A CHANGING CLIMATE

VULNERABILITY IN CALIFORNIA'S EASTERN SIERRA

Adaptation & Resilience Assessment

Natural Capital & Ecosystem Services Analysis

Recommended Actions

EASTERN SIERRA
Sustainable Recreation Partnership

SUSTAINABLE RECREATION & TOURISM INITIATIVE

Funded by a grant from Proposition 68 and the Sierra Nevada Conservancy

MAY 2021

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Eastern Sierra Sustainable Recreation and Tourism Initiative

Prepared for:

Town of Mammoth Lakes
on behalf of
The Eastern Sierra Sustainable Recreation Partnership
and for the delivery of
The Sustainable Recreation and Tourism Initiative

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ACKNOWLEDGEMENTS

FUNDING

Funding for this project has been provided by the Sierra Nevada Conservancy, an agency of the State of California, under the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access for All Act of 2018 (Proposition 68) and in support of the Sierra Nevada Watershed Improvement Program.

PROJECT TEAM

PlaceWorks is one of the West's preeminent planning, design, and environmental consulting firms, serving both public- and private-sector clients in the fields of climate action and resiliency, comprehensive planning, environmental review, urban design, landscape architecture, community outreach, and GIS. For more information about PlaceWorks, visit www.placeworks.com. PlaceWorks led the consultant team, preparation of the Climate Change Vulnerability Assessment, development of climate adaptation and resilience projects, and report preparation.

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Atlas Planning Solutions is a small, woman-owned, disabled veteran business enterprise that specializes in hazard mitigation, emergency management, and climate resilience for jurisdictions throughout California. For more information about Atlas Planning Solutions, visit www.atlasplanning.org. Atlas Planning Solutions supported the development of the Climate Change Vulnerability Assessment and development of climate adaptation and resilience projects.

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The **Mammoth Lakes Trails and Public Access Foundation**, MLTPA, is a 501(c) 3 non-profit organization incorporated in 2007 as a public benefit corporation in the State of California. MLTPA has been engaged with local and regional issues of sustainable recreation and collaboration in California's Eastern Sierra since its inception and provides technical support to a regional public/public recreation-based solution, the Eastern Sierra Sustainable Recreation Partnership.

For this effort, MLTPA provided a variety of services, including grant and project management, meeting content development, research, meeting convening, public and participant communications, and document production. Visit mltpa.org for more information on our work.

THE EASTERN SIERRA SUSTAINABLE RECREATION PARTNERSHIP

The Eastern Sierra Sustainable Recreation Partnership (ESSRP) is a unique public/public partnership among local Eastern Sierra governments, state agencies, and federal agencies.

In July of 2018, a Non-Funded Challenge Cost-Share Agreement was signed between Mono County; the Town of Mammoth Lakes, California; and the U.S. Department of Agriculture Forest Service Pacific Southwest Region, Inyo National Forest and Intermountain Region, and Humboldt-Toiyabe National Forest memorializing the Eastern Sierra Sustainable Recreation Partnership (ESSRP).

Subsequently, Alpine County voted to join the ESSRP on August 20, 2019, the City of Bishop voted to join on September 9, 2019, and Inyo County voted to join on October 8, 2019. Additionally, the Bureau of Land Management, California Department of Transportation (Caltrans), and the National Park Service have all formally indicated their desire to join the ESSRP.

For more information, please visit:
https://mltpa.org/essrp/sustainable-recreation-and-tourism-project.

THE SUSTAINABLE RECREATION AND TOURISM INITIATIVE

In spring 2019, the Sierra Nevada Conservancy's Governing Board demonstrated a pioneering commitment to rural California's outdoor recreation economy and natural resources by authorizing Proposition 68 funding for the "Sustainable Recreation and Tourism Initiative," a project to benefit the conservancy's eastern subregion, including Inyo, Mono, and Alpine counties.

The initiative supports the ESSRP in its goals to "… design, plan, implement, and report out projects to improve and maintain recreational opportunities as well as restore ecosystems to their natural resiliency and functions." The initiative is composed of four tracks, or areas of focus, with specific deliverables: Regional Recreation Stakeholder Engagement; Climate Adaptation & Resilience Assessment; Connection to the Eastern Sierra Visitor Audience; and Project Development & Prioritization for Funding.

LAND ACKNOWLEDGEMENT

Public lands in the United States hold the creation stories, burial grounds, and ceremonies of indigenous people who were killed or forcibly removed from their ancestral homes during territorial acquisition.

Many tribes, composed of different bands, continue to live in the Eastern Sierra region, caring for their native lands as they coexist with the ongoing impacts of colonization. Past or present tribes and bands associated with the region that this effort is aware of include, but are not limited to, the Miwok, Mono Lake Kutzadika'a, Mono/Monache, Nüümü (Paiute), Newe (Shoshone), Timbi-Sha, Utu Utu Gwaitu Paiute, and Washoe.

Two Nüümü terms describe the region and provide important context to ideas offered in this document. The first is Pamidu Toiyabe (Western Mountains), and the other, more widely known place name is Payahuunadü (The Place Where Water Flows).

This acknowledgement is an invitation to all organizations, residents, and visitors to recognize the way this history has shaped the present as all parties work together in anticipation of a better future.

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Introduction

The Eastern Sierra is a high-desert landscape in California that shares a common border with the state of Nevada. Composed of three California counties (Alpine, Mono, and Inyo), the region is defined by the Sierra Nevada range, the western terminus of the Northern Basin and Range.

More than 90 percent of the region's 17,148 square miles is managed by federal government agencies, including the U.S. Forest Service, the National Park Service, and the Bureau of Land Management. The principal owner of the region's private property, the Los Angeles Department of Water and Power, acquired more than 450 square miles of farm and ranchland in the early years of the 20th century to secure water rights for the Los Angeles region. The remaining private property and gateway communities are dispersed across the region, home to a permanent population of about 35,000 residents.

Unparalleled opportunities for outdoor recreation have compelled visitation to the region for many generations. The Eastern Sierra hosts both the highest peak and lowest valley in the 48 contiguous United States, as well as the oldest living thing on Earth, the Great Basin bristlecone pine (*Pinus longaeva).* Annual visitor estimates range between 4 and 7 million, principally from Southern California, but from across the country and globe as well. Visitation drives the region's recreation-based tourism economy and represents the primary challenge as well as the essential opportunity for achieving regional economic, social, and environmental sustainability.

Key Terms

Resiliency: The ability of a community to withstand, recover from, and learn from past climate disasters to strengthen future response and recovery efforts.

Adaptation: The process of making changes in response to current or future environmental conditions, usually to reduce harm and take advantage of new opportunities.

Vulnerability: The degree to which natural, built, and human systems are susceptible to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt.

Ecosystem Services: The benefits that humans receive from ecosystems. These services are broadly disaggregated into provisioning, regulating, supporting, and cultural services.

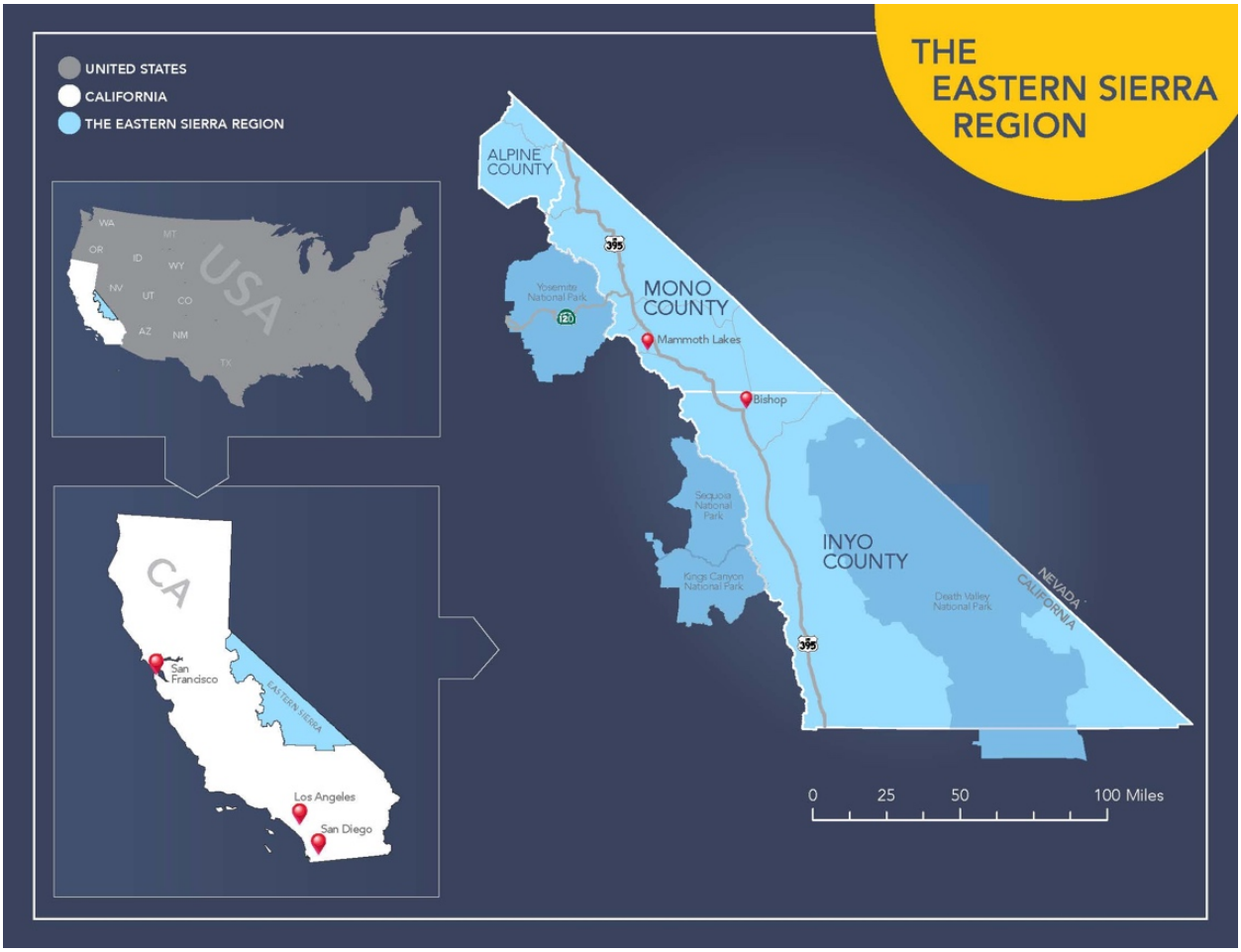
Benefit Transfer: Estimating the value of ecosystem services from existing studies and applying them to a new context. It is broadly broken into benefit function transfer and benefit value transfer.

Sustainable Recreation: The set of recreation settings and opportunities in the National Forest System that is ecologically, economically, and socially sustainable for present and future generations.

Sources: California Governor's Office of Emergency Services, 2020, *California Adaptation Planning Guide*, https://www.caloes.ca.gov/climate; ICF, 2021, "Sustainable Recreation and Tourism Initiative: Baseline Natural Capital Assessment"; Forest Service Handbook (fsh) 1909.12

The Eastern Sierra region is largely dependent on natural ecosystems and essential resources to sustain the recreation and tourism economy. Climate change poses a threat by potentially increasing the frequency and intensity of natural hazards, which in turn may threaten or destroy critical ecosystem services needed for local communities and visitors. Natural hazards associated with climate change may also adversely affect or degrade the unique landscape in the Eastern Sierra that provides for the recreation-based economy that local communities depend on. To proactively manage for these potential risks posed by climate change, this report, *Vulnerability in California's Eastern Sierra,* summarizes the results of the Sustainable Recreation and Tourism Initiative's (SRTI's) "Climate Adaptation and Resilience Assessment," which includes an Adaptation & Resilience Assessment and a Natural Capital Assessment. Based on these efforts, the report provides Recommended Actions for the Eastern Sierra's adaptation to climate change. The purpose of this report is to provide an understanding of the economic value supplied by the ecosystem services in the SRTI Study Area (Study Area), shown in **Figure ES-1**, analyze how climate change may threaten the people, assets, and economic benefits of ecosystem services in the region, and specifically focus on how the effects of climate change may directly or indirectly affect outdoor recreation, tourism, and economic stability.

Figure ES-1. Sustainable Recreation and Tourism Initiative Study Area



Vulnerability in California's Eastern Sierra presents the results of two technical analyses: a Climate Change Vulnerability Assessment and a Natural Capital Assessment. The Climate Change Vulnerability Assessment looks at the severity and likelihood of how climatic changes to air quality, increased drought, flooding, wildfires, severe weather, etc. may affect specific populations and recreational activities that contribute to the Study Area's recreational economy. The Climate Change Vulnerability Assessment also analyzes the direct effects to infrastructure and other assets that support these activities. The resulting Vulnerability Assessment Matrix, shown in **Figure ES-2,** assigns a vulnerability score for each population and asset according to each climate change hazard analyzed. For example, outdoor workers in the Study Area have the highest vulnerability rating (or are most vulnerable) to climatic effects of increased smoke and ash from wildfires.

Figure ES-2. Example of the Vulnerability Assessment Matrix

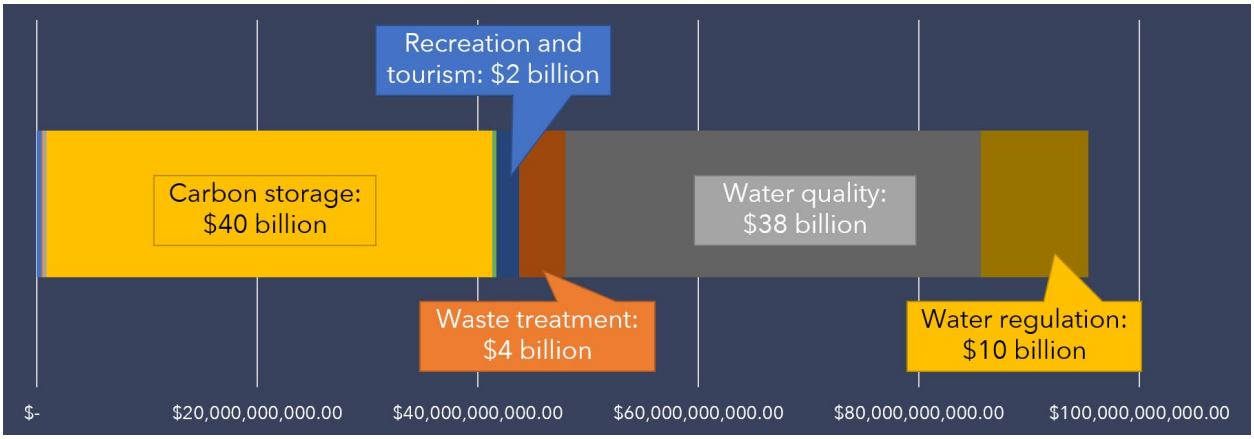
Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases
Populations					
Hospitality workers	V5	V4	V3	V3	-
Indoor tourism workers	V4	V3	-	V3	-
Outdoor workers	V5	V3	V4	V3	V4
Persons in tribal communities	V5	V4	V4	V4	V4
Retail workers	V4	V3	V3	V3	-
Seasonal residents	V3	V2	V3	V2	V3
Seasonal residents who live on single access roads	V3	-	-	V5	V4
Short-term visitors	V3	V4	V2	V3	V2
Travel industry workers	V5	V3	V3	V2	-
Infrastructure					
Airports - charter/recreation/general aviation	-	-	-	V2	-
Airports - commercial service	-	-	-	-	-
Bicycle trails (California State Parks)	-	V2	-	V2	V2
Bicycle trails (City and County)	-	V2	-	V3	V3
Bicycle trails (Death Valley National Park)	-	-	-	V2	-

The Natural Capital Assessment takes an economic approach by using benefit transfer methods* to assign annual monetary values to various types of ecosystem services, as shown in **Figure ES-3**. This includes analyzing each ecosystem's climate regulation benefit through carbon sequestration and storage, erosion prevention, and increased water quality and flow regulation. Habitat enhancements and cultural value are also analyzed. This approach estimates the natural capital

*Benefit transfer is an approach that involves using estimates of the value of ecosystem services from existing studies and applying them to a new context.

currently available to the region that may be jeopardized by the impacts of climate change.

Figure ES-3. Example of Ecosystem Services Included in Natural Capital Assessment



Federal and State Policy Alignments

The *Vulnerability in California's Eastern Sierra* report provides valuable social and economic analysis that will assist the region's evaluation of programs and projects for funding in alignment with the following federal and state policy goals for sustainable recreation and a resilient future.

Great American Outdoors Act

The Great American Outdoors Act* was signed into law on August 4, 2020, with the goal to provide permanent funding of the Land and Water Conservation Fund at $900 million per year and to provide up to $1.9 billion per year for five years for needed maintenance for critical facilities in national parks, forests, wildlife refuges, recreation areas, and tribal lands across the United States. National forests and national parks in the Study Area host millions of visitors per year, creating significant infrastructure maintenance needs for roads, trails, restrooms, water treatment systems, and visitor facilities. Many of these buildings and infrastructure are aging and were built for fewer visitors; therefore, they do not currently meet the needs of the region.

The influx of funding to the Land and Water Conservation Fund through the Great American Outdoors Act will enable a backlog of maintenance and upgrade projects to be completed, ensuring sustainable recreation can be achieved in the Study Area. Several of the short-term and long-term projects proposed in the Climate Adaptation and Resilience Assessment can be funded through the Land and Water Conservation Fund.

Agreement for Shared Stewardship of California's Forests and Rangelands

Executed on August 12, 2020, the Agreement for Shared Stewardship of California's Forests and Rangelands† is a shared long-term strategy between the State of California and the U.S. Forest Service, Pacific Southwest Region, to reduce wildfire risks, restore watersheds, protect habitat and

* https://www.congress.gov/bill/116th-congress/senate-bill/3422/text.
† https://www.gov.ca.gov/wp-content/uploads/2020/08/8.12.20-CA-Shared-Stewardship-MOU.pdf.

biological diversity, and help meet California's climate objectives. This agreement includes a commitment by the U.S. Forest Service to match California's goal of reducing wildfire risks on 500,000 acres of forest land per year to protect public safety and ecology.

Many of the forest management activities included in this agreement will be funded by the Land and Water Conservation Fund that has been revitalized through the Great American Outdoors Act. The *Vulnerability in California's Eastern Sierra* report is consistent with this agreement and provides short- and long-term project-based solutions to sustainably manage forest land in the Eastern Sierra region to reduce the effect from wildfire and increase the resiliency for forest ecosystems.

Nature-Based Solutions

In October 2020, California Governor Newsom signed Executive Order N-82-20*, enlisting the network of natural and working lands, including forests, rangelands, farms, wetlands, coasts, deserts, and urban green spaces to help reduce greenhouse gas emissions and contribute to achieving carbon neutrality and building climate resilience. This Executive Order established a State goal of conserving 30 percent of California's lands and coastal waters by 2030, launched the California Biodiversity Collaborative, and elevated the role of natural and working lands in the California climate change strategy. The Nature-Based Solutions strategy includes accelerating and expanding climate smart land management across California, increasing carbon removal and sequestration, better protecting communities and ecosystems from climate-driven threats, and catalyzing partnerships and leveraging resources.

The *Vulnerability in California's Eastern Sierra* report is focused on ecosystem services provided by natural lands that support sustainable outdoor recreation in the Eastern Sierra region. Recommendations in the report provide project-based solutions to protect ecosystem services and increase the resiliency of the regional outdoor recreation economy.

Advancing California Policy Goals

Recommended actions of this report are consistent with the objectives of CALREC Vision, which identifies using cross-jurisdictional collaboration to align California policy goals with federal land management practices, including:

- Assembly Bill 32 Climate Change Scoping Plan
- Access for All Initiative
- Agreement for Shared Stewardship of California's Forest and Rangelands
- California 2030: Natural and Working Lands Climate Change Implementation Plan
- Cutting Green Tape Initiative
- Destination Stewardship and Sustainable Travel Plan
- Health in All Policies
- Integrated Climate Adaptation and Resiliency Program
- Local Government General Plan Guidance
- Regions Rise Together
- Statewide Comprehensive Outdoor Recreation Plan Program

visit www.calrecvision.org

* https://www.gov.ca.gov/wp-content/uploads/2020/10/10.07.2020-EO-N-82-20-.pdf.

Report Preparation

The SRTI Project Team completed the Climate Adaptation and Resilience Assessment through a three-step process, including a **Baseline Natural Capital Assessment** (phase one of the Natural Capital Assessment), a **Climate Change Vulnerability Assessment**, and a **Climate Change Natural Capital Assessment** (phase two of the Natural Capital Assessment), with each step building from the results of the previous step.

1. **Baseline Natural Capital Assessment.** As a starting point, the Project Team identified the environmental baseline, characterizing the current provision of ecosystem services within the Study Area as part of the Baseline Natural Capital Assessment. The Baseline Natural Capital Assessment is designed to provide a detailed understanding of the economic benefits of ecosystem services. This economic value arises from the services that ecosystems provide, including such services as carbon sequestration and storage, water quality, and erosion prevention. To estimate the economic value of the natural capital within the Study Area, the Project Team conducted an analysis at the individual ecosystem service level, estimating the total annual economic value of ecosystem services provided by lands within the boundaries of the Study Area to range from approximately $43.6 billion to $190.9 billion, with an average annual value of $95.4 billion.
2. **Climate Change Vulnerability Assessment.** The Project Team conducted a Climate Change Vulnerability Assessment using the recommended process in the *California Adaptation Planning Guide* and relying on key regional sources, such as the U.S. Forest Service's *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* and *Climate Change Vulnerability and Adaptation in the Intermountain Region* and EcoAdapt's *Southern California and Sierra Nevada Climate Adaptation Projects*. The Climate Change Vulnerability Assessment identifies populations and assets related to the recreation and tourism economy, identifies exposure of these populations and assets to climate change hazards, assesses impacts and adaptive capacity, and prioritizes vulnerability.
3. **Climate Change Natural Capital Assessment.** Following the Climate Change Vulnerability Assessment, the Project Team conducted a Climate Change Natural Capital Assessment to provide an understanding of the economic value of ecosystem services at risk from climate change. This analysis monetizes the impacts of climate change on ecosystem services where data and methods are available. The Project Team found that billions of dollars of ecosystem services are at risk from the impacts of climate change, particularly impacts from drought, heat waves, and wildfires.

Key Findings

The Climate Change Vulnerability Assessment and Natural Capital Assessment resulted in several key findings for the Study Area. This includes findings that directly impact communities outside of the Study Area, such as the Southern California communities that receive water resources from the Study Area. These important findings include:

- Ecosystem services provide an average of $95 billion per year in services to the Eastern Sierra region, with the highest valued service being carbon storage and water quality.
- Poor air quality, drought, extreme heat, and wildfire are projected to reduce the value ecosystem services by an average of $270 million (per year). Other hazards are also projected to have significant impacts.
- Wildfire creates the most vulnerabilities for all populations, recreation activities, and other community assets compared to other hazards in the region.
- Energy and water systems are the most vulnerable infrastructure to climate change hazards.
- Tribal communities and other frontline groups* face substantial health risk from climate change hazards.
- Homes, campgrounds, lodging, ranger stations, administrative centers, and other buildings are at risk of damage from climate change hazards.
- More precipitation is likely to fall as rain instead of snow, reducing the winter recreation season and associated economic activities.
- Water-based recreation activities are likely to decrease due in large part to increases in drought and extreme heat conditions.
- Summer recreation activities in all jurisdictions will likely be disrupted by climate change hazards.
- Changing temperature and precipitation patterns will likely cause widespread harm to forests, wetland, and aquatic habitats.
- Recreation and tourism industry workers are likely to face economic harm when recreation activities are disrupted.

* Based on the *Defining Vulnerable Communities in the Context of Climate* Change report developed by the ICARP Technical Advisory Council, frontline communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts.

Recommended Actions

The Climate Change Vulnerability Assessment and Climate Change Natural Capital Assessment provide valuable information on which populations and infrastructure in the Eastern Sierra region are most at risk from climate change. The ecosystem services analysis provides information on which ecosystems provide the most natural capital as sources of protection from the effects of climate change on these vulnerable communities and infrastructure. This report provides a framework to make decisions on which programs and projects to invest in for the greatest resiliency of this unique region, specifically through the lens of a sustainable recreation economy, and through a list of recommended actions for implementation. These recommended actions are provided in an "umbrella" format, each including multiple smaller projects and tasks that incorporate other objectives from the SRTI.

- **SRTI Climate: Funding Ready Projects**
    - Projects that have climate resiliency/sustainability co-benefits and that have been identified by the SRTI "Recreation Stakeholders;" hazard-reduction projects; or projects proposed by the U.S. Forest Service, National Park Service, and other regional partners that are ready to fund plan preparation, permitting, or construction.
- **SRTI Climate: Regional Asset Inventory**
    - An Asset Inventory of all buildings and infrastructure and related assets for all jurisdictions located within the Study Area, including Global Positioning System (GPS)/geographic information system (GIS) spatial data and location information for mapping purposes along with key attribute information regarding the individual assets.
- **SRTI Climate: Gap Assessment**
    - A Gap Assessment to follow the completion of the SRTI Asset Inventory to analyze what is currently on the ground for what is needed to meet the current and future demands of sustainable recreation activities and climate change in the region.
- **SRTI Climate: Sustainable Infrastructure Master Plan**
    - A Sustainable Infrastructure Master Plan building off of the SRTI Climate: Gap Assessment, which will provide a recommended set of projects and programs to help the region address the gaps identified. Detailed projects would be added from the SRTI Climate: Gap Assessment.
- **SRTI Climate: Sustainable Recreation Outreach and Education**
    - Programs for incorporation into the SRTI "Visitor Connection Package" to educate residents, visitors, and workers about Sustainable Recreation and Stewardship, tribal culture, climate change hazards, and historical and interpretive opportunities within the Study Area.

These project recommendations seek to align the Eastern Sierra with California climate change policy, and in so doing, increase the region's eligibility for state and federal funding to plan for and implement solutions for climate change vulnerabilities and successful adaptation. This report and its recommendations establish the foundation for climate resiliency in California's Eastern Sierra.

Funding for this report and the "Sustainable Recreation and Tourism Initiative" has been provided by the Sierra Nevada Conservancy, an agency of the State of California, under the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access For All Act of 2018 (Proposition 68) and in support of the Sierra Nevada Watershed Improvement Program."

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SECTION 1: INTRODUCTION

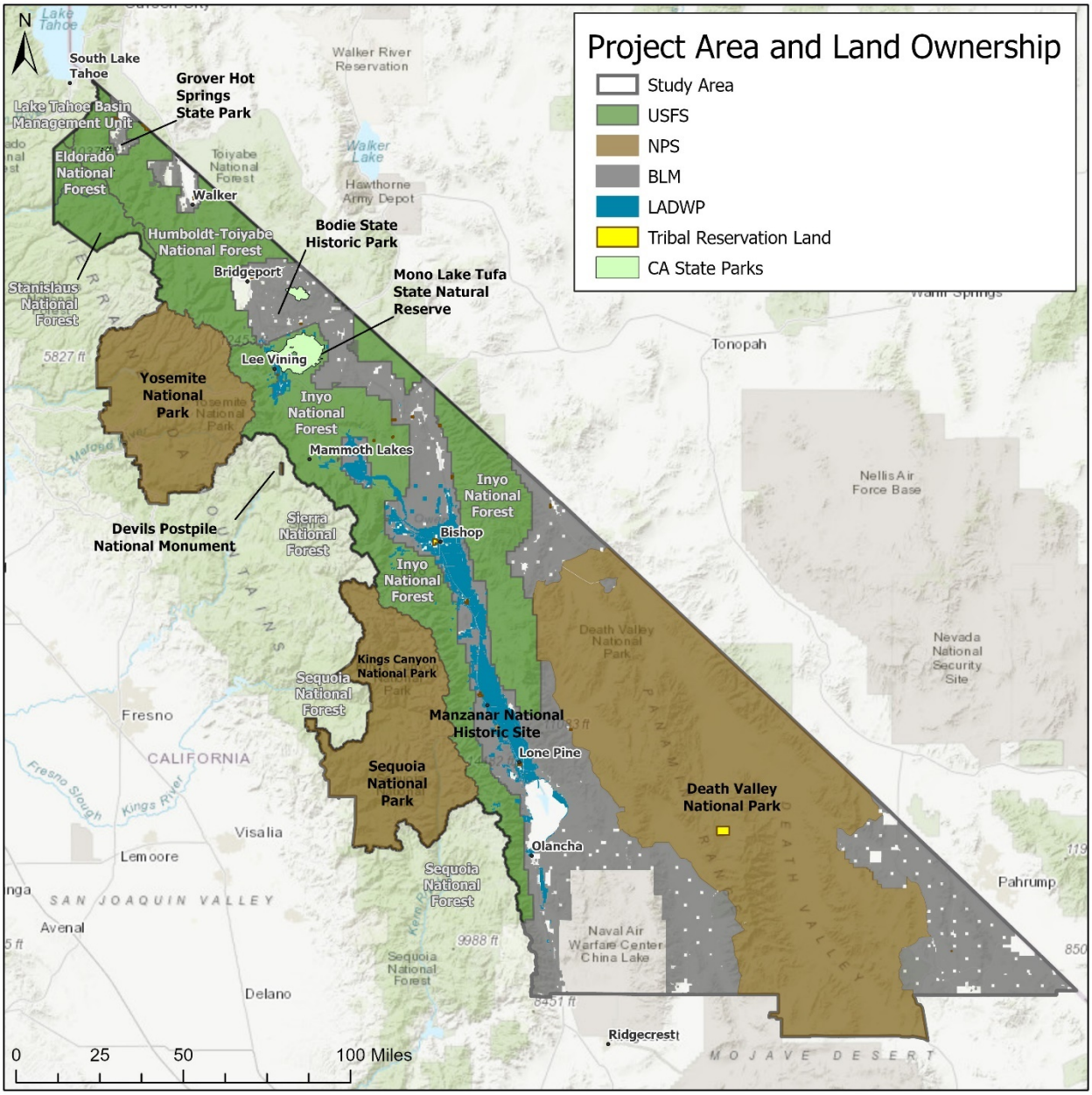
The Eastern Sierra region is largely dependent on recreation and tourism to sustain the regional economy. The region's varying elevations and pristine natural ecosystems provide essential ecosystem services (the benefits that humans receive from ecosystems) that directly support the recreation economy. Climate change will likely increase annual average temperatures and change precipitation patterns, causing hazards that threaten recreation and tourism activities supported by the unique landscape in the Eastern Sierra region.

On March 7, 2019, the Sierra Nevada Conservancy Governing Board authorized Proposition 68 funding to the Town of Mammoth Lakes for the "Sustainable Recreation and Tourism Initiative" (SRTI), a project to benefit the Sierra Nevada Conservancy's eastern subregion, including Inyo, Mono, and Alpine counties. In consultation with the Eastern Sierra Council of Governments, the Town of Mammoth Lakes submitted the grant application on behalf of its regional partners. The purpose of the project is to support the Eastern Sierra Sustainable Recreation Partnership (ESSRP), a unique and locally generated public/public partnership between Eastern Sierra governments, state agencies, and federal agencies, including the U.S. Forest Service (USFS), National Park Service (NPS), and the Bureau of Land Management. As documented in the ESSRP's agreement, the stated goal of the ESSRP is to "…design, plan, implement, and report out projects to improve and maintain recreational opportunities as well as restore ecosystems to their natural resiliency and functions."[1]

The USFS has provided staff support for the establishment of the ESSRP—which includes two USFS forests and two USFS regions—through its office in Washington, D.C., desiring to use this public/public partnership as a replicable model for USFS units and their gateway communities across the country. The ESSRP is a direct outcome of forest management planning for the Inyo National Forest, one of eight "Early Adopter" forests to use the USFS's 2012 Planning Rule, which resulted in the establishment of three primary focus areas for the Inyo National Forest's new management plan: fire management, ecological integrity, and sustainable recreation. Sierra Nevada Conservancy project funding will facilitate and ensure on-the-ground implementation for projects developed and recommended for funding by the ESSRP through four deliverables: (1) Regional Recreation Stakeholder Engagement; (2) Climate Adaptation and Resilience Assessment; (3) Connection to Eastern Sierra Visitor Audience; and (4) a Project Prioritization and Implementation Plan.

This report is the final product of the Climate Adaptation and Resilience Assessment, which includes a Climate Change Vulnerability Assessment and adaptation strategy for the Eastern Sierra that values the region's natural resources, including outdoor recreation and the tourism economy. The objective of this report is to provide an understanding of the climate vulnerabilities and economic value supplied by the ecosystem services in the SRTI Study Area. The Study Area, shown in **Figure 1**, covers Alpine, Mono, and Inyo counties; USFS lands managed by the Humboldt-Toiyabe and Inyo National Forests; Bureau of Land Management lands; and Death Valley, Yosemite, and Sequoia and Kings Canyon National Parks, the Devils Postpile National Monument, and the Manzanar National Historic Site.

Figure 1. The Study Area



This report includes the following sections:

- Section 1: Introduction, which summarizes the purpose of this report and provides an overview of the Study Area.
- Section 2: Natural Capital Assessment Method, describing what this assessment is and the methods used to prepare it.
- Section 3: Climate Vulnerability Assessment Method, describing the Climate Change Vulnerability Assessment and how it was prepared.
- Section 4: Baseline Natural Capital Assessment Ecosystem Service Impacts, presenting the benefits of ecosystem services in the Study Area under baseline conditions.
- Section 5: Climate Change Hazards of Concern, discussing the climate-related hazards in the Study Area and how these are projected to change as a result of climate change.
- Section 6: Critical Vulnerabilities, providing the results of the Climate Change Vulnerability Assessment to indicate how populations and assets in the Study Area may be harmed by climate-related hazards.
- Section 7: Assessment of Hazards on Ecosystem Services, describing how ecosystem service benefits are expected to be harmed under future climate conditions.
- Section 8: Conclusions and Recommended Actions, discussing how the results of these assessments may be used to increase resilience and support climate adaptation in the Study Area.

This report also contains a glossary, list of abbreviations, and appendices as supporting materials.

Purpose of the Climate Adaptation and Resilience Assessment

Climate change is a long-term change in the average meteorological conditions in an area. Currently, the global climate is changing due to an increase in greenhouse gas (GHG) emissions that trap heat near the Earth's surface. This can lead to an increase in frequency and intensity of climate change hazards. According to the *California Adaptation Planning Guide* (APG), climate change hazards have the potential to cause fatalities, injuries, property and infrastructure damage, interruption of recreation and tourism, and other types of harm or loss.[2] These hazards can include flooding, severe weather, wildfires, landslides, and drought conditions, among others.

The Climate Adaptation and Resilience Assessment evaluates the impacts of these hazards on recreation and tourism; the ability of populations, assets (e.g., buildings and infrastructure, natural environment, and key services), and recreational activities in the Study Area to resist these hazards; and which components of the recreation and tourism economy in the Study Area are most vulnerable to climate change. The Climate Adaptation and Resilience Assessment includes a Climate Change Vulnerability Assessment and a Natural Capital Assessment.

The Climate Change Vulnerability Assessment looks at how severe climate change hazards are likely to be for the Study Area's visitors and populations who contribute to the Study Area's recreational economy, assets, and recreation activities. The assessment uses this information to identify which groups of people, assets, and recreational activities face the greatest threat from climate change hazards. This report summarizes the method and results of the Climate Change Vulnerability Assessment, which the SRTI will use as a foundation to develop a set of prioritized sustainable recreation projects that will be implemented to increase resiliency of the recreation and tourism economy in the Eastern Sierra region against both current and future hazard conditions.

The Natural Capital Assessment first describes the economic value of land within the Study Area by estimating the ecosystem services through the Baseline Natural Capital Assessment. The Baseline Natural Capital Assessment uses benefit transfer methods* to ascribe annual values to various types of ecosystem services. The Climate Change Natural Capital Assessment section synthesizes the findings of the Baseline Natural Capital Assessment and the Climate Change Vulnerability Assessment to provide an understanding of the economic value of ecosystem services at risk from climate change. For example, as the climate changes, precipitation patterns change within regions, which affects different vegetation types and may degrade ecosystems that directly support resources that human populations rely on. This report attempts to monetize these potential impacts of climate change where data and methods are available.

The values presented in the Climate Change Natural Capital Assessment section represent the potential value of ecosystem services that are at risk from climate-related hazards rather than actual expected damages. Climate data and forecasting are not yet precise enough to accurately estimate specific damages and their costs. Additionally, values in this section cannot be combined across climate hazards because that would count them more than once.

The Climate Change Vulnerability Assessment, Climate Change Natural Capital Assessment, and prioritized project list will improve the region's eligibility for grant funding to implement projects, setting the groundwork for short-term and long-term climate resiliency planning in the Study Area.

* Benefit transfer is an approach that involves using estimates of the value of ecosystem services from existing studies and applying them to a new context.

What is resiliency?

Resiliency is the ability of a community to withstand, recover, and learn from past climate disasters to strengthen future response and recovery efforts.

What is adaptation?

Adaptation is the process of making changes in response to current or future environmental conditions, usually to reduce harm and take advantage of new opportunities.

What is vulnerability?

Vulnerability is the degree to which natural, built, and human systems are susceptible to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt.

What are ecosystem services?

The benefits that humans receive from ecosystems. These services are broadly disaggregated into provisioning, regulating, supporting, and cultural services.

What is benefit transfer?

Benefit transfer involves estimating the value of ecosystem services from existing studies and applying them to a new context. It is broadly broken into benefit function transfer and benefit value transfer.

Sources:
California Governor's Office of Emergency Services, 2020, *California Adaptation Planning Guide*, https://www.caloes.ca.gov/climate; ICF, 2021, "Sustainable Recreation and Tourism Initiative: Baseline Natural Capital Assessment."

Subarea Profiles

The Eastern Sierra is a high-desert landscape in California that shares a border with the state of Nevada. Composed of three California counties (Alpine, Mono, and Inyo), the region is defined by the Sierra Nevada mountain range, which is the western terminus of the Northern Basin and Range.

More than 90 percent of the region's 17,148 square miles is managed by federal government agencies, including the USFS, the NPS, and the Bureau of Land Management. The principal owner of the region's private property, the Los Angeles Department of Water and Power (LADWP), acquired more than 450 square miles of farm and ranchland in the early years of the 20th century to secure water rights for the city of Los Angeles. The remaining private property and gateway communities are dispersed across the region, home to a permanent population of about 35,000 residents.

Unparalleled opportunities for outdoor recreation have attracted visitors for many generations. The Eastern Sierra hosts both the highest peak (Mount Whitney) and lowest valley (Badwater Basin, Death Valley) in the 48 contiguous United States, as well as the oldest living thing on Earth, the bristlecone pine. The difference in elevation creates a wide variety of habitats and ecosystems

within the Study Area, the majority of which consists of desert shrubland, conifer forests, shrubland, and woodlands.[3] The Study Area has millions of visitors every year who travel to the area to participate in recreational activities in pristine natural environments. The most visited areas of the Study Area are Yosemite National Park and Inyo National Forest, attracting over 4 million visitors and 2 million visitors annually, respectively.[4] Over half of the visitors to the Inyo National Forest visit the Town of Mammoth Lakes, which receives approximately 1.3 million visitors annually.[5] Visitation drives the region's recreation-based tourism economy and represents the primary challenge as well as the essential opportunity for achieving regional economic, social, and environmental sustainability. **Figure 1**, above, provides an overview of the Study Area, which is bounded by Lake Tahoe to the north, Nevada to the east, San Bernardino County to the south, and the western side of the Sierra Nevada to the west.

As shown in **Figure 1**, the Study Area consists of 20 different jurisdictions, parks, forests, and sites, which are primarily owned and managed by the USFS, NPS, and Bureau of Land Management. Local and state jurisdictions include California State Parks, Alpine County, Mono County, Inyo County, the Town of Mammoth Lakes, and the City of Bishop. **Table 1** describes the balance of landowners and managers within the Study Area and gives an overview of the location of each jurisdiction, the agencies managing the land, constraints that the agencies may have that could affect adaptive capacity, vegetation and land cover, the recreation activities available in each jurisdiction, the agencies' role in providing recreation opportunities, and whether the jurisdiction relies on summer or winter recreation activities.

Different Vulnerabilities Between Agencies

There are several land management jurisdictions and agencies overseeing the operation and maintenance of infrastructure in the Study Area. Each of these agencies has different funding mechanisms, staff capacity, and volunteer networks.

For example, Yosemite National Park is one of 419 national parks and monuments managed by the NPS. However, because it is one of the most visited national parks, it may be provided with more funding for maintenance costs. Yosemite National Park also has an extensive and well-known volunteer network that helps with the maintenance and operation of infrastructure in the park.

In contrast, only a small portion of Humboldt-Toiyabe National Forest is in the Study Area and California. Funding is likely to be lower for Humboldt-Toiyabe than a major national park such as Yosemite, and is likely to go to other areas of the forest than the portion in the Study Area. Also, there may not be an extensive volunteer network to help with infrastructure maintenance.

To account for the variability between agencies and locations of assets in the Study Area, the building and infrastructure assets, such as hiking and horseback riding trails or campgrounds, were divided by the jurisdictions or agencies that own or manage them. Because the NPS and USFS manage the majority of land within the region, these were further broken out by unit. Cities, counties, and California State Parks own and/or manage a smaller portion of the Study Area, and therefore were not broken out into specific units.

Table 1. Subarea Profiles

Agency/ Jurisdiction Name	Location in the Study Area	Role/Mission of Managing Agency	Agency Constraints for Recreation and Tourism	Vegetation and Land Cover	Available Winter Recreation Activities [a]	Available Summer Recreation Activities [b]
Counties and Cities						
Alpine County	Northernmost section of the Study Area. Bounded by El Dorado County to the north, Nevada to the east, Mono and Tuolumne counties to the south, and Amador and Calaveras counties to the west.	Addressing and managing environmental constraints, economic growth, orderly development in specific areas, and public services costs.[6]	Small rural county with no incorporated communities. Majority of land is owned and/or managed by the USFS, Bureau of Land Management, and California State Parks.	Coniferous forest, deciduous forest, grassland, shrubland, barren, agriculture, open water	Cross-country skiing, downhill skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, hunting, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
Mono County	Central section of the Study Area. Bounded by Alpine County to the north, Nevada to the east, Inyo and Fresno counties to the south, and Madera, Mariposa, and Tuolumne counties to the west.	Maintaining and enhancing orderly growth, minimizing land use conflicts, supporting local tourist and agriculturally based economy, and protecting the scenic, recreational, cultural, and natural resources of the area.[7]	Majority of land is owned and/or managed by USFS, Bureau of Land Management, California State Parks, and LADWP.	Desert scrub, coniferous forest, shrubland, barren, deciduous forest, grassland, open water, wetland, urban, agriculture	Cross-country skiing, backcountry skiing, downhill skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, hunting, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
Inyo County	Southern section of the Study Area. Bounded by Mono County to the north, Nevada to the east, San Bernardino and Kern counties to the south, and Fresno and Tulare counties to the west.	Coordinating with federal land managers in preparation of plans for lands they manage in Inyo County; improving overall communication and coordination between the county, agencies, and tribes; and ensuring there is no loss of private land within the county.	Majority of land is owned and/or managed by USFS, NPS, Bureau of Land Management, California State Parks, and LADWP.	Desert shrub, desert woodland, coniferous forest, shrubland, barren, deciduous forest, grassland, wetland, urban, agriculture, open water	Backcountry skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, hunting, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
Town of Mammoth Lakes	Within southwest Mono County and the Inyo National Forest. Bounded by the Sierra Nevada to the north, south, and west and Owens Valley to the east.	Providing the very highest quality of life for its residents and the highest quality of experience for its visitors.	Town is entirely surrounded by the Inyo National Forest, managed by USFS. The management of Mammoth Creek is restricted by a settlement between Mammoth Community Water District and LADWP. A population of approximately 8,316 lives there year-round, which can quadruple during the peak ski season.[8]	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water, wetland, urban	Cross-country skiing, downhill skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
City of Bishop	Within northern Inyo County and Owens Valley. Bounded by North Fork Bishop Creek to the north, Bishop Creek Canal to the east, agricultural land to the south, and the Bishop Paiute Reservation to the east.	Maintaining the rural integrity of Bishop; stimulating the tourist/recreation/convention industry, recognizing the natural environment as the greatest asset to offer; and maintaining the character and enhancing the economic strength of the downtown.	The majority of land within the city is owned by LADWP. The cost of updating city park facilities is high, and the availability of land is limited.	Desert shrub, shrubland, deciduous forest, grassland, open water, wetland, urban, agriculture	None	Bicycling, driving for pleasure, hiking/walking, picnicking, viewing natural features and wildlife, wellness

Table 1. Subarea Profiles

Agency/ Jurisdiction Name	Location in the Study Area	Role/Mission of Managing Agency	Agency Constraints for Recreation and Tourism	Vegetation and Land Cover	Available Winter Recreation Activities [a]	Available Summer Recreation Activities [b]
National Park Service						
Death Valley National Park	Covers 3,396,172 acres in eastern Inyo County and is the largest national park in the conterminous 48 states.9 Bounded by the Inyo National Forest and Bureau of Land Management land to the north and west, the State of Nevada to the east, and Bureau of Land Management land to the south.	NPS: conserving the scenery and the natural and historic objects and the wildlife therein and providing for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.10 Death Valley National Park: protecting significant desert features that provide world-class scenic, scientific, and educational opportunities for visitors and academics to explore and study.	The park landscape spans from 11,049 feet above sea level to 282 feet below sea level, which can cause hazards to occur differently throughout the national park. Death Valley is one of the warmest places in the United States and receives very little rainfall. Death Valley National Park is one of 419 park units managed by the NPS, and the budget is allocated through the U.S. Department of Interior.11	Desert shrub, coniferous forest, shrubland, barren, desert woodland, urban	Bicycling, camping, backpacking, primitive camping, driving for pleasure, hiking/walking, horseback riding, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, wellness	Bicycling, camping, backpacking, primitive camping, driving for pleasure, hiking/walking, horseback riding, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, wellness
Devils Postpile National Monument	Covers approximately 800 acres west of the Town of Mammoth Lakes and within the Inyo National Forest. The monument provides access to Ansel Adams Wilderness and John Muir Wilderness areas. The Pacific Crest Trails runs through the northern portion of the monument.[12]	NPS: conserving the scenery and the natural and historic objects and the wildlife therein and providing for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.[13] Devils Postpile National Monument: preserving and protecting the glacially exposed columns of the Devils Postpile, the scenic Rainbow Falls, and the wilderness landscape of the upper Middle Fork San Joaquin River in the Sierra Nevada for scientific value, public interest, and inspiration.[14]	There is only one access road, which is closed in the winter. Devils Postpile National Monument is one of 419 park units managed by the NPS, and the budget is allocated through the U.S. Department of Interior.[15]	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water	Backcountry skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, hiking/walking, horseback riding, picnicking, , viewing natural features and wildlife, wellness
Kings Canyon and Sequoia National Parks	Covers 865,964 acres in the southeastern portion of the Study Area.[16] Bounded by Sierra National Forest to the north, Inyo National Forest and Mount Whitney to the east, Inyo National Forest and Sequoia National Forest to the south, and Bureau of Land Management land to the west.	NPS: conserving the scenery and the natural and historic objects and the wildlife therein and providing for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.[17] Kings Canyon and Sequoia National Parks: protecting forever the greater Sierran ecosystem—including the sequoia groves and high Sierra regions of the parks—and its natural evolution, and providing appropriate opportunities to present and future generations to experience and understand park resources and values.[18]	The parks are primarily accessible via roadways in the westernmost areas of the park, but can also be accessed by numerous hiking and backpacking trails from the Eastern Sierra including via Bishop Pass, Taboose Pass, Baxter Pass, Kearsarge Pass. Snow closes portions of the parks in the winter. Difficult to control native plant communities due to pests, pathogens, and air pollution from the Central Valley.[19] Kings Canyon and Sequoia National Parks are two of 419 park units managed by the NPS, and the budget is allocated through the U.S. Department of Interior.[20]	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water, wetland, urban	Backcountry skiing, cross-country skiing, other snow activities	Camping, backpacking, primitive camping, driving for pleasure, fishing, hiking/walking, horseback riding, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness

Table 1. Subarea Profiles

Agency/ Jurisdiction Name	Location in the Study Area	Role/Mission of Managing Agency	Agency Constraints for Recreation and Tourism	Vegetation and Land Cover	Available Winter Recreation Activities [a]	Available Summer Recreation Activities [b]
Manzanar National Historic Site	Covers 814 acres in Inyo County along Highway 395.[21] Bounded by LADWP land to the north, east, south, and west, and Bureau of Land Management land to the northwest.	NPS: conserving the scenery and the natural and historic objects and the wildlife therein and providing for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.[22] Manzanar National Historic Site: preserving Manzanar's cultural and natural resources and interpreting the forced removal and incarceration of Japanese Americans and Japanese immigrants during World War II.[23]	Funds for site improvements largely depend on funding from donations. Manzanar National Historic Site is one of 419 park units managed by the NPS, and the budget is allocated through the U.S. Department of Interior.[24]	Barren, shrubland	None	Hiking/walking, picnicking, viewing natural features and wildlife
Yosemite National Park	Covers 747,956 acres in the northwestern portion of the Study Area.[25] Bounded by the Stanislaus National Forest to the north, Mono County to the east, the Sierra National Forest to the south, and Stanislaus National Forest and Sierra National Forest to the west.	NPS: conserving the scenery and the natural and historic objects and the wildlife therein and providing for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.[26] Yosemite National Park: preserving the dynamic natural setting within the park's boundaries, including soaring granite domes, dramatic cliffs, towering waterfalls, ancient sequoia groves, expansive wilderness terrain, and free-flowing wild and scenic rivers; celebrating the cultural and historic traditions of the Central Sierra Nevada, including thousands of years of human history; perpetuating the American conservation ethic; and providing opportunities for scientific exploration, recreation, education, and inspiration for generations to come.[27]	One of the most visited national parks, with over 4.4 million visitors in 2019.[28] A majority of the park is designated as wilderness, and Highway 120 and Glacier Point Road are closed due to snow in the winter. Yosemite National Park is one of 419 park units managed by the NPS, and the budget is allocated through the U.S. Department of Interior.[29]	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water, wetland, urban	Backcountry skiing, downhill skiing, cross-country skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, hiking/walking, horseback riding, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
U.S. Forest Service						

Table 1. Subarea Profiles

Agency/ Jurisdiction Name	Location in the Study Area	Role/Mission of Managing Agency	Agency Constraints for Recreation and Tourism	Vegetation and Land Cover	Available Winter Recreation Activities [a]	Available Summer Recreation Activities [b]
El Dorado National Forest	Covers approximately 600,000 acres across California and Nevada, including 50,278 acres in northern Alpine County.30 This portion of the El Dorado National Forest includes the Mokelumne Wilderness. Bounded by El Dorado County and North Tahoe Basin Management Unit to the north, Humboldt-Toiyabe National Forest to the east, Stanislaus National Forest to the south, and Amador County to the west.	Sustaining the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations.31	Aging recreation and visitor infrastructure. Limited time, funding, and resources to rapidly respond to uncertain conditions.32	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water	Downhill skiing, cross-country skiing, backcountry skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, hunting, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
Humboldt-Toiyabe National Forest	Covers approximately 6.3 million acres across Nevada and California.33 The sections of the Humboldt-Toiyabe National Forest within the Study Area are in Alpine County and Mono County. Bounded by the Lake Tahoe Basin Management Unit to the north; state of Nevada to the east; Bureau of Land Management land and Inyo National Forest to the south; and Yosemite National Park, Stanislaus National Forest, and El Dorado National Forest to the west.	Sustaining the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations.34	Aging recreation and visitor infrastructure. Limited time, funding, and resources to rapidly respond to uncertain conditions.35 Few volunteer organizations in the Study Area.	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water	Cross-country skiing, backcountry skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
Inyo National Forest	Covers approximately 2 million acres in California and Nevada. The sections of the Inyo National Forest in the Study Area are located in Mono County and Inyo County. Elevations range from 3,800 in Owens Valley to 14,495 feet at the peak of Mount Whitney.[36] Bounded by Humboldt-Toiyabe National Forest and Bureau of Land Management land to the north, the state of Nevada and Death Valley National Park to the east, Bureau of Land Management land to the south, and Sequoia National Forest, Kings Canyon and Sequoia National Parks, Sierra National Forest, and Yosemite National Park to the west.	Sustaining the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations.[37]	Aging recreation and visitor infrastructure. Limited time, funding, and resources to rapidly respond to uncertain conditions.[38]	Desert scrub, coniferous forest, shrubland, barren, deciduous forest, desert woodland, grassland, open water, wetland, urban	Downhill skiing, cross-country skiing, backcountry skiing, other snow activities, rock climbing, camping, backpacking, primitive camping.	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, hunting, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness

Table 1. Subarea Profiles

Agency/ Jurisdiction Name	Location in the Study Area	Role/Mission of Managing Agency	Agency Constraints for Recreation and Tourism	Vegetation and Land Cover	Available Winter Recreation Activities [a]	Available Summer Recreation Activities [b]
Stanislaus National Forest	Covers approximately 898,099 acres on the western slope of the Sierra Nevada.[39] The portions of the Stanislaus National Forest in the Study Area are in Alpine County. Bounded by El Dorado National Forest to the north, Humoldt-Toiyabe National Forest to the west, Tuolumne County to the south, and Tuolumne and Calaveras counties to the west.	Sustaining the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations.[40]	Aging recreation and visitor infrastructure. Limited time, funding, and resources to rapidly respond to uncertain conditions.[41]	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water	Cross-country skiing, backcountry skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, hunting, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
Lake Tahoe Basin Management Unit	Covers approximately 154,851 acres in California and Nevada. The portion in the Study Area is located in Alpine County.[42] Bounded by El Dorado County to the north and west, Humoldt-Toiyabe National Forest to the west, and El Dorado National Forest to the south.	Sustaining the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations.[43]	Aging recreation and visitor infrastructure. Limited time, funding, and resources to rapidly respond to uncertain conditions.[44]	Coniferous forest, shrubland, barren, deciduous forest, grassland, open water	Downhill skiing, cross-country skiing, other snow activities	Bicycling, camping, backpacking, primitive camping, fishing, gathering forest products, hiking/walking, horseback riding, hunting, rock climbing, viewing natural features and wildlife, wellness
California Department of Parks and Recreation						
Bodie State Historic Park	Covers 324 acres in Mono County, 12 miles southeast of Bridgeport.[45] Bounded by Bureau of Land Management land to the north, east, south, and west.	Preserving, protecting, and interpreting Bodie's natural and cultural resources.[46]	Land within and surrounding Bodie State Historic Park is owned and/or managed by the Bureau of Land Management.	Shrubland, barren, deciduous forest, grassland, urban	None	Driving for pleasure, hiking/walking, picnicking, viewing natural features and wildlife, wellness
Grover Hot Springs State Park	Covers approximately 553 acres in the northern portion of the Study Area, within Alpine County. Bounded by Humboldt-Toiyabe National Forest to the north, east, south, and west.	Providing for the health, inspiration, and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high-quality outdoor recreation.[47]	Land within and surrounding Grover Hot Springs is entirely surrounded by the Humboldt-Toiyabe National Forest.	Coniferous forest, shrubland, grassland	None	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, picnicking, viewing natural features and wildlife, water-based activities, wellness
Mono Lake Tufa State Natural Reserve	Covers approximately 116,000 acres in the central portion of the Study Area, within Mono County.[48] Bounded by Inyo National Forest and LADWP land to the north, east, south, and west.	Providing for the health, inspiration, and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high-quality outdoor recreation.[49]	LADWP has water rights to the lake through the Los Angeles Aqueduct, which has diverted much of its water in the past. As of 1991, LADWP water extraction has been limited to allow Mono Lake to rise 20 feet above 1991 levels.	Desert scrub, shrubland, deciduous forest, grassland, open water	Cross-country skiing, hiking/walking, picnicking, viewing natural features and wildlife, wellness	Driving for pleasure, hiking/walking, picnicking, viewing natural features and wildlife, water-based activities, wellness

Table 1. Subarea Profiles

Agency/ Jurisdiction Name	Location in the Study Area	Role/Mission of Managing Agency	Agency Constraints for Recreation and Tourism	Vegetation and Land Cover	Available Winter Recreation Activities [a]	Available Summer Recreation Activities [b]
Other Agencies						
Bureau of Land Management	Covers the majority of land in the Study Area outside of national parks, national forests, and land owned by LADWP.	Sustaining the health, diversity, and productivity of public lands for the use and enjoyment of present and future generations.[50]	The land is managed for multiple uses, some of which may conflict with recreation uses.	Desert scrub, coniferous forest, shrubland, barren, deciduous forest, desert woodland, grassland, open water, wetland, urban, agriculture/cropland	None	Bicycling, camping, backpacking, primitive camping, driving for pleasure, fishing, gathering forest products, hiking/walking, horseback riding, hunting, motorized trail activities, picnicking, rock climbing, viewing natural features and wildlife, water-based activities, wellness
LADWP	Covers approximately 69,204 acres of land within the Study Area along the Owens River and as far north as Mono Lake.[51] LADWP is the largest nonlocal landowner in the region.	Providing our customers and the communities we serve safe, reliable, and cost-effective water and power in a customer-focused and environmentally responsible manner.[52]	The primary role of the agency is to provide water and power to its customers.	Desert scrub, coniferous forest, shrubland, barren, deciduous forest, grassland, open water, wetland, agriculture/cropland	None	Camping, backpacking, primitive camping, fishing, gathering forest products, hiking/walking, hunting, picnicking, rock climbing, viewing natural features and wildlife, wellness

Notes:

a. For the full list of winter recreation activities, please see Appendix B, List of Populations and Assets. This includes snowmobiling and other motorized winter recreation, ice skating, and snow-shoeing, among others.

b. For the full list of summer recreation activities, please see Appendix B, List of Populations and Assets. This includes motorized and non-motorized trail activities, fishing, hiking/walking, picnicking, and water-based activities, among others.

