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Building Tribal Transportation Resilience to Climate Change

2024

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16. Abstract

Indigenous Tribes are on the frontline of climate change impacts in North America. According to the Fourth National Climate Assessment, Tribes face disproportionate impacts on their economies, cultural practices, and livelihoods compared to other communities. Tribal Communities are also driving innovative adaptation responses in part through actions that incorporate traditional Indigenous knowledges. This report summarizes a project completed by the Federal Highway Administration (FHWA) Western Federal Lands Highway Division to assist seven Tribes across the United States in assessing the vulnerability of their transportation networks to climate change hazards. These vulnerability assessments applied FHWA's Vulnerability Assessment and Adaptation Framework to complete each assessment. Partner Tribes includes the Karuk Tribe, the Native Village of Kwigillingok, the Mescalero Apache Tribe, the Coushatta Tribe of Louisiana, the Rosebud Sioux Tribe, the Ottawa Tribe of Oklahoma, and the Modoc Nation. This report provides a summary of the technical vulnerability assessments completed for each Tribe, feedback, challenges, and lessons learned from applying FHWA's framework, and recommendations for how FHWA can improve the applicability of its framework for Tribes and better support Tribal Nations in addressing climate risks.

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Acronyms and Abbreviations

Acronym/Abbreviation	Definition
ADAP	Adaptation Decision-Making Assessment Process
BIA	Bureau of Indian Affairs
CASC	Climate Adaptation Science Center
CRA	Climate Risk Assessment
DOT	department of transportation
EF	Enhanced Fujita
°F	degree Fahrenheit
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	Geographic Information System
ITEP	Institute for Tribal Environmental Professionals
LOCA	Localized Constructed Analogs
NOAA	National Oceanic and Atmospheric Administration
POC	Point of Contact
RCP	Representative Concentration Pathway
SR	State Route
TAG	Technical Advisory Group
TEK	Traditional Ecological Knowledge
TTP	Tribal Transportation Program
USACE	U.S. Army Corps of Engineers
USFS	U.S. Forest Service
USGS	U.S. Geological Survey

Glossary

Term	Definition
Adaptation[1]	The process of adjustment to the actual or anticipated climate and its effects. In human systems, adaptation seeks to moderate harm or make use of beneficial opportunities. In natural systems, human intervention may facilitate adjustment to the expected climate and its effects.
Climate change[2]	Changes in average weather conditions that persist over long periods of time, usually 30-year periods or longer, encompassing increases and decreases in temperature and changes in trends such as shifts in precipitation.
Coupled Model Integration Project	A large compendium of Global Climate Models that are developed and run by institutions around the world to provide a larger sample size, accounting for potential biases in the different ways the code of the models is written.
Ensemble average	The mean value of a subset of climate model projections.
Exposure	The presence of people, assets, and infrastructure in places where they could be adversely affected by hazards (e.g., a road that is in a floodplain).
Global Climate Model	Numerical representations of the climate system based on the physical, chemical, and biological properties of its components. Global Climate Models are developed and run by institutions around the world based on computer code that simulates the Earth system and its patterns and responses to different stimuli.
Hazard[3]	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
Localized Constructed Analogs	A method of statistical downscaling to take the large outputs from Global Climate Models (usually hundreds of miles large for each grid cell of information) and make them smaller (3.7 miles squared per grid cell) and more regionally informative based on localized factors like topography and weather.
Mitigation	Strategies and actions taken to reduce greenhouse gas emissions that contribute to climate change.
Representative Concentration Pathway[4]	Scenarios that include time series of emissions and concentrations of the full scale of greenhouse gases and land use/land cover. The word “representative” means that each Representative Concentration Pathway (RCP) provides one of several possible scenarios in the future. RCPs are labelled with different numbers, referring to the warming that would occur under that scenario (in watts per square meter of radiation). RCP 4.5 refers to a scenario wherein peak fossil fuel dependance occurs in 2040 and declines in the centuries following, coupled with strong policy and social mitigation strategies to reduce emissions. RCP 8.5 assumes little to no action to mitigate emissions and a continued dependence on fossil fuels throughout the remainder of the century.
Return period	Also known as “recurrence intervals” or “annual exceedance probabilities,” return periods indicate the likelihood of an event (e.g., heavy precipitation) occurring or being exceeded based on the estimated average time between events over a long period of time. For example, a 100-year storm has a 1 percent likelihood of occurring each year.
Risk[5]	The overall likelihood of exposure and loss due to hazards or threats, taking into account the vulnerability of an asset and economic and social consequences of the damage.

[1] United Nations Intergovernmental Panel on Climate Change Glossary. https://apps.ipcc.ch/glossary/
[2] Investing in Transportation Resilience: A Framework for Informed Choices (2021)
[3] United Nations Intergovernmental Panel on Climate Change Glossary. https://apps.ipcc.ch/glossary/
[4] United Nations Intergovernmental Panel on Climate Change Glossary. https://apps.ipcc.ch/glossary/
[5] Investing in Transportation Resilience: A Framework for Informed Choices (2021)

Term	Definition
Vulnerability[6]	The predisposition to be adversely affected by something. Vulnerability can mean sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

[6] United Nations Intergovernmental Panel on Climate Change Glossary. https://apps.ipcc.ch/glossary/

1 Introduction

Native American Tribes are on the frontline of climate change impacts in North America. Tribes face disproportionate impacts on their economies, cultural practices, and livelihoods than other communities. Despite this risk, many Tribes have not been able to assess the long-term impacts of climate change on their transportation and mobility, due to limited resources, information, and/or funding. The Federal Highway Administration (FHWA) is helping to fill this gap through its projects and programs geared toward building Tribal transportation resilience.

FHWA worked with seven Tribes to assess climate impacts on their transportation networks:

The Karuk Tribe, Native Village of Kwigillingok, Mescalero Apache Tribe, Coushatta Tribe of Louisiana, Rosebud Sioux Tribe, Ottawa Tribe of

FHWA's Office of Tribal Transportation (OTT) provides support for all FHWA activities affecting Tribal transportation, including administration of the Tribal Transportation Program (TTP). The TTP provides funding to federally recognized Tribes for transportation-related activities and is administered in partnership with the Bureau of Indian Affairs (BIA). Additionally, OTT provides stewardship and oversight under TTP direct funding agreements with 135 federally recognized Tribes. The OTT also administers supplemental funding programs like the Tribal Transportation Bridge Program and Tribal Transportation Program Safety Fund, discretionary grants awarded to Tribes, and the transfer of funds from States and other local governments.

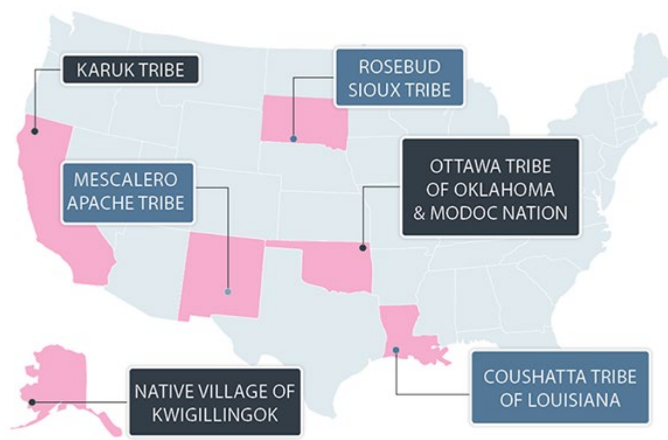

Figure 1 -1 Location of Tribal Nations that participated in the FHWA Building Tribal Transportation Resilience to Climate Change project.

The Office of Federal Lands Highway's Interagency Research Program funded this project, Building Tribal Transportation Resilience to Climate Change, with the Office of Tribal Transportation to assist Tribal Nations in understanding and responding to the impacts of climate change. For this project, several vulnerability assessments were conducted for Tribal Nations to assess potential impacts on their transportation networks. This Summary Report provides an overview of the project, including results of the vulnerability assessments, unique challenges faced while creating these assessments, and lessons learned and recommendations for the development of future vulnerability assessments for Tribal Communities.

1.1 Purpose and Need

We conducted climate change vulnerability assessments for seven Tribes to help them identify physical impacts on their transportation system and consequences to travel and mobility. These Tribes are the Karuk Tribe in Northern California, the Native Village of Kwigillingok on the southwestern coast of Alaska, the Mescalero Apache Tribe in New Mexico, the Coushatta Tribe of Louisiana, the Rosebud Sioux Tribe in South Dakota, the Ottawa Tribe of Oklahoma, and the Modoc Nation in Oklahoma. The FHWA Vulnerability Assessment and

Adaptation Framework (Third Edition) was used to guide the development of each assessment.[7]

The vulnerability assessments performed intended to help Tribes with:

- Understanding regional climate change and how it will affect Tribal transportation systems and travel.
- Identifying and prioritizing facilities on their transportation systems that need additional analysis or adaptation responses.
- Supporting future grant applications to fund transportation improvements and additional climate change projects.
- Evaluating the effectiveness of using FHWA's Vulnerability Assessment and Adaptation Framework for Tribal vulnerability assessments.
- Identifying barriers encountered when using the framework and lessons learned for preparing vulnerability assessments.

1.2 Report Organization

The report is organized into the following sections:

- **Study Approach:** Defines the general approach taken for each vulnerability assessment, including an overview of the FHWA Vulnerability Assessment and Adaptation Framework and its steps.
- **Tribal Transportation Vulnerability Assessment Summaries:** Summarizes each of the Tribal transportation vulnerability assessments, including the climate hazards studied, consequences of climate change to transportation assets and regional travel, top vulnerabilities or priority assets, and recommended next steps for each Tribe.
- **Challenges and Successes:** Documents the challenges and successes encountered throughout the project, specifically surrounding the use of the FHWA Vulnerability Assessment and Adaptation Framework for Tribal Communities.
- **Implementation Plan:** Discusses how to conduct successful Tribal transportation network vulnerability assessments for Tribes and those working with Tribes. The Implementation Plan includes resources and recommendations for community engagement, data collection, and securing grant funding that is supplemental to the FHWA Vulnerability Assessment and Adaptation Framework.
- **Appendices:** The appendices provide supplementary information developed over the course of the project, including names of everyone involved in the project (Appendix A) and feedback collected from Tribal partners on the project and process (Appendix B).

For readers looking for a summary of the Building Tribal Transportation Resilience to Climate Change project, see Study Approach, Tribal Transportation Vulnerability Assessment Summaries, and Challenges and Successes. For Tribes and their partners looking for resources to develop climate change vulnerability assessments and other climate change projects (e.g., adaptation plans), see the Implementation Plan. For access to one or more of the complete, tribal transportation network climate change vulnerability assessments, please contact Amit Armstrong (amit.armstrong@dot.gov).

[7] FHWA. 2017. Vulnerability Assessment and Adaptation Framework, Third Edition. https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/index.cfm

2 Study Approach

The Tribes that participated in this study are incredibly diverse in terms of geography, population, culture, infrastructure, resources, transportation access and needs, and more. FHWA's Vulnerability Assessment and Adaptation Framework is flexible in the way it can be applied and is meant as a guiding, rather than a prescriptive, framework. This allowed the transportation network vulnerability assessments to follow the framework while embodying the specific needs and characteristics of each Tribe. Ultimately the methodologies for each Tribe varied as they focused on different types of assets, climate hazards, and Tribal priorities. Each Tribe received a technical memorandum summarizing data collected, methodology, results, and next steps. These technical documents may be provided upon request from FHWA.

This section provides a brief overview of the key actors that guided the development of the vulnerability assessments and this final report. It also summarizes the FHWA Vulnerability Assessment and Adaptation Framework and how it was applied.

2.1 Tribal Partners

The most important partners on this project were representatives from the Tribes themselves. FHWA worked closely with one to three main points of contact (POCs) from each Tribe, typically transportation planners or directors, or other staff persons familiar with the transportation system. These POCs were critical to defining the scope of the study, collecting data and information needed to inform the work, and making connections between the project team and other internal and external parties. Other Tribal staff often provided input as well, such as representatives from other Tribal departments or offices. Additional local partners included representatives from State departments of transportation (DOTs) and local transit agencies with whom the Tribes often worked closely. The full list of Tribal partners is provided in the Appendix (Appendix A). FHWA appreciates the commitment of all the Tribal POCs and their local partners to this project.

2.2 Technical Advisory Group

The study was also guided by a multidisciplinary Technical Advisory Group (TAG) consisting of Federal agency representatives, State DOTs, universities, non-profits, and other subject matter experts who are knowledgeable about climate change risk and vulnerability. The TAG met four times throughout the study and provided input and feedback on study research, data, methods, findings, and products. The list of advisory group members is provided in the Appendix (Appendix A). FHWA appreciates the support and contributions of the TAG in developing this project.

2.3 FHWA Vulnerability Assessment and Adaptation Framework

Each assessment followed FHWA's Vulnerability Assessment and Adaptation Framework, which was written for transportation agencies and their partners to assess the vulnerability of transportation infrastructure and systems to extreme weather and climate change. For this project, FHWA compiled the challenges and successes of using the pre-existing framework for Tribal Communities and their partners. At the end of the process, recommendations were made for how the Framework can be used to support Tribes and their partners or consultants in completing Tribal transportation vulnerability assessments.

The assessments followed the first four steps of the FHWA framework, which are focused on the vulnerability assessment itself. The framework steps are as shown in Figure 2-1.

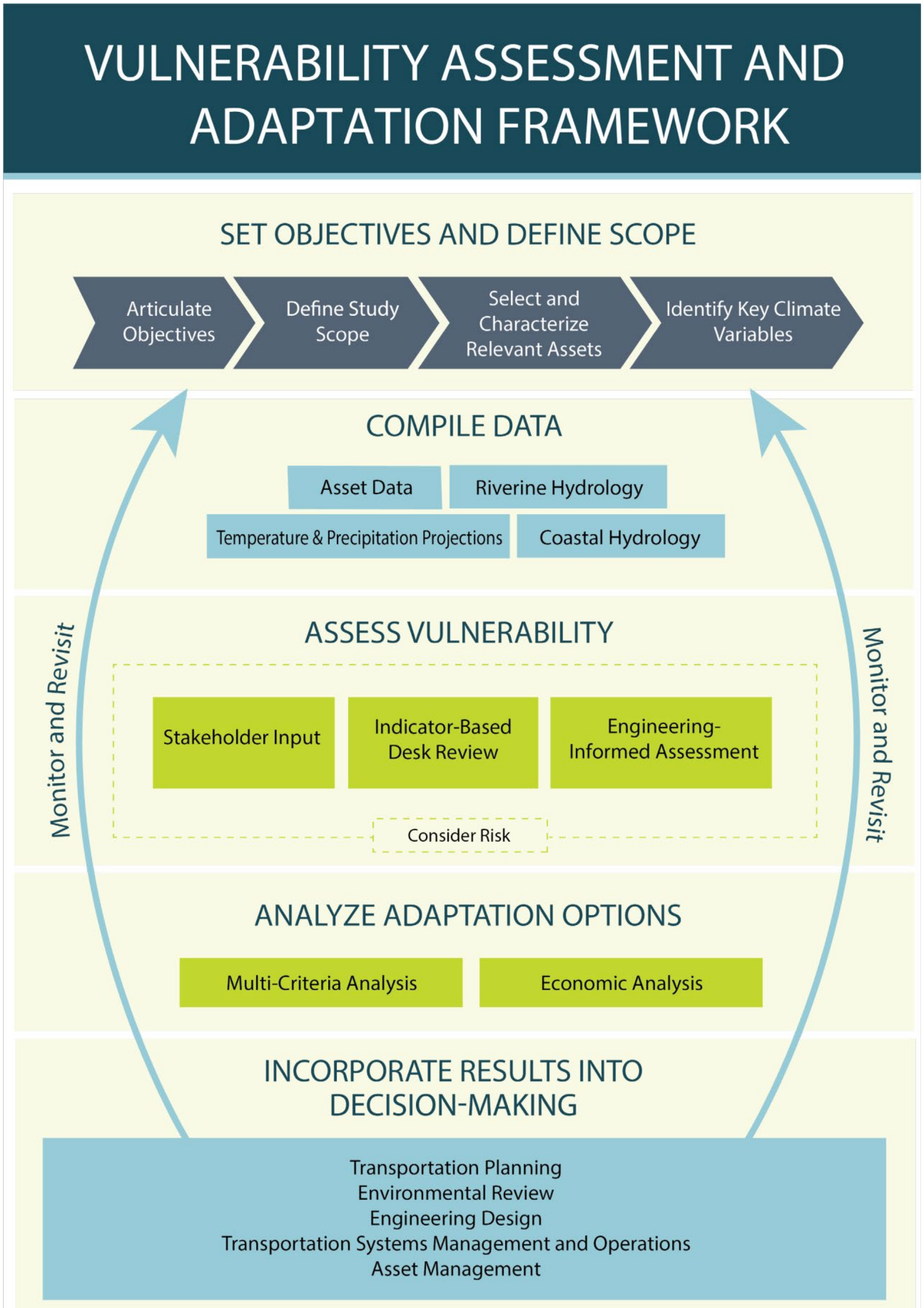

Figure 2-1 **FHWA Vulnerability Assessment and Adaptation Framework**

The Vulnerability Assessment and Adaptation Framework steps are:

1. Define study objectives and scope.
2. Obtain asset data.
3. Obtain climate data.
4. Assess asset vulnerability to climate change hazards.
5. Identify, analyze, prioritize adaptation options.
6. Incorporate assessment results into decision-making.
7. Monitor and revisit.

The steps undertaken as part of this project are explained in more detail in the following sections. The remaining steps of the framework (steps five through seven) were not completed as part of this project but can be pursued by the Tribes and their partners in further studies.

2.3.1 DEFINE STUDY OBJECTIVES AND SCOPE

The assessments began by defining study objectives, scope, and identifying relevant assets and climate hazards to include in the study. This step began with a kickoff meeting between the project team and the Tribal POCs to start the discussion of the goals and expected outcomes of the vulnerability assessment. This conversation typically continued over several more meetings after the kickoff and sometimes included other Tribal representatives and interested parties. The project team would typically ask questions such as the following, targeted to each community:

- What are your main goals for the study?
- What are the primary areas of concern on the transportation network?
- Are there any assets on the transportation network that have been repeatedly damaged by weather or climate events (e.g., flooding)?
- What climate hazards are you most worried about and affected by? Have you noticed changes over time?
- Have you completed any other climate change projects we should review?
- Are there others in the community who we should speak with?

These questions helped to define the scope of the study and identify what information and data was available.

2.3.2 COMPILE DATA

The project team reviewed past climate change projects for each Tribe, which included past climate change vulnerability assessments or adaptation plans, as available. The team then conducted a review of available data and reports on relevant hazards, transportation assets, and climate change impacts. These intentional approaches helped avoid duplication of past efforts and ensure the results would not be repetitive.

Tribes typically had asset data in Geographic Information System (GIS) formats, though some more specific data would often be missing, in hard copy, or only known by certain staff (e.g., maintenance activities). The project team would then hold interviews with staff to collect data that was not readily available but known by individuals.

Wherever possible, the project team tried to collect regional or local climate data. Oftentimes there was no regionally downscaled climate data available. In those cases, the team relied on national sources. Detailed explanations of data collected for each assessment are provided in the vulnerability assessments technical memorandums created for each Tribe.

2.3.3 ASSESS VULNERABILITY

The FHWA framework outlines three different pathways for completing a vulnerability assessment:

- **Tribal input approach:** This approach relies on local, institutional knowledge to identify vulnerabilities. This allows for consideration of information that is not readily available through data or records but is instead only known through staff and/or community experience. This approach uses engagement techniques like interviews and surveys to understand how assets are used, how they are currently affected by weather or climate-related issues, and how they may be affected in the future. The approach relies heavily on Tribal institutional knowledge, but community members can also be consulted to provide input on asset vulnerabilities.

  The FHWA Framework refers to this approach as the "stakeholder input approach," but here we refer to it as the Tribal input approach for the purposes of this project. This language was chosen because Tribal Nations are not traditional stakeholders, and this term can be problematic. Tribes are sovereign nations, and communications between Tribes and local, State, and Federal governments and agencies are government-to-government consultations. Traditional stakeholders who may be consulted to inform this approach include the Tribe's neighboring local jurisdictions, local transit districts, State DOTs, and other partners who work with the Tribe to manage transportation assets. This approach could also consider the input of the entire community, not just Tribal staff and their partners.
- **Indicator-based desk review approach:** This technique involves scoring and ranking asset vulnerability based on available data and attributes such as those related to asset exposure (e.g., is it in a floodplain?) and sensitivity (e.g., would the asset be damaged if it got wet?). Different metrics are weighted and scored so that each asset receives an overall vulnerability score. This approach is a relatively low-cost and simple way to assess systemwide vulnerability. However, this approach has limitations as it does not always capture "on-the-ground" conditions and community knowledge.
- **Engineering-informed assessments:** These assessments are typically focused on the asset level and apply more detailed data to test how the asset will perform under different climate scenarios, and how adaptation strategies may protect against future damages and costs. These assessments are very useful for informing decision-making at the asset level but are cost intensive and more difficult at the system level.

Each Tribal vulnerability assessment used one or more of these vulnerability assessment approaches to guide the completion of the study. The specific methodologies applied in each assessment are explained in the Tribal Transportation Vulnerability Assessment Summaries section (Section 3) and complete Tribal vulnerability assessment technical memorandums are provided in Appendix C.

2.4 Overview of Assessment Terminology

While each Tribal vulnerability assessment took a different approach to assessing climate hazards, they all use a consistent set of terminology to describe climate projections. This section provides background on these terms so they can be easily understood when reviewing each of the Tribal Transportation Vulnerability Assessment Summaries (Section 3). Common definitions can also be found in the Glossary and under Acronyms and Abbreviations.

