects.

Park staff assessment – relevant to GFIP Project:

☐ Yes

☐ No

Increased drought frequency, intensity, magnitude, and duration

Rising air temperatures and changing precipitation patterns are exacerbating drought risk in many parts of the United States (Wehner et al. 2017). Droughts occur in the Pacific Northwest when warm or dry winters reduce snowpack or when hot, dry summers reduce soil moisture and streamflow (Dalton et al. 2013, Dello and Dalton, 2015). A record warm 2015 winter led to historically low snowpack in much of the Northwestern mountains as winter precipitation fell as rain instead of snow, resulting in drought, water scarcity, and wildfire throughout the region (Mote et al. 2016, May et al. 2018). Climate change-driven temperature increases are expected to deepen droughts in this region, particularly in areas with snowpack. Declining snowpack is expected to amplify summer drought conditions, increasing vulnerability to typical droughts caused by inter-annual precipitation variability (Vose et al. 2016, May et al. 2018).

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) and impair water quality (Mosley 2015). The 2015 drought necessitated use of \$7 million of relief funds to be used for backup emergency water supplies in Washington (May et al. 2018). Drought can also affect soil heaves and shrinkages (Fernandes et al. 2015) and will increase other related risks such as wildfire (Halofsky et al. 2020; see next section for more information on wildfire risk).

Park staff assessment – relevant to GFIP Project:

☐ Yes

☐ No

Increased wildfire frequency, intensity, magnitude, and duration

Wildfire is a natural part of many forest, woodland, and grassland ecosystems. Excessive fire, however, can damage ecosystems, kill people, and damage infrastructure. Climate change is intensifying the heat that drives wildfire (Jolly et al. 2015) and altering the distribution and density of vegetation that comprises the fuel for wildfires (Gonzalez et al. 2010). The effects of climate change on wildfire vary across landscapes and 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). 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, mainly through drying of vegetation (Abatzoglou and Williams 2016). Under the highest greenhouse gas emissions scenario, projected climate change could increase the frequency of large fires (>50 km², 20 sq. mi.) up to three times across the forests of the western U.S. by 2050 (Barbero et al. 2015).

Wildfires during the drier summer months of the Pacific Northwest are of particular concern (Frankson et al. 2017). The wildfire season of 2015 was the most destructive in Washington's history, with over 1 million acres burned, more than 6 times the average (Frankson et al. 2017). Snowpack in the mountains provides an important source of water during the drier summer months. Drier summers, along with warmer temperatures and earlier melting of the snowpack, increases the frequency and extent of wildfires (Frankson et al. 2017). For areas where projected climate change increases fire risk, buildings, cultural landscapes, or other infrastructure located under or near tree canopies or dense grasslands are vulnerable to burning and destruction.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Lake and reservoir water level change

Water levels at Grand Coulee Dam and Lake Roosevelt are impacted by changes in precipitation, which may result in low lake levels during dry periods due to diminished inputs and increased evaporation, or high water levels due to intense storms or consistent precipitation over a prolonged period. Hydrological projections under a high emissions scenario project a slight increase in annual Columbia River flow at the Grand Coulee Dam by 2080, decreased summer flow, a one-month shift of peak flow to earlier in the year, and a 5% increase in potential evapotranspiration (Hamlet et al. 2013).

Reservoirs and lakes with controls on inlet and outlet flows are used to manage surface water levels; however, climate change may result in extremes that limit the ability to meet water level requirements for user needs or overwhelm control systems resulting in flooding.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Riverine flood/Flash flood

Extreme precipitation events and the risk of flooding are expected to regionally intensify with a changing climate (Dethier et al. 2020, Tabari 2020). Model projections for southwest Washington state indicate extreme precipitation events will likely increase in the future (Mote et al. 2013). Heavier rains could also increase the likelihood of avalanches, and Lazar and Williams (2008) predicted the onset of wet avalanche activity is likely to begin earlier in the season, based on a climate change assessment of Aspen Mountain, Colorado. Furthermore, the intensity of extreme precipitation events increase with increasing temperatures (Easterling et al. 2017).