SECTION 2: NATURAL CAPITAL ASSESSMENT METHOD

Baseline Natural Capital Assessment

Land Cover Types in the Study Area

In the first step of this Baseline Natural Capital Assessment, the Project Team identified the land cover types in the SRTI Study Area (Study Area) using geographic information system (GIS) data and the Classification and Assessment with Landsat of Visible Ecological Groupings (CALVEG) dataset (**Table 2**). The largest land cover type is desert shrub, which covers over 47 percent of the total Study Area, followed by coniferous forest (19 percent), shrubland (17 percent), and barren land (10 percent). The remaining land cover types make up less than 7 percent of the total Study Area.

Table 2. Study Area Land Cover Types

CALVEG Land Cover	Land Cover	Area (Acres)	Percentage (%)
Desert Shrubland	Desert Shrub	5,157,149	47%
Conifer Forest / Woodland	Coniferous Forest	2,103,843	19%
Shrub	Shrubland	1,837,064	17%
Barren / Other	Barren	1,058,250	10%
Hardwood Forest / Woodland	Deciduous Forest	182,159	2%
Desert Woodland	Desert Woodland	162,687	1%
Herbaceous	Grassland	124,552	1%
Water	Open Water	99,632	1%
Wetland	Wetland	96,064	1%
Urban	Urban	25,951	Less than 1%
Agriculture	Agriculture / Cropland	16,495	Less than 1%
Total		**10,863,847**	**100%**

Source: Based on the CALVEG dataset for the Study Area.

Ecosystem Service Valuation

An ecosystem is a dynamic complex of plants, animals, microorganisms, and the nonliving environment that interact as a functional unit. The processes through which ecosystems sustain themselves are known as ecosystem functions. These ecosystem functions result in *ecosystem services*, which are the benefits that humans receive from ecosystems.[53] Humans use ecosystems, and thus receive value from ecosystem services, in diverse ways. Some values are directly tied to market activity, such as extractive activities (the taking of timber, raw materials, food, and fuel). Other values may be only indirectly or not at all tied to market activity. Values of goods and services that fall outside of market activity are called *non-market values*. The objective of this analysis is to estimate a baseline economic value for ecosystem services, including both market and non-market values, provided by the land cover types in the Study Area.

At the highest level, the values attributed to ecosystem services can be described as *use* or *non-use values*. Within the set of use values, the most straightforward way in which ecosystem services provide economic value is through *direct use* by humans. Some direct uses of ecosystem services involve human consumption, such as harvesting timber and other forest products, food, and fuel.

Other direct uses, such as viewing wildlife, hiking, and enjoying scenic vistas, do not involve any actual consumption (and are thus called *non-consumptive*).

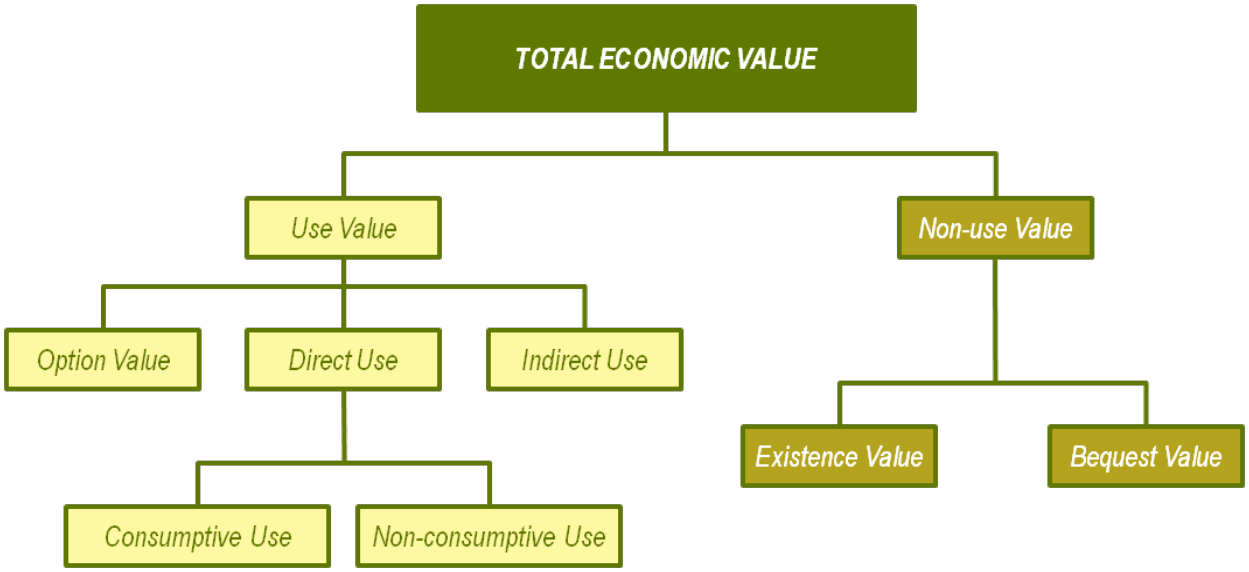
Human beings also can use ecosystem services indirectly, which occurs when an ecosystem service is an input to something else that is directly used by people. For example, when people directly use plants and animals, consumptively or non-consumptively, they *indirectly use* the habitats of those plants and animals. Other examples of indirect use include regulation of water flow, waste assimilation, and climate regulation (i.e., carbon storage and sequestration).

In addition to current use of ecosystem services, people can benefit from (and therefore place a value on) the knowledge that they can use a good or service in the future, which is called option value. One example of option value is the value an individual might place on preserving wildlife habitat they hope to visit in the future or the value they place on a species of bird they hope to someday view.

Ecosystem services also generate societal value through non-use values, which do not involve any actual direct or indirect use of an ecosystem service. One type of non-use value is *existence value*, which is the value people assign to a particular good just because it exists, even if they have no plans to use it personally. For example, people might value the protection of endangered species, natural areas such as old-growth forests, or unique natural areas such as Mammoth Mountain, the Golden Trout Wilderness, or the Bristlecone Pine Forest, even apart from their expected use of those species or areas. Similarly, *bequest value* refers to the value people place on a good or service being available to future generations, distinct from their own personal use.

Figure 2 summarizes the components of value described above.[54] "Total economic value" is the sum of all the different possible components of value described above, or the sum of the use and non-use values of ecosystem services.

Figure 2. Values of Ecosystem Services



The Project Team analyzed individual ecosystem services to quantify the total economic value provided by each land cover type in the Study Area. This Baseline Natural Capital Assessment enables the Project Team to evaluate the current benefits provided by the landscapes in the Study Area, to understand how these benefits may change as a result of climate change and future management activities and to help identify the values attributed to specific ecosystem service improvements. An ecosystem services framework, described below, was used to clarify the complex and often interlocking effects of the various management activities, ensuring that the benefits ascribed to the management activities are not overestimated because of double counting. This baseline ecosystem service valuation will help to produce a clear and transparent pathway from the physical landscape changes resulting from climate change and the resulting changes in ecosystem processes and functions to changes in ecosystem services and the effects that these changes have on human well-being.

Ecosystem services are commonly divided into four distinct groups:

- **Provisioning Services** provide products that are used directly by people, such as food, water, and raw materials.
- **Regulating Services** are outputs from the normal functioning of ecosystems that benefit people in direct ways, such as the regulation of climate, air and drinking water quality, soil formation and retention, moderation of extreme events, and biological control.
- **Habitat and Supporting Services** are processes that are necessary for the production of other ecosystem services, such as habitat for plants and animals, conservation of genetic diversity, and cycling of nutrients.
- **Cultural Services** provide benefits to people through meaningful interactions with nature, such as aesthetic enjoyment, recreation, spiritual enrichment, and cognitive development.[55]

A listing of the ecosystem services commonly included in each of these groups is presented in **Table 3** and **Figure 3**.

Table 3. Categorization of Ecosystem Services

Ecosystem Service	Definition
Provisioning Services	
Food	Biomass for human consumption
Raw Materials	Biological materials used for fuel, art, and building; geological materials used for construction or other purposes
Genetic Resources	Genetic resources and evolution in wild plants and animals (e.g., for crop improvement and medicinal purposes)
Medicinal Resources	Biological materials used for medicines (e.g., biochemical products, models and test organisms)
Drinking Water	Water for human consumption
Regulating Services	
Air Quality Regulation	Removal of air pollutants by vegetation
Climate Regulation	Regulation of greenhouse gases, absorption of carbon and sulfur dioxide, and creation of oxygen
Regulation of Water Flows	Water absorption during rains and release in dry times, temperature and flow regulation for plant and animal species
Erosion Prevention	Erosion protection provided by plant roots and tree cover
Water Quality and Waste Treatment	Absorption of organic waste, filtration of pollution
Biological Control	Natural control of pest species
Pollination	Fertilization of plants and crops through natural systems
Moderation of Extreme Events	Protection from storms and flooding, and drought recovery
Habitat and Supporting Services	
Soil Formation	Formation of sand and soil through natural processes
Nutrient Cycling	Transfer of nutrients from one place to another, transformation of critical nutrients from unusable to usable forms
Biodiversity and Habitat	Providing for the life history of plants and animals
Primary Productivity	Growth by plants provides basis for all terrestrial and most marine food chains
Cultural Services	
Aesthetic	The role natural beauty plays in attracting people to live, work, and recreate in an area
Recreation and Tourism	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities
Scientific and Educational	Value of natural resources for educational and scientific research
Spiritual and Religious	Use of nature for religious or historic purposes

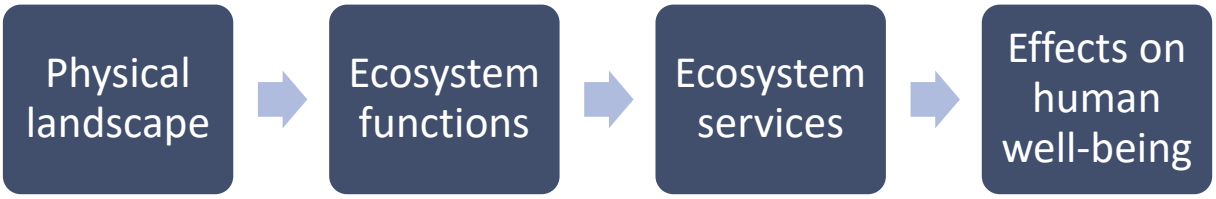
Sources: De Groot, R., B. Fisher, and M. Christie, 2010, "The Economics of Ecosystems and Biodiversity, Ecological and Economic Foundations," United Nations Environment Programme, Geneva, Switzerland; Ruhl, J. B., et al., 2007, *The Law and Policy of Ecosystem Services*, Washington, DC: Island Press.

Figure 3. Ecosystem Service Types

Source: The Economics of Ecosystems and Biodiversity

The Project Team applied an "ecosystem services framework" to determine which ecosystem services are commonly identified with the land cover types listed in **Table 2**. The first step of the framework is understanding the physical landscape—that is, land cover types and attributes of the identified area—which determines the ecosystem functions of each land cover type. The ecosystem functions are then assessed for their capacity to generate ecosystem services, and finally, ecosystem service values indicate the societal impacts and outcomes associated with human well-being. **Figure 4** illustrates the process associated with the ecosystem services framework.

Figure 4. Ecosystem Service Framework



Applying the ecosystem service framework enables the regional stakeholders to evaluate the potential beneficial effects of recreation and land management activities and to focus on the values attributed to specific ecosystem service improvements. In later project tasks the Project Team quantified and monetized the relevant ecosystem services in the Study Area through the ecosystem service framework.

Table 4 presents a comprehensive list of ecosystem services by land cover type. Cells that contain a symbol (either "✔" or "X") indicate that a land cover type provides a specific ecosystem service. The Project Team selected the ecosystem services that will be quantified and monetized (indicated by a "✔") based on their relevance to the Study Area (site specificity), valuation availability (data availability), and relative impact. Conversely, ecosystem services that lack available, substantive, or reliable data are not quantified or monetized in this analysis. Other ecosystem services that have the potential to be double counted are also not considered in this analysis due to the challenge posed by the double counting. Drinking water is a prime example of the double counting issue. The Study Area provides water resources for the surrounding region and is an important source of water for Los Angeles. For valuation purposes, however, drinking water and water quality are interrelated and a separate drinking water valuation is not feasible. Ecosystem services that are not captured in this Natural Capital Assessment are indicated by an "X" in **Table 4**.

Table 4. Ecosystem Services Provided by Study Area Land Covers

Ecosystem Service	Conifer / Deciduous Forests	Grassland / Shrubland	Crop-lands	Wetland / Riparian	Open Water	Desert (wood and shrub)
Provisioning Services						
Food	X	X	X	X		X
Raw Materials	X	X	X			X
Genetic Resources	X	X	X	X	X	X
Medicinal Resources	X		X			X
Drinking Water	X	X	X	X	X	
Regulating Services						
Air Quality Regulation	✓	✓	✓	✓		✓
Climate Regulation	✓	✓	✓	✓		✓
Regulation of Water Flows	✓	✓	✓	✓	✓	
Erosion Prevention	✓	✓	✓	✓	✓	
Water Quality and Waste Treatment	✓	✓		✓	✓	
Biological Control	✓			✓		✓
Pollination	✓		✓	✓		✓
Moderation of Extreme Events	X			X		
Habitat and Supporting Services						
Nutrient Cycling	X	X	X			
Soil Formation	X	X	X	X		
Biodiversity and Habitat	X	X	X	X	X	X
Primary Productivity	X	X	X	X		
Cultural						
Aesthetic	X	X	X	X	X	X
Recreation and Tourism	✓	✓	✓	✓	✓	✓
Scientific and Educational	X	X	X	X	X	X
Spiritual and Religious	X	X		X	X	X

Exclusions/Applications of the Ecosystem Service Framework

Exclusions

For several reasons, the Project Team did not try to ascribe values to certain ecosystem services. In general, the valuation of ecosystem services tends to be location specific, especially for biodiversity and habitat values, as well as for protection against extreme weather and climate-related hazards. For example, in the case of a wildfire, the value of the protection against wildfires provided by an ecosystem is dependent on potential avoided damages. In a rural setting, the potential avoided damages from a wildfire (in terms of property damage or injuries and fatalities) are relatively low. In suburban or urban areas, the potential avoided damages are much greater, yielding a higher value for the protection from wildfires provided by ecosystems. This value disparity is generally not accounted for in the literature, or it is represented by very large ranges in the estimated values for this ecosystem service, making it challenging to apply a value to a specific Study Area. Additionally, some ecosystem services are considered intermediary inputs to

other, broader services used and valued by humans. Valuation of these intermediate services would result in double counting when the values are also ascribed to the end products of these intermediate services. Habitat and Supporting Services are a good example of intermediate services, and this set of ecosystem services is commonly excluded from natural capital assessments for this reason. Other services are excluded because they are exceptionally specific to a site or case. Cultural Services, such as educational or spiritual enrichment, generally reflect individual locations within a Study Area; therefore, valuations tend to be subjective or inconsistently applied throughout a Study Area. Additionally, there is a lack of data and information on how to ascribe monetary values to the Cultural Services of educational and spiritual enrichment; the Project Team, therefore, excluded the valuation of such ecosystem services from our analysis.

In addition, the Project Team also excluded ecosystem services where data availability would limit the effectiveness of our analysis. For example, very few studies exist that have attempted to value ecosystem services such as genetic resources and medicinal resources (as well as many Cultural Services). The monetized value of these services can thus fluctuate wildly (if monetized values exist at all), which can skew the valuation results. We therefore excluded the valuation of these ecosystem services from our analysis.

Applications

The Project Team collected values for each land cover type and ecosystem service in **Table 4** from available natural-capital literature and then used benefit transfer methods to adapt these values to the Study Area. Benefit transfer is an approach that involves using estimates of the value of ecosystem services from existing studies and applying them to a new context. There are two possible approaches to conducting benefit transfers: benefit value transfer and benefit function transfer. First, benefit value transfer involves taking point estimates, or values, from the primary source and applying them directly to the new Study Area, under the assumption that the Study Area is similar to the primary study site.[56] Second, benefit function transfer involves taking the function used to estimate benefits in the original study and applying the function to the new study context. As part of transferring the benefit function, the independent variables in the function are updated with values that reflect the characteristics of the new study site.[57] Of the two approaches, benefit function transfer is viewed as the preferred approach, as it allows for the original values to be adapted to a greater degree than is possible with benefit value transfer. Despite these advantages, it is not always possible to conduct benefit function transfers, as the functions used to estimate benefits may not be available. **Table 5** displays the specific benefit transfer method used by the Project Team for each of the ecosystem services assessed.

Table 5. Methods for Estimating Ecosystem Services

Ecosystem Service	Method
Air Quality Regulation	Benefit Value Transfer
Biological Control	Benefit Value Transfer
Carbon Sequestration	Benefit Function Transfer
Carbon Storage	Benefit Function Transfer
Erosion Prevention	Benefit Function Transfer
Pollination	Benefit Function Transfer
Waste Treatment	Benefit Value Transfer and Benefit Function Transfer
Water Quality	Benefit Value Transfer
Water Regulation	Benefit Function Transfer
Recreation & Tourism	Benefit Function Transfer

Climate Change Natural Capital Assessment

The baseline assessment estimated the value of the ecosystem services, which are presented in **Table 3**. The baseline assessment used a variety of data, benefit transfer techniques, and methods to arrive at monetized estimates for each of these ecosystem services. It estimated the value of recreation and tourism using data from the U.S. Forest Service (USFS) and the National Park Service (NPS). The USFS reports average consumer surplus per person per primary activity day, defined as one person recreating for some portion of a day.[58] The USFS tracks activity participation in each national forest by primary activity. Because the NPS does not report activity participation rates, the Project Team assumes that the Inyo National Forest's activities and values are representative for the Study Area because of its location in the Study Area. As a result of data source mismatches, USFS primary activities must be mapped to the activities presented later in the vulnerability assessment. **Table 6** presents the definitions and National Visitor Use Monitoring categories of primary recreational activities represented in the Recreation Use Values Database in the first three columns,[59] and the fourth column maps these recreational activities to the relevant primary activities from the Climate Change Vulnerability Assessment. Some recreation activities that are important for the region, such as rock climbing, are not separated out in the available USFS or NPS datasets. These activities are still considered as part of the "other recreation" category.

Table 6. Definitions and Categories of Primary Recreational Activities Mapped to the Climate Change Vulnerability Assessment Activities

Primary Activity	Definition	National Visitor Use Monitoring Activity Represented	Climate Change Vulnerability Assessment Activities
Backpacking	Camping at primitive or dispersed backcountry sites	Primitive camping, backpacking	Backpacking, primitive or dispersed camping
Biking	Mountain and leisure biking	Bicycling	Bicycling
Cross-country skiing	Cross-country skiing	Cross-country skiing and snowshoeing	Cross-country skiing
Developed camping	Camping at sites with developed amenities such as fire pits, electricity, toilets, picnic tables, and parking	Developed camping	Camping
Downhill skiing	Downhill skiing and snowboarding	Downhill skiing and snowboarding	Downhill skiing and backcountry skiing
Fishing	Freshwater fishing: all species, bodies of water, and angling techniques	Fishing	Fishing
Hiking	Hiking, walking, jogging, and trail running that does not include backcountry camping	Hiking and walking	Hiking/walking
Hunting	Big game, small game, and waterfowl hunting	Hunting	Hunting
Motorized boating	All types of motorized boating	Motorized water activities	Water-based activities
Nature related	Nature watching and visitor center use	Nature center activities, nature study, viewing wildlife, viewing natural features, visiting historic sites	Viewing natural features and wildlife, visiting historic sites and nature centers
Nonmotorized boating	Floating, kayaking, rafting, and all types of nonmotorized boating	Nonmotorized water activities	Water-based activities
Off-highway vehicle use, snowmobiling	Snowmobiling and off-road and all-terrain vehicle riding	Off-highway vehicle use, motorized trail activity, snowmobiling, other motorized activity	Motorized trail activities & Other snow activities
Other recreation	Primary and general recreational activities not accounted for in other categories	Relaxing, horseback riding, gathering forest products, resort use, other nonmotorized activities, other activities	Driving for pleasure, Gathering forest products, Horseback riding, Rock climbing, & Wellness
Picnicking	Picnicking	Picnicking	Picnicking

Sources: Rosenberger et al., 2017, "Recreation Economic Values for Estimating Outdoor Recreation Economic Benefits From the National Forest System," U.S. Department of Agriculture; Appendix C (Climate Change Vulnerability Assessment Results Matrix)

Notes: While Rosenberger et al. include "gathering forest products" under "other recreation," gathering forest products reflected zero percent of the primary activities in which visitors participated. As a result, zero economic value is attributed to gathering forest products in the model. Henceforth, gathering forest products is excluded from the estimation of economic activity derived from recreational activities at risk in the Climate Change Vulnerability Assessment.

SECTION 3: CLIMATE CHANGE VULNERABILITY ASSESSMENT METHOD

The Climate Change Vulnerability Assessment follows the recommended process in the *California Adaptation Planning Guide* (APG), which is the state's guidance for how local communities should conduct climate adaptation planning efforts, including vulnerability assessments. This document was recently updated by the California Governor's Office of Emergency Services (Cal OES) and provides the steps for jurisdictions in California to identify and reduce climate change hazards. The analysis also incorporated the evaluation and findings of the U.S. Forest Service's USFS's) *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* and *Climate Change Vulnerability and Adaptation in the Intermountain Region* and EcoAdapt's *Southern California and Sierra Nevada Climate Adaptation Projects*. The Climate Change Vulnerability Assessment also relies on local, regional, and statewide datasets and studies to support the assessment and can be easily replicated in other regions; can be used at various scales; and can consider benefits, unique opportunities, impact, and adaptive capacity as factors for prioritizing vulnerabilities.

Adaptation Planning Guide Method

The APG suggests that vulnerability assessments follow a four-step process, which is shown in **Figure 5** and described in the text that follows.

Figure 5. California Adaptation Planning Guide Vulnerability Assessment Method

Identify exposure: In a vulnerability assessment, *exposure* is the presence of people; infrastructure; natural systems; and economic, cultural, and social resources in areas that are subject to harm. A *hazard* is an event or physical condition that has the potential to cause types of harm or loss, such as a drought or wildfire. To prepare the Climate Change Vulnerability Assessment, the Project Team looked at which climate change hazards the different populations, assets, and recreation activities in the SRTI Study Area (Study Area) are likely to be exposed to.

This step included confirming applicable hazards in the Study Area, describing historical hazards, describing how hazards are expected to change, and mapping the hazard-prone areas.

Analyze sensitivity and potential impacts: *Sensitivity* is defined as the level to which a species, natural system, community, government, etc., would be affected by changing climate conditions. Potential *impacts* are the effects of a climate change hazard, or the combination of *exposure* and *sensitivity*. For example, if an increase in drought conditions on a water body used for recreational activities is the exposure, then the risk of lower water levels on water-based activities is the impact, and the degree to which water recreation activities will be impacted is the sensitivity. Each population, asset, and recreation activity in the Study Area is likely to experience different impacts. The Project Team assessed the sensitivities and potential impacts to each population, asset, or recreation activity from each applicable climate change hazard.

Evaluate adaptive capacity: *Adaptive capacity* is the ability of people, assets, and recreational activities to adjust to potential damage, take advantage of opportunities, or respond to the impacts of climate change, given currently available or planned resources. The Project Team looked at the adaptive capacity of each population, asset, and recreation activity for each identified hazard as part of the Climate Change Vulnerability Assessment. This included reviewing recreation and land management plans, jurisdiction and agency budgets, and implemented programs or projects that could increase resilience of specific assets or recreation activities in the Study Area.

Conduct vulnerability scoring: *Vulnerability* is defined as the combination of impact and adaptive capacity as affected by the level of exposure to changing climate conditions. Following the process in the APG, the Project Team used the impact and adaptive capacity scoring to identify and prioritize the most vulnerable populations, assets, and recreation activities in the Study Area.

Assessment Process

After selecting the hazards, populations, assets, and recreational activities to include in the Climate Change Vulnerability Assessment, the Project Team conducted the Climate Change Vulnerability Assessment based on the APG's recommended process and the recommendation in our Methods Memo dated August 12, 2020.[60] This recommendation included using the USFS's *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* as a basis for the infrastructure and recreation activities chosen for the assessment, as well as EcoAdapt's *Southern California and Sierra Nevada Climate Adaptation Projects* for the ecosystem portion of the assessment. Additionally, the assessment integrated hazard and climate change data from the USFS project and the Town of Mammoth Lakes Climate Change Vulnerability Assessment, which was scaled up to use at the regional scale of the Study Area.[61,62,63]

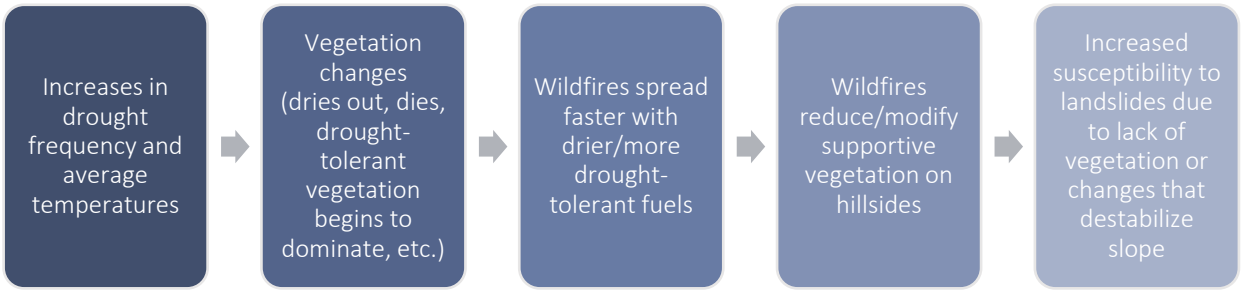
Applicability Review

The Project Team looked at which hazards are likely to affect which populations, assets, and recreational activities because not all hazards would affect all three. For example, human health hazards are likely to impact populations, but they would not affect the structural stability of a bridge or a parking lot. The outcome of this step was a matrix that identified if a population, asset, or recreation activity is likely to be exposed to a hazard and was then used for the impact and adaptive capacity scoring.

Hazards that have the potential to affect a population, asset, or recreational activity directly or indirectly were marked as applicable to that population/asset/activity. Direct impacts affect physical assets, recreational activities, or key services, and they can lead to indirect impacts on the broader system or community, including asset types in a different category. For example, severe weather can *directly* damage electrical transmission lines, causing power outages, which can *indirectly* impact retail workers or hospitality workers who depend on the electricity for their employers to stay open. Therefore, electrical transmission lines, retail workers, and hospitality workers were marked as being potentially affected by severe weather and would be evaluated for vulnerability to severe weather events in the assessment.

Additionally, this step was where cascading effects were first considered in the analysis. Cascading or compounding climate change effects are instances where one climate change hazard can lead to another, which can "cascade" into additional hazardous conditions. **Figure 6** provides an example of these cascading effects. Human health hazards can also have cascading effects, such as workers being unable to work or visitors being unable to travel to an area, which can harm both recreation activities and key community services. These were accounted for when developing the applicability matrix and later stages of the assessment.

Figure 6. Example of Cascading Effects



Assessing Impacts

To assess the potential impacts that climate change hazards may have on populations, assets, and recreational activities, the Project Team considered various questions to ensure that the assessment broadly covered the range of potential harm. The questions below address physical or other impacts, the length of the impact, and how many people/assets/recreational impacts could be directly or indirectly harmed. These questions allowed the Project Team to account for both direct and indirect impacts.

- What type of potential impacts may occur?
- Could the potential impacts cause physical injury or damage? If not, is there a risk of harm to recreational activities, loss of economic activity, or other nonphysical harm?
- How many people, assets, or recreational activities could be affected by both direct and indirect harm?
- How long would the impacts persist after the exposure?
- Is there a substantial chance of death or widespread destruction?

Based on the results of the impact assessment, the Project Team ranked each population, asset, and recreation activity on a five-point scale (0 to 4) for each relevant hazard. IM0 is the lowest impact, and IM4 is the highest impact. An impact is considered a negative quality, and therefore a higher impact score means that there is a higher potential for harm to a population or asset. A lower impact score means that there is a lower potential for harm to a population or asset. **Table 7** provides more detail about what each score means.

Table 7. Impact Scoring Matrix

Impact Score	Meaning (Populations and Ecosystems)	Meaning (Buildings, Infrastructure, Services, and Recreation Activities)
IM0. Minimal Impact	Community members may not notice any change.	Damage, interruption in service, or impacts on the local economy are small or intermittent enough to mostly go unnoticed.
IM1. Low Impact	Community members notice minor effects. Daily life may experience mild, occasional disruptions.	There are minor but noticeable interruptions in service, damage, or negative effects on the economy.
IM2. Moderate Impact	There is a marked impact to the community. Quality of life may decline. Impacts may be chronic and at times substantial.	Damage, service interruptions, and other impacts are clearly evident. Impacts may be chronic and occasionally substantial.
IM3. Significant Impact	The well-being of the community declines significantly. The community's current lifestyle and behavior may no longer be possible.	Impacts are chronic. Buildings, infrastructure, and services may be often or always unable to meet community demand. Large sections of the economy experience major hardships.
IM4. Severe Impact	There is a severe risk of widespread injury or death to people, or of significant or total ecosystem loss.	Buildings, infrastructure, and services cannot function as intended or needed. Economic activities, including recreational efforts, are not viable.

Evaluating Adaptive Capacity

The Project Team next evaluated the adaptive capacity of the individual populations, assets, and recreation activities for each relevant hazard. Following a similar process used to analyze impacts, the Project Team considered various questions to help ensure that the adaptive capacity assessment covered the full ability of a population, asset, or recreation activity to resist and recover from harm, given current programs and resources. Examples of these questions include:

- Are there existing programs, policies, or funding to provide assistance?
- Are there barriers that limit response or recovery? Are these barriers financial limitations, political challenges, lack of access to technology or other resources, or others?
- Do alternatives exist in other regions of the Study Area that community members and visitors can use?

Based on the results of the adaptive capacity assessment, the Project Team ranked each population, asset, or recreation activity on a five-point scale (0 to 4) ranging from AC0 (the lowest adaptive capacity) to AC4 (the highest adaptive capacity). Adaptive capacity is considered a positive attribute, so a higher adaptive capacity score means that a population, asset, or recreational activity may be more adaptable to the hazard. A lower adaptive capacity score means that a population, asset, or recreational activity may have a harder time adjusting to the changing conditions. **Table 8** provides more detail about what each score means.

Table 8. Adaptive Capacity Scoring Matrix

Adaptive Capacity Score	Meaning
AC0. No Adaptive Capacity	Currently, there are no feasible means of adapting.
AC1. Low Adaptive Capacity	Adaptive solutions are available, but they are expensive, technologically difficult, and/or politically unpopular. Alternatives may not exist that can provide similar services.
AC2. Some Adaptive Capacity	Some adaptation methods are available, but not always feasible. Adapting may create significant challenges for some sensitivities. Some alternatives exist within the jurisdiction area that can provide similar services.
AC3. High Adaptive Capacity	Adaptation solutions are feasible for most or all populations, assets, and recreational activities. There may be occasional or small-scale challenges to implementing adaptation methods. Many alternatives exist in the area that can provide similar services.
AC4. Outstanding Adaptive Capacity	Populations, assets, and recreational activities can adapt with little or no effort. Quality of life is unchanged or may improve.

Vulnerability Scoring

The Project Team used the impact and adaptive capacity scores for each population, asset, and recreation activity for each relevant hazard to determine the vulnerability score. The vulnerability score reflects how susceptible a population or asset is to harm from a particular hazard. Vulnerability is assessed on a scale of V1 to V5, as shown in **Figure 7**. The matrix in **Table 9** shows how impact and adaptive capacity scores combine and translate into a vulnerability score.

Figure 7. Vulnerability Scale

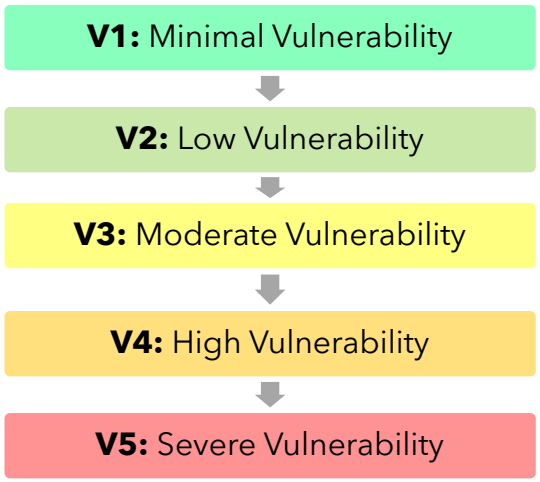


Table 9. Vulnerability Scoring Matrix

		Impact Score				
		IM0	**IM1**	**IM2**	**IM3**	**IM4**
Adaptive Capacity Score	**AC0**	V3	V4	V5	V5	V5
	AC1	V2	V3	V4	V5	V5
	AC2	V1	V2	V3	V4	V5
	AC3	V1	V1	V2	V3	V4
	AC4	V1	V1	V1	V2	V3

Data Sources

The Climate Change Vulnerability Assessment must be based on the best available science and information. The Project Team used data from a variety of credible sources to prepare the Climate Change Vulnerability Assessment, determine the impact and adaptive capacity scores, and support the vulnerability scoring conclusions. These sources include scholarly research, regionally provided data, and state and federal agency data.

Scholarly Research

The Project Team relied on an extensive body of scientific research that analyzes and summarizes how climate change may affect populations, assets, and recreational activities and tourism in the Study Area. In some cases, this research was not done in the Study Area, but the results are applicable and relevant. Much of this research is peer reviewed to ensure greater accuracy, and it includes studies published in academic journals such as the *Proceedings of the National Academy of Science, Geophysical Research Letters,* and *Climate Change*. The Project Team backed the information in these studies and reports with websites and publications from scientific and academic institutions, government organizations, and credible local and national sources.

State and Federal Data

Due to the scale of the Climate Change Vulnerability Assessment and the primary land managers in the Study Area, the Project Team relied on data from state and federal agencies, including published reports and datasets. Key resources from federal agencies include general management plans and recreation management plans for the national parks and national forests in the Study Area. The Project Team used information from several agencies, including the U.S Forest Service (USFS), National Park Service (NPS), the U.S. Department of Interior, the U.S. Global Change Research Program, California State Parks, Centers for Disease Control and Prevention, Federal Emergency Management Agency, the United States Geological Survey, Caltrans Region 9, the California Energy Commission, the California Geological Survey, the California Department of Public Health, the California Division of Safety of Dams, Cal OES, the California Governor's Office of Planning Resources, and the California Department of Forestry and Fire Protection (CAL FIRE).

The USFS's Region 5 report, *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada,* and associated datasets were used as a basis for impact and adaptive capacity justifications for buildings, infrastructure, and recreation activities throughout the Study Area. This report, developed in partnership with the State of Washington Office of Sustainability and Climate, the USFS's Pacific Southwest Research Station, and Adaptation Partners throughout the Sierra Nevada region, is intended to be a resource for the USFS and its partners, including helping to inform land management planning efforts. The focus of this report is climate change's effects on water resources, infrastructure, and outdoor recreation, and the ability of the USFS and partnering agencies to adapt to these effects. The Project Team also used spatial data from this report and the Rocky Mountain Research Station's National Forest Climate Change Maps for hazards, assets, and recreational activities in the Study Area.[64]

The primary resource for the ecosystem and natural resources in the Climate Change Vulnerability Assessment was EcoAdapt's *Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada.* This assessment was developed for USFS Region 5 in 2014 and focuses on specific ecosystems and habitats in the Study Area instead of the built environment. The research and findings of this assessment were used to evaluate vulnerabilities to specific hazards.

The Study Area also consists of areas outside the Sierra Nevada, primarily Death Valley National Park and surrounding desert region, and therefore information from EcoAdapt's 2017 *Southern California Climate Adaptation Project* was used in a similar manner to supplement this information.

Key state resources include the following guidance documents, reports, and tools:

- The state's APG and the Fourth Climate Change Assessment—including the *Sierra Nevada Regional Report*, the *Summary Report from Tribal and Indigenous Communities within California*, and the *Climate Justice Summary Report*—provided extensive information about climate-related exposures and vulnerabilities in addition to federal reports such as the *National Climate Assessment*.

- Cal-Adapt, a web-based tool developed by the California Energy Commission, provided highly specific information about historical climate conditions and future climate projections for extreme heat, drought, severe weather, and wildfire.
- Caltrans's *Climate Change Vulnerability Assessment* for Region 9 provided spatial data for highways and roadways in the Study Area as well as specific information about how evacuation routes, roadway materials, and operations and maintenance will be affected by climate change.

Local and Regional Data

Local and regional government agencies, including the counties and cities in the Study Area, have already prepared several plans and reports that support the Climate Change Vulnerability Assessment or contain information relevant to the analysis. The Project Team supplemented state and federal data with several local and regional plans to prepare the Climate Change Vulnerability Assessment, including:

- *City of Bishop General Plan* (1993)
- *Inyo County General Plan* (2001)
- *Mono County General Plan* (2015)
- *Alpine County General Plan* (2017)
- *Inyo County Multi-Jurisdictional Hazard Mitigation Plan* (2017)
- *Alpine County Multi-Jurisdictional Hazard Mitigation Plan* (2018)
- *Mono County Multi-Jurisdictional Hazard Mitigation Plan* (2019)
- *Town of Mammoth Lakes Vulnerability Assessment* (2019)
- *Town of Mammoth Lakes General Plan* (2019)

The Project Team also relied on spatial datasets from Alpine County, Mono County, Inyo County, the Town of Mammoth Lakes, and the City of Bishop. These data show the locations of various buildings and infrastructure, recreation sites and trails, different land uses, boundaries, critical facilities, and other items of importance to the Climate Change Vulnerability Assessment.

SECTION 4: BASELINE NATURAL CAPITAL ASSESSMENT ECOSYSTEM SERVICE IMPACTS

This section summarizes impacts for each ecosystem service and land cover type and presents the methods used to calculate these impacts.

Summary of Results

The Project Team estimates the total annual economic value of ecosystem services provided by lands within the boundaries of the SRTI Study Area (Study Area) to range from approximately $43.6 to $190.9 billion, with an average value of $95.4 billion (all values in this report are presented in 2019$). **Table 10** and **Table 11** present low, average, and high total values based on the range of potential impacts. The range of impacts (low, average, high) is based on the literature used as part of the benefit transfer methods. Where we identified multiple literature sources for a single ecosystem service and land cover type, we identified the lowest and highest estimate provided by the literature and calculated the average of all values identified. We carried this structure through the analysis to emphasize the range of values that ecosystem services provide. The range provided by this analysis is an expected outcome and similar to other analyses of this type. Annual values in these tables differ slightly due to rounding. **Table 10** presents the annual value by ecosystem service, with the carbon storage and water quality services providing the greatest value. Their annual values range from approximately $19.4 to $64.7 billion (with an average of $40.4 billion) for carbon storage and $14.6 to $89.6 billion (with an average of $37.7 billion) for water quality. **Table 11** presents impacts by land cover type, with the coniferous forest and shrubland land cover providing the most value. Their total annual values range from $18.8 to $89.3 billion (with an average of $44.0 billion) for coniferous forest and from $16.5 to $56.4 billion (with an average of $33.4 billion) for shrubland.

Table 10. Summary of Total Annual Ecosystem Service Values by Ecosystem Service for the Study Area, Millions of 2019 Dollars

Ecosystem Service	Total Value / Year		
	Low	Average	High
Air Quality Regulation	$416.3	$479.6	$559.1
Biological Control	$68.0	$85.0	$126.1
Carbon Sequestration	$146.7	$314.1	$493.2
Carbon Storage	$19,382.6	$40,438.2	$64,688.8
Erosion Prevention	$0.4	$87.1	$291.5
Pollination	$90.5	$271.4	$452.3
Recreation and Tourism [a]	$2,066.7		
Waste Treatment	$180.9	$4,217.8	$19,774.2
Water Quality	$14,595.7	$37,658.0	$89,561.7
Water Regulation	$6,611.0	$9,732.20	$12,853.4
Total	**$43,558.7**	**$95,350.0**	**$190,866.9**

Notes:
a. Recreation and Tourism only includes a single value because this value was calculated differently. Please see the "Recreation and Tourism Section" section for additional detail.

Table 11. Summary of Total Annual Ecosystem Service Values by Land Cover Type for the Study Area, Millions of 2019 Dollars

Land Cover Type	Area (Acres)	Total Value / Year		
		Low	Average	High
Desert Shrub	5,157,149	$3,573.9	$5,200.8	$6,827.8
Coniferous Forest	2,103,843	$18,770.2	$44,025.7	$89,375.7
Shrubland	1,837,064	$16,503.0	$33,381.1	$56,357.4
Barren	1,058,250	$0.0	$0.0	$0.0
Deciduous Forest	182,159	$850.8	$2,894.3	$6,651.0
Desert Woodland	162,687	$145.5	$258.9	$342.6
Grassland	124,552	$1,022.7	$2,193.9	$3,852.8
Open Water	99,632	$347.1	$506.6	$1,011.9
Wetland	96,064	$254.2	$4,754.5	$24,232.3
Urban	25,951	$1.6	$2.1	$3.4
Agriculture/ Cropland	16,495	$23.1	$65.3	$145.5
Total [a]	**10,863,846**	**$41,492.1**	**$93,283.2**	**$188,800.4**

Notes:
a. Total does not include Recreation and Tourism impacts as they could not be disaggregated by land cover type.

Provisioning Services

Provisioning services include ecosystem goods and services that are used directly by humans, including food, raw materials such as fossil fuels and timber, genetic resources, medicinal resources, and drinking water. Unlike the other categories of ecosystem services, most provisioning services are directly traded in markets. The Project Team did not assign values to provisioning services as part of the Baseline Natural Capital Assessment, because much of the Study Area is in national forests and national parks, with limited availability for farming or logging; however, these areas protect and provide most of the state's drinking water resources. The industry sectors of mining, quarrying, and oil and gas extraction make up less than 0.2 percent of jobs in the Study Area.[65] The agricultural lands in the Study Area produced over $58 million (2019$) annually in agricultural commodities.[66]

The Importance of Water in the Eastern Sierra Region

Water is one of the most significant resources in the Study Area. Ecosystem services provided by water resources in this region is difficult to quantify; however, the value of this resource can be illustrated through the extensive history of human water management activities beginning with tribal nations who built small earthen dams and water diversions on Sierra Nevada creeks that fed an intricate system of ditches to irrigate native plant crops in the Owens Valley and beyond.

This water management system was taken over or destroyed by Euro-American ranchers in the mid to late 1800s. Power companies developed large, high-elevation dams on glacial lakes and hydroelectric powerhouses on Sierra Nevada creeks to produce electricity for gold and silver mining in eastern California and Nevada. In 1905, the City of Los Angeles, nearly 250 miles southwest of the Study Area, filed for water rights in the Eastern Sierra region. The Inyo National Forest was established by Theodore Roosevelt in 1907 to preserve the headwaters of this valuable commodity and to accommodate construction of the Los Angeles Aqueduct project, which was completed in 1913. Los Angeles Department of Water and Power (LADWP) continues to actively divert and pump ground water for consumption in the greater Los Angeles area from the Mono Basin watershed and Owens Valley. The Tuolumne River and Hetch Hetchy Dam in Yosemite National Park are also diverted to provide drinking water to the San Francisco Bay Area. Therefore, ecosystem services provided by water resources, specifically drinking water, remains one the most important issues in this region because large population centers throughout California depend on this valuable resource.

The Project Team did not include the value of provisioning services in the Baseline Natural Capital Assessment to avoid double counting ecosystem service values already accounted for under regulating services (see subsequent section). For example, a third of the agricultural commodities (by value) such as alfalfa are pollinated.[67] The value of these crops is thus accounted for in the values ascribed to the regulating service of pollination. The remaining values of agricultural commodities in the Study Area are largely derived from livestock. It is assumed that pastureland for livestock is either grassland or shrubland and thus the ecosystem services ascribed to these land cover types are included in regulating services.

Water resources are incredibly important both for the Study Area and for many other regions in California, which source their water from the Study Area. The economic valuation of drinking water resources, however, is complicated because there are several water-based ecosystem services, including drinking water (provisioning service), as well as water quality and water regulation (regulating services). It is not possible to value all of these services without double counting the economic value of water services. As such, the value of drinking water is captured within the discussion of water quality regulating service that follows.

Regulating Services

Regulating services include ecosystem processes and functions that are part of the maintenance of ecosystems that also provide benefits to humans. The Project Team estimated the economic value of the following set of regulating ecosystem services: air quality regulation, biological control, carbon sequestration, carbon storage, erosion prevention, pollination, waste treatment, water quality, and water regulation.

Air Quality Regulation

Ecosystems provide air quality regulation services through the filtering of air pollutants by trees and other vegetation, including particulate matter, ammonia, sulfur dioxide, nitrogen oxide compounds, mercury, carbon dioxide (CO_2), and methane. The air quality regulation services of ecosystems are particularly important in urban areas where they may lead to human populations experiencing reductions in air pollution–related risks of mortality and morbidity. Human populations in less populated areas, however, may also benefit from air quality regulation services, but likely to a lesser extent than populations in urban areas. The Project Team estimated the value of air quality regulation services provided by different land cover types based on the absorption of pollutants by land cover types and by the external, or indirect, costs of these pollutants that would be avoided.

Due to many uncertainties around the air quality regulation benefits, the Project Team was unable to identify existing studies that were suitable for use in a benefit function transfer. Examples of these uncertainties include the lack of information about the geographic location of polluting activities, the ambient concentration of air pollutants in the relevant areas, and the proximity of human populations to areas providing air quality regulating services. In addition, the fact that the affected areas are generally more rural than urban adds further uncertainty to the estimation of the benefits of air quality regulation services.

Due to the inability to conduct a benefit function transfer, the Project Team instead estimated the value of air quality regulation services for the various affected land cover types based on obtaining a minimum, maximum, and average of a range of estimates from previous studies on air quality benefits provided by various land cover types in non-urban settings. These estimates represent the annual value of cleaner air and pollution removal, including the value of reduced cases of asthma and other respiratory diseases. **Table 12** presents the range of annual per-acre values for the affected land cover types based on the review of suitable source data. The range of per-acre values for each land cover type reflects variations in the estimated values of damages caused by air pollutants and variations in the amount of air quality regulation services provided by different land cover types.

Owens Lake Air Pollution

Southern Inyo County is home to Owens Lake, a dry exposed lake bed created from water diversions into the Los Angeles Aqueduct. The dry lake produces large amounts of airborne pollution in the form of PM_{10}. Owens Lake is considered the largest producer of windblown dust in the United States and LADWP has had difficulty adhering to regulations set by the U.S. Environmental Protection Agency's National Ambient Air Quality Standards and California air quality standards.

LADWP has been implementing dust control measures such as shallow flooding, managed vegetation, and gravel cover to reduce particulate pollution. Costs of LADWP mitigation efforts have exceeded $2 billion over the last 20 years. The Project Team acknowledges Owens Lake's contribution to ambient concentrations of air pollutants.

The natural ecosystems in the surrounding area help filter the air pollutants produced at Owens Lake, potentially reducing overall costs of implementing dust control measures by supporting the mitigation of the negative environmental impacts of PM_{10}.

Sources: Great Basin Unified Air Pollution Control District, n.d., "Owens Lake Background," https://gbuapcd.org/OwensLake/Background/; GBUAPCD 2021.

Table 12. Annual Air Quality Regulating Service Rates by Land Cover Type

Land Cover Type	Value /Acre/Year (2019$)		
	Low	Average	High
Agriculture / Cropland	$0.0	$56.1	$111.4
Barren	$0.0	$0.0	$0.0
Coniferous Forest	$171.0	$189.8	$216.4
Deciduous Forest	$67.4	$182.5	$297.7
Desert Shrub	$4.7	$4.7	$4.7
Desert Woodland	$4.7	$4.7	$4.7
Grassland	$4.9	$5.15	$5.4
Open Water	$0.0	$0.0	$0.0
Shrubland	$4.9	$5.2	$5.4
Urban	$61.0	$61.0	$61.0
Wetlands	$82.2	$94.4	$106.7

Source: Project Team analysis of existing studies. See Appendix A for a list of studies.

After estimating ranges of per-acre values for each affected land cover type, the Project Team multiplied the per-acre values by the acreage of each land cover type in the Study Area. **Table 13** presents estimated minimum, average, and maximum total annual values for air quality regulation services benefits for the land cover types found in the Study Area. The Project Team estimates the range of total annual value of air quality regulation services to be between $416.3 and $559.1 million, with an average of $479.6 million. Of the various land cover types in the Study Area, coniferous forests provide the greatest air quality regulation services, valued from $359.7 to $455.3 million annually, with an annual average of $399.4 million.

Table 13. Total Annual Values of Air Quality Regulation Services by Land Cover Type, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value/ Year		
		Low	Average	High
Agriculture / Cropland	16,495	$0.0	$0.9	$1.8
Barren	1,058,250	$0.0	$0.0	$0.0
Coniferous Forest	2,103,843	$359.7	$399.4	$455.3
Deciduous Forest	182,159	$12.3	$33.3	$54.2
Desert Shrub	5,157,149	$24.5	$24.5	$24.5
Desert Woodland	162,687	$0.8	$0.8	$0.8
Grassland	124,552	$0.6	$0.6	$0.7
Open Water	99,632	$0.0	$0.0	$0.0
Shrubland	1,837,064	$8.9	$9.5	$10.0
Urban	25,951	$1.6	$1.6	$1.6
Wetland	96,064	$7.9	$9.1	$10.2
Total:	**10,863,846**	**$416.3**	**$479.6**	**$559.1**

Source: Project Team analysis of existing studies.