2.4.1 EMISSIONS SCENARIOS

Emissions scenarios are used to model different pathways for the amount of greenhouse gases emitted into the atmosphere. The Tribal vulnerability assessments conducted for this project used two emissions scenarios, also known as Representative Concentration Pathways (RCPs), which represent the amount and concentrations of greenhouse gases emitted up to 2100. The word “representative” means that each RCP provides one of several possible scenarios in the future. RCPs are labelled with numbers referring to the warming that would occur under that scenario (in watts per square meter of solar radiation).[8] The RCPs used in the Tribal transportation vulnerability assessments are as follows:

- RCP 4.5 (“low emissions scenario”): This scenario projects that annual greenhouse gas emissions will increase and reach their peak by 2040 before declining.
- RCP 8.5 (“high emissions scenario”): This scenario assumes that annual greenhouse gas emissions will continue to rise throughout the century without any significant mitigation measures.

2.4.2 TIME FRAMES

Climate change is the change in average weather conditions that persist over long periods of time, usually 30-year periods or longer.[9] To understand how climate is changing, 20- or 30-year periods are assessed to account for interannual variability. The Tribal transportation vulnerability assessments conducted for this project use 30-year average periods to represent mid and end of century. The common time horizons used across assessments are:

- Historical (30-year average from 1976 to 2005)
- 2050s (30-year average from 2040 to 2069)
- 2080s (30-year average from 2070 to 2099)

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8 United Nations Intergovernmental Panel on Climate Change Glossary. https://www.ipcc-data.org/guidelines/pages/glossary/glossary_c.html

9 Investing in Transportation Resilience: A Framework for Informed Choices (2021), https://nap.nationalacademies.org/catalog/26292/investing-in-transportation-resilience-a-framework-for-informed-choices

3 Tribal Transportation Vulnerability Assessment Summaries

This project involved completing climate change vulnerability assessments focused on the transportation networks of seven federally recognized, Indigenous Tribes across the United States, compiled into vulnerability assessment reports (or technical memorandums). Assessments were completed for the Karuk Tribe, the Native Village of Kwigillingok, the Mescalero Apache Tribe, the Coushatta Tribe of Louisiana, the Rosebud Sioux Tribe, the Ottawa Tribe of Oklahoma, and the Modoc Nation.

The results of these assessments will inform Tribal decision-making processes for their transportation systems. The findings of these reports could be used to address potential impacts of climate change by informing the development of adaptation strategies to increase the resilience of transportation infrastructure.

Table 3-1. Overview of Tribes Involved in the Project

Tribe	Primary Climate Hazards Assessed	Tribal Membership	Location
Karuk Tribe	▪ Temperature rise and extreme heat ▪ Heavy precipitation events and flooding ▪ Wildfires ▪ Landslides and debris flows	Over 3,500 Tribal Members	800 acres in Northern California
Native Village of Kwigillingok	▪ Temperature rise ▪ Heavy precipitation events and flooding ▪ Sea level rise and coastal flooding ▪ Geotechnical issues (permafrost melt, erosion)	Approximately 400 residents in the village	Approximately 57 acres in southeastern Alaska, near the Yukon-Kuskokwim Delta
Mescalero Apache Tribe	▪ Temperature rise and extreme heat ▪ Heavy precipitation events and flooding ▪ Wildfires	Approximately 5,200 members	Approximately 463,000 acres in central New Mexico
Coushatta Tribe	▪ Heavy precipitation events and flooding	Approximately 960 members	Approximately 7,120 acres in Allen Parish, Louisiana
Rosebud Sioux Tribe	▪ Temperature rise and extreme heat ▪ Heavy precipitation events and flooding ▪ Wildfires ▪ Storms and tornadoes	Approximately 33,210 members	Approximately 882,416 acres in South Dakota, bordering Nebraska

Ottawa Tribe of Oklahoma	▪ Temperature rise and extreme heat ▪ Heavy precipitation events and flooding ▪ Storms and tornadoes	Approximately 2,500 enrolled members, 737 living on the reservation	Approximately 15,500 acres in northeastern Oklahoma
Modoc Nation	▪ Temperature rise and extreme heat ▪ Heavy precipitation events and flooding ▪ Storms and tornadoes	496 enrolled members living across different States	Approximately 4,600 acres in northeastern Oklahoma (the Tribe is also re-procuring part of their aboriginal land in Northern California; this land was not included in the assessment).

3.1 Karuk Tribe

3.1.1 ASSESSMENT OVERVIEW

The Karuk Tribe owns and oversees transportation assets within its aboriginal territory, on land that now covers approximately 900 acres held in trust by the Tribe in Northern California (see Figure 3-1). The Karuk Tribe Department of Transportation is responsible for managing and maintaining Tribally owned assets on the transportation network, which spans 115 miles across Caltrans Districts 1 and 2. The Karuk Tribe does not own all of the transportation assets the community uses within its territory, and relies heavily on Caltrans, Siskiyou County, Humboldt County, and U.S. Forest Service (USFS)-owned roads for local transportation and access/egress to and from the area. The Karuk Tribe Department of Transportation is a small department with limited resources to address existing hazards and maintenance issues, let alone the expected impacts posed by future climate hazards.

Given the mountainous and rural area that the Karuk Tribe lives in, the roadway network is sparse with limited redundancy. The network is also plagued by hazards such as wildfires, floods, and landslides, causing road closures with limited and sometimes very long detours around closures. State Route (SR) 96 is the primary north-south artery crossing 72 miles through the Karuk Aboriginal Territory. SR 96 is important for local travel and for community access/egress as it connects with Interstate 5 to the east and SR 299 to the southwest. When SR 96 is closed, oftentimes the only alternative routes available are USFS or county roads which may not be maintained or suited for regular use.

The primary climate hazards that threaten Karuk transportation assets and community access are temperature rise, heavy precipitation events and flooding, wildfires, and landslides and debris flows. As climate changes, these events are expected to become more frequent and severe over time, putting additional pressure on the Karuk transportation infrastructure. The most vulnerable assets, including routes important for access and egress, were identified through input collected from our Tribal partners.

Source: Karuk Tribe

Figure 3-1. Karuk Aboriginal Territory in the Klamath River Basin

3.1.2 SUMMARY OF FINDINGS

3.1.2.1 Temperature Rise

On the North Coast, increases in annual average daily temperatures across the region were under 1 degree Fahrenheit (°F) over the last century and are expected to increase by 5°F to 9°F by the end of the century under moderate and high emissions scenarios. Coastal temperature rise is tempered by the Pacific Ocean, and the greatest temperature increases are projected in Siskiyou County. The average maximum temperature over seven days is rising across the Karuk territory, which could lead to pavement rutting and warping and more frequent pavement maintenance in the future.

3.1.2.2 Heavy Precipitation Events and Flooding

Precipitation is inherently very difficult to project in California and future trends are uncertain. In the North Coast region, model predictions of annual precipitation are close to historical conditions, with a trend towards slightly higher precipitation by end of century. While average annual precipitation may not change much, extreme precipitation events are expected to become more frequent and severe.

3.1.2.3 Wildfires

The Karuk Tribe has long used fire for cultural practices (including for ceremonial purposes), for ecological practices (including promoting the growth of certain plants), and for creating more opportune sites for hunting. Changing land management practices, including the practice of fire suppression, has limited the Karuk Tribe's ability to conduct controlled burns and has altered fuel conditions in the mid-Klamath region. As temperatures rise and vegetation is dried out, the risk of high severity wildfires continues to grow. The analysis found that almost every asset on the Karuk transportation network is exposed to increasing likelihood of large wildfires, even under lower emissions and nearer-term scenarios.

3.1.2.4 Landslides and Debris Flow

The Karuk transportation network is already highly vulnerable to and affected by landslides. The mountainous terrain of the area also lends itself to a higher likelihood of larger landslide events, such as deep-seated landslides that can move acres of land at a time. As is the case with the wildfire projections, almost every asset on the Karuk transportation network is exposed to deep-seated landslide susceptibility.

3.1.2.5 Top Vulnerabilities

This assessment took a Tribal input-based approach with Karuk and Caltrans maintenance staff to identify existing problem areas on the Karuk transportation network. Some of these locations have experienced repeated impacts from hazards such as heavy precipitation, flooding, landslides, and/or wildfires. These areas already demonstrate impacts from weather and climate-related events, which will likely only become more frequent and severe as climate changes and these assets are stressed further (see Figure 3-2).

The most persistent problem area on the Karuk network is at Crowded Bench on SR 96 southwest of Happy Camp, where there have been repeated landslides. The climate hazard analysis found that this section of SR 96 is in a high to very high deep-seated landslide susceptibility zone and moderate to high wildfire concern zones. When this segment of SR 96 is closed, travelers going between Happy Camp and Somes Bar are cut off and would need to take SR 3 to circumvent the slide area, which is an approximately 2-hour detour.

One of the next most vulnerable problem spots is on SR 96 east of Happy Camp in what was described by maintenance staff as the Old Faithful Slide area, which has experienced recurring slides. In this area, the deep-seated landslide susceptibility is classified as very high, and the area is exposed to moderate to high risk of wildfire. In addition, the roadway touches the edge of the Slater Fire scar, where there is a low risk (0 percent to 20 percent chance) of debris flow under lower intensity precipitation.

Other highly vulnerable locations include those where multiple past events were reported. Landslide activity was reported on SR 96 along Irving Creek, close to where recurring issues were noted at Terwater Sink. SR 96 at Windy Point was another location where repeated slides were reported. There were also multiple slides and impacts documented at the Saint Fitzpatrick Day Slide, Paul's Slide, and Independence Slide along SR 96.

Another location worth noting is Red Cap Road, which experiences regular slides in a place called "The Lookout" and is critical to residents in the area who would have no alternative way to get out of the area if the road is closed.[10]

[10] Karuk Tribe. 2022. Karuk Climate Transportation Adaptation Plan. https://karuktribeclimatechangeprojects.files.wordpress.com/2022/03/karuk-climate-transportation-adaptation-plan-final-2022-1.pdf

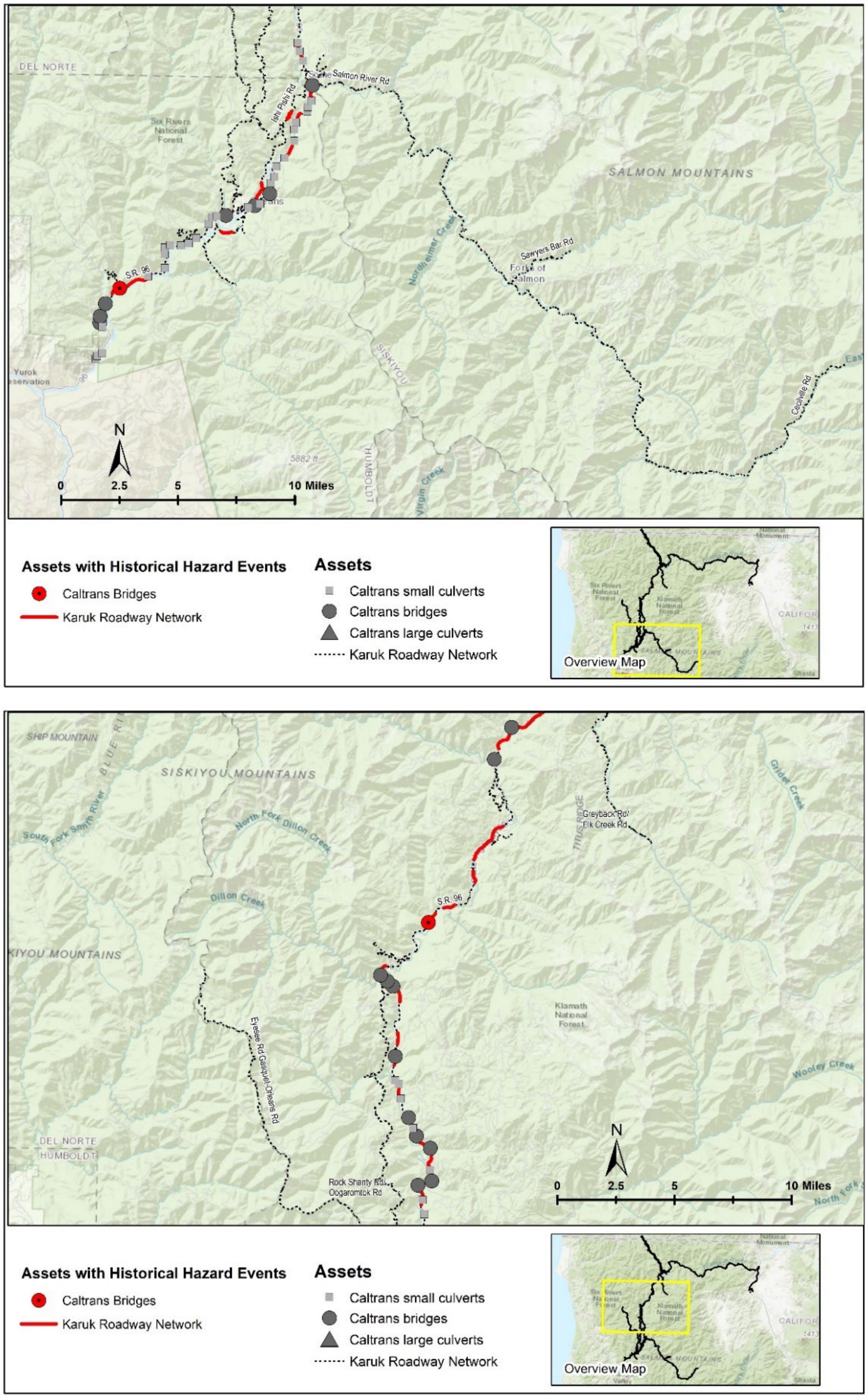
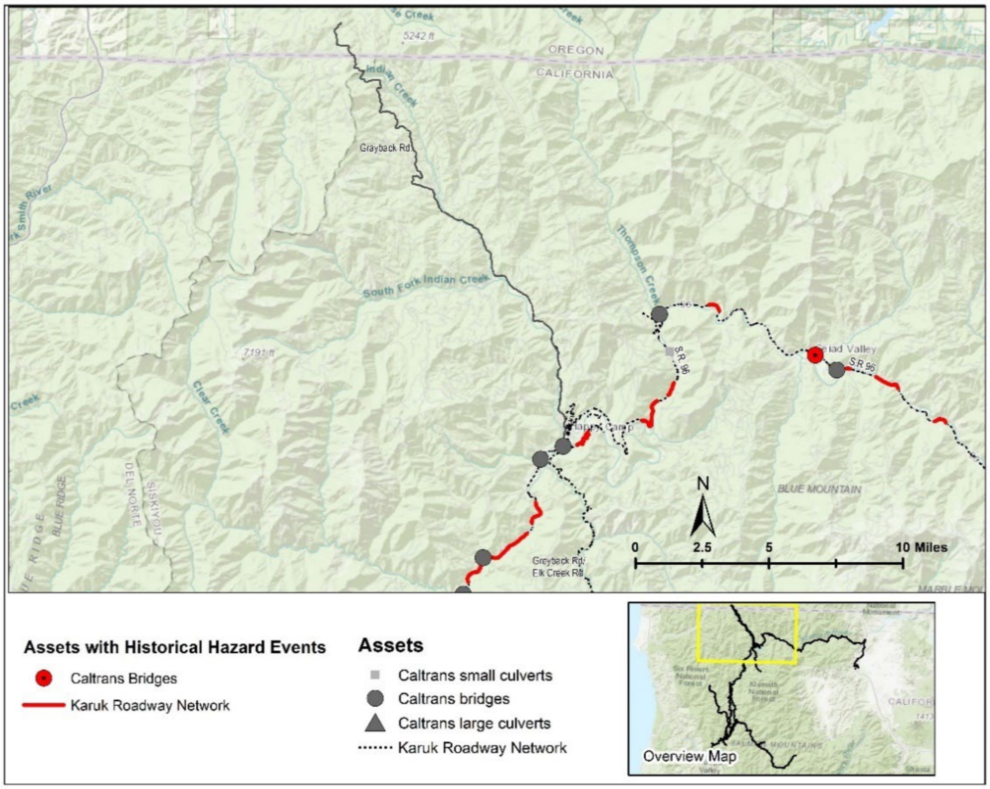
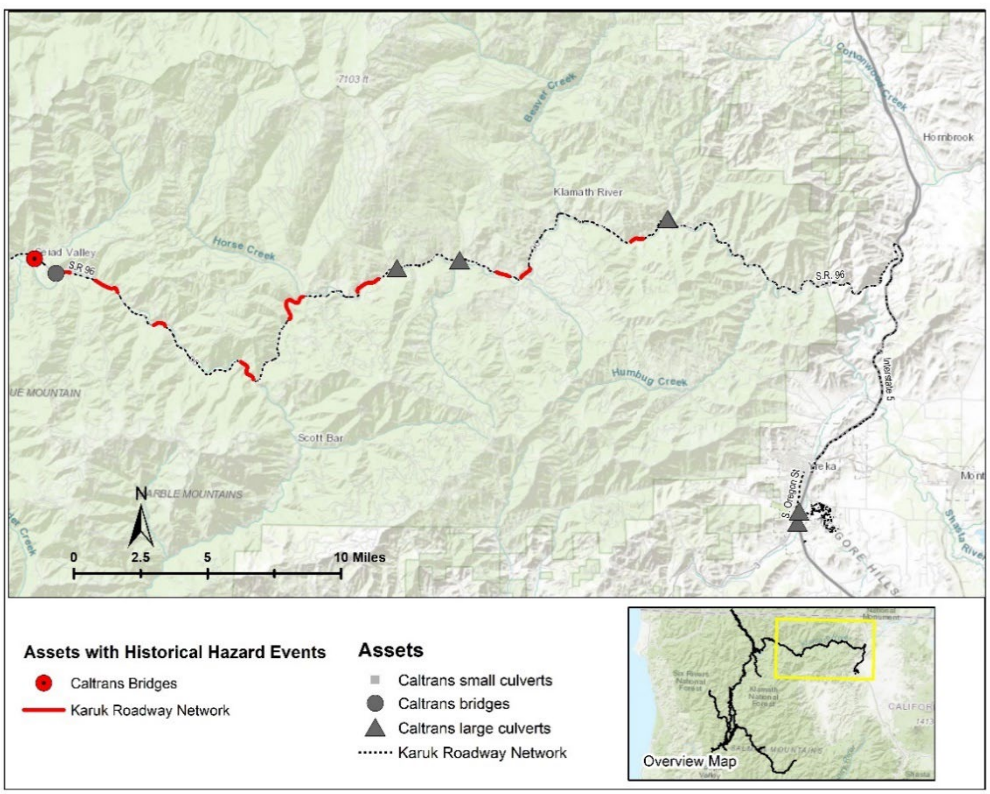


Figure 3-2. Karuk Transportation Assets Damaged by Historical Hazard Events





Source: FHWA

Figure 3-2. Karuk Transportation Assets Damaged by Historical Hazard Events (continued)

3.2 Native Village of Kwigillingok

3.2.1 ASSESSMENT OVERVIEW

The Native Village of Kwigillingok is a Tribal Community located in southwestern Alaska near Kuskokwim Bay (Figure 3-3). Kwigillingok's transportation system relies on a system of wooden boardwalks and all-terrain vehicles, a barge landing, and the Kwigillingok Airport. Given its low-lying location on the wetlands of the Yukon-Kuskokwim Delta, the community experiences periodic flood events, which impact the Village and its transportation infrastructure.

The Native Village of Kwigillingok's Tribal Transportation Climate Change Vulnerability Assessment used a Tribal input approach to assess how changing climate and associated hazards could affect the transportation system and those who depend on it. Four climate hazards were included in the assessment: temperature rise, heavy precipitation and flooding, sea level rise and coastal flooding, and geotechnical hazards. The team summarized available climate change projections for the region, reviewed potential impacts on transportation, and provided a gap assessment for the Village of Kwigillingok to understand data needs for further analysis.

Source: Google Earth

Figure 3-3. Satellite Image of the Native Village of Kwigillingok

3.2.2 SUMMARY OF FINDINGS

3.2.2.1 Temperature Rise

Future projections compared to historic averages show that there is an estimated increase in average annual temperature in Kwigillingok, with a greater degree of increase seen under a higher global greenhouse gas emission scenario.

3.2.2.2 Heavy Precipitation Events and Flooding

Flooding in Kwigillingok is primarily driven by runoff from precipitation events and storm surges. Projected average annual precipitation in Kwigillingok shows an expected increase in average annual precipitation, especially under a high global greenhouse gas emission scenario.

3.2.2.3 Sea Level Rise and Coastal Flooding

While flood events in Kwigillingok result from both precipitation events and storm surge, a combination of high tide events and storm surge is the dominant cause. Kwigillingok lacks floodplain mapping and sufficient documentation of past flood events. This has historically prevented some of the most at-risk communities in Alaska, such as Kwigillingok, from being accurately assessed for flood risk and from accessing funding for hazard mitigation projects. Sea level rise may amplify the impacts of storm surge and high tides.

3.2.2.4 Geotechnical Vulnerabilities

Permafrost warming and melting, in addition to erosion, are geotechnical concerns for the Village of Kwigillingok because the community resides on coastal land next to the Kwigillingok River, which is characterized by discontinuous permafrost erosion. Studies conducted in Kwigillingok estimate that the community is losing about 48,000 square feet of land per year due to erosion.

3.2.2.5 Top Vulnerabilities

Several of the Kwigillingok assets most vulnerable to climate change were identified through discussion with the Transportation Director and through the findings of the analysis and literature review. Two critical and threatened assets are Airport Road and the village barge landing.

The Tribe's Transportation Director noted that Airport Road is one of the routes he is most concerned with and has recently needed more repairs. The roadway runs approximately 1 mile between the airport and the village, stopping before it reaches the Kwigillingok River. Sections of the roadway have sunk and flooded in the past. Accounting for staff and fuel assumptions, the project team estimated that the total cost to repair Airport Road would be between about $2,400 and $7,850 following each flood or other disruptive event. The Transportation Director noted that such unexpected costs can be challenging to accommodate as the village's maintenance budget is only $50,000. The even greater cost is carried by the community in the event of a closure on Airport Road, which could take days or weeks depending on the event. This would cut off the community, which relies upon the airport for supplies, travel to and from the village, and access to medical facilities.

