

# Addressing Resilience in Project Development



U.S. Department of Transportation  
Federal Highway Administration

## Overview

FHWA's *Synthesis of Approaches for Addressing Resilience in Project Development* (2017) study<sup>1</sup> evaluated engineering approaches for assessing current and future weather hazards, and developed solutions and methodologies that transportation agencies may apply to increase the resilience of transportation assets and systems.

## Purpose

Changes in weather extremes and other environmental conditions may affect the ability of transportation infrastructure to perform as intended over its service life. Past conditions may no longer serve as a reliable guide to design requirements for long-lived infrastructure.

To address these concerns, FHWA examined ways to integrate consideration of resilience into the process of developing transportation projects, especially during the initial stages of planning, scoping, and preliminary design and engineering, and conducted or supported a range of engineering-informed adaptation studies across the country to better understand asset vulnerabilities and potential solutions.

This work has two primary goals:

- Demonstrate the process for translating projections of future environmental conditions into information that transportation agencies can use in project-level specifications and design.
- Develop methodologies and solutions that project engineers across the nation can use in developing transportation infrastructure that is resilient to future environmental conditions.

## Products

- The *Synthesis of Approaches for Addressing Resilience in Project Development* study incorporated lessons learned and innovations from recent FHWA studies and pilot projects for:
  - Addressing resilience in the project development process;
  - Developing and applying resilience information and economic analysis in assessing and selecting adaptation options; and
  - Examining sensitivities, guidance, lessons learned, and adaptation strategies for coastal hydraulics, riverine flooding, pavement and soils, and mechanical and electrical systems.
- Nine case studies focused on asset-level engineering and economic analyses of resilience and development of adaptation options. These addressed specific asset-stressor gaps, and fed into the report.

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<sup>1</sup> See <https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/> for more information on this study and access to its products. The study was the final report of the effort, which included development of nine Transportation Engineering Approaches to Climate Resilience (TEACR) case studies to fill identified asset-stressor gaps.

Banner photo source: Colorado Department of Transportation

## Addressing Resilience in Project Development

### Case Study: Culverts and Wildfires

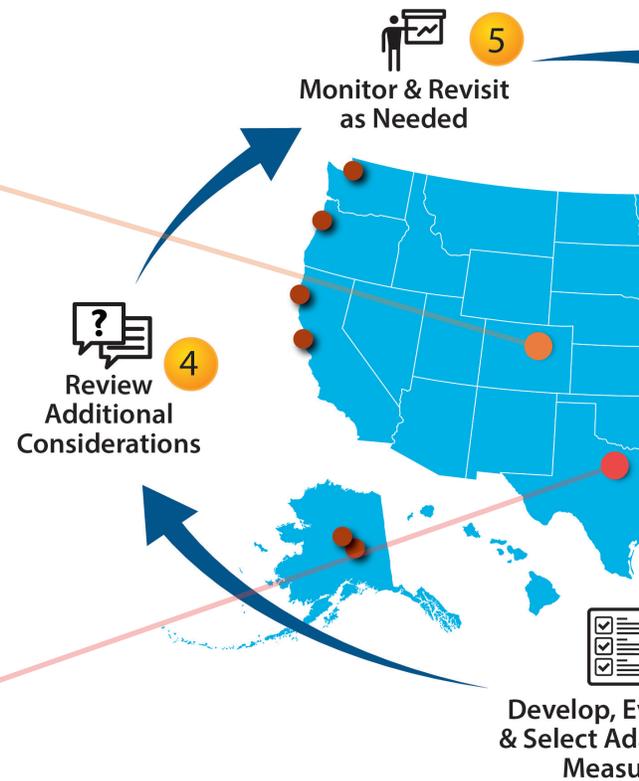
Investigated the combined impacts of changing precipitation and wildfire risk on the performance of a culvert structure. Adaptation options included pre-fire culvert replacement, post-fire culvert adaptation, and post-fire watershed treatments.

#### Key Lessons Learned

- The impacts of wildfires on watershed land cover greatly increases the volume of watershed precipitation-induced stream flow runoff.
- Averaging across models to develop precipitation projections masks the fact that plausible future conditions at this location range from wetter to drier conditions. To capture the range of possible futures, the study used a binned approach that pulled out samples of future conditions.
- Adapting the culvert after a fire (rather than preemptively) is recommended because the probability of a wildfire event in the watershed is expected to be low and replacement costs are high.
- If a culvert is scheduled for replacement, upsizing it to accommodate projected increases in extreme precipitation events would be a minor increase in cost and therefore may be worthwhile.