Biological Control

Ecosystems provide biological control services through the control of pests and disease-spreading organisms (such as mosquitoes and deer ticks) and species of insects that prey on crops. Natural pest control through an ecosystem-based approach can reduce pesticide use and enhance biodiversity while ensuring production. Biological control has the potential to maintain healthy ecosystem functionality or restore ecosystem health by preventing land degradation and suppressing disease.

To value this ecosystem service, the Project Team conducted a literature review of studies that have estimated the value of biological control services in areas similar to those found in the Study Area, as listed in **Appendix A.** These values represent the avoided costs of additional pesticide spraying and disease prevention mechanisms that would need to be initiated in the absence of natural biological control. The Project Team then averaged a range of values from previous studies that were deemed the most suitable source data for a benefit value transfer. The results of this literature search are shown in **Table 14**, which presents estimates of the low, average, and high annual per-acre values of biological control services for the Study Area. The range of values in the source data reflects variations in the estimated costs of providing biological control services by other means if these services were lost. **Table 14** shows that grasslands provide the highest annual value for biological services among the land cover types in the Study Area, ranging from $16.0 to $345.7 per acre, with an average of $79.5 per acre.

Table 14. Annual Biological Service Rates by Land Cover Type

Land Cover Type	Value/ Acre/Year (2019$)		
	Low	Average	High
Agriculture/ Cropland	$0.0	$59.8	$221.5
Barren	$0.0	$0.0	$0.0
Coniferous forest	$8.6	$11.5	$12.6
Deciduous Forest	$5.0	$16.5	$33.1
Desert Shrub	$1.7	$1.7	$1.7
Desert Woodland	$1.7	$1.7	$1.7
Grassland	$16.0	$79.5	$345.7
Open Water	$0.0	$0.0	$0.0
Shrubland	$20.5	$20.5	$20.5
Urban	$0.0	$0.0	$0.0
Wetland	$0.0	$0.0	$0.0

Source: Project Team analysis of existing studies.

Next, the Project Team multiplied the per-acre values for biological control services by the acres of land of the various types found in the Study Area. **Table 15** presents the estimated total annual minimum, average, and maximum values for biological control services by land cover type for the Study Area. The Project Team estimates the range of total annual value for biological control services to be between $68.0 and $126.1 million, with an annual average of $85.0 million. Of the land cover types present in the Study Area, shrublands provide the largest biological control services value, estimated at $37.7 million annually.

Table 15. Total Annual Values of Biological Control Services by Land Cover Type, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value/ Year		
		Low	Average	High
Agriculture / Cropland	16,495	$0.0	$1.0	$3.7
Barren	1,058,250	$0.0	$0.0	$0.0
Coniferous Forest	2,103,843	$18.2	$24.2	$26.4
Deciduous Forest	182,159	$0.9	$3.0	$6.0
Desert Shrub	5,157,149	$8.9	$8.9	$8.9
Desert Woodland	162,687	$0.3	$0.3	$0.3
Grassland	124,552	$2.0	$9.9	$43.1
Open Water	99,632	$0.0	$0.0	$0.0
Shrubland	1,837,064	$37.7	$37.7	$37.7
Urban	25,951	$0.0	$0.0	$0.0
Wetland	96,064	$0.0	$0.0	$0.0
Total:	**10,863,846**	**$68.0**	**$85.0**	**$126.1**

Source: Project Team analysis of existing studies.

Climate Regulation

Climate regulation benefits arise from two distinct ecosystem functions: carbon sequestration and carbon storage. Carbon sequestration refers to the removal of carbon dioxide (CO_2) from the atmosphere by trees and other plants. Carbon storage refers to the carbon that is retained in living biomass, such as plants and soils. Both processes contribute to the mitigation of climate change by mitigating GHG emissions, and both of these processes are affected by the characteristics of the vegetation on a landscape. These two distinct ecosystem functions work in tandem and, when combined, represent climate regulation services. These two ecosystem functions are valued separately in this analysis, and valuing both of these functions does not result in double counting of climate regulation services.*

Carbon Sequestration

As mentioned above, carbon sequestration refers to the removal of carbon dioxide from the atmosphere by trees and other plants. Net carbon sequestration by vegetation is based on a variety of factors, such as water availability, nutrients, temperature, and age. To quantify the effect of future management activities on the tons of carbon sequestered, the Project Team conducted a literature review to determine rates of carbon sequestration per acre for the different land cover types found in the Study Area. These per-acre sequestration rates represent the average amount of carbon sequestered on an annual basis for an acre of land with the characteristics (e.g., amount and type of vegetation) common to each land cover type. **Table 16** presents the per-acre carbon sequestration rates for the affected land cover types. Cropland and forests provide the largest per-acre sequestration rates due to the biomass and vegetation in their respective areas.

* The separation of Carbon Sequestration and Carbon Storage is typical within ecosystem service analyses. Most of the economic literature separates them into two distinct services.

Table 16. Annual Carbon Sequestration by Land Cover Type

Land Cover Type	Metric Tons of Carbon per Acre		
	Low	Average	High
Agriculture / Cropland	0.00	1.80	6.89
Barren	0.00	0.00	0.00
Coniferous Forest	0.55	1.78	3.01
Deciduous Forest	1.43	2.22	3.01
Desert Shrub	0.16	0.16	0.16
Desert Woodland	0.65	0.65	0.65
Grassland	0.00	0.50	1.65
Open Water	0.00	0.00	0.00
Shrubland	0.29	0.50	0.70
Urban	0.00	0.00	0.00
Wetlands	0.00	0.92	2.82

Source: Project Team analysis of existing studies.

The Project Team then estimated the monetary value of the tons of carbon sequestered by the land cover types found in the Study Area using a per-ton value of the social cost of carbon, which is a monetary value ascribed to the damages attributable to a small increase (measured as a metric ton) of carbon dioxide emissions in a given year.[68] The social cost of carbon represents a comprehensive estimate of the damages that can be attributed to climate change, including changes in net agricultural productivity, human health, and property damages from increased flood risk.* The Project Team estimated the total annual carbon sequestration benefits by multiplying the per-acre values for carbon sequestration by the total acreage of each land cover type in the Study Area. **Table 17** presents estimated minimum, average, and maximum total annual values for the carbon sequestration benefits for the affected land cover types in the Study Area in total. The Project Team estimated the range of total annual value for carbon sequestration services to be between $146.7 and $493.2 million, with an annual average of $314.1 million. Of the land cover types in the Study Area, coniferous forests and shrublands provide the greatest carbon sequestration services on an annual basis, ranging from $58.9 to $322.4 million (with an average of $190.6 million) for coniferous forests, and from $27.1 to $65.5 million (with an average of $46.3 million) for shrublands.

* It is important to note that the social cost of carbon attempts to estimate the contribution of climate change to categories of damages, and not the full *value* of the categories of damages themselves.

Table 17. Total Annual Values of Carbon Sequestration Services by Land Cover Type, Millions of 2019$

Land Cover Type	Total Value/ Year		
	Low	Average	High
Agriculture / Cropland	$0.0	$1.5	$5.8
Barren	$0.0	$0.0	$0.0
Coniferous Forest	$58.9	$190.6	$322.4
Deciduous Forest	$13.3	$20.6	$27.9
Desert Shrub	$42.0	$42.0	$42.0
Desert Woodland	$5.4	$5.4	$5.4
Grassland	$0.0	$3.2	$10.5
Open Water	$0.0	$0.0	$0.0
Shrubland	$27.1	$46.3	$65.5
Urban	$0.0	$0.0	$0.0
Wetland	$0.0	$4.5	$13.8
Total:	**$146.7**	**$314.1**	**$493.2**

Source: Project Team calculations.

Carbon Storage

The total amount of carbon stored by various vegetation types is proportional to their biomass, both above the ground (stem or trunk and canopy) and below ground (roots), and biomass is a function of plant species and age. To estimate a value for carbon storage, the Project Team used a process similar to the one to estimate the value of carbon sequestration, and conducted a literature review to determine low, average, and high rates of carbon stored per acre for the different land cover types in the Study Area. These per-acre storage rates represent the average amount of carbon stored annually for an acre of land with the characteristics (e.g., amount and type of vegetation) common for each land cover type. The ranges of per-acre values for carbon storage result from using lower-bound, average, or upper-bound values for the carbon storage rates for the affected land cover types in the calculations. **Table 18** presents the per-acre carbon storage rates for the affected land cover types. Land cover types with large amounts of biomass, including forested land, cropland, and wetlands, provide the largest carbon storage rates per acre.

Table 18. Annual Carbon Storage Rates by Land Cover Type

Land Cover Type	Metric Tons of Carbon per Acre		
	Low	Average	High
Agriculture / Cropland	12.15	50.41	127.88
Barren	0.00	0.00	0.00
Coniferous Forest	155.50	310.86	466.22
Deciduous Forest	73.22	210.08	346.94
Desert Shrub	0.20	0.20	0.20
Desert Woodland	0.38	0.38	0.38
Grassland	7.14	39.97	106.85
Open Water	68.39	68.39	68.39
Shrublands	15.66	42.81	97.12
Urban	0.00	0.00	0.00
Wetland	26.05	101.32	259.81

Source: Project Team analysis of existing studies.

The Project Team estimated the monetary value of the tons of carbon stored using a per-ton value of the social cost of carbon, which ascribes a monetary value to the damages attributable to a small increase (measured as a metric ton) of carbon dioxide emissions in a given year.[69] The social cost of carbon represents a comprehensive estimate of the damages that can be attributable to climate change, including changes in net agricultural productivity, human health, and property damages from increased flood risk.[70] The Project Team estimated the total annual carbon storage benefits by multiplying the per-acre values for carbon storage for the affected land cover types by acreage of the land cover types found in the Study Area. **Table 19** presents estimated minimum, average, and maximum total annual values for the carbon storage benefits of the affected land cover types across the Study Area in total. The Project Team estimates the range of total annual value for carbon storage services to be between $19.4 and $64.7 billion, with an annual average of $40.4 billion. Of the land cover types in the Study Area, the coniferous forest provides the most carbon storage services value, ranging from $16.7 to $49.9 billion annually, with an annual average of $33.3 billion.

Table 19. Total Annual Values of Carbon Storage Services by Land Cover Type, Millions of 2019$

Land Cover Type	Total Value/ Year		
	Low	Average	High
Agriculture / Cropland	$10.2	$42.3	$107.4
Barren	$0.0	$0.0	$0.0
Coniferous Forest	$16,653.8	$33,292.5	$49,931.3
Deciduous Forest	$679.0	$1,948.1	$3,217.2
Desert Shrub	$52.5	$52.5	$52.5
Desert Woodland	$3.1	$3.1	$3.1
Grassland	$45.3	$253.4	$677.5
Open Water	$346.9	$346.9	$346.9
Shrubland	$1,464.5	$4,003.8	$9,082.4
Urban	$0.0	$0.0	$0.0
Wetland	$127.4	$495.5	$1,270.5
Total	**$19,382.6**	**$40,438.2**	**$64,688.8**

Source: Project Team calculations.

Summary of Climate Regulation Services

Together, the Project Team estimates that the annual value of carbon sequestration and carbon storage services to be between $19.5 and $65.2 billion, with an annual average of $40.8 billion (as presented in **Table 20**). The majority of the carbon regulation services are provided by coniferous forest land, which contributes between $16.7 and $50.3 billion annually, with an annual average of $33.5 billion.

Table 20. Total Annual Values of Climate Regulation Services, Millions of 2019$

Land Cover Type	Total Value / Year		
	Low	Average	High
Agriculture / Cropland	$10.2	$43.8	$113.2
Barren	$0.0	$0.0	$0.0
Coniferous Forest	$16,712.7	$33,483.1	$50,253.7
Deciduous Forest	$692.3	$1,968.7	$3,245.1
Desert Shrub	$94.5	$94.5	$94.5
Desert Woodland	$8.5	$8.5	$8.5
Grassland	$45.3	$256.6	$688.0
Open Water	$346.9	$346.9	$346.9
Shrubland	$1,491.6	$4,050.1	$9,147.9
Urban	$0.0	$0.0	$0.0
Wetland	$127.4	$500.0	$1,284.3
Total	**$19,529.3**	**$40,752.3**	**$65,182.0**

Source: Project Team calculations.

Erosion Prevention

Natural areas provide an important ecosystem function by serving as a buffer that reduces erosion and the flow of sediment into waterways. Sediment in waterways can have adverse impacts on water quality, which negatively affects drinking water (or increases water treatment costs), impairs the health of streams used by wildlife, and decreases the aesthetic and recreational value of waterways. Areas with intact root systems from vegetation have lower erosion rates compared to developed land that may have impervious surfaces or barren land without any intact plant root systems.

To estimate the value of erosion prevention services, the Project Team first quantified the potential effects of erosion prevention by conducting a literature search on the erosion rates of different land cover types. The Project Team assumed that the value of erosion prevention services is equal to the difference in erosion rate between natural land cover and barren land, where barren land sees significant erosion due to a lack of vegetation root systems or biomass to slow down rushing water.[71] With this information, the Project Team was able to compare the erosion rate for natural land cover with the erosion rate for land that is in a developed or disturbed state (barren land). The Project Team used these differences in erosion rates to estimate the tons of sediment loss avoided for each land cover type in the Study Area.[72] **Table 21** presents the minimum, average, and maximum annual values obtained by the Project Team for erosion rates for the affected land cover types. Land cover types with significant biomass, including forests, grasslands, and cropland, have the highest erosion prevention rates (lowest total erosion) per acre.

Table 21. Annual Erosion Prevention Rates by Land Cover Type (Tons per Acre per Year)

Land Cover Type	Low	Average	High
Agriculture / Cropland	0.53	2.74	7.83
Barren	0.00	0.00	0.00
Coniferous Forest	0.00	3.3445	8.4113
Deciduous Forest	0.00	3.3445	8.4113
Desert Shrub	0.00	0.00	0.00
Desert Woodland	0.00	0.00	0.00
Grassland	0.53	2.74	7.83
Open Water	0.00	0.00	0.00
Shrubland	0.0	2.36	6.45
Urban	0.16	2.9309	7.59
Wetland	0.00	0.00	0.00

Source: Project Team analysis of existing studies

Having obtained the difference in erosion volume resulting from disturbance of different land cover types, the Project Team estimated the change in monetary value associated with erosion prevention based on estimates of the damage per ton of sediment for different regions of the country.* These per-ton damage values for erosion (as shown in **Table 22**) reflect the costs associated with the removal of sediment in different areas.[73]

Table 22. Annual Values of Erosion Prevention by Subregion ($ per Ton)

Region	2019$/Ton Erosion		
	Minimum	Average	Maximum
Nevada / California	$7.0	$10.0	$13.0

Source: U.S. Department of Agriculture, 2009.

Next, the Project Team multiplied the per-acre tonnage and the monetary value per-ton for erosion prevention services by the acreage of the various land cover types found in the Study Area. **Table 23** presents the estimated minimum, average, and maximum total annual values for erosion prevention services provided by affected land cover types in the subregions and across the Study Area in total. This range of values is based on using the minimum, maximum, or average values for both soil erosion rates by land cover type and for the per-ton estimated damages from erosion for the regions affected in the various source studies. The Project Team estimates the range of total annual value of erosion prevention services to be between $390,000 and $291.5 million, with an annual average of $87.1 million. Of the land cover types included in the Study Area, coniferous forests and shrublands provide the greatest erosion prevention services, estimated at up to $159.3 million and $106.7 million per year, respectively.

Table 23. Total Annual Values of Erosion Prevention Services by Land Cover Type, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value / Year		
		Low	Average	High
Agriculture / Cropland	16,495	$0.0	$0.3	$1.2
Barren	1,058,250	$0.0	$0.0	$0.0
Coniferous Forest	2,103,843	$0.0	$49.3	$159.3
Deciduous Forest	182,159	$0.0	$4.3	$13.8
Desert Shrub	5,157,149	$0.0	$0.0	$0.0
Desert Woodland	162,687	$0.0	$0.0	$0.0
Grassland	124,552	$0.3	$2.4	$8.8
Open Water	99,632	$0.0	$0.0	$0.0
Shrubland	1,837,064	$0.0	$30.3	$106.7
Urban	25,951	$0.0	$0.5	$1.8
Wetland	96,064	$0.0	$0.0	$0.0
Total:	**10,863,846**	**$0.4**	**$87.1**	**$291.5**

Source: Project Team analysis of existing studies
Note: Numbers may not sum due to rounding

* Dollar values for the minimum, average, and maximum erosion prevention rate are $7.00, $10.00, and $13.00, respectively.

Pollination

Insect pollination is a crucial ecosystem service for many annual crops, including most fruits and vegetables. Natural areas such as grasslands and forests provide habitat for insects that pollinate nearby croplands, and these pollination services can be diminished or lost if these areas are degraded or disturbed. Preserved habitats and natural systems are expected to result in a higher number of pollinators and a greater level of efficiency of pollination services.

To value pollination services, the Project Team first developed estimates of the total per-acre values of pollination services for the affected subregions. The Project Team used a study presenting information on the value of crops by state (**Table 24**) and combined this with information on the percentage of crops grown in these areas that depend on pollination services, otherwise known as pollination dependency, to estimate these values.[74] Multiplying the per-acre value of crops by the pollination dependency of each land subregion resulted in a total per-acre value of pollination services for each land cover type, as shown in **Table 24**.

Table 24. Annual Values of Pollination Services by Subregion

State	2019$ per Acre
California	$424.3

Source: Project Team analysis of existing studies

The use of a pollination factor helps prevent an overestimation of pollination services, as not all land within the Study Area will be close enough to cropland to provide pollination services. The Project Team used pollination factors of 5 percent (minimum), 15 percent (average), and 25 percent (maximum) to represent the amount of land that provides pollination services. The range of values is due to use of lower-bound, upper-bound, or average pollination factors representing land close to cropland where pollination services would be provided. Next, the Project Team multiplied the per-acre values for pollination services by the land acreages of productive land cover types. **Table 25** presents the estimated annual minimum, average, and maximum values for pollination services for the Study Area in total for the land cover types that provide pollination services. The Project Team estimates the range of total annual value for pollination services to be between $90.5 and $452.3 million, with an annual average of $271.4 million. Of the land cover types in the Study Area, coniferous forests and shrublands provide the most pollination services per year, valued between $44.6 and $223.2 million (with an annual average of $133.9 million) for coniferous forests and between $39.0 and $194.9 million (with an annual average of $116.9 million) for shrublands.

Table 25. Total Annual Values of Pollination Services by Land Cover Type, Millions of 2019$

Land Cover Type	Area (Acres)	Average Pollination Value / Acre	Total Value / Year		
			Min	Average	Max
Agriculture/ Cropland	16,495	$424.3	$0.3	$1.0	$1.7
Barren	1,058,250	$0.0	$0.0	$0.0	$0.0
Coniferous Forest	2,103,843	$424.3	$44.6	$133.9	$223.2
Deciduous Forest	182,159	$424.3	$3.9	$11.6	$19.3
Desert Shrub	5,157,149	$0.0	$0.0	$0.0	$0.0
Desert Woodland	162,687	$0.0	$0.0	$0.0	$0.0
Grassland	124,552	$424.3	$2.6	$7.9	$13.2
Open Water	99,632	$0.0	$0.0	$0.0	$0.0
Shrubland	1,837,064	$424.3	$39.0	$116.9	$194.9
Urban[1]	25,951	$0.0	$0.0	$0.0	$0.0
Wetland	96,064	$0.0	$0.0	$0.0	$0.0
Total:	**10,863,846**		**$90.5**	**$271.4**	**$452.3**

Source: Project Team analysis of existing studies.

a. While urban cities like Bishop have numerous fruit trees, orchards, and pollinating plants, there is a gap in the economic literature for the valuation of these ecosystem services.

Waste Treatment

Wetlands and, to a lesser extent, other land cover types provide waste treatment services by removing nitrogen and phosphorus from wastewater. Excess amounts of these nutrients pollute surface waters and can result in algae blooms, which can deplete oxygen in water ecosystems. To estimate the value of waste treatment services by wetlands, the Project Team reviewed studies that calculated the value of waste treatment services by multiplying the nutrient removal rates by the cost of nutrient removal by other means—such as the cost of nutrient removal by a waste treatment plant. From this literature, the Project Team first determined the minimum, average, and maximum rates of nitrogen and phosphorus removal by wetlands in the western United States, which are shown in **Table 26**. The Project Team then conducted a similar literature review to determine the cost to remove nitrogen and phosphorus from water by other means if the nutrients were not filtered out by wetlands. This literature review resulted in determination of minimum, average, and maximum cost for the removal of nitrogen and phosphorus by sanitation plants, as shown in **Table 26**.

Table 26. Annual Absorption Rates and Removal Costs for Nitrogen and Phosphorus

Wetlands	Minimum	Average	Maximum
Absorption Rate (kilograms/acre)			
Nitrogen	141.64	4437.72	12,949.96
Phosphorous	32.37	125.49	311.61
Removal Costs (2019$/kilogram)			
Nitrogen	$3.2	$7.6	$13.1
Phosphorous	$23.8	$54.8	$94.3

Source: Project Team analysis of existing studies.

To identify a value for the waste treatment services provided by other land cover types, the Project Team conducted a literature review of studies that have valued waste treatment services by different land cover types. Based on this review for land cover types in geographies similar to the Study Area, the Project Team estimated minimum, average, and maximum annual per-acre values for waste treatment values by land cover type, as shown in **Table 27**. This range of values is based on using the lower-bound, upper-bound, or average values for nitrogen and phosphorus removal by various land cover types, except wetlands. For wetlands, the range of estimates is based on the minimum, average, and maximum nitrogen and phosphorus removal rates as well as the monetary costs (and thus the marginal avoided cost) of waste treatment from the source data. These values are included in **Table 27**, which presents annual per-acre values of waste treatment services by land cover type. Coniferous and deciduous forests provide the most waste treatment services for non-wetlands, valued at between $26.3 and $232.7 per acre, with an annual average of $106.2 per acre.

Table 27. Annual Values of Waste Treatment Services by Land Cover Type ($ per Acre)

Land Cover Type	2019$ per acre per year		
	Low	Average	High
Agriculture / Cropland	$30.2	$30.2	$30.2
Barren	$0.0	$0.0	$0.0
Coniferous Forest	$26.3	$106.2	$232.7
Deciduous Forest	$26.3	$106.2	$232.7
Desert Shrub	$0.0	$0.0	$0.0
Desert Woodland	$0.0	$0.0	$0.0
Grassland	$1.2	$37.7	$66.2
Open Water	$0.0	$0.0	$0.0
Shrubland	$1.2	$37.7	$66.2
Urban	$0.0	$0.0	$0.0
Wetland [a]	NA	NA	NA

Source: Project Team analysis of existing studies.

Notes:

a. Wetland value is estimated based on values in Table 26, above, rather than per-acre values.

Next, the Project Team multiplied the per-acre values for waste treatment services of land cover types by the acreage of land of various types found in the Study Area. **Table 28** presents the estimated minimum, average, and maximum total annual values for waste treatment services provided by affected land cover types in the Study Area. The Project Team estimates the range of total annual value for waste treatment services to be between $181.9 million and $19.8 billion (with an annual average of $4.2 billion). Of the land cover types in the Study Area, wetlands provide the largest amount of waste treatment services, estimated at between $118 and $19,111.9 million per year, with an annual average of $3,900.6 million. Coniferous forests provide a distant second-largest amount of these services.

Table 28. Total Annual Values of Waste Treatment Services by Land Cover Type, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value/ Year		
		Low	Average	High
Agriculture / Cropland	16,495	$0.5	$0.5	$0.5
Barren	1,058,250	$0.0	$0.0	$0.0
Coniferous Forest	2,103,843	$55.3	$223.4	$489.6
Deciduous Forest	182,159	$4.8	$19.3	$42.4
Desert Shrub	5,157,149	$0.0	$0.0	$0.0
Desert Woodland	162,687	$0.0	$0.0	$0.0
Grassland	124,552	$0.1	$4.7	$8.2
Open Water	99,632	$0.0	$0.0	$0.0
Shrubland	1,837,064	$2.2	$69.3	$121.6
Urban	25,951	$0.0	$0.0	$0.0
Wetland	96,064	$118.0	$3,900.6	$19,111.9
Total	**10,863,846**	**$180.9**	**$4,217.8**	**$19,774.2**

Source: Project Team analysis of existing studies.

Water Quality

Ecosystems contribute to water quality through the filtration of water that can be used for human consumption. Water filtration services provide value through the natural purification of potable water and by maintaining a level of water quality that is clean relative to purification by other means. Water quality is impacted primarily through human activity whereby contaminants such as nitrogen, phosphorus, and other soluble pollutants reach excessive levels, typically through agriculture and mining activities. Water treatment costs can vary depending on the existing water quality and treatment technologies, the initial and target concentrations of contaminants, and the scale of water maintenance facility required.

Water Provision to Surrounding Area

The Owens River, Mono Lake Basin, and reservoirs in the Sierra Nevada provide 430 million gallons of water to Los Angeles daily via the Los Angeles Aqueduct, representing about a third of Los Angeles's water supply. (University of Southern California Viterbi School of Engineering, n.d., "Los Angeles Water Issue: Why It's Not Just a Drought," https://viterbi.usc.edu/water.) The ecosystems in the Study Area provide water quality and filtration services by naturally cleaning the water that is used by Los Angeles. The Project Team did not monetize this value separately because there would be double counting between this value and the value of water quality regulation services already estimated in this analysis.

Due to many uncertainties around the water quality regulation benefits, the Project Team was unable to identify existing studies that were suitable for use in a benefit function transfer. Examples of these uncertainties include the lack of information about the geographic location of polluting activities, the concentration of water pollutants in the relevant areas, and the proximity of human populations to areas providing water quality regulation services. In addition, the fact that the affected areas are generally more rural than urban adds further uncertainty to the estimation of the benefits of water quality regulation services.

Due to the inability to conduct a benefit function transfer, the Project Team instead estimated the value of water quality regulation for the various affected land cover types based on obtaining a minimum, a maximum, and an average of a range of estimates from previous studies on water quality benefits provided by various land cover types in non-urban settings. These estimates represent the value of cleaner water and pollutant removal. **Table 29** presents the range of annual per-acre values for the affected land cover types based on the review of suitable source data. The range of per-acre values for each land cover type reflects variations in the estimated values of avoided costs of water filtration and variations in the amount of water quality regulation services provided by different land cover types. Land cover types with the most biomass, such as shrublands, grasslands, wetlands, and forests, provide the greatest per-acre water quality services.

Table 29. Annual Values of Water Quality Services by Land Cover Type ($ per Acre)

Land Cover Type	2019$ per acre per year		
	Low	Average	High
Agriculture / Cropland	$0.0	$0.0	$0.0
Barren	$0.0	$0.0	$0.0
Coniferous Forest	$6.5	$3,520.8	$16,504.9
Deciduous Forest	$6.5	$3,593.5	$16,504.9
Desert Shrub	$0.0	$0.0	$0.0
Desert Woodland	$167.1	$549.0	$747.7
Grassland	$7,418.6	$14,784.9	$24,071.4
Open Water	$2.5	$1,603.7	$6,675.4
Shrubland	$7,418.6	$14,784.9	$24,071.4
Urban	$0.0	$0.0	$0.0
Wetland	$9.0	$3,589.7	$39,825.4

Source: Project Team analysis of existing studies.

After estimating ranges of per-acre values for each affected land cover type, the Project Team multiplied the per-acre values by the acreage of each land cover type in the Study Area. **Table 30** presents estimated minimum, average, and maximum total annual values for the water quality regulation benefits for the land cover types found in the Study Area. The Project Team estimates the range of total annual value for water quality services to be between $14.6 and $89.6 billion, with annual average of $37.7 billion. Of the land cover types included in the Study Area, shrublands provide the most water quality services, valued between $13.6 and $44.2 billion annually (with an annual average of $27.2 billion), with coniferous forests providing the second-most water quality services, which are valued up to $34.7 billion annually.

Table 30. Total Annual Values of Water Quality Services by Land Cover Type, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value/ Year		
		Low	Average	High
Agriculture / Cropland	16,495	$0.0	$0.0	$0.0
Barren	1,058,250	$0.0	$0.0	$0.0
Coniferous Forest	2,103,843	$13.8	$7,407.2	$34,723.8
Deciduous Forest	182,159	$1.2	$654.6	$3,006.5
Desert Shrub	5,157,149	$0.0	$0.0	$0.0
Desert Woodland	162,687	$27.2	$89.3	$121.6
Grassland	124,552	$924.0	$1,841.5	$2,998.1
Open Water	99,632	$0.3	$159.8	$665.1
Shrubland	1,837,064	$13,628.5	$27,160.8	$44,220.7
Urban	25,951	$0.0	$0.0	$0.0
Wetland	96,064	$0.9	$344.8	$3,825.8
Total	**10,863,846**	**$14,595.7**	**$37,658.0**	**$89,561.7**

Source: Project Team analysis of existing studies.

Water Regulation

Ecosystems capture, slow, and redirect the flow of rainwater. Ecosystems that have been developed or disturbed lose some of the ability to stabilize water flows, which results in increased volumes of runoff into larger bodies of water and into built environments. In both rural and urban areas, increased runoff volumes can overwhelm retention ponds and other water control structures and increase the turbidity of streams, which can impair habitat and reproductive functioning for aquatic organisms and can interfere with filtration systems for irrigated agriculture where surface waters are used for irrigation. The value of water regulation services is evidenced in part by the fact that in both rural and urban areas, U.S. Environmental Protection Agency regulations require the control of stormwater runoff from industrial development, mining, and other forms of construction, even when built environments are not threatened by runoff.[75]

To estimate the effect of runoff on water flow regulation, regulation, the Project Team used information on vegetative cover, rainfall, and runoff retention rates to develop runoff curves for different land cover types. The runoff curves method (developed by the U.S. Department of Agriculture) calculates the amount of runoff volume for different land cover and soil types.[76] The runoff curve number is assigned to an area based on the land cover type, the quality of the land, and the hydrologic soil group of the land in that area. Given the extent of the Study Area, the Project Team used the average curve number across hydrologic soil groups for each land cover, essentially assuming a consistent soil group. Additionally, the Project Team assumed that the quality of the land cover is currently at the "fair" level.* Using the runoff curve method, the Project Team could then calculate the amount of runoff volume for the natural land cover and the runoff volume for an impervious surface (or the post degradation land cover type). **Table 31** presents the runoff curve values and resulting total runoff volumes per land cover type used to estimate this relationship. Coniferous and deciduous forests provide the largest annual value of water flow regulation services, ranging between $774.3 and $1,447.1 per acre, with an annual average of $1,095.7 per acre.

* The definition of fair hydrologic condition varies by land cover type, but land is generally considered to be in fair condition if there is 30 to 75 percent ground cover.

Table 31. Annual Values of Water Flow Regulation Services by Land Cover Type ($ per Acre)

Land Cover Type	Runoff Value	Prevented Runoff (m^3)	Per Acre		
			Min	Average	Max
Agriculture / Cropland	70.25	17.9	$729.8	$1,074.36	$1,418.9
Barren	85.25	0.0	$0.0	$0.0	$0.0
Coniferous Forest	64.50	18.2	$744.3	$1,095.7	$1,447.1
Deciduous Forest	64.50	18.2	$744.3	$1,095.7	$1,447.1
Desert Shrub	73.50	16.4	$668.2	$983.7	$1,299.2
Desert Woodland	73.50	16.4	$668.2	$983.7	$1,299.2
Grassland	80.33	9.4	$383.0	$563.8	$744.61
Open Water	85.25	0.0	$0.0	$0.0	$0.0
Shrubland	61.33	17.3	$705.0	$1,038.0	$1,370.6
Urban	85.25	0.0	$0.0	$0.0	$0.0
Wetland	85.25	0.0	$0.0	$0.0	$0.0

Source: Project Team analysis of existing studies.

The Project Team then estimated the monetary value of this change in runoff volume on a per-acre basis by calculating the costs to contain the additional amount of runoff in ponds or other types of catchments. For this calculation, the Project Team relied on data from a U.S. Environmental Protection Agency study to estimate minimum, average, and maximum construction costs per cubic meter for runoff containment of $41.0, $60.0, and $79.0.* **Table 32** presents minimum, average, and maximum estimates of the annual per-acre values for the affected land cover types for water regulation services. This range of values results from different per-cubic-meter construction cost estimates for water retention facilities, which differ based on geographic location, economies of scale, and other features of the specific setting for the relevant source data.[77] **Table 32** presents estimated total annual minimum, average, and maximum values for the water regulation benefits for the affected land cover types in the Study Area. The Project Team estimates the range of total annual value for water regulation services to be between $6.6 and $12.9 billion, with an annual average of $9.7 billion. Of the land cover types included in the Study Area, desert shrub provides the largest amount of water regulation services, valued between $3.4 and $6.7 billion annually, with an annual average of $5.1 billion.

* Dollar values for the minimum, average, and maximum construction cost per cubic meter are $41.00, $60.00, and $79.00 respectively.

Table 32. Total Annual Values of Water Regulation Services by Land Cover Type, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value / Year		
		Low	Average	High
Agriculture / Cropland	16,495	$12.0	$17.7	$23.4
Barren	1,058,250	$0.0	$0.0	$0.0
Coniferous Forest	2,103,843	$1,565.9	$2,305.2	$3,044.5
Deciduous Forest	182,159	$135.6	$199.6	$263.6
Desert Shrub	5,157,149	$3,446.0	$5,073.0	$6,699.9
Desert Woodland	162,687	$108.7	$160.0	$211.4
Grassland	124,552	$47.7	$70.2	$92.7
Open Water	99,632	$0.0	$0.0	$0.0
Shrubland	1,837,064	$1,295.1	$1,906.5	$2,517.9
Urban	25,951	$0.0	$0.0	$0.0
Wetland	96,064	$0.0	$0.0	$0.0
Total:	**10,863,846**	**$6,611.0**	**$9,732.2**	**$12,853.4**

Source: Project Team analysis of existing studies.

Habitat and Supporting Services

Habitat and supporting services provide inputs to other categories of ecosystem services, including providing refuge and reproductive habitat to wild plants and animals, formation of soil, nutrient cycling, and primary productivity. The Project Team did not estimate the benefits of enhancements to habitat and supporting services, however, because these services generally provide inputs to other services, for which the Project Team *has* estimated values.

Cultural Services

Cultural services provide meaningful interactions between human beings and nature, including traditional foods, medicines, and materials, aesthetic enjoyment, recreation, science and education, and spiritual and historical purposes. There are seven federally recognized tribes in Inyo and Mono counties:

- Big Pine Paiute Tribe of Owen's Valley
- Bishop Paiute Tribe
- Bridgeport Indian Colony
- Fort Independence Indian Reservation
- Lone Pine Paiute-Shoshone Reservation
- Timbisha Shoshone Tribe
- Utu Utu Gwaitu Paiute Tribe of the Benton Reservation

Indigenous Peoples

The Eastern Sierra, known as Pamidu Toiyabe by many tribes in the region, has been and continues to be inhabited by the Nüümü (Paiute), Newe (Shoshone), Timbisha, and Washoe peoples and likely more tribes that are not currently federally recognized or known about throughout the Study Area. Indigenous people have long been and continue to be part of the fabric of this area. The cultural importance of the land within the Study Area to these indigenous people is significant, and not something that can be monetized. The Project Team did not attempt to monetize the cultural or spiritual value of the Study Area.

Another tribe not federally recognized in Mono County is the Mono Lake Kutzadika'a Indian Community. A federally recognized tribe in Alpine County is the Washoe.

A map of the historic indigenous territories of the Study Area is presented in **Figure 8**.

The Project Team estimated the value of recreation and tourism services, but did not ascribe a value to other cultural services. Most of these other cultural services are difficult, or impossible, to quantify, and others are location-specific, meaning that it is challenging to use values from other studies as a basis for a benefit transfer. The methods that the Project Team used to estimate the value of recreation and tourism services for the Study Area are included below.

The Study Area is home to exceptional natural beauty, landscapes, and history, as evidenced by the large number of National Park Service (NPS) and U.S. Forest Service (USFS) lands. As shown in **Figure 9,** the Study Area contains mostly federal lands (Bureau of Land Management, NPS, and USFS) as well as California State lands; Los Angeles Department of Water and Power (LADWP) land; and Benton Paiute, Bishop, and Indian Creek tribal reservation lands.

Figure 9 shows the federal lands disaggregated, comprising Death Valley National Park, Devils Postpile National Monument, Kings Canyon National Park, Manzanar National Historic Site, Sequoia National Park, and Yosemite National Park, all operated by NPS, as well as Inyo and part of the Humboldt-Toiyabe National Forests.

Figure 8. Historic Tribal Lands in the ESSRP Study Area

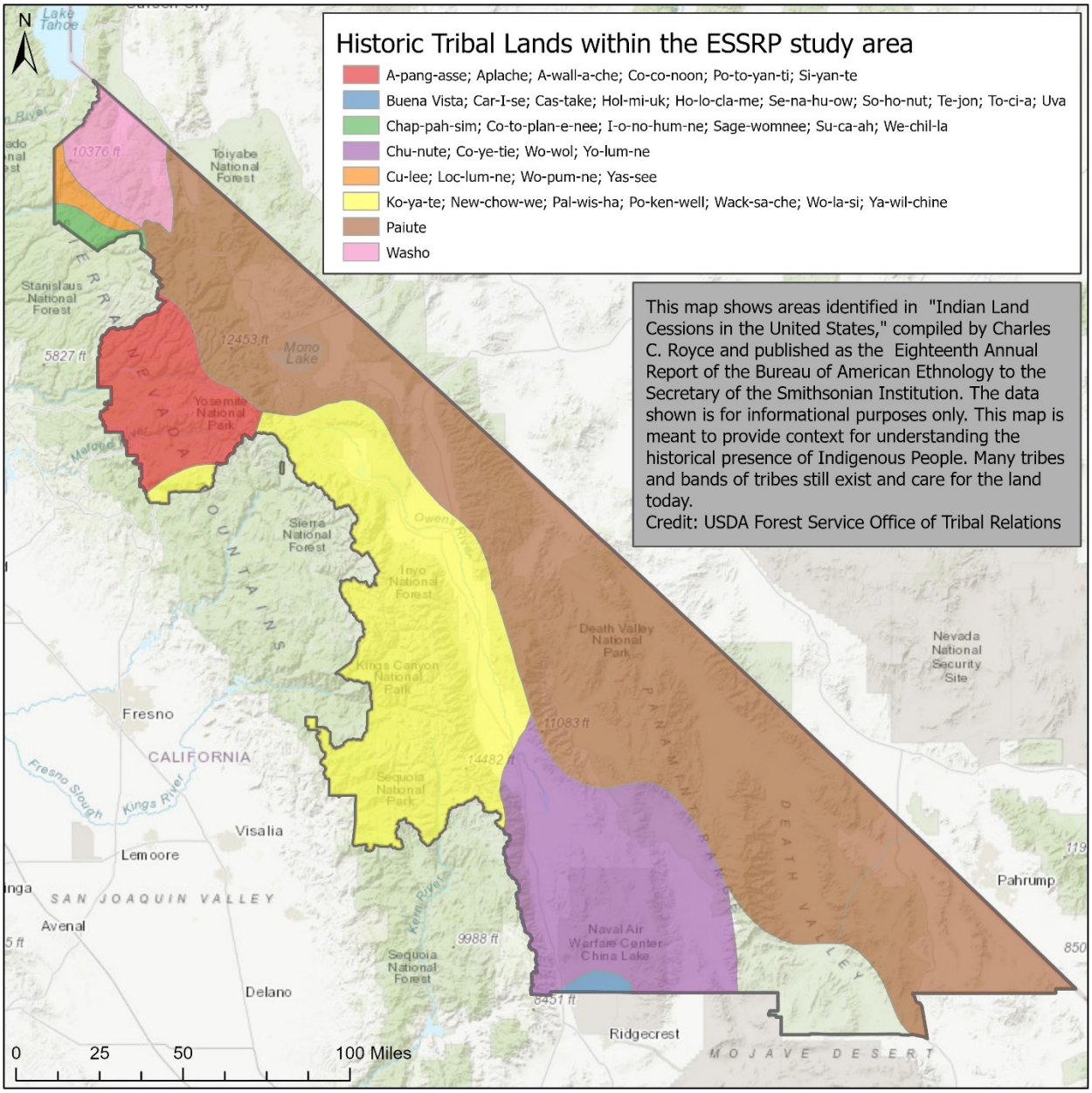
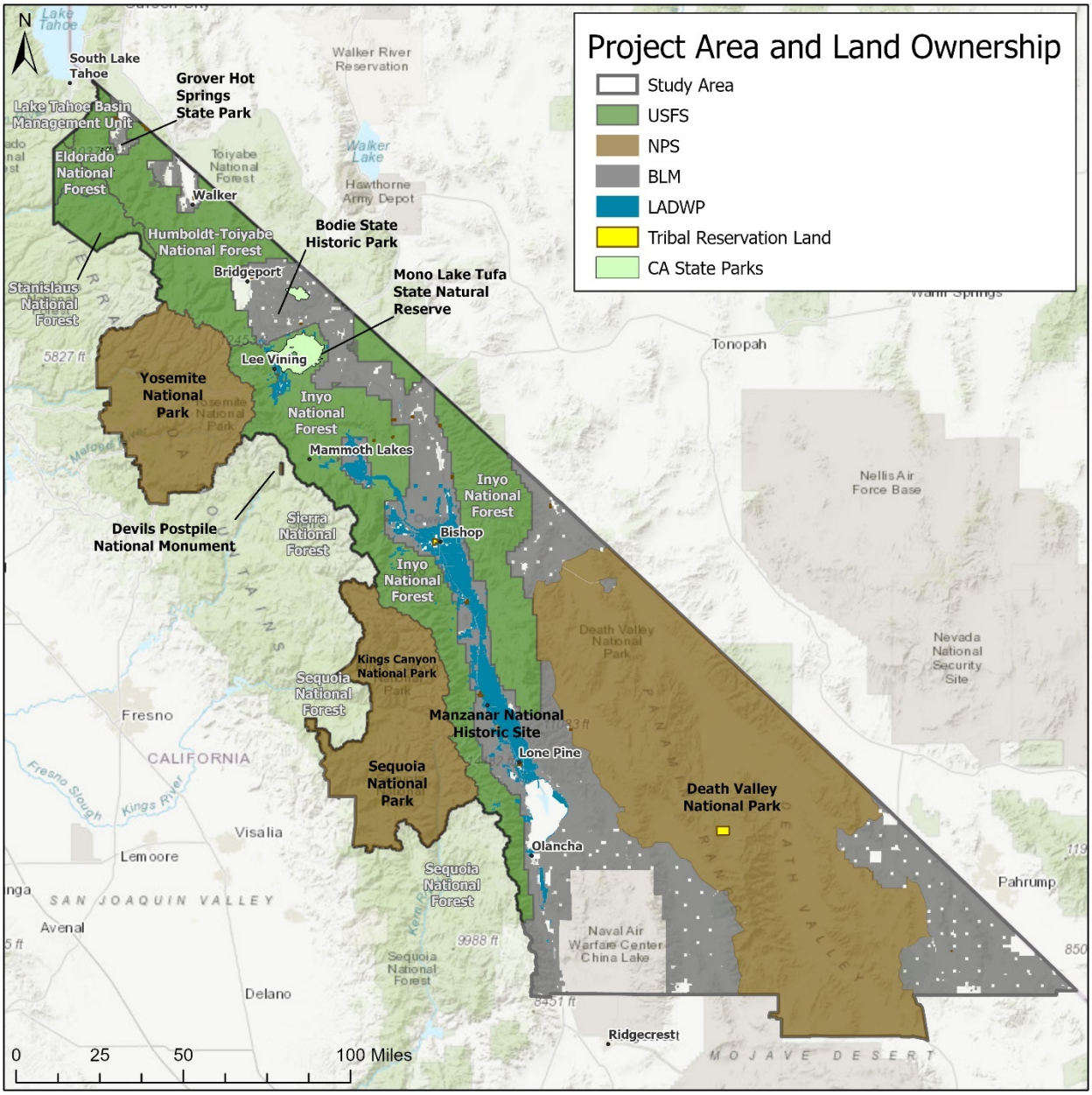


Figure 9. Managed Lands in the Study Area



These federal lands host millions of visitors annually for recreational purposes, as shown in **Table 33**. Recreational activities in the Study Area include opportunities to hike, ski, view wildlife, camp, backpack, fish, ride off-highway vehicles, rock climb, bicycle, and more.

Table 33. Federal Lands Visitation in the Study Area

Federal Lands Area	Year	Visitors [b]
Death Valley National Park	2019	1,740,945
Devils Postpile National Monument	2019	147,864
Kings Canyon National Park	2019	632,110
Manzanar National Historic Site	2019	97,380
Sequoia National Park	2019	1,246,053
Yosemite National Park	2019	4,422,861
Inyo National Forest	2016	2,309,000
Humboldt-Toiyabe National Forest (outside Spring Mountain)[a]	2016	134,468
Total	**NA**	**10,730,681**

Sources: U.S. National Parks Service, n.d., "Stats Report Viewer," https://irma.nps.gov/STATS/SSRSReports/Park%20Specific%20Reports/Summary%20of%20Visitor%20Use%20By%20Month%20and%20Year%20(1979%20-%20Last%20Calendar%20Year); U.S. Department of Agriculture, n.d., "Natural Resource Manager," U.S. Forest Service, https://apps.fs.usda.gov/nvum/results/A04217.aspx/FY2016.

Notes:

a. As the vast majority of the Humboldt-Toiyabe National Forest is located outside of the Study Area, only the visits proportional to the land area in the Study Area are included.

b. The visit data for NPS reflects "Recreation Visitors"; the visit data for USFS reflects "A National Forest Visit," defined as the entry of one person onto a national forest site or area to participate in recreation activities for an unspecified amount of time.

Though people must pay various costs to engage in these activities, the value they receive in their own well-being usually exceeds these expenses. The difference between the value that an individual receives from a good or service, such as participating in outdoor recreation in this case, and what they must pay for it is known as consumer surplus. The USFS estimates the average consumer surplus associated with primary recreational activities by USFS region (as shown in **Table 34**). Humboldt-Toiyabe National Forest is in the Intermountain region (Region 4), and Inyo National Forest is in Pacific Southwest region (Region 5). Consumer surplus is estimated as the total willingness to pay for a day of a recreational activity minus the cost an individual needs to pay to engage in it. In other words, consumer surplus in this case is a measure of an individual's gain in welfare from engaging in a day of an outdoor recreational activity.[78]

Table 34. Average Consumer Surplus per Person per Primary Activity Day, 2016$

Primary Activity	Region 4	Region 5
Backpacking	$42.8	$26.6
Biking	$96.4	$80.2
Cross-country skiing	$66.2	$50.0
Developed camping	$45.3	$29.1
Downhill skiing	$91.9	$75.7
Fishing	$81.1	$65.0
Hiking	$94.1	$76.0
Hunting	$87.1	$70.9
Motorized boating	$68.0	$51.9
Nature related	$69.8	$53.6
Nonmotorized boating	$118.6	$102.4
Off-highway vehicle use/snowmobiling	$60.1	$43.9
Other recreation	$74.7	$58.5
Picnicking	$58.8	$42.7

Source: U.S. Department of Agriculture, 2017, "Recreation Economic Values for Estimating Outdoor Recreation Economic Benefits from the National Forest System," U.S. Forest Service, https://www.fs.fed.us/pnw/pubs/pnw_gtr957.pdf.

In addition to individuals gaining consumer surplus from participating in recreational activities, recreational visitors to national parks and forests often spend money in the surrounding area. Local recreational visitors may pay for gas to reach a site and buy equipment, purchase food and drink, and make other purchases locally. Non-locals have similar spending patterns, but also pay for lodging, restaurants, guides, and outfitters. All these actions generate local economic activity. Expenditures by non-local recreationists are particularly important because they represent new economic activity in the region. The NPS estimated that visitor spending at the six NPS park units in the Study Area totaled over $865,000 in 2019, for an average of over $100 per recreational visit. The USFS estimated that average spending per recreational visit to the Inyo National Forest was $185. A summary of average spending in the Study Area is shown in **Table 35**.

Table 35. Visitor Spending on Federal Lands in the Study Area, 2019$

Federal Lands Area	Annual Visitors [b]	Total Visitor Spending (2019$)	Estimated Spending per Recreation Visit (2019$)
Death Valley National Park	1,740,945	$147,122,000	$84.5
Devils Postpile National Monument	147,864	$9,667,000	$65.4
Kings Canyon National Park	632,110	$56,084,000	$88.7
Manzanar National Historic Site	97,380	$10,390,000	$106.7
Sequoia National Park	1,246,053	$96,035,000	$77.0
Yosemite National Park	4,422,861	$546,596,000	$123.6
Inyo National Forest	2,309,000	NA	$185.0
Humboldt-Toiyabe National Forest (outside Spring Mountain)[a]	134,468	NA	$218.2
Total	**10,730,681**	**$865,894,000**	**NA**

Sources: U.S. National Parks Service, 2018, "Visitor Spending Effects: Economic Contributions of National Park Visitor Spending," https://www.nps.gov/subjects/socialscience/vse.htm; U.S. Forest Service, 2020, "Ecosystem Services Data: Working," July 20.

Notes:

a. As the vast majority of the Humboldt-Toiyabe National Forest is located outside of the Study Area, only the visits proportional to the land area in the Study Area are included.

b. The visit data for NPS reflects "Recreation Visitors." The visit data for USFS reflects "A National Forest Visit," defined as the entry of one person onto a national forest site or area to participate in recreation activities for an unspecified amount of time.

In addition to direct impacts, visitor spending yields indirect and induced impacts on the local economy. A variety of tools are available to estimate regional economic impacts, but by far the most widely used tools are economic input-output models, which estimate the total employment and income effects associated with spending on recreational goods and services. These impacts include the following:

- **Direct** – Direct effects result from direct spending on outdoor recreation. Examples of direct impacts are entrance fees, equipment, lodging, food, and other goods related to outdoor recreational visits.
- **Indirect** – Indirect effects represent impacts resulting from the inter-industry linkages caused by industries purchasing from other industries. An example of an indirect impact is the seasonal employment of a chair lift repair person during ski season.
- **Induced** – Induced effects represent the impacts on all local industries due to visitors' consumption expenditures that are generated by the direct and indirect effects. An example of an induced impact is the spending of wages by an employee of the NPS.

Indirect and induced impacts are known as "multiplier effects." Economic input-output models apply a "multiplier" to estimate how spending circulates through the local economy. A higher multiplier indicates that spending circulates at a high rate locally. A typical California county multiplier ranges from 1.3 to 2.5, with Mono County having a multiplier value of 1.4.[79] Multipliers were unavailable for Alpine and Inyo counties.

To estimate the value of recreational and tourism services for the Study Area, the Project Team calculated consumer surplus, direct visitor spending, and the indirect and induced impacts of direct visitor spending. The Project Team used USFS data for this calculation. USFS reports average consumer surplus per person per primary activity day. USFS defines a primary activity day as one person recreating for some portion of a day. Because only total USFS visits are reported, not primary activity days, the consumer surplus of primary activity days must be converted into visits. A USFS visit can include multiple activity days, and the USFS provides guidance on converting activity days to visits by, for example, using column B in **Table 36** for Region 5.[80]

Table 36. Estimating Consumer Surplus per Recreational Visit, USFS Region 5, 2016$

Primary Activity	Average Consumer Surplus per Person per Primary Activity Day	Conversion Coefficient (Activity Day to Visit Day)	Average Consumer Surplus per Person per Visit by Primary Activity
	[A]	[B]	[C] = [A] x [B]
Backpacking	$26.6	2.8	$74.6
Biking	$80.2	1.1	$88.3
Cross-country skiing	$50.0	1.1	$55.0
Developed camping	$29.1	2.8	$81.5
Downhill skiing	$75.7	1.1	$83.3
Fishing	$65.0	1.3	$84.5
Hiking	$78.0	1.1	$85.8
Hunting	$70.9	1.5	$106.4
Motorized boating	$52.0	1.3	$67.4
Nature related	$53.6	1.1	$59.0
Nonmotorized boating	$102.4	1.4	$143.4
Off-highway vehicle use/snowmobiling	$43.9	1.2	$52.7
Other recreation	$58.5	1.1	$64.3
Picnicking	$42.7	1.2	$51.2

Source: U.S. Department of Agriculture, 2017, Tables 4 and 5, "Recreation Economic Values for Estimating Outdoor Recreation Economic Benefits from the National Forest System," U.S. Forest Service, https://www.fs.fed.us/pnw/pubs/pnw_gtr957.pdf.

USFS also tracks activity participation in each national forest, detailed as either the main activity or secondary activities, and they also track the proportion of time spent doing the main activity. Activity participation rates for Inyo and Humboldt-Toiyabe (excluding Spring Mountain National Recreation Area) national forests are presented in **Table 37**. Because NPS does not report consumer surplus estimates by activity or activity participation rates, the Project Team assumes that the Inyo National Forest's activities and values are representative of the Study Area because of its diversity, which reflects the Study Area as a whole. The available activities for the NPS lands are assumed based on their respective websites.