Two erosion assessments completed for Kwigillingok, one in 2009 and the other in 2021, identified that the barge landing is vulnerable to erosion from the Kwigillingok River. Erosion of the riverbend near the barge landing may lead to two riverbends joining into one, which could create a new channel across an existing point bar. The forecasted erosion and change to the existing river channel could put a total of 18,388 square feet of the barge landing in harm's way by 2075. The barge landing is also vulnerable to flooding due to its low-lying position on the Kwigillingok River. Besides the airport, the barge landing is the only way to receive shipments of supplies and materials to Kwigillingok.

3.3 Mescalero Apache Tribe

3.3.1 ASSESSMENT OVERVIEW

The Mescalero Apache Tribe is a federally recognized Indian Tribe with 463,000 acres of ancestral land located in south-central New Mexico in the Sacramento Mountains. As of 2017, the Tribe had approximately 5,087 citizens. The Tribe's transportation network is vulnerable to flooding, with roads sometimes closing for days at a time. The main transportation corridor is Highway 70 and there are about 660 miles of roads in the Mescalero Apache Tribe's network. Most of the Tribe's land is forested area. As such, the main concerns for the Tribe are wildfires and subsequent flooding during the monsoon season. These climate hazards are expected to increase in frequency and severity with climate change.

This vulnerability assessment examined the impacts of changing temperature, precipitation, and wildfire potential and identified vulnerable areas on the Mescalero Apache Tribe transportation network based on these forecasts. The team reached out to key Tribal partners and visited the Reservation for an on-site visit to engage with relevant parties and to observe the transportation network. The team also developed a general approach for how the Mescalero Apache Tribe Public Works Department could begin to assess precipitation projections in the Tribe's drainage studies and account for changing heavy storm events in its drainage infrastructure designs.

3.3.2 SUMMARY OF FINDINGS

3.3.2.1 Temperature Rise

The team centered the temperature analysis on temperature metrics that are used to inform pavement design so that these projections can be directly applied to future pavement design decisions in partnership with the New Mexico Department of Transportation. The team also examined annual projections of average minimum and maximum temperatures across the Mescalero transportation network and Ztrans bus stops to summarize changing temperature range, which is also an input to pavement design. Average maximum temperature projections are summarized to demonstrate the high end of changing temperature ranges across the Reservation. Changing high temperatures are especially important when considering health impacts on travelers, such as Ztrans riders.

3.3.2.2 Wildfires

Wildfires are the biggest concern for the Mescalero Apache Tribe. Hotter, drier conditions are resulting in wildfires that are more frequent, severe, intense, and widespread. The Mescalero Apache Tribe transportation network has already suffered impacts from wildfires and subsequent flood events from stormwater runoff, including from the Soldier Canyon Fire (2018), Tularosa Fire (2008), and Chino Well Fire (1996). The Tribe has closed roadways for days at a time due to wildfires and subsequent stormwater runoff. The most recent significant wildfires led to evacuation and heavy damages.

As discussed during meetings with the Tribe, there is a high wildfire risk throughout the Reservation, which has caused drastic impacts in terms of damages and cutting off access for community members. These climate impacts compound as the fire burn scars cause flooding that drains into the valley where major roads, including Highway 70, reside. Most of the Tribe's transportation network is in "Very High" wildfire potential zones.

3.3.2.3 Heavy Precipitation Events and Flooding

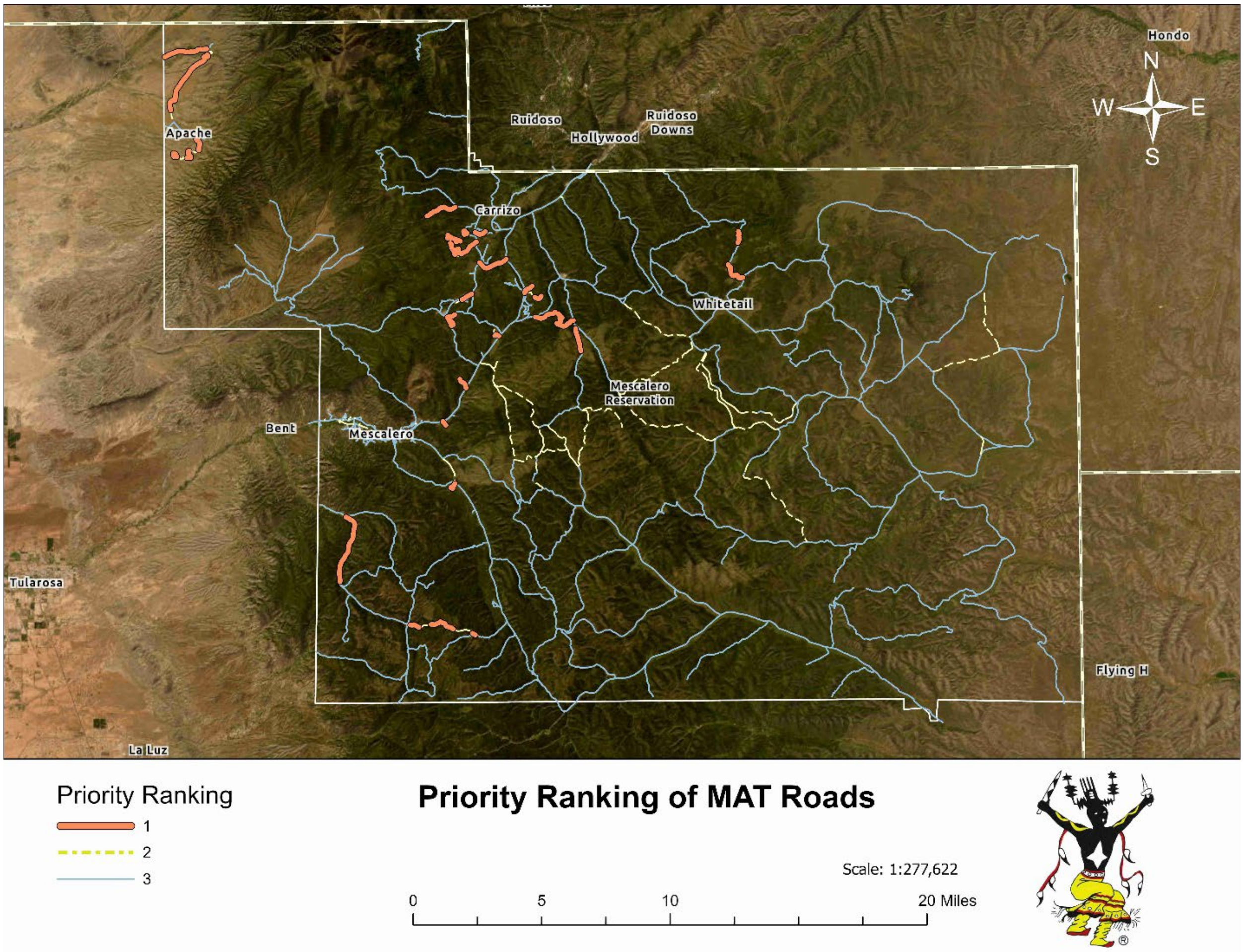
The transportation network of the Mescalero Apache Tribe has been repeatedly damaged by heavy rain and subsequent flooding events, which have closed roadways for days at a time. As the climate changes and extreme weather events become more frequent and severe, the Mescalero Apache are concerned about the risk of repeated flooding due to drainage systems being overwhelmed. According to members of the Public Works Department, the summer monsoon season is delivering shorter, more intense periods of rainfall, causing flooding throughout the Reservation. This is matched with a longer, drier dry season and an expected increase in the average 1-day (24-hour) maximum rainfall amount by mid-century with a high-emissions scenario. These intensifying events can cause large infrastructure impacts, especially as ground burned by wildfires is not able to absorb heavy precipitation. This has caused roads to flood and debris to flow onto Mescalero Apache roads, creating long delays and detours or cutting people off completely and increasing repair and maintenance costs.

3.3.2.4 Top Vulnerabilities

These existing and changing hazards negatively impact the Mescalero Apache transportation network and make it more vulnerable to failure. To identify priority assets that could benefit from adaptation measures, the project team examined impacts on the Mescalero Apache Tribe roads in half-mile segments and on Ztrans bus stops from heavy precipitation and wildfires. The project team developed an indicator-based ranking system for assets based on potential heavy precipitation and wildfire impacts and community input. Input about existing asset vulnerability and past damages was collected through listening sessions with the Tribe's Public Works Department, the New Mexico Department of Transportation, and Ztrans, the local transit operator. The following ranking system was used to prioritize assets based on vulnerability to current and future stressors:

- Priority 1: Assets that have experienced past damage and are exposed to higher 100-year return period flows **and** wildfire potential greater than Moderate (3).
- Priority 2: Assets that have experienced past damage and are exposed to wildfire potential greater than Moderate (3) **or** higher 100-year return period flows.
- Priority 3: Assets exposed to either existing or future hazards.
- Non-priority/no priority: Assets with no known past impacts and damages, not exposed to climate hazards.

From this analysis, the project team created a prioritized list of vulnerable assets ranging from priority one to three for segments of roadway and Ztrans bus stops. Figure 3-4 summarizes the priority rankings for the Mescalero Apache Tribe roadways.



Source: FHWA

Figure 3-4. Priority Ranking of MAT Roads Based on Vulnerability Assessment Prioritization

3.4 Coushatta Tribal Transportation Vulnerability Assessment

3.4.1 ASSESSMENT OVERVIEW

The Coushatta Tribe of Louisiana is a federally recognized Indian Tribe located in Allen Parish, Louisiana. The Tribe's reservation is vulnerable to frequent flooding, mainly caused by storm events and runoff surface water accumulation, which can result in rapid and extensive flooding in low-lying or poorly drained areas. According to the Tribe, flooding events occur on an annual basis, with the potential to cause extensive damage and disrupt transportation by inundating and closing roads. This project was the Tribe's first comprehensive assessment of its transportation network's vulnerability to climate change hazards. The vulnerability assessment specifically focused on heavy precipitation events and flooding as this is the primary climate hazard of concern for the Coushatta.

Given the susceptibility of the Coushatta road network to current rainfall and run-off from these events, the Tribe is planning to build an evacuation road to help facilitate movement out of the area in an emergency. However, the Coushatta vulnerability assessment indicates that the current design is not sufficient to withstand extreme precipitation events and will require design improvements. The team worked closely with the Coushatta Tribe to thoroughly understand the existing vulnerabilities in the Coushatta territories and Allen Parish. Due to limited resources and an inability to address current hazards and maintenance issues, the team also produced a list of potential funding sources for the Coushatta Tribe's consideration in the vulnerability assessment.

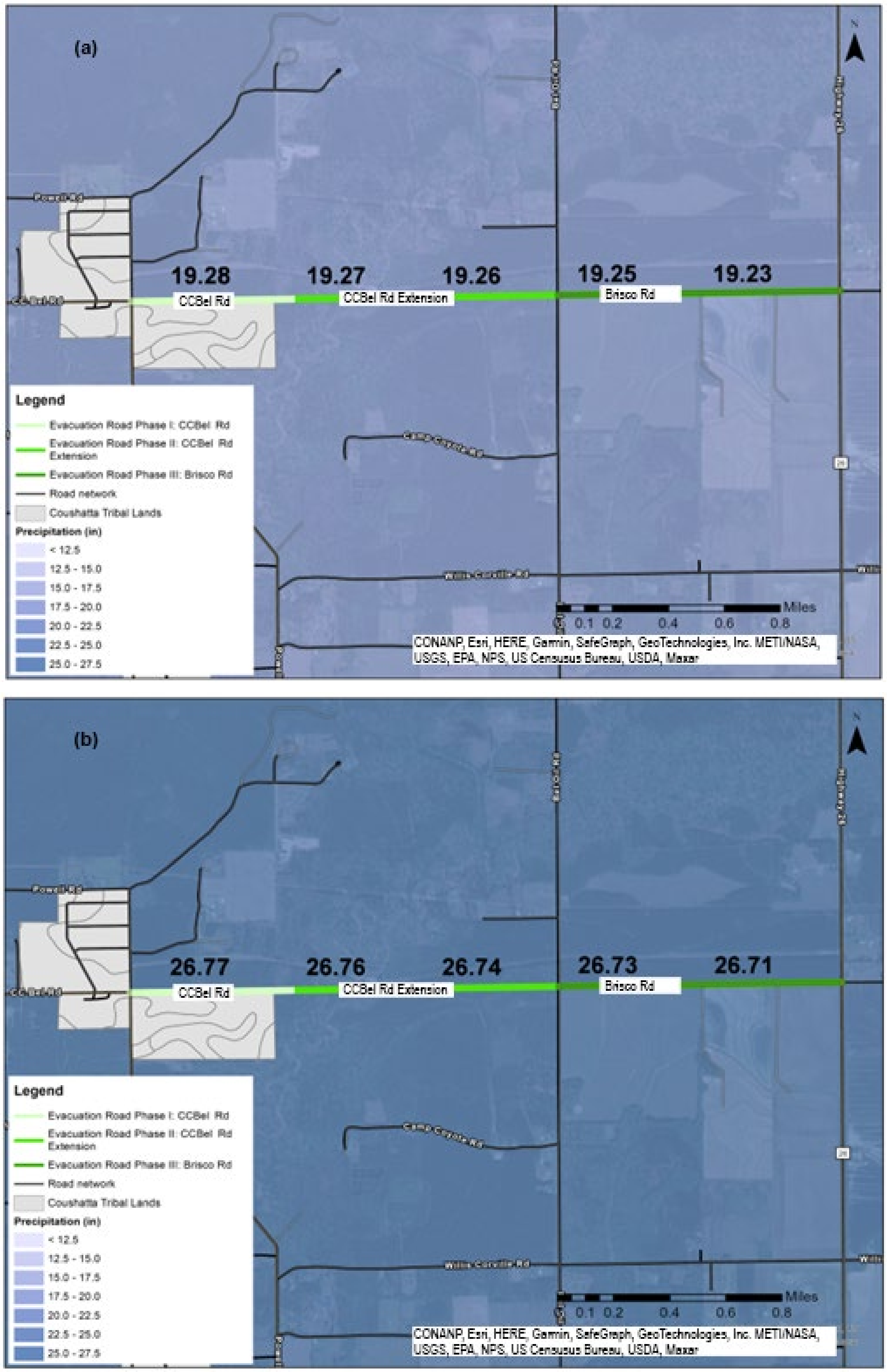
The vulnerability assessment was carried out using the Tribal input approach and drew inspiration from the engineering-informed assessment approach. The focus was to identify transportation assets and critical facilities that have been significantly affected during past heavy precipitation events and have a high priority for protection and resilience planning. The project team also developed precipitation projections to supplement existing data.

3.4.2 SUMMARY OF FINDINGS

3.4.2.1 Heavy Precipitation Events and Flooding

The most important climate hazard of concern to the Tribe is flooding due to heavy precipitation. The Coushatta Tribe's transportation assets and community access are primarily threatened by heavy precipitation events and flooding. The primary cause of flooding in the area is associated with surface water runoff, lack of stormwater management on roadways, and excessive ponding resulting from high-intensity rain events. Tribal citizens have reported impacts on the transportation network (including road closures) caused by flooding at least once per year. The frequency and intensity of extreme precipitation events are expected to increase, putting additional stress on the Tribe's transportation infrastructure.

The Coushatta Tribal lands are in low-lying areas and the capacity of the drainage system on the Coushatta roads is insufficient to handle increased rainfall. This is especially problematic given the significant increase projected in rainfall volumes from the 50-year and 100-year precipitation events by mid-century and end of the century. Hazard exposure was evaluated for assets located in areas exposed to the 50-year and 100-year precipitation events. The projections of these events by mid-century and end of the century indicate that the entire Coushatta road network will be exposed to events that present a significant threat to the daily operations of the Tribe and the ability to evacuate in case of emergency during extreme rainfall events.



Source: FHWA

Figure 3-5. Projected 24-Hour Rainfall on Evacuation Road (RCP 8.5): (a) 50-year event, (b) 100-year event (2080s)

3.4.2.2 Top Vulnerabilities

The Coushatta Tribe applied for grant funding in 2018 with the goal of constructing an emergency evacuation road. This road would provide a safer alternative route for citizens of the Tribe and rural Allen Parish residents during periods of heavy rainfall. The proposed evacuation road is planned to be constructed to the Louisiana Department of Transportation and Development guidelines and standards, with a design capacity for 25-year storm events. However, the Coushatta roads frequently experience more intense rainfalls and have been overwhelmed by extreme events like Hurricane Barry. Rainfall from Hurricane Barry exceeded the historical 100-year rainfall level by several inches, causing significant disruptions to transportation and posing a threat to the safety of residents. Rainfall projections indicate that future storm events will likely overwhelm current drainage design standards. For example, by mid-century, it is expected that a 100-year rainfall event will produce 25.5 inches of rainfall, which is approximately 40 percent more than the amount produced by Hurricane Barry. Figure 3-5 shows the projected 50-year and 100-year rainfall anticipated in one day on the proposed evacuation route (under the RCP 8.5 emissions scenario).

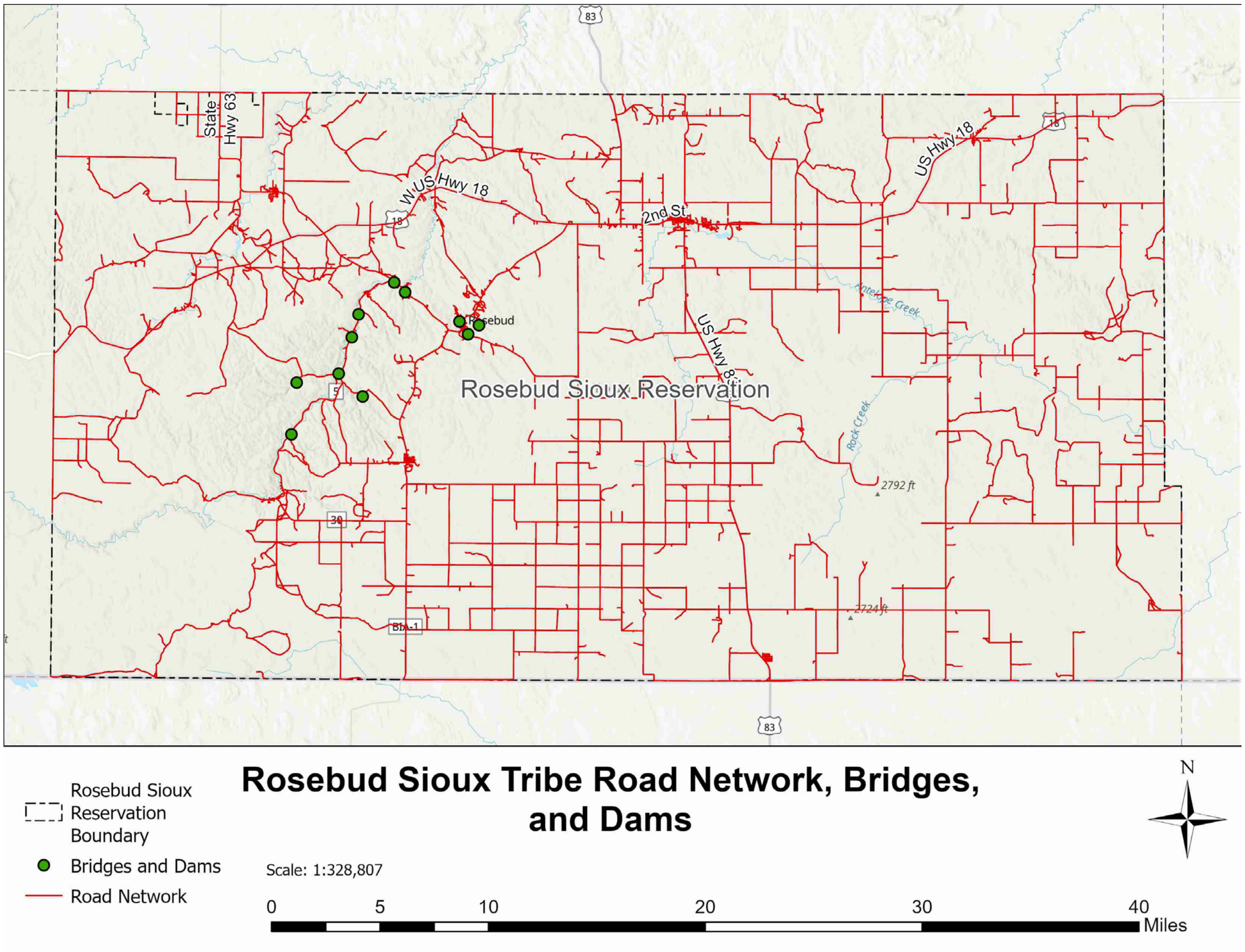
3.5 Rosebud Sioux Tribal Transportation Vulnerability Assessment

3.5.1 ASSESSMENT OVERVIEW

The Rosebud Sioux Tribe is a federally recognized Indian Tribe with 21,245 enrolled citizens living on the reservation, a land area of 882,416 acres in south central South Dakota bordered by the Pine Ridge Reservation, the White River, and Cherry County, Nebraska. The land of the reservation is primarily semi-arid hills, and climate hazards include extreme heat, extreme cold, increased soil erosion, storms, wildfires, and drought. In recent years, long-term groundwater level declines have been observed, increasing the reservation's vulnerability to drought.