Factors such as snow and rain-dominance play a key role in determining changing flood risk with climate change in the western U.S. Hamlet and Lettenmaier (2007) found that for many snowmelt-dominant basins and cooler transition basins in the western interior flood risk is unchanged (because warming and precipitation have comparable magnitude and are in opposite directions). Large differences in flood risk occur in response to Pacific Decadal Oscillation and El Niño-Southern Oscillation patterns (Hamlet and Lettenmaier 2007).

Changes to the frequency of rain-on-snow events will also play a large role in determining future flood risk in many western states. Musselman et al. (2018) found in a warmer climate, rain-on-snow becomes less frequent at lower elevations because of snowpack decline, particularly for the Pacific maritime region. For higher elevation areas where snow cover is expected to persist, rain-on-snow events are projected to become more frequent due to a shift from snow to rainfall. Runoff is projected to increase for 55% for western basins, and in some areas increases flood risk 20-200% (Musselman et al. 2018).

Within region flood trends show high spatial variability depending on catchment conditions and the flood generating mechanism. In many cases climate is just one factor leading to flooding, with urbanization and other land cover changes exerting a strong influence (Peterson et al. 2013). Projected increases in heavy rainfall events for Washington state by mid-century could further increase flood risk (Frankson et al. 2017). In some cases, it is inadequate to assume that design flood values will remain stationary in the future as climate changes (Van Dusen et al. 2020). As a result, local studies to characterize changes in extreme flows (VanDusen et al. 2020) or increases in current safety factors may be necessary to account for climate change in infrastructure design.

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.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Tornadoes

Climate change can increase the frequency of severe thunderstorms, which generate tornadoes. Historical records from 1954 to 2017 show mixed trends in tornado occurrences with no statistically significant trend for the U.S. as a whole (Agee et al. 2016, Brooks et al. 2014, Gensini and Brooks 2018), although some studies suggest the number of days with over 30 tornadoes (Brooks et al. 2014, Elsner et al. 2015) and the number of tornadoes per tornado outbreak have increased (Moore 2017, Tippet and Cohen 2016). Moreover, tornado power, a function of wind speed, tornado path area, and air density, has increased $5\% \pm 1\%$ per year from 1994 to 2016 (Elsner et al. 2019). Tornadoes can result in catastrophic damage to infrastructure from high winds, and associated debris, hail, and flash flooding.

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Pest infestation

Increased temperatures and CO₂, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of pests (IPCC 2014). 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 Pacific Northwest (Buczowski and Bertelsmeier 2017). Across western North America climate change has caused bark beetle outbreaks leading to the most extensive tree mortality in the last 125 years (Raffa et al. 2015). According to the [Forest Health Advisor System](#), 9% of tree biomass is at risk to forest pests in LARO (Krist et al. 2014).

Pests can directly infest buildings and other infrastructure. Facilities may be impacted indirectly through other mechanisms exacerbated by climate change such as forest insect pest invasions or fluctuating ground water levels leading to increased tree mortality, hazard trees, and treefall. Rooting and burrowing mammals and termites have the potential to cause direct damage to power, water, transportation, and building facilities (Vissichelli 2018).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

Invasive species

Increased temperatures and CO₂, changes in precipitation, and disturbance due to extreme climate events can increase the survival, spread, growth, and establishment of invasive species (IPCC 2014). Weeds and aquatic mussels have the potential to cause direct damage to power, water, transportation, and building facilities (Vissichelli 2018). Non-native species that may not currently impact facilities may become harmful due to changes in local climates (NRC 2002, IPCC 2014).

The economic, recreational, and ecological impacts of aquatic invasive species (AIS) are well documented. While Lake Roosevelt is currently relatively free of AIS, non-native plants, animals, and pathogens are a potential threat that could negatively impact visitor use and enjoyment of Lake Roosevelt. AIS such as quagga and zebra mussels, New Zealand mudsnail, and Eurasian watermilfoil can clog cooling systems on boats, foul hulls and equipment, and adversely impact lakeshore recreation and facilities. Areas of the lake have been invaded by Eurasian watermilfoil and rusty crayfish; where facilities projects may require infrastructure and equipment to interact with the lake waters, it will be important to explicitly and actively take measures (clean, drain, dry) such that equipment and boats do not spread these AIS to other areas of the lake.

