



U.S. Department
of Transportation

Federal Highway
Administration

FHWA Climate Resilience Pilot Program:

Arizona Department of Transportation

The Federal Highway Administration's (FHWA)'s Climate Resilience Pilot Program seeks to assist state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and Federal Land Management Agencies (FLMAs) in enhancing resilience of transportation systems to extreme weather events and climate change. In 2013-2015, nineteen pilot teams from across the country partnered with FHWA to assess transportation vulnerability to extreme weather events and climate change and evaluated options for improving resilience. For more information about the pilot programs, visit: http://www.fhwa.dot.gov/environment/climate_change/adaptation/.

A rizona Department of Transportation conducted a pilot study to identify hotspots where highways are vulnerable to extreme weather, including high temperatures, drought, and intense storms. These factors can contribute to dust storms, wildfire, and flash floods, depending on the surrounding vegetation and landscape. The risks are different in the lower desert and grassland areas than in the forested mountain portions of the state. Understanding the risks and identifying vulnerable sections of roads will help ADOT plan to spend its construction and maintenance dollars more efficiently while improving public safety and ensuring continued services.



Scope

The project focused on the interstate corridor connecting Nogales, Tucson, Phoenix, and Flagstaff. Due to the focus on interstates, the entire corridor (which includes a variety of urban areas, landscapes, biotic communities, and climate zones and presents a range of weather conditions applicable to much of Arizona) was considered critical. The project focused on high temperatures, drought, and intense storms. It examined how these stressors contribute to dust storms, freeze-thaw cycles, wildfire, and flash flooding and, in turn, affect pavement, bridges, culverts, and road closures.

Objectives

ADOT seeks to develop a multi-stakeholder decision-making framework to cost-effectively enhance the resilience of Arizona's transportation system to extreme weather risks. In an effort to achieve this long-term goal, this project's objectives were the following:

- Identify and prioritize vulnerable assets and stressors of most concern within the study corridor.
- Qualitatively assess the risks of extreme weather on critical transportation infrastructure.
- Seek feedback from stakeholders to inform and enhance the assessment and propose a collaborative structure for future adaptation efforts.
- Contribute to the ongoing refinement of FHWA's Vulnerability Assessment Framework.



August 2014 flooding that closed part of Interstate 17. Photo credit: ADOT



Dust storm along a highway in Arizona. Photo credit: ADOT



Cars backed up on Interstate 17 due to the Badger Fire. Photo credit: ADOT

Approach

Engage stakeholders. The project team engaged numerous internal and external stakeholders (including scientific stakeholders, state-wide focus groups, and district focus groups comprised of a mix of federal and state and local government agencies, universities, and non-profit organizations) through a series of meetings. The meetings provided a forum for identification of relevant extreme weather conditions, transportation system impacts, and proper data sources and analytical methods, as well as interpretation of project findings.

Select the study corridor and land cover.

Environmental factors beyond the immediate right-of-way (ROW) were considered in order to evaluate the range of weather conditions and impacts across the diverse conditions of the study corridor. As a result, the boundaries of the watersheds that cross the corridor were selected to define the study area. Because land cover and dominant vegetation type can influence the impact of weather-related stressors on transportation assets, the project team identified relevant land cover datasets through literature reviews, stakeholder meetings, and previous studies. Eight main biotic communities were identified in the study area, which were consolidated into four land cover categories: *Desert and Urbanized Areas*, *Chaparral*, *Grasslands*, and *Forests* (see Figure 1). ADOT biologists and the project

team determined how these land cover types might alleviate or exacerbate the risk of various extreme weather phenomena to transportation infrastructure, with an emphasis on wildfire risk.

Collect and process climate data. ADOT convened a workshop of scientific stakeholders to help the project team select and apply the most relevant and robust models, emissions scenarios, and downscaling techniques. The team selected future timeframes of 2025 to 2055 and 2065 to 2095 and used temperature and precipitation observations from 1950 through 1999. The project team used the U.S. DOT CMIP Climate Data Processing Tool to retrieve climate data, eventually modifying the tool to facilitate processing larger batches of data and deriving a wider range of variables. Using the highest greenhouse gas emissions scenarios to consider extreme conditions, the selected climate models project increases of between 7° to 9°F in average daily maximum temperatures and increases in the average number of days above 100°F in the study corridor, regardless of land cover type (see Figure 2). The average of all model outputs project small increases in the magnitude of rainfall associated with the 100-year event and in average annual precipitation, although there is significant disagreement among models (indicating less certainty for future precipitation).