The Rosebud Sioux roadway network is made up of 312 miles of roads, which are primarily owned by the BIA and managed by the Rosebud Sioux Tribe (Figure 3-6). They are directly funded and when possible partner with the BIA for road maintenance endeavors. While the roads within Tribal lands are owned by various public authorities, the Tribe takes a central role in managing the transportation system to meet the needs of their citizens. They work with various public authorities to address transportation needs, and for TTP-funded projects, the public authority is afforded an opportunity to review and comment on the Tribe's plans, specifications, and estimates for projects on their roads. Tribally owned roads account for less than 1 mile of the transportation network. Todd County and the State of South Dakota also maintain roads within the Tribal boundaries. One of the primary concerns for the Rosebud Sioux transportation network is extreme heat, as many pedestrians use the transportation network every day.

Based on community input, some of the challenges currently faced by the Tribe related to the vulnerability of transportation infrastructure to climate-related events include riverine flooding, tornadoes, ice storms, extreme temperatures, drought, soil erosion, and wildfires. These events result in temporary road closures and increased maintenance needs that are likely to be exacerbated due to climate change. This Tribal transportation network vulnerability assessment focused on the following climate hazards and their impacts: temperature rise and extreme heat, freeze-thaw days, extreme precipitation, wildfire, and storms and tornadoes.



Source: FHWA

Figure 3-6. Map of the Rosebud Sioux Tribe Reservation and Roadway Network

3.5.2 SUMMARY OF FINDINGS

3.5.2.1 Temperature Rise

3.5.2.1.1 Extreme Heat

The National Weather Service's heat index reflects the "feels-like" temperature, the combination of heat and humidity. Under humid conditions, the heat index can be significantly higher than the dry-bulb temperature (what is measured by a conventional thermometer). The number of days with a high heat index is projected to increase.

Between 1976 and 2005, there was one day when the heat index exceeded 103°F, the National Weather Service's threshold for a Dangerous likelihood of heat disorders with prolonged exposure or strenuous activity. The number of days above this threshold is modeled to rise to between 8 and 13 days in the 2050s and between 12 and 34 days in the 2080s. This is a significant increase and presents a public health concern.

Extreme heat events disproportionately impact vulnerable populations, such as those who cannot afford air conditioning or cooling technology and are therefore exposed to high temperatures for extended amounts of time. These events can be exacerbated by power outages caused by an overload of electricity demand for powering air conditioners.

Extreme heat can also damage infrastructure. For example, equipment in power rooms for mechanical equipment can be damaged in high-temperature operating conditions. Damages to pavement and concrete on roads and bridges from extreme heat can include the rutting and shoving of asphalt surfaces, increased hardening of asphalt binder, concrete curling and warping, subgrade shrinking, and blow ups due to slab expansion.[11]

3.5.2.1.2 Freeze-Thaw Days

Freeze/thaw days are the number of days that have a minimum temperature below an identified bottom threshold (15.8°F) and a maximum temperature above freezing temperature (32°F). Minimum temperatures are projected to increase. Warmer minimum temperatures mean that recuperation from periods of extreme heat will be more challenging for humans, animals, and ecosystems. However, rising minimum temperatures may have a beneficial effect on infrastructure. The binding material in pavement is rated down to -7.6°F, so when the temperature dips to -7.6°F or lower, the pavement can degrade. Minimum daily temperatures are estimated to increase by 8°F on the reservation, which may have a positive effect on pavements. Freeze/thaw days, or days that have a minimum temperature below 15.8°F and a maximum temperature above 32°F, are projected to decrease as well, which may have beneficial effects as water is not freezing (and expanding) and thawing (and contracting) in pavement as often.

3.5.2.2 Heavy Precipitation Events and Flooding

The intensity, duration, and frequency of extreme precipitation events are increasing as climate change progresses. The analysis conducted on the frequency of occurrence for extreme precipitation events showed that all precipitation return periods, otherwise known as the probability of a certain depth of precipitation occurring in any given year expressed as an average recurrence interval (i.e., 100-year storm), are projected to increase for 24-hour precipitation events. On average, the values slightly increase for each scenario and each return period. For example, the baseline for a 100-year event is 4.9 inches. This is projected to increase by approximately half an inch (10 to 14 percent) by the 2080s under both emissions scenarios. Compared to the historical baseline, a 2-year event is likely to increase by 9 percent from 2.3 inches to 2.5 inches for all scenarios, and the 200-year event is expected to rise from 5.5 inches to between 6.1 inches (11 percent) and 6.2 inches (13 percent) for all scenarios. A precipitation-related area of concern for the Rosebud Sioux Tribe is the flood risk for the bridges, dams, and lakes within the Tribal lands.

3.5.2.3 Wildfire

The Federal Emergency Management Agency (FEMA) National Risk Index provides an index for wildfire as a risk, and the study area has scores ranging from 97.1 to 99.3, combined with other risk components to yield a relatively moderate to relatively high expected annual loss, a very high social vulnerability, and a very low community resilience.[12] The Tribe experienced a large wildfire in June 2022 that burned over 12 square miles. Though the fire was contained before any structures were destroyed, the fire did cause damage and threatened homes on the edge of the Grass Mountain community.

3.5.2.4 Storms and Tornadoes

The Enhanced Fujita (EF) scale is used to rate tornado severity. The only EF5 tornado that has occurred in South Dakota (the strongest tornado possible on the EF scale) occurred just east of the reservation in 1965. Cumulatively, since 1950, there have been nearly 1,900 tornadoes in

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[11] U.S. Department of Transport (Federal Highway Administration), 2015, Climate Change Adaptation For Pavements, Tech Brief (FHWA-HIF-15-015), https://www.fhwa.dot.gov/pavement/sustainability/hif15015.pdf

[12] FEMA. n.d. National Risk Index. https://hazards.fema.gov/nri/map

South Dakota that have caused over $250 million in property damage, nearly 500 injuries, and approximately 20 fatalities.[13]

How climate change will affect the frequency, intensity, and development of tornadoes, derechos, thunderstorms, and winter weather events is uncertain as they occur over short time periods and over small areas of land, making it difficult to detect and predict trends. However, according to the Fourth National Climate Assessment (2018), thunderstorm-related weather hazards have increased more than any other type of extreme weather since 1980 in the United States, and there is some indication that conditions conducive to severe thunderstorms will likely increase, likely within the Midwest and Southern Great Plains.

3.5.2.5 Top Vulnerabilities

Climate projections show that freeze-thaw and precipitation changes are projected to impact the entire study area with little spatial disparity. All transportation assets would be similarly affected by those impacts. Wildfire, storms, and tornadoes show a similar spatial scenario, and the entire transportation network will see similar risk. However, for extreme heat, there are spatial differences across the reservation. Therefore, the assessment categorized levels of vulnerability based on projected changes to extreme heat using an indicator-based approach. This approach was also guided by community input, as impacts on pedestrian health and mobility were identified as a priority.

The National Weather Service's heat index provides classifications of risk that show how likely heat disorders are with prolonged exposure or strenuous activity. The categories of the heat index are "caution," "extreme caution," "danger," and 'extreme danger.' For the road vulnerability classification, the assessment used days where the "danger" classification is reached (above 103°F heat index). The roadway network was overlaid with the heat index maps to find roads that are exposed to a heat index over 103°F for both the 2055 and 2085 projections (Figure 3-7).

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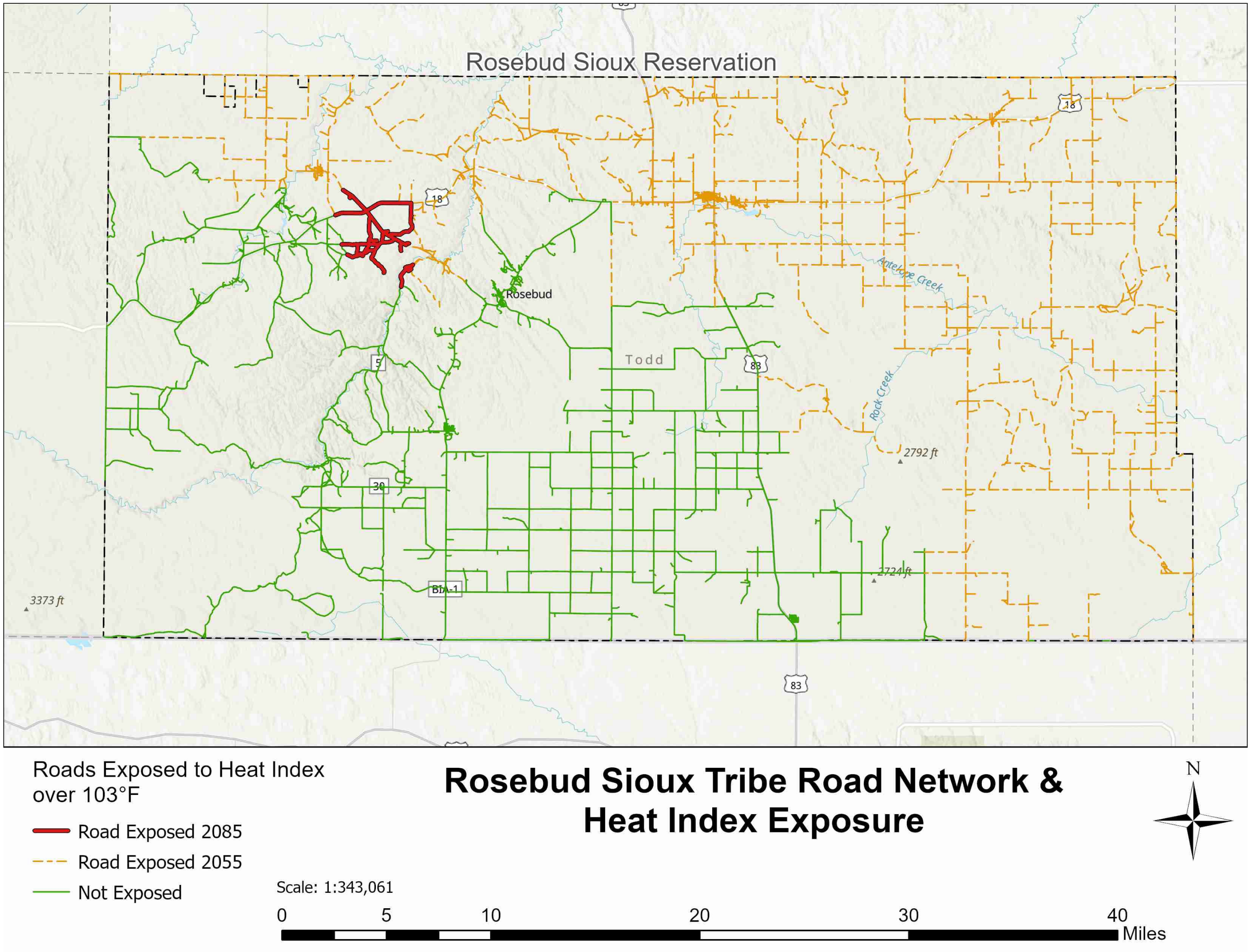
[13] Argus Leader. (2023). *A history of twisters: Tornadoes in South Dakota since 1950.* https://data.argusleader.com/tornado-archive/



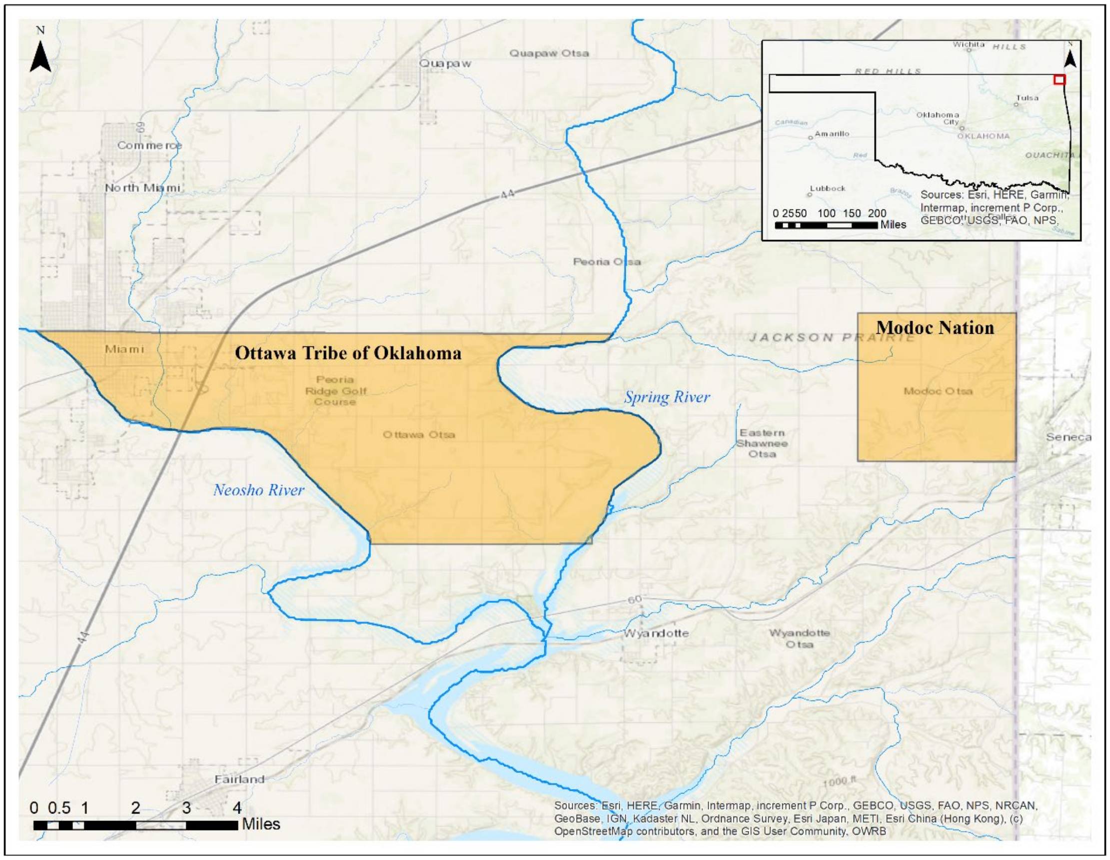
Source: FHWA

Figure 3-7. Rosebud Sioux Tribe Reservation Roadway Exposure to Heat Index Over 103°F

3.6 Ottawa and Modoc Tribal Transportation Vulnerability Assessment

3.6.1 ASSESSMENT OVERVIEW

The Ottawa Tribe of Oklahoma and Modoc Nation Tribes are located in Ottawa County in eastern Oklahoma, surrounded by the Neosho River in the west and the Spring River to the east (Figure 3-8). The Ottawa Tribe of Oklahoma has a territory of approximately 15,500 acres, 2,500 Tribe citizens, and 760 residents. The Modoc Nation has territories in both Oklahoma and California. In Oklahoma, the Modoc Nation consists of 4,600 acres of land and 200 Tribe residents.



Source: FHWA

Figure 3-8. Reservation Lands of the Ottawa Tribe and Modoc Nation

The vulnerability assessment for the Ottawa Tribe and Modoc Nation examined the impacts of historic and predicted flooding, precipitation, extreme heat, freeze-thaw, storms, and tornadoes on their respective transportation networks. A vulnerability ranking for the road assets of the Ottawa Tribe and Modoc Nation was conducted. The intent was to understand which roads are most important in terms of three parameters: functionality, exposure to a FEMA flood zone, and the drainage condition of the roadway exposed to FEMA flood zones.

3.6.2 SUMMARY OF FINDINGS

3.6.2.1 Temperature Rise

Extreme heat is projected to increase throughout the remainder of the century. Historically, the area has had an average of 3 days per year above 100°F. By 2085, however, an average year under the high emissions scenario is projected to have 37 days above 100°F. For days over 105°F, the area has had zero days in an average year. However, by 2085 under the higher scenario, this is expected to increase to 16 days per year. Both average temperatures and maximum temperatures may increase by nearly 10°F under the higher scenario by 2085.

3.6.2.2 Heavy Precipitation Events and Flooding

A total of 35 precipitation scenarios were generated for this study, looking at precipitation depth in inches. Heavy precipitation is expected to increase in 2055 and 2085. Ottawa County has dealt with severe flooding that has impacted both the Ottawa Tribe and the Modoc Nation. The Ottawa Tribe's territory is bounded by the Neosho and Spring Rivers, and both Tribes' lands contain areas in FEMA flood zones. Floods in the past two decades have closed roads and damaged the transportation networks of both Tribes. With an increase in frequency and severity of extreme weather events due to a changing climate, there are increasing concerns about the risks to the transportation network and drainage systems of the Tribes.

Road assets from the study were mapped on top of the FEMA Flood Maps to understand their level of exposure to flooding. Forty percent of the Ottawa Tribe and 7 percent of the Modoc Nation roads are in a flood zone. For the Modoc Nation, 18 percent of roads have severe drainage problems.

Some of the challenges currently faced by the Tribes from flooding and/or extreme rainfall-related issues include road/bridge closures, pavement deterioration/failure, roadbed erosion, and bridge/drainage structure scour. These events result in temporary road closures and increased maintenance needs that are likely to exacerbate due to climate change.

3.6.2.3 Storms and Tornadoes

Tornadoes pose a significant hazard in Ottawa County. From 1950 to 2022, 36 tornadoes occurred within the county. According to the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information Storm Events Database, there have been 214 hail events, 7 ice storms, and 20 winter storms since 1950 (as of 2022). Derechos (wide-spread, long-lived windstorms that often are accompanied by thunderstorms and rain) can also occur on Ottawa and Modoc lands. Derechos can be incredibly damaging and cause destruction equal to that of a tornado but along a longer and largely straight path.

Derechos can drop large amounts of rain at once, causing flash flooding, tearing up trees and infrastructure, and causing injury, death, and damage. Derechos can also cause microbursts, small pockets of very intense wind or rain that can reach over 150 miles per hour and can range from 50 to 150 yards long. Derechos often cause damage similar to that of a tornado.

As noted above in the Rosebud Sioux Tribe summary, how climate change will affect the frequency, intensity, and development of tornadoes, derechos, thunderstorms, and winter weather events is uncertain. However, according to the Fourth National Climate Assessment (2018), thunderstorm-related weather hazards have increased more than any other type of extreme weather since 1980 in the United States, and there is some indication that conditions conducive to severe thunderstorms will likely increase within the Midwest and Southern Great Plains.

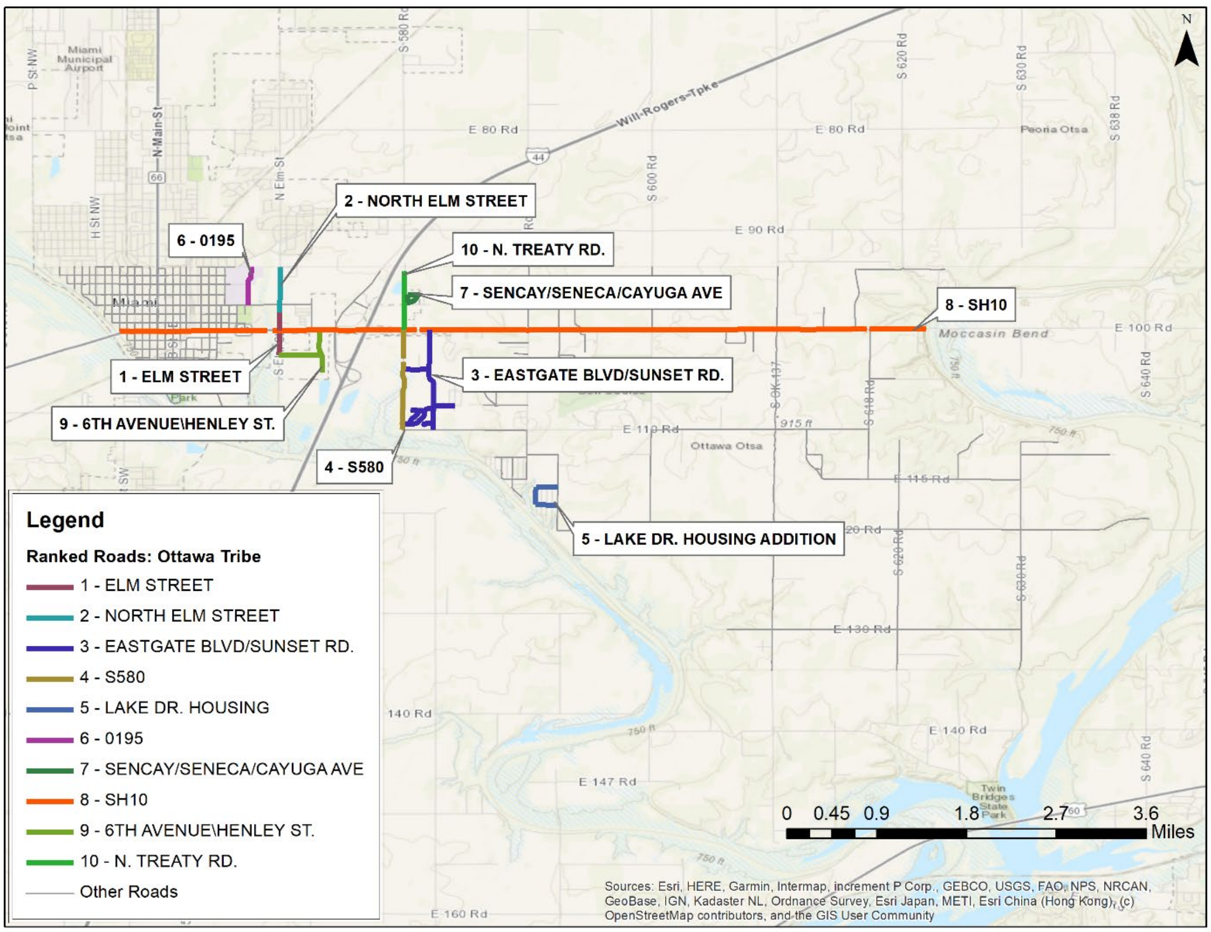
3.6.2.4 Top Vulnerabilities

An indicator-based approach was taken to identify top asset vulnerabilities at each Tribe. The ranking exercise was completed through the following steps:

1. Road importance based on functionality: Assign a functionality weight for roads based on their importance. In this sense, major roads are given a higher priority than lower-serving roads.
2. Road percentage in flood zone: Identify the percentage of the roadway exposed to FEMA flood zones and their drainage condition.
3. Estimate ranking parameter: A weighted average of 40 percent for road importance and 60 percent for flood zone was assigned.
4. Organize in descending order the database from the ranking parameter obtained, to identify the priority roads.