Fire and natural resource management efforts such as fuel reduction and hazard tree removals to accommodate and protect facilities will require attention and efforts to limit the spread of invasive weeds like: spotted knapweed (*Centaurea maculosa*), diffuse knapweed (*C. diffusa*), yellow star-thistle (*C. solstitialis*), leafy spurge (*Euphorbia esula*), Dalmatian toadflax (*Linaria dalmatica*), Canadian thistle (*Cirsium arvense*), tumbleweed (*Sisymbrium altissimum*), and cheat grass (*Bromus tectorum*).

Park staff assessment – relevant to GFIP Project:

- ☐ Yes
- ☐ No

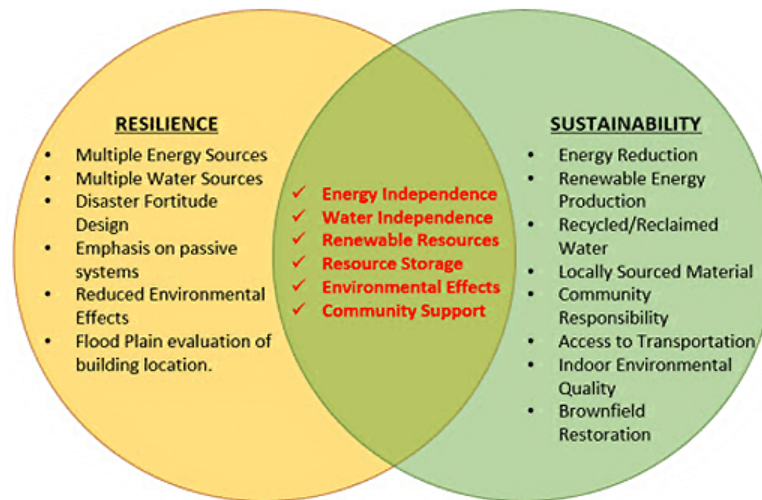
Step 2: Consider adaptation and resiliency strategies

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

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

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

It is important to note that resilient park operations can be supported through the use of green infrastructure such as sustainable landscaping, as well as sustainable energy, water, and building envelope solutions. The figure below illustrates this relationship.



Lists of adaptation strategies for different types of infrastructure projects in response to different hazards can be found here: [Incorporating Climate Change Adaptation in Infrastructure Planning and Design](#) (see Chapter 4, Tables 25-34). If used, these adaptation strategies will need to be modified for proposed park projects.

Buildings and assets within national parks may include cultural resources (e.g., historic and pre-historic buildings and structures). The adaptation and resiliency options for cultural resources often overlap with those defined for facilities; however, NPS has detailed specific strategies when dealing with cultural resources and climate change in national parks ([Cultural Resources Climate Change Strategy](#)). “Climate change poses an especially acute problem for managing cultural resources because they are unique and irreplaceable — once lost, they are lost forever” ([NPS Policy Memorandum 14-02](#)).

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

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

Question 16: What risks or hazards (current and projected, e.g. effects of climate change) are likely to affect this project? If applicable, what adaptation strategies and/or resiliency measures have been identified for scenarios that pose high risks to project assets?

Example from Grand Teton National Park: Road improvement project

Several climate change related hazards have been identified that may affect projects in GRTE, 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. The primary hazard affecting this project is spring runoff and flooding. Projected warmer and wetter spring seasons are likely to result in increased rain on snow events, which lead to higher peak spring runoff volume, flooding, and streambank scour/erosion. Increased flooding along with potential impacts from increased wildfire (erosion and reduced infiltration) will cause the river channel to become even more dynamic and increase the likelihood of road bank failure.