Table 37. Activity Participation Rates in the Study Area

Primary Activity	Humboldt-Toiyabe (excluding Spring Mountain)	Inyo National Forest	Assumed Activities - Yosemite	Assumed Activities - Death Valley, Devils Postpile, Kings Canyon, and Sequoia	Assumed Activities - Manzanar National Historic Site
Backpacking	0.4%	2.2%	3.2%	3.4%	NA
Biking	1.0%	8.3%	12.1%	12.7%	17.4%
Cross-country skiing	3.2%	5.6%	8.1%	8.5%	NA
Developed camping	3.5%	3.7%	5.3%	5.6%	NA
Downhill skiing	20.4%	32.8%	4.0%	NA	NA
Fishing	0.3%	5.9%	8.5%	9.0%	NA
Hiking	47.6%	16.5%	24.0%	25.2%	34.5%
Hunting	0.9%	0.5%	NA	NA	NA
Motorized boating	0.0%	0.1%	NA	NA	NA
Nature related	5.8%	10.3%	14.9%	15.6%	21.4%
Nonmotorized boating	0.4%	0.5%	0.7%	NA	NA
Off-highway vehicle use/snowmobiling	4.9%	0.4%	NA	NA	NA
Other recreation	11.2%	12.8%	18.5%	19.5%	26.7%
Picnicking	0.4%	0.4%	0.6%	0.6%	NA

Sources: From Table 3 of U.S. Department of Agriculture, 2017, "Recreation Economic Values for Estimating Outdoor Recreation Economic Benefits from the National Forest System"; National Park Service, 2012, "Devils Postpile: Things to Do"; NPS, 2016, "Death Valley: Things to Do"; NPS, 2020, "Manzanar: Things to Do"; NPS, 2020, "Sequoia & Kings Canyon: Places to Go."; NPS, 2020, "Yosemite: Things to Do," https://www.nps.gov/.

The Project Team estimated consumer surplus for a visit to each federal land area by multiplying the average consumer surplus per person per visit by primary activity (USFS Region 5's is presented in **Table 36**, column C) by the activity participation rates (**Table 37**). The Project Team converted these values to 2019$ using the Consumer Price Index.[81] The resulting values are presented in column C of **Table 38**. Visitor spending in each federal land area per visit (**Table 35**) is also presented in column B of **Table 38**. Imputed indirect and induced spending impacts, column E of **Table 38**, applies Mono County's multiplier of 1.4 to estimate impacts that are equal to 40 percent of visitor spending. Results indicate that visits to the national parks and forests in the Study Area are estimated to yield over $2.1 billion in annual direct spending, indirect and induced impacts, and consumer surplus.

Table 38. Total Annual Value of Recreation and Tourism by Recreation Area

Recreation Area	Data Year	Visits [a]	Estimated Spending per Visit [b]	Estimated Consumer Surplus per Visit [c]	Total Spending	Spending Indirect and Induced Impacts [d]	Total Consumer Surplus	Total Value (2019$)[e]
		[A]	[B]	[C]	[D]=[A]x[B]	[E]=[D]x0.4	[F]=[A]x[C]	[G]=[D]+[E]+[F]
Death Valley National Park	2019	1,740,945	$84.5	$79.3	$147,122,000	$58,848,800	$138,053,327	$344,024,127
Devils Postpile National Monument	2019	147,864	$65.4	$79.3	$9,667,000	$3,866,800	$11,725,308	$25,259,108
Kings Canyon National Park	2019	632,110	$29.7	$79.3	$18,754,940	$7,501,976	$50,125,012	$76,381,928
Manzanar National Historic Site	2019	97,380	$106.7	$80.0	$10,389,893	$4,155,957	$7,792,393	$22,338,244
Sequoia National Park	2019	1,246,053	$18.7	$79.3	$23,237,863	$9,295,145	$98,809,418	$131,342,426
Yosemite National Park	2019	4,422,861	$43.3	$80.2	$191,530,224	$76,612,089	$354,792,417	$622,934,730
Inyo National Forest	2016	2,309,000	$185.0	$82.8	$427,264,228	$170,905,691	$191,260,093	$789,430,012
Humboldt-Toiyabe National Forest (outside Spring Mountain)[f]	2016	134,468	$218.2	$103.1	$29,335,135	$11,734,054	$13,870,891	$54,940,080
Total		**10,730,681**			**$857,301,284**	**$342,920,513**	**$866,428,859**	**$2,066,650,656**

Sources: See endnote.[82]

Notes:

a. The visit data for the National Park Service reflects "Recreation Visitors." The visit data for the National Forests reflects "A National Forest Visit," defined as the entry of one person onto a national forest site or area to participate in recreation activities for an unspecified amount of time.

b. Due to the majority of access to Kings Canyon, Sequoia, and Yosemite National Parks being outside of the Study Area, only visitor spending within the parks is estimated by applying the percentage of visitors that stayed overnight in the parks.

c. Because the NPS does not publish their own estimates of consumer surplus by activity type in each national park, the value for each activity type was applied from USFS region 5, Pacific Southwest. Additionally, each national park has its own mix of available activities. The consumer surplus values for each available activity were selected based on the respective national parks home page.

d. Mono County has an impact multiplier of 1.4 on spending (or 40 percent of spending) to estimate indirect and induced benefits.

e. The total value is the sum of total spending, indirect and induced spending, and consumer surplus.

f. Because the vast majority of the Humboldt-Toiyabe National Forest is outside of the Study Area, only the visits proportional to the land area in the Study Area are included.

Similarly, **Table 39** presents the estimated annual value of recreation and tourism from consumer surplus, visitor spending, and estimated indirect and induced spending impacts by recreational activity. USFS reports activity participation rates for the Inyo and Humboldt-Toiyabe (excluding Spring Mountain National Recreation Area) national forests. NPS does not report activity participation rates; thus, the Project Team assumed that the Inyo National Forest's activities and values are representative of the Study Area as a whole. The available activities for the NPS lands are assumed to be available based on their respective websites.

Table 39. Total Annual Value of Recreation and Tourism by Recreational Activity, 2019$ Millions

Primary Activity	Consumer Surplus	Estimated Spending	Estimated Indirect and Induced Spending Impacts	Total Estimated Value
Backpacking	$26.3	$23.8	$9.5	$59.6
Biking	$115.2	$86.1	$345	$2358
Cross-country skiing	$47.7	$573	$22.9	$127.9
Developed camping	$46.6	$37.9	$152.2	$99.6
Downhill skiing	$85.7	$153.8	$61.5	$301.0
Fishing	$76.9	$59.5	$23.8	$160.2
Hiking	$229.2	$184.6	$73.8	$487.7
Hunting	$1.5	$24	$1.0	$4.9
Motorized boating	$0.2	$0.4	$0.2	$0.8
Nature related	$98.2	$107.4	$43.0	$248.6
Nonmotorized boating	$6.9	$3.7	$1.5	$12.1
Off-highway vehicle use/ snowmobiling	$1.1	$3.2	$1.3	$5.5
Other recreation	$128.1	$132.8	$53.1	$314.1
Picnicking	$3.2	$4.2	$1.7	$9.1
Total	**$866.8**	**$857.3**	**$342.9**	**$2,067.0**

Baseline Natural Capital Assessment Results

In the baseline assessment, the Project Team estimated that the total annual economic value of ecosystem services provided by lands within the Study Area, under historical climate conditions, ranges from approximately $43.6 to $190.9 billion, with an annual average of $95.4 billion. **Table 40** and **Table 41** present annual ecosystem service values across assumptions of a range of low, average, and high impacts. Annual values in these tables differ slightly due to rounding. **Table 40** presents the estimated annual values by ecosystem service. As shown in the table, carbon storage and water quality services provide the greatest value, with annual values ranging from approximately $19.4 to $64.7 billion (with an annual average of $40.4 billion) and $14.6 to $89.6 billion (with an annual average of $37.7 billion), respectively. **Table 41** presents ecosystem service values by land cover type, with the value for each land cover type representing the sum of the ecosystem services that it provides. As shown in the table, coniferous forest and shrubland

provide the most value, with total annual values ranging from $18.8 to $89.3 billion (with an annual average of $44.0 billion) and $16.5 to $56.4 billion (with an annual average of $33.4 billion), respectively. For additional discussion of methods and results, see the Baseline Natural Capital Assessment in Section 2.

Table 40. Summary of Total Annual Ecosystem Service Values by Ecosystem Service for the Study Area, Millions of 2019$

Ecosystem Service	Total Value/ Year		
	Low	Average	High
Air Quality Regulation	$416.3	$479.6	$559.1
Biological Control	$68.0	$85.0	$126.1
Carbon Sequestration	$146.7	$314.1	$493.2
Carbon Storage	$19,382.6	$40,438.2	$64,688.8
Erosion Prevention	$0.4	$87.1	$291.5
Pollination	$90.5	$271.4	$452.3
Recreation & Tourism	$2,066.7 [a]		
Waste Treatment	$180.9	$4,217.8	$19,774.2
Water Quality	$14,595.7	$37,658.0	$89,561.7
Water Regulation	$6,611.0	$9,732.2	$12,853.4
Total	**$43,558.7**	**$95,350.0**	**$190,866.9**

Note: Values may differ due to rounding.

a. Recreation & Tourism only includes a single value, as this value was calculated differently.

Table 41. Summary of Total Annual Ecosystem Service Values by Land Cover Type for the Study Area, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value / Year		
		Low	Average	High
Desert Shrub	5,157,149	$3,573.9	$5,200.8	$6,827.8
Coniferous Forest	2,103,843	$18,770.2	$44,025.7	$89,375.7
Shrubland	1,837,064	$16,503.0	$33,381.1	$56,357.4
Barren	1,058,250	$0.0	$0.0	$0.0
Deciduous Forest	182,159	$850.8	$2,894.3	$6,651.0
Desert Woodland	162,687	$145.5	$258.9	$342.6
Grassland	124,552	$1,022.7	$2,193.9	$3,852.8
Open Water	99,632	$347.1	$506.6	$1,011.9
Wetland	96,064	$254.2	$4,754.5	$24,232.3
Urban	25,951	$1.6	$2.1	$3.4
Agriculture/ Cropland	16,495	$23.1	$65.3	$145.5
Total [a]	**10,863,846**	**$41,492.1**	**$93,283.2**	**$188,800.4**

Note: Values may differ due to rounding.

[a] Total does not include Recreation and Tourism impacts as they could not be disaggregated by land cover type.

In the baseline assessment and as described in **Appendix A**, the Project Team estimated the total annual economic value of recreation in the federal lands within the boundaries of the ESSRP to be approximately $2.07 billion annually. Similarly, **Table 42** presents the estimated annual value of recreation and tourism, from consumer surplus, visitor spending, and estimated indirect and induced spending impacts by recreational activity.*

Table 42. Total Annual Value of Recreation and Tourism by Recreational Activity, Millions of 2019$ Millions

Primary Activity	Consumer Surplus	Estimated Spending	Estimated Indirect and Induced Spending Impacts	Total Estimated Value
Backpacking	$26.3	$23.8	$9.5	$59.6
Biking	$115.2	$86.1	$345	$235.8
Cross-country skiing	$47.7	$57.3	$22.9	$127.9
Developed camping	$46.6	$37.9	$152.2	$99.6
Downhill skiing	$85.7	$153.8	$61.5	$301.0
Fishing	$76.9	$59.5	$23.8	$160.2
Hiking	$229.2	$184.6	$73.8	$487.7
Hunting	$1.5	$2.4	$1.0	$4.9
Motorized boating	$0.2	$0.4	$0.2	$0.8
Nature related	$98.2	$107.4	$43.0	$248.6
Nonmotorized boating	$6.9	$3.7	$1.5	$12.1
Off-highway vehicle use/ snowmobiling	$1.1	$3.2	$1.3	$5.5
Other recreation	$128.1	$132.8	$53.1	$314.1
Picnicking	$3.2	$4.2	$1.7	$9.1
Total	**$866.8**	**$857.3**	**$342.9**	**$2,067.0**

Note: Values may differ due to rounding.

* USFS reports activity participation rates for the Inyo and Humboldt-Toiyabe (excluding Spring Mountain National Recreation Area) national forests. NPS does not report activity participation rates, thus ICF assumed that the Inyo National Forest's activities and values are representative for the Study Area. The available activities for the NPS lands are assumed based on their respective websites.

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SECTION 5: CLIMATE CHANGE HAZARDS OF CONCERN

As described in the *California Adaptation Planning* Guide (APG), hazards are events or physical conditions that have the potential to cause fatalities, injuries, property and infrastructure damage, interruption of the economy, and other types of harm or loss. The Project Team reviewed extensive scientific reports and datasets to assess which hazards apply to the SRTI Study Area (Study Area). These reports and datasets include a number of state and federal reports as well as regional planning documents, such as county multi-jurisdictional hazard mitigation plans and the U.S. Forest Service (USFS) Region 5 report *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*. The Project Team only considered climate change–related hazards for inclusion in the Climate Change Vulnerability Assessment. For example, seismic hazards such as earthquakes may be harmful to areas in the Study Area, but they do not have a known substantive connection with climate change that would affect the region. Climate change–related hazards focus on natural hazards that can change in frequency and intensity due to climate change. In some cases, an exposure can be an entirely new hazard, such as a new pest insect that did not live in the area before.

After reviewing reports and data, the Project Team selected 10 hazards to consider in the Climate Change Vulnerability Assessment.

1. Air Quality, Smoke, and Ash
2. Drought
3. Extreme Heat and Warm Nights
4. Flooding
5. Forestry Pests and Diseases
6. Human Health Hazards
7. Landslides and Debris Flows
8. Severe Weather
9. Severe Winter Weather
10. Wildfire

When selecting these hazards and applying them to the Study Area, the Project Team acknowledged different climate scenarios for the hazard projections. As with any forecast, there is some uncertainty in the projections of climate change hazards. Climate change is caused by GHG emissions, and therefore changes in the amount of emissions emitted in the near term compared to the distant future will have an effect on the severity of potential climate change effects. Higher volumes of emissions over a shorter period of time are likely to lead to more severe effects. These uncertainties depend in part on factors such as population levels, economic activities, government policies, and personal behavior.

This Climate Change Vulnerability Assessment uses data and reports that look at multiple scenarios of future GHG emissions and severity of climate change. The global scientific community most commonly uses four different scenarios, known as "representative concentration pathways" (RCP):

- RCP 2.6: This scenario assumes that global GHG emissions peak around 2020, then decline quickly. Under this scenario, emissions of carbon dioxide from human activities reach zero around 2075.
- RCP 4.5: This scenario assumes that global GHG emissions peak around 2040, and then decline. Carbon dioxide emissions decline to less than half of current levels by 2080.

- RCP 6: This scenario assumes that global GHG emissions peak around 2060. Human-caused carbon dioxide emissions decline after 2060, although they remain above current levels at the end of the century.
- RCP 8.5: This scenario assumes that global emissions continue to climb until at least the end of the century.[83]

In California, the most accurate and detailed data are available for the RCP 4.5 and RCP 8.5 scenarios, and the Project Team used RCP 4.5 and RCP 8.5 to prepare this Climate Change Vulnerability Assessment using both federal and statewide datasets. The data under the RCP 2.6 and RCP 6 scenarios are only available at a large scale and would not provide enough detail to accurately identify changes to climate conditions in the Study Area.

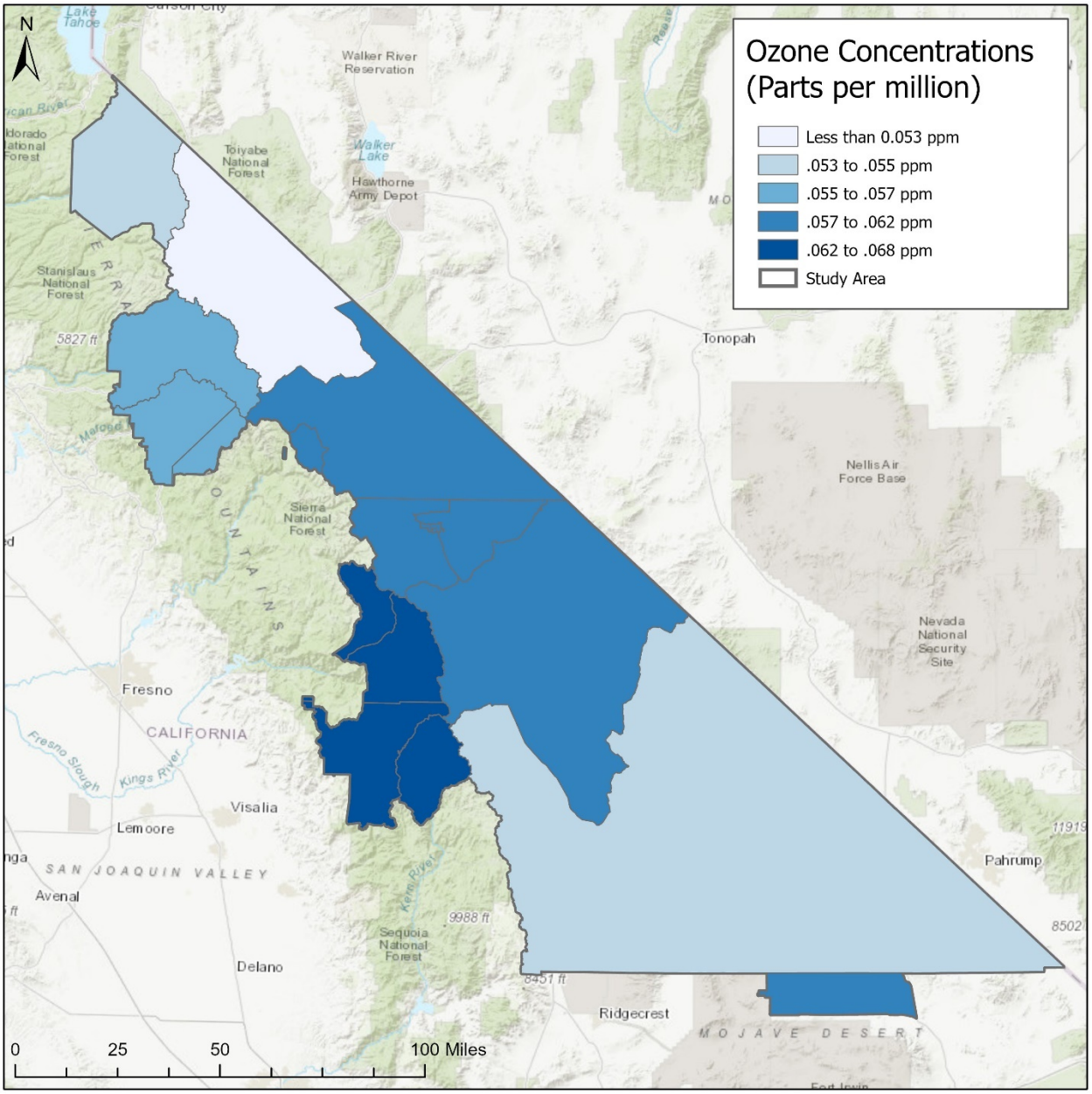
Air Quality, Smoke, and Ash

The dominant components of poor air quality in the Study Area are ozone pollution from vehicle exhaust and smoke and ash from regional wildfires. Higher temperatures, such as those in the south and southeastern portions of the Study Area, can increase surface ozone concentrations because sunlight causes chemical reactions between oxygen-containing compounds and other air pollutants. Sunlight intensity, atmospheric conditions, and temperatures can all affect the rate of this reaction, and by extension the amount of ozone produced.[84] As shown in **Figure 10**, Death Valley and Owens Valley have summed ozone concentrations of 0.062 parts per million, which is among the highest concentrations (91st percentile) in California.[85] Ground-level ozone is associated with a variety of negative health outcomes, including reduced lung function, pneumonia, asthma, cardiovascular diseases, and premature death. As temperatures rise in the Study Area, ozone concentrations are projected to increase in most places, especially in places that already experience high levels, such as in Death Valley.[86]

The smoke and ash generated by wildfires can also be a dangerous air pollutant in the Study Area. Smoke is made up of gases and very small particles, usually between 0.4 and 0.7 micrometers across (0.000016 to 0.000028 inches).[87] These particles can irritate people's eyes and lungs and cause health problems, especially in people with existing health conditions or less robust respiratory systems. Ash, which is made up of larger particles, can also be dangerous if it is inhaled and may be harmful to people with sensitive skin. If smoke and ash reach indoors, the particles and smell can be difficult to remove. Even if smoke and ash levels are not high enough to pose a health risk, they can lead to unpleasant conditions that may restrict outdoor activity and tourism. This ultimately could deter visitors from traveling to the Study Area to participate in recreation and tourism activities.

Smoke and ash can spread far beyond the area burned by a regional wildfire. Though wildfires within or near the Study Area can create some of the highest levels of air pollution, smoke and ash can reach dangerous levels more than 100 miles away from an active fire. For example, residents in the Town of Mammoth Lakes reported being affected by smoke from the December 2017/January 2018 Thomas Fire, which burned over 220 miles south of the town in Ventura and Santa Barbara counties.

Figure 10. Ozone Concentrations



Wildfires are expected to become more intense, to burn larger areas, and to have a longer season throughout the year due to climate change.[88] This means that there are likely to be more days with higher levels of smoke and ash in the Study Area as well as throughout the rest of the state. It is possible that the average intensity of days with high smoke and ash levels will increase, although further research is needed.

Drought

A drought is when conditions are drier than normal for a long period of time, making less water available for people (especially if local water supply depends on surface water) and ecosystems. Communities within the Study Area may experience water shortages during drought conditions, which could lead to lower water levels at water recreation sites and water restrictions for both residential and commercial purposes. Lower water levels in lakes, rivers, and streams can decrease water quality, which can affect the wildlife that depend on these habitats and the recreation activities that these ecosystems support. Economic activities that depend on rain or snow, including boating, skiing, and fishing, may have to be cut back or halted. In more severe cases, water supplies may be so low that people may have to limit use to essential purposes only.

Droughts are a regular occurrence in California; however, in the past 50 years, there have been four major statewide droughts plus smaller regional droughts.[89] Scientists expect that climate change will lead to more frequent and more intense droughts statewide. In the Study Area, overall precipitation levels are expected to increase slightly, as shown in **Figure 11**, with more frequent years of extreme levels of precipitation, both high and low, as a result of climate change.[90] This is expected to cause more droughts that are more intense and last longer compared to historical norms.[91]

Snowpack

Snowpack is the amount of snow that accumulates during the winter. Snowpack serves as a natural reservoir to store water during the winter, which slowly melts in the spring and summer to feed streams and rivers and replenish groundwater supplies. The southwest region of the United States relies on this snowmelt to supply 50 to 80 percent of the lake, reservoir, river, and creek inflows for both water supply and recreational activities.

Snowpack levels lowered by 25 percent during the 2011 to 2016 drought, and average springtime snowfall is expected to drop 64 percent by 2100. Loss of snowpack will increase future drought impacts, which are likely to be more frequent.

Source: ARCCA, 2018, From Mountain to Cities: Exploring California's Urban Connections to Sierra Nevada Ecosystems. https://arccacalifornia.org/wp-content/uploads/2018/08/ARCCA-Urban-Rural-Whitepaper.pdf

In the Study Area, drought conditions and water supply depend on the levels of snowpack, which feed reservoirs, rivers, and creeks that provide critical water storage for the Eastern Sierra region and California. At lower elevations in the Study Area, most precipitation falls as rain. However, at high elevations, such as the Town of Mammoth Lakes or Carson Pass, most precipitation falls as snow. As shown in **Figure 12**, snowpack is projected to decrease throughout the Study Area. Although precipitation levels are not expected to change much, more precipitation is expected to

fall as rain instead of snow, reducing snowpack over the winter. Warmer temperatures are expected to melt the snowpack sooner, which is likely to cause higher-than-normal runoff in late winter and early spring. However, the amount of melting snow and other runoff in the Study Area is projected to be approximately half of normal levels by the summer because the reduced snowpack melts away sooner. Throughout much of the Sierra Nevada, snowpack levels are expected to decline by as much as 90 percent by 2100.[92] In the central Sierra Nevada, years with unusually low snowpack levels (sometimes called "snow droughts") are expected to happen two to four times more often by 2100 than they have historically.[93]

Figure 11. Projected Precipitation Levels in the Study Area

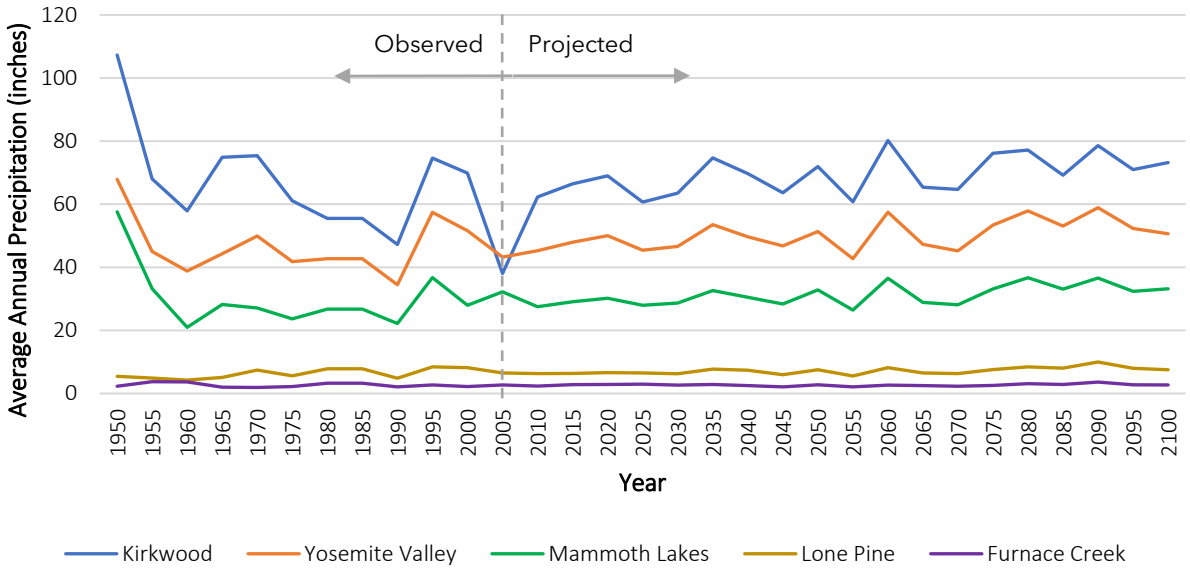
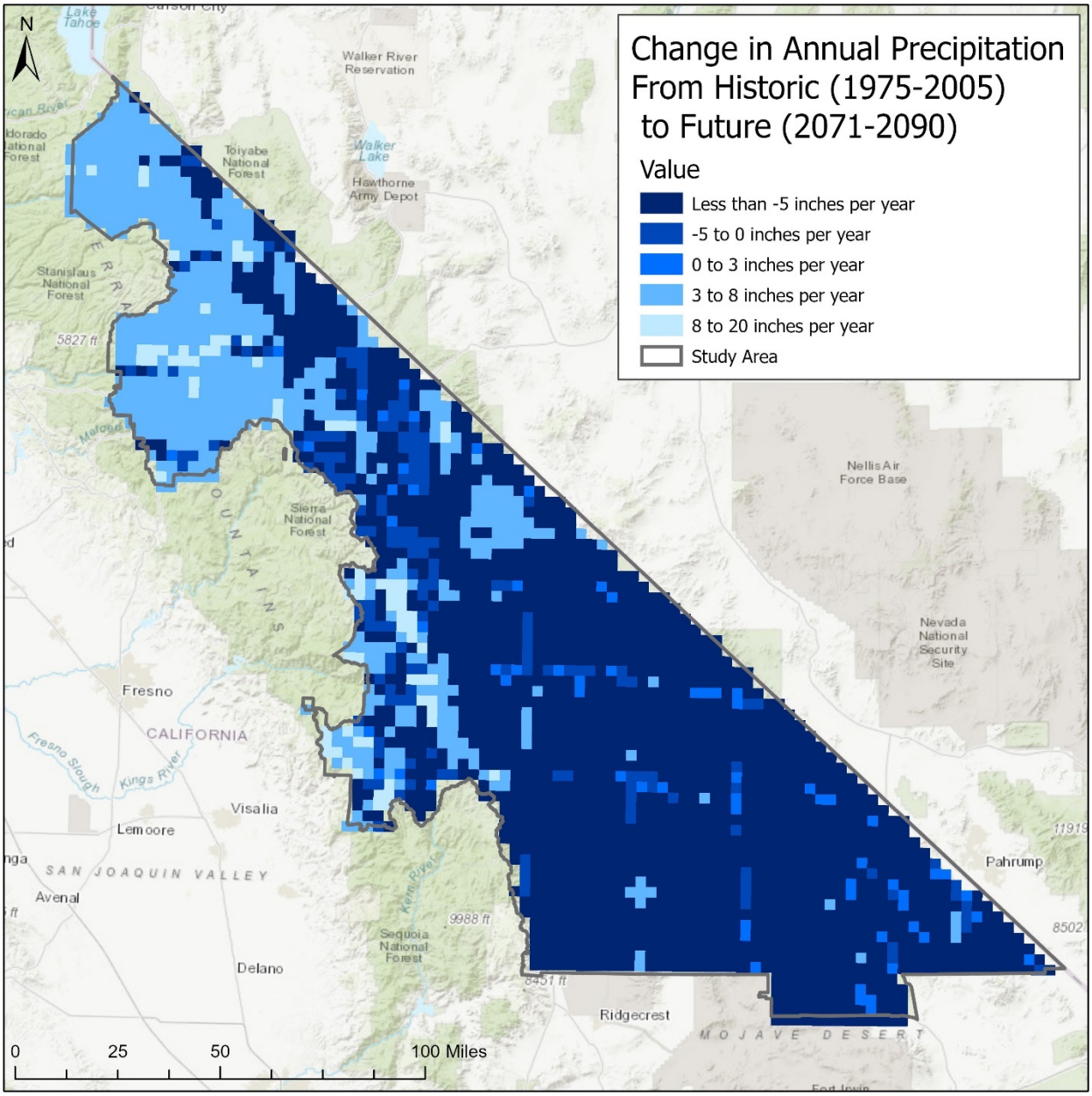


Figure 12. Annual Precipitation Changes



Extreme Heat and Warm Nights

"Extreme heat" is a relative term—temperatures of 100 degrees Fahrenheit are normal in Death Valley, but almost unprecedented in Alpine County or June Lake. Although temperatures are lower in the northern portions of the Study Area, it is still dangerous when temperatures are higher than usual for people and assets that are not accustomed to them. Warm nights, when the daily minimum temperatures remain significantly above normal levels, can worsen an extreme heat day, because people and assets may not get relief from the high temperatures. The Study Area has different extreme heat and warm night thresholds in different regions of the Study Area, as shown in **Table 43**.

Table 43. Extreme Heat and Warm Night Temperature Thresholds in the Study Area

Location	Extreme Heat Threshold (°f)	Warm Night Threshold (°f)
Kirkwood	78.6	49.8
Yosemite Valley	88.4	52.7
Mammoth	79.9	47.6
Lone Pine	100.8	68.0
Furnace Creek	118.4	92.9

Source: California Energy Commission, 2018, "Extreme Heat Days & Warm Nights." https://cal-adapt.org/tools/extreme-heat/.

Historically, the Study Area has experienced an average of four extreme heat days per year. This number is expected to increase dramatically due to climate change. By the middle of the 21st century (2040 to 2070) the Study Area is likely to see an average of 25 to 42 extreme heat days per year. By the end of the century (2070 to 2100), the Study Area is projected to experience an average of 50 to 71 extreme heat days per year. **Figure 13**[94] shows the projected increase in extreme heat days in five different communities in the Study Area. As shown in **Figure 14**,[95] the number of warm nights per year in the Study Area is projected to increase from an average of 5 historically to 21 to 49 by midcentury, and to 47 to 89 by the end of the century. Additionally, extreme heat events are expected to occur earlier and later in the year and expected to last longer. **Figure 15** shows the snow water equivalence change in the Study Area.

Extreme heat can cause heat-related illnesses, such as heat cramps, heat exhaustion, and heat stroke. These temperatures can also harm animals and plants that are not adapted to these conditions. Some types of infrastructure, including power lines and roadways, face greater stresses during high temperatures, which make materials unstable and failure more likely. Very high temperatures make people less likely to venture outside, hurting recreation and tourism economies that depend on outdoor activities. Extreme heat can also increase wildfire conditions by drying out plant material, and prolonged high temperatures can contribute to drought conditions.

Extreme heat conditions themselves are unlikely to affect snow conditions in the Study Area, but general increases in temperatures are likely to create significant changes. Warmer temperatures mean that there will be fewer days with temperatures cold enough to allow for snowfall, meaning that the Study Area can expect to see more rain and less snow even if the total level of precipitation does not change

Figure 13. Frequency of Extreme Heat Days in the Study Area

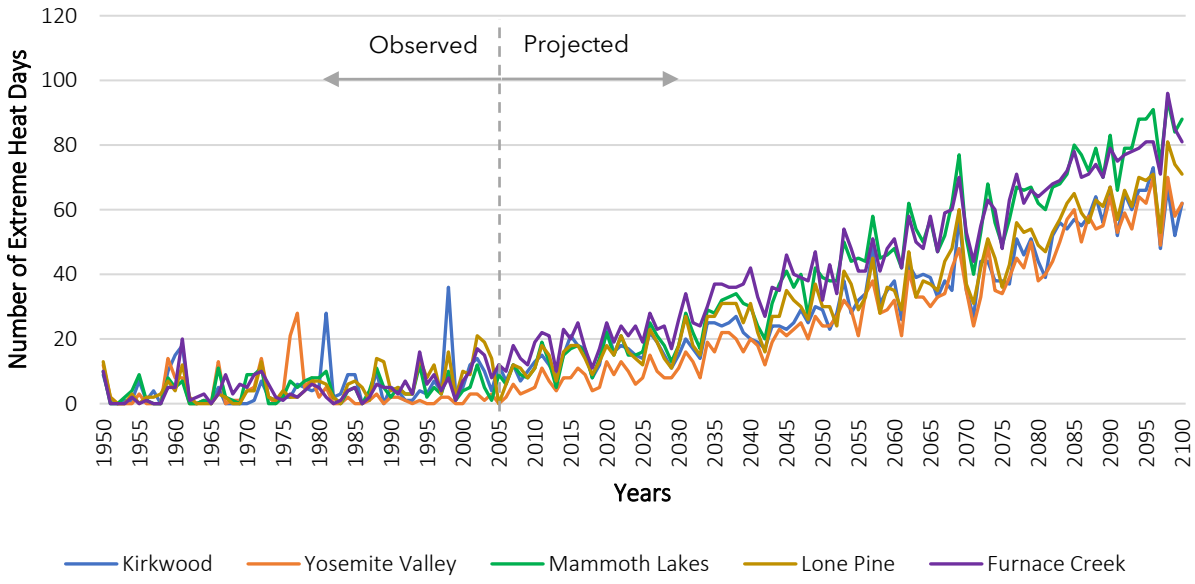


Figure 14. Frequency of Warm Nights Days in the Study Area

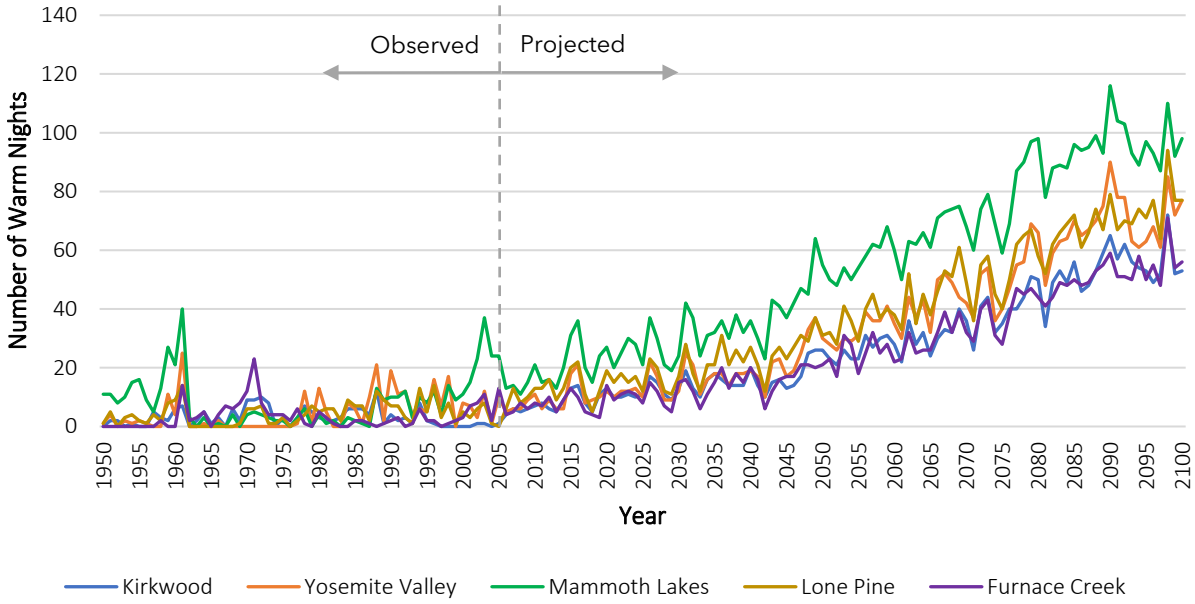


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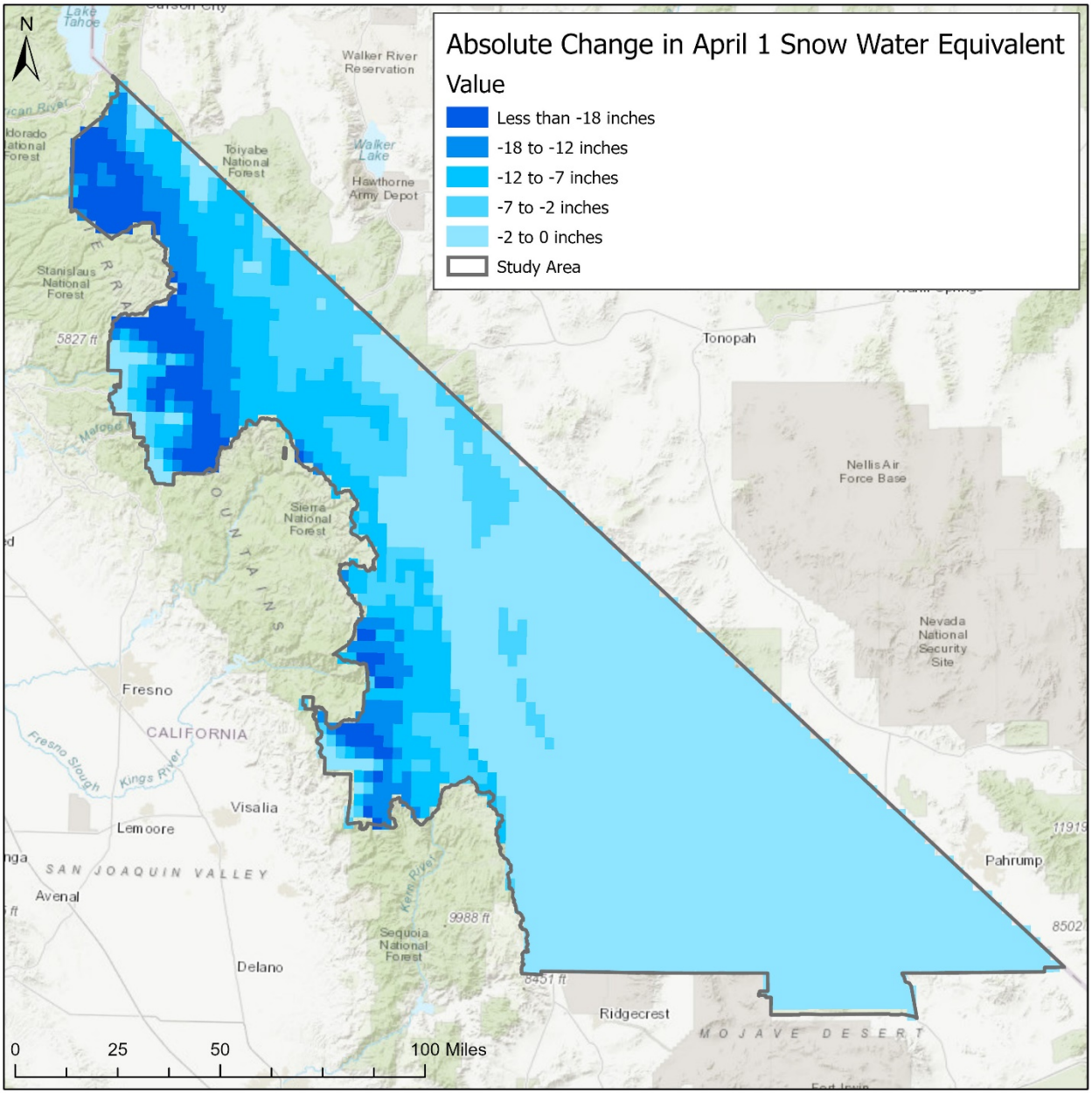
Figure 15. Snow Water Equivalence Change



Flooding

When there is too much water to be held in local water bodies, carried away by creeks and rivers, or soak into the soil, it can flood—that is, wash into normally dry areas—and cause significant harm to buildings, people, and ecosystems. Floodwaters can be deep enough to drown people and may move fast enough to carry away people or heavy objects (such as cars). In some cases, floods can lift buildings off their foundations. Floods can be caused by heavy rainfall, long periods of moderate rainfall, or blocked drainage areas during rainfall. In rare instances, a break in a dam, water pipe, or water tank can also cause flooding. Floods that develop very quickly are called flash floods and can be especially dangerous because they give little or no warning. Additionally, summer thunderstorms can also cause flooding.

Although climate change is expected to increase the frequency and intensity of droughts, scientists also project that it will increase the frequency and intensity of floods in the Study Area, although precipitation levels are expected to increase only slightly. Up to half of California's precipitation comes from a relatively small number of intense winter storms, which are expected to become more intense with climate change. For example, what is currently a 20-year storm, or one that could occur once in 20 years, would increase in frequency by a factor of more than three by the end of the century.[96] **Figure 16** shows the current 100-year and 500-year flood hazard areas that may face elevated flood risks.

Change to snowfall and snowpack in the Study Area is expected to contribute to an increase in flooding. A greater proportion of precipitation is expected to fall as rain rather than snow, and because rain runs off quickly rather than melting over a long period, rain events are more likely to cause flooding. Additionally, warmer temperatures are projected to cause snow to melt faster, especially in the late winter and early spring, and runoff in the eastern side of the Sierra Nevada may be 150 percent to 240 percent above normal levels. This also increases the risk of rain falling on accumulated snow ("rain-on-snow" events), which further increases the potential for flooding.[97] During these events, the snow also blocks storm drains, increasing the flood risk even more. Rain-on-snow events are expected more often in the future.

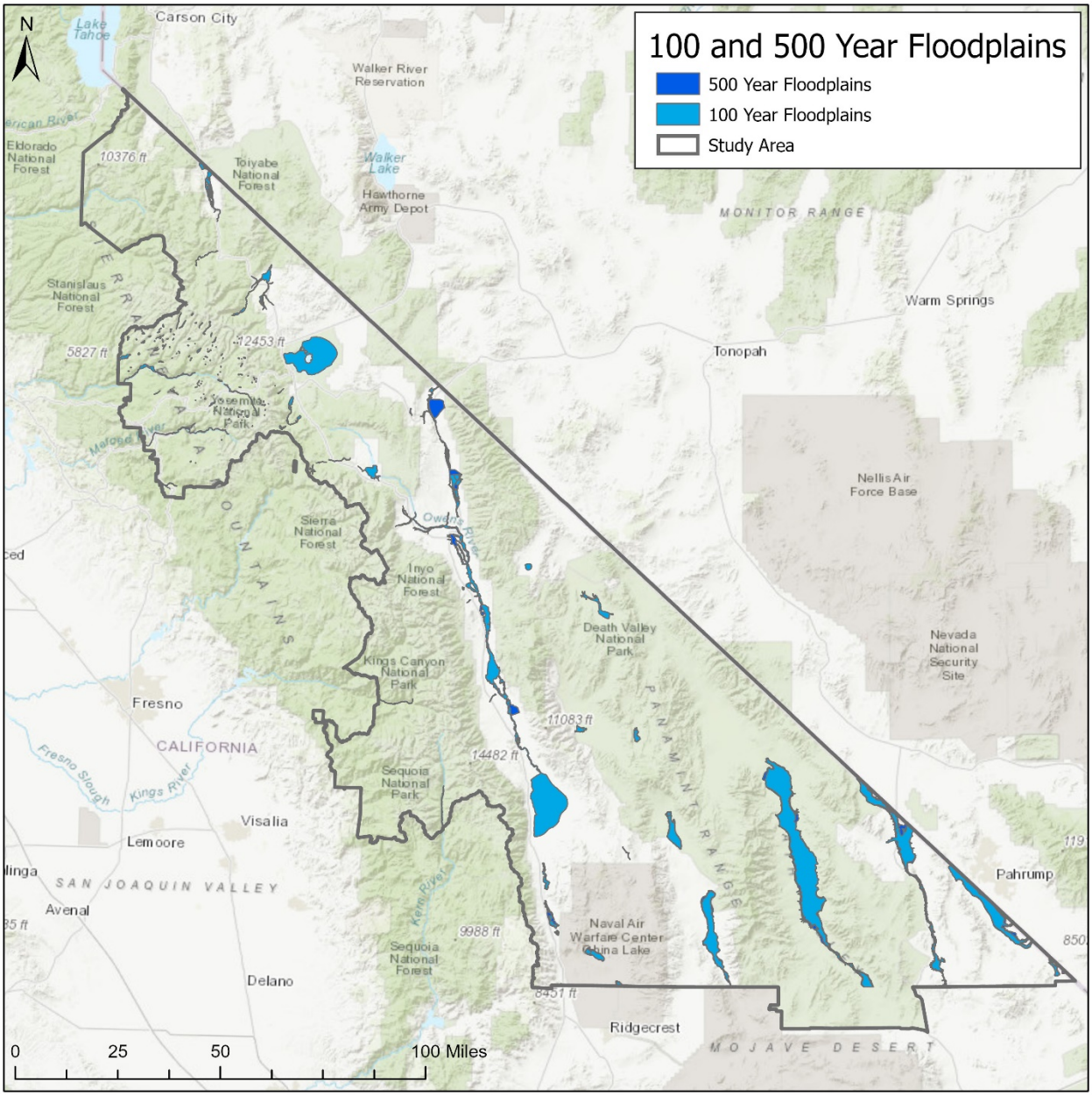
Drought, Flood, and Precipitation

Scientists expect overall precipitation levels in the Study Area to increase only slightly, but both droughts and floods are likely to happen more often. How is this possible?

Climate change is likely to shift precipitation patterns in California toward the extremes. Storms are expected to become stronger, dropping more precipitation statewide. At the same time, dry periods are likely to become drier and more frequent.

The "normal" conditions in California are likely to become more extreme during both wet and dry periods. However, the more intense and frequent very wet and very dry periods are expected to average out, so overall precipitation levels are not expected to change much.

Figure 16. 100-Year and 500-Year Flood Hazard Areas



Forestry Pests and Diseases

The forests of California face harm from a number of insects and other pests, diseases caused by bacteria or viruses, fungal infections, and other conditions that can affect the health of forest trees and plants. Bark beetles are among the most well-known of these forestry pests and diseases in California because of the devastation they have caused in the Sierra Nevada over the past several years, but there are many others, including black stain root disease, pine needle scale, mountain pine beetle, lodgepole pine needleminer, fir engraver, western pine beetle, mountain hemlock dwarf mistletoe, white pine blister rust, and Ips engraver beetle.[98] Pest or disease infections can cause trees and other plants to grow more slowly, damage them so they are less able to function in an ecosystem, or kill them outright. Forest and wilderness managers can cure or treat some pests or diseases or control their spread. However, in some cases, there is nothing that can be done.

One of the most direct effects of climate change is that average temperatures will increase; this has a bearing on many pests and diseases. Many pests and organisms that carry diseases are most active during warmer months, so the threat of infection or infestation is higher during this time of year. Temperatures are expected to become warmer earlier in the year and remain warmer until later in the year due to climate change, creating a wider activity window for pests and diseases. Climate change can also create a greater risk of forestry pests and diseases indirectly. Forests may be harmed and weakened by warmer temperatures and changes in precipitation, which can leave them more susceptible to pests and diseases and inhibit their ability to fight infestations or infections.

Forestry pests and diseases are harmful to the health of the forest but can also be damaging to the local community. In the Study Area forests are a scenic and recreation attraction, so aesthetics are an important contributor to visitor quality of experience, and forestry pests and diseases can cause significant economic harm. Dead trees or tree limbs may fall, especially during high winds, and can damage or destroy buildings and structures, cars, and other property. Falling trees or tree limbs may block roadways and cause injuries or even fatalities to residents and visitors. Dead trees and other plants can also create more fuel for wildfires. **Figure 17** shows the recent tree mortality levels throughout the Study Area.

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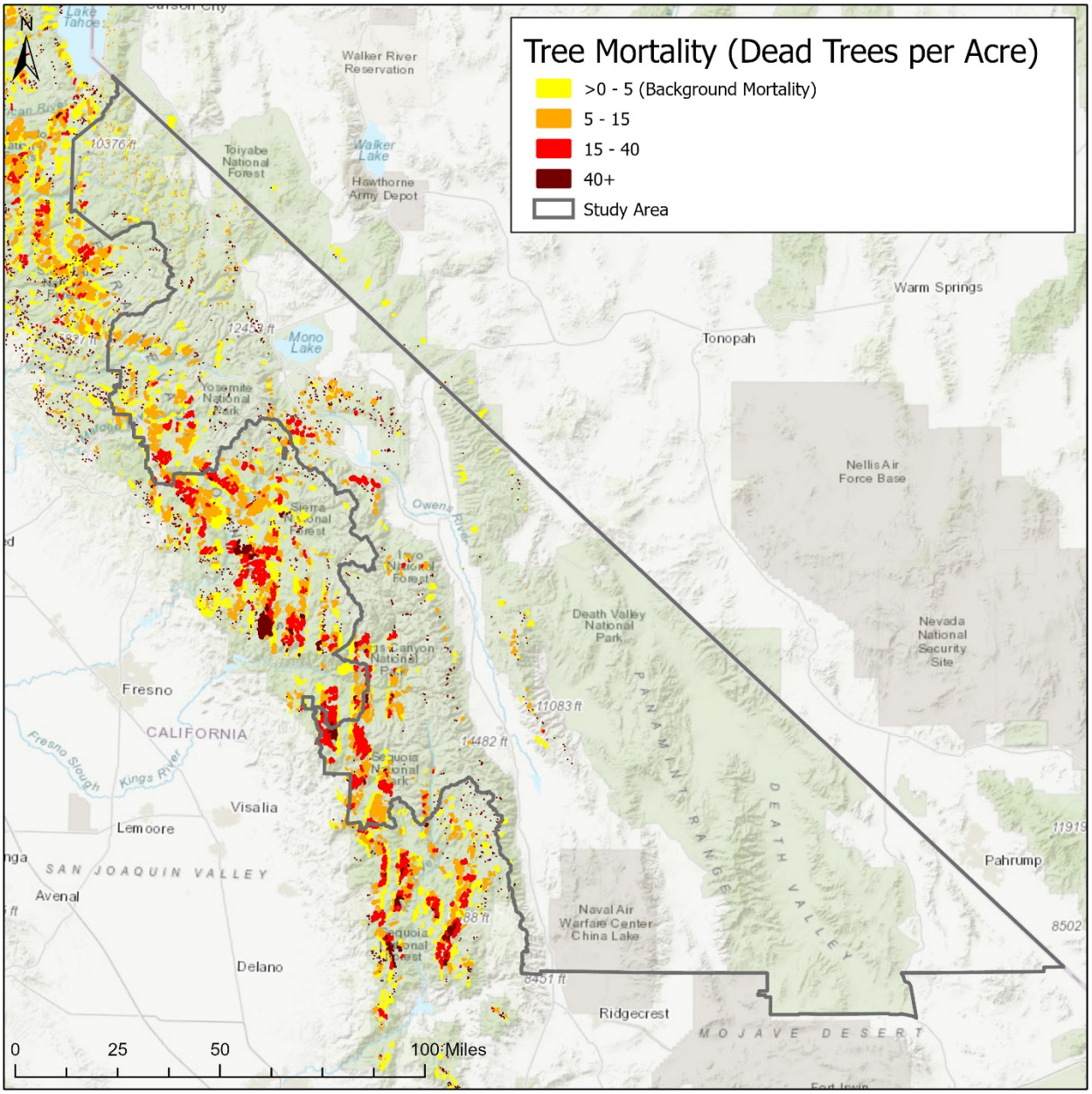
Figure 17. Tree Mortality in the Study Area



Human Health Hazards

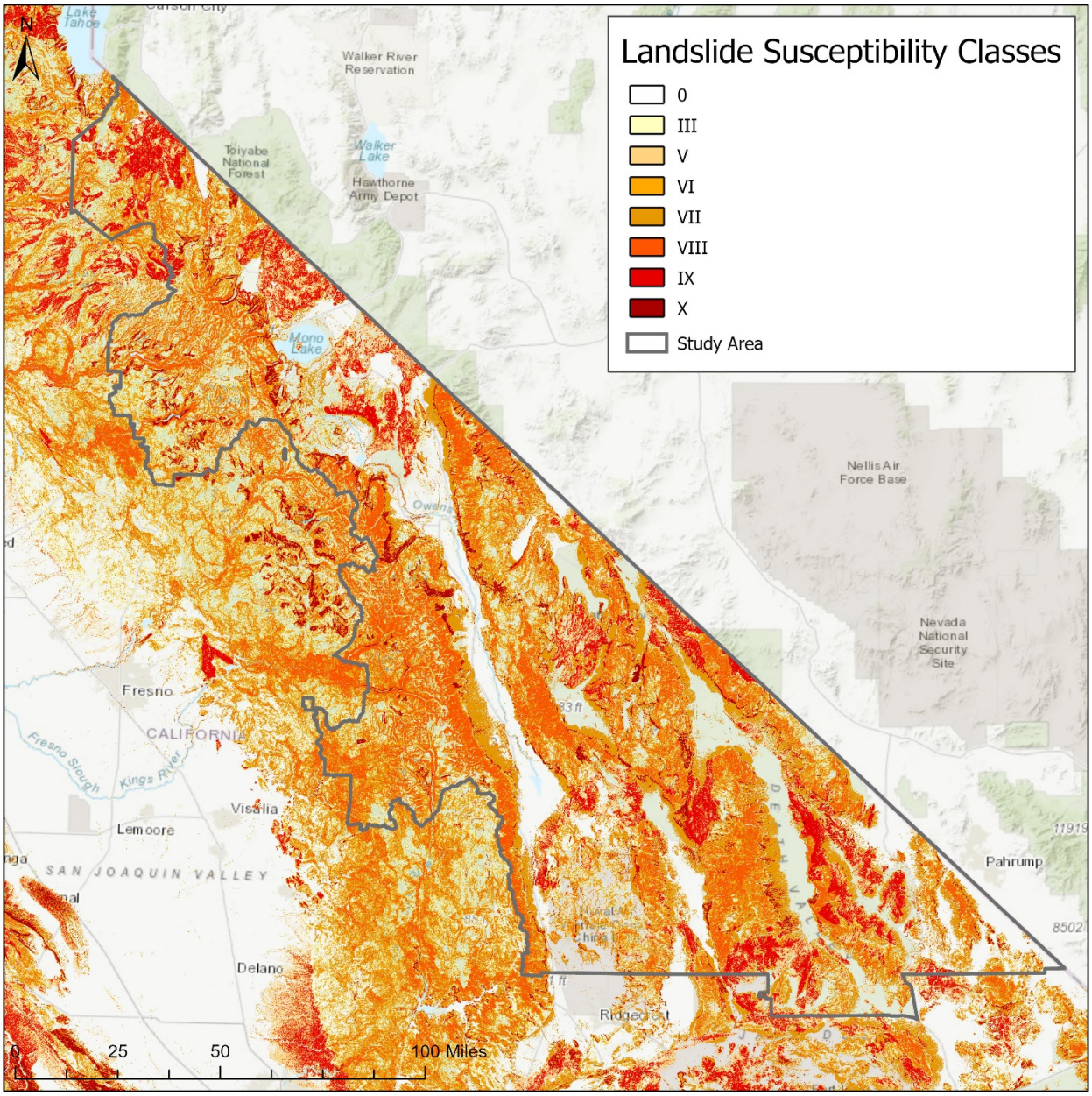
Human health hazards are bacteria, viruses, parasites, and other organisms that can cause diseases and illnesses in people. Some of these diseases may only cause mild inconvenience, but others are potentially life threatening. Examples include hantavirus pulmonary syndrome, Lyme disease, West Nile virus, and influenza, which can be debilitating or fatal for some of the population. Some diseases are carried by animals such as mice and rats, ticks, and mosquitos, which are usually seen as pests even if they do not cause infections.