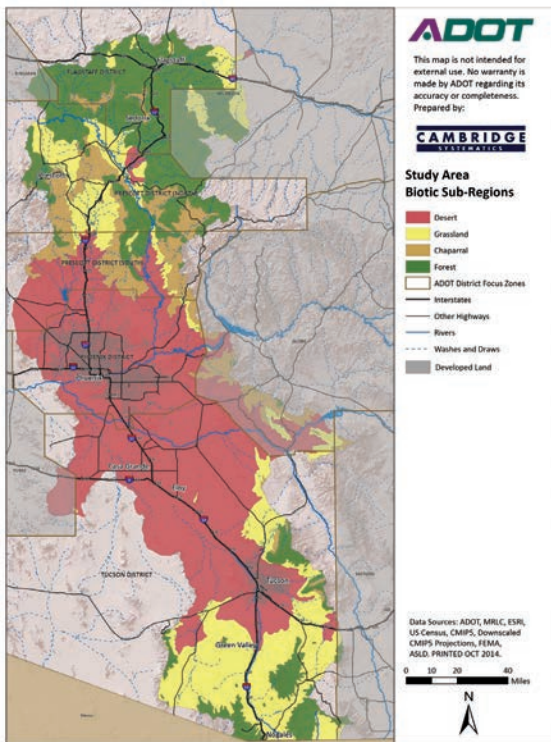


Figure 1. Consolidated land cover types in the study corridor. Red indicates *Desert and Urbanized Areas*, yellow indicates *Grasslands*, brown indicates *Chaparral*, and green indicates *Forests*.

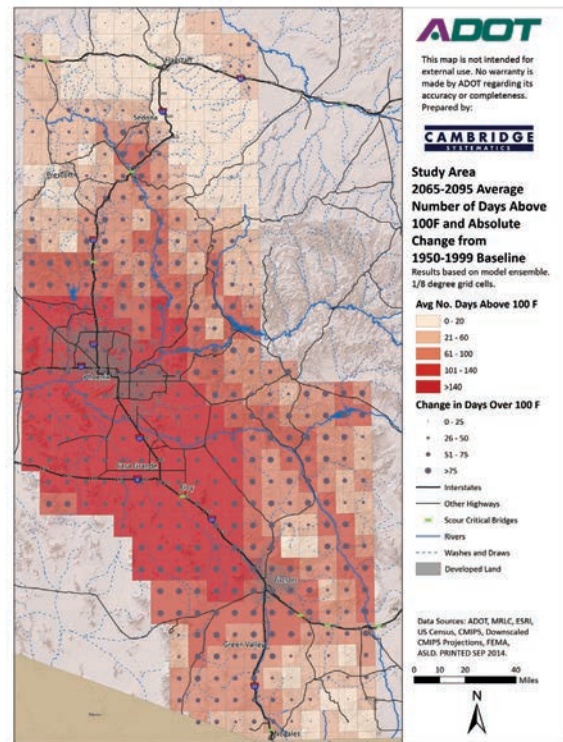


Figure 2. Projected average number of days above 100°F. Darker red areas of the map indicate a greater average number of days above 100°F per year, and larger circles in each grid cell indicate a greater change in days over 100°F per year.

Assess vulnerability of critical assets. The project team integrated the climate data, transportation asset data, and land cover data into a Geographic Information System (GIS) and analyzed the potential change in existing transportation-related vulnerabilities over the next century. The assessment qualitatively addressed the complex and often uncertain interactions between climate and extreme weather, land cover types, and transportation facilities. Because details of local asset characteristics (e.g., conveyance capability of specific drainage infrastructure) throughout the more than 300-mile corridor were not readily available for use in the assessment, the downscaled

projection values and land cover data were considered at the level of the four ADOT Construction/Maintenance Districts to provide a more general and regional projection of risk. The team treated climate variables as factors that influence risk and considered land cover as a risk modifier (i.e., a factor that could potentially alleviate or aggravate the impact of a climate event or trend on transportation facilities or operations). The assessment generated qualitative rankings based on the expected relationship between the climate variables and dominant land cover types and did not consider more complex phenomena or localized factors.

Key Results & Findings

Table 1 summarizes the high-level findings regarding the projected impacts of concern for different areas. More detailed findings follow.

	Extreme Heat	Freezing Temperatures	Extreme Precipitation	Wildfire Risk
I-17 Corridor Northcentral/ Northwest Districts	Neutral/Not Relevant	Positive	Neutral/Not Relevant	Negative, but Uncertain
I-17 Corridor Central/ Northwest Districts	Negative	Neutral/Not Relevant	Negative, but Uncertain	Neutral
10/I-19 Corridor Southcentral District	Negative	Positive	Negative, but Uncertain	Negative, but Uncertain

Table 1. High level findings from the ADOT extreme weather study.

Extreme heat will impact pavement, construction windows, and worker safety. While areas that already frequently experience extreme heat have incorporated heat-resistant pavement mixtures into their design criteria, such standards may need to be reevaluated as temperatures above 110°F become more common and long-lasting. Extreme heat may affect construction windows and the safety of workers in outdoor conditions. Worker safety protocols may need to be updated as temperatures above 100°F and 110°F become more common. For instance, the climate projections showed 144 days over 100°F annually by 2080 for desert areas such as Phoenix. The incidence of shredded truck tires on roads generally increases under very hot conditions, affecting motorist and worker safety.