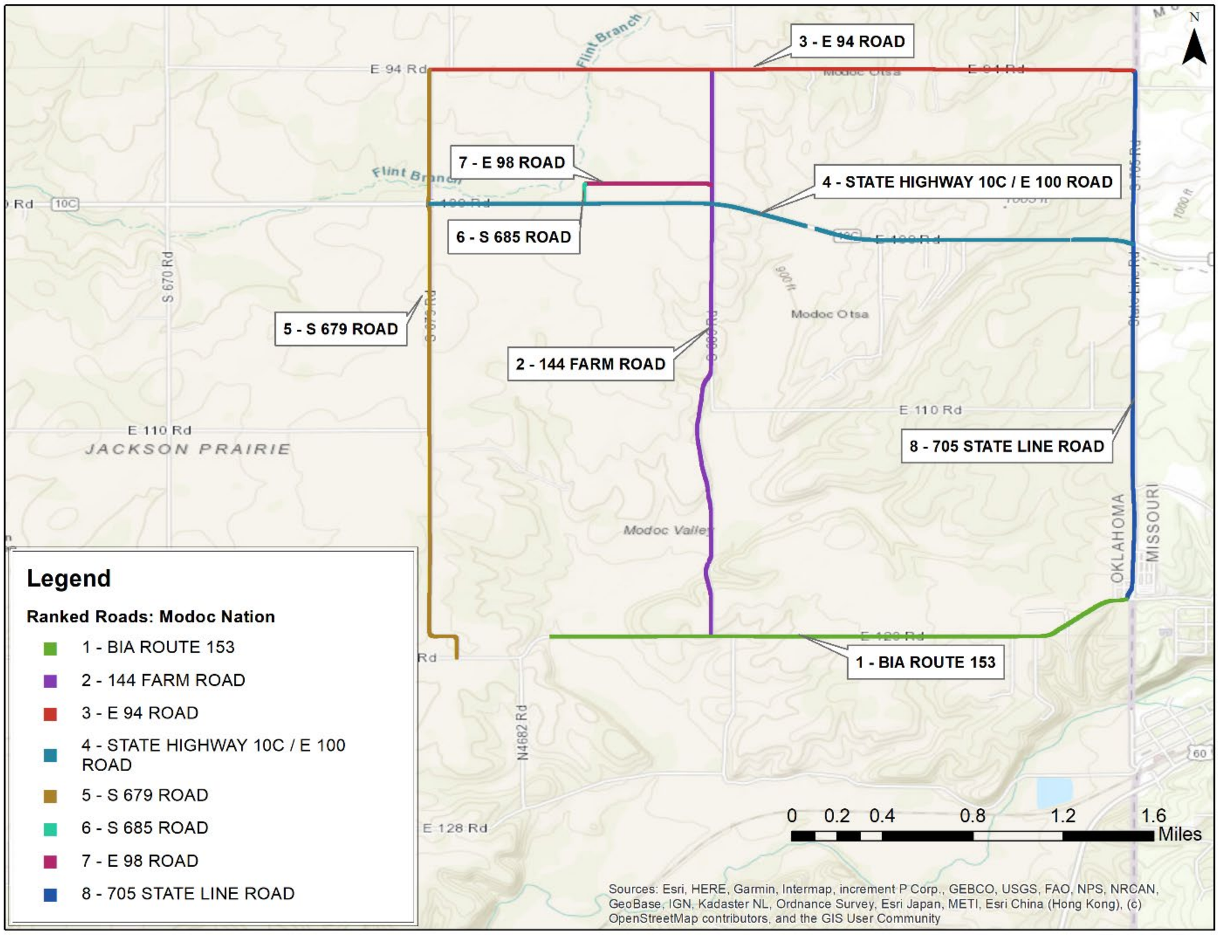
Given that overall the exposure to the other hazards presented is similar throughout the study area, the flood exposure was the only hazard parameter used in the prioritization. These results intend to give guidance to Ottawa and Modoc decision-makers regarding which assets should be prioritized for further analysis and improvements.

The results of this analysis are summarized in Figure 3-9 and Figure 3-10.



Source: FHWA

Figure 3-9. Roadway Priority Ranking for the Ottawa Tribe of Oklahoma



Source: FHWA

Figure 3-10. Roadway Priority Ranking for the Modoc Nation

4 Challenges and Successes

FHWA evaluated the challenges and successes encountered by using the FHWA Vulnerability Assessment and Adaptation Framework in the development of the vulnerability assessments. Observations about achievements and barriers to success were collected from the internal project team and the Tribe POCs. Challenges and successes of using the Framework were collected to identify how well the current Framework does or does not work for Tribal transportation vulnerability assessments. Other project successes, barriers, and gaps were considered as well to inform how similar studies could be conducted more effectively.

4.1 Tribal POC Feedback Collection Process

The project team used several different methods to collect feedback on the vulnerability assessment development process. Each of the Tribe POCs was asked to provide feedback on the following:

- Helpful findings from the vulnerability assessments.
- Any needs of the community that they felt were not met.
- Any perceived gaps in the analysis.
- How useful the FHWA Vulnerability Assessment and Adaptation Framework was in guiding their assessment.

To collect this feedback, the project set up an anonymous, online feedback form that was distributed to each of the POCs so that they could provide any criticism that they may not be comfortable sharing directly. The project team also held closeout meetings with each of the Tribes during which they were also encouraged to share their feedback.

The feedback form was distributed to the Karuk Tribe, the Mescalero Apache Tribe, the Coushatta Tribe of Louisiana, the Ottawa Tribe of Oklahoma, and the Modoc Nation. The feedback form was not sent to the Rosebud Sioux Tribe as the assessment had not been completed at the time. Therefore, feedback from the Rosebud Sioux POC was collected directly. The project team did not receive any feedback from the Native Village of Kwigillingok.

4.1.1 TRIBAL FEEDBACK SUMMARY

The project team distributed a feedback form to Tribe POCs using Microsoft Forms. There were three anonymous responses to the survey. For the complete responses to the feedback form, see Appendix B. Other responses were collected through debrief conversations.

In general, respondents expressed the following feedback:

- They were previously aware of some of the issues identified in the reports, but the project helped form a more in-depth understanding of the causes of the issues and potential solutions.
- The report aligned very well with the lived experiences of community members and accurately acknowledged the climate change impacts they are already seeing.
- The reports could be used for the planning of future infrastructure improvement projects under the Tribes' jurisdiction.
- The information provided was very useful, with multiple Tribes noting that they plan to use the information to communicate the challenges their communities face and to drive future infrastructure decisions.

- Specifically, some of the Tribes planned to use assessment outputs to inform Long Range Transportation Plans, grant applications, and other documents.
- The Tribe POCs found the FHWA Vulnerability Assessment and Adaptation Framework to be a useful resource for guiding the transportation vulnerability assessments.
- The project was able to help identify relevant grant funding opportunities, of which most of the respondents were previously unaware or which their communities are considering applying.
- Communication with the project team was effective, noting that staff were very responsive, available to answer questions, and kept the study on track and moving forward.
- Holding site visits with the project team was helpful to get to know the team and ensure that the core team is familiar with the location and community.

No part of the project process or analysis was lacking or failed to sufficiently meet expectations; however, several respondents highlighted some of the challenges they generally face when working with Federal agencies on climate adaptation. One Tribe POC noted that additional collaboration and coordination with various Federal agencies is needed to pool resources during "times of adversity, such as major road closures during wildfires, flooding, landslides, slip-outs, and snow." Another highlighted the challenges faced in securing grant funding when Federal grants have match requirements, as oftentimes the Tribe does not have the necessary funds and they have limited local partnerships to leverage for project support. They expressed a need for FHWA to consider this when designing grants and to allow for TTP funds to be used to meet Federal grant match requirements.

Additionally, one respondent said their biggest takeaway from the project process was recognizing that "climate consideration[s] are equally or more important than other [transportation] project criteria". This same respondent mentioned that the Tribe plans on using the information provided in this project when considering future projects, such as helping to explain project goals to Tribal partners when they make future project decisions.

4.2 Project Team Feedback

The internal project team also identified challenges and successes throughout the project and shared these topics in a debrief meeting towards the end of the process.

The following topics were identified as successes of the overall project:

- The structure of the Framework and key project partnerships allowed for each assessment to form naturally. The Framework was not overly prescriptive.
- The project team created data and processed climate projections to fill data gaps, which could then be tailored to the specific needs of the Tribe and assessment. This was crucial to the success of the project.
- The project team found that opportunities to meet in person were effective.
- Strong partnerships were developed throughout the life of the project around the goals and priorities of each Tribe.
- The deep understanding that the Tribes had of their vulnerabilities, priorities, and transportation networks led to the overall success of the assessments.

The following topics were mentioned as challenges to the overall project:

- Certain characteristics of the Framework were challenging. The Framework is very general, and in some cases more guidance is desired.
- Data availability regarding historical events, asset repairs, and asset maintenance.
- Acquiring sufficient data to conduct the vulnerability assessments.
- Barriers to funding for Tribes to implement resilience and infrastructure improvements.
- Tribes possess limited capacity and resources to address climate change.
- In some cases, it was difficult to communicate with and acquire the required information from groups who had an interest in or were involved in the project.

Overall, the feedback collected from the project team and Tribal POCs was very positive, and all felt that this was a useful and rewarding process. Tribal partners intended to use the outcomes of their vulnerability assessments to secure additional funding for adaptation planning, studies, and transportation improvement projects.

4.3 Recommendations for Improvements

This section provides suggestions and recommendations regarding how the Framework could be better applied to Tribal transportation systems. It also provides some general recommendations for how FHWA can better support Tribes in conducting vulnerability assessments and adaptation projects.

4.3.1 COMMUNITY ENGAGEMENT

The Framework could provide more specificity about engagement with Tribes for consultant and/or Tribal partner audiences. It could provide general guidance about effective communication strategies for community outreach. It could also provide more guidance on how to collect institutional knowledge to support the Tribal input approach (or "stakeholder input approach" in the original framework) for Tribes and their partners.

4.3.2 DATA COLLECTION

The team suggested that the Framework outline the minimum amount of information needed to sufficiently complete each Framework step. This would allow for more assurance that the Framework is applied correctly. For example, in step two (obtain asset data), it may be helpful for the Framework to note what type of asset data is required (e.g., GIS shapefiles of transportation assets) to complete a thorough assessment. Where this data is lacking, the Framework could provide some guidance on how to move forward without it (e.g., through a qualitative assessment, rather than a GIS-based one).

4.3.3 VULNERABILITY ASSESSMENT APPROACH

Generally, more guidance is needed for how a Tribe/Tribal partners should select a vulnerability assessment pathway and how to apply the approach.

- **Tribal input approach** – Suggested the Framework provide examples of questions to ask, types of qualitative data to collect, and tips for community outreach. The Framework could also provide guidance on capacity building and how to build strong relationships with Tribes for Tribal partners or consultants.
- **Indicator-based desk review approach** – Recommended the Framework provide guidance about when this approach is useful and its pros and cons. A "how to" summary of how to complete the indicator-based assessment may also be useful.
- **Engineering-informed assessments** – No specific recommendations were made.

4.3.4 KNOWLEDGE BUILDING AND TRAININGS

The project team suggested FHWA could provide vulnerability assessment and adaptation courses, trainings, or convenings through its Tribal Technical Assistance Program to help the Tribes build knowledge and confidence around climate change topics. FHWA could also partner with nonprofits and academic institutions that already conduct similar work.

4.3.5 GRANT SUPPORT

The project team suggested that the FHWA Tribal Technical Assistance Program provide specific technical assistance for climate change-related grants. FHWA's Office of Tribal Transportation could also help collect relevant funding opportunities for Tribes.

5 Implementation Plan

This Implementation Plan provides guidance on how Tribes can maximize the success of their transportation network vulnerability assessments using the FHWA Vulnerability Assessment and Adaptation Framework or another approach or framework. FHWA developed this guidance to be supplementary to what is provided in the FHWA Framework. Even if not using the Framework, this Implementation Plan is intended to support Tribes and those working in partnership with Tribes with completing climate change vulnerability assessments and other climate change projects (e.g., site-specific analyses of assets, adaptation plans).

5.1 Data Collection

This section summarizes types of asset and climate data and formats that are beneficial to developing a vulnerability assessment, data that is oftentimes missing, and how data availability may influence the final vulnerability assessment methodology.

5.1.1 ASSET DATA

First, Tribes and their partners will need to collect asset data to assess asset vulnerability to climate change. Most transportation network vulnerability assessments will be conducted using GIS and therefore asset data is needed in a compatible format, typically GIS shapefiles. At a minimum this GIS data will show where each asset lies on the transportation system. Supplemental information that is useful and often provided in GIS attribute data include the following:

- Information about the asset condition (e.g., condition rating).
- Asset usage (e.g., average daily traffic (ADT)).
- Maintenance or repair information (e.g., dates of last repair).
- Asset management information (e.g., asset types, maintenance schedules).
- If the asset is on an evacuation route or other critical route.
- Known hazard information (e.g., if the asset is in a floodplain).
- Priority assets (e.g., assets prioritized for future improvements).
- Design information (e.g., design criteria or specifications).

This information can also be compiled in an Excel workbook or other format and converted into a compatible GIS format as needed.

5.1.1.1 Data that is often missing

Many Tribes will have much of this information available already through their asset inventories compiled for the TTP or their long-range transportation planning. However, there is some data that is useful for vulnerability analysis that is frequently missing or not in a readily accessible format and needs to be collected or generated. These missing pieces often include the following:

- Community experience (e.g., how delays from closed assets affects daily life, cost of delays or detours).
- Asset cost information (e.g., initial cost at installation, maintenance cost, repair or replacement cost).
- Information on past climate-related transportation disruptions (e.g., how long the asset was closed for repairs after an event, type and severity of damage, any injuries or loss of life).

- Known design thresholds for the asset, above which damage is likely (e.g., maximum flow that a culvert can accommodate before failing).

Staff or community members may already know this information, but this information may need to be collected and compiled into a useable format for the assessment. The Tribal input approach, described further below, can be used to collect these missing data through interviews and surveys. In other cases, data may need to be generated. For example, where design information and thresholds are not known by staff, the Tribe may need to consult with other entities (e.g., State DOT, engineering consultants) to determine these thresholds. Once collected, the project team recommends that Tribes continue to maintain and collect these data.

These data are particularly useful for generating information on costs to the Tribe and the community. For example, knowing how long an asset has been closed in the past due to a flood and estimating the costs to the community and costs of repair allows the Tribe to develop an order of magnitude estimate of how much it costs them every time the asset is out of service. This information can be used to prioritize assets for improvements, support grant applications, and estimate the total costs of climate change to the community based upon future climate projections.

5.1.1.2 Asset data variations by vulnerability assessment approach

This information is useful to all types of vulnerability assessments, regardless of the specific approach taken. However, certain approaches to vulnerability assessments may require specific data, which if not available may need to be generated. For example, an indicator-based approach may be able to rely on available GIS data and general asset information, whereas a risk-based approach will need more information about the cost of asset repair and replacement. The data and resources available to produce supplemental information will influence the final vulnerability assessment methodology.

The Vulnerability Assessment Approach section below provides more guidance on selecting an approach, the kinds of asset data needed for each, and the types of information developed.

5.1.2 CLIMATE DATA

As climate science evolves and updated data become available, climate models can provide higher confidence levels and more useful information. The suite of climate models used for most data and assessments is continually updated as the sophistication of model algorithms improves. The generation of models used in these assessments is the fifth iteration of the Coupled Model Integration Project. However, the sixth iteration of the Coupled Model Integration Project has been released and is now being downscaled to useful data resolutions for regional assessments.

The number of scenarios that can be run in algorithm-intensive climate models is heavily dependent on computing power, and as technology improves, so too does the ability to run models more efficiently. The second iteration of the data used in most of the Tribal assessments conducted in this study, the Localized Constructed Analogs (LOCA) statistically downscaled dataset, has recently been made publicly available. This dataset, LOCA2, is based on the newer Coupled Model Integration Project models and provides updated downscaled projections with a greatly increased number of model ensemble runs, correcting some known biases (such as the chronic underestimation of extreme precipitation) that were present in the prior LOCA dataset. Updated datasets such as these should be used in future assessments as is feasible to gain more understanding of potential future conditions.

Federal agencies like NOAA, the U.S. Geological Survey (USGS), and the U.S. Army Corps of Engineers; national research organizations like the Transportation Research Board, National Cooperative Highway Research Program, and National Science Foundation; university climate research centers; State climatology offices; and State and local agencies may develop updated projections or undertake complex modeling efforts in the coming years, providing new resources and tools to understand relevant hazards.

Although broad scale datasets like LOCA2 cover the contiguous United States, there are additional datasets that organizations and agencies such as these can provide on more localized scales, often leading to a more robust understanding of regional conditions. For example, in the Mescalero Apache Tribal Assessment, wildfire data developed by the New Mexico Energy, Minerals and Natural Resources Department was used, providing more localized and "ground-truthed" outputs. In the Kwigillingok Tribal Assessment, the Scenarios Network for Alaska and Arctic Planning datasets produced by the University of Alaska Fairbanks were used for multiple variables, providing more detailed data and incorporating regional climate models. These types of resources are continually being developed, and partnering with organizations such as these can improve the quality of data outputs in similar assessments.

The two organizations described below are national programs with regional branches that provide climate data and technical support to Tribal Nations. The regional branches of these organizations can be helpful starting points for identifying regional climate data sources, connecting with useful contacts, and identifying project partners.

5.1.2.1 National Climate Adaptation Science Centers

The USGS works in partnership with academic institutions across the United States to run a National Climate Adaptation Science Center (CASC) and nine regional centers that work alongside scientists, natural and cultural resource managers, and local communities to help "fish, wildlife, water, land, and people adapt to a changing climate."[14] These regional centers are hosted out of a local university and are composed of multi-jurisdictional partnerships focused on providing leadership, guidance, data, and collaboration around climate change adaptation. The regional centers and the States they serve include the following:

- Alaska CASC - Alaska
- Midwest CASC - Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Michigan, and Ohio
- North Central CASC - Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, and Kansas
- Northeast CASC - Virginia to Maine
- Northwest CASC - Washington, Oregon, Idaho
- Pacific Islands CASC - Hawai'i and the U.S.-affiliated Pacific Islands
- South Central CASC - Oklahoma, Texas, Louisiana, and New Mexico
- Southeast CASC - North Carolina, South Carolina, Georgia, Alabama, Mississippi, Florida, Tennessee, Arkansas, and the U.S. Caribbean
- Southwest CASC - Arizona, Utah, California, and Nevada

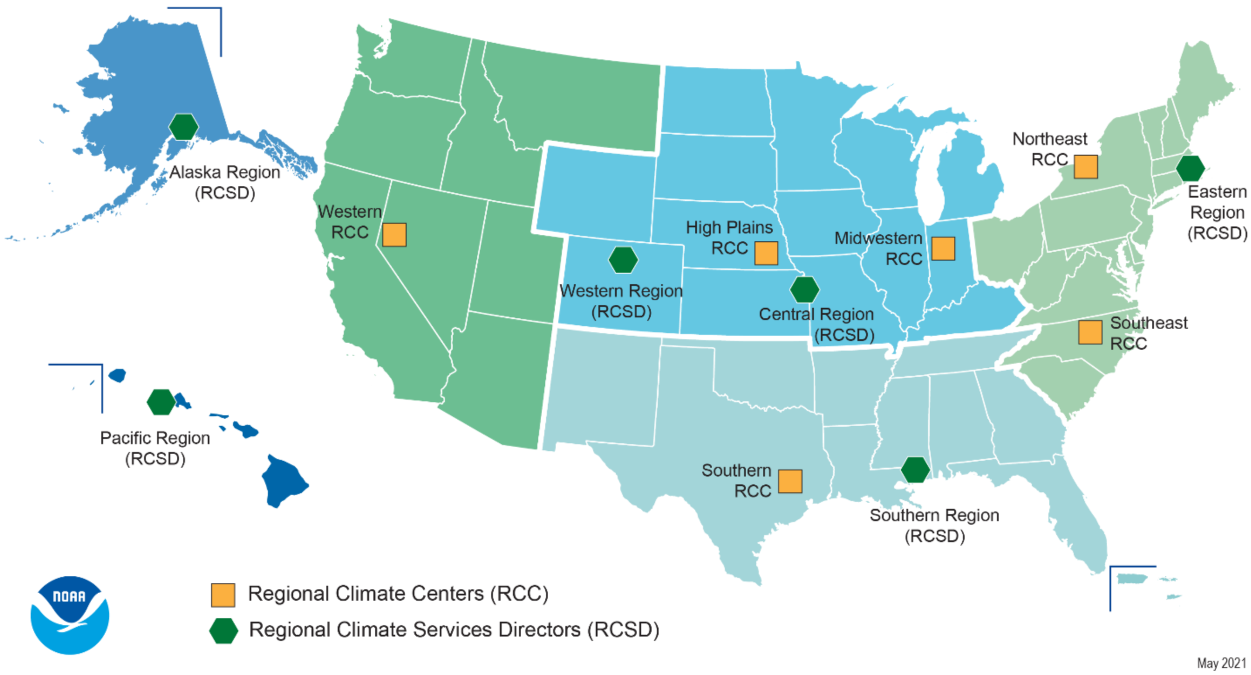
Each of the CASCs work closely with Indigenous communities who are disproportionately affected by the impacts of climate change and have Tribal liaisons who support this effort. The CASCs help Tribes with understanding their climate change vulnerabilities, providing

[14] https://www.usgs.gov/programs/climate-adaptation-science-centers

climate science data and information, and assisting with adaptation planning. Reaching out to the regional CASC's Tribal liaisons is a great way to identify local resources and gain project support.