Similar to forestry pests and diseases, changes in temperature and precipitation can increase the rates of infections because many of the animals that carry diseases are more active during warmer weather. Warmer temperatures earlier in the spring and later in the winter can cause these animals to be active for longer periods, increasing exposure to disease. Warmer temperatures and higher levels of rainfall also lead to increased populations of animals such as mosquitos, rodents, and ticks, creating a greater risk of diseases carried by these animals

Landslides and Debris Flows

Landslides are most common on steep slopes made up of loose soil and other material, but they can also occur on shallower slopes. Types of landslides include slow-moving earth flows, mudflows, debris flows, rockfalls, and alluvial fans.[99] This Climate Change Vulnerability Assessment looks at landslides that are caused by precipitation, although the shaking of an earthquake can also trigger landslides. Steep slopes made of loose or fractured material are more likely to slide. In some cases, hillsides may become so saturated that slope failure results in a mudslide (a mixture of soil and water moving downslope). Landslides and mudslides can move fast enough to damage or destroy buildings or other structures in their path, block roads or trails, and injure or kill people caught in them. Precipitation is likely to fall in fewer, more intense rain events throughout the year due to climate change. Dry hillsides and mountainsides can quickly absorb this rainfall and become saturated, leading to slope failure. As a result, climate change may increase the frequency of landslides. As shown in **Figure 18**, much of the land in the national parks and national forests in the Study Area is in areas of high or very high landslide susceptibility.

Figure 18. Landslide Susceptibility Areas



Severe Weather

Severe weather includes strong winds, dust storms, hail, lightning, and heavy rainfall. Severe weather is usually caused by intense storm systems, although types of strong winds can occur without a storm. Severe winds are generally above 47 miles per hour but can reach speeds up to 115 miles per hour in some areas of the Study Area. They can damage or destroy buildings, knock over trees, and damage power lines and electrical equipment (potentially causing wildfires).[100] Strong winds in Death Valley and the Owens Valley area also stir up dust from dry lake beds or salt flats, creating large dust storms throughout the southern portion of the Study Area.[101] These dust storms can damage electronic and mechanical equipment and may carry elevated levels of heavy metals that can cause respiratory illnesses and chronic health issues.[102] Heavy rainfall, which is characterized by rainfall greater than 4 millimeters per hour, can lead to flooding in both rural and urban areas of the Study Area.[103] Heavy rainfall in mountain areas can also lead to flash floods in lower valley or desert areas of the Study Area. While less common, hail can damage buildings and plants (and in extreme cases injure people), and lightning can spark fires, injure people, or cause fatalities.

Severe Winter Weather

Severe winter weather includes blizzards, ice storms, and extreme cold. Blizzards and ice storms can damage buildings and other structures, knock over electricity lines and trees, and block roadways. Ice can form on roadways and paths, creating slippery conditions that make it difficult or even hazardous to get around, especially for visitors who may not be used to icy conditions. Very cold temperatures create a health risk for people who are exposed to them, including the possibility of trench foot, frostbite, or hypothermia.

In the high-elevation areas of the Study Area, significant snowfall and very cold temperatures are a normal part of the climate. The Study Area often sees at least one month a year with several feet of snow, with several roads, highways, campgrounds, and other facilities closed throughout the winter months. The peaks in the Study Area, such as Mount Whitney, Mount Williamson, Mammoth Mountain, Mount Hoffmann, and other peaks, often receive much more snow than other locations in the Study Area. Temperatures usually drop below zero degrees Fahrenheit in the mountain areas at least a few times a year.

Winter storms may become more intense in the Study Area because of climate change. Intense storms are expected to become stronger, and the most intense storms (that normally have a small chance of occurring in any given year) may become more frequent. Strong storms that occur during very cold temperatures can create severe winter conditions, so there is a potential for severe winter weather to become more frequent and intense in the Study Area. Warmer temperatures are likely to cause severe winter weather to occur during a smaller period of the year, as temperatures in late autumn and early spring may be too warm for a strong winter storm.[104] However, these storms can still cause flooding and create other severe weather, even if conditions are too warm for snow and ice.

Wildfire

Wildfires are a regular feature of the landscape in much of California. The forested mountain landscape in the Sierra Nevada, including the Study Area, is especially fire prone. Winter rains support plant growth, and the summer dry season dries out vegetation, increasing the potential for ignition during the late summer and autumn when temperatures are high for several months without precipitation. Fires can be sparked by lightning, malfunctioning equipment, vehicle crashes, and many other causes. As shown in **Figure 19**, historical wildfires have occurred in throughout the Sierra Nevada region of the Study Area.

Wildfires typically burn in natural areas, although they can easily spread into developed areas, such as the Town of Mammoth Lakes, between urban and wildland zones, known as the wildland-urban interface. The wildland-urban interface can expose people and property to the flames, increasing the risk of injury, death, and property damage or destruction. **Figure 20** shows wildfire hazard severity zones in the Study Area and the agencies responsible for fire protection. The Study Area is primarily managed by the National Park Service (NPS), USFS, and Bureau of Land Management, and therefore many of the firefighting and fuels management activities are conducted through these federal agencies. Outside of these lands, fire protection is provided by CAL FIRE as well as city and county fire departments.

Climate change is expected to lead to an increase in wildfires throughout California. Warmer temperatures, an increase in drought conditions, and forestry pests and diseases are likely to create more fuel for fires throughout the Study Area, leading to a greater chance that a spark will grow into a potentially dangerous blaze. Climate change is also expected to extend the fire season throughout much (or even all) of the year and increase the likelihood of a catastrophic wildfire. Fire activity in the Southeast Sierra Nevada is projected to increase from approximately 14,555 annual acres burned historically in the Study Area to 20,122 annual acres burned by midcentury, and 25,944 annual acres burned by the end of the century. **Figure 21** shows the projected acres burned throughout the Study Area. This is an annual average, and some years may see significantly larger fires.[105] Because wildfires burn the trees and other vegetation that help stabilize a hillside and absorb water, more areas burned by fire may also lead to an increase in landslides and floods.

Figure 19. Historical Wildfire Perimeters

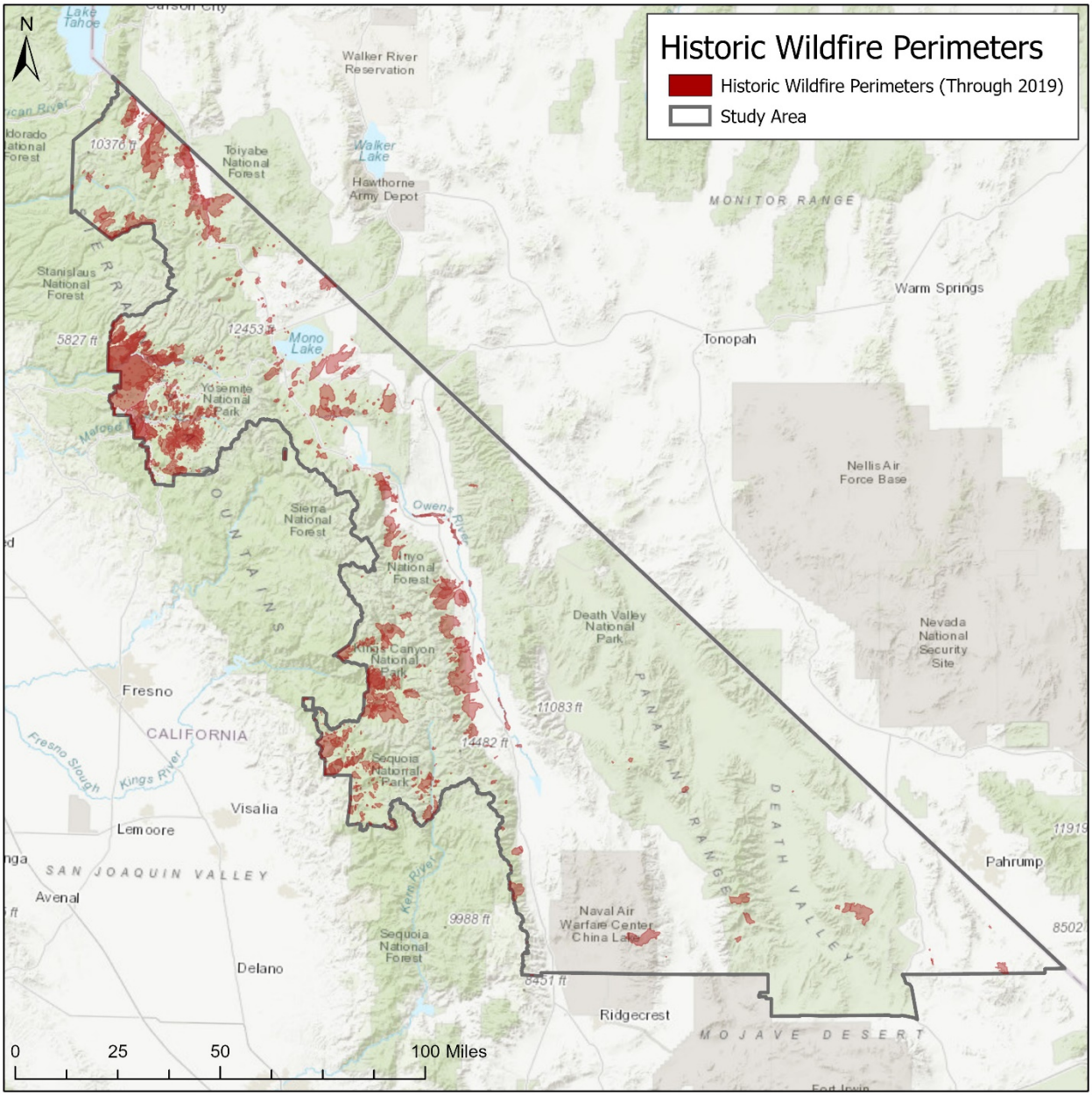


Figure 20. Fire Hazard Severity Zones

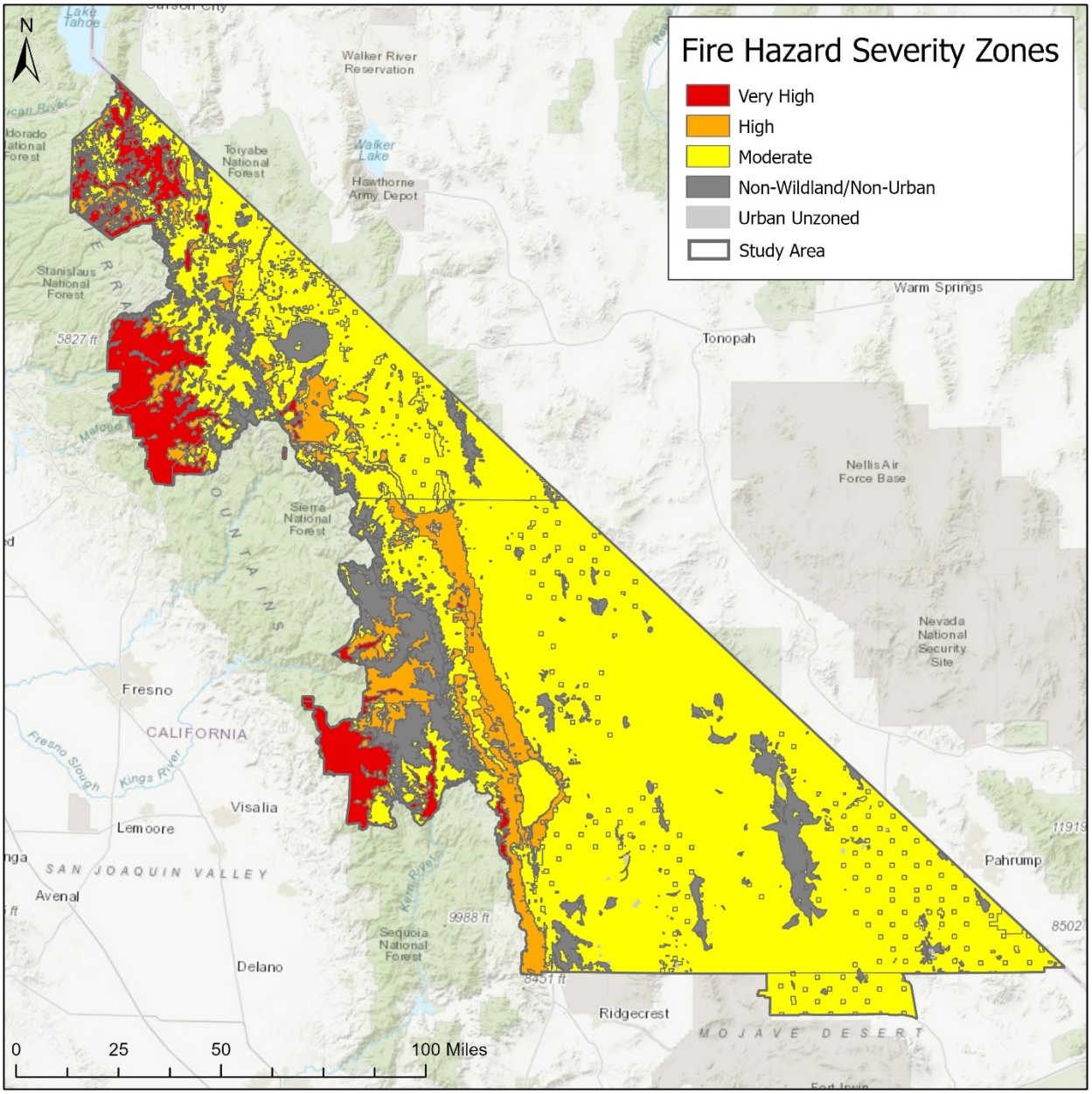
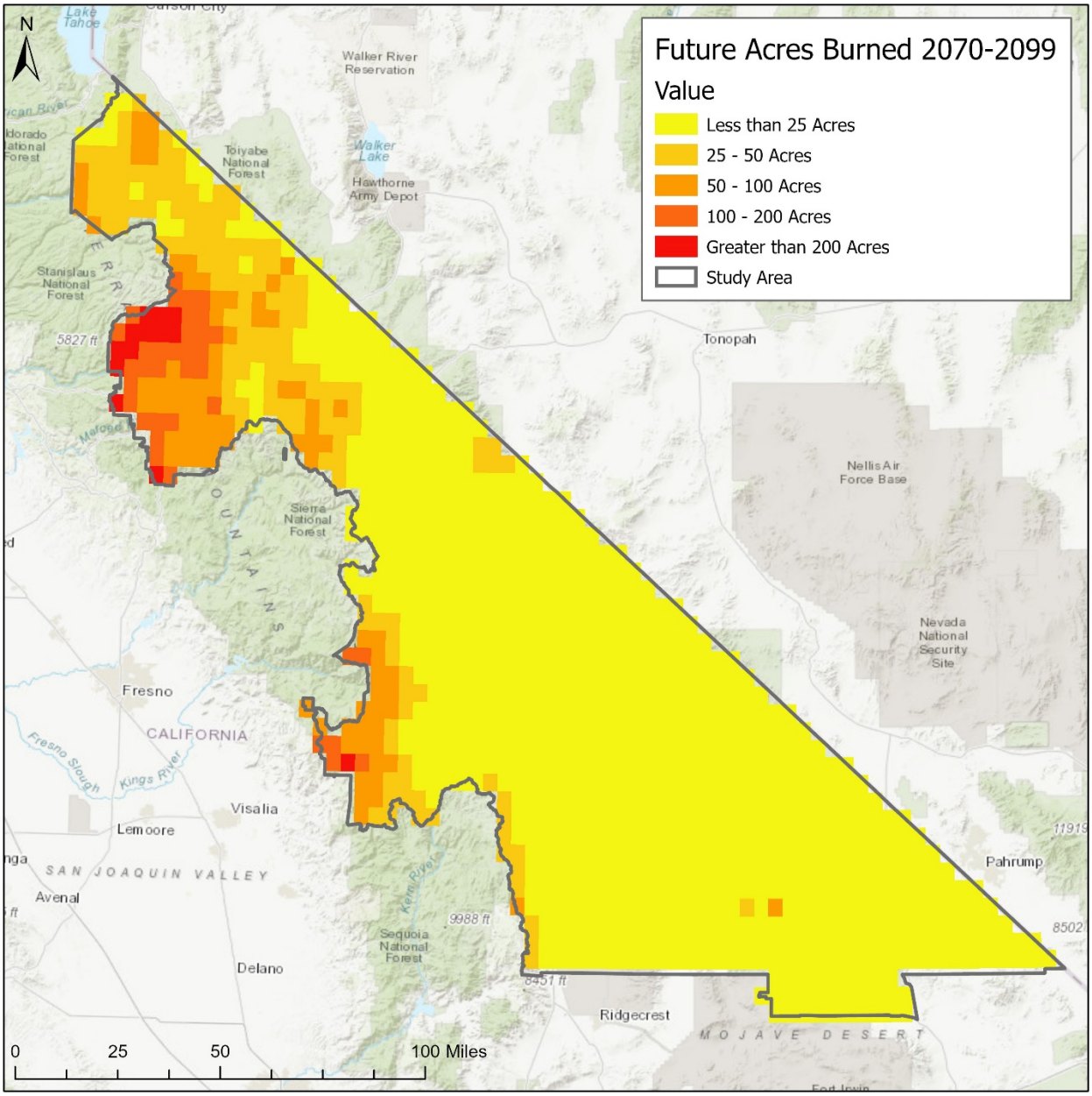


Figure 21. Projected Future Acres Burned



SECTION 6: CRITICAL VULNERABILITIES

The Climate Change Vulnerability Assessment considers six distinct categories of populations and assets, directly or indirectly related to the recreation and tourism economy, which may be exposed to climate change hazards, including the following:

- Populations: Persons living, working, and/or visiting the Eastern Sierra region who are likely to be disproportionately harmed by climate change.
- Infrastructure: Local, regional, state, and federal infrastructure and other structures that provide important services for recreation and tourism.
- Buildings and Facilities: Essential buildings and facilities that support recreation and tourism activities.
- Recreation and Tourism Activities: Specific recreation and tourism activities that contribute significantly to the Eastern Sierra economy.
- Ecosystems and Natural Resources: A range of natural environments and priority resources in the Eastern Sierra region.
- Key Services: Critical functions carried out by both local, regional, state, federal, and private agencies throughout the community.

The profiles of vulnerable populations and assets discussed in this section focus on the climate change hazards that result in high or severe vulnerabilities, scoring V4 or V5 in the Climate Change Vulnerability Assessment. Other climate change hazards may result in less significant but still meaningful vulnerabilities. These discussions do not review all potential hazards that may harm the population or asset. To understand the severity of potential harm created by each climate change hazard evaluated as part of this analysis, please see **Appendix C**.

Population and Asset Considerations

While selecting and assessing various populations, assets, and recreational activities to include in the Climate Change Vulnerability Assessment, the Project Team kept a number of considerations in mind, including 1) the limitations of the data sources for the SRTI Study Area (Study Area) that were used to prepare this assessment and 2) how some population and asset categories may appear to refer to the same thing. For a complete list of populations, assets, and recreational activities, please see **Appendix B**.

Data Limitations

The Climate Change Vulnerability Assessment pulled in data from a wide array of sources. The Project Team only used reliable, credible sources with the best available information. In some cases, the Climate Change Vulnerability Assessment was constrained by the lack of high-quality information or spatial information about the geographic distribution of particular assets or recreation activities. For example, the Project Team was unable to find accurate information about the distribution of seasonal residents in the Study Area, and even information about the total number of seasonal residents in each county is an educated estimate. Because of this, the Climate

Change Vulnerability Assessment considers seasonal residents but cannot identify specific areas where they may face elevated risk from certain hazards.

Related Assets

Among the 136 populations, assets, and recreational activities in the Climate Change Vulnerability Assessment, there are a few that may appear redundant. For example, the Climate Change Vulnerability Assessment looks at both airports (as an Infrastructure asset) and at air services (as a Key Services asset). To be as comprehensible as possible, the Climate Change Vulnerability Assessment looked at physical infrastructure separately from the services or benefits they provide. In the same way, the Climate Change Vulnerability Assessment looked at persons in tribal communities separately from the tribal cultural sites they rely on, the homes that they live in, or the industries where they are employed.

Populations

Populations Category

The Climate Change Vulnerability Assessment evaluated nine populations that may be disproportionately harmed by climate change hazards. These populations include workers who may work directly in the recreation and tourism economy, such as those who help with trail management or those working in stores and restaurants. Other populations may support the recreation and tourism economy or be part of the visiting population to the Study Area. The following populations were included in the Climate Change Vulnerability Assessment:

- Hospitality workers
- Indoor tourism workers
- Outdoor workers
- Persons in tribal communities
- Retail workers
- Seasonal residents
- Seasonal residents who live on single access roads
- Short-term visitors
- Travel industry workers

Critically Vulnerable Populations

Persons in tribal communities: Persons living in tribal communities were found to be the most vulnerable population in the Study Area, as climate change is likely to negatively impact tribal communities' way of life and quality of life.[106] Persons in tribal communities are severely vulnerable to air quality, smoke, and ash hazards, particularly from winds blowing toxic dust from the dry lake bed of Owens Lake to nearby communities and reservation land in Inyo County, such as the Death Valley Timbi-Sha Shoshone Tribe, Lone Pine Paiute-Shoshone Tribe, Fort Independence Indian Community of Paiute Indians, and Big Pine Paiute Tribe of Owens Valley.[107] Persons in tribal communities also depend on natural water sources from Sierra Nevada creeks, such as Mill Creek, Lee Vining Creek, Rush Creek, Bishop Creek, Big Pine Creek, Independence Creek, Lone Pine Creek, and Tuttle Creek for drinking water as well as Mono Lake and the Owens River for both drinking water and as cultural resources. These have been altered and depleted over the last century due to the Los Angeles Department of Water and Power's (LADWP's) water-

gathering activities.[108] This means that persons in tribal communities are highly vulnerable to drought, because drought conditions could cause water levels to drop even lower, and there are few alternative water sources in the Study Area. Tribal communities are also highly vulnerable to extreme heat, because many live at lower elevations in the Study Area and may live in homes without air conditioning or may not have the financial means to turn it on. This can lead to an increase in heat-related illnesses, especially for elders, who are more likely to experience health impacts from extreme heat. Tribal communities are also highly vulnerable to flooding, forestry pests and diseases, and severe weather, which can damage homes and other buildings, or block roadways in the region and affect traditional food and other resources. Persons in tribal communities are also highly vulnerable to wildfire because they may not be able to effectively evacuate from a wildfire nearby. Traditionally, persons in tribal communities use prescribed burns and vegetation management techniques to reduce exposure to wildfire; however, they do not have much control over the nearby forested lands due to federal land management policies.[109]

Seasonal residents who live on single access roads: Seasonal residents living on single access roads are severely vulnerable to flooding, severe weather, severe winter weather, and wildfires, because these hazards can damage or block roadways, preventing access in or out in case of an emergency. These seasonal residents are also highly vulnerable to forestry pests and diseases and landslides, which can also block or damage roadways. If roadways become impassable, seasonal residents living on single access roads may be unable to obtain essential services or resources such as food, medicine, and emergency services. Depending on the location and agency managing the roadways, residents may have restrictions on maintaining these single access roadways. These residents can be prepared with emergency kits and gather emergency supplies to be prepared for these hazards; however, there may be few alternative trails or roadways that can be used in the event of an evacuation.

Outdoor workers: Individuals working outdoors face greater exposure to climate change hazards because they do not work in sheltered locations and often do physically intensive work. Outdoor workers can easily face economic hardship if work is halted or delayed or if they are unable to work due to hostile outdoor environments.[110] Therefore, outdoor workers are severely vulnerable to air quality, smoke, and ash; extreme heat; forestry pests and diseases; human health hazards; and wildfire. Extreme heat can cause individuals to overheat and cause dehydration and heat stroke; smoke and ash can irritate the respiratory system and create difficulty breathing with extended exposure; and vectors such as ticks, mosquitos, and rodents may carry harmful illnesses that outdoor workers are directly exposed to.[111] Some climate change hazards, such as wildfires, can also create potentially deadly outdoor working conditions. Some outdoor work sites can make water, shelter, and protective gear available, although this may not be possible for all outdoor workers in the recreation sector. Persons working outdoors are often aware of the warning signs of heat-related illnesses, although access to medical care may be more limited in remote outdoor work sites. If recreation infrastructure such as campgrounds or interpretive sites are damaged or destroyed by a hazard condition, that can reduce job opportunities for outdoor workers, increasing the risk of economic harm. Forestry pests and diseases would deter visitors from traveling to the Study Area due to damaged forests, which could indirectly affect outdoor workers. People who work in outdoor recreation may have few alternative options if the industry suffers sufficient economic damage from loss of trees and wildfires.

Short-term visitors: Short-term visitors are people who visit the Eastern Sierra region for short periods of time, weekends, or a few days, and are not seasonal residents of the region. Short-term visitors are severely vulnerable to wildfire and highly vulnerable to drought, human health hazards, and severe weather. Short-term visitors may not be aware of wildfires or severe weather in the region while participating in some recreational activities, such as backpacking or primitive camping, and may not be able to effectively prepare for these events. Due to the nature of their stay, short-term visitors may not receive local emergency notifications and know available evacuation routes to use in the event of an emergency. There are websites available to assist with these notifications; however, short-term visitors may not be aware of these. In some cases, severe weather, wildfires, and human health hazards may deter short-term visitors from traveling to the Study Area, which would negatively affect the recreation and tourism economy in the region. Drought conditions may also hinder snow activities, water recreation sites, and nature viewing, affecting the economy in the Study Area.[112]

Recreation- and tourism-related workers: Recreation and tourism workers (e.g., hospitality workers, indoor tourism workers, retail workers, and travel industry workers) are highly or severely vulnerable to air quality, smoke, and ash, and hospitality workers are highly vulnerable to drought. Poor air quality, smoke, and ash can deter visitors from traveling to the Study Area and staying in hotels, going to indoor tourism sites, or shopping at stores, which could create economic hardships for businesses and workers employed at those businesses. Hospitality workers are especially at risk from economic hardship, as there may also be fewer visitors in the Study Area due to drought conditions that cause lower snow and water levels.[113] If these conditions persist for an extended period of time, recreation- and tourism-related workers may be unable to find consistent work.

Infrastructure

Infrastructure Category

The Climate Change Vulnerability Assessment assessed the vulnerability of 19 different types of infrastructure in the Study Area. These infrastructure categories help support the recreation and tourism industries as well as the key services that agencies or jurisdictions provide to residents and visitors. The Project Team included transportation, energy delivery, recreation, and water management infrastructure types as part of the assessment. Many of these infrastructure assets are managed by different land use agencies or serve different functions in the Study Area, and therefore were separated out into specific agencies or agency type or function to ensure a more accurate vulnerability score. Infrastructure assets that were separated by different agencies are airports, bicycle trails, hiking and horseback riding trails, and off-road vehicle areas. The infrastructure section of the Climate Change Vulnerability Assessment focuses on the physical effects of climate change hazards on infrastructure itself instead of the services it provides. The following infrastructure assets were included in the Climate Change Vulnerability Assessment:

- Airports – charter/recreation/general aviation
- Airports – commercial service
- Bicycle trails (California State Parks)
- Bicycle trails (City and County)

- Bicycle trails (Death Valley National Park)
- Bicycle trails (El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit (LTBMU))
- Bicycle trails (Humboldt-Toiyabe National Forest)
- Bicycle trails (Inyo National Forest)
- Bicycle trails (Yosemite National Park)
- Bridges
- Communication facilities
- Culverts
- Dams
- Electric vehicle (EV) charging stations
- Electrical substations
- Electrical transmission lines
- Erosion control structures
- Flood control infrastructure
- Hiking and horseback riding trails (City and County)
- Hiking and horseback riding trails (Death Valley National Park)
- Hiking and horseback riding trails (Devils Postpile National Monument)
- Hiking and horseback riding trails (El Dorado National Forest, Stanislaus National Forest, LTBMU)
- Hiking and horseback riding trails (Humboldt-Toiyabe National Forest)
- Hiking and horseback riding trails (Inyo National Forest)
- Hiking and horseback riding trails (Kings Canyon/Sequoia National Parks)
- Hiking and horseback riding trails (Yosemite National Park)
- Lookout points
- Major roads and highways
- Off-road vehicle areas (California State Parks)
- Off-road vehicle areas (City and County)
- Off-road vehicle areas (Death Valley National Park)
- Off-road vehicle areas (El Dorado National Forest, Stanislaus National Forest, LTBMU)
- Off-road vehicle areas (Humboldt-Toiyabe National Forest)
- Off-road vehicle areas (Inyo National Forest)
- Parking lots
- Power plants
- Ski areas
- Water and wastewater infrastructure

Critically Vulnerable Infrastructure

Energy delivery infrastructure: Energy delivery infrastructure (e.g., electric transmission lines, substations, EV charging stations, and power plants) are vulnerable to several hazards. Electric transmission lines are the most vulnerable part of the energy delivery infrastructure—severely vulnerable to wildfire and highly vulnerable to extreme heat, forestry pests and diseases, severe weather, and severe winter weather. Electrical transmission lines in the Study Area run through wildfire-prone areas and can be damaged or destroyed in these events.[114] Extreme heat reduces the efficiency of transmission lines so they carry less power. With increased electricity usage for air conditioning, heat waves can overtax electrical transmission lines and transformers, which may malfunction or fail, causing power outages. Severe weather knocks trees over and may have wind speeds that cause transmission lines to sway close to each other, potentially leading to arcing. This can generate sparks and excessive heat, and damage the lines. In recent years, infrastructure owners have turned off the electrical transmission lines during high wind events to reduce the possibility of sparking. Severe winter weather can put excessive weight on the power lines due to heavy snowfall, avalanches, and ice storms, causing damage or breakage. Those who manage the power lines can turn off power, retrofit older lines, and create defensible space around transmission lines to prevent extensive damage. However, when electrical transmission lines are damaged or turned off, residents and business owners experience power outages, which can cause economic and other hardships throughout the county.

Substations throughout the Study Area are also located in wildfire-prone areas. These substations can be damaged by the flames and may not continue to function properly after wildfires, which could cut off electricity to wildfire-prone areas of the Study Area. Similar to electric transmission lines, vegetation management and defensible space can be used to protect substations. However, if substations are damaged, remote areas may not have reliable sources of power. Substation upgrades and localized energy sources could be expensive to implement.

Power plants in the region are highly vulnerable to drought and landslides. The rivers in the Study Area and northern Sierra Nevada generate approximately half of all hydropower in California and about 15 percent of all electricity in the state.[115] Drought conditions can reduce water supplies in both reservoirs and rivers, which in turn reduces the output capacity of hydroelectric power plants in the Study Area because fewer turbines are online to meet peak demands throughout California.[116] Approximately half the hydroelectric power plants in the Study Area are also in a landslide hazard zone. Landslides and debris flows can cause instability of a dam or seepage of a dam structure, which can cause dams to fail and hydroelectric plants to become inoperable.[117] There are several other power plants in the Study Area that are outside of landslide-prone areas, and dams in California are highly regulated to prevent failures. However, there is little that can be done to replenish reservoirs if droughts reduce water supplies.

EV charging stations provide electricity supplies to electric cars and are a crucial part of sustainable travel to recreation sites. EV charging stations are highly vulnerable to severe weather, severe winter weather, and wildfire. EV chargers can lose power and usability if severe winds, cold temperatures, or wildfires cause public safety power shutoffs or power outages in the Study Area. These facilities can also be damaged by dust storms, avalanches, or wildfires. Damaged or unusable EV charging facilities can leave visitors or residents without electricity to charge their EVs. There is very little redundancy of EV charging stations in the Study Area, especially in

national parks, and damage or an outage to these charging stations could dramatically affect visitors with EVs trying to access the area.

Transportation infrastructure: Transportation infrastructure (e.g., major roads and highways, bridges, and airports) is vulnerable to flooding, landslides, severe weather, severe winter weather, and wildfire. Major roads and highways can be damaged by landslides in the form of rockslides or debris flows and become impassable. Landslides can cover roadways and damage the foundations of the road, making them impassable. This is detrimental to areas that rely on these roadways for shipments of vital goods, evacuations, and emergency medical response. Landslides can block not only Highway 395, which is the main highway through the region, but also major routes that connect to key recreation areas, such as Yosemite Valley, Sabrina Lake, or Grover Hot Springs State Park. Major roadways throughout the Study Area are also vulnerable to wildfires and flooding, which can cause them to close or become impassable, isolating visitors, residents, and recreation areas. Severe weather and severe winter weather can cause roads to be covered in ice, snow, or fallen trees, damaging or blocking roadways. Some highways through mountain passes completely close during the winter months due to heavy snowfall, further limiting travel options. Major roads and highways can be cleared of vegetation and fuels to reduce the chance of wildfires burning directly next to the roadway, retrofitted to resist landslides and prevent flooding, and repaired when damaged. However, hydrologic conditions stabilizing mountain roadways can change after a wildfire, increasing the potential for debris flows around the roadways.[118] Major roads and highways are the primary method of travel in the Study Area for visitors, and therefore any disruptions could harm the recreation and tourism economy.

Bridges are severely vulnerable to landslides and highly vulnerable to flooding and severe weather. Flooding can cause bridges to be completely covered, making them periodically impassable. Landslides and severe weather that knock down trees can also block bridges.[119] Heavy rainfall from severe weather can increase runoff, causing bridge failures due to washout, plugging of stormwater infrastructure, overtopping, stream diversion, and erosion.[120] Blocked and impassable bridges are especially harmful for isolated people who rely on these bridges as key roadway connections to other areas of the Study Area and for visitors to access the area. If one bridge is down along a highway, residents and visitors may have to drive hours out of their way to travel to a destination or to evacuate in an emergency.

Airports in the Study Area, particularly Lone Pine, Independence, and Alpine County airports, are within high fire hazard areas and are highly vulnerable to wildfires. Hangars, lighting, and navigational signage may be damaged by wildfire flames. This could hinder operations at these airports, which are also used to help fight wildfires in some cases. Creating defensible space and conducting vegetation management around the airports can prevent damage from flames. However, if damaged, these airports may not be able to rebuild quickly due to their remote locations, and facilities may not be available to emergency services.

Ski areas: Ski areas within the Study Area include Kirkwood Ski Area, Heavenly Ski Area, Carson Pass Snow Park, Mammoth Mountain Ski Area, June Mountain Ski Area, Badger Pass, and cross-country skiing areas. Ski areas are severely vulnerable to severe weather and highly vulnerable to flooding, landslides, and wildfire. Severe weather, such as high winds and hail, and landslides can damage winter recreation infrastructure (e.g., ski runs, chair lifts, and lodges), which can affect

both winter and summer recreation activities in ski areas. Severe weather can also make the mountain unsafe for outdoor activities. Flooding, in the form of rain-on-snow events, can cause wet slide avalanches and flooding of ski areas, damaging essential ski infrastructure. Wildfires can also damage chair lifts and lodges, both hindering ski area operations and deterring visitors from traveling to the Study Area to participate in skiing and snow play activities. Severe winter weather and other hazards may create additional hardships. Ski areas can harden infrastructure to reduce potential damage from these hazards; however, there may be few alternatives in the Study Area that are within driving distance if conditions become unsafe for winter recreation.

Hiking and horseback riding trails: Hiking and horseback riding trails throughout the Study Area are vulnerable to forestry pests and diseases, landslides, and wildfires. The hiking and horseback riding trails in Devils Postpile National Monument may be more vulnerable because there is one primary access point for many of the trails in the monument. The monument is also located within a heavily forested area with steep slopes and in a difficult-to-reach portion of the Study Area, so its isolation creates additional vulnerabilities. Hiking and horseback riding trails in Devils Postpile National Monument and Humboldt-Toiyabe National Forest are highly vulnerable to forestry pests and diseases and landslides due to remote locations and limited financial resources for maintenance available to these jurisdictions. The trees in these areas are more likely to be affected by bark beetle infestations, which can weaken trees and cause them to fail on the trails.[121] These trails are also more likely to be blocked by landslides or rockslides, which can significantly impede outdoor recreation and associated economic benefits. Severe weather, flooding, and other climate change-related hazards may cause further harm. These trails can be cleared of dead and weakened trees or retrofitted to prevent interruption from landslides; however, the agencies managing these trails may not have the staff or volunteers to complete this work, or reconstruction may be difficult to complete due to local topography changes.

Hiking and horseback riding trails in Devils Postpile National Monument, Humboldt-Toiyabe National Forest, cities, counties, El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit, and Inyo National Forest are severely or highly vulnerable to wildfires. Yosemite National Park and Sequoia Kings Canyon National Park have fuel management plans that include prescribed burns and vegetation management, making these national parks less vulnerable to wildfire than other jurisdictions in the Study Area. Wildfires can force closure of the hiking and horseback riding trails, damage supportive buildings and structures, and degrade the scenic appearance of the lands along the trails.[122] Relatively little can be done to protect hiking and horseback riding trails from wildfires, other than creating defensible space and conducting fuel reduction projects.

Water and flood management: Water and flood management infrastructure includes dams, flood control infrastructure, culverts, and erosion control structures. The most vulnerable of these assets are culverts, which are severely vulnerably to flooding and highly vulnerable to landslides and severe winter weather. Flooding from both heavy rainfall and rain-on-snow events can overwhelm culverts and lead to flooding on roads and bridges in the Study Area.[123] Damage to culverts and erosion control structures from flooding can cause landslides and debris flows in the surrounding areas. Severe winter weather can bring cold temperatures and heavy snowfall, which can chronically block culverts in areas where they are not working properly. Flood control infrastructure is highly vulnerable to severe weather because heavy rainfall can create fast-moving

runoff that could overtop or damage flood control infrastructure. Culverts, erosion control structures, and flood control infrastructure can be retrofitted or enlarged to accommodate floodwaters and freezing temperatures. However, these structures can be expensive to replace or upgrade and may require grant funding to do so.

Several dams (29 out of the 54 in the Study Area) are in landslide-susceptible areas.[124] Landslides and debris flows can cause instability of a dam or seepage within dam structures.[125] This can cause dams to fail and to flood recreation and tourism areas that lie below the dams, such as Lee Vining, Mammoth Lakes, and Bishop. Landslides account for approximately 30 percent of dam failures.[126] Dams in California are highly regulated and can be retrofitted or re-engineered to account for landslides within the dam structure or reservoir. However, retrofits are expensive and may take a long time to complete. All of the certified dams in the county have a condition assessment of satisfactory or better.[127]

Bicycle trails: Bicycling trails, like hiking and horseback riding trails in the Study Area, are vulnerable to forestry pests and diseases, landslides, and wildfire. Many bicycle trails go through forested areas that have been affected by bark beetles, a pest outbreak that is projected to worsen with drought and higher temperatures. Affected trees can fall on bicycle trails, damaging the trails or blocking the path. Bicycle trails in Humboldt-Toiyabe National Forest are especially vulnerable because this national forest does not have as large of a volunteer workforce compared to other forests and parks in the region to help with trees and debris removal on bicycle trails. Landslides, debris flows, and rockfalls can block, damage, or destroy bicycle trails in mountainous areas of the Study Area, especially on or below steep slopes.[128] Wildfires may force the closure of bike trails, damage supportive infrastructure, and degrade the scenic appearance of the area surrounding bicycle trails, which may deter visitors from traveling to the Study Area to participate in bicycle activities. Bicycle trails can be retrofitted to resist landslides, and vegetation management can reduce risk from wildfires, but these actions can be expensive and require extensive staffing to complete. Other bicycle trails, such as the one in Yosemite Valley, are vulnerable to damage from flooding during heavy rainfall and snowmelt events. Severe weather poses a lower but still elevated potential for harm to bicycle trails.

Off-road vehicle areas: Off-road vehicle areas in El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit, Humboldt-Toiyabe National Forest, and Inyo National Forest are vulnerable to landslides and wildfire. Off-road areas, primarily those in Humboldt-Toiyabe National Forest, are highly vulnerable to landslides, which can undermine the foundations of dirt roads and off-road vehicle trails or completely block them. Slope stabilization can be put in place to prevent landslides if resources are available, but the Humboldt-Toiyabe National Forest has few and scattered volunteer organizations available to help with maintenance of these areas. Off-road vehicle areas in all five of these national forests are vulnerable to wildfire, which can damage supportive infrastructure and degrade the scenic views in the area. Wildfires can damage supportive infrastructure, even if they do not harm the off-road trails. Impacts could be greater than those to hiking and horseback riding trails, and funding for repairs would likely be more limited. Winter off-road vehicle areas may be able to recover from wildfire damage, but summer off-road vehicle areas may have little that can be done other than creating defensible space and conducting fuel management to lower the risk of large wildfires.

Communication facilities: Communication facilities throughout the Study Area are highly vulnerable to severe weather and severe winter weather. High winds, lightning, or hail can damage communication facilities or cut off their power, preventing communities from receiving or relaying emergency notifications and other essential communications.[129] Severe weather can cause public safety power shutoffs, which also shuts off power to internet and cell tower communications. Heavy snowfall, extreme cold, and avalanches could also damage communication facilities, leaving visitors without internet or cell phone reception. Such infrastructure may also be damaged by other hazards, although the threat of such harm is lower. Due to the remote nature of the Study Area, there is little redundancy in communication facility infrastructure. Backup generators can be installed to increase resiliency of communication facilities in the region. Inyo and Mono counties also have hazard mitigation measures in their multi-jurisdictional hazard mitigation plans that can help ensure communication facilities stay operable during emergencies in all types of weather.

Water and wastewater infrastructure: Water and wastewater infrastructure, such as water and sewage piping, septic systems, and wastewater treatment facilities, are severely vulnerable to flooding. Flooding associated with a rain-on-snow event or heavy rainstorm can cause high-velocity floodwaters to damage water pipelines, water processing facilities, wastewater treatment facilities and pipelines, and septic systems. Parks such as Yosemite National Park and Kings Canyon and Sequoia National Parks have funds designated for upgrading wastewater infrastructure, but much of the Study Area may not be able to make such upgrades.[130] Household septic systems would be less expensive to retrofit to resist damage from flooding.

Buildings and Facilities

Buildings and Facilities Category

The Climate Change Vulnerability Assessment assessed the vulnerability of 21 different types of buildings and facilities in the Study Area. These building and facility categories help support the recreation and tourism industries as well as the key services that agencies or jurisdictions provide to residents and visitors. The Project Team included recreation, historic and cultural, government, and emergency building types as part of the assessment. Many of these facility assets are managed by different land use agencies in the Study Area, and therefore were separated by specific agencies or agency type to ensure a more accurate vulnerability score that reflects the distinctions between different locations and agencies. Building and facility assets that were separated by different agencies are campgrounds, government and administrative buildings, interpretive sites, public safety buildings, ranger stations, and water recreation sites. The buildings and facilities section of the Climate Change Vulnerability Assessment focuses on the physical effects of climate change hazards to the structures themselves instead of the services they provide. The following building and facilities assets were included in the Climate Change Vulnerability Assessment:

- Campgrounds (Bureau of Land Management)
- Campgrounds (City and County)
- Campgrounds (Death Valley National Park)
- Campgrounds (Devils Postpile National Monument)

- Campgrounds (El Dorado National Forest, Stanislaus National Forest)
- Campgrounds (Humboldt-Toiyabe National Forest)
- Campgrounds (Inyo National Forest)
- Campgrounds (Kings Canyon/Sequoia National Parks)
- Campgrounds (Yosemite National Park)
- Community centers
- Developed picnic areas
- Gas stations
- Golf courses
- Government and administrative buildings (California State Parks)
- Government and administrative buildings (City and County)
- Government and administrative buildings (NPS: Death Valley, Yosemite, Sequoia, Kings Canyon, Devils Postpile National Monument)
- Government and administrative buildings (U.S. Forest Service (USFS): El Dorado, Sequoia, LTBMU, Humboldt-Toiyabe, Inyo)
- Historic buildings and facilities
- Homes and residential structures
- Hotels and lodging
- Interpretive sites (California State Parks)
- Interpretive sites (Death Valley National Park)
- Interpretive sites (El Dorado National Forest, Stanislaus National Forest, LTBMU)
- Interpretive sites (Humboldt-Toiyabe National Forest)
- Interpretive sites (Inyo National Forest)
- Interpretive sites (Kings Canyon/Sequoia National Parks)
- Interpretive sites (Yosemite National Park)
- Medical facilities
- Miscellaneous visitor-serving park facilities
- Public safety buildings (City and County)
- Public safety buildings (NPS: Death Valley, Yosemite, Sequoia, Kings Canyon, Devils Postpile National Monument)
- Public safety buildings (USFS: El Dorado, Sequoia, LTBMU, Humboldt-Toiyabe, Inyo)
- Ranger Stations (National Park Service: Death Valley, Yosemite, Sequoia, Kings Canyon, Devils Postpile National Monument)
- Ranger stations (USFS: Humboldt-Toiyabe, Inyo)
- Restaurants and food establishments
- Retail centers
- Short-term rentals
- Tribal cultural sites
- Visitor centers

- Water recreation sites (Bureau of Land Management land)
- Water recreation sites (El Dorado National Forest, Stanislaus National Forest, LTBMU)
- Water recreation sites (Humboldt-Toiyabe National Forest)
- Water recreation sites (Inyo National Forest)
- Water recreation sites (Kings Canyon/Sequoia National Parks)
- Water recreation sites (Los Angeles Department of Water and Power (LADWP) Land)
- Water recreation sites (Yosemite National Park)

Critically Vulnerable Buildings and Facilities

Homes and residential structures: Homes and residential structures are vulnerable to more hazards than any other building and are critical to supporting the local workforce in the Study Area. Homes in the Study Area are severely vulnerable to wildfires and highly vulnerable to flooding, which can damage or destroy homes. If flooding does not destroy a home, waterlogged buildings can lead to growth of mold and mildew, making the structure uninhabitable. Landslides can undermine the foundations of homes or cover homes in their path, damaging or destroying the structure. Homes, especially older homes, can also be damaged by high winds, hail, and fallen trees weakened by forestry pests and diseases. Home weatherization programs for low-income residents and homeowners may be available in portions of the Study Area to retrofit their homes. Homes can also be hardened against flooding and landslides, and defensible space can be created to prevent damage from wildfires. However, these adaptive options can be expensive and are not always feasible for all property owners, especially if located on federally controlled land that requires approval from the USFS, NPS, or Bureau of Land Management.

Campgrounds: Campgrounds are located on lands managed by nearly all the agencies and jurisdictions in the Study Area. Campgrounds in Humboldt-Toiyabe National Forest, Devils Postpile National Monument, and Inyo National Forest are the most vulnerable campgrounds in the Study Area. Nevertheless, Yosemite, and Kings Canyon- Sequoia National Parks, El Dorado National Forest, Stanislaus National Forest, LTBMU, and the Bureau of Land Management have campgrounds vulnerable to at least one hazard. Several campgrounds are near lakes or rivers, or in floodplains, such as those along Highway 108, Twin Lakes, Highway 168, North Lake, South Lake, Yosemite Valley, High Sierra camps, and Highway 120, which increases the risk of damage to campground facilities from floodwaters.[131] There may be additional campgrounds that are outside of mapped floodplains that may still be harmed by occasional floods, such as those in Death Valley. Many campgrounds in mountain areas in national forests and national parks are in landslide-susceptible areas and can be damaged by debris flows and rockfalls. Landslides may occur more frequently as more precipitation falls as rain instead of snow.[132] Campgrounds in national parks, national forests, and Devils Postpile National Monument are in heavily forested areas and can be damaged by fallen trees during severe weather events. Wildfires can damage or destroy signage, fire pits, tables, and other campground facilities. In Yosemite National Park, campgrounds can also be damaged by heavy snowfall, such as the 18 to 24 inches of snow that fell in February 2019, damaging campsite facilities and housing units in the park.[133] While under

repair, these campgrounds may not be able to meet the needs of the recreation visitors in the Study Area, since there is a consistent high demand for campsites in the region.[134] Campgrounds can be retrofitted to reduce hazards, treated for vegetation management, and repaired when damaged; however, this may be expensive for national forest and national parks and there may be limited staffing to complete these activities.

Historic buildings and facilities: Historic buildings are highly vulnerable to landslides, severe weather, severe winter weather, and wildfire. These buildings can be damaged or destroyed due to landslides and wildfires, which may result in a loss of visitors. Historic buildings may also be more easily damaged by severe windstorms, hail, heavy rainfall, and freezing temperatures, which can cause these buildings to leak and grow mold. The infrastructure attached to these facilities may also be old and easily damaged by severe weather. Historic buildings can be repaired or retrofitted to prevent damage from hazards; however, repairs could be difficult because historic significance could diminish if damaged or destroyed. Retrofits and repairs can also be expensive for historic buildings and may not be feasible for the facility owners.

Water recreation sites: Water recreation sites within the Study Area include lakes, rivers, and streams that support water-based recreation. All water recreation sites in the Study Area are severely vulnerable to drought conditions because they depend on a natural inflow of water to maintain operations. If water levels drop, water recreation facilities may not function as intended and water-based recreation could decrease.[135] Lower water levels could degrade water quality, decreasing the economic viability of the recreation facility. Alternative water sources are generally not available to replace natural water supplies, especially as snowpack decreases. On LADWP-owned land, water recreation is a secondary use of the water supply, and therefore this land is even less adaptable to drought conditions. In Sequoia-Kings Canyon National Parks and Yosemite National Park, the water recreation sites along rivers (Kern, Kaweah, Kings, Merced, and Tuolumne rivers) are highly vulnerable to flooding, which can damage facilities, increase maintenance and costs to remove debris from water recreation facilities, and affect recreation activities like whitewater rafting and kayaking. Water recreation sites in Inyo National Forest and Sequoia-Kings Canyon National Parks are highly vulnerable to landslides, which can damage boat launches, disrupt water flow, increase maintenance and costs to remove debris, and destroy visitor facilities at recreation sites. These facilities can be repaired; however, funding may be limited, and these hazards may become more frequent due to climate change. Water recreation sites in all national parks and national forests within the Study Area are also highly vulnerable to wildfire, because ash or fire retardants degrade water quality. Recently burned slopes are also highly vulnerable to landslides or mudflows, and there is some potential for flooding to create challenges for water recreation sites. Fuels management and defensible space can be used surrounding water recreation sites. However, forest and park managers may not have adequate funding to complete these activities, and when rain and snow events occur in the winter, there may also not be a feasible way to keep chemicals out of the water.

Interpretive sites: Interpretive sites are considered recreation sites that inform visitors of the meaning and relationships contained in the area through personal experience and illustrations. The interpretive sites in Humboldt-Toiyabe National Forest are highly vulnerable to forestry pests and diseases, severe weather, and wildfire. Interpretive sites in this national forest go through heavily forested areas, which may have been harmed by bark beetle infestations such as fir engravers and root diseases such as black stain root disease, causing the trees to become weak and more likely to fall and damage interpretive sites.[136] These interpretive sites, in addition to interpretive sites in El Dorado National Forest, Stanislaus National Forest, LTBMU, and Inyo National Forest, are in high fire hazard areas. If burned, the sites may be closed until repairs and debris removal are completed. Death Valley National Park's only interpretive site, the Salt Creek Interpretive Trail, is highly vulnerable to flooding. Floods and flash floods can damage or destroy walkways and signage. Many national parks and forests have few alternative interpretive sites that fulfill the same purpose. Many national forest and national parks may have limited funding or staff capacity to retrofit or repair these sites, and many forests lack a strong volunteer network to help.