### Case Study: Soil Shrink and Swell

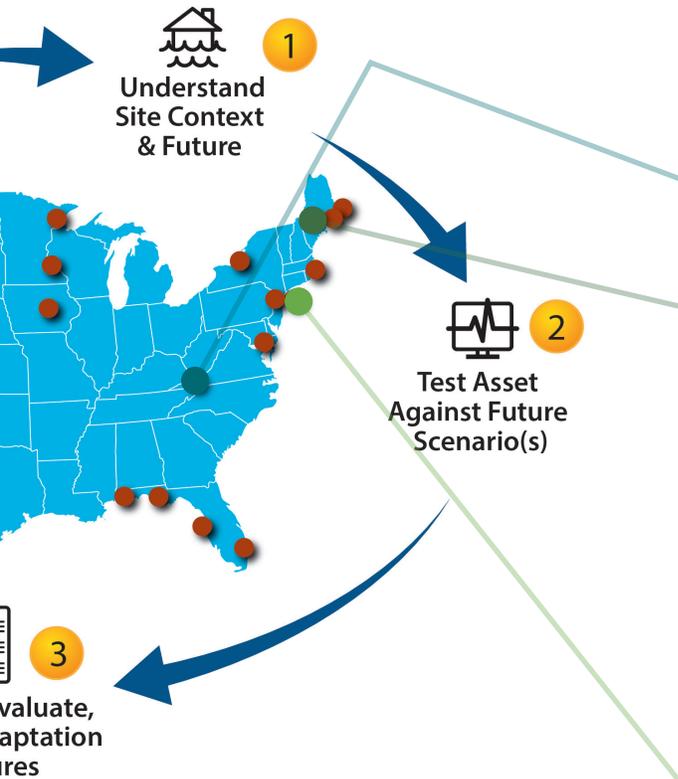
Evaluated potential impacts of projected changes in temperature and precipitation on expansive soils and the overlying pavement performance. Adaptation options included using stiffer, currently available asphalt binders in flexible pavement mixes, and increasing steel content in rigid (concrete) pavements to enhance rigidity.



The synthesis report drew from a range of engineering studies, including the *Coast 2 Study*, the *FHWA Hurricane Sandy Followup Study*, and the *FHWA Pavement Condition Survey* website. The numbered steps illustrate the process of addressing resilience in project development.

#### Key Lessons Learned

- Environmental conditions influence how pavement performs over its lifetime, and any change can have long-term adverse consequences on the performance of pavements.
- The marginal cost of adaptation is low for a single project, but could be more substantial when considering the larger highway network.
- A proactive approach to pavement preservation, maintenance, and renewal decisions, along with asset management that considers risks and solutions for whole categories of assets, can make the costs of pavement adaptation more manageable.



Locations shown on the map, including the *USDOT Gulf* the engineering pilots described on FHWA's Resilience in transportation project development.

environmentally appropriate measures to provide initial resilience until a more traditional, engineered structure is required for greater protection.

### Case Study: Slope Stability

Evaluated potential impacts of projected changes in precipitation and freeze-thaw cycles on rock and soil slope stability.

#### Key Lessons Learned

- Identifying failure thresholds for a slope can allow for a screening-level assessment of precipitation impacts on soil slope stability without detailed temperature and precipitation projections, by analyzing the worst case scenario.
- The timing and amounts of precipitation immediately preceding a freezing event influence the severity of freeze-thaw damage. Local temperature and precipitation projections must be considered together when projecting the potential for rock slope failure.

### Case Study: Sea Level Rise

Examined the feasibility of living shorelines for coastal road protection. Adaptation options included traditional protection (armoring), elevating and armoring, living shoreline protection, relocation, and abandonment.

#### Key Lessons Learned

- Natural and nature-based adaptation strategies, such as living shorelines, have the potential to reduce vulnerabilities.
- In most locations, sea level rise projections and frequency-based storm surge data are readily available. Existing data provide suitable information for conducting adaptation assessments.
- Even where living shorelines may not provide comprehensive protection in the long term, they can be used as cost-effective and

### Case Study: Economic Analysis

Explored how economic assessment methods, discount rates, and stressor-damage relationships affect the estimated benefits of adaptive measures.

#### Key Lessons Learned

- Considering a range of future scenarios and adaptation options in economic analyses is a useful way to ensure the selection of a robust adaptation option.
- When there is uncertainty in the preferred course of action, it is wise to conduct sensitivity tests of different stressor-damage relationships to ensure selection of the most robust option.
- Monte Carlo and areas under the curve analyses yield similar end results. The Monte Carlo approach provides more richness in the types of results generated.



## Additional Lessons

### Economic Analysis

Economic analyses can help identify adaptation options that are most efficient, inform tradeoffs among options, and justify investments that enhance resilience.

- Economic analyses for adaptation projects are highly sensitive to the discount rate chosen. Cumulative expected damage costs vary depending on which discount rate is used, and the choice of discount rate can cause a project alternative to switch from having a positive net present value to a negative one.
- Traditional lifecycle cost analyses for transportation projects do not consider the socioeconomic costs of extreme weather events and other hazards (e.g., increased travel delay costs, disruptions to the regional economy). Failing to include these costs may underestimate the benefits of resilience measures.

### Improving Resilience

- A basic understanding of how hazards may affect a given location and facility enables practitioners to identify data needs.
- Assets' performance should be tested against several future scenarios to understand the range of possible impacts. FHWA's *HEC-25 Volume 2* and *HEC-17* provide detailed guidance on how to select scenarios, make decisions about models and timeframes, and adjust regional global projections so that they reflect local conditions.
- The selection of adaptation measure(s) should include consideration of the surrounding environment, the future of the transportation system of which the asset is a part, and socioeconomic considerations. Budgetary considerations may also come into play.

- Adaptation solutions should be flexible. The transportation system, surrounding communities, and projections of future conditions may change over time. Integrating adaptive design measures into an asset management system may facilitate flexibility.

## For More Information

### Resources

*Transportation Engineering Approaches to Climate Resiliency (TEACR)*  
[project website](#)

*HEC-25 Volume 2: Assessing Extreme Events*

*HEC-17: Floodplains, Extreme Events, and Resilience*

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