5.1.2.2 NOAA Regional Climate Centers

NOAA's National Centers for Environmental Information manage the Regional Climate Centers Program. This program provides climate change services and data to six regions across the United States (Figure 5-1). Figure 5-1 shows both the Regional Climate Centers and Regional Climate Services Directors across the United States. Specifically, the Regional Climate Centers support with the development of sector-specific data and services, establishing digital infrastructure for providing climate change information, and storage of non-NOAA climate data and traditional NOAA data sources.[15]



Source: NOAA

Figure 5-1. NOAA's Regional Climate Centers

5.2 **Vulnerability Assessment Approach**

This section provides supplementary information to the FHWA Vulnerability Assessment and Adaptation Framework Section 4, which outlines three different approaches to assess vulnerability: 1) the Tribal input approach, 2) the indicator-based desk review approach (or, indicator-based approach), and 3) the engineering-informed assessment. More guidance is provided on each of these three approaches and when to select each pathway, to support Tribes and their partners in developing well-informed and useful vulnerability assessments. This section also summarizes a fourth approach, the risk-based approach, which can be used on its own or alongside one or more of the other approaches. The risk-based approach is used to assess the "do nothing" costs of climate change, i.e., the costs of climate change from physical, economic, and societal impacts if no action is taken to avoid, minimize, and/or mitigate them. Defining this cost can be useful to prioritizing adaptation projects, making a

[15] https://www.ncei.noaa.gov/regional/regional-climate-centers

strong case for project funding, and understanding the true impacts of climate change. It was not discussed in the FHWA framework and is summarized in a standalone form here.

5.2.1 TRIBAL INPUT APPROACH AND FACILITATING MEANINGFUL ENGAGEMENT

The Tribal input approach "relies on institutional knowledge to identify and rate potential vulnerabilities."[16] This knowledge comes from the on-the-ground experiences of Tribal Nation staff, their partners, and sometimes the community, to assess a transportation system's vulnerability to climate change. By taking this approach, Tribes and their partners can ensure that local knowledge is captured in the assessment, which may otherwise be missing from available asset and climate data. This method also builds engagement and ownership over the assessment and ensures that the final products make sense to the community, are fact-checked by local staff, and will be incorporated into staff decisions and processes. Information can be collected through a variety of engagement activities, including workshops, interviews, listening sessions, and surveys. Engagement with local staff should include a variety of disciplines where applicable, including transportation planners and engineers, asset managers, maintenance staff, natural resource managers, and those with expertise in hydrology, geology, and climate change. Staff expertise will vary depending on each Tribe and Tribal partners/other interested groups.

This approach can be used alongside any of the other vulnerability assessment approaches. Doing so ensures that local feedback is collected and incorporated into an indicator-based, engineering-informed, or risk-based approach. All the vulnerability assessments conducted for this project used this approach in some form, working with Tribe POCs to collect information about existing vulnerabilities, past asset damages and events, and community observations and concerns. For example, the Karuk Tribe vulnerability assessment collected information from Tribe DOT staff about past events such as wildfires, landslides, and floods, which was used to prioritize assets that have been repeatedly damaged in the final asset prioritization. Information was also collected from the rest of the community through a public survey. Survey findings were used to identify priority routes used by the community, especially critical routes for access and egress. These findings informed a supplemental analysis of detour travel times for travelers if critical routes were to close due to an impact.

5.2.1.1 Guidance on Selecting This Approach

The Tribal input approach can be used to inform other vulnerability assessment methodologies. Therefore, it is appropriate to use in a variety of contexts. Most vulnerability assessments will involve an engagement step targeted to the public and/or interested parties at the start of the process, and institutional knowledge can be collected at this stage to supplement other data. This approach can also be used on its own if project resources are limited, other data is limited or unavailable (e.g., asset GIS data, climate projections), and/or if there is already deep community knowledge of climate change vulnerabilities.

5.2.1.1.1 Benefits

- Incorporates Tribal and local knowledge that may not be readily accessible in other formats (e.g., GIS data).
- Builds community interest and ownership over final products.
- More affordable.

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16 https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/climate_adaptation.pdf

5.2.1.1.2 Drawbacks

- Analyses that only rely on local input are qualitative, and this may not be what is needed depending on the goals of the project (e.g., if seeking other outputs that require quantitative analysis).
- Reliant on the quality of outreach and local collaboration.

5.2.1.2 Tips for Meaningful Engagement

Tribes in the United States are sovereign nations and therefore have a government-to-government relationship with the Federal government. This Tribal sovereignty is based on Article 1, Section 8 of the U.S. Constitution as well as numerous treaties, statutes, executive orders, and judicial rulings that have followed.[17] Federal agencies are required to formally consult with Tribes under a number of statutes, executive orders, and memoranda. Additionally, the Federal Government has a legal obligation to protect Tribal treaty rights, lands, assets, and resources through the Federal Indian trust responsibility. Recognizing the unique status Tribes hold is essential as a basis upon which federal agencies and other entities can establish meaningful engagement.

The following section is written primarily for those working in partnership with Tribes on a climate change project and summarizes tips for meaningful engagement in conducting climate change vulnerability assessments with Tribes and their partners. These recommendations can be used for an assessment that takes a Tribal input approach or in tandem with one of the other approaches.

5.2.1.2.1 Building Reciprocal Relationships with Tribes and Their Partners

Tribal Communities are often asked for their input on projects and participation on working groups, advisory committees, etc., which can require a lot of staff time and energy. Rather than just conducting one-time surveying of Tribal Community members and staff, it is important to be mindful of their time, what they will get out of this engagement, and build long-term relationships.

The nonprofit, Climate Science Alliance, developed a resource guide for climate practitioners demonstrating how to meaningfully engage with Tribes in a respectful and reciprocal way. This resource guide was developed in partnership with the Southwest Climate Adaptation Science Center. The recommendations provided in the guide are summarized by topic below. More information can be found on their website (linked above).

- **Understand Tribal sovereignty:** Build a foundational understanding of Tribal sovereignty and the history of U.S. Tribal policies, including land cessation, forced assimilation, and the reservation system. Identify and acknowledge Tribal traditional lands by using resources such as the Native Land Digital Map and the Digital Atlas of California Native Americans.
- **Participate in active listening:** Recognize that Tribes and all people are different. Take time to understand common communication and cultural practices in each community. Be an active listener. Have accommodations prepared for community members and staff participating in workshops or meetings (e.g., identify convenient meeting locations, bring snacks or meals for participants).
- **Center collaboration on respect and reciprocity:** Ensure that Tribes maintain control over data and information provided throughout the project (e.g., confirm preferences about what is public and what is private). Support community events and attend in-person events where possible to build relationships. Develop reciprocal relationships

17 https://www.nature.com/articles/s41599-022-01420-0

where information is not just collected from the community, but they receive direct benefits from the project (e.g., through final products, financial support).

- **Plan for equal and long-term partnerships:** Build relationships with Tribes ahead of time where possible, not just when a project or an emergency comes up. Find ways to continue relationships after a project ends.

5.2.1.2.2 Traditional Ecological Knowledge

Traditional Ecological Knowledge (TEK) is the "on-going accumulation of knowledge, practice and belief about relationships between living beings in a specific ecosystem that is acquired by Indigenous people over hundreds or thousands of years through direct contact with the environment, handed down through generations, and used for life-sustaining ways."[18] If a Tribe is interested in incorporating TEK into a climate change vulnerability assessment, the Tribal input approach is one way of collecting this information and integrating it into the assessment. In this way, western science of climate change projections and TEK collected through observations of the physical world can be used in tandem.

5.2.1.2.3 Data Sovereignty

The Climate Science Alliance defines Indigenous Data Sovereignty as "the right to determine the means of collection, access, analysis, interpretation, management, dissemination and reuse of data pertaining to the Indigenous peoples from whom it has been derived, or to whom it relates."[19] Data and information collected from Tribes for the purposes of a project or study should be respected and managed by the Tribe. For example, this may involve confirming what information can be public and what should remain for private use only. The topic of data sovereignty is important to raise because of prior misuse of data collected from Tribes or collected without the community's participation. This can lead to the belief that data collection on Indigenous peoples is to service government (or other requirements) rather than supporting their own needs.[20]

5.2.1.2.4 Example Questions to Ask at Project Start

One of the recommendations identified by the project team to improve the FHWA Vulnerability Assessment and Adaptation Framework is to include example questions to ask asset managers at project start. The team developed a list of questions as a starting point, which were used in collecting institutional knowledge from Tribe POCs and their partners (e.g., other Tribal departments, State DOTs, local transit agencies). These questions can be targeted to specific communities and can be expanded upon:

1. What are the transportation assets we should be thinking about for this assessment? Are there transit stops, bus depots, trails, or other types of assets to consider?
2. Can you explain what the Tribe's Department of Transportation is responsible for on your network in terms of planning, design, and maintenance?
3. What is the Tribe's involvement when there's an impact to a State or county road? Are there other transportation asset managers in the area you work with?
4. How did past events impact the transportation system and mobility in the community?
5. What are the primary areas of concern on the transportation network?

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[18] https://www.nps.gov/subjects/tek/description.htm

[19] https://www.climatesciencealliance.org/info/meaningful-engagement

[20] Kukutai, T. and Taylor, J. 2016. *Indigenous Data Sovereignty: Toward an Agenda.* ANU Press. *https://www.jstor.org/stable/j.ctt1q1crgf*

6. What are your concerns regarding climate change? How have you witnessed weather/climate change?
7. What work has been done in the area to study climate change?
8. What would be your desired project outcomes?
9. Are there others at the Tribe who you think we should meet with to ask these questions?
10. Would you like to incorporate TEK or other historical/cultural knowledge into the assessment?
11. How would you like to consider community impacts and public health into the assessment and project outcomes?

5.2.2 INDICATOR-BASED APPROACH

The indicator-based approach involves the identification of variables or factors that seem to indicate an increased level of concern for assets, with that level of concern used to target investments and additional analysis to refine the understanding of risk. Most often these measures are expressed as relative scores, with a higher score indicating a need for sooner action. Generally, if an asset is older, heavily utilized, and exhibits concerns relating to condition or past damages, it scores higher by this measure.

Table 5-1. Example Spreadsheet Demonstrating How to Set Up and Weigh Metrics Used in an Indicator-Based Vulnerability Assessment for Two Types of Stressors and a Selection of Metrics

Metric	Floodings					Wildfire		
Scour rating	NA	5%	NA	NA	NA	NA	NA	NA
Bridge capacity	NA	30%	NA	NA	NA	NA	NA	NA
Culvert condition rating	NA	NA	5%	NA	NA	NA	NA	NA
Culvert material	NA	NA	5%	NA	NA	NA	5%	NA
Culvert capacity	NA	NA	30%	NA	NA	NA	5%	NA
Facility Volume/Capacity Ratio	5%	NA	NA	NA	NA	5%	NA	NA
Facility Volume	15%	10%	10%	NA	NA	15%	15%	NA
Facility Truck Volume	5%	NA	NA	NA	NA	5%	NA	NA
Airport class	NA	NA	NA	NA	35%	NA	NA	NA
Detour time	10%	5%	NA	NA	NA	10%	5%	NA
Maximum change in 100-year precipitation for the 2010-2039 timeframe	10%	NA	NA	10%	10%	NA	NA	NA
Maximum change in 100-year precipitation	10%	NA	NA	10%	10%	NA	NA	NA

Note: This is an example of how an indicator scoring spreadsheet is set up and the types of metrics used in this kind of analysis. The table is incomplete and not all relevant metrics and stressors are listed.
NA = Not Applicable.

5.2.2.1 Guidance on Selecting This Approach

Indicator methods, or proxy indicator methods as they're often called, were identified very early on in the history of vulnerability assessments. This approach often combines available data from asset management programs and asset GIS data to develop a relational score that allows for comparison of one asset to another as noted above.

5.2.2.1.1 Benefits

- Introduces general concerns relative to change in climate conditions.
- Can bring parties together to review climate projections and impacts.
- Contributes to discussion of the role of asset condition as a contributor to concerns.
- Highlights the value of infrastructure as a community benefit.

5.2.2.1.2 Drawbacks

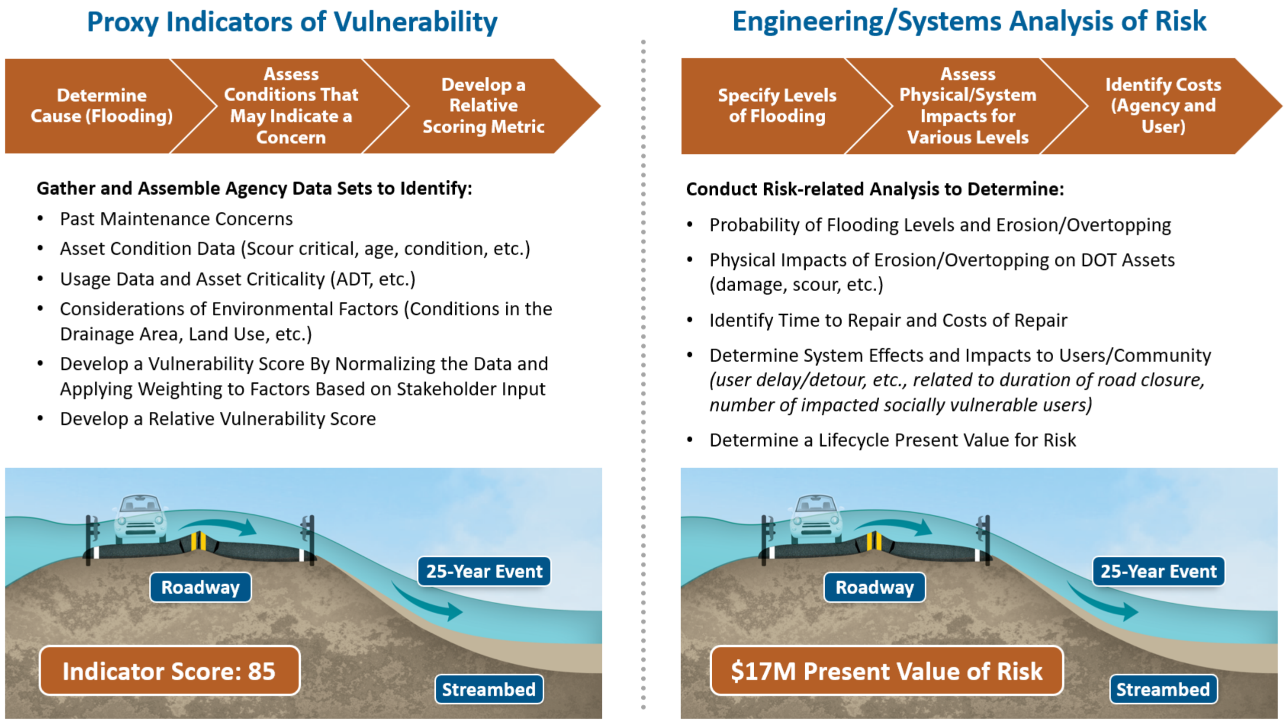
- Applies data intended for other purposes to address concerns relating to infrastructure resilience.
- Findings have little correlation to predicting physical effects of existing and future conditions.
- The basis for scoring the assets, often done through a numerical scoring system including normalized values and applied weights, is difficult to relay to other parties and the public.
- The approach is often not seen as valuable by technical practitioners due to relying on generalized measures to identify system vulnerabilities. This can limit follow-on action.

Tribes and their partners should consider the potential drawbacks of this approach before selecting this pathway. An indicator-based approach may be applicable when there are limited project resources, and the Tribe is interested in conducting a systems-level analysis to gain a preliminary understanding of climate change impacts and priority assets. If selected, it is recommended to keep the indicator-based prioritization simple, rather than combining dozens of metrics to determine a score for each asset. Combining many variables can make results muddled and hard to explain. It is also easy for certain variables to get "lost" in the analysis if they are given lower weights. In the Tribal vulnerability assessments that used the indicator-based approach for this project, the project team used a few, high-priority variables to score asset vulnerability. For example, the Mescalero Apache Tribe assessment prioritized assets based upon three categories of exposure: 1) asset exposure to historical events (experienced past damages), 2) asset exposure to wildfire risk, and 3) asset exposure to more severe 100-year precipitation events. Using this method made it clear which assets were more vulnerable based upon historical and projected exposure to climate hazards, made the analysis easy to explain, and made it possible to ground-truth findings based upon known past damages, wildfire, and flood events.

It is also recommended to conduct the indicator-based analysis in combination with the community engagement approach, involving diverse groups in the development of the analysis (e.g., selecting indicators and their weights). This community input is needed to ensure that on-the-ground and lived experiences are captured in the assessment. Otherwise, this input can be overlooked if relying only on available data. The engineering-informed approach can also be used following the completion of an indicator-based, system-level analysis, allowing the Tribe to conduct more detailed assessment of specific assets.

Typically, follow-on analysis, such as an engineering-informed or risk-based assessment, are still necessary after completing a system-level indicator-based assessment. This is because more information is needed on the cost and consequences of climate change impacts to be able to make informed decisions about adaptations and transportation improvements. This method can be misapplied in many circumstances, directing capital expenditures without a more analytical basis on which to identify whether physical risks exist.

Figure 5-2 demonstrates the types of information that go into and are produced in an indicator-based approach versus an engineering-informed or risk-based approach.



Source: FHWA

Figure 5-2. Example of Inputs and Outputs from an Indicator-Based Approach Versus Engineering-Informed and/or Risk-Based Approach to Vulnerability Assessments

5.2.3 RISK-BASED APPROACH

The risk-based approach is an analytical approach taken to understand the cause, effect, and consequences of climate change. This analysis method combines spatial analysis, modeling, and engineering best practices to identify assets that may be at risk from future conditions (flooding, temperatures, sea level rise, etc.). Measures on potential repairs, system effects, and localized social and economic impacts are identified and, where possible, quantified in terms of monetary values. These costs are referred to as the “do nothing” costs of climate change, quantifying the cost of impact without any intervention.

Risk is discussed in the FHWA Vulnerability Assessment and Adaptation Framework, but a risk-based approach was not presented as an alternative vulnerability assessment pathway. This approach and guidance for applying a risk-based methodology is summarized in more detail below.

5.2.3.1 Guidance on selecting this approach

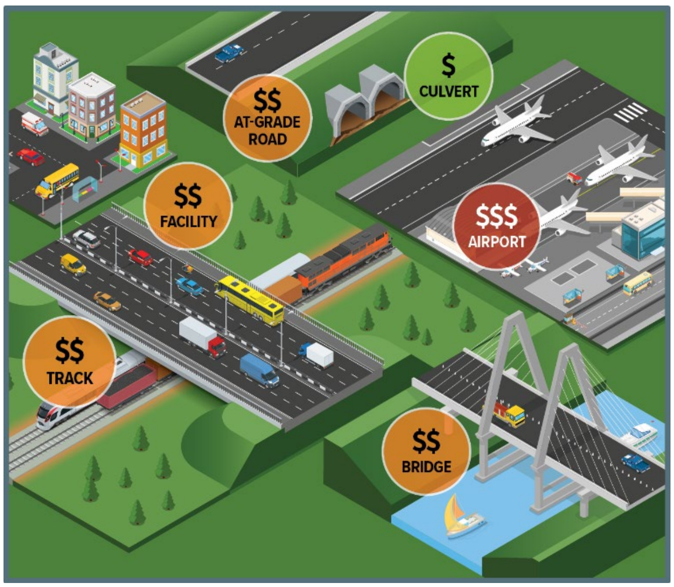
Methods used to determine values for risk are a more recent development, relying on and benefitting from the growth in data available to assess future conditions in a more detailed manner. It is recommended that Tribes start generating the information needed to apply the risk-based framework. Specifically, the following information is needed for a risk-based assessment:

- Representations of future conditions (i.e., flood levels, future temperatures, etc.).

- The physical impacts of future conditions on assets, systems, or communities (commonly referred to as a stress or damage function).
- Estimates of repair costs and times associated with physical impacts.
- Impacts or costs of loss of system service for the repair period, extending to system users and community members.

This information can then be used to develop a life cycle cost estimate for assets based on probability and impact measures over the asset's intended life. In other words, this information can be used to understand what the cost of climate change is to a Tribe at a system or asset level.

If Tribes can use the risk-based approach for their vulnerability assessments, it will allow them to clearly describe the risks they face today and in the future. They will be able to provide cost information required to make an effective case for future investments to reduce risks (especially useful for grant applications and other funding requests). The data and information developed through the assessment will also help Tribes communicate adaptation decisions and priorities to local, regional, and national partners/parties.



Source: FHWA

Figure 5-3. Example of How a Risk-Based Approach Can Quantify Costs of Climate Impacts for Different Assets in a System

5.2.3.1.1 Benefits

- Provides a sophisticated framing of how climate change poses risk to infrastructure, summarizing cause and effect relationships of impacts and consequences.
- Applies engineering expertise to generate results that are acceptable to technical leads responsible for the next phase of implementation (e.g., developing transportation improvements).
- The methodology is easier to communicate to other parties and the public.
- The scoring, expressed as present value of risk in dollars, is useful for identifying priority projects and to applying for funding in multiple grant programs (e.g., FEMA's Emergency Relief and other programs) (Figure 5-3).

5.2.3.1.2 Drawbacks

- Requires more resources to create data inputs and conduct analysis (staff time, cost).
- Oftentimes, necessary asset specific information is missing or needs to be generated (e.g., asset designs, cost of maintenance and repair).
- Requires specific technical expertise from engineers and climate scientists to estimate climate impacts and their costs.
- Risk-based analysis is a growing but largely still underrepresented capability in traditional civil engineering efforts.
- The presentation of results as a financial metric (dollars) requires calculating annual costs, discounting, and calculation of present value which can be challenging concepts to communicate at first. However, this framework is the basic framework applied on most Federal processes in justifying investments (FEMA, US Department of Housing and Urban Development, etc.)