Past weather-related impacts at Gros Ventre Road include:

- The Gros Ventre River is a braided river that is roughly 1,500 feet wide and the active flow channels frequently migrate and avulse across the braided channel. In recent years, unprecedented spring high water flows have caused the main channels of the river to erode the bank adjacent to and undercutting the Gros Ventre Road. In 2017, the road washed out and required \$6M in repairs.

Future climate changes that may impact this project could include:

Precipitation changes

- Expected warmer and wetter spring seasons are likely to result in rain over snow events, which lead to higher peak spring runoff volume and water velocity. It is predicted that the temporary fixes have a limited lifespan if runoff and higher than average spring flows continue to increase, and the river does not change course.
- If precipitation increases or changes, this too may cause increased soil moisture which may affect the structural integrity of the roads and slopes.

Increased temperatures may contribute to pavement degradation. Crack/heave damage occurs in drier soils.

The park will consider the following measures to improve resilience to these hazards:

- Design and Engineering Enhancements:
 - This project will either armor the bank or relocate the roadway away from the river (onto a nearby bench away from the highly eroded riverbank allowing the river to maintain a more natural course), depending on future studies (archeological, hydrologic, engineering, etc.), environmental analysis, and potential lifecycle costs of both options taking into account the future potential hazard of increased flows and the river changing course.
 - Slopes may need to be adjusted and properly placed culverts installed.
- Planning
 - Revegetation will be a vital component to increase resilience to precipitation changes and increased temperatures. Design and maintenance are vital.

This project will advance sustainability through the following strategies:

- The 2006 Transportation Plan which analyzed 22.5 miles of multiuse pathways and 18.8 miles widened shoulders to be used as a bike lane, including this segment of the Gros Ventre Road. These pathways and widened shoulders are not only used by park visitors recreationally, but also for local residents commuting to and from work in the park and the town of Jackson, providing enhanced recreational and transportation opportunities that are low carbon output.

Example for Glen Canyon National Recreation Area:

Several climate change hazards may affect building-related projects at GLCA, including hotter average days, more extreme heat days, increased impacts from wind and flooding, altered precipitation patterns (i.e. drought), increased extreme precipitation (e.g. flash flooding), and potential wildfire. Adaptation and resiliency strategies for the expected hazards are described below:

- Changes in building design or building systems may allow maintenance of appropriate temperatures and humidity without increasing energy use (which would increase greenhouse gas emissions and exacerbate climate change). Energy conservation and renewable energy systems can prevent any increase in fossil fuel energy use.
- Hotter average days and more extreme heat days will increase demand and requirements for higher capacity air conditioning systems unless accommodated through modified building designs or other systems.
- Water source needs and availability have been identified and water conservation measures will be prioritized. New restroom facilities will use water efficient fixtures.
- As water levels change, NPS must update and adjust infrastructure, like boat ramps, to accommodate those changes and continue boater access to water. GLCA has made adjustments and will continue to make adjustments to keep boating recreation open to the public after the adjustments. For example, at Lake Powell, the Hite boat ramp was closed several years ago and replaced by a relocated ramp that works at a lower water elevation.
- Winter and spring precipitation is projected to increasingly fall in the form of heavier precipitation events with earlier spring snow melt, which can increase flooding and runoff. Road construction may require larger culverts to accommodate heavy runoff. Buildings, infrastructure, and roads in existing flood zones may need additional mitigation.
- Increased temperatures and crack/heave damage in drier soils, which may contribute to pavement degradation.
- Hotter and drier conditions will likely lead to an increase in wildfires. It will be important to maintain or increase the park's prescribed fire program and design any structures susceptible to wildfire damage with fire-resistant materials.
- Clearing any flammable vegetation, hazard trees, or other material away from buildings.
- 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 monitoring and treatment post construction.
- Use native and/or local landscape plants and materials that ameliorate harsh environmental conditions, fit into the landscape, and require little special care.
- Implement noxious weed and pest management programs that include early detection, monitoring, and eradication efforts, as well as construction mitigation to avoid new introductions.

