# U.S. Forest Service Climate Change and Transportation Resiliency Guidebook

## Addressing and Assessing Climate Change Impacts on U.S. Forest Service Transportation Assets

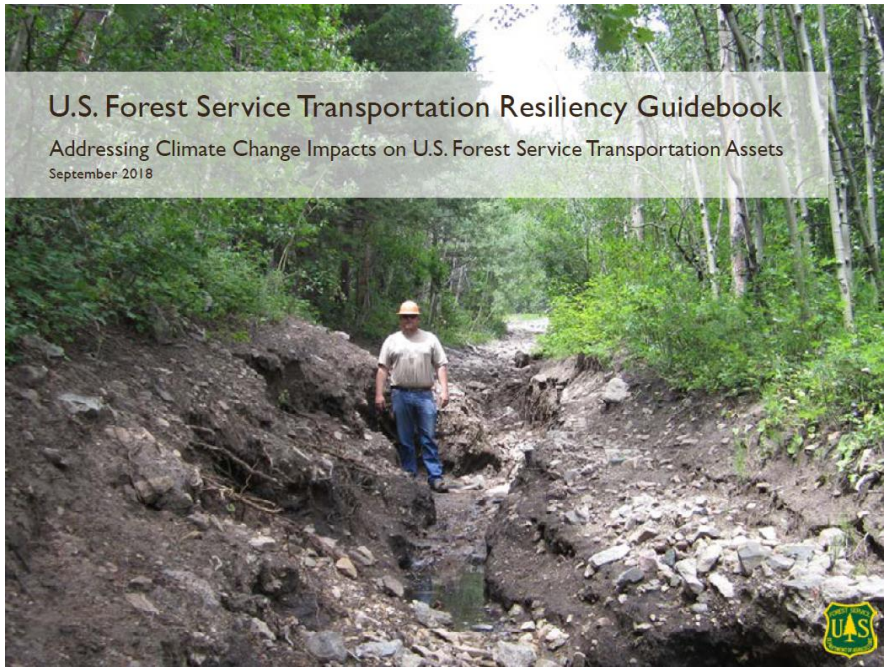
Volpe The National Transportation Systems Center

*Advancing transportation innovation for the public good*

U.S. Department of Transportation
**Office of the Secretary of Transportation**
John A. Volpe National Transportation Systems Center

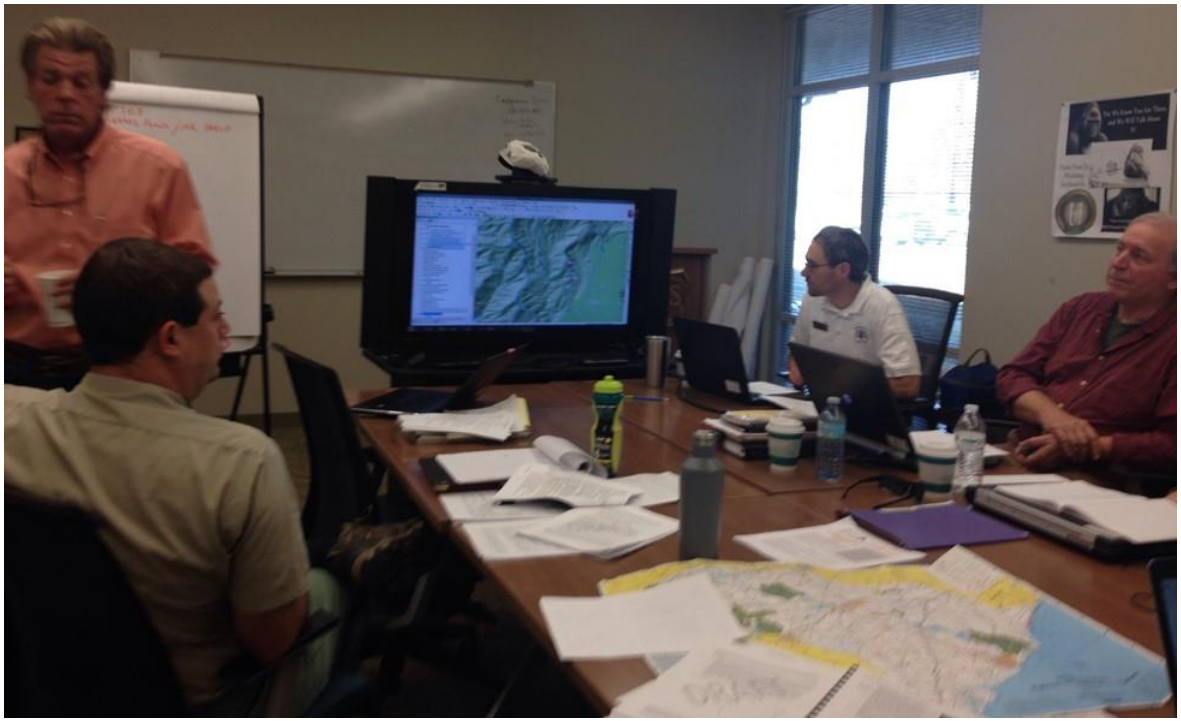
# Guidebook Overview

- Drafted in 2016
- Applied for FHWA grant in Feb. 2018
- Field tested February 2018
- Published September 2018
- Sections:
  1. Identifying Vulnerability
  2. Reducing Vulnerability
  3. Implementation Opportunities
  4. Appendix: Regional Profiles