5.2.4 ENGINEERING-INFORMED APPROACH

While the community engagement and indicator-based approaches described in the FHWA Framework are primarily used for systems-level analysis, an engineering-informed assessment focuses on a specific asset (also referred to as asset- or facility-level assessments). Oftentimes, the systems-level analyses will be completed first, and then highly vulnerable assets are prioritized for an engineering-informed or asset-level analysis. These are detailed, risk-based assessments that consider current asset design and how the design may be exceeded under different climate scenarios (more on the risk-based approach to vulnerability assessments is provided in Section 5.2.3). Where data and resources are available to complete these assessments, they can be critical to understanding the costs of climate impacts to a specific asset due to damage and repair. They are also useful for evaluating different design alternatives and how well they would perform under the scenarios studied.

The National Highway Institute recently developed a free, web-based training course on conducting engineering-informed assessments titled "Adaptation Analysis for Project Decision Making."

5.2.4.1 Guidance on Selecting This Approach

An engineering-informed approach will be most applicable to Tribes and their partners when they know of a specific asset or route that is vulnerable to climate hazards, which needs to be assessed to identify improvements. For example, the Coushatta Tribe of Louisiana vulnerability assessment was inspired by the engineering-informed pathway as it focused on precipitation and flooding impacts to one critical roadway: the Tribe's proposed evacuation route. The assessment analyzed various extreme precipitation scenarios and how current design may be exceeded by those events. For the purposes of this project, the assessment did not review adaptation alternatives and how they would perform under future precipitation scenarios. This would be the next step for the Coushatta Tribe to identify a more resilient design for the roadway using an engineering-informed approach.

The Mescalero Apache Tribe vulnerability assessment did not use the engineering-informed approach. However, for their assessment the project team developed an analysis methodology that will help the Tribe and their contractors incorporate future climate projections into drainage designs. This step-by-step methodology is essentially an engineering-informed assessment for new drainage assets.

See Appendix C for more information on the Coushatta and Mescalero Apache Tribe vulnerability assessments.

5.2.4.1.1 Benefits

- Helps agencies anticipate the effectiveness of specific adaptation measures and their return on investment.
- Necessary for ensuring asset improvements and new assets are designed to future conditions rather than relying on historical data.
- Provides confidence in decision-making that is often lacking in systems level analyses.
- Provides clear outputs that are easy to communicate and are well-understood by engineering disciplines.

5.2.4.1.2 Drawbacks

- Requires more resources to create data inputs and conduct analysis (staff time, cost).
- Oftentimes, necessary asset specific information is missing or needs to be generated (e.g., asset designs, cost of maintenance and repair).
- Requires specific technical expertise from engineers and climate scientists to estimate climate impacts and their costs.

5.2.4.2 Using the FHWA Adaptation Decision-Making Assessment Process

FHWA developed another process to guide engineering-informed assessments: the Adaptation Decision-Making Assessment Process (ADAP). ADAP is a tool built for planners and engineers to work together to account for climate data in asset designs. It is a risk-based tool that helps decision-makers assess project alternatives and select the best design option based on asset life cycle cost.[21]

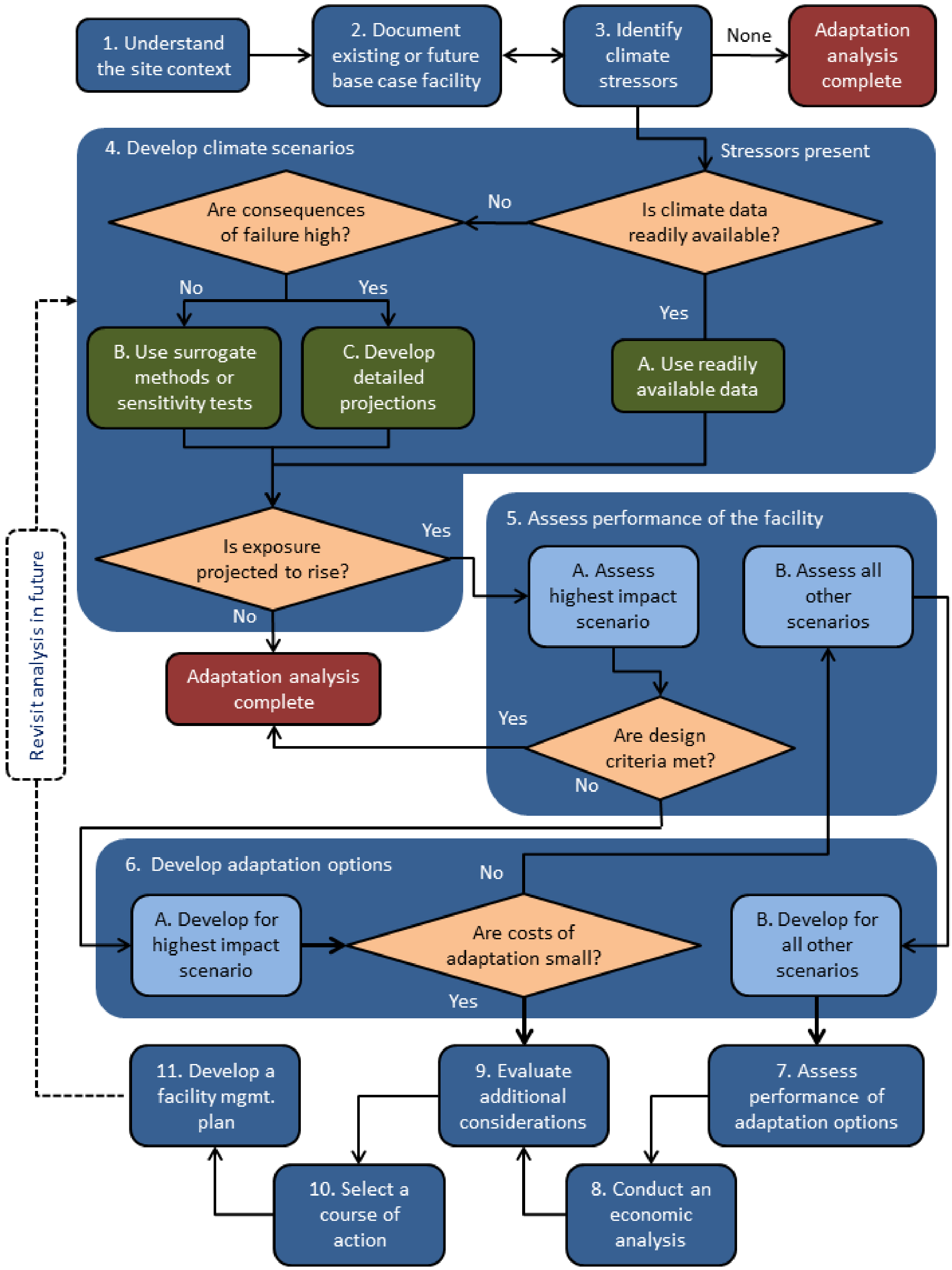
ADAP follows 11 steps, which can be modified as needed based on the specific needs of the Tribe. These steps are shown in Figure 5-4 and are briefly summarized as follows:

12. **Understand the site context** – Identify the asset's location and function in the transportation network, community, and environment.
13. **Document existing or future base case facility** – Identify the existing or proposed asset design (e.g., dimensions, design criteria). A full design may not be necessary, but preliminary design is needed to understand climate impacts to the asset.
14. **Identify climate stressors/hazards** – Identify the climate hazards (e.g., precipitation, temperature rise) that the asset is exposed to. The assessment may focus on one hazard but, if possible, should consider all applicable stressors and how they interact.
15. **Develop climate scenarios** – Develop a suite of climate scenarios to consider in the assessment, considering the range of possible outcomes for any one climate hazard. For example, Tribes may consider selecting low, medium, and high scenarios for temperature rise to use in the study. Use timeframes that overlap with the expected life of an asset.
16. **Assess performance of the facility** – This step is often done in parallel with step 6. First, assess the performance of the existing or proposed asset against the highest impact scenario as an initial stress test. Remember that the highest impact scenario could be for a combination of stressors if multiple are considered in the analysis. If the asset will

[21] Federal Highway Administration. 2019. Adaptation Decision-Making Assessment Process. https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/adap/index.cfm#toc462734201

perform well under these conditions, the analysis is complete. If not, then the assessment moves to step 6.

17. **Develop adaptation options** – Develop adaptation options that will ensure the asset design is sufficient to withstand the highest impact scenario. If expected costs of this design option are acceptable, the analysis can skip to step 9. If this is cost prohibitive or seems overly conservative, steps 5 and 6 can be repeated considering the other climate scenarios developed in step 4. This would involve developing multiple adaptations based on the other scenarios considered and then assessing them in step 7.
18. **Assess performance of the adaptation options** – Assess performance of the adaptation alternatives against each scenario.
19. **Conduct an economic analysis** – Assess the costs and benefits of each adaptation option, relative to the existing or proposed design, under each climate scenario. This information is used to identify the option that is the most cost effective.
20. **Evaluate additional considerations** – Before deciding on a final adaptation option, consider additional factors that may influence this decision, such as permitting constraints, community concerns or needs, and environmental impacts.
21. **Select a course of action** – Choose a final adaptation option based on the information developed in the steps above.
22. **Develop a Facility Management Plan** – Create a plan for the asset to monitor its performance and make corrective decisions as needed.



Source: Federal Highway Administration. 2019. Adaptation Decision-Making Assessment Process. https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/adap/index.cfm#toc462734201

Figure 5-4. Federal Highway Administration Adaptation Decision-Making Assessment Process For Completing an Engineering-Informed Assessment

5.2.4.3 Using the FHWA Climate Risk Assessment Tool

FHWA is currently working on another tool to support the development of engineering-informed and risk-based assessments: the Climate Risk Assessment (CRA) Tool and Guidebook. The CRA tool will help the user quantify the risks of changing climatic conditions and assess the benefits and costs of adaptation alternatives (Step 8 of ADAP).

The tool will use the following inputs:

- Climate change projections for different scenarios, return periods, and analysis years.
- Cost information for different design alternatives.
- Damage cost and disruption durations for different events.
- Asset usage information (e.g., travel volume).

This information is used to calculate expected costs during each year of the analysis period for each climate scenario and adaptation alternative. Outputs will be provided in the form of discounted costs, benefit cost ratios, and net present value calculations. These outputs can be used in grant applications to make the case for adaptation project funding.

The CRA tool and guidebook are expected to be complete in 2024.

5.3 Knowledge Building and Trainings

This section provides resources for knowledge building and training on climate change literacy, developing climate change vulnerabilities assessments, capacity building, TEK, and other related topics. Resources are listed by institution.

5.3.1 BUREAU OF INDIAN AFFAIRS

The BIA Branch of Tribal Climate Resilience provides learning opportunities through the following:

- The Native Youth Climate Adaptation Leadership Congress - BIA, in partnership with other U.S. Federal agencies, brings together high school and college-aged students from Tribal Communities across the United States to build understanding of environmental and conservation challenges.
- Climate Adaptation Training - BIA partners with the Institute for Tribal Environmental Professionals (ITEP) Tribes and Climate Change Program at Northern Arizona University to host climate adaptation trainings at national and regional scales. Training topics include fire and climate change, Indigenous climate adaptation planning, integrating climate into hazard mitigation plans, and more. They also host a bi-annual National Tribal and Indigenous Climate Conference.
- A Tribal Climate Resilience Resource Directory - Compiles resources for Tribal Nations and Alaska Native villages to enhance their climate change preparedness. This includes presentations and webinars, guidance documents, and resources and technical assistance contacts by U.S. region.

5.3.2 NATIONAL HIGHWAY INSTITUTE

The National Highway Institute provides trainings related to understanding climate projections and how to incorporate this information into transportation planning and design. Many of these trainings are free and available online. Others must be registered and paid for. A selection of relevant and free online trainings include the following:

- Adaptation Analysis for Project Decision Making - A course on conducting engineering-informed assessments.

- Understanding Past, Current, and Future Climate Conditions – Provides "an introduction to future projections of precipitation, temperature, and sea levels, basic scientific principles, and an overview of potential impacts of these changes on transportation facilities."
- Introduction to Temperature and Precipitation Projections – Describes methods and tools used to process projections for project needs.
- Roadway Interactions with Rivers and Floodplains: Basic Concepts – Introduction to interactions between bridges, culverts, and roadways, and rivers and floodplains.

5.3.3 NATIONAL CLIMATE ADAPTATION SCIENCE CENTERS

As described above, the National Climate Adaptation Science Center is run by USGS in partnership with academic institutions across the United States. It is made up of nine regional centers hosted out of a local university and are comprised of multi-jurisdictional partnerships focused on providing leadership, guidance, data, and collaboration around climate change adaptation. In addition to developing and supplying climate data, the CASCs provide knowledge and training resources provided for and in partnership with Tribes. These resources are summarized below.

5.3.3.1 Tribal Resilience Liaisons

The CASCs work with the BIA to support regional Tribal Resilience Liaisons. These liaisons work with Tribal Nations, consortia, and organizations to support information needs and research projects. They also "serve as extension agents, facilitating research, linking Tribal needs to available resources, and coordinating trainings, workshops, forums and exchanges."[22] See the Tribal Resilience Liaisons directory to identify a regional liaison.

5.3.3.2 Workshops and Trainings

The CASCs support Tribal Nation capacity building by hosting educational workshops and trainings regarding climate change topics. Each of the CASCs hosts their own workshops, some of which are held in-person and others are online. For example, the South Central Climate Adaptation Science Center holds "Climate 101" workshops that cover many of the basic concepts and terminologies surrounding climate change. Past presentation materials are available in an archive.

5.3.3.3 Incorporating Traditional Knowledge into Adaptation

The CASC network also works directly with Tribes to help them use TEK in adaptation planning. For example, the Northwest and National CASCs worked with the Coeur d'Alene Tribe of Idaho to turn Schitsu'umsh knowledge into a three-dimensional virtual reality simulation and develop actions for using the information in adaptation decisions.

5.3.4 CLIMATE SCIENCE ALLIANCE

The Climate Science Alliance is committed to protecting "natural and human communities in the face of a changing climate."[23] They engage meaningfully with and work to ensure data sovereignty of information provided by their Indigenous partners. In addition to their resource guide on meaningful engagement (summarized in the Tribal Input Approach and Facilitating Meaningful Engagement section), the Climate Science Alliance offers various capacity building resources, including trainings, conferences/convenings, and a Stewardship Pathways Program that aims to "build capacity, support economic development, and

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[22] BIA. n.d. "Tribal Climate Resilience Liaisons." Accessed August 9, 2023 https://www.bia.gov/bia/ots/tcr/our-work-partnerships#Tribal-climate-resilience-liaisons

[23] Climate Science Alliance. 2023. "Climate Science Alliance." Accessed August 9, 2023. https://www.climatesciencealliance.org/

advance co-stewardship of ancestral lands through various training pathways."[24] Trainings are provided through four pathways:

- Native Plant Conservation, Propagation, and Restoration
- Indigenous Fire Stewardship
- Water Wisdom
- Climate Adaptation Training and Tools

The Climate Adaptation Training and Tools cover various topics related to climate change adaptation including using climate tools, GIS, grant writing, project management, and business development.

5.3.5 INSTITUTE FOR TRIBAL ENVIRONMENTAL PROFESSIONALS

The ITEP based out of Northern Arizona University established a Tribes and Climate Change Program in 2009. The ITEP team provides support and resources to Tribes who are preparing for and currently dealing with the impacts of climate change.[25] Their website offers a collection of climate change resources to Tribes and those working with Tribal Communities, including:

- Funding sources
- A Tribal Climate Change Newsletter
- A Tribal Climate Change Adaptation Planning Toolkit
- Tribal Climate Change Fact Sheets
- Climate change reports produced by ITEP

ITEP staff also offer trainings and events for Tribal environmental professionals on a number of climate change topics and related issues, including climate science, adaptation planning, and developing hazard mitigation plans. They also host frequent webinars on climate resilience and adaptation, managed retreat, land use, funding opportunities, and more.

5.4 Grant Support

5.4.1 GRANT WRITING SUPPORT AND TECHNICAL ASSISTANCE

There are numerous Federal support programs available for Tribes that provide a variety of technical assistance. This technical assistance often includes grant submission support, such as identifying relevant funding sources, providing feedback on applications, and assisting with developing competitive bids.

5.4.1.1 FHWA Tribal Technical Assistance Program

FHWA's Tribal Technical Assistance Program (TTAP) is distributed into eight TTAP Centers across the United States (Figure 5-5). The program is focused on supporting all federally recognized Tribes in managing their highway assets, hosting trainings, and providing additional support through technical assistance. The Centers also assist Tribes with securing access to FHWA TTP funding. The office headquarters of each Center are provided below:

- Alaskan TTAP Center:
  1764 Tanana Loop, ELIF Suite 240

[24] Climate Science Alliance. 2023. "Stewardship Pathways." Accessed August 9, 2023. https://www.climatesciencealliance.org/stewardship-pathways/background

[25] ITEP. 2023. "About Us." Accessed October 4, 2023. http://www7.nau.edu/itep/main/tcc/About/

PO Box 755910
Fairbanks, Alaska 99775-5910

- Western TTAP Center
  (Local address to be determined)

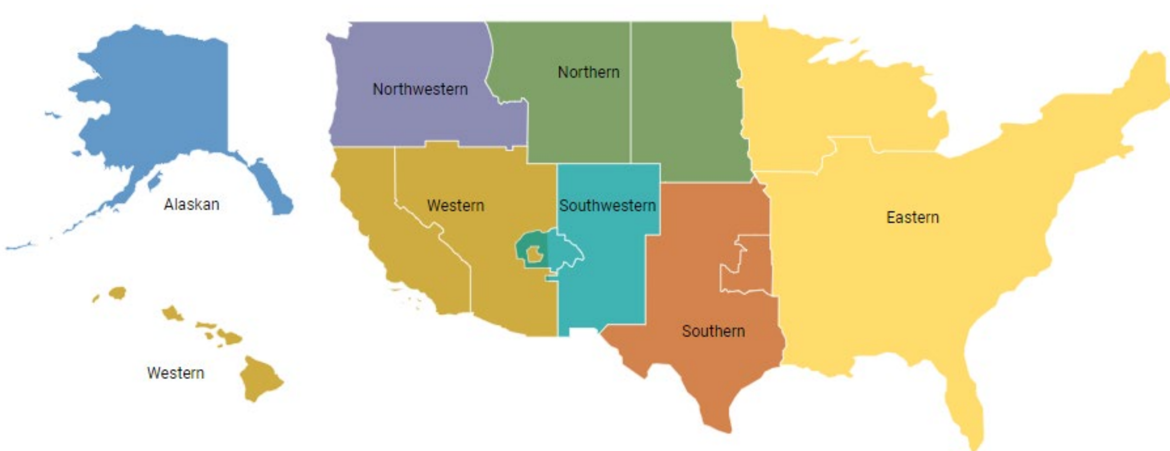
- Northwestern TTAP Center Address:
  University of Washington, Civil and Environmental Engineering
  More Hall Room 121F
  Seattle, WA 98195-2700

- Northern TTAP Center Address:
  608 East Boulevard Avenue
  Bismarck, ND 58505-0700

- Southwestern TTAP Center Address:
  100 Sun Ave NE Suite 650
  Albuquerque, NM 87109

- Southern TTAP Center Address:
  1201 S Innovation Way Drive
  Stillwater, OK 74074

- Eastern TTAP Center Address:
  2205 Engineering Hall
  1415 Engineering Drive
  Madison, WI 53706



Source: FHWA. n.d. "Tribal Technical Assistance Program (TTAP)." Accessed August 9, 2023. *https://www.fhwa.dot.gov/clas/ttap/*

Figure 5-5. Geographical boundaries for FHWA's TTAP centers.

5.4.1.2 FEMA Building Resilient Infrastructure and Communities Direct Technical Assistance

The FEMA Building Resilient Infrastructure and Communities program includes a non-financial, direct technical assistance component. This work is centered on helping communities with their climate resilience planning and developing projects for adaptation solutions (Figure 5-6). FEMA and their contractors will provide a range of support based upon the needs of each community, such as assisting with risk assessments, project development, community engagement, and partnership building. Federally recognized Tribal governments are eligible entities and will be prioritized through a set-aside amount for Tribal governments and in the application selection process.

Source: FEMA. 2022. https://www.fema.gov/sites/default/files/documents/fema_fy22-bric-technical-assistance-psm.pdf

Figure 5-6. Desired FEMA Building Resilient Infrastructure and Communities Technical Assistance Outcomes

5.4.1.3 Environmental Protection Agency Environmental and Climate Justice Program

The Environmental Protection Agency Environmental and Climate Justice program provides $200 million for technical assistance to support environmental and climate justice activities for underserved communities. Tribal Nations are eligible and encouraged to apply.

5.4.2 GRANT FUNDING OPPORTUNITIES

The issue of climate change presents significant challenges for Tribal governments, necessitating the need for funding to increase community and infrastructure resilience. This section highlights Federal funding opportunities available to Tribes to address the impacts of climate change to their transportation networks.

5.4.2.1 Department of Transportation

Rebuilding American Infrastructure with Sustainability and Equity: A $1.5 billion grant to help State projects and local level projects for municipalities, Tribes, and counties as well as other critical passenger and freight transportation infrastructure projects. Fifty percent of the grants will be allocated to rural projects, and the rest will be awarded to urban projects. The minimum grant award for rural and urban projects are $1 million and $5 million, respectively.

Federal Lands Access Program: This program is designed to improve transportation facilities that are located within/adjacent to Federal Lands or provide access to them. On average, the Federal Lands Access Program awards $297 million annually. Applicants should coordination with and confirm support from a Federal Land Management Agency such as the National Park Service, U.S. Fish and Wildlife Service, and USFS.