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 **Lake Roosevelt 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 ☐	• Inadequate HVAC • Road surface degradation • Lack of water due to increased water for irrigation • Increased humidity • Danger to staff	• National Climate Assessment • State climate summary	• National Climatic Data Center • DAYMet gridded climate data • National park historical and projected climate change

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Increased drought frequency, intensity, magnitude, and duration	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	- Limited water supply for cooling, landscaping, structural fire suppression, other equipment - Increased competition for available water and water rights conflicts - Crack/heave damage in drier soils - Increased vulnerability to wildfire (below)	Drought Monitor National Integrated Drought Information Center National Climate Assessment State climate summary	Drought Monitor National Integrated Drought Information Center
Increased wildfire frequency, intensity, magnitude, and duration	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	- Damage to facilities and contents - Smoke damage - Air quality dangerous to staff and visitors - Increased runoff - Increased erosion - Damage to water treatment plants	Barbero et al. 2015 International Journal of Wildland Fire	NIFC International Wildland-Urban Interface Code

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 • Evaluations are mostly at regional scales
Riverine flood/flash flood	Known Hazard ☐ Potential Hazard ☒ Not Applicable ☐	• Damage or destruction of infrastructure • Stream channel migration • Stream bank erosion/extreme erosion • Safety • Water quality diminished • Damage to water source and delivery infrastructure • Changing requirements for culvert flow capacity	• FEMA Flood map service	• FEMA Map Service Center • Floodplain maps for HUD projects • Van Dusen et al. 2020 (for select parks) • May require a special flood study

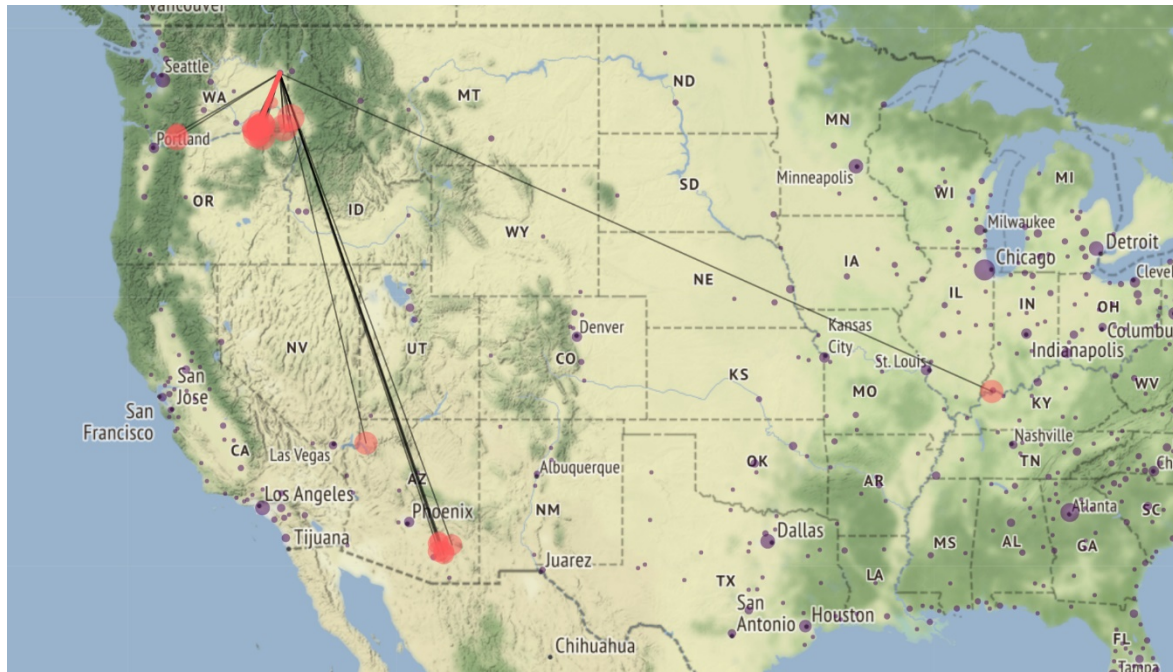
Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Sea level change and coastal storm surge	Known Hazard ☐ Potential Hazard ☐ Not Applicable ☒	• Rising sea and lake levels • Rising water – wind 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
Lake and reservoir level change	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐			
Hurricanes and tornadoes	Known Hazard ☐ Potential Hazard ☒ Not Applicable ☐	• Building destruction • Flying debris • Storm surge • Tree fall (see other categories for associated intense rainfall and floods)		• Wind speed data – from local codes • International Building Code • FEMA Map Service Center