# Section 1: Identifying Vulnerability

- **Step 1. Establish a leadership team and define objectives**
- Step 2. Define the scope: select and characterize relevant assets
- Step 3. Define the scope: identify key climate stressors
- Step 4. Assess vulnerability: develop information on asset sensitivity to climate
- Step 5. Assess vulnerability: collect asset data
- Step 6. Assess vulnerability: develop climate inputs
- Step 7. Assess vulnerability: develop indicators
- Step 8. Assess vulnerability: identify and rate vulnerability problem spots



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|---|---|---|---|---|---|---|---|
| | Increased Flows | More Tree Mortality | In Floodplain | History of Damage | Cost to Repair | Average Daily Traffic | |
| **Asset 1** | | | | | | | |
| **Asset 2** | | | | | | | |
| **Asset 3** | | | | | | | |
| **Etc.** | | | | | | | |

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|---|---|---|---|---|---|---|---|
| | Increased Flows | More Tree Mortality | In Floodplain | History of Damage | Cost to Repair | Average Daily Traffic | |
| Asset 1 | + + + | + + | + + + | + + | + + | + + + | **2** |
| Asset 2 | + + | + + + | + + + | + + + | + + + | + + | **1** |
| Asset 3 | + + | + + | + + | + + + | + + | + + + | **3** |
| Etc. | | | | | | | |

# Section 2: Reducing Vulnerability (i.e., Adaptation)

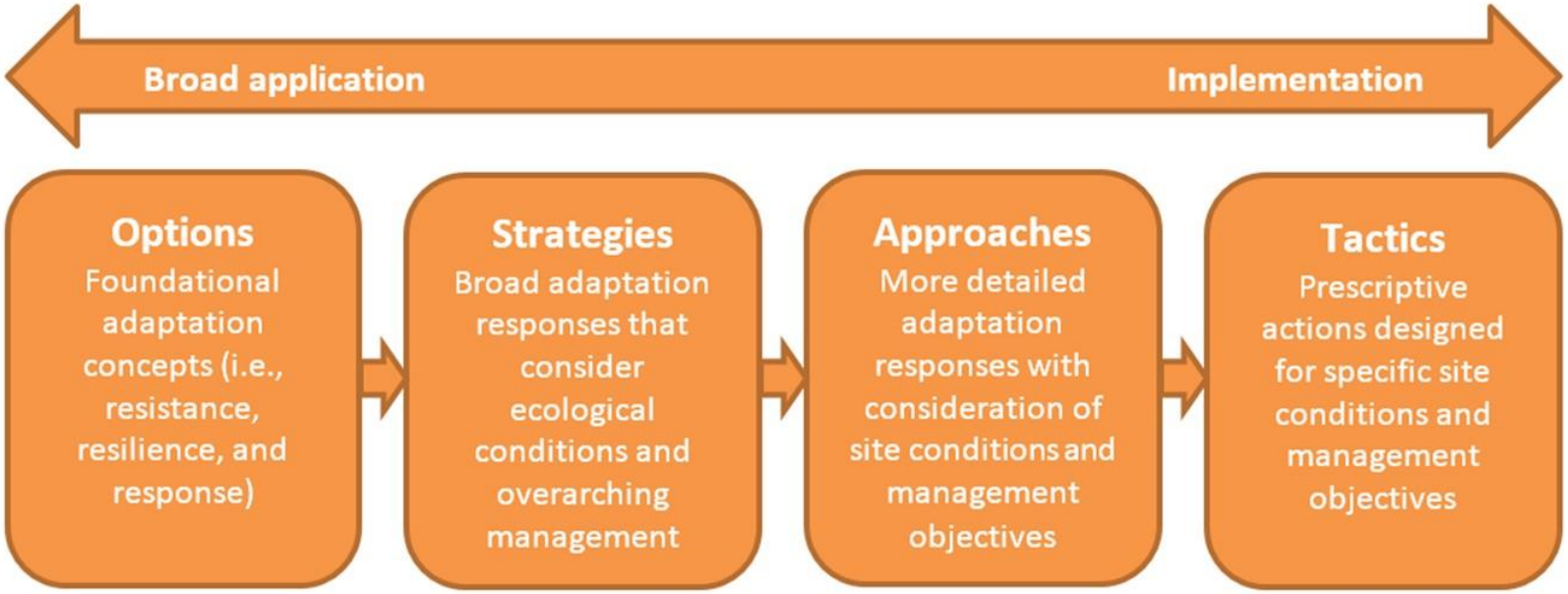


Figure 4. Continuum of adaptation actions (adapted from Janowiak et al. 2011.)