Emergency and public safety facilities: Emergency and public safety facilities include public safety buildings, ranger stations, and medical facilities in the Study Area. These facilities are highly vulnerable to flooding, landslides, and severe weather throughout the Study Area. National park and national forest public safety buildings and ranger stations can be damaged by flooding, causing mold and mildew growth or complete destruction of the facilities, as occurred in Yosemite National Park during floods in 1997.[137] In national parks, both public safety buildings and ranger stations can be damaged or destroyed by landslides, mudflows, or rockfalls, preventing these facilities from providing adequate services. High winds, hail, and heavy rainfall can damage medical facilities and ranger stations in both national parks and national forests in the Study Area. Medical facilities can be weatherized and retrofitted to defend against severe weather. However, funding constraints may prevent national parks or national forests from completing repairs to ranger stations. All emergency and public safety facilities can be retrofitted, moved, and/or repaired to prevent flooding from damaging these facilities in the future. However, repairs could cost a substantial amount of money, which may not be available to all national parks and forests.

Hotels, lodging, and short-term rentals: Hotels, lodging, and short-term rentals are highly or severely vulnerable to wildfire. Similar to homes and residential structures, short-term rentals in the Study Area can be damaged or destroyed by wildfires, reducing the number of lodging opportunities available for visitors. For hotels and other lodging establishments, this may cause economic hardships for the business and those who work there. Flooding and landslides can render a short-term rental uninhabitable or completely destroy the home, impacting the availability of short-term rentals for visitors. Short-term rentals can be repaired or reconstructed after a wildfire, flooding, or landslide, but funding may be limited if these are second homes. Short-term rentals and hotels can be constructed or retrofitted to protect against wildfires; however, short-term rental owners may not have the financial means to make some of these changes.

Tribal cultural sites: Tribal cultural sites include the tribal lands of the approximately 20 tribal nations in the Study Area that support recreation and tourism. These sites are highly vulnerable to drought, severe weather, and severe winter weather. Tribal facilities can be damaged or destroyed by heavy winds, fallen trees, hail, and freezing temperatures, which damage commercial, cultural, and residential structures that support recreation and tourism on tribal lands. Access to fewer financial resources than some other communities can make it hard for tribal communities to retrofit or repair tribal cultural sites from severe weather or prepare for more frequent severe weather events, and sufficient assistance may not always be available.[138]

Government and administrative buildings: Government and administrative buildings in national parks and national forests are the most vulnerable government buildings in the Study Area. National park government and administrative buildings are severely vulnerable to landslides and highly vulnerable to flooding. In national forests, these buildings are highly vulnerable to flooding and landslides. Rain-on-snow events or flooding can damage administrative buildings, by causing mold and mildew growth or complete destruction of the buildings, depending on the building materials, as occurred in Yosemite National Park during the 1997 flood.[139] Landslides can also damage or destroy these buildings, rendering them unusable for administrative purposes. Buildings can be retrofitted, moved, or repaired to prevent floods and landslides from damaging them in the future. However, if buildings are damaged, repairs could cost a substantial amount of money, which may not be available to all national forests and national parks.

Community centers and visitor centers: Community centers and visitor centers throughout the Study Area are highly vulnerable to wildfires. Community centers in Mammoth Lakes and Crowley Lake and visitor centers throughout the Study Area are in heavily forested areas and susceptible to damage or destruction from wildfires. Defensible space and vegetation management can be used to reduce potential harm from wildfires. These centers can also be retrofitted with fire sprinklers and fire-resistant roofing. However, the nonvital nature of community centers and limited budgets for maintenance can preclude retrofits. Similarly, state and federal agencies may not have the funding or personnel to complete vegetation management or retrofit work.

Commercial centers: Commercial centers include restaurants, food establishments, and retail centers. These centers are highly vulnerable to wildfires, which can damage or destroy them, reducing the goods and services available to visitors and residents in the Study Area. Both restaurants and retail centers typically rely on seasonal residents and visitors to sustain their businesses. This can limit the money available to create defensible space or rebuild after a wildfire.

Gas stations: Many gas stations in the Study Area are in landslide-susceptible areas. There are few gas stations in the Study Area, but if damaged by a landslide or debris flow, they can release toxic chemicals into the air, soil, and water supplies, subsequently harming the surrounding community. Gas stations are highly regulated due to the toxic chemicals required on-site; however, retrofitting gas stations can be difficult due to technology and financial means of the business owners.

Recreation and Tourism Activities

Recreation and Tourism Activity Category

The Climate Change Vulnerability Assessment assessed the vulnerability of 19 different types of recreation and tourism activities in the Study Area. Recreation and tourism activities were chosen based on Table 5.12 of the USFS's *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*. These activities are the primary economic drivers of the economy in the Study Area, encouraging visitors to travel to the area to participate in recreation and tourism activity year-round. The Project Team included a full spectrum of summer and winter recreation activities in both the backcountry and more urban areas. Recreation activities are separated into more focused subcategories where there are sufficient differences, such as differentiating between downhill skiing, backcountry skiing, and cross-country skiing. The recreation and tourism activity section of the Climate Change Vulnerability Assessment focuses on the feasibility of visitors participating in specific activities, if visitors would be deterred from traveling to the Study Area, and the economic benefits that these activities provide. The following recreation and tourism activities were included in the Climate Change Vulnerability Assessment:

- Backcountry skiing
- Bicycling
- Camping, backpacking, primitive camping
- Cross-country skiing
- Downhill skiing
- Driving for pleasure
- Fishing
- Gathering forest products
- Hiking/walking
- Horseback riding
- Hunting
- Motorized trail activities
- Other snow activities
- Picnicking
- Rock climbing
- Viewing natural features and wildlife
- Visiting historic sites and nature centers
- Water-based activities
- Wellness

Critically Vulnerable Recreation and Tourism Activities

Water-reliant recreation activities: Water-reliant recreation activities include water-based recreation and fishing, which are the most vulnerable recreation and tourism activities. Both activity types are severely vulnerable to air quality, smoke, and ash; drought; severe weather; and wildfire, and highly vulnerable to extreme heat; human health hazards; and severe weather. These recreation activities heavily rely on high water quality, which can be affected by ash, high temperatures, and wildfire or by increasing nutrient content of the water and reducing dissolved oxygen content, causing algae to grow.[140] Droughts can lead to a reduction in streamflow, which can lower water levels and increase the concentration of nutrients and algae. During the 2012 to 2016 drought, June Lake water levels dropped 20 feet, increasing the uranium concentrations

above safe drinking-water limits.[141] Severe weather, such as heavy rainfall, can cause erosion and convey contaminants, damaging surface water quality, which is essential for water-reliant recreation activities.[142] Reduced water quality and dissolved oxygen concentration can cause fish die-offs, which directly affects fishing activities in the Study Area and may result in some streams or lakes being closed for fishing.[143] Earlier snowmelt and more precipitation falling as rain may decrease the availability of water-based activities, because lakes may run dry and rivers may not have the capacity to support whitewater rafting and kayaking without snowmelt.[144] Water-reliant recreation activities in heavily forested areas can also be harmed by post-wildfire landslides (increasing sediments in the water) or fire retardants that enter into the water. For visitors participating in fishing or water-based recreation, there may be higher risks of vector-borne illnesses such as Lyme disease or West Nile virus as temperatures continue to warm.[145] Reduced water quality, closed water recreation sites, and lower water levels will likely deter visitors from traveling to the Study Area to participate in water-based recreation and fishing. There is little that recreation managers can do to manage water quality or water levels if drought conditions persist or more precipitation falls as rain instead of snow.

Snow-reliant recreation activities: Snow-reliant recreation activities include backcountry skiing, cross-country skiing, downhill skiing, snowmobiling, and other snow activities. These activities are severely vulnerable to drought and extreme heat and are highly vulnerable to severe winter weather. Backcountry skiing and downhill skiing are severely and highly vulnerable to landslides, respectively. Downhill skiing is also highly vulnerable to severe weather. A reduction in precipitation due to drought conditions can reduce the amount of snow available for snow-reliant activities. This could decrease the length of the ski and snow activity season.[146] Cross-country skiing activities are especially at risk, because they typically take place on flat areas at lower elevations.[147] Extreme heat will likely cause more precipitation to fall as rain instead of snow, in addition to causing snow to melt more quickly in the springtime.[148] While downhill skiing and other snow activity sites can make artificial snow to supplement natural snowfall, the temperatures still have to be low enough that the snow does not melt, and artificial snowmaking is an energy-intensive process.[149] While severe winter weather generates increased natural snowfall, it can also disrupt snow-reliant recreation activities, because skiers may not be able to access backcountry areas, ride chair lifts, or safely participate in winter outdoor activities. Some visitors may be deterred from traveling to the area during severe weather and severe winter weather and may not buy lift tickets or other tickets due to unfavorable weather. Though ski resorts, cities and counties, and parks and forests provide notifications of severe winter storms, not all visitors may see these or follow the directions provided. Landslides can also prevent visitors from traveling to snow recreation areas or block them from traveling back home if single access roadways are blocked by landslides and rockslides.[150] Visitors may travel to other regions of California or outside of the state to participate in snow-reliant activities if these activities are not feasible or too expensive in the Study Area.

Camping: Camping, backpacking, and primitive camping activities are severely vulnerable to flooding and wildfire and highly vulnerable to air quality, smoke and ash, human health hazards, landslides, and severe weather. Several campsites throughout the Study Area are in floodable areas or could be flooded by quickly melting snow, which can damage the sites and prevent visitors from using camping facilities. Wildfires can also render camping activities infeasible as flames can destroy camping facilities or surrounding camping areas. Poor air quality, smoke, and ash can create unhealthy conditions for all types of camping, as people would be primarily outside and directly exposed to poor air quality conditions. Campers can also be directly exposed to vector-borne illnesses and diseases, and in severe cases, such as the hantavirus outbreak in Yosemite National Park in 2012, parks and forests may temporarily close.[151] Visitors may be deterred from traveling to the Study Area for camping during these conditions if human health hazards, smoke, or air quality conditions are too severe.[152] As more precipitation falls as rain instead of snow, landslides can damage campgrounds or block roadways and trails leading to backpacking and primitive camping sites in the Study Area.[153] Fallen trees can also block roadways and trails and damage camping facilities, rendering a campsite unusable for days or weeks, depending on the severity of the damage. There are alternative camping, backpacking, and primitive camping areas that could support visitors in the summer months; however, due to the high demand for this activity in the Study Area, there may not be adequate facilities to support all camping visitors in the region. Camping activities are located in all jurisdictions in the Study Area and therefore management staffing, funding, and methods may be different in addressing these hazards.

Gathering forest products: Gathering forest products includes collecting firewood, plants, rocks, or minerals throughout the Study Area. This activity is severely vulnerable to forestry pests and diseases and wildfire and highly vulnerable to air quality, smoke and ash, drought, and human health hazards. Gathering forest products is highly dependent on healthy forest ecosystems, which can be decimated by forestry pests such as bark beetles and root diseases, as well as crown fires that burn through the understory and canopy of forests in the Study Area. Drought can harm the forests and other vegetation that provide products for this activity. Poor air quality, smoke, and ash can create unhealthy conditions for gathering forest products or expose people to human health hazards because people would be primarily outside in forested areas. Visitors may be deterred from traveling to the Study Area to participate in gathering forest products if the quality of the products is degraded, it is not safe for people to be in the forest or other outdoor environments, or if the products no longer exist. Some forests may be adapted to wildfires and drought, and recreationists can wear protective masks and clothing to prevent illnesses; however, there is little that can be done to manage the land forestry pests and diseases and to ensure that all forest products are available for this activity.

Rock Climbing

While "climbing" – whether it be on rock, mountain, or boulder - is not recognized as one of the "primary" recreation activity types in the U.S Forest Service's National Visitor Use Monitoring Program (NVUM), it is considered in the "Other Recreation" category, and has deep roots in the region. The Eastern Sierra and Yosemite have lured rock and mountain climbers for centuries, including Native Americans, Spaniards, early American military expeditions, and even expeditions from the California Geological Survey in 1860. The late 1800s and early 1900s saw many first ascents of high mountain peaks by the likes of James Hutchinson and the legendary Norman Clyde who made over a thousand ascents in the Sierra in the 1920s. Royal Robbins and Warren Harding emerged as true rock climbers in the late 1950s and 1960s, intent on conquering the "big walls" of Yosemite. The last three decades have seen the advent of indoor climbing gyms that have made the sport more accessible and thus more mainstream. Bouldering, which requires no ropes and very little gear, has grown in popularity, especially at places like the Buttermilks and Happies outside of Bishop. The increased popularity of climbing has inspired grass-roots organizations like the Bishop Area Climbers Coalition to provide a voice for climbers to support stewardship, education, and community engagement. The Coalition is tackling dispersed camping issues in the Owens Valley and has partnered with the Bishop Tri-County Fairgrounds to open a "Climbers Campground" with bathrooms, electricity, and showers. Climbing in all of its iterations is a primary driver of visitation to the Eastern Sierra, attracting climbers from all over the world.

Rock climbing: Rocking climbing activities are severely vulnerable to severe weather and highly vulnerable to air quality, smoke and ash, human health hazards, landslides, and wildfire. Rock climbers are directly exposed to severe weather, which may create dangerous conditions for climbers due to heavy rainfall, high winds, and lightning. Rock climbers can wait until severe weather has passed to engage in this activity, but some visitors may be deterred from traveling to the area. Poor air quality, smoke, and human health hazards could both deter visitors from traveling to the Study Area and cause illnesses for rock climbers. Access to rock climbing areas can be damaged or blocked by landslides and wildfire, preventing residents and visitors from reaching rock climbing destinations. There are alternative rock climbing sites in the Study Area; however, similar severe weather, poor air quality, human health hazards, wildfires, and landslides may occur at the alternative locations.

Hiking, walking, horseback riding: Hiking, walking, and horseback riding are highly vulnerable to air quality, smoke and ash, severe weather, and landslides. Hiking is highly vulnerable to human health hazards, and horseback riding is highly vulnerable to wildfire. Smoke and ash can create poor air quality conditions for these activities, as both people and horses would be outside and directly exposed. Landslides and wildfire can block or damage the trails used for hiking, walking, and horseback riding, or the facilities that support them, which can deter visitors from traveling to the Study Area. While hiking, visitors are more likely to be exposed to mosquitos, ticks, and rodents that carry vector-borne diseases and illnesses. Trails could close temporarily if human health hazards increase. Trails burned by wildfires could be unstable for horses to travel on, reducing the number of trails available for horseback riding. Trails supporting these activities could be managed to prevent wildfires and landslides; however, people would still be susceptible

to harm from poor air quality, smoke, and human health hazards. Other hazards, such as severe winter weather, may also limit these activities.

Viewing natural features: The activity of viewing natural features is highly vulnerable to air quality, smoke and ash, forestry pests and diseases, and wildfire. Smoke and ash can block views of natural features and wildlife, making this activity limited or impossible. Visitors who travel to the Study Area specifically for this activity may not do so during these conditions or if natural features are damaged by forestry pests and diseases. Scenic views and wildlife may be altered or harmed by wildfires that burn through the Study Area. This may deter visitors from traveling to view the Eastern Sierra through Owens Valley, traveling to the Bristlecone Pine Forest, driving through Yosemite Valley, or viewing wilderness areas in the backcountry. Prescribed burns, vegetation management, and pest management can help ensure viewing of natural features is available; however, due to the vast acreage of land in the Study Area, this could be difficult to complete. There is little if anything that can be done for the activity of viewing natural features to adapt to increased smoke and poor air quality conditions.

Hunting: Hunting is highly vulnerable to air quality, smoke and ash, and human health hazards. Hunting requires visitors to be outside for an extended period of time. In poor air quality or smoke conditions, this can lead to respiratory or other illnesses. Hunters are also more exposed to mosquitos, ticks, and rodents, which carry vector-borne diseases such as Lyme disease and West Nile virus. Parks and forests may also close if there is an outbreak of a human health hazard or poor air quality in the region. Visitors may be deterred from traveling to the Study Area to hunt in the event of these hazards. Hunters can wear masks and other protective equipment to reduce the risk of illness.

Bicycling: Bicycling within the Study Area is severely vulnerable to air quality, smoke, and ash. These hazards can create unhealthy conditions for bicycling because people would be primarily outside and directly exposed to poor air quality conditions. This may deter visitors from traveling to the area to participate in bicycling activities. Alternatively, national parks and national forests may close if smoke or air quality conditions are too severe.[154] Persons participating in bicycling can wear masks to protect themselves from smoke inhalation; however, an N95 mask may not be feasible for strenuous bicycling. Additionally, trails may need to close until the smoke clears, which is highly dependent on weather patterns and wildfire control.

Wellness: Wellness activities are highly vulnerable to air quality, smoke, and ash. Poor air quality and smoke can cause respiratory illnesses and asthma, which would reduce the ability to engage in wellness activities in the Study Area. Visitors could go to other regions of the Study Area for this activity; however, if a regional wildfire is the cause, the entire region may be impacted by smoke.

Ecosystems and Natural Resources

Ecosystem and Natural Resources Categories

There are eight primary ecosystem types in the Study Area, although many can be subdivided into specific habitats. The Climate Change Vulnerability Assessment analyzes eight ecosystems as well as scenic views and sensitive wildlife species. **Table 44** provides an overview of the acreage and land cover for each ecosystem type within the Study Area. The ecosystems and natural resources section of the Climate Change Vulnerability Assessment focuses on how the plants and wildlife in ecosystems are likely to be affected by climate change hazards and the currently ability of these systems to adapt to changing conditions. The primary resource for this analysis is EcoAdapt's *Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada*. The following ecosystems and natural resources were included in the Climate Change Vulnerability Assessment:

- Aquatic and open water
- Deciduous forest
- Desert scrub
- Desert woodland
- Grassland
- Mixed conifer forest
- Scenic views
- Sensitive and critical species
- Shrubland
- Wetland

Table 44. Acreage and Land Cover Type in the Study Area

National Climate Assessment Land Cover	VA Land Cover	Area (Acres)	Percentage (%)
Desert shrub	Desert scrub	5,157,149	47%
Coniferous forest	Mixed conifer forest	2,103,843	19%
Shrubland	Shrubland	1,837,064	17%
Barren	N/A	1,058,250	10%
Deciduous forest	Deciduous forest	182,159	2%
Desert woodland	Desert woodland	162,687	1%
Grassland	Grassland	124,552	1%
Open water	Aquatic and open water	99,632	1%
Wetland	Wetland	96,064	1%
Urban	N/A	25,951	Less than 1%
Agriculture / cropland	N/A	16,495	Less than 1%
	Total	**10,863,847**	**100%**

Source: Project Team, 2021, Baseline Natural Capital Assessment.

Notes: Scenic views and sensitive and critical species are not considered specific ecosystems or land cover, and therefore are not included in this table.

Critically Vulnerable Ecosystems and Natural Resources

Sensitive and critical species: Sensitive and critical species in the Study Area include burrowing owl, mountain yellow-legged frog, sage grouse, Sierra Nevada yellow-legged frog, Yosemite toad, Pacific fisher, Sierra Nevada bighorn sheep, fish slough milk-vetch and whitebark pines (*Pinus albcaulis*). These species are severely vulnerable to drought, extreme heat, forestry pests and diseases, and wildfire and highly vulnerable to smoke and ash. Yosemite toad, fish slough milk-vetch, Sierra Nevada yellow-legged frog, and mountain yellow-legged frog are highly dependent on water quantity and quality in streams and lakes in the Study Area.[155] Drought and extreme heat can lower water level and water quality, which could harm these species. Aquatic and wetland ecosystems can be managed to ensure that these sensitive species thrive; however, prolonged droughts, heat waves, and lack of precipitation may make this very difficult for park, forest, and local jurisdiction land managers.[156] The Pacific fisher, Sierra Nevada and Mountain yellow-legged frog, and sage grouse can be harmed by forestry pests and diseases and wildfire that change or destroy the habitats that they rely on.[157] Loss of forested lands may lead to die-offs of sensitive species, even if they are already protected due to their statewide or federal sensitive species status. Similar to humans, these sensitive species could inhale large amounts of smoke, which can harm respiratory systems.[158] This could lead to a reduction in population size, which would harm the critical wildlife species further. Natural water supplies could also be contaminated by ash.[159]

Aquatic and open water: Aquatic and open water ecosystems include the lakes, rivers, and streams that provide ecosystem services for the Study Area. This ecosystem is severely vulnerable to smoke and ash, drought, and extreme heat and highly vulnerable to wildfire. Smoke, ash, fire retardants, and sediment from nearby wildfires that enter lakes and waterways can pollute the water to the point that the ecosystem cannot filter out the pollutants.[160] Ash can reduce water quality and cause die-off of aquatic species. Chronic ash, sediment, and fire-retardant contamination may damage the ecosystems and cause higher levels of runoff in the area. Drought can cause lower water levels and water quality, in addition to raising water temperatures in aquatic habitats. Extreme heat can also raise water temperatures in aquatic systems, leading to changes in dissolved oxygen, nutrient cycling, and overall water quality.[161] Drought and extreme heat can lead to more frequent algal blooms and increased disease outbreaks among both plant and wildlife species.[162] Degraded aquatic habitats may be less able to recover from drought and extreme heat events if water temperatures continue to warm. If native species are outcompeted by nonnative species, the entire ecosystem may change permanently. Other threats to overall forest health, such as those from forestry pests, may also impact aquatic environments.

Mixed conifer forest: Mixed conifer forests provide the highest valued ecosystem services and cover almost 20 percent of the Study Area. These forests are severely vulnerable to extreme heat, forestry pests and diseases, and wildfire and highly vulnerable to drought. Extreme heat can stress the trees, making them more susceptible to damage from forestry pests or infestation. Most conifer forest species are moderately susceptible to harm during drought events, especially saplings of ponderosa and Jeffrey pines, as well as those at lower elevation.[163] Forestry pests and diseases can weaken or kill conifer trees that are already weakened by extreme heat and drought, as they are unable to effectively resist infestations, damaging the wider mixed conifer ecosystem.[164] Weakened trees in mixed conifer forests can turn into dry fuel for wildfires. These wildfires can burn at higher temperatures and higher into the canopy, decimating the ecosystem plants and animals. Mixed conifer forest ecosystems that cannot adapt to changing climate

conditions may shift in composition to deciduous and other sprouting species that can outcompete conifer trees.[165] Some mixed conifer forests may move upslope to escape rising temperatures, but warmer and drier conditions can reduce the recovery potential of conifer forests from all hazards.

Wetlands: Wetland ecosystems consist of marshes, ponds, or edges of lakes that are low lying and frequently flooded. Wetlands are severely vulnerable to drought and extreme heat and highly vulnerable to smoke and ash. Wetland and wet meadow ecosystems are largely dependent on snowpack and rainfall for their water sources throughout the year. Droughts can decrease snowpack levels, which can reduce spring and summer soil moisture in wetlands and wet meadows, which can cause tree and shrub encroachment on this ecosystem.[166] Extreme heat can cause more precipitation to fall as rain instead of snow and lead to earlier snowmelt, reducing the amount of water available to wetland habitats year-round. Smoke and ash particles that end up in wetlands and wet meadows can pollute the water to the point that the ecosystem cannot filter out the pollutants. Ash can reduce water quality and disrupt species that depend on this ecosystem for survival. Wetland habitats are fragmented and degraded in many areas, which limits their ability to adapt to changing conditions. This ecosystem is also highly dependent on water availability and may not be able to recover without an influx of water.[167] Other management methods for wetlands can be expensive and not always feasible if the land is managed for other uses.

Deciduous forests: Deciduous forests consist of broadleaf trees, shrubs, and perennial herbs and mosses, including oaks, beeches, birches, chestnuts, aspens, elms, and maples.[168] Deciduous forests are highly vulnerable to extreme heat and forestry pests and diseases. Extreme heat and higher temperatures can reduce moisture availability for deciduous forests, causing stress and limiting distribution and establishments of the ecosystem.[169] Disturbance due to disease could cause shifts in species composition, loss of cultural resources, and reduced food and habitat resources for wildlife.[170] Deciduous forests typically can migrate to higher elevations over time to find cooler temperatures and recover from natural disturbance regimes; however, this could take a substantial amount of time and these forests may outcompete other critical habitats in the Study Area.[171] Sudden oak death may also not be manageable with increased drought conditions.[172] Other hazards, such as wind events, may cause additional hardships for these ecosystems.

Scenic views: Scenic views are visual resources that attract people to the Study Area for their intrinsic beauty. Scenic views can be directly harmed by reduced visibility created by smoke and ash, as well as wildfires that burn forested ecosystems and indirectly impact water and lake ecosystems. If scenic views are harmed, this could lead to fewer visitors in the Study Area, creating economic hardships for recreation and tourism-dependent businesses in the area. Drought and forestry pests and diseases can also make the local scenery less appealing and may contribute to a higher risk of wildfires and smoke and ash in the Study Area. Currently, there are no feasible means of scenic views adapting to smoke and ash.

Shrubland: Shrubland consists of alpine dwarf-shrub, bitterbrush, sagebrush, low sage, montane chaparral, mixed chaparral, chamise-redshank chaparral, juniper, aspen, montane riparian, and valley foothill riparian habitats. This ecosystem is severely vulnerable to extreme heat. Riparian areas within shrubland habitat can experience higher water temperatures in extreme heat conditions, leading to changes in dissolved oxygen, nutrient cycling, and overall water quality.[173] Riparian areas with sufficient tree canopy cover and vegetation could recover from extreme heat

conditions once they subside. However, some riparian areas may dry up during hotter conditions due to evaporation, leaving plants and wildlife in these ecosystems without a surface water supply.

Key Services

Key Services Category

The Climate Change Vulnerability Assessment assessed the vulnerability of 14 different types of services in the Study Area. These key services categories provide essential goods and services to residents and visitors in the Study Area and support the recreation and tourism industries. These services are provided by public, private, and non-profit agencies and organizations, but are considered regionwide and are not separated out into subareas. The key services section of the Climate Change Vulnerability Assessment focuses on the actions and services provided in these categories instead of the physical buildings and infrastructure that support the services. The following key services were included in the Climate Change Vulnerability Assessment:

- Air services
- Communication services
- Electricity delivery
- Emergency medical services
- Government services
- Information services
- Mail service
- Public safety response
- Road access
- Search and rescue
- Trail maintenance
- Transit access
- Vital goods
- Water and wastewater

Critically Vulnerable Key Services

Electricity delivery: Energy delivery services in the Study Area are dependent on overhead power lines owned and operated by utility companies such as Pacific Gas and Electric Company or Southern California Edison. These power lines are susceptible to extreme heat, fallen trees from forestry pests and diseases and high winds, severe weather, landslides, and wildfire. Extreme heat can cause power outages due to mechanical failure of electrical equipment, heat damage to the above-ground infrastructure, and a high demand for electricity due to air conditioning units. Solar and hydroelectric energy production could also decrease due to extreme heat. Solar photovoltaic panels experience a decrease in efficiency of 10 percent to 25 percent as temperatures rise because of the excessive heat generated when converting solar energy to electric energy. Reduced efficiency of solar panels on private homes and businesses can lead to higher utility bills if owners have to purchase more electricity to offset the lower solar generation. The reservoirs that produce hydroelectric energy may experience higher rates of evaporation and lower water levels due to extreme heat and drought, which reduces the amount of water available to generate electricity, although other sources of power are usually available from elsewhere. Electrical lines that are close to forested areas could be damaged by falling trees affected by pests and diseases and severe weather. These impacts could become chronic as conifer forest ecosystems weaken. Landslides can damage electrical transmission lines if their

foundations are undermined or fail. Freezing temperatures and heavy snowfall from severe winter weather can put weight on the electrical transmission lines, causing them to fail. High winds from severe weather can also cause utility companies to turn off electricity to prevent sparks, as part of a public safety power shutoff, which disrupts energy delivery to nearly every area of the Study Area. This can be dangerous for residents and visitors in the Study Area during the winter because electricity is one of the primary heating fuels for homes and businesses. Wildfires can also damage power lines and substations. Utility companies can retrofit power lines and other equipment to insulate them against extreme heat events, severe winter weather, and severe weather and remove diseased or dead trees surrounding the lines to protect them from falling trees and wildfires. However, these measures can be expensive and require yearly or seasonal management activities.

Trail maintenance: Trail maintenance is severely vulnerable to landslides and wildfires and highly vulnerable to flooding, forestry pests and diseases, human health hazards, and severe weather. Landslides, wildfires, flooding, forestry pests and diseases, and severe weather could block roadways and trails for trail maintenance crews to complete their job, as well as create more trail maintenance needs than existing staff and volunteers can provide. Existing trail maintenance needs may not be able to meet the demand of the Study Area. Trails may be difficult and dangerous to access due to debris flows or washouts from landslides and flooding. Trail maintenance crews could also be more exposed to mosquitos, ticks, rodents, and other animals that carry vector-borne diseases while completing trail maintenance activities. If parks or forests are closed, trail maintenance may not be possible because it is largely completed by volunteer personnel. National parks and national forests can increase trail maintenance budgets and staffing to meet the needs of the Study Area; however, many trail maintenance organizations are volunteer or non-profit based and may not be able to expand operations every year.

Road access: Road access is highly vulnerable to flooding, landslides, severe weather, severe winter weather, and wildfire. Flooding, landslides, and wildfires can block access to roadways in remote, mountainous, and heavily forested regions in the Study Area. Flooding and landslides can also undermine the foundations of roadways along rivers and steep slopes. If major routes such as Highway 395, Highway 120, or Highway 168 are blocked by these hazards, visitors and residents could become isolated from other areas in the region. Severe weather and severe winter weather can also block roadways through fallen trees, heavy snow, or high winds, causing routes to become dangerous and impassable. This could prevent road access for days or weeks. Caltrans and other roadway managers can clear roadways of debris, snow, and rockfalls; however, more frequent hazard events could make this difficult and expensive. Yearly vegetation management, slope stabilization, and defensible space can help keep roads open for emergency personnel and visitors, but this would require coordination and funding from multiple agencies.

Search and rescue: Search and rescue efforts include services provided by fire departments, sheriff's departments, and volunteers to help those who become lost or injured outdoors, including during recreation and tourism activities. These services are severely vulnerable to air quality, smoke and ash, and wildfire and highly vulnerable to forestry pests/diseases, landslides, and severe winter weather. Wildfires and the smoke and ash they produce may reduce visibility in the Study Area, preventing search and rescue crews from effectively doing their job. This can increase the risk of injury and death for those participating in recreational activities, especially those in backcountry areas. Search and rescue crews may be constrained from providing services more often with increased frequency of wildfires, because it may not be safe enough for them to go into wilderness or forested areas. Search and rescue workers can wear N95 masks and filters to

protect themselves from smoke inhalation. However, helicopters and other aircraft may not be able to safely fly in smoky conditions, and decreased visibility may prevent search and rescue personnel from finding people. Search and rescue services can also be hindered by fallen trees due to forestry pests and diseases, landslides and rockfalls that block roads and trails, and heavy snowfall or avalanches. These hazards could also increase the need for search and rescue services, and these services may not be able to meet the needs of the Study Area. Search and rescue crews may include public safety personnel or volunteers, which could limit the capacity and capabilities of conducting rescues with the threat of wildfire and other hazards in the area.

Vital goods: Due to the remote location of many regions in the Study Area, the delivery of vital goods such as food, medicine, and fuel is severely vulnerable to severe winter weather and highly vulnerable to flooding, landslides, severe weather, and wildfire. Severe winter weather, severe weather, flooding, and landslides can create dangerous conditions on the roadways and prevent vital goods from being delivered to the Study Area. If a wildfire was burning in the region, road closures may interrupt the delivery of vital goods, causing hardship on residents and visitors. This could harm the entire community if stores do not have enough of supplies such as food or medicine, or if residents and visitors using propane for home heating do not have a sufficient supply of fuel. The impacts could persist for days or weeks depending on the severity of the hazard. The Study Area could attempt to adapt by creating local food supplies, although such options are likely limited, and there are no local sources of propane. Cities and counties in the Study Area could also fly in vital goods, although this option would be expensive and not always feasible due to dangerous conditions created by winter weather, wildfires, and severe storms. If prices increase and become unaffordable, local residents may not be able to afford these vital goods and there may be limited availability if local residents are competing with visitors.

Transit access: Transit access depends on clear and safe road conditions to remain an effective service, and thus it is highly vulnerable to flooding, landslides, severe weather, and severe winter weather. Transit access can be negatively impacted if roads are washed out during flood events, collapse or become blocked due to landslides, or become impassable due to snow and ice conditions. Individuals who rely on transit to travel to the Study Area may not be able to find other transportation options. Service disruptions could be substantial at times. Transit in the Study Area may be able find alternative routes if roads are washed out or plow if covered in snow, but roads damaged by landslides may not be able to be repaired for public transit. There may be few alternative routes in remote areas of the Study Area.

Water and wastewater: Water and wastewater services are severely vulnerable to drought, and highly vulnerable to smoke and ash, flooding, and wildfire conditions. Short-term and extended droughts can cause significant reduction in water supplies. The Study Area can implement stringent water conservation measures; however, recreation activities may not be able to do so. Wastewater infrastructure could also be damaged by wildfires and flooding events. Several wastewater treatment facilities and septic facilities are in flood hazard areas and could overflow due to flooding, releasing raw sewage in the surrounding water and soil. Water sources can become contaminated due to sediment, ash, and fire retardants flowing into rivers and streams. Depending on the source of contamination, existing filtration processes of contaminated water supplies may be sufficient to remove most contaminants from drinking water. Damaged water and wastewater infrastructure can be repaired after a fire. However, both of these are expensive and may take months or years to complete after a fire occurs. Water conservation measures, use of more recycled water, and more extensive filtering equipment can protect the water services

throughout the county. Wastewater services that rely on wastewater treatment plants may have a more difficult time adapting due to the expensive nature of moving wastewater infrastructure.

Air services: Air services, including commercial passenger flights, charter flights, and air freight, depend on visibility and wind speeds that allow the aircraft to safely land and take off from the airports in the Study Area. Thus, air services are highly vulnerable to severe winter weather, smoke and ash, and wildfire. Severe winter weather can cause "white outs" and high winds that can impede on the ability of air services to reach the Study Area, especially at higher elevations. Smoke and ash can impact the air quality in the area, and the Federal Aviation Administration could restrict flight in the region.[174] Wildfires in the region can also cause delays or cancellation of air services. Many airports also serve as a staging area for CAL FIRE crews and may not be able to handle the capacity of the fire crews and commercial or private air services during a wildfire. This impact would be temporary but may be chronic as more wildfires occur in the region. The Study Area relies in part on air services to bring seasonal residents and tourists into the area, and thus the economy would be negatively impacted if air services were impeded. Air services could be rerouted to airports in other regions of the Study Area if there are no flight restrictions; however, these airports may be much farther away from final destinations of passengers. Other hazards, such as severe weather, may also impact air services.

Communication services: Communication services are highly vulnerable to landslides, severe weather, and wildfires. These hazards can damage communication facilities or cut off the power to them, preventing regions of the Study Area from receiving or relaying emergency notifications and other essential communications. Wildfires can also cause more public safety personnel to travel to the Study Area to help fight the fires. If communication networks are not set up to accommodate an increased number of users, this can overwhelm the limited communication system in isolated or rural areas, causing degradation of service.

Emergency medical response: Emergency medical response efforts are highly vulnerable to air quality, smoke and ash, and human health hazards. Smoke and ash may reduce visibility in the Study Area, which can prevent emergency medical personnel from using helicopters and other aircraft to transport patients. This can increase the risk of injury and death for those participating in recreational activities, especially those in backcountry areas. Human health hazards can cause emergency medical services to be unable to meet the needs of both residents and visitors if human health hazards affect a large portion of the population. There may be shortages of health care, equipment, pharmaceuticals, and personnel able to provide service if health care workers become sick or if supply chains are disrupted. Regional medical centers and providers can strengthen medical supply chains and prepare emergency contingency plans for if and when human health hazards increase in frequency and intensity. However, this may take time and require extensive coordination. Severe weather and landslides may also disrupt emergency medical response, as these hazards may close roads.

Public safety response: Public safety response is highly dependent on roadways being open and clear for vehicles to reach community members in need. Because of this, public safety response is highly vulnerable to landslides and wildfires. Landslides and mudflows can block roadways, making it difficult to evacuate individuals or respond to public safety calls. The impacts could be long term, as debris, rocks, and soil can take time to clean up and recover from. When a wildfire is burning in the region, public safety personnel may be assigned to help fight the fire. The remaining public safety responders may not be able to meet the needs of the Study Area. This impact would be temporary, but could become chronic if wildfires increase in the region.

Public safety response may face challenges adapting to landslides, which are often unpredictable. Additionally, public safety responder teams can be added during wildfire events to respond to all emergencies if jurisdictions and agencies in the Study Area have the financial means to do so.

SECTION 7: ASSESSMENT OF HAZARDS ON ECOSYSTEM SERVICES

This section of the report provides a quantitative and qualitive assessment of the hazard-specific impacts to ecosystem services.

Air Quality, Smoke, and Ash

Low air quality can have a significant negative impact on both ecosystem services and recreational activities. Air quality hazards include pollution, such as ozone and particulate matter, within the atmosphere that can disrupt vegetation photosynthesis (as well as other natural processes) and can make it difficult for wildlife and people to breathe. Air quality within the SRTI Study Area (Study Area) can be impacted by urban smog from the Central Valley, but the largest fluctuations in air quality are driven by wildfires both within and outside the Study Area.

Climate change impacts on the Study Area suggest that drought and wildfire frequency are set to increase, which is likely to result in larger and more intense wildfires.[175] The smoke and ash associated with these wildfires have the potential to negatively impact ecosystem services and recreation within the Study Area. Based on the vulnerability assessment, the aquatic, scenic, and vulnerable ecosystems and natural resources described in **Table 45** are most at risk. Similarly, the vulnerability assessment suggests that most outdoor recreational activities are rated as severely vulnerable as a result of potential respiratory issues. **Table 45** presents findings from the vulnerability assessment.

Table 45. Ecosystem Services, Land Covers, Natural Resources, and Recreational Activities at Risk from Air Quality, Smoke, and Ash

Ecosystem or Resource	Score			Discussion
	V	IM	AC	
Ecosystem Services, Land Covers, and Natural Resources				
Aquatic and open water	V5	IM3	AC1	Severe vulnerability based on moderate impacts and low AC. As ash settles and pollutes waterways, wildlife and vegetation suffer with little ability to adapt.
Scenic views	V5	IM3	AC0	Severe vulnerability based on moderate impacts as view distance is decreased and outdoor activities are limited. There is no AC associated with scenic views.
Sensitive and critical species	V4	IM2	AC1	High vulnerability based on moderate impacts and low AC for bird and mammal species such as the burrowing owl, sage grouse, Pacific fisher, and Sierra Nevada bighorn sheep (Hermance, 2018), leading to reductions in population size and contaminated water sources (McDonald and Doan-Crider 2015).
Wetland	V4	IM3	AC2	High vulnerability based on significant impacts, such as water pollution, and low AC.

Ecosystem or Resource	Score			Discussion
	V	IM	AC	
Recreational Activity				
Bicycling	V5	IM3	AC1	Severe vulnerability based on significant impacts and low AC. Poor air quality creates unhealthy conditions for bicycling, which may deter bicycling activities (Halofsky et al., 2020). N95 mask wearing is an option for less strenuous bicycling, but trails may still close due to weather conditions.
Camping, backpacking, primitive or dispersed camping	V4	IM2	AC1	High vulnerability based on moderate impacts and low AC. Direct outdoor exposure to poor air quality may be unhealthy and limit participation. Campsites may close due to poor weather conditions.
Fishing	V5	IM3	AC1	Severe vulnerability based on significant impacts and low AC. Fishing relies heavily on water quality, which may be severely reduced. Increased nutrient content of the water and reduced dissolved oxygen content may negatively impact fishing activities. Site closures for water quality and fish restocking may help keep healthy levels but could limit participation days.
Gathering forest products	V4	IM2	AC1	High vulnerability based on moderate impacts and low AC. Outdoor activities may be dangerous due to poor air quality, and sites may close due to weather conditions.
Hiking/walking	V4	IM2	AC1	High vulnerability based on moderate impacts and low AC. Poor air quality can create unhealthy conditions for hiking/walking, and N95 masks may not be feasible for strenuous hikes. Areas may be closed due to poor weather conditions.
Horseback riding	V4	IM2	AC1	High vulnerability based on moderate impacts and low AC. Poor air quality can create unhealthy conditions for both horses and people. While people may be able to wear masks, such protection is not feasible for horses.
Hunting	V4	IM2	AC1	High vulnerability based on moderate impacts and low AC. Outdoor recreational activities may make it unhealthy for hunting activities, and limited visibility may impact success. Areas may be closed due to weather conditions.

Ecosystem or Resource	Score			Discussion
	V	IM	AC	
Rock climbing	V4	IM2	AC1	High vulnerability based on moderate impacts and low AC. Poor air quality may make strenuous climbing activities unsafe, and mask wearing may be infeasible for certain activities. Areas may be closed due to weather conditions.
Viewing natural features and wildlife	V5	IM3	AC0	Severe vulnerability based on significant impacts and low AC. Low visibility and poor air quality may make viewing in the Study Area difficult or impossible if areas are closed due to weather conditions.
Water-based activities	V5	IM3	AC1	Severe vulnerability based on significant impacts and low AC. Water-based activities rely heavily on water quality, which is likely to be degraded. Areas may be closed due to weather conditions.
Wellness activities	V4	IM3	AC2	High vulnerability based on significant impacts and some AC. Poor air quality may make it unhealthy for outdoor recreational activities.

Based on the vulnerability assessment, the Project Team estimates that $15.2 to $110.3 billion of non-recreation annual ecosystem service values are at risk from climate-related air quality, smoke, and ash hazards. This value represents the value of ecosystem services provided by open water and wetland land cover, as well as the water quality services provided by other land cover types. **Table 46** presents the breakdown of these findings. It is possible that additional services, such as air quality regulation or climate regulation services, may be impacted as a result of low air quality, but the Project Team did not include them in this estimate because it is difficult to understand the extent to which these services may be damaged. In addition, the Project Team estimates that more than $1.6 billion in recreational activities are at risk from climate change–related air quality, smoke, and ash hazards. This value represents the consumer surplus of participating in recreational activities, plus the direct, indirect, and induced impacts of spending related to the recreational activity (see the baseline assessment for a more detailed discussion of the estimation of these values). **Table 46** presents the sum of these findings.

In total, combining recreation and non-recreation ecosystem services, the Project Team estimates that roughly $16.8 to $111.9 billion (with an average of $44.0 billion) in annual ecosystem services value is at risk from the climate change–related impacts of air quality, smoke, and ash. This value represents the potential value of ecosystem services that are at risk from air quality, smoke, and ash damages, rather than actual expected damages. These values should not be combined across climate hazards, as this would result in double counting.

Table 46. Ecosystem Services at Risk from Air Quality, Smoke, and Ash, Millions of 2019$

Land Cover Type	Total Value / Year		
	Low	Average	High
Ecosystem Services, Land Covers, and Natural Resources			
Open water	$347.1	$506.6	$1,011.9
Wetland	$254.2	$4,754.5	$24,232.3
Non-aquatic water quality services	$14,594.6	$37,153.4	$85,070.8
Total ecosystem services, land covers, and natural resources	$15,195.9	$42,414.5	$110,315.0
Recreational Activities			
Bicycling			$235.3
Camping, backpacking, primitive or dispersed camping			$156.8
Fishing			$159.9
Hiking/walking			$486.7
Hunting			$4.9
Water-based activities			$12.8
Nature related: [a] Viewing natural features and wildlife			$248.1
Other recreation: [b] Horseback riding Rock climbing Wellness activities			$328.0
Total Recreational Activities			$1,632.5
Total	**$16,828.4**	**$44.047.0**	**$111,947.5**

Notes: Values may differ due to rounding.

a. Nature related encompasses: nature center activities, viewing natural features, nature study, and viewing wildlife.

b. Other recreation encompasses: relaxing, driving for pleasure, horseback riding, other non-motorized, resort use, some other activity, and visiting historic sites.

Drought

Drought includes both a loss of total precipitation and a decrease in snowpack due to a greater proportion of precipitation falling as rain than as snow. Decreased precipitation is likely to reduce the amount of snow available for back-country, cross-country, and downhill skiing, as well as for other snow-related activities. As shown in **Table 47**, snowpack in the central Sierra Nevada region is projected to decrease by 38 to 77 percent by 2079, and the southern Sierra region will see decreases in snowpack from historical averages by 58 to 86 percent by 2079.[176] Precipitation projections range from a decrease of 10 percent to an increase of 16 percent by 2079. **Figure 22** shows these central and southern regions.[177] **Table 48** presents findings from the vulnerability assessment.

Table 47. Projected Annual Change

	Historical (1971-2000)	2010-2029	2030-2049	2060-2079
Annual Snowpack				
Central Sierra Nevada	1,153 mm	-38% to -40%	-47% to -53%	-64% to -77%
Southern Sierra Nevada	2,237 mm	-58% to -64%	-67% to -70%	-72% to -86%
Annual Precipitation				
Central Sierra Nevada	1,119 mm	+1% to +5%	+1% to +11%	-9% to +13%
Southern Sierra Nevada	528 mm	+2% to +7%	+1% to +8%	-10% to +16%

Source: EcoAdapt, Geos Institute, and Conservation Biology Institute, 2013, "Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California," https://www.cakex.org/sites/default/files/documents/SierraProjections_DRAFT130225sm.pdf.

Based on the vulnerability assessment, the Project Team estimates that roughly $19.4 to $114.6 billion in annual ecosystem services value is at risk from the climate impacts of drought. In addition, the Project Team estimates that more than $607.5 million in recreational activities are at risk from climate-related drought hazards on an annual basis. This value represents the consumer surplus of participating in recreational activities, plus the direct, indirect, and induced impacts of spending related to the recreational activity (see the baseline assessment for a more detailed discussion of the estimation of these values). Combined, these estimates amount to $20.0 to $115.2 billion (with an average of $49.9 billion) in annual ecosystem services value at risk. This value represents the potential value of ecosystem services that are at risk from drought damages, rather than actual expected damages. These values should not be combined across climate hazards, as this would result in double counting. **Table 49** presents the breakdown of these findings.

Figure 22. Map of Sierra Zones

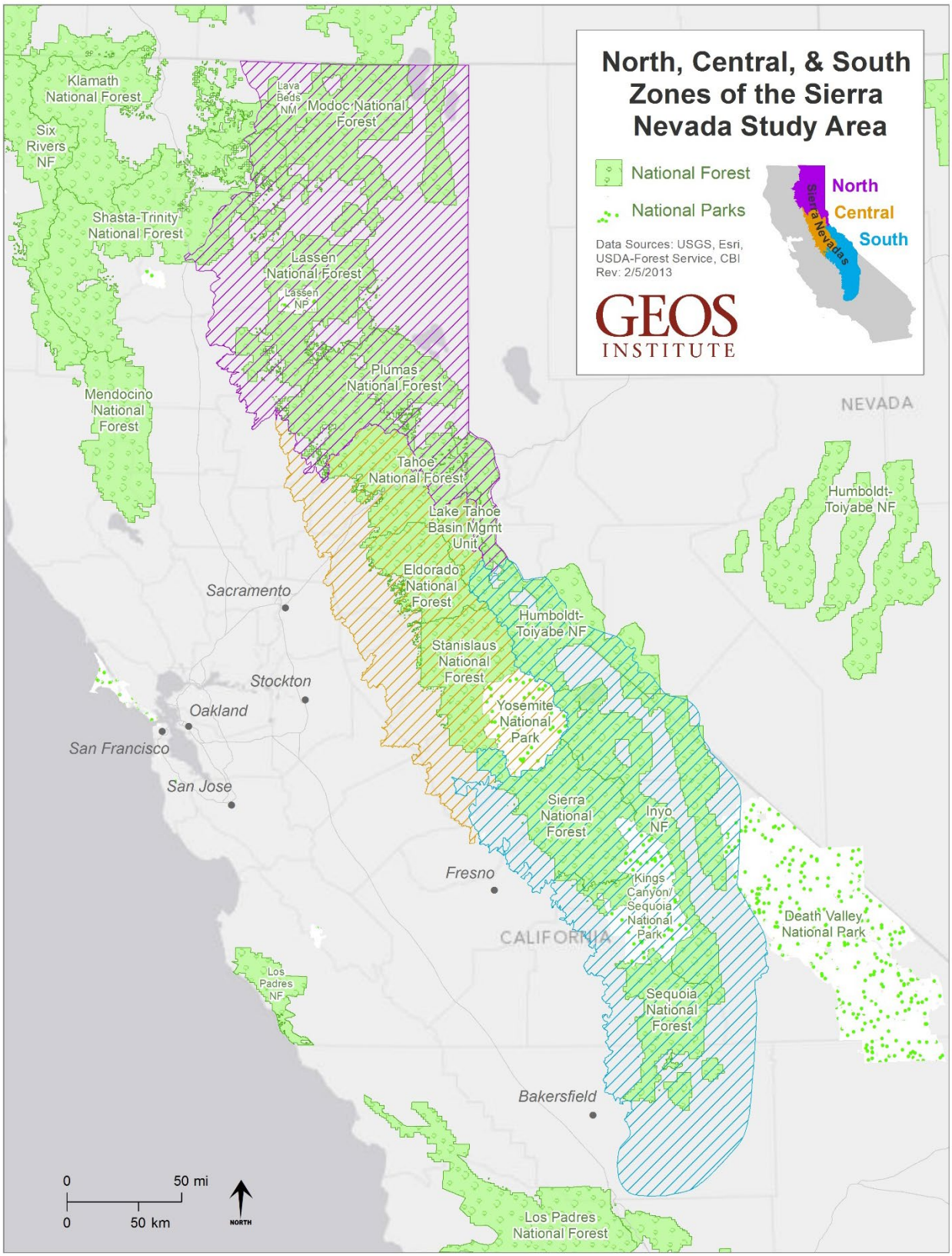


Table 48. Ecosystem Services, Land Covers, Natural Resources, and Recreational Activities at Risk from Drought

Ecosystem or Resource	Score			Discussion
	V	I	AC	
Ecosystem Services, Land Covers, and Natural Resources				
Aquatic and open water	V5	IM4	AC1	Severe vulnerability based on severe impacts to water levels and water quality, in addition to raising water temperatures in aquatic habitats. Can result in harmful algal blooms. Low AC as some aquatic ecosystems may not be able to recover.
Mixed conifer forest	V4	IM2	AC1	High vulnerability based on moderate impacts to most conifer forests that are susceptible to harm during drought conditions, particularly samplings of ponderosa and Jeffrey pines. Stress from drought can substantially weaken trees. Low AC from drought stressed trees that are susceptible to pests and disease.[178]
Sensitive and critical species	V5	IM3	AC1	Severe vulnerability based on significant impacts to the Yosemite toad, fish slough milk-vetch, Sierra Nevada yellow-legged frog, and mountain yellow-legged frog are highly dependent on water quantity and quality in streams and lakes within the Study Area. Low AC as wetland ecosystems can be managed to ensure sensitive species thrive, but prolonged drought may make this difficult for wildlife managers.[179]
Wetland	V5	IM3	AC1	Severe vulnerability based on significant impacts to water levels since wetland and wet meadow ecosystems are largely dependent on snowpack and rainfall. Droughts can lower the water levels, which can cause tree and shrub encroachment into this ecosystem.[180] Low AC resulting from difficulty adapting to drought conditions, although ecosystem managers can restore function and reduce negative impacts.
Recreational Activity				
Backcountry Skiing	V5	IM4	AC1	Severe vulnerability based on severe impacts from decreased precipitation reducing the amount of snow available for backcountry skiing. Due to the remote nature of these sites, there are few adaptive options available to preserve the skiing areas.
Cross-country skiing	V5	IM4	AC1	Severe vulnerability based on severe impacts from decreased precipitation reducing the amount of snow available for cross-country skiing. Artificial snow can be produced at cross-country ski sites to support this activity during periods of drought. However, this can be expensive, may not be feasible at all sites, and is very energy intensive and therefore generates a large amount of greenhouse gas emissions.[181]
Downhill skiing	V5	IM3	AC1	Severe vulnerability based on significant impacts from decreased precipitation reducing the amount of snow available for downhill skiing. The aquifers that support this activity may not have enough water to support artificial snow production. Some resorts could add infrastructure to make recreation areas available at higher elevations, but this can also be expensive and not always feasible.

Ecosystem or Resource	Score			Discussion
	V	I	AC	
Fishing	V5	IM4	AC1	Severe vulnerability based on severe impacts from decreased precipitation reducing quantity and quality of water, on which fishing is highly dependent. Some streams of lakes may be closed for fishing if there isn't enough rainfall.[182]
Gathering forest products	V4	IM3	AC2	High vulnerability as drought could harm forests and other vegetation that provide products for this activity.
Other snow activities	V5	IM3	AC1	Severe vulnerability based on significant impacts from decreased precipitation reducing the amount of snow available. This may prevent other snow activities or deter visitors from traveling to the area to participate in these activities.[183] Artificial snow can be produced at some snow activity sites to support these activities during periods of drought. However, this can be expensive, may not be feasible at all sites.[184]
Water-based activities	V5	IM4	AC0	Severe vulnerability based on severe impacts from decreased precipitation reducing quantity and quality of water. Lakes, reservoirs, and other water recreation sites depend on an inflow of water to maintain operations. No alternative source of water is generally available to replace declines in natural supplies from drought conditions.