Potential Climate Hazard	Best Professional Judgment	Examples of risk or secondary hazard	Sources of General Non-site specific Data	Sources for Site Specific Data
Pest infestation	Known Hazard ☒ Potential Hazard ☐ Not Applicable ☐	• Historic/facility fabric loss • Vegetation loss • Disease vectors may increase • Termites and other woodboring pests expanding range with warming and increased humidity	• USFS Forest Health Advisory System	• NPS Pest and Invasive Species Management Contacts • Fisichelli et al. forest pests • USFS maps
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 Will the Park Climate Feel Like in 60 Years?

The map below is intended to help visualize how the present-day climate in the region of **Lake Roosevelt National Recreation Area** is projected to change as a result of climate change (Fitzpatrick and Dunn 2019). Under a high greenhouse gas emission scenario, Spokane, Washington's climate in 2080 may feel like today's climate near Walla Walla, Washington. The typical summer in Walla Walla, Washington is 5.9°F (3.3°C) warmer and 30.2% drier than summer in Spokane, Washington. The red line shows the average of the 27 climate models; the black lines show the 27 individual projections assuming continued high emissions, providing a sense of the plausible range of future climates. The size of a red circle gives a sense of how good of a match that location is, with smaller circles indicating better matches; all circles (red or purple) denote cities used in the analysis. The analysis is based on twelve

climate metrics, including minimum and maximum temperature and precipitation by season (spring, summer, fall, winter). More details are available in the reference cited above and the website <https://fitzlab.shinyapps.io/cityapp/>.



References

- Abatzoglou, J. T., and A. P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences* **113**:11770-11775.
- Agee, E., J. Larson, S. Childs, and A. Marmo. 2016. Spatial redistribution of U.S. tornado activity between 1954 and 2013. *Journal of Applied Meteorology and Climatology* **55**: 1681-1697.
- Agee, J. K., and C. N. Skinner. 2005. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* **211**:83-96.
- Barbero, R., J. T. Abatzoglou, N. K. Larkin, C. A. Kolden, and B. Stocks. 2015. Climate change presents increased potential for very large fires in the contiguous United States. *International Journal of Wildland Fire* **24**:892-899.
- Brooks, H.E., G.W. Carbin, and P.T. Marsh. 2014. Increased variability of tornado occurrence in the United States. *Science* **346**: 349-352.
- Buczowski, G., and C. Bertelsmeier. 2017. Invasive termites in a changing climate: A global perspective. *Ecol Evol* **7**:974-985.
- Dalton MM, Mote PW, Snover AK [eds]. 2013. *Climate change in the Northwest: Implications for our landscapes, waters, and communities*. Island Press, Washington DC.
- Dello, K., and M. Dalton. 2015. *Drought in the Pacific Northwest: A report for the Bureau of Land Management*. Department of Homeland Security. 2015. *Drought Impacts to Critical Infrastructure*. Office of Cyber and Infrastructure Analysis. April 23, 2015.