# Look familiar?

# Section 2: Reducing Vulnerability

- **Step 1. Select "Problem Spot"/vulnerable locations and assess risks**
- Step 2. Identify and develop adaptation strategies
- Step 3. Integrate climate change considerations into existing and future programs, projects, and planning processes
- Step 4. Identify and develop adaptation tactics
- Step 5. Evaluate feasibility and likelihood of success
- Step 6. Prioritize strategies and tactics
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| | Increased Flows | More Tree Mortality | In Floodplain | History of Damage | Cost to Repair | Average Daily Traffic | |
| Asset 1 | + + + | + + | + + + | + + | + + | + + + | 2 |
| Asset 2 | + + | + + + | + + + | + + + | + + + | + + | 1 |
| Asset 3 | + + | + + | + + | + + + | + + | + + + | 3 |
| Etc. | | | | | | | |

# Risk Matrix

Figure 3. Example of a risk assessment matrix[19]

| Probability of Damage or Loss | Magnitude of Consequences | | |
|---|---|---|---|
| | RISK | | |
| | Major | Moderate | Minor |
| Very likely | Very high | Very high | Low |
| Likely | Very high | High | Low |
| Possible | High | Intermediate | Low |
| Unlikely | Intermediate | Low | Very low |

**Probability of Damage or Loss:**

The following descriptions provide a framework to estimate the relative probability that damage or loss would occur (to reduce the subjectivity of these ratings, develop criteria to express these more quantitatively).

Very likely: Nearly certain occurrence (greater than 90 percent).

Likely: Likely occurrence (greater than 50 percent to less than 90 percent).

Possible: Possible occurrence (greater than 10 percent to less than 50 percent).

Unlikely: Unlikely occurrence (less than 10 percent).

**Magnitude of Consequences:**

Major: Loss of life or injury to humans, major road damage, irreversible damage to critical natural or cultural resources.

Moderate: Possible injury to humans, likely long term, but temporary road closure and lost use of major road or road system, degradation of critical natural or cultural resources resulting in considerable or long-term effects.

Minor: Road damage minor, little effect on natural or cultural resources resulting in minimal, recoverable or localized effects.

**Risk and Priority:**

A. Very high and High risk: Highest priority of SDRR treatments.

B. Intermediate risk: SDRR treatments needed; may be incorporated into annual maintenance.

C. Low and Very low risk: SDRR treatments may not be necessary.

# Section 2: Reducing Vulnerability

- Step 1. Select "Problem Spot"/vulnerable locations and assess risks
- **Step 2. Identify and develop adaptation strategies and approaches**
- Step 3. Integrate climate change considerations into existing and future programs, projects, and planning processes
- Step 4. Identify and develop adaptation tactics
- Step 5. Evaluate feasibility and likelihood of success
- Step 6. Prioritize and select tactics
- Step 7. Identify and develop monitoring programs
- Step 8. Revise strategies, approaches, and tactics as necessary

| | Strategies | Approaches | Stressors | Tactics | Feasibility | Likelihood of Success | Select |
|---|---|---|---|---|---|---|---|
| Asset 2 | Redesign | $A_R$ | | | | | |
| | | $B_R$ | | | | | |
| | | $C_R$ | | | | | |
| | | $D_R$ | | | | | |
| | Divest | $A_D$ | | | | | |
| | | $B_D$ | | | | | |
| | | | | | | | |
| | | $C_D$ | | | | | |
| Asset 1 | | | | | | | |
| | | | | | | | |

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| | Strategies | Approaches | Stressors | Tactics | Feasibility | Likelihood of Success | Select |
|---|---|---|---|---|---|---|---|
| Asset 2 | Redesign | $A_R$ | Flooding | | | | |
| | | $B_R$ | | | | | |
| | | $C_R$ | | | | | |
| | | $D_R$ | | | | | |
| | Divest | $A_D$ | | | | | |
| | | $B_D$ | | | | | |
| | | | | | | | |
| | | $C_D$ | | | | | |
| Asset 1 | | | | | | | |
| | | | | | | | |

# Sample template for adaptation strategies

| | | | | | |
|---|---|---|---|---|---|
| *Road Maintenance* | *Planning* | *Flooding* | *Culvert capacity*<br>*Water diversion*<br>*Fill-slope failures*<br>*Stream-adjacent road risk* | *Prioritize road treatment by watershed risk and road risk (the roads