Table 49. Ecosystem Services at Risk from Drought, Millions of 2019$ Millions

Land Cover Type	Total Value / Year		
	Low	Average	High
Ecosystem Services, Land Covers, and Natural Resources			
Coniferous forest	$18,770.2	$44,025.7	$89,375.7
Open water	$347.1	$506.6	$1,011.9
Wetland	$254.2	$4,754.5	$24,232.3
Total Ecosystem Services, Land Covers, and Natural Resources	$19,371.5	$49,286.8	$114,619.9
Recreational Activities			
Downhill skiing/Backcountry Skiing			$301.0
Cross-country skiing and snowshoeing			$127.9
Fishing			$160.2
Other snow activities:			$5.5
Off-highway vehicle use, snowmobiling			
Water-based activities:			$12.9
Motorized boating/water activities			
Nonmotorized boating			
Total Recreational Activities			$607.5
Total	**$19,979.0**	**$49,894.3**	**$115,227.4**

Note: Values may differ due to rounding.

While Rosenberger includes "gathering forest products" under "Other recreation," gathering forest products reflected zero % of the primary activities in which visitors participated in. As a result, zero economic value is attributed to gathering forest products in the model and is thus excluded from the estimation of economic activity derived from recreational activities at risk in the vulnerability assessment.[185]

Economic Impact of Snowpack

A 2021 environmental economics paper by Parthum and Christensen estimates variation in the recreation revenue from snowpack under future climate scenarios. The paper estimates that 89.5 percent of California ski resort revenues are attributable to snowpack. In other words, a 0.895 percent change in ski resort revenues is expected to result from a 1 percent change in snowpack . Applying the estimates of EcoAdapt et al. and Parthum and Christensen, the lower bound of a 58 percent reduction in snowpack could result in a 52 percent (58% x 89.5%) reduction of current revenues, and the upper bound of an 86 percent reduction in snowpack could result in a 77 percent (86% x 89.5%) reduction of current revenues. If a ski resort in the Study Area is earning $125 million annually during the ski season, $64.9 to $96.2 million are at risk from climate change's impact on snowpack.

Certain adaptive actions, such as the production of artificial snow, can be used to curb climate change impacts. Artificial snow can be produced at cross-country and downhill ski sites to supplement the lack of natural snowfall during periods of drought. However, this can be expensive, may not be feasible at all sites, and is very energy intensive and therefore generates a large amount of greenhouse gas emissions (see Stewart-Severy 2018). The aquifers that support the production of artificial snow may not have enough water to support artificial snow production. Some resorts could add infrastructure to make recreation areas available at higher elevations, but this can also be expensive and is not always feasible.

Sources: EcoAdapt, Geos Institute, and Conservation Biology Institute, 2013, "Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California," https://www.cakex.org/sites/default/files/documents /SierraProjections_DRAFT130225sm.pdf; Parthum, B., and P. Christensen, 2021, "Recreation Elasticities of Mountain Snowpack and Implications for a Changing Climate," https://bryanparthum.s3.us-east-2.amazonaws.com /Parthum_Christensen_2019a.pdf; Stewart-Severy, Elizabeth, 2018," Snow-Making for Skiing During Warm Winter Comes with Environmental Cost," https://www.npr.org/2018/02/17/584494192/snow-making-for-skiing-during-warm-winters-comes-with-environmental-cost.

Extreme Heat and Warm Nights

Linked with other climate change impacts, such as drought and increased temperatures, increasing extreme heat and warm nights are likely to stress ecosystems. These impacts occur when temperatures are significantly above normal levels. Long-term temperature changes can impact the rain/snow elevation line (i.e., the elevation above which precipitation falls as snow, and below which precipitation falls as rain), as well as vegetation elevation lines and habitat zones (i.e., areas within which certain types of vegetation can thrive).

According to EcoAdapt et al., air temperatures are expected to increase, particularly in the summer months, and these temperature increases could result in drier conditions overall.[186] **Table 50** presents a summary of the temperature projections for the central and southern Sierra Nevada.

Table 50. Expected Temperature Increases in the Central and Southern Sierra Nevada

Season	Historical (1971–2000)	2010–2029	2030–2049	2060–2079
Central Sierra Nevada				
Annual	51.3°F	+2.2° to +2.3°F	+2.7° to +3.2°F	+5.0° to +5.6°F
Summer	66.0°F	+1.4° to +2.5°F	+2.9° to +3.8°F	+4.3° to +6.5°F
Winter	38.3°F	+1.8°F	+1.4° to +2.9°F	+4.1° to +4.7°F
Southern Sierra Nevada				
Annual	48.2°F	+2.3° to +2.5°F	+3.1° to +3.4°F	+5.2° to +6.1°F
Summer	64.4°F	+1.4° to +2.7°F	+2.9° to +4.3°F	+4.3° to +7.2°F
Winter	34.5°F	+2.0°F	+1.8 to +3.4°F	+4.9°F

Source: EcoAdapt, Geos Institute, and Conservation Biology Institute, 2013, "Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California," https://www.cakex.org/sites/default/files/documents/SierraProjections_DRAFT130225sm.pdf.

These temperature increases could result in degraded ecosystem services, and the drier conditions could result in negative impacts on ecosystems and recreational activities. Based on the Climate Change Vulnerability Assessment, several ecosystem types as well as snow- and water-based activities are severely at risk. **Table 51** presents the findings of the Climate Change Vulnerability Assessment.

Table 51. Ecosystem Services, Land Covers, Natural Resources, and Recreational Activities at Risk from Extreme Heat and Warm Nights

Ecosystem or Activity	Score			Discussion
	V	IM	AC	
Ecosystem Services, Land Covers, and Natural Resources				
Aquatic and open water	V5	IM3	AC1	Severe vulnerability based on significant impacts related to extreme heat affecting aquatic systems (dissolved oxygen and nutrient cycling) and low AC.[187]
Deciduous forest	V4	IM3	AC2	High vulnerability based on significant impacts related to reduced moisture available for forests and some AC.[188]
Mixed conifer forest	V5	IM3	AC1	Severe vulnerability based on significant impacts related to increased stress on forests as scrublands and grasslands expand into their area.[189,190]
Sensitive and critical species	V5	IM3	AC1	Severe vulnerability for Sierra Nevada yellow-legged frog and Yosemite toad, along with other sensitive species that rely on aquatic systems, which are expected to see significant impacts with low AC.
Shrubland	V5	IM3	AC1	Severe vulnerability based on riparian areas within shrubland habitat experiencing significant impacts with low AC.[191]
Wetland	V5	IM3	AC1	Severe vulnerability based on less snowfall and earlier snowmelt reducing the amount of water available for wetland habit.[192]

Ecosystem or Activity	Score			Discussion
	V	IM	AC	
Recreational Activity				
Backcountry skiing	V5	IM3	AC1	Severe vulnerability based potential impacts on snowfall and low AC. Extreme heat may cause more precipitation to fall as rain and snow to melt earlier in the spring, which could substantially reduce the backcountry ski season and deter visitors from traveling to the area.[193]
Cross-country skiing	V5	IM3	AC1	Severe vulnerability based potential impacts on snowfall and low AC. Extreme heat may cause more precipitation to fall as rain and snow to melt earlier in the spring, which could substantially reduce the ski season and deter visitors.[194] Alternative locations may be available at higher elevations.[195]
Downhill skiing	V5	IM3	AC1	Severe vulnerability-based potential impacts on snowfall and low AC. Downhill skiing is currently and may continue to see shorter ski seasons as snow melts earlier and more precipitation falls as rain instead of snow.[196] Several downhill ski resorts can make snow to support the ski season and slow the melting of snow.[197]
Fishing	V5	IM3	AC1	Severe vulnerability based on significant impacts to sensitive ecosystems.[198]
Water-based activities	V4	IM2	AC1	High vulnerability based on moderate impacts to aquatic ecosystems.

Based on the vulnerability assessment, the Project Team estimates that roughly $36.7 billion to $177.6 billion in annual ecosystem services value is at risk from the climate impacts of extreme heat and warm nights. These values represent ecosystem services listed in **Table 51**. **Table 52** presents the breakdown of these findings and the potential value of ecosystem services that are at risk from damages due to extreme heat and warm nights, rather than actual expected damages.

Based on the Climate Change Vulnerability Assessment, the Project Team estimates that more than $607.5 million in recreational activities are at risk from extreme heat and warm nights on an annual basis. This estimate represents the value of ecosystem services and recreational activities listed in **Table 52**. **Table 52** presents the breakdown of these findings.

Table 52. Ecosystem Services, Land Covers, Natural Resources, and Recreational Activities at Risk from Extreme Heat and Warm Nights, Millions of 2019$

Ecosystem or Activity	Total Value / Year		
	Low	Average	High
Ecosystem Services, Land Covers, and Natural Resources			
Open Water	$347.1	$506.6	$1,011.9
Deciduous Forest	$850.8	$2,894.3	$6,651.0
Mixed Conifer Forest	$18,770.2	$44,025.7	$89,375.7
Shrubland	$16,503.0	$33,381.1	$56,357.4
Wetland	$254.2	$4,754.5	$24,232.3
Total Ecosystem Services, Land Covers, and Natural Resources	**$36,725.3**	**$85,562.2**	**$177,628.3**
Recreational Activities			
Downhill skiing/Backcountry Skiing			$301.0
Cross-country skiing and snowshoeing			$127.9
Fishing			$160.2
Other snow activities:			$5.5
Off-highway vehicle use, snowmobiling			
Water-based activities:			$12.9
Motorized boating/water activities			
Nonmotorized boating			
Total Recreational Activities			**$607.5**
Total	**$37,332.8**	**$86,169.7**	**$178,235.8**

Note: Values may differ due to rounding.

In total, the Project Team estimates that roughly $37.3 billion to $178.2 billion (with an average of $86.2 billion) in annual ecosystem services, land covers, natural resources, and recreational activities are at risk from the climate impacts of extreme heat and warm nights. These values should not be combined across climate hazards, as this would result in double counting.

Flooding

Inland flooding occurs when there is too much water for natural systems such as creeks, rivers, and soil to remove or absorb, and when artificial drainage systems are overwhelmed. This flooding can be associated with both rain and snowmelt events. Ecosystems provide natural water regulation services. The Baseline Natural Capital Assessment estimated that the Study Area provides $6.6 to $12.9 billion annually in flood prevention services.

While the climate data suggest that overall precipitation levels are likely to likely to remain at historical levels (see **Table 53** for more information), changes in temperature are likely to result in more rain compared to snow at lower elevations, and faster snowmelt in summer, as a result of climate change. These impacts may lead to increased flood risk within the Study Area. Based on the Climate Change Vulnerability Assessment, a few recreational activities are at risk, but there are no ecosystem services or natural resources at severe (V5) or high (V4) vulnerability. **Table 53** presents the findings of the Climate Change Vulnerability Assessment.

Table 53. Recreational Activities at Risk from Flooding

Recreational Activity	Score			Discussion
	V	IM	AC	
Camping, backpacking, primitive camping	V5	IM3	AC1	Severe vulnerability based on significant impacts from proximity of recreation sites and floodable areas. If campsites become unusable, the supply of campsites may be unable to meet the demands of visitors during peak season. This could deter visitors from traveling to the area. Low AC.
Water-based activities	V4	IM3	AC2	High vulnerability based on significant impact from damage to water recreation facilities and erosion of channels. Some AC.

The Project Team did not monetize the potential impacts of flooding on ecosystems and recreational activities. Impacts are likely to be highly specific to locations and circumstances, and the Project Team thus could not quantify or monetize the impacts based on the available data about risk and vulnerability.

Forestry Pest and Diseases

Forested land, including deciduous forest, coniferous forest, and desert woodland, covers 2.4 million acres, or roughly 23 percent of the Study Area. The Project Team's Natural Capital Baseline Assessment estimates that these land covers provide $20.0 billion to $96.4 billion in ecosystem service value annually. The Climate Change Vulnerability Assessment suggests that several ecosystems and services are at risk from forestry pests and diseases, fungal infections, and other conditions that may thrive under future climate conditions. **Table 54** presents the findings of the Climate Change Vulnerability Assessment.

Table 54. Ecosystem Services, Land Covers, Natural Resources, and Recreational Activities at Risk from Forestry Pests and Diseases

Ecosystem or Activity	Score			Discussion
	V	IM	AC	
Ecosystem Services, Land Covers, and Natural Resources				
Deciduous forest	V4	IM3	AC2	High vulnerability based on significant impacts from diseases, which may cause shifts in species composition. Some AC as deciduous forests can typically recover, although sudden species death may not be overcome.[199]
Mixed conifer forest	V5	IM3	AC1	Severe vulnerability based on significant impacts to conifer forest, particularly if already weakened by heat and drought. Several pests exist that can decimate conifer forests.[200] Low AC as a result of expected stress from heat and drought.
Sensitive and critical species	V5	IM3	AC1	Severe vulnerability based on significant impacts to sensitive species such as the Pacific fisher and the yellow-legged frog.[201] Low AC.

Ecosystem or Activity	Score			Discussion
	V	IM	AC	
Recreational Activities				
Gathering forest products	V5	IM3	AC1	Severe vulnerability based on significant impacts to forests from bark beetles and other pests and diseases. Low AC as a result of large Study Area and limited resources.
Viewing natural features and wildlife	V4	IM3	AC2	High vulnerability based on significant impacts to forested land. Some AC as a result of large Study Area and limited resources.

The Project Team did not explore the impacts of forestry pests and diseases in additional detail. Pest and disease migration are specific to circumstances, and the Project Team thus could not quantify or monetize the impacts based on the available data about risk and vulnerability.

Human Health Hazards

As temperatures rise due to climate change, regions may become more habitable for diseases, new pathogens, and organisms that can carry diseases. Climate-related human health hazards are often diseases carried by animals that are considered pests, such as mice and rats, mosquitos, and ticks, but can also be spread by humans. While specific ecosystems may not be at risk, many outdoor recreational activities that bring people into close contact with nature may increase their risk of disease. For example, increasing drought and heat conditions are expected to create beneficial conditions for the presence of West Nile virus within the region, threatening many recreational activities. The Climate Change Vulnerability Assessment estimates that no ecosystem services or natural resources are at severe (V5) or high (V4) vulnerability. **Table 55** presents the findings of the Climate Change Vulnerability Assessment.

Rock Climbing

A recent economic impact assessment of rock climbers in Bishop, California, found that climbers visiting Bishop/Inyo County spend an estimated $15.6 million dollars annually in Bishop and Inyo County in a typical year. For comparison, the study found that the COVID-19 pandemic decreased visitation by nearly 65 percent, resulting in a loss to Bishop and Inyo County of over $10 million dollars in potential climber expenditures in 2020.

Source: Maples et al., n.d., Eastern Kentucky University, Division of Regional Economic Assessment and Modeling.

Table 55. Recreational Activities at Risk from Human Health Hazards

Recreational Activity	Score			Discussion
	V	IM	AC	
Camping, backpacking, and primitive camping	V4	IM3	AC2	High vulnerability due to significant impacts from vector-borne diseases and other illnesses. If human health hazards increase, such as the hantavirus in Yosemite National Park, parks and forests may temporarily close, deterring visitors from traveling to the Study Area.[202] Some AC as campgrounds can be managed and safety precautions can be taken.
Fishing	V4	IM3	AC2	High vulnerability due to significant impacts from proximity to water and potential vector-borne illnesses from mosquitos and ticks. Examples include Lyme disease or West Nile virus.[203] Some AC from prevention and safety measures.
Gathering forest products	V4	IM3	AC2	High vulnerability due to significant impacts from vector-borne diseases and other illnesses. Some AC from prevention and safety measures.
Hiking/walking	V4	IM3	AC2	High vulnerability due to significant impacts from exposure to mosquitos, ticks, and rodents, which carry diseases. Some AC from prevention and safety measures.
Hunting	V4	IM3	AC2	High vulnerability due to significant impacts from exposure to mosquitos, ticks, and rodents, which carry diseases. Some AC from prevention and safety measures.
Rock climbing	V4	IM3	AC2	High vulnerability due to significant impacts from exposure to mosquitos, ticks, and rodents, which carry diseases. Some AC from prevention and safety measures.
Water-based Activities	V4	IM3	AC2	High vulnerability due to significant impacts from proximity to water and potential vector-borne illnesses from mosquitos and ticks. Examples include Lyme disease or West Nile virus.[204] Some AC from prevention and safety measures.

The Project Team did not monetize the impacts of human health hazards because data gaps make it difficult to quantify impacts. Vector-borne diseases are expected to increase as a result of climate change, but the exact incidence rate is unclear. Further research could attempt to close this data gap and facilitate the monetization of potential health impacts.

Landslides and Debris Flows

Several recreational activities are particularly at risk of damages from landslides and debris flows, including isolated activities such as backcountry skiing and camping. Landslides and debris flows may occur more frequently as more precipitation falls as rain instead of snow, which may result in recreational activities being directly impacted, or recreation areas may become isolated if transportation systems are disrupted. The Climate Change Vulnerability Assessment estimates that no ecosystem services or natural resources are at severe (V5) or high (V4) vulnerability. **Table 56** presents the findings of the Climate Change Vulnerability Assessment.

Table 56. Recreational Activities at Risk from Landslides and Debris Flows

Recreational Activity	Score			Discussion
	V	IM	AC	
Backcountry skiing	V5	IM3	AC1	Severe vulnerability due to significant impacts resulting from damages to steep mountainous areas, which can alter ski areas season to season or block access to these areas. Low AC due to remote nature of the ski areas.
Camping, backpacking, and primitive camping	V4	IM3	AC2	High vulnerability due to significant impacts from several campgrounds being within or below landslide susceptibility areas. Some AC if areas are able to complete slope stabilization measures.
Downhill skiing	V4	IM3	AC2	High vulnerability due to significant impacts from areas that can be damaged by landslides, causing closure. Area may become isolated and trap those in the area.[205] Some AC resulting from slope stabilization in the off season.
Hiking/walking	V4	IM3	AC2	High vulnerability due to significant impacts to trails resulting from damages from mudslides. Landslides can trap hikers as well—e.g., a rockslide on Highway 168 blocked people from traveling out of the North Lake and Lake Sabrina Area in 2018.[206] Some AC resulting from slope stabilization.
Horseback riding	V4	IM3	AC2	High vulnerability due to significant impacts to trails resulting from damages from mudslides. Some AC resulting from slope stabilization.
Rock climbing	V4	IM3	AC2	High vulnerability due to significant impacts from landslides and remote nature of activity. Some AC resulting from slope stabilization.

The Project Team did not monetize the potential impacts of landslides on ecosystems and recreational activities. Impacts are likely to be highly specific to locations and circumstances, and

the Project Team thus could not quantify or monetize the impacts based on the available data about risk and vulnerability.

Severe Weather

Certain recreational activities are considered vulnerable to the impacts of severe weather conditions. According to the Climate Change Vulnerability Assessment, severe weather includes intense winds, lightning, hail, and intense rainstorms, among other severe events. Severe weather has the potential to disrupt normal operation, access, and safety of popular recreational activities found in the Study Area. Unfavorable conditions for popular recreational activities due to severe weather may result in less participation and a reduction in benefits (e.g., revenue generated). The Climate Change Vulnerability Assessment estimates that no ecosystem services or natural resources are at severe (V5) or high (V4) vulnerability. **Table 57** shows the findings from the Climate Change Vulnerability Assessment for severe weather impacts.

Table 57. Recreational Activities at Risk from Severe Weather

Recreational Activity	Score			Discussion
	V	IM	AC	
Camping, backpacking, and primitive camping	V4	IM3	AC2	High vulnerability due to significant impacts from severe weather as visitors may be deterred from camping. Campgrounds could also be damaged by severe weather, causing them to close and reducing capacity.[207] If campgrounds are damaged, there may not be an adequate supply to meet the needs of visitors.
Downhill skiing	V4	IM2	AC1	High vulnerability due to significant impacts from severe weather from potential interference to ski lifts from high winds or low visibility.
Fishing	V5	IM3	AC1	Severe vulnerability due to significant impacts from severe weather because fishing sites and fish can be harmed by hail and atmospheric rivers that increase the volume and velocity of water in lakes and streams. Visitors can wait until severe weather passes to engage in this activity.
Rock climbing	V5	IM3	AC1	Severe vulnerability due to significant impacts from severe weather as rock climbers are directly exposed, which may create dangerous conditions for climbers. Rock climbers can wait until severe weather has passed to engage in this activity.
Water-based Activities	V5	IM3	AC1	Severe vulnerability due to significant impacts from severe weather as water-based recreational activities can become dangerous, such as in hail or lightning storms. Visitors can wait until severe weather has passed to engage in this activity.

Although severe weather events are likely to discourage many recreational activities while these events persist, these events are not expected to result in long-lasting damages across wide regions of the Study Area. Due to the limited nature of these expected impacts, the Project Team did not attempt to quantify or monetize the impacts based on the available data about risk and vulnerability.

Severe Winter Weather

Certain recreational activities are considered vulnerable to the impacts of severe winter weather conditions. According to the Climate Change Vulnerability Assessment, severe winter weather includes heavy snowfall, ice storms, extreme cold, and avalanches, among other similar severe winter events. Severe winter weather has the potential to disrupt normal operation, access, and safety of popular recreational activities found in the Study Area. Unfavorable conditions for popular recreational activities due to severe winter weather will likely result in less participation and a reduction in benefits (e.g., revenue generated). **Table 58** shows the findings from the Climate Change Vulnerability Assessment for severe winter weather impacts.

Table 58. Recreational Activities at Risk from Severe Winter Weather

Recreational Activity	Score			Discussion
	V	IM	AC	
Backcountry skiing	V4	IM2	AC1	High vulnerability due to moderate impacts from severe winter weather because it may prevent backcountry skiers from accessing these sites, and avalanche conditions, extreme cold, or heavy snowfall may limit access to the region. There is little that can be done to protect this activity from disruption during severe winter weather.
Cross-country skiing	V4	IM2	AC1	High vulnerability due to moderate impacts from severe winter weather because cross-country skiing can be disrupted by heavy snowfall or extreme cold that make conditions difficult for the activity. Visitors may be deterred from traveling to the area for this activity during unfavorable conditions. Storms could last for days or weeks.
Downhill skiing	V4	IM3	AC2	High vulnerability due to significant impacts from severe winter weather because downhill skiers may be deterred from buying lift tickets or traveling to the ski resorts if the weather creates dangerous conditions. Some individuals may travel to the Study Area during severe winter weather events to ski on freshly fallen snow. However, driving can be dangerous during winter storms.
Other snow activities	V4	IM3	AC2	High vulnerability due to significant impacts from severe winter weather because visitors may be deterred from participating in these activities or traveling to the Study Area if the severe winter weather creates dangerous conditions. Many snow activity areas have adapted to severe winter weather and may have snow removal systems and barriers to freezing temperatures.

While many of the winter-related recreational activities could potentially benefit from heavy snowfall or lower temperatures, severe winter weather may prevent participation due to unfavorable or dangerous conditions. Severe weather events are likely to discourage many winter-recreational activities while events persist and conditions remain unfavorable. Similar to the severe weather hazard, although these events are likely to discourage many recreational activities while they persist, they are not expected to result in long-lasting damages across wide regions of the Study Area. Due to the limited nature of these expected impacts, the Project Team did not attempt to quantify or monetize the impacts based on the available data about risk and vulnerability.

Wildfire

Wildfires are an essential part of the ecology of the Study Area. Many plant species native to the Sierra Nevada can tolerate, benefit from, or even accelerate fires. Large wildfires are becoming more common, and recent scientific literature estimates that future wildfires could continue to increase in frequency and severity. The escalating size and intensity of wildfires can be highly damaging and costly to the ecosystem and land management organizations. Changes in wildfire regimes driven by climate change are likely to impact ecosystem services on which California citizens rely, including carbon sequestration in California forests; quality, quantity, and timing of water runoff; air quality; wildlife habitat; viewsheds; and recreational opportunities.[208]

Wildfire Management

California state government is investing heavily in wildfire management with $1 billion to address a comprehensive wildfire and forest resilience strategy. The California Department of Forestry and Fire Protection has spent an average of approximately $700 million on fire suppression expenditures between 2015 and 2019 with expenditures peaking in 2019 at $890 million. This value will likely grow due to future climate changes impacting wildfires.

Sources: Officer of the Governor, 2021, "Governor Newsom Proposes 2021-22 State Budget," https://www.gov.ca.gov/2021/01/08/governor-newsom-proposes-2021-22-state-budget/; CAL FIRE, 2020, Emergency Fund Fire Suppression Expenditures, updated September,

Wildfire can be beneficial to the maintenance of various land cover types, leading to healthy and diverse ecosystems. Certain land cover types found in the Study Area depend on periodic wildfires for regeneration and ecological balance.[209] Beneficial wildfires tend to burn at lower intensities, can help manage fuel buildup, activate certain seeds, and help soil regeneration (releasing nutrients and allowing for more sunlight). These benefits act as catalysts for biological diversity, and they also improve soil retention and water filtration capabilities. Climatic changes resulting in earlier snowmelt and higher temperatures have also resulted in longer fire seasons, two months longer than the average in the 1970s.[210] The expansion of human populations and inhabited areas has also resulted in more human-caused fires.[211]

Wildfire can be ecologically destructive depending on fire size, frequency, intensity, and type of vegetation burned. High-intensity burns consume vegetation from crowns to roots, burn deep into the ground, damage soils, and lengthen the recovery time between burn intervals. Increased temperatures, earlier snowmelt, and increased human population interaction have increased the sources of ignition for large uncontrolled wildfires. Warmer temperatures (i.e., increased evaporation), reduced precipitation, increased fuel loading, increased human ignitions, and changing weather patterns (e.g., shorter winters) have contributed to the increased size, severity, and frequency of wildfires and are likely to continue doing so in the future. **Table 59** shows the findings from the Climate Change Vulnerability Assessment for wildfire.

Table 59. Ecosystem Services, Land Covers, Natural Resources, and Recreational Activities at Risk from Wildfire

Ecosystem or Activity	Score			Discussion
	V	IM	AC	
Ecosystem Services, Land Covers, and Natural Resources				
Aquatic and open water	V4	IM3	AC2	High vulnerability based on significant impacts related to fire retardants and sediment from fighting wildfires and post-wildfire runoff into aquatic habitats. This can pollute the water to the point that the ecosystem cannot filter out the pollutants. Reduced water quality can cause die-off of water-dependent species. Aquatic habitat may have a difficult time adapting to increased wildfires in their watersheds.
Mixed conifer forest	V5	IM3	AC1	Severe vulnerability based on significant impacts related to loss of mature conifer trees and wildlife habitat in conifer forests from wildfire. The ecosystem may shift in composition.[212] Warmer and drier conditions can reduce the recovery potential for conifer forests to wildfires.[213] Conifer forests may also migrate upslope to escape rising temperatures.
Scenic Views	V5	IM3	AC0	Severe vulnerability based on significant impacts related to the destruction of forested ecosystems and impacts on water and lake ecosystems from wildfire. This harms the scenic views in and surrounding the Study Area and causes visitors not to travel. Currently, there are no feasible means for scenic views to adapt to wildfires.
Sensitive and critical species	V5	IM3	AC1	Severe vulnerability based on significant impacts related to sensitive species, such as sage grouse, whose habitat may be lost or degraded due to wildfires in the region.[214] This could reduce the population numbers in already sensitive species. Sensitive, threatened, or endangered species may be protected by state and federal laws but may face difficulties adapting to an increase in wildfires in the region.
Recreational Activity				
Camping, backpacking, and primitive camping	V5	IM3	AC1	Severe vulnerability based on significant impacts related to the location of campgrounds in wildfire-prone areas. Wildfires can damage these sites, rendering them unusable for visitors. Defensible space and fuel management programs by local jurisdictions, National Park Service (NPS), and U.S. Forest Service (USFS) can reduce damage to campgrounds across the Study Area.
Fishing	V5	IM3	AC1	Severe vulnerability based on significant impacts related to fishing sites being damaged by post-wildfire erosion and landslides, as well as fire retardants that affect water quality. This can reduce available sites, deterring visitors. Some fishing sites may also close due to a nearby wildfire. Post-fire slope stabilization and erosion control can help ensure fishing is a viable recreational activity in the Study Area.
Gathering forest products	V5	IM3	AC1	Severe vulnerability based on significant impacts related to dependence on healthy forest ecosystems. More frequent and severe wildfires can destroy or damage forest products.

Ecosystem or Activity	Score			Discussion
	V	IM	AC	
Horseback riding	V4	IM2	AC1	High vulnerability based on moderate impacts related to the potential of wildfires burning horseback riding trails. They may not be suitable for horses to travel on, which would reduce the number of horseback riding trails available in the Study Area.
Rock climbing	V4	IM2	AC1	High vulnerability based on moderate impacts related to the potential for rock climbing areas to be located in wildfire hazard areas. Wildfires can harm the trails and roadways that rock climbers use to get to these sites. The vistas that rock climbers may look forward to may also be altered by more frequent wildfires.
Viewing natural features and wildlife	V5	IM3	AC1	Severe vulnerability based on significant impacts related to wildfire burns scarring scenic views. Prescribed burns and vegetation management can reduce wildfires and ensure that natural features are not harmed as severely from wildfires. However, this can be expensive and may be difficult to accomplish in wilderness areas. There may not be alternatives that provide the same scenic views in other areas.
Water-based activities	V5	IM3	AC1	Severe vulnerability based on significant impacts related to wildfires potentially harming water-based activities from post-wildfire landslides or degradation in water quality from fire retardants. This could reduce the availability of several different types of water-based recreational activities. Post-fire slope stabilization and erosion control can also help ensure water-based activities remain a viable recreational activity.

Over the last five years, the Study Area has reported a total of 391,689 acres burned by wildfire and 10,316 acres burned by prescribed burns.[215] For this analysis, the Project Team anticipates future wildfires to burn on average 78,338 acres per year (391,689 ÷ 5).[216] This historical annual average allows the Project Team to define a range of plausible outcomes for potential changes in wildfire regimes, which can then be used in future work to assess the effectiveness of combined adaptation and mitigation decisions.

EcoAdapt et al. predict that by 2060 to 2079, the area burned by wildfire in the Sierra Nevada region is expected to increase by 35 to 169 percent, with forested areas in the north and central Sierra showing greater potential increases in area burned.[217] The frequency of large fires and the total area burned in California are predicted to continue increasing over the next century, with total area burned increasing 7 to 41 percent by 2050 and 12 to 74 percent by 2085.[218] Models by Westerling et al. project annual area burned in the central and southern Sierra Nevada to increase 59 to 169 percent, and 35 to 88 percent, respectively.[219] **Table 60** shows the projected average annual increase in wildfire acreage burned for the next century.

Table 60. Projected Increase in Average Acreage Burned

Area Burned	2005–2034	2035–2064	2065–2099
Central Sierra Nevada	**+8 to +38%**	**+33 to +72%**	**+59 to +169%**
Southern Sierra Nevada	**+4 to 25%**	**+17 to +53%**	**+35 to +88%**

Source: EcoAdapt, Geos Institute, and Conservation Biology Institute, 2013, "Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California."

Note: This table uses historical wildfire data from 1961 to 1990.

The process of monetizing the impacts of wildfires begins with quantifying the various effects wildfires may have on the vegetation found in the Study Area. The Project Team's method for estimating this economic impact relies on quantifying the size and scope of likely wildfires. For this analysis, the Project Team used historical wildfire data to estimate an average acreage burned combined with percentage of basal area (BA) loss to represent the severity of a fire. basal area loss is an estimate of the volume of vegetation burned, not just the surface area. basal area loss is a simple and effective assessment of real fire damage to vegetation.

To evaluate the size of wildfire impacts to ecosystem services, the Project Team relied on historical wildfire data for the Study Area. From 2015 to 2019, the Study Area has reported a total of 391,689 acres burned, or an average of 78,338 acres per year, as mentioned above.[220] The Project Team recognizes that recent fire activity has become larger, more severe, and more frequent. This analysis is intended to present a rough order of magnitude estimate for the value of ecosystem services at risk of being lost, interrupted, or damaged by wildfires.

To evaluate the scope of wildfire impacts to ecosystem services, the Project Team used existing scientific literature that links the loss of ecosystem service function capacity to percentage decreases in basal area (or damage). Geospatial data from the U.S. Department of Agriculture National Forest System Rapid Assessment of Vegetation Condition after Wildfire (RAVG) system were used to estimate changes in vegetation coverage after wildfires.[221] The RAVG program provides assessments of vegetation conditions (burn severity) following large wildland fires on forested National Forest System lands, and the program is ideal for detecting the change from healthy green vegetation to dead vegetation, bare soil, and ash. The Project Team recognizes that the type of land cover mix burned, and the intensity of a wildfire are inherently unpredictable; therefore, the resulting analysis uses averages across all land cover types susceptible to wildfire within the Study Area.

Table 61 provides estimates of the reduction in ecosystem service function capacity within each level of basal area loss associated with fire severity. This method allows the Project Team to differentiate between a range of ecosystem services at risk from wildfire damage based on the severity of the fire. The combination of acreage burned and basal area loss (lost ecosystem function capacity) allowed the Project Team to quantify and monetize the impacts from current wildfire regimes.

Table 61. Ecosystem Service Function Capacity due to Basal Area Loss

Severity	Basal Area Loss %	ES Function Capacity %
No Fire	0%	100%
Low	0–25%	90%
Medium	25–75%	50%
High	75–100%	10%

Source: Batker et al., 2013, "Preliminary Assessment: The Economic Impact of the 2013 Rim Fire on Natural Lands," *Earth Economics*.

The Natural Capital Baseline Assessment estimates that the Study Area provides a total of $41.5 billion to $188.8 billion in annual ecosystem services. To estimate the potential economic value of future wildfire scenarios, the Project Team selected land cover types most impacted by wildfires, including coniferous forest, deciduous forest, desert shrub, desert woodland, grassland, and shrubland, and removed specific land cover types from the total, such as open water, wetlands, and barren, which are not expected to be impacted. This calculation results in a total of $40.9 billion and $163.4 billion of annual ecosystem services at risk to changes in wildfire frequency and severity. **Table 62** shows the range of ecosystem service dollar amounts for the land cover types most likely impacted by wildfires.

Table 62. Value of Selected Land Cover Types Potentially Impacted by Wildfires, Millions of 2019$

Land Cover Type	Area (Acres)	Total Value / Year		
		Low	Average	High
Coniferous Forest	2,103,843	$18,770.2	$44,025.7	$89,375.7
Deciduous Forest	182,159	$850.8	$2,894.3	$6,651.0
Desert Shrub	5,157,149	$3,573.9	$5,200.8	$6,827.8
Desert Woodland	162,687	$145.5	$258.9	$342.6
Grassland	124,552	$1,022.7	$2,193.9	$3,852.8
Shrubland	1,837,064	$16,503.0	$33,381.1	$56,357.4
Total:	**9,567,454**	**$40,866.1**	**$87,954.8**	**$163,407.2**

Source: Baseline Assessment

Notes: Values may differ due to rounding. Values in this table exclude recreational activities.

The total ecosystem service values from the Natural Capital Baseline Assessment were used to derive per-acre dollar values for each land cover type.* **Table 63** below shows the per-acre monetized value for each land cover type at risk of a service interruption or damage used in this wildfire case study.

* To derive per-acre dollar values for each land cover type, the Project Team divided total value of ecosystem services by land cover, from the baseline assessment, by the land cover area (in acres) found in the Study Area.

Table 63. Total Ecosystem Service Value per Acre by Land Cover Type at Risk for Wildfire Damage

Land Cover Type	Area (Acres)	Per Acre Value / Year (2019$)		
		Low	Average	High
Coniferous Forest	2,103,843	$8,921.9	$20,926.3	$42,482.1
Deciduous Forest	182,159	$4,670.9	$15,888.8	$36,511.8
Desert Shrub	5,157,149	$693.0	$1,008.5	$1,323.9
Desert Woodland	162,687	$894.2	$1,591.5	$2,105.8
Grassland	124,552	$8,210.9	$17,614.1	$30,933.2
Shrubland	1,837,064	$8,983.3	$18,170.9	$30,678.0

Note: Values in this table exclude recreational activities.

To estimate a typical wildfire's impact on the value of ecosystem services, the Project Team used ESSRP's average acreage burned annually for the last five years (78,338 acres, as mentioned previously). The Project Team then multiplied the per-acre values for each land cover type by this average annual acreage to approximate the total loss of services for an entire land cover type (e.g., a scenario where an entire land cover type is burned). The Project Team then used the capacity percentages from **Table 60** to determine the range of the ecosystem service values lost based on the severity of the fire. The tables found in **Appendix C** show the estimated reduction in ecosystem service capacity based on wildfire severity for an entire land cover type.

Wildfire Impacts to Recreation

The Project Team estimates that recreation generates $2.0 billion in value to the region on an annual basis. Wildfires place the majority of land cover types, and the recreational activities they provide, at risk of being damaged, interrupted, or lost. Recreation impacts from wildfires will vary depending on the location and the site-specific activity (e.g., campsites compared to rural areas). Damage to any recreational activity will be additive to ecosystem damages.

The Project Team anticipates a typical wildfire to burn a combination of land cover types; therefore, the Project Team averaged each land cover's estimated ecosystem service capacity reduction value to approximate a likely impact across the selected land cover types susceptible to fires. Table 64 summarizes the averaged monetized value of ecosystem services lost at each level of fire severity.

Table 64. Average Value of Reduced Ecosystem Capacity due to Basal Area Loss, Millions of 2019$

Severity (% Capacity)	Low	Average	High
No fire (100%)	$0.0	$0.0	$0.0
Low (90%)	$42.3	$98.2	$188.1
Medium (50%)	$211.3	$490.9	$940.3
High (10%)	$380.4	$883.7	$1,692.5
Total loss (0%)	$422.7	$981.8	$1,880.6

Note: Values may differ due to rounding.

Values in this table exclude recreational activities.

Results from **Table 64** show the range of annual monetized impacts for the average acreage burned in the Study Area. The total annual value of the ecosystem services at risk of being lost, damaged, or interrupted by wildfire can range from $423.0 million to $1.9 billion (with an average of $981.8 million), or approximately 1 percent of the total ecosystem services from the Natural Capital Baseline Assessment.* Although the likelihood of a destructive wildfire resulting in a total ecosystem service loss is small, the values in **Table 64** are representative of a typical yearly loss of economic value due to wildfire.

There are several important caveats to this analysis. The Project Team acknowledges the speculative nature of wildfire occurrence. In any given period, the effects from a single wildfire can accumulate or be compounded due to land cover recovery time between burn intervals, the size and scale of multiple wildfires, and the uncertain mix of land cover types burned.

Additionally, the Project Team acknowledges that using basal area may underestimate the actual impacts of wildfire, and losses of ecosystem services may be significantly larger. Wildfire history demonstrates that the initial basal area loss reported postfire does not capture basal area loss that continues after the immediate analysis. Ecosystem services may take considerable time to recover back to pre-burn valuation levels.

The Project Team also acknowledges that wildfire is a natural element of many ecosystem lifecycles and expects wildfires to contribute to the restoration or replenishment of select ecosystem services following a burn. Each ecosystem will express different capacity losses and varying recovery rates over time. While some wildfire damage may be tolerated by various ecosystems, the values in **Table 64** display the magnitude of potential damage at risk from wildfire annually.

* To arrive at this value, the Project Team divided the cost of ecosystem services at risk from wildfire by the total ecosystem services (from the Baseline Natural Capital Assessment).

SECTION 8: RECOMMENDED ACTIONS

Conclusions

The Climate Change and Resilience Assessment conducted for *A Changing Climate | Vulnerability in California's Eastern Sierra* provide several key findings related to how climate change will affect sustainable recreation and tourism in the Eastern Sierra region. These important findings include:

- Ecosystem services provide an average of $95 billion per year in services to the Eastern Sierra region, with the highest valued service being carbon storage and water quality.
- Poor air quality, drought, extreme heat, and wildfire are projected to reduce the value ecosystem services by an average of $270 million (per year). Other hazards are also projected to have significant impacts.
- Wildfire creates the most vulnerabilities for all populations, recreation activities, and other community assets compared to other hazards in the region.
- Energy and water systems are the most vulnerable infrastructure to climate change hazards.
- Tribal communities and other frontline groups* face substantial health risk from climate change hazards.
- Homes, campgrounds, lodging, ranger stations, administrative centers, and other buildings are at risk of damage from climate change hazards.
- More precipitation is likely to fall as rain instead of snow, reducing the winter recreation season and associated economic activities.
- Water-based recreation activities are likely to decrease due in large part to increases in drought and extreme heat conditions.
- Summer recreation activities in all jurisdictions will likely be disrupted by climate change hazards.
- Changing temperature and precipitation patterns will likely cause widespread harm to forests, wetland, and aquatic habitats.
- Recreation and tourism industry workers are likely to face economic harm when recreation activities are disrupted.

Recommended Actions

The Project Team used the results of the Baseline Natural Capital Assessment, Climate Change Vulnerability Assessment, and Climate Change Natural Capital Assessment, as well as state and

* Based on the *Defining Vulnerable Communities in the Context of Climate* Change report developed by the ICARP Technical Advisory Council, frontline communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts.

federal guidance, legislation, and funding opportunities, to develop a set of five projects for the SRTI Study Area to reduce vulnerabilities and increase sustainable, resilient recreation in the short-and long-term. The projects are provided in an "umbrella" format, each including multiple smaller tasks or projects that incorporate the results from other tracks in the SRTI. The goal of this format is to build off of the results of the other tracks in the SRTI effort, while also addressing climate change vulnerabilities, to create a comprehensive set of implementable projects in the Study Area. These projects bring together elements from all portions of the Study Area to accomplish the following goals:

1. Steward, protect, and conserve natural and cultural resources.
2. Identify and enhance opportunities for sustainable recreation.
3. Improve critical infrastructure and emergency response systems to create climate resilient communities.

The following five recommended actions provide an overview of projects and represent how the Eastern Sierra region can meet these goals. Included are statements of purpose, brief descriptions, and timelines for implementation.

SRTI Climate: Funding Ready Projects

The Funding Ready Projects should include projects that have climate resiliency and/or sustainability co-benefits. The projects have been identified by the SRTI "Recreation Stakeholders," the Climate Adaptation and Resilience Assessment Project Team or proposed by the U.S. Forest Service, National Park Service, and other regional partners as ready to fund for plan preparation, permitting, or construction. Co-benefits are considered side results of a project that are beneficial but may not be directly related to sustainable recreation. To be funding ready, projects must meet the criteria of having a defined location, including steps that can be funded, and provide or include physical structures or hazard-reduction programs. The Funding Ready Projects are intended to be implemented in the short-term (one to five years) as funding becomes available through federal, state, or public-private partnership sources.

SRTI Climate: Regional Asset Inventory

The Regional Asset Inventory should include an inventory of all buildings, infrastructure, and related assets for all jurisdictions located within the SRTI Study Area. This would include Global Positioning System (GPS) and Geographic Information System (GIS) spatial data for mapping purposes that would create a database of assets with key attribute information. The inventory would focus on physical, natural, and cultural assets to establish a baseline of understanding for key Study Area conditions. Asset inventory components would include, but are not limited to, asset name, category or type, location, jurisdiction, natural features, historic significance, and current condition. This project would be implemented in the short-term, or within approximately one year of funding.

SRTI Climate: Gap Assessment

The Gap Assessment would follow the completion of the SRTI Climate: Asset Inventory to analyze what is currently on the ground and what is needed to meet the current and future demands of sustainable recreation activities and climate change in the region. Using the established baseline,

the Gap Assessment would identify the projected demand for sustainable recreation and tourism within the Study Area and the assets necessary to support this demand. The Gap Assessment would recognize that an influx of recreationists requires new ways of managing and providing recreation activities, which calls for an analysis of changing trends within the Study Area and changing demands for season-oriented recreation. This project would be implemented in the short-term, approximately one year after the SRTI Climate: Regional Asset Inventory is completed.

SRTI Climate: Sustainable Infrastructure Master Plan

The Sustainable Infrastructure Master Plan would build off of the SRTI Climate: Gap Assessment and would provide a recommended set of projects and programs to help the region address the gaps identified. Detailed projects would be added from the SRTI Climate: Gap Assessment. The master plan document would include an overview of the Study Area, projections that form the basis for future infrastructure needs, identification of SRTI Asset Owners, SRTI Infrastructure Improvement Projects, and SRTI Infrastructure Phasing and Implementation. This master plan would be a dynamic document that could be updated regularly as projects are completed and new needs arise to meet the needs of future sustainable recreation. This project would be implemented in the medium-term, with plan development taking approximately two years and long-term implementation taking between five and 30 years depending on funding.

SRTI Climate: Sustainable Recreation Outreach and Education

Sustainable Recreation Outreach and Education includes programs for incorporation into the SRTI "Visitor Connection Package" to educate residents, visitors, and workers about Sustainable Recreation and Stewardship, tribal culture, climate change hazards, and historical and interpretive opportunities within the Study Area. The intent of this project is to build off of the work already occurring at the local, state, and federal level and develop consistent and comprehensive content that reinforces regional priorities. The outreach and education programs would focus on t climate change adaptation, community resilience messaging, and related information as both standalone and supportive materials. Implementation actions would include data gathering, developing a vision and purpose, collateral development, and collateral review and rollout. This could be completed in the short-term, with materials development taking 12 to 18 months and information dissemination occurring over three years, prior to revisiting and revising program elements.

Federal and State Regulation Alignment

The assessments conducted as part of *A Changing Climate | Vulnerability In California's Eastern Sierra* and the five recommended actions align with federal and State regulations for sustainable recreation, greenhouse gas reduction, and a resilient future. Several of the short-term and long-term projects proposed in this section could be funded through the Land and Water Conservation Fund, which received an influx of funding through the Great American Outdoors Act for needed maintenance of critical facilities in national parks, forests, wildlife refuges, recreation areas, and tribal lands across the United States. On a statewide level, the analyses conducted and actions recommended as part of this report emphasize the need for a multi-jurisdictional approach to sustainable recreation and community resilience, which is the primary goal of the CALREC Vision, which emphasizes that local and regional organizations must work with State policymakers to create partnerships and begin the on-the-ground work to create a sustainable future for outdoor recreation in the State. *A Changing Climate | Vulnerability In*

California's Eastern Sierra is also consistent with the Agreement for Shared Stewardship of California's Forests and Rangelands, providing short- and long-term project-based solutions to sustainably manage forest land in the Eastern Sierra region to reduce the threat of wildfire and increase the resiliency of forest ecosystems.

Most importantly, *A Changing Climate | Vulnerability In California's Eastern Sierra* is focused on the natural lands that support outdoor recreation in the Eastern Sierra region. The assessments conducted as part of the report connect the watersheds, mountains, plants, wildlife, and other natural features throughout the Study Area that provide benefits to a diversity of people and communities. The recreation provided by the Eastern Sierra region offers opportunities for people to connect to the natural world and benefit from the abundant ecosystem services in the region. The recommended actions present project and nature-based solutions to protect ecosystem services and increase the resiliency of the region's outdoor recreation economy. This is consistent with the goals of the recent California Executive Order N-82-20, which contains the following objectives to achieve greenhouse gas reduction and increase community resilience:

1. Safeguard our State's economic sustainability and food security.
2. Protect and restore biodiversity.
3. Enable enduring conservation measures on a broad range of landscapes, including natural areas and working lands, in partnership with land managers and natural resource user groups.
4. Build climate resilience, reduce risk from extreme climate events and contribute to the State's effort to combat climate change.
5. Expand equitable outdoor access and recreation for all Californians.

SECTION 9: GLOSSARY AND ABBREVIATIONS

Abbreviations

AC: Adaptive capacity

APG: *California Adaptation Planning Guide*

CAL FIRE: California Department of Forestry and Fire Protection

Cal OES: California Governor's Office of Emergency Services

CALVEG: Classification and Assessment with Landsat of Visible Ecological Groupings

CO_2: Carbon dioxide

ESSRP: Eastern Sierra Sustainable Recreation Partnership

EV: Electric vehicle

GHG: Greenhouse gas

GIS: Geographic Information System

ICF: ICF International, LLC

IM: Impact

LADWP: Los Angeles Department of Water and Power

LTBMU: Lake Tahoe Basin Management Unit

MLTPA: Mammoth Lakes Trails and Public Access Foundation

NPS: National Park Service

RAVG: Rapid Assessment of Vegetation Condition after Wildfire

RCPs: Representative Concentration Pathways

SRTI: Sustainable Recreation and Tourism Initiative

USFS: United States Forest Service

V: Vulnerability

Glossary

Adaptation: Making changes in response to current or future conditions (such as the increased frequency and intensity of climate-related hazards), usually to reduce harm and to take advantage of new opportunities.[222, 223]

Adaptive Capacity: The "combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities".[224]

Asset: A valued feature of a community that may be harmed by climate change. Assets may include buildings, infrastructure, community services, ecosystems, and economic drivers.

Benefit Transfer: Involves taking the estimates of the value of ecosystem services from existing studies and applying them to a new context. Broadly broken into benefit function transfer and benefit value transfer.

Benefit Function Transfer: Involves taking the function used to estimate benefits in the original study and applying the function to the new study context.

Benefit Transfer Value: Involves taking point estimates, or values, from the primary source and applying them directly to the new study area, under the assumption that the study area is similar to the primary study site.

Bequest Value: The value individuals might place on knowing that a good or service would be available for use by future generations, distinct from their own personal use.

Climate Change: A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties (such as average rainfall or high temperatures), and that persists for an extended period, typically decades or longer.

Consumer Services: The value that human beings derive from meaningful interactions with nature, such as aesthetic enjoyment, recreation, spiritual enrichment, and cognitive development.

Consumer Surplus: The difference between the value that an individual receives from a good or service, such as participating in outdoor recreation in this case, and what they must pay for it.

Consumer Value: The value that human beings derive from the consumption of ecosystem goods and services, such as harvesting timber and other forest products, food, and fuel.

Direct Effects: An assessment of the net increase in economic activity (e.g., jobs or revenues) from spending, or an event. In this report we examine the direct effects of recreation spending.

Direct Use Value: The value of ecosystem services that results from direct use of them by humans, and then state that this can be consumptive or non-consumptive.

Ecosystem Services: The benefits that humans receive from ecosystems.[225] These services are broadly disaggregated into provisioning, regulating, supporting, and cultural services.

Existence Value: The value people place on the knowledge that a particular good exists, even if they have no plans to use it personally.

Exposure: The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm.[226]

Extreme Event: When a weather or climate variable exceeds the upper or lower thresholds of its observed range.[227, 228]

Frontline Communities: These communities experience the impacts of issues such as environmental pollution, climate change, and the economic crisis first and most severely.

Habitat and Supporting Services: Ecosystem services that are necessary for the production of other ecosystem services, such as habitat for plants and animals, conservation of genetic diversity, and cycling of nutrients.

Hazard: An event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural losses, damage to the environment, interruption of business, or other types of harm or loss.[229]

Hazard Mitigation: Sustained action taken to reduce or eliminate the long-term risk to human life and property through actions that reduce hazard, exposure, and vulnerability.[230]

Impact: The effects (especially the negative effects) of a hazard or other conditions associated with climate change.

Indirect Effects: The impacts due to the inter-industry linkages caused by industries purchasing from other industries.

Indirect Use Value: Value obtained through a non-removable product in nature (e.g., sunset, waterfall).

Induced Effects: The impacts on all local industries due to visitors' consumption expenditures that are generated by the direct and indirect effects. These effects result from the income spent by workers in the area.

Non-Market Value: Values of goods and services that fall outside of market activity. The estimated values that are not traded for money but are valued in terms of what reasonable people should be willing to pay rather than go without them.

Non-Use Value: The value that human beings receive from ecosystem services that do not involve any actual direct or indirect use of them.

Probability: The likelihood of hazard events occurring. Probabilities have traditionally been determined from the historic frequency of events. With changing climate and the introduction of non-climate stressors, the probability of hazard events also changes.[231]

Provisioning Services: Ecosystem services that provide products that are used directly by people, such as food, water, and raw materials.

Regulating Services: Outputs from the normal functioning of ecosystems that benefit people in direct ways, such as the regulation of climate, air and drinking water quality, soil formation and retention, moderation of extreme events, and biological control.

Resilience: The capacity of any entity—an individual, a community, an organization, a service, an activity, or a natural system—to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience. Community resilience is the ability of communities to withstand, recover, and to learn from past disasters to strengthen future response and recovery efforts.

Risk: The potential for damage or loss created by the interaction of hazards with assets such as buildings, infrastructure, or natural and cultural resources.

Sensitivity: The level to which a species, natural system, or community, government, etc., would be affected by changing climate conditions.[232]

Social Cost of Carbon: A monetary value that represents the damages attributable to a small increase (measured as a metric ton) of carbon dioxide emissions in a given year.

Susceptibility: A person or population's potential for vulnerability due to demographic, socioeconomic, and geolocation characteristics.

Use Value: Value derived from the direct use of a good or service, such as hunting, fishing, birdwatching, or hiking, or indirect use.

Vulnerability: Climate vulnerability describes the degree to which natural, built, and human systems are susceptible "…to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt."[233]

Vulnerability Assessment: An analysis of how a changing climate may harm a community and which elements—people, buildings and structures, resources, and other assets—are most vulnerable to its effects based on an assessment of exposure, sensitivity, the potential impact(s), and the community's adaptive capacity.

Vulnerable Communities: Vulnerable communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts. These disproportionate effects are caused by physical (built and environmental), social, political, and/or economic factor(s), which are exacerbated by climate impacts.[234]

Vulnerable Populations: Vulnerable populations include, but are not limited to, recreation and tourism-related workers, short-term workers, outdoor workers, seasonal residents, and persons in tribal communities.