Temperature increases may reduce winter maintenance and operations costs. Certain cooler areas of the study corridor, such as areas of the Southcentral, Northcentral, and Northwest Districts, commonly experience freezing temperatures, snow, and freeze-thaw cycles that create frequent wintertime maintenance. However, projected higher temperatures may decrease the number of opportunities for freeze-thaw and snow events, thereby potentially reducing winter maintenance and

operations costs. Construction activities requiring warmer minimum temperatures might also be possible earlier in the spring or later in the fall.

Extreme precipitation may have a negative impact on roadways, though the extent is uncertain. While projections of future average precipitation generally are uncertain, the contribution of extreme precipitation to localized flooding may increase around the Phoenix and Tucson areas, posing a threat to depressed freeways and other low-lying areas.

Potential wildfire impacts are harmful but uncertain. The one area of the study corridor most at risk from wildfire is the Northcentral District, though future trends for roadway-adjacent wildfire risk are uncertain. Wildfire can damage infrastructure both directly and as a result of post-fire floods. Wildfire can cause major traffic delays while in progress. Much of the Flagstaff District is comprised of land cover types that exhibit high wildfire risk. However, large scale forest thinning projects are underway, which could reduce risks to roadways if implemented in strategic watershed locations. ADOT is pursuing cooperative planning with the National Forests and other partners to reduce future risks to transportation infrastructure.

Lessons Learned

Leverage existing tools to meet study needs. The project team faced a data acquisition and processing challenge. The study corridor was large and geographically diverse. High spatial resolution of climate data was preferred. The team modified the U.S. DOT CMIP Climate Data Processing Tool to include batch processing of multiple models for over a dozen variables over three time periods (baseline, mid-century, and end-of-century) for approximately 450 grid cells in a single run of the tool. The team also added extreme rainfall (100- and 200-year rainfall events) variables.

Understand uncertainty within climate projections.

The scientific stakeholders highlighted the uncertainty of climate projections, especially related to precipitation. Secondary stressors such as wildfire and flooding, which are influenced by climate and non-climate factors, compound that uncertainty for localized analyses. Instead of assigning definitive vulnerabilities, the project team decided to characterize current extreme weather vulnerabilities and highlight potential future changes in key risk factors.

Balance study scope with resources needed. The study encompassed several extreme weather vulnerabilities, many of which have a complex array of causal factors. Robust modeling of these relationships was outside the scope and resources of the study.

Stakeholder input is invaluable. The project team found stakeholder feedback to be extremely valuable in conducting the assessment. Focus group meetings with ADOT and external stakeholders early in the study helped the team develop an initial understanding of existing and future regional and statewide transportation vulnerabilities. Practitioners within ADOT offered observations about current conditions that improved the quality of the assessment. The scientific stakeholders' input guided the project by identifying best practices for climate data processing and helped ensure that uncertainty was appropriately addressed in the results.

Next Steps

ADOT is developing a Resilience Pilot Program that will incorporate existing planning, design, construction, operations, and maintenance criteria to identify a strategic and systematic framework for assessing resilience. The program will build on available technologies, tools, and partnerships, as well as the information in ADOT's 2014 *Preliminary Study of Climate Adaptation for the Statewide Transportation System in Arizona* and the 2015 *Extreme Weather Vulnerability Assessment Final Report*, and contribute to the national conversation surrounding these topics. Since ADOT has a long history considering the balance between predictable asset deterioration curves and the unknown, erratic, and abrupt incidents of flood, overtopping, system hotspots, hydraulic-related failure, and extreme weather impacts, these topics were identified to make up the core of the pilot program.

"Working with different groups across the State, we created a synergy of information... we're planning to continue to coordinate with regional stakeholders and adapt to extreme weather together."

– ADOT Pilot Team

In addition, ADOT will continue in its national leadership role pioneering large geographic area climate data downscaling, mainstreaming these fledgling activities inside a State DOT, and the development of appropriate, cost effective approaches to these issues. Regionally, ADOT will also continue as an early adopter and assessor of these effects and serve as a statewide collection point for these efforts as they relate to transportation and our system stakeholders.

For More Information

Final report available at:
www.fhwa.dot.gov/environment/climate/adaptation/2015pilots/

Contacts:

Kris Gade, PhD
Roadside Resources Specialist
Arizona Department of Transportation
KGade@azdot.gov, 602-292-0301

Steve Olmsted
Project Manager/Environmental Planning
Arizona Department of Transportation
SOlmsted@azdot.gov, 602-712-6421

Thor Anderson
Performance Management and Research
Arizona Department of Transportation
TAnderson@azdot.gov, 602-712-4574

Becky Lupes
Sustainable Transport & Climate Change Team
Federal Highway Administration
Rebecca.Lupes@dot.gov, 202-366-780



U.S. Department of Transportation
Federal Highway Administration