National Culvert Removal, Replacement, and Restoration Grant Program: The program awards $200 million annually to support projects that meaningfully improve/restore passage for anadromous fish.

FHWA Federal-aid Funding Programs:

- Federal-aid Essentials for Local Public Agencies: Helping local public agencies access local programs, resources, and assistance.
- Highway Safety Improvement Program: The program is a Federal-aid program to reduce traffic fatalities and injuries on public roads, including roads on Tribal lands and those that are not State-owned.
- Transportation Alternatives Program: The purpose of the program is to support strengthening the intermodal transportation system by expanding travel choice, improving local economies, and quality of life while protecting the environment.
- Multimodal Project Discretionary Grant: A consolidated Federal grant opportunity that allows one application for funding for the following three programs.
- Infrastructure for Rebuilding America: The program awards $1.6 billion annually for multimodal freight and highway projects of national or regional significance. The minimum grand award is $5 million for small projects and $25 million for large projects.
- National Infrastructure Project Assistance: The program awards $1 billion annually and funds large and complex projects which will generate national or regional economic, mobility, or safety benefits and are difficult to receive funding from other sources.
- Rural Surface Transportation Grant: The grant awards $300 to $500 million annually to support projects that improve and expand rural transportation infrastructure. The maximum award of the grant is $25 million.

Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation: A $1.4 billion program that supports resilience improvement projects, such as for developing plans, community resilience, identifying or improving evacuation routes, and protecting at-risk infrastructure. TTP funds can be used to meet matching requirements.

Charging and Fueling Infrastructure: A $2.5 billion program funded through 2026 that supports the deployment of publicly accessible electric vehicle charging and hydrogen, propane, and natural gas fueling infrastructure on alternative fuel corridors. Funds can also be used for operating assistance for first five years of infrastructure operations. TTP funds can be used to meet grant matching requirements.

Tribal Transportation Facility Bridge Program: The program has two sources of funding.

- Bridge Formula Program: Awards $165 million annually to support replacement, rehabilitation, preservation, protection, and construction of Tribal transportation facility bridges.
- Bridge Investment Program: Allocates $36-44 million annually to fund projects that improve bridge conditions and the reliability, safety and efficiency of people and freights over bridges.

Nationally Significant Federal Lands and Tribal Projects Program: The Nationally Significant Federal Lands and Tribal Projects Program, administered by the FHWA within the U.S. Department of Transportation, funds transportation facilities construction, reconstruction, and rehabilitation within, adjacent to, or providing access to Federal and Tribal lands.[26] Projects with a value of at least $12.5 million are eligible for funding and are 100 percent federally funded for Tribal projects. Eligible entities include those eligible under the Federal Lands Access Program, Federal Lands Transportation Program, Tribal Transportation Program, and Federal Lands Planning Program. State, county, or local governments can only apply with sponsorship from an eligible Federal land management agency or a federally recognized Tribe.

FHWA Tribal Technical Assistance Program: Provides transportation training and technical assistance to Tribal Communities, building skills and expertise to ensure the safety and maintenance of Tribal roads.

5.4.2.2 Department of Interior

The Tribal Climate Resilience annual award program is administered by the Branch of Tribal Climate Resilience within the BIA to distribute financial support for Federally recognized Tribal nations through an annual funding program. [27] The annual award program provides various avenues to receive funding through two categories of funding. Category 1 is for planning projects, has a maximum award of $250,000, and does not include funding for implementation activities. Example topics for planning projects include adaptation planning; ocean and coastal management planning; relocation, managed retreat, and protect-in-place planning; trainings or workshops; and internships and/or youth engagement. Category 2 is for implementation projects, has a maximum award of $4,000,000, and projects under this category must identify whether they include construction. Example topics for implementation projects include climate adaptation implementation and relocation, managed retreat, and protect-in-place implementation. Separate from these two Categories of funding, the program has also set aside funds for First Time Awardees, Habitat Restoration and Adaptation, as well as Relocation, Managed Retreat, or Protect-in-Place Coordinators, which will be awarded separately from Categories 1 and 2. These set asides are as follows:

- First Time Applicants: (maximum $250,000) does not include funding for implementation activities.
- Habitat Restoration and Adaptation: (no maximum) if there are multiple competitive proposals then individual amounts may be reduced to fund all selected; projects may be planning or implementation and must identify whether they include construction if they are implementation projects.
- Relocation, Managed Retreat, or Protect-in-Place Coordinator: (maximum $150,000 per year for up to three years) does not include funding for implementation activities.

The program is focused on supporting Tribes to become more resilient to changes in climate and seeks to support Tribes by providing technical assistance (science and data, educational training, networks) and financial assistance (awards program and coastal management efforts, with additional funding from the bipartisan infrastructure law for relocation-related

[26] Federal Highway Administration. 2023. "Nationally Significant Federal Lands and Tribal Projects Program. https://highways.dot.gov/federal-lands/programs/significant

[27] U.S. Department of Interior. (2022). Annual Awards Program – BIA TCR Annual Awards Program. https://www.bia.gov/service/tcr-annual-awards-program

support).[28] $120 million in over 800 awards have been distributed since 2011.[29] Funding opportunity and application materials are located on their website.

Voluntary Community-Driven Relocation Program: Announced in November 2022 and will assist Tribes that are severely affected by climate and environmental threats to relocate.

5.4.2.3 Federal Emergency Management Agency

Building Resilient Infrastructure and Communities: Discretionary grants for infrastructure projects, planning and design, and technical assistance to improve pre-disaster community resilience and reduce disaster suffering, mitigate loss of life, and decrease disaster costs. Replaces FEMA's Pre-Disaster Mitigation Grant Program. An additional $1 billion will go to the program through the Bipartisan Infrastructure Law.

Pre-Disaster Mitigation Grant Program: Provides $233 million in funding for 100 projects for States, Tribes, territories, and local communities to plan for and implement cost-effective measures designed to reduce the risk from future natural disasters. All applicants and sub applicants must have a FEMA-approved Hazard Mitigation Plan by the application deadline and at the time of the obligation of funds. Addressing significant impacts caused by climate change are applicable mitigation activities under the program.

Flood Mitigation Assistance: Provides $3.5 billion to fund projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program.

5.4.2.4 Environmental Protection Agency

Environmental and Climate Justice Community Change Grants Program: This new program will provide approximately $2 billion for financial assistance for disadvantaged communities to advance environmental and climate justice activities. Eligible project types would reduce pollution, increase climate resilience, and improve the community's ability to respond to environmental and climate justice issues.

5.4.2.5 Department of Energy

Grid Resilience State/Tribal Formula Grant Program: The program will distribute up to $2.3 billion over 5 years and will provide grants to States, territories, and Tribes based on a formula that includes, among other things, population size, land area, probability and severity of disruptive events, and a locality's historical expenditures on mitigation efforts. Priority will be given to projects that generate the greatest community benefit providing clean, affordable, and reliable energy.

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28 U.S. Department of Interior. (2022). Annual Awards Program – BIA TCR Annual Awards Program. https://www.bia.gov/service/tcr-annual-awards-program

29 U.S. Department of Interior. (2022). Annual Awards Program – BIA TCR Annual Awards Program. https://www.bia.gov/service/tcr-annual-awards-program

Appendix A: Tribal POCs and TAG Members

Tribal POCs

Name	Title	Tribal Nation or Agency
Barry Hughes	Division Chief, Division of Transportation	BIA Eastern Oklahoma Region (standing in for Ottawa Tribe of Oklahoma)
Steve Manuel	Road Maintenance/Transportation	Coushatta Tribe of Louisiana
Bethany Crochet	Coushatta Environmental Division Manager	Coushatta Tribe of Louisiana
Skyler Bourque	Coushatta Environmental Division Manager	Coushatta Tribe of Louisiana
Misty Rickwalt	Transportation Director	Karuk Tribe
Christopher Little	Public Works Director	Mescalero Apache Tribe
Damian Morgan	Utility Manager	Mescalero Apache Tribe
Troy LittleAxe	Gaming Commissioner	Modoc Nation
Travis Manchuak	Transportation Planner	Native Village of Kwigillingok
LaJuanda Stands and Looks Back	Transportation Planner	Rosebud Sioux Tribe

Names are organized by Tribal Nation or Agency, in alphabetical order.

TAG Members

Name	Title	Organization or Agency
Anna Bosin	Tribal Relations Liaison	Alaska DOT
Clancy De Smet	Climate Change Adaptation Branch Chief	Caltrans District 1
Christina Thomure	Climate Change Specialist	Caltrans District 2
Kathy Grah	Office Chief, Regional and Community Planning	Caltrans District 2
Rebecca Lupes	Climate Change Resilience	FHWA
Anthony Spann	Karuk Tribal Coordinator	FHWA Office of Tribal Transportation
Terry Schumann	Environmental Protection Specialist	FHWA Office of Tribal Transportation
Pat McMahon	Transportation Fellow	FHWA/National Park Service
Joe Regula	Transportation Planning Program Manager	National Park Service
April Taylor	Tribal Liaison	South Central Climate Adaptation Science Center
Jake Palazzi	Tribal Liaison	South Central Climate Adaptation Science Center
Sharon Hausam	Climate Adaptation Planner and Research Scientist	South Central Climate Adaptation Science Center

Name	Title	Organization or Agency
Yvette Wiley	Tribal Liaison	South Central Climate Adaptation Science Center
Billy Connor	Director, Alaska University Transportation Center	University of Alaska Fairbanks
Renee McPherson	Director, University of Oklahoma Southern Plains Transportation Center	University of Oklahoma
Kari Norgaard	Professor of Sociology and Environmental Studies	University of Oregon
Karin Bumbaco	Assistant State Climatologist	University of Washington
Jon Godt	Landslide Hazards Program Director	USGS
Stephen Slaughter	Landslide Hazards Associate Program Coordinator	USGS
Carol Lee Roalkvam	Policy Branch Manager	Washington DOT

Names are organized by Organization or Agency, in alphabetical order.

Appendix B: Tribal Feedback Collected

The project team distributed an anonymous feedback form to Tribe POCs using Microsoft Forms to collect information about their experience throughout the project. Contacts from each Tribe were asked to provide feedback about:

- Helpful findings from the vulnerability assessments.
- Any needs of the community that they felt were not met.
- Any perceived gaps in the analysis.

The following questions were asked in the online feedback form:

1. How much has this project helped you understand your transportation infrastructure vulnerabilities? (Please explain)
    a. Gained a better and more robust understanding
    b. Gained somewhat of a better understanding or learned something new
    c. Understanding has not changed
2. How was communicating with the WSP project team? (Please explain)
    a. Communication was effective
    b. Communication was somewhat effective
    c. Communication was not effective
3. How do the conclusions of the report align with the lived experiences of your community members? (Please explain)
    a. Very aligned
    b. Somewhat aligned
    c. Not aligned
4. How useful was the information provided through the project or report? (Please explain)
    a. Very useful
    b. Somewhat useful
    c. Not very useful
5. Were your expectations for the project met? (Please explain)
    a. Expectations were exceeded
    b. Expectations were met
    c. Expectations were not met
6. Are there any other areas of the project process or analysis that were lacking or did not sufficiently meet your expectations? (Please explain)
    a. Expectations were exceeded
    b. Expectations were met
    c. Expectations were not met

7. Do you feel that the Federal Highway Administration Vulnerability Assessment Framework was a useful resource for guiding your community's transportation vulnerability assessment?
    a. Yes
    b. No
    c. No opinion
8. Please explain any ways you think the FHWA framework could have been more useful to the project or your community.
9. Based on the information provided in the report, on which topics would additional analysis best serve your community?
10. Did this project identify any relevant grant funding opportunities that you were previously unaware of **or** that the community is now considering applying to? (Please explain)
    a. Yes
    b. No
11. How else does your community plan to use the information provided in the vulnerability assessment?
12. Please describe your biggest takeaway from this process or from the final report.

There were three anonymous responses to the survey. The feedback form was distributed to all Tribes except the Rosebud Sioux Tribe because their vulnerability assessment was still ongoing at the time. In this case, the project team collected feedback from the Rosebud Sioux Tribe POC directly.

Form Responses

Respondents either gained a better and more robust understanding of their transportation infrastructure vulnerabilities or gained somewhat of a better understanding or learned something new (Figure 5-7).

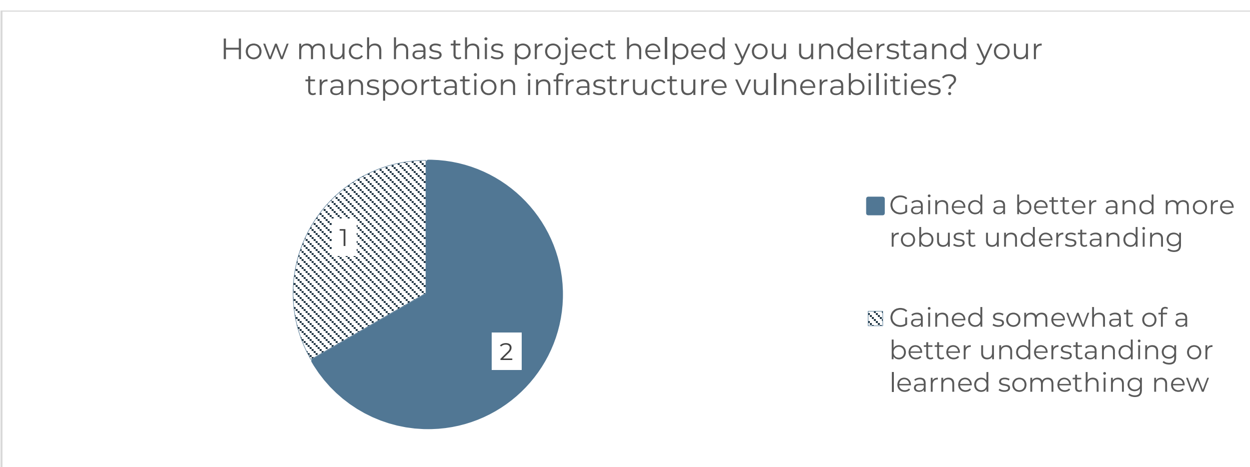

Figure 5-7. Overall, respondents gained a better understanding of their transportation infrastructure vulnerabilities or learned something new.

Respondents noted that they were previously aware of some of the issues identified in the reports, but the project helped form a more in-depth understanding of the causes of the issues and provide potential solutions to the issues. The conclusions of the report aligned very well with the lived experiences of the Tribal Community members and accurately acknowledged that the climate change impacts analyzed in the report are not merely inconveniences for Tribe citizens but are also a “major financial and health concern for members and limit access to outside resources.”

Additionally, respondents felt that the findings of these reports could be used for the planning of future infrastructure improvement projects under the Tribes’ jurisdiction. All respondents felt that the information provided through the project was very useful, noting that they plan to use the information to communicate the challenges their communities face and to drive future infrastructure decisions.

The expectations for the project were met for all respondents, with most respondents saying that their expectations were exceeded (Figure 5-8). No part of the project process or analysis was lacking or failed to sufficiently meet expectations; however, one respondent noted that additional analysis on collaboration and coordination with various agencies to pool resources during “times of adversity, such as major road closures during wildfires, flooding, landslides, slip-outs, and snow” would greatly benefit their community.

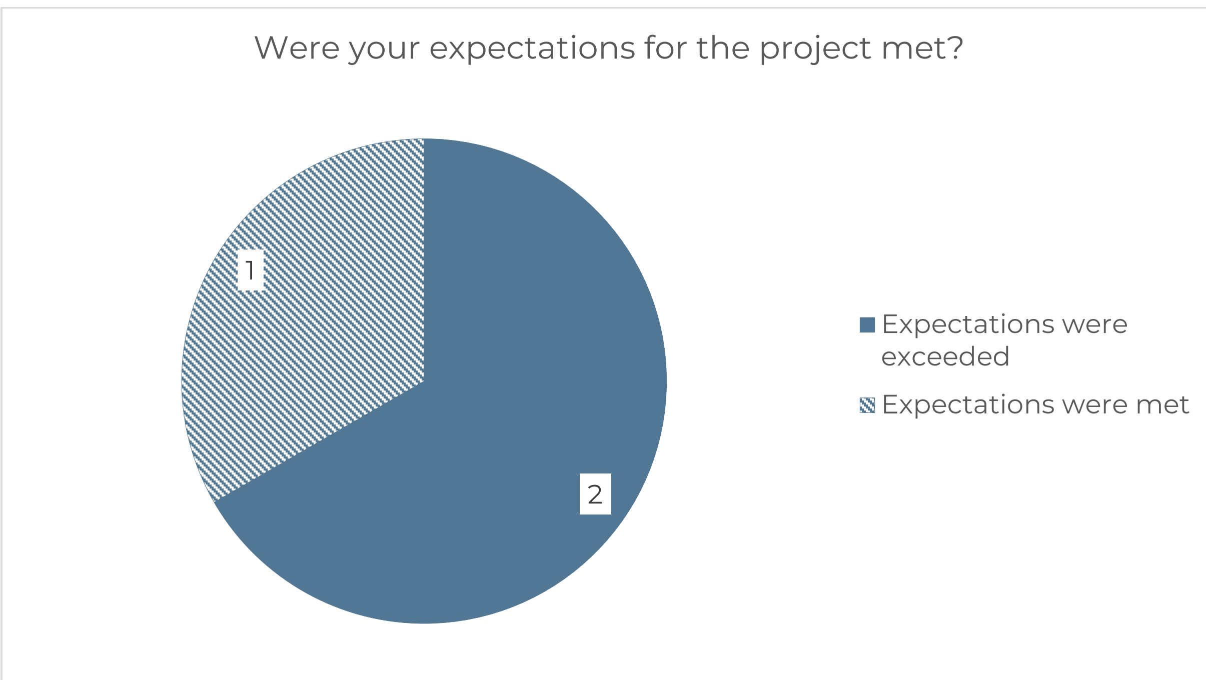

Figure 5-8. All respondents felt their expectations for the project were met or exceeded.

Furthermore, all respondents felt that the FHWA Vulnerability Assessment Framework was a useful resource for guiding their communities' transportation vulnerability assessment. The project was able to help identify relevant grant funding opportunities of which most of the respondents were previously unaware or which their communities are considering applying to (Figure 5-9).

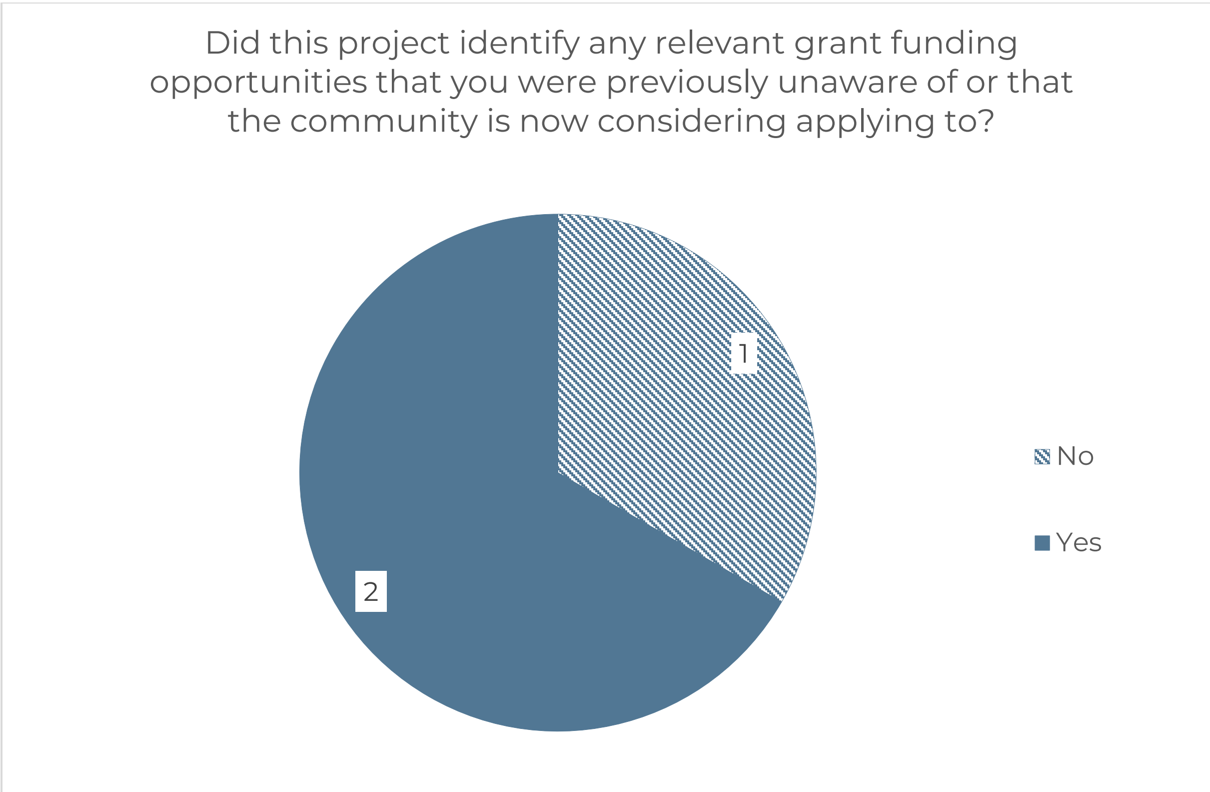

Figure 5-9. The project identified relevant grant funding opportunities for most respondents and their communities.

Finally, one respondent said their biggest takeaway from the project process was recognizing that "climate consideration[s] are equally or more important than other [transportation] project criteria." This same respondent mentioned that the Tribe plans on using the information provided in this project when considering future projects, such as helping to explain project goals to Tribal partners when they make future project decisions.

All respondents found that communication with the project team was effective, noting that staff were very responsive, available to answer questions, and kept the study on track and moving forward.

Photo source: FHWA

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