- Dethier, E. N., S. L. Sartain, C. E. Renshaw, and F. J. Magilligan. 2020. Spatially coherent regional changes in seasonal extreme streamflow events in the United States and Canada since 1950. *Science Advances* 6:eaba5939.
- Easterling, D. R., J. R. Arnold, T. Knutson, K. E. Kunkel, A. N. LeGrande, L. R. Leung, R. S. Vose, D. E. Waliser, and M. F. Wehner. 2017. Ch. 7: Precipitation Change in the United States. *Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program.*
- Elsner, J.B., T. Fricker, and Z. Schroder. 2019. Increasingly powerful tornadoes in the United States. *Geophysical Research Letters* 46: 392-398.
- Elsner, J.B., S.C. Elsner, and T.H. Jagger. 2015. The increasing efficiency of tornado days in the United States. *Climate Dynamics* 45: 651-659.
- Fernandes, M., A. Denis, R. Fabre, J.-F. Lataste, and M. Chrétien. 2015. In situ study of the shrinkage-swelling of a clay soil over several cycles of drought-rewetting. *Engineering Geology* 192:63-75.
- Fisichelli, N.A., Schuurman, G.W., Monahan, W.B., and Ziesler, P.S. 2015. Protected area tourism in a changing climate: will visitation at US national parks warm up or overheat? *PLoS One* doi: 10.1371/journal.pone.0128226.
- Fitzpatrick, M. C., and R. R. Dunn. 2019. Contemporary climatic analogs for 540 North American urban areas in the late 21st century. *Nature Communications* 10:614. <https://fitzlab.shinyapps.io/cityapp/>.
- Frankson, R., K. Kunkel, S. Champion, D. Easterling, L. Stevens, K. Bumbaco, N. Bond, J. Casola, and W. Sweet. 2017. Washington State Climate Summary. NOAA Technical Report NESDIS 149- WA, 4 pp.
- Gensini, V.A. and H.E. Brooks. 2018. Spatial trends in United States tornado frequency. *Climate and Atmospheric Science* 1: 38. doi:10.1038/s41612-018-0048-2.
- Gonzalez, P., F. Wang, M. Notaro, D. J. Vimont, and J. W. Williams. 2018. Disproportionate magnitude of climate change in United States national parks. *Environmental Research Letters* 13:104001.
- Gonzalez, P. 2014. Climate change summary, Lake Roosevelt National Recreation Area, Washington. Resource brief. Natural Resource Stewardship and Science, U.S. National Park Service, Washington D.C.
- Gonzalez, P., R. P. Neilson, J. M. Lenihan, and R. J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography* 19: 755-768.
- Halofsky, J. E., D. L. Peterson, and B. J. Harvey. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. *Fire Ecology* 16:4.
- Hamlet, A.F., M.M. Elsner, G.S. Mauger, S.Y. Lee, I. Tohver, and R. A. Horheim. 2013. An overview of the Columbia Basin climate change scenario projections project: Approach, methods, and summary of key results. *Atmosphere-Ocean* 51: 392-415.
- Hamlet, A. F., and D. P. Lettenmaier. 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S. *Water Resources Research* 43.
- IPCC. 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf.
- Jolly, W. M., M. A. Cochrane, P. H. Freeborn, Z. A. Holden, T. J. Brown, G. J. Williamson, and D. M. Bowman. 2015. Climate-induced variations in global wildfire danger from 1979 to 2013. *Nature Communications* 6:7537.
- Krist, F.J., Jr., Ellenwood, J. R., Woods, M. E., McMahan, A.J., Cowardin, J. P., Ryerson, D. E., Sapio, F. J., Zweifler, M. O., Romero, S.A. 2014. 2013-2027 National Insect and Disease Forest Risk Assessment. FHTET-14-01. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Forest Health Technology Enterprise Team.