APPENDICES

APPENDIX A.1: ECOSYSTEM SERVICE VALUATION SOURCES

Table A-1. Ecosystem Service Valuation Sources

Ecosystem Service	2019 Value		Units	Source	Original Source
	Low	High			
Air Quality Regulation					
Forest	$171.00		2019$ / acre / year	Wilson (2008)	
Forest	$216.40			Wilson (2010)	
Deciduous Forest	$67.42	$297.67		Batker et al. (2014)	Mates and Reyes (2004)
Coniferous Forest	$182.15	$182.15		Batker et al. (2014)	Wilson (2008)
Grasslands	$5.44			Wilson (2008)	Costanza et al. (1997)
Grasslands	$4.86			Anielski and Wilson (2010)	Costanza et al. (1997)
Cultivated	$110.43	$110.43		Batker et al. (2014)	Canadian Urban Institute (2006)
Cultivated	$0.00	$111.37		Batker et al. (2014)	Sandhu et al. (2008)
Cropland	$2.43			Anielski and Wilson (2010)	Costanza et al. (1997)
Urban Land	$60.96			Hecht et al. (2012)	
Wetlands	$82.17			Jenkins (2010)	
Wetlands	$106.67			Jenkins (2010)	
Desert (Shrub & Woodland)	$4.74			Taylor et al. (2017)	
Carbon Storage					
Forest	151.6			Kurz and Apps (1999)	
Forest	259.81			Keith et al. (2008)	
Forest	197.08			Wilson (2010)	
Forest	228.45			Wilson (2010)	
Forest	137.59			Wilson (2012)	Kurz and Apps (1999)
Forest	49.34	55.7		Zhu and Reed (2012)	
Coniferous Forest	155.5	466.22		Batker et al. (2014)	
Deciduous Forest	73.22	346.94		Batker et al. (2014)	
Mixed Forest	73.22	466.22		Batker et al. (2014)	
Grasslands	57.47			Wilson (2010)	Lacelle (1997)
Grassland	17.31	106.85		Batker et al. (2014)	
Grassland/ Shrubland	7.14	11.08		Zhu and Reed (2012)	
Cropland	16.5	95.7		Batker et al. (2014)	
Croplands	12.15	16.62		Wilson (2010)	Lacelle (1997)

Ecosystem Service	2019 Value		Units	Source	Original Source
	Low	High			
Croplands	127.88		Carbon/ acre	Batker et al. (2014)	
Croplands	33.59		Metric tons	Zhu and Reed (2012)	
Shrub	15.66	15.66		Wilson (2010)	Lacelle (1997)
Shrublands	97.12			Wilson (2012)	Wilson (2008)
Wetland	26.05	28.77		Zhu and Reed (2012)	
Swamp	143.66			Wilson (2010)	Lacelle (1997)
Swamp	44.92			Wilson (2012)	Wilson (2008)
Marsh	55.77			Wilson (2012)	Wilson (2008)
Marsh	101.98			Wilson (2010)	Lacelle (1997)
Shallow water	68.39			Wilson (2010)	Lacelle (1997)
Fen	142.04			Wilson (2010)	Lacelle (1997)
Bog	259.81			Wilson (2010)	Lacelle (1997)
Other Wetland	108.86			Wilson (2010)	Lacelle (1997)
Desert - Shrub	0.2			Taylor et al. (2017)	
Desert - Woodland	0.38			Taylor et al. (2017)	
Carbon Sequestration					
Coniferous Forest	0.55	3.01		Batker et al. (2014)	
Deciduous Forest	1.43	3.01		Batker et al. (2014)	
Mixed Forest	0.55	3.01		Batker et al. (2014)	
Grassland	0.4	0.77		Batker et al. (2014)	
Shrub	0.29	0.7		Batker et al. (2014)	
Wetlands	0.26	2.82		Batker et al. (2014)	
Cropland	0.04	6.89	Carbon/ acre	Batker et al. (2014)	
Pasture	0.04	1.65	Metric tons	Batker et al. (2014)	
Forest	0.12	0.49		Zhu and Reed (2012)	
Grass and Shrublands		0.15		Zhu and Reed (2012)	
Cropland		0.27		Zhu and Reed (2012)	
Wetlands		0.6		Zhu and Reed (2012)	
Desert - Shrub	0.16			Taylor et al. (2017)	
Desert - Woodland	0.65			Taylor et al. (2017)	

Ecosystem Service	2019 Value		Units	Source	Original Source
	Low	High			
Waste Treatment					
Forest	$26.30		2019$ / acre / year	Wilson (2008)	
Forest	$59.55			Costanza (2006)	
Forest	$232.71			Wilson (2008)	
Grasslands	$66.20			Wilson (2008)	
Grasslands	$59.82			Wilson (2008)	
Grasslands	$60.39			Anielski and Wilson (2010)	
Grasslands	$1.19	$21.06		Wilson (2008)	Olewiler (2004)
Pasture	$17.59			Costanza (2006)	Costanza 1997
Cropland	$30.19			Anielski and Wilson (2010)	
Desert (Shrub & Woodland)	$0.00			Taylor et al. (2017)	
Biological Control					
Forest	$8.64		2019$ / acre / year	Hecht et al. (2012)	
Forest	$11.77			Wilson (2008)	
Forest	$11.95			Anielski and Wilson (2010)	
Deciduous Forest	$11.36	$11.36		Batker et al. (2014)	Krieger (2001)
Deciduous Forest	$4.97	$4.97		Batker et al. (2014)	Pimentel (1998)
Deciduous Forest	$33.08	$33.08		Batker et al. (2014)	Pimentel (1998)
Coniferous Forest	$12.57	$12.57		Batker et al. (2014)	Wilson (2008)
Grasslands	$27.06	$27.06		Batker et al. (2014)	Rein (1999)
Grasslands	$345.68	$345.68		Batker et al. (2014)	Rein (1999)
Grasslands	$18.13			Wilson (2008)	
Grasslands/ Rangelands	$15.96			Anielski and Wilson (2010)	Costanza et al. (1997)
Cultivated	$15.54	$221.47		Batker et al. (2014)	Cleveland et al. (2006)
Cultivated	$90.45	$90.45		Batker et al. (2014)	Pimentel et al. (1995)
Cultivated	$62.26	$62.27		Batker et al. (2014)	Pimentel et al. (1995)
Cultivated	$0.00	$53.04		Batker et al. (2014)	Sandhu et al. (2008)
Cropland	$25.12			Anielski and Wilson (2010)	
Cropland	$20.54			Anielski and Wilson (2010)	
Cropland	$16.24			Costanza (2006)	
Shrubland	$20.54			Anielski and Wilson (2010)	

Ecosystem Service	2019 Value		Units	Source	Original Source
	Low	High			
Pasture	$20.36	$20.36		Batker et al. (2014)	Pimentel et al. (1995)
Pasture	$19.22	$19.22		Batker et al. (2014)	Wilson (2008)
Pasture	$16.24			Costanza (2006)	Costanza (1997)
Desert (Shrub & Woodland)	$1.73			Taylor et al. (2017)	

APPENDIX A.2: REDUCTION IN ECOSYSTEM SERVICE VALUE DUE TO ACRES BURNT BY SEVERITY

Tables in **Appendix A.2** show the likely reduction in ecosystem service values due to basal area loss. Basal area loss (**Table A-2**) is a metric used to measure wildfire severity ranges and estimate an associated impact on ecosystem service function capacity. The associated percentage reduction was used to derive the economic value. Values in the tables below were calculated using the following percentages of ecosystem service function capacity within each level of severity: 0%, -10%, -50%, -90%, and -100%.

Table A-2. Reduction in Ecosystem Service Value due to 0 Percent Loss of Basal Area, Millions of 2019$

Land Cover Type	Acres Burned	Low	Average	High
Coniferous Forest	78,338	$0.0	$0.0	$0.0
Deciduous Forest		$0.0	$0.0	$0.0
Desert Shrub		$0.0	$0.0	$0.0
Desert Woodland		$0.0	$0.0	$0.0
Grassland		$0.0	$0.0	$0.0
Shrubland		$0.0	$0.0	$0.0
Average:		**$0.0**	**$0.0**	**$0.0**

Note: 5-year average acres burned from 2015–2019

Table A-3. Reduction in Ecosystem Service Value due to a 25 Percent Loss of Basal Area, Millions of 2019$

Land Cover Type	Acres Burned	Low	Average	High
Coniferous Forest	78,338	$69.9	$163.9	$332.8
Deciduous Forest	78,338	$36.6	$124.5	$286.0
Desert Shrub	78,338	$5.4	$7.9	$10.4
Desert Woodland	78,338	$7.0	$12.5	$16.5
Grassland	78,338	$64.3	$138.0	$242.3
Shrubland	78,338	$70.4	$142.3	$240.3
Average:		**$42.3**	**$98.2**	**$188.1**

Note: 5-year average acres burned from 2015–2019

Table A-4. Reduction in Ecosystem Service Value due to a 50 Percent Loss of Basal Area, Millions of 2019$

Land Cover Type	Acres Burned	Low	Average	High
Coniferous Forest	78,338	$349.5	$819.7	$1,664.0
Deciduous Forest	78,338	$183.0	$622.3	$1,430.1
Desert Shrub	78,338	$27.1	$39.5	$51.9
Desert Woodland	78,338	$35.0	$62.3	$82.5
Grassland	78,338	$321.6	$670.0	$1,211.6
Shrubland	78,338	$351.9	$711.7	$1,201.6
Average:		**$211.3**	**$490.9**	**$940.3**

Note: 5-year average acres burned from 2015–2019

Table A-5. Reduction in Ecosystem Service Value due to a 90 Percent Loss of Basal Area, Millions of 2019$

Land Cover Type	Acres Burned	Low	Average	High
Coniferous Forest	78,338	$629.0	$1,475.4	$2,995.2
Deciduous Forest	78,338	$329.3	$1,120.2	$2,574.2
Desert Shrub	78,338	$48.9	$71.1	$93.3
Desert Woodland	78,338	$63.0	$112.2	$148.5
Grassland	78,338	$578.9	$1,241.9	$2,180.9
Shrubland	78,338	$633.4	$1,281.1	$2,162.9
Average:		**$380.4**	**$883.7**	**$1,692.5**

Note: 5-year average acres burned from 2015–2019

Table A-6. Reduction in Ecosystem Service Value due to 100 Percent Loss of Basal Area, Millions of 2019$

Land Cover Type	Acres Burned	Low	Average	High
Coniferous Forest	78,338	$698.9	$1,639.3	$3,328.0
Deciduous Forest	78,338	$365.9	$1,244.7	$2,860.3
Desert Shrub	78,338	$54.3	$79.0	$103.7
Desert Woodland	78,338	$70.0	$124.7	$165.0
Grassland	78,338	$643.2	$1,379.9	$2,423.2
Shrubland	78,338	$703.7	$1,423.5	$2,403.2
Average:		**$422.7**	**$981.8**	**$1,880.6**

Note: 5-year average acres burned from 2015–2019

APPENDIX A.3: ANNUAL VALUE OF RECREATION AND TOURISM

The Baseline Assessment presented in **Table A-7** estimates consumer surplus for a visit to each federal land area by multiplying the average consumer surplus per person per visit by primary activity and then by the activity participation rates for each federal land area. Visitor spending in each federal land area per visit is presented in column B of **Table A-7**. Imputed indirect and induced spending impacts, listed in column E of **Table A-7**, applies Mono County's multiplier of 1.4 to the direct spending estimates and is equal to 40% of visitor spending.[16] Similarly, **Table 39** (within Section 4: Baseline Natural Capital Assessment Ecosystem Service Impacts) presents the estimated annual value of recreation and tourism, from consumer surplus, visitor spending, and estimated indirect and induced spending impacts by recreational activity.

[16] The Mono County multiplier of 1.4 is applied to all counties due to Alpine and Inyo Counties not having their county-level multiplier publicly available.

Table A-7. Total Annual Value of Recreation and Tourism by Recreation Area

Recreation Area	Data Year	Visits [a]	Estimated Spending per Visit [b]	Estimated Consumer Surplus per Visit [c]	Total Spending	Spending Indirect & Induced Impacts [d]	Total Consumer Surplus	Total Value (2019$)[e]
		[A]	[B]	[C]	[D]=[A]x[B]	[E]=[D]x0.4	[F]=[A]x[C]	[G]=[D]+[E]+[F]
Death Valley National Park	2019	1,740,945	$84.51	$79.30	$147,122,000	$58,848,800	$138,053,327	$344,024,127
Devils Postpile National Monument	2019	147,864	$65.38	$79.30	$9,667,000	$3,866,800	$11,725,308	$25,259,108
Kings Canyon National Park	2019	632,110	$29.67	$79.30	$18,754,940	$7,501,976	$50,125,012	$76,381,928
Manzanar National Historic Site	2019	97,380	$106.69	$80.02	$10,389,893	$4,155,957	$7,792,393	$22,338,244
Sequoia National Park	2019	1,246,053	$18.65	$79.30	$23,237,863	$9,295,145	$98,809,418	$131,342,426
Yosemite National Park	2019	4,422,861	$43.30	$80.22	$191,530,224	$76,612,089	$354,792,417	$622,934,730
Inyo National Forest	2016	2,309,000	$185.04	$82.83	$427,264,228	$170,905,691	$191,260,093	$789,430,012
Humboldt-Toiyabe National Forest (outside Spring Mountain)[f]	2016	134,468	$218.16	$103.15	$29,335,135	$11,734,054	$13,870,891	$54,940,080
Total		**10,730,681**			**$857,301,284**	**$342,920,513**	**$866,428,859**	**$2,067,013,332**

Sources: NPS, n.d.; USDA, n.d.; NPS, 2018; USFS, 2020; USDA, 2017; NPS, 2012; NPS, 2016; NPS, 2020a; NPS, 2020b; NPS, 2020c

Notes: All monetized values are in 2019 dollars.

a. The visit data for the NPS reflects "Recreation Visitors"; the visit data for the National Forests reflects "A National Forest Visit," defined as the entry of one person onto a national forest site or area to participate in recreational activities for an unspecified amount of time.

b. Due to the majority of access to Kings Canyon, Sequoia, and Yosemite National Parks being outside of the Study Area, only visitor spending within the parks is estimated by applying the percentage of visitors who stayed overnight in the parks.

c. As the NPS does not publish their own estimates of consumer surplus by activity type in each national park, the value for each activity type was applied from USFS Region 5, Pacific Southwest. Additionally, each national park has its own mix of available activities. The consumer surplus values for each available activity were selected based on the respective national park's home page.

d. Mono County has an impact multiplier of 1.4 on spending (or 40% of spending) to estimate indirect and induced benefits.

e. The total value is the sum of total spending, indirect and induced spending, and consumer surplus.

f. As the vast majority of the Humboldt-Toiyabe National Forest is located outside of the Study Area, only the visits proportional to the land area in the Study Area are included.

APPENDIX B: LIST OF POPULATIONS AND ASSETS

Populations and Assets Included in the Vulnerability Assessment

The Vulnerability Assessment considers six distinct categories of populations and assets, directly or indirectly related to the recreation and tourism economy, which may be exposed to climate change hazards, including the following:

- **Populations:** Persons living, working, and/or visiting the Eastern Sierra region who are likely to be disproportionately harmed by climate change.
- **Infrastructure:** Local, regional, state, and federal infrastructure and other structures that provide important services for recreation and tourism.
- **Buildings and Facilities:** Essential buildings and facilities that support recreation and tourism activities.
- **Recreation and Tourism Activities:** Specific recreation and tourism activities that contribute significantly to the Eastern Sierra economy.
- **Ecosystems and Natural Resources:** A range of natural environments and priority resources in the Eastern Sierra region.
- **Key Services:** Critical functions carried out by local, regional, state, federal, and private agencies throughout the community.

Table B-1 provides a list of specific populations and assets for inclusion in the SRTI Climate Change Vulnerability Assessment. In the assessment, the Project Team distributed assets into location-specific categories as appropriate, such as campgrounds in the Inyo National Forest or bicycle trails in Yosemite National Park. This provided a more detailed and location-specific evaluation.

Table B-1. List of Populations and Assets

Population or Asset	Description	Data Source
Populations		
Hospitality workers	Persons working in or supporting the hotel and lodging industry in the Eastern Sierra region.	U.S. Census
Outdoor workers	People who primarily work outdoors, including tour guides, trail and road maintenance personnel, utility workers, and people working for the national parks/forests, state parks, or local/regional parks.	U.S. Census
Persons in tribal communities	American Indian Council of Mariposa County/Southern Sierra Miwuk Nation, Antelope Valley Indian Community, Big Pine Band of Owens Valley Paiute Shoshone Indians of the Big Pine Reservation, Bishop Paiute Tribe, Bridgeport Paiute Indian Colony, Death Valley Timbisha Shoshone Tribe, Fort Independence Indian Community of Paiute Indians of the Fort Independence Reservation, Kawaiisu or "Nuwa" American Indian Tribe, Kern Valley Indian Community, North Fork Rancheria of Mono Indians, North Fork Mono Tribe, Mono Lake Kutzadika Indian Community, Paiute Shoshone Indians of the Lone Pine Community of the Lone Pine Reservation, Timbisha Shoshone Tribe, Tubatulabals of Kern Valley, Tuolumne Band of Me-Wuk Indians, Utu Utu Gwaitu Paiute Tribe of the Benton Paiute Reservation, Walker River Paiute Tribe, Washoe Tribe of Nevada and California, Yosemite-Mono Lake Paiute Indian Community.	Bureau of Indian Affairs. 2018. American Indian Reservations / Federally Recognized Tribal Entities. https://gis.wim.usgs.gov/arcgis/rest/services/AIR_NDGA/AIR_NDGA/MapServer/0 California Native American Commission. http://nahc.ca.gov/. Native American Heritage Commission (NAHC) Digital Atlas NAHC and Native Land website: https://nativeland.ca/?utm_campaign=In%20honor%20of%20Native%20American%20Heri&utm_term=find%20your%20area%20on%20this%20map&utm_medium=email&utm_source=directmailmac.
Retail workers	Persons working in retail stores and restaurants located in the Eastern Sierra region who provide goods and services to both local communities and visitors.	U.S. Census
Seasonal residents	Persons who live in the Eastern Sierra region multiple months in a year, but not year-round.	Not mapped
Seasonal residents who live on single access roads	Persons who live in the Eastern Sierra region year-round or multiple months in a year and live on a single access road.	Not mapped
Short-term visitors	People who visit the Eastern Sierra region for short periods of time, weekends, or a few days, and who are not permanent residents of the region.	Not mapped

Population or Asset	Description	Data Source
Indoor tourism workers	Persons working in the indoor tourism industry, such as at museums historical sites, visitor centers, and chambers of commerce.	U.S. Census
Travel industry workers	Persons works in industries such as airlines, rental car services, and bus lines and transient medical workers who support the Eastern Sierra recreation economy.	U.S. Census
Infrastructure		
Airports – commercial service	Eastern Sierra Regional Airport and Mammoth Yosemite Airport.	Caltrans. 2019. Airport Boundaries. https://gisdata.dot.ca.gov/arcgis/rest/services/Aviation/Airport_Boundaries/MapServer
Airports – charter/recreation/general aviation	Furnace Creek Airport, Independence Airport, Stovepipe Wells Airport, Alpine County Airport, Lee Vining Airport, Lone Pine Airport, Bryant Airport, Shoshone Airport.	Caltrans. 2019. Airport Boundaries. https://gisdata.dot.ca.gov/arcgis/rest/services/Aviation/Airport_Boundaries/MapServer
Bridges	83 state highway bridges, 61 local roadway bridges, U.S. Forest Service and National Park bridges.	Caltrans. 2019. Local Bridges. https://gisdata.dot.ca.gov/arcgis/rest/services/Highway/Local_Bridges/MapServer/0 Caltrans. 2019. State Highway Bridges. https://gisdata.dot.ca.gov/arcgis/rest/services/Highway/State_Highway_Bridges/MapServer/0
Bicycle trails	Bicycle trails or trails that allow bicycles in local and regional jurisdictions. This includes but is not limited to: City and County, California State Parks, Death Valley National Park, El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit Humboldt-Toiyabe National Forest, Inyo National Forest, and Yosemite National Park.	MLTPA ArcGIS Online (AGOL) Site: USFS Trails, NPS Trails, MCRAT, ICRAT, MMSA Trails
Communication facilities	Cell towers, radio towers, and other communication facilities within the 3 counties, Yosemite National Park, and Kings Canyon-Sequoia National Park.	Mono County GIS. 2018. Communication Sites. https://gis.mono.ca.gov/webgis/rest/services/OpenData/UtilityNetworks/MapServer/16 Cal OES. 2018. Cal OES – CAPSNET System. https://services.arcgis.com/BLN4oKB0N1YSgvY8/arcgis/rest/services/Statewide_Microwaves/FeatureServer
Culverts	A structure that allows water to flow under a road, railroad, or trail from one side to the other.	Mono County GIS. 2018. Culverts. https://gis.mono.ca.gov/webgis/rest/services/OpenData/UtilityNetworks/MapServer/9

Population or Asset	Description	Data Source
Dams	54 dams within the Eastern Sierra region.	Department of Water Resources, Division of Safety of Dams. 2018. California Jurisdictional Dams. https://gis.water.ca.gov/arcgis/rest/services/Structure/i17_California_Jurisdictional_Dams/FeatureServer
Electrical substations	41 electrical substations in the Eastern Sierra region.	California Energy Commission. 2020. California Electrical Substations. https://services3.arcgis.com/bWPjFyq029ChCGur/arcgis/rest/services/Substation/FeatureServer
Electrical transmission lines	LADWP and Southern California Edison transmission lines.	California Energy Commission. 2020. California Electric Transmission Lines. https://services3.arcgis.com/bWPjFyq029ChCGur/arcgis/rest/services/Transmission_Line/FeatureServer
Electric vehicle (EV) charging stations	14 EV charging stations in the Eastern Sierra Region. Five are private and nine are for public use.	National Renewable Energy Laboratory. 2018. AlternativeFuelStation_USEnergy_2017. https://services3.arcgis.com/bWPjFyq029ChCGur/arcgis/rest/services/AlternativeFuelStation_USEnergy_2017/FeatureServer
Erosion control structures	Erosion control structures on trails or paths in local, regional, state, and federal jurisdictions, for the sections of these assets located within the established Study Area.	*Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*
Flood control infrastructure	Levees or general structures in local, regional, state, and federal jurisdictions.	FEMA National Flood Hazard Layer
Hiking and horseback riding trails	Trails that allow hiking and/or horseback riding in cities and counties, California State Parks, Death Valley National Park, Devils Postpile National Monument, El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit, Humboldt-Toiyabe National Forest, Inyo National Forest, Kings Canyon-Sequoia National Park, and Yosemite National Park.	MLTPA AGOL Site: ESSRP Developed Recreation Sites, ICRAT, MCRAT, NPS_Trails, USFS_Trails_NonMotorized
Lookout points	Cape Horn Vista Point, Leavitt Falls Vista Point, Grant Lake Scenic Viewpoint, Bald Mountain Lookout, Black Point Fissures, and Twin Lakes Vista.	MLTPA AGOL Site: ESSRP Developed Recreation Sites
Major roads and highways	US-6, US-395, SR-4, SR-41, SR-88, SR-89, SR-108, SR-120, SR-127, SR-136, SR-140, SR-158, SR-168, SR-182, SR-190, SR-203, and SR-266.	Caltrans. 2017. California_State_Highway. https://services1.arcgis.com/8CpMUd3fdw6aXef7/arcgis/rest/services/California_State_Highway/FeatureServer

Population or Asset	Description	Data Source
Off-road vehicle areas	Snowmobile or off-road vehicle paths for both summer and winter use in cities and counties, California State Parks, Death Valley National Park, El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit, Humboldt-Toiyabe National Forest, and Inyo National Forest.	MLTPA AGOL Site: ESSRP Developed Recreation Site, NPS_Trails, USFS_OSV_Routes
Parking lots	Parking areas and parking lots associated with outdoor recreation and tourism facilities in local, regional, state, and federal jurisdictions.	MLTPA AGOL Site: ESSRP Developed Recreation Site, ICRAT, MCRAT, Alpine County Parks, Mono County Parks, Inyo County Parks
Power plants	33 power plants (1 natural gas, 2 solar, 7 geothermal, and 23 hydro-electric) in the Eastern Sierra region.	California Energy Commission. 2019. California Electric Power Plants. https://services3.arcgis.com/bWPjFyq029ChCGur/arcgis/rest/services/Power_Plant/FeatureServer/0
Ski Areas	Kirkwood Ski Area, Heavenly Ski Area, Carson Pass Snowpark, Mammoth Mountain Ski Area, June Mountain Ski Area, Badger Pass, and cross-country skiing areas.	MLTPA AGOL Site: ESSRP Developed Recreation Site
Water and wastewater infrastructure	These facilities treat water for public use and treat wastewater so it can be safely discharged into the environment. These facilities service local, regional, state, and federal jurisdictions.	State Water Resource Control Board. 2020. Wastewater Treatment Facilities. https://gispublic.waterboards.ca.gov/portalserver/rest/services/Emergency_Response/Wastewater_Treatment_Facilities/MapServer
Buildings and Facilities		
Campgrounds	184 campgrounds (including RV parks) within the cities and counties, California State Parks, Bureau of Land Management, Death Valley National Park, Devils Postpile National Monument, El Dorado National Forest, Stanislaus Forest, Humboldt Toiyabe National Forest, Inyo National Forest, Kings Canyon-Sequoia National Parks, and, Yosemite National Park.	MLTPA AGOL Site: ESSRP Developed Recreation Sites. Yosemite National Park website, Kings Canyon and Sequoia National Parks website.
Community centers	Kirkwood Community Center, Turtle Rock Park Community Center, Antelope Valley Community Center, Mono County Senior Citizens, Mono County Community Center, Community Center Park, Benton Community Center, Crowley Lake Community Center, Chalfant Community Center, and Inyo Mono Senior Program.	Review of Google Maps

Population or Asset	Description	Data Source
Developed picnic areas	27 picnic areas within the Eastern Sierra region.	MLTPA AGOL Site: ESSRP Developed Recreation Site
Gas stations	An establishment along a roadway that sells gasoline and diesel products.	Cal OES. 2019. CA Energy Commission – Gas Stations. https://services.arcgis.com/BLN4oKB0N1YSgvY8/arcgis/rest/services/CA_GasStations/FeatureServer
Golf courses	Six golf courses within the Eastern Sierra region.	MLTPA AGOL Site: ESSRP_Golf_Courses.
Government and administrative buildings	The administrative and operational facilities in cities and counties, California State Parks, national parks, and national forests.	Review of Google maps.
Historic buildings and facilities	Buildings and facilities listed on the National Register of Historic Places and/or on the California Office of Historic Preservation list of California Historic Landmarks.	Cal OES. 2019. National Register of Historic Places (Public). https://mapservices.nps.gov/arcgis/rest/services/cultural_resources/nrhp_locations/MapServer
Homes and residential structures	Homes and residential structures within the Eastern Sierra Region that support permanent residents, seasonal residents, and seasonal visitors.	N/A
Hotels and lodging	Establishments providing accommodations, meals, and other services to travelers or visitors.	Local and regional land use and zoning maps
Interpretive sites	Recreation sites that inform visitors of the meaning and relationships contained in the area through personal experience and illustrations. These are located in California State Parks, Death Valley National Park, El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit, Humboldt-Toiyabe National Forest, Inyo National Forest, Kings Canyon-Sequoia National Parks, and Yosemite National Park.	MLTPA AGOL Site: ESSRP Developed Recreation Site
Medical facilities	Mammoth Hospital, Northern Inyo Hospital, and Southern Inyo Healthcare District.	American Hospital Association. 2020. CA_Hospitals_DHCS. https://services6.arcgis.com/mDUBwXYmClmffPXw/arcgis/rest/services/CA_Hospitals_DHCS/FeatureServer
Miscellaneous visitor-serving park facilities	Restrooms, play structures, and other facilities in local, regional, state, and federal jurisdictions.	MLTPA AGOL Site: ESSRP Developed Recreation Site
Public safety buildings	Local and regional fire stations, police stations, and sheriff stations in cities and counties, national parks, and national forests.	Review of Google maps

Population or Asset	Description	Data Source
Ranger Stations	5 ranger stations in the national forests, 7 ranger stations in Yosemite National Park, 14 ranger stations within Kings Canyon/Sequoia National Parks, 1 ranger station in Devils Postpile National Monument, and 3 ranger stations in Death Valley National Park.	U.S. Forest Service. 2020. ArcGIS Tool. https://usfs.maps.arcgis.com/apps/MapJournal/index.html?appid=8e405de85b964f7592d83b53303cd82a National Park Service websites for each park or monument
Restaurants and food establishments	Establishments where people sit and eat meals that are prepared and served on-site.	Local and regional land use and zoning maps
Retail centers	Buildings that support economic activities such as retail and tourism.	Local and regional land use and zoning maps
Short-term rentals	Homes that are rented out for short periods of time to persons in the short-term visitor category.	*Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*
Tribal cultural sites	Cultural sites on tribal lands that support recreation and tourism. Tribal lands include, but are not limited to, lands owned or managed by American Indian Council of Mariposa County/Southern Sierra Miwuk Nation, Antelope Valley Indian Community, Big Pine Band of Owens Valley Paiute Shoshone Indians of the Big Pine Reservation, Bishop Paiute Tribe, Bridgeport Paiute Indian Colony, Death Valley Timbisha Shoshone Tribe, Fort Independence Indian Community of Paiute Indians of the Fort Independence Reservation, Kawaiisu or "Nuwa" American Indian Tribe, Kern Valley Indian Community, North Fork Rancheria of Mono Indians, North Fork Mono Tribe, Mono Lake Kutzadika Indian Community, Paiute Shoshone Indians of the Lone Pine Community of the Lone Pine Reservation, Timbisha Shoshone Tribe, Tubatulabals of Kern Valley, Tuolumne Band of Me-Wuk Indians, Utu Utu Gwaitu Paiute Tribe of the Benton Paiute Reservation, Death Valley Timbi-Sha Shoshone Band of California, Walker River Paiute Tribe, Washoe Tribe of Nevada and California, and Yosemite-Mono Lake Paiute Indian Community.	Bureau of Indian Affairs. 2018. American Indian Reservations / Federally Recognized Tribal Entities. https://gis.wim.usgs.gov/arcgis/rest/services/AIR_NDGA/AIR_NDGA/MapServer/0 California Native American Commission. http://nahc.ca.gov/. Native American Heritage Commission (NAHC) Digital Atlas NAHC and Native Land website: https://nativeland.ca/?utm_campaign=In%20honor%20of%20Native%20American%20Heri&utm_term=find%20your%20area%20on%20this%20map&utm_medium=email&utm_source=directmailmac
Visitor centers	Buildings and facilities that provide educational information to visitors about the park, site, or general area.	MLTPA AGOL Site: ESSRP Developed Recreation Site

Population or Asset	Description	Data Source
Water recreation sites	Lakes, rivers, and streams that support water-based recreation. There are water recreation sites on the Bureau of Land Management land, El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit, Humboldt-Toiyabe National Forest, Inyo National Forest, Kings Canyon-Sequoia National Parks, LADWP land, and Yosemite National Park.	MLTPA AGOL Site: ESSRP Developed Recreation Site, ICRAT, MCRAT, American Whitewater Data
Recreation and Tourism Activities[235,236]		
Backcountry Skiing	Skiing or snowboarding in the backcountry, not on a developed ski area. This sport is characterized by human-powered ascents and downhill-style ski descents typically conducted on federal public lands. Human-powered snow sports include backcountry skiing and alpine touring.	MLTPA AGOL Site: Backcountry Ski Zones (delivery and upload pending)
Bicycling	Riding bicycles or other non-motorized vehicles on paved or unpaved trails.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Camping, backpacking, primitive camping	The activity of staying away from home in a shelter such as a tent or RV. Camping typically occurs at designated campsites. Primitive camping may occur in a tent or recreation vehicle but is not located at a designated campsite. Backpacking is where participants hike into backcountry areas without designated campsites and primarily sleep in tents.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Cross-country skiing	Skiing or snowshoeing where skiers rely on their own momentum to move across snow-covered terrain.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Downhill skiing	Skiing, snowboarding, or related activity on a downhill slope, usually involving chairlifts or pully systems.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.

Population or Asset	Description	Data Source
Driving for pleasure	Driving in a car, motorcycle, or other vehicle for reasons related to fun or pleasure.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Fishing	The activity of catching fish for either food or sport.	MLTPA AGOL Site: ESSRP Developed Recreation Site, ICRAT, MCRAT, CA Lakes Clipped to ESSRP Extent. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Gathering forest products	The activity of collecting forest products such as firewood, plants, or rocks and minerals.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Hiking/walking	The activity of going on long walks, usually on a trail or footpath.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Horseback riding	Riding horses in designated areas or trails.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Hunting	The activity of catching terrestrial animals or game for either food or sport.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Motorized trail activities	A non-snow activity of using an off-road vehicle on a designated trail or path.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.

Population or Asset	Description	Data Source
Other snow activities	Activities that occur during winter or when snow is on the ground (excluding downhill and cross-country skiing) such as snowmobiling, ice skating, and snowshoeing.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Picnicking	The activity of eating outdoors in a park or designated picnic site.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Rock climbing	Rock climbing is a multidisciplinary activity in which humans move over stone in a variety of ways. Some of the different disciplines include bouldering, sport climbing, traditional climbing, scrambling, and peak bagging.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Viewing natural features and wildlife	Viewing scenic features, natural resources, or wildlife.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Visiting historic sites and nature centers	The activity of traveling to designated historic sites, cultural centers, or nature centers.	MLTPA AGOL Site: ESSRP Developed Recreation Site. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Water-based activities	Motorized boating, jet skiing, kayaking, stand-up paddle boarding, canoeing, windsurfing, swimming, and other water-based activities that do not include fishing.	MLTPA AGOL Site: ESSRP Developed Recreation Site, ICRAT, MCRAT, CA Lakes Clipped to ESSRP Extent. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Wellness	The activity of reducing tension or anxiety in nature.	MLTPA AGOL Site: ESSRP Developed Recreation Site, ICRAT, MCRAT. *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.

Population or Asset	Description	Data Source
Ecosystems and Natural Resources[237]		
Aquatic and open water	Ecosystems that have permanent sources of water, such as lakes, streams, and rivers.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Mixed conifer forest	Montane hardwood conifer, Sierran mixed conifer, subalpine conifer, eastside pine, Jeffrey pine, pinyon-juniper, ponderosa pine, and red fir.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Deciduous forest	Broadleaf trees, shrubs, perennial herbs, and mosses.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Desert scrub	At higher, elevations, Joshua tree and pinyon-juniper. At lower elevations, desert wash, desert riparian, palm oasis, desert succulent shrub, and alkali scrub.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Desert woodland	Very dry woodlands with high temperatures and lack of regular precipitation.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Grassland	Annual grassland, perennial grassland.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Shrubland	Alpine dwarf-shrub, bitterbrush, sagebrush, low sage, montane chaparral, mixed chaparral, chamise-redshank chaparral, juniper, aspen, montane riparian, and valley foothill riparian.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Wetland	Marshes, ponds, or edges of lakes that are low-lying and frequently flood.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions.
Sensitive and critical species	The critical habitat identified by the U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, or a bi-state report for burrowing owl, mountain yellow-legged frog, sage grouse, Sierra Nevada yellow-legged frog, Yosemite toad, Pacific fisher, Sierra Nevada bighorn sheep, and Fish Slough milk-vetch. This includes both animal and plant species as appropriate.	EcoAdapt Adaptation Projects for the Sierra and Southern California regions and the Inyo National Forest Land Management Plan.
Scenic Views	A visual resource that attracts people to the town and wider area for its intrinsic beauty.	N/A
Key Services		
Air services	Air services include private planes and commercial airlines that provide passenger and freight access to and from other regions of California and the United States.	Caltrans. 2019. Airport Boundaries. https://gisdata.dot.ca.gov/arcgis/rest/services/Aviation/Airport_Boundaries/MapServer *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*

Population or Asset	Description	Data Source
Communication services	Communication services include radio, television, cellular and landline phone, and Internet.	Mono County GIS. 2018. Communication Sites. https://gis.mono.ca.gov/webgis/rest/services/OpenData/UtilityNetworks/MapServer/16 Cal OES. 2018. Cal OES – CAPSNET System. https://services.arcgis.com/BLN4oKB0N1YSgvY8/arcgis/rest/services/Statewide_Microwaves/FeatureServer *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*
Emergency medical services	Emergency medical response services are usually ambulances but may also be fire or police respondents if ambulances are not available.	American Hospital Association. 2020. CA_Hospitals_DHCS. https://services6.arcgis.com/mDUBwXYmClmffPXw/arcgis/rest/services/CA_Hospitals_DHCS/FeatureServer
Electricity delivery	Services provided by Southern California Edison, LADWP, Liberty Utilities, Pacific Gas and Electric, and other electrical providers.	California Energy Commission. 2020. California Electric Transmission Lines. https://services3.arcgis.com/bWPjFyq029ChCGur/arcgis/rest/services/Transmission_Line/FeatureServer *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*
Information services	Services that provide park and emergency information to seasonal residents and visitors.	*Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Government services	Local, regional, state, and federal government administration services such as those that provide fishing and access permits.	Recreation and General Management Plans.
Mail service	Services provided by the United States Postal Service, Amazon, FedEx, and other mail or package delivery services in the Eastern Sierra region.	United States Postal Service *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*
Public safety response	Fire and police services provided by local police and fire departments, county sheriff and fire departments, CAL FIRE, California Highway Patrol, and the U.S. Forest Service.	Recreation and General Management Plans.
Road access	Road clearing services (snow and tree removal) provided by County Public Works Department, Caltrans, National Park Service, and U.S. Forest Service.	*Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.

Population or Asset	Description	Data Source
Search and Rescue	Services provided by fire departments, sheriff departments, and volunteers to help those who become lost or injured during recreation and tourism activities.	*Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Trail maintenance	Trail maintenance and restoration services provided by, the U.S. Forest Service, National Park Service, Bureau of Land Management, and a variety of local partners.	*Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Transit access	Public transit access is provided by the Eastern Sierra Transit agency. This agency provides transit services to the Eastern Sierra region including Mammoth Lakes, Sierra Hikers, Dial-a-Ride, and longer routes along US Route 395.	MLTPA AGOL Site: ESSRP Transit Stops *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.
Vital goods	Delivery of goods and services that provide basic needs for health and comfort. These include food, fuels such as gasoline and propane, medicine, basic hygiene supplies, and clothing, among others.	Recreation and General Management Plans.
Water and wastewater	These services involve treating and transporting water to be used by customers and transporting and treating wastewater so it can be safely released into the environment. These services are provided by water districts, community services districts, public utility districts, private wells, and septic systems.	*Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada* Recreation and General Management Plans.

APPENDIX C: CLIMATE VULNERABILITY ASSESSMENT RESULTS MATRIX

Table C-1. Vulnerability Assessment Results Matrix

Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases	Human Health Hazards	Landslides and Debris Flows	Severe Weather	Severe Winter Weather	Wildfire
Populations										
Hospitality workers	V5	V4	V3	V3	-	V3	V3	V2	V1	V3
Indoor tourism workers	V4	V3	-	V3	-	V3	V3	V2	V1	V3
Outdoor workers	V5	V3	V4	V3	V4	V4	V3	V3	V3	V5
Persons in tribal communities	V5	V4	V4	V4	V4	V3	V3	V4	V3	V4
Retail workers	V4	V3	V3	V3	-	V2	V3	V1	V1	V3
Seasonal residents	V3	V2	V3	V2	V3	V2	V2	V3	V3	V3
Seasonal residents who live on single access roads	V3	-	-	V5	V4	V2	V4	V5	V5	V5
Short-term visitors	V3	V4	V2	V3	V2	V4	V3	V4	V2	V5
Travel industry workers	V5	V3	V3	V2	-	V3	V2	V2	V2	V3
Infrastructure										
Airports – charter/recreation/general aviation	-	-	-	V2	-	-	V3	V3	V1	V4
Airports – commercial service	-	-	-	-	-	-	-	V3	V1	V3
Bicycle trails (California State Parks)	-	V2	-	V2	V2	-	V4	V1	V1	-
Bicycle trails (City and County)	-	V2	-	V3	V3	-	V4	V2	V1	V4
Bicycle trails (Death Valley National Park)	-	-	-	V2	-	-	-	V2	-	-
Bicycle trails (El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit)	-	V3	-	V3	V3	-	V4	V2	V1	V4
Bicycle trails (Humboldt-Toiyabe National Forest)	-	V3	-	V3	V4	-	V3	V3	V2	V4
Bicycle trails (Inyo National Forest)	-	V3	-	V3	V3	-	V4	V2	V1	V4
Bicycle trails (Yosemite National Park)	-	V3	-	V4	V2	-	V3	V2	V1	V3

Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases	Human Health Hazards	Landslides and Debris Flows	Severe Weather	Severe Winter Weather	Wildfire
Bridges	-	-	V2	V4	-	-	V5	V4	V3	V3
Communication facilities	-	-	V3	V1	-	-	V3	V4	V4	V3
Culverts	-	-	-	V5	-	-	V4	V3	V4	V3
Dams	-	V2	-	V3	-	-	V4	-	-	V2
Electric vehicle charging stations	-	-	V3	V2	-	-	V3	V4	V4	V4
Electrical substations	-	-	V3	V2	-	-	V3	V3	V3	V4
Electrical transmission lines	-	-	V4	V2	V4	-	V3	V4	V4	V5
Erosion control structures	-	-	-	V3	-	-	V4	V3	V1	V2
Flood control infrastructure	-	-	-	V3	V3	-	V3	V4	V1	V2
Hiking and horseback riding trails (City and County)	-	V2	-	-	V3	-	V4	V2	V1	V3
Hiking and horseback riding trails (Death Valley National Park)	-	-	-	-	V2	-	V3	V2	V1	V2
Hiking and horseback riding trails (Devils Postpile National Monument)	-	V3	-	V2	V4	-	V4	V3	V2	V5
Hiking and horseback riding trails (El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management)	-	V3	-	V2	V3	-	V3	V2	V1	V4
Hiking and horseback riding trails (Humboldt-Toiyabe National Forest)	-	V3	-	V3	V4	-	V4	V3	V2	V4
Hiking and horseback riding trails (Inyo National Forest)	-	V3	-	V2	V3	-	V3	V2	V1	V4
Hiking and horseback riding trails (Kings Canyon/Sequoia National Park)	-	V3	-	V2	V2	-	V3	V2	V1	V3
Hiking and horseback riding trails (Yosemite National Park)	-	V3	-	V2	V2	-	V3	V2	V1	V3
Lookout points	-	-	-	V2	V1	-	V2	V2	V2	V2
Major roads and highways	-	-	V2	V4	V2	-	V4	V4	V4	V5
Off-road vehicle areas (California State Parks)	-	V1	-	V2	-	-	-	V2	V2	V3

Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases	Human Health Hazards	Landslides and Debris Flows	Severe Weather	Severe Winter Weather	Wildfire
Off-road vehicle areas (City and County)	-	V2	-	V2	V3	-	V2	V3	V2	V3
Off-road vehicle areas (Death Valley National Park)	-	V2	-	-	-	-	V2	V1	-	V1
Off-road vehicle areas (El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit)	-	V2	-	V2	V2	-	V2	V2	V2	V4
Off-road vehicle areas (Humboldt-Toiyabe National Forest)	-	V2	-	V3	V3	-	V4	V3	V2	V4
Off-road vehicle areas (Inyo National Forest)	-	V2	-	V2	V2	-	V3	V2	V2	V4
Parking lots	-	-	-	V3	V2	-	V3	V3	V2	V1
Power plants	V1	V4	V3	V3	V1	-	V4	V2	V3	V3
Ski areas	-	V3	-	V4	V3	-	V4	V5	V4	V4
Water and wastewater infrastructure	-	V2	-	V5	-	-	V3	V2	V3	V3
Buildings and Facilities										
Campgrounds (Bureau of Land Management)	-	-	-	-	V2	-	V3	V3	V2	V4
Campgrounds (City and County)	-	-	V1	V3	V3	-	V2	V2	V1	V3
Campgrounds (Death Valley National Park)	-	-	V3	-	V2	-	V2	V2	V1	-
Campgrounds (Devils Postpile National Monument)	-	-	-	-	V4	-	-	V5	V2	V5
Campgrounds (El Dorado National Forest, Stanislaus National Forest)	-	-	V2	V4	V3	-	V4	V3	V1	V4
Campgrounds (Humboldt Toiyabe National Forest)	-	-	V2	V5	V3	-	V5	V4	V2	V5
Campgrounds (Inyo National Forest)	-	-	V2	V4	V3	-	V4	V4	V2	V5
Campgrounds (Kings Canyon/Sequoia National Park)	-	-	V1	V3	V3	-	V4	V4	V3	V4
Campgrounds (Yosemite National Park)	-	-	V1	V4	V2	-	V4	V3	V4	V4
Community centers	-	-	V2	V3	-	-	V3	V2	V1	V4
Developed picnic areas	-	-	V2	V3	V1	-	V2	V1	V2	V3

Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases	Human Health Hazards	Landslides and Debris Flows	Severe Weather	Severe Winter Weather	Wildfire
Gas stations	-	-	V2	V3	V2	-	V4	V3	V3	V2
Golf courses	-	V3	V3	V1	V2	-	V1	V2	V2	V2
Government and administrative buildings (California State Parks)	-	-	V3	V2	V2	-	V2	V2	V2	V3
Government and administrative buildings (City and County)	-	-	V3	V3	V2	-	V3	V2	V1	V3
Government and administrative buildings (National Park Service: Death Valley, Yosemite, Sequoia, Kings Canyon, Devils Postpile National Monument)	-	-	V3	V4	V3	-	V5	V2	V2	V2
Government and administrative buildings (USFS: El Dorado, Stanislaus, Lake Tahoe Basin Management Unit, Humboldt-Toiyabe, Inyo)	-	-	V3	V4	V3	-	V4	V3	V2	V3
Historic buildings and facilities	-	-	V3	V3	-	-	V4	V4	V4	V4
Homes and residential structures	-	-	V3	V4	V4	-	V4	V4	V3	V5
Hotels and lodging	-	-	V2	V3	-	-	V2	V2	V3	V4
Interpretive sites (California State Parks)	-	V1	V2	V2	V2	-	V3	V3	V2	V3
Interpretive sites (Death Valley National Park)	-	-	V3	V4	-	-	V2	V2	V1	V1
Interpretive sites (El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit)	-	V1	V2	-	V3	-	V2	V3	V2	V4
Interpretive sites (Humboldt-Toiyabe National Forest)	-	V1	V2	-	V4	-	V3	V4	V2	V4
Interpretive sites (Inyo National Forest)	-	V1	V2	V2	V2	-	V1	V3	V2	V4
Interpretive sites (Kings Canyon/Sequoia National Park)	-	V1	V2	V4	V3	-	V3	V3	V2	V3
Interpretive sites (Yosemite National Park)	-	V1	V2	V2	V2	-	V2	V2	V1	V3
Medical facilities	-	-	V2	-	-	-	-	V4	V3	V1
Miscellaneous visitor-serving park facilities	-	V2	V2	V3	V3	-	V3	V3	V1	V3
Public safety buildings (City and County)	-	-	V1	V2	V1	-	V3	V3	V1	V2

Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases	Human Health Hazards	Landslides and Debris Flows	Severe Weather	Severe Winter Weather	Wildfire
Public safety buildings (National Park Service: Death Valley, Yosemite, Sequoia, Kings Canyon, Devils Postpile National Monument)	-	-	V2	V4	V2	-	V4	V3	V2	V3
Public safety buildings (USFS: El Dorado, Stanislaus, Lake Tahoe Basin Management Unit, Humboldt-Toiyabe, Inyo)	-	-	V2	V4	V2	-	V3	V3	V2	V3
Ranger stations (National Park Service: Death Valley, Yosemite, Sequoia, Kings Canyon, Devils Postpile National Monument)	-	-	V2	V4	V3	-	V4	V4	V2	V3
Ranger stations (USFS: Humboldt-Toiyabe, Inyo)	-	-	V2	V4	V3	-	V3	V4	V2	V3
Restaurants and food establishments	-	-	V3	V3	V2	-	V2	V1	V3	V4
Retail centers	-	-	V3	V3	V2	-	V2	V1	V3	V4
Short-term rentals	-	-	V2	V4	-	-	V4	V3	V3	V5
Tribal cultural sites	-	V4	V3	V3	V3	-	V2	V4	V4	V2
Visitor centers	-	-	V2	-	V2	-	V3	V3	V3	V4
Water recreation sites (Bureau of Land Management)	V3	V5	V3	V1	V2	-	-	V2	V2	V2
Water recreation sites (El Dorado National Forest, Stanislaus National Forest, Lake Tahoe Basin Management Unit)	V3	V5	V3	V3	V2	-	V3	V2	V3	V4
Water recreation sites (Humboldt-Toiyabe National Forest)	V3	V5	V3	V3	V3	-	V3	V2	V3	V4
Water recreation sites (Inyo National Forest)	V3	V5	V3	V3	V2	-	V4	V2	V3	V4
Water recreation sites (Kings Canyon/Sequoia National Parks)	V3	V5	V3	V4	V2	-	V4	V2	V3	V4
Water recreation sites (LADWP)	V3	V5	V3	V1	V2	-	-	V2	V2	V4
Water recreation sites (Yosemite National Park)	V3	V5	V3	V4	V1	-	V3	V2	V3	V4
Recreation and Tourism Activities										
Backcountry skiing	V1	V5	V5	-	V1	V1	V5	V3	V4	V1

Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases	Human Health Hazards	Landslides and Debris Flows	Severe Weather	Severe Winter Weather	Wildfire
Bicycling	V5	V1	V3	V3	V3	V2	V3	V2	V1	V3
Camping, backpacking, primitive camping	V4	V2	V3	V5	V3	V4	V4	V4	V3	V5
Cross-country skiing	V1	V5	V5	-	-	V1	-	V3	V4	V1
Downhill skiing	V1	V5	V5	-	V3	V2	V4	V4	V4	V2
Driving for pleasure	V3	V1	V1	V1	V1	V1	V2	V2	V2	V3
Fishing	V5	V5	V5	V3	V2	V4	V3	V5	-	V5
Gathering forest products	V4	V4	V3	V2	V5	V4	V3	V3	V2	V5
Hiking/walking	V4	V2	V3	V2	V3	V4	V4	V2	V1	V3
Horseback riding	V4	V2	V3	V3	V3	V3	V4	V2	V1	V4
Hunting	V4	-	V3	V2	V2	V4	V2	V3	V3	V3
Motorized trail activities	V3	V1	V3	V2	-	V3	V3	V1	V3	V3
Other snow activities	V1	V5	V5	-	-	V2	V2	V2	V4	V3
Picnicking	V3	-	V1	V3	V1	V3	V1	V2	V1	V3
Rock climbing	V4	-	V3	V3	-	V4	V4	V5	V3	V4
Viewing natural features and wildlife	V5	V2	V3	V1	V4	V2	V2	V2	V2	V5
Visiting historic sites and nature centers	V1	-	V2	V2	-	V1	V3	V1	V2	V3
Water-based activities	V5	V5	V4	V4	V2	V4	V2	V5	V1	V5
Wellness	V4	-	V2	V1	V1	V3	V1	V1	V1	V3
Ecosystems and Natural Resources										
Aquatic and open water	V5	V5	V5	V1	V2	-	V3	V2	V1	V4
Deciduous forest	V2	V3	V4	V1	V4	-	V1	V3	V1	V3
Desert scrub	-	V2	V3	V3	-	-	-	V2	-	V2
Desert woodland	V2	V3	V3	V3	V3	-	V3	V3	-	V3

Populations and Assets	Air Quality, Smoke, Ash	Drought	Extreme Heat and Warm Nights	Flooding	Forestry Pests and Diseases	Human Health Hazards	Landslides and Debris Flows	Severe Weather	Severe Winter Weather	Wildfire
Grassland	V3	V3	V2	V3	-	-	V2	V2	V2	V3
Mixed conifer forest	V1	V4	V5	V2	V5	-	V2	V3	V1	V5
Scenic views	V5	V3	-	V2	V3	-	V3	V3	V2	V5
Sensitive and critical wildlife species	V4	V5	V5	V2	V5	-	V3	V3	V3	V5
Shrubland	V2	V3	V5	V3	-	-	V2	-	V1	V2
Wetland	V4	V5	V5	V1	-	-	V2	-	-	V2
Key Services										
Air services	V4	-	V3	V3	-	V3	V2	V3	V4	V4
Communication services	-	-	V3	V1	-	-	V4	V4	V3	V4
Electricity delivery	V3	V4	V4	V2	V5	-	V4	V5	V4	V5
Emergency medical services	V4	-	V2	V3	V2	V4	V3	V3	V2	V3
Government services	V1	-	V1	V1	-	V1	V2	V1	V1	V2
Information services	V2	-	V1	V1	-	V1	V1	V3	V2	V2
Mail service	-	-	-	V3	V3	V2	V2	V3	V3	V3
Public safety response	V3	-	V2	V3	V2	V2	V4	V2	V3	V4
Road access	-	-	-	V4	V3	-	V4	V4	V4	V4
Search and Rescue	V5	-	V3	V3	V4	V3	V4	V3	V4	V5
Trail maintenance	V3	V3	V2	V4	V4	V4	V5	V4	V2	V5
Transit access	V3	-	V3	V4	V3	V2	V4	V4	V4	V3
Vital goods	V3	-	-	V4	V3	V3	V4	V4	V5	V4
Water and wastewater	V4	V5	V3	V4	-	-	V3	V2	V3	V4

ENDNOTES

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Endnotes - Glossary and List of Abbreviation

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[235] This selection is based on the Table 5.12 of the U.S. Forest Service's *Climate Change Vulnerability and Adaptation for Infrastructure and Recreation in the Sierra Nevada*.

[236] Each asset type will be assessed based on location in a specific jurisdiction, park, or forest.

[237] The ecosystems and natural resources are based on ICF's land cover types in the Study Area and focal habitats.

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