- Lazar, B., and M. Williams. 2008. Climate change in western ski areas: Potential changes in the timing of wet avalanches and snow quality for the Aspen ski area in the years 2030 and 2100. *Cold Regions Science and Technology* 51:219-228.
- May, C., C. Luce, J. Casola, M. Chang, J. Cuhaciyan, M. Dalton, S. Lowe, G. Morishima, P. Mote, A. Petersen, G. Roesch-McNally, and E. York. 2018. Northwest. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1036–1100. doi: 10.7930/NCA4.2018.CH24
- Monahan, W.B., and N.A. Fisichelli. 2014. Climate exposure of US national parks in a new era of change. *PLoS ONE* 9(7): e101302. Doi: 10.1371/journal.pone.0101302.
- Moore, T.W. 2017. On the temporal and spatial characteristics of tornado days in the United States. *Atmospheric Research* 184: 56-65.
- Mosley, L. M. 2015. Drought impacts on the water quality of freshwater systems; review and integration. *Earth-Science Reviews* 140:203-214.
- Mote, P. W., D. E. Rupp, S. Li, D. J. Sharp, F. Otto, P. F. Uhe, M. Xiao, D. P. Lettenmaier, H. Cullen, and M. R. Allen. 2016. Perspectives on the causes of exceptionally low 2015 snowpack in the western United States. *Geophysical Research Letters*, 43 (20), 10,980-10,988. doi:10.1002/2016GL069965.
- Mote, P., J. Abatzoglou, and K. Kunkel. 2013. Climate change and variability in the past and future. In: Dalton, M.M.; Mote, P.W.; Snover, A.K., eds. *Climate change in the Northwest: implications for our landscapes, waters and communities*. Washington, DC: Island Press: 25–40.
- Musselman, K. N., F. Lehner, K. Ikeda, M. P. Clark, A. F. Prein, C. Liu, M. Barlage, and R. Rasmussen. 2018. Projected increases and shifts in rain-on-snow flood risk over western North America. *Nature Climate Change* 8:808-812.
- National Park Service. 2000. Fire management plan environmental assessment: Lake Roosevelt National Recreation Area.
- NRC. 2002. *Predicting Invasions of Nonindigenous Plants and Plant Pests*; National Academies Press: Washington, DC, USA. ISBN 978-0-309-08264-8.
- Peterson, T. C., Heim, R. R., Jr., Hirsch, R., Kaiser, D. P., Brooks, H., Diffenbaugh, N. S., Dole, R. M., Giovannettone, J. P., Guirguis, K., Karl, T. R., Katz, R. W., Kunkel, K., Lettenmaier, D., McCabe, G. J., Paciorek, C. J., Ryberg, K. R., Schubert, S., Silva, V. B. S., Stewart, B. C., Vecchia, A. V., Villarini, G., Vose, R. S., Walsh, J., Wehner, M., Wolock, D., Wolter, K., Woodhouse, C. A., & Wuebbles, D. 2013. Monitoring and Understanding Changes in Heat Waves, Cold Waves, Floods, and Droughts in the United States: State of Knowledge, *Bulletin of the American Meteorological Society*, 94(6), 821-834.
- Raffa, K. F., B. H. Aukema, B. J. Bentz, A. L. Carroll, J. A. Hicke, and T. E. Kolb. 2015. Responses of tree-killing bark beetles to a changing climate. In *Climate Change and Insect Pests* (pp. 173-201). CABI International.
- Sims, S. R., and A. G. Appel. 2017. Climate change and the new dynamics of urban pest management in North America. Pages 31–49 in P. Dhang, editor. *Climate change impacts on urban pests*. CABI, Wallingford.
- Tabari, H. 2020. Climate change impact on flood and extreme precipitation increases with water availability. *Scientific Reports* 10:13768.
- Tippett, M.K. and J.E. Cohen. 2016. Tornado outbreak variability follows Taylor’s power law of fluctuation scaling and increases dramatically with severity. *Nature Communications* 7: 10668. doi:10.1038/ncomms10668.
- Van Dusen, P., B. Rajagopalan, D. J. Lawrence, L. E. Condon, G. Smillie, S. Gangopadhyay, and T. Pruitt. 2020. 21st Century flood risk projections at select sites for the U.S. National Park Service. *Climate Risk Management* 28:100211.

- Vissicelli, M. 2018. Invasive species impacts on federal infrastructure. National Invasive Species Council Secretariat, Washington, DC.
https://www.doi.gov/sites/doi.gov/files/uploads/invasive_species_impacts_on_federal_infrastructure.pdf
- Vose, J., J. S. Clark, C. Luce, and T. Patel-Weynand [Eds.]. 2016. Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis. Gen. Tech. Rep. WO-93b. U.S. Department of Agriculture, Forest Service, Washington Office, Washington, DC, 289 pp. URL.
- Wehner, M. F., J. R. Arnold, T. Knutson, K. E. Kunkel, and A. N. LeGrande. 2017. Droughts, floods, and wildfires. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 231-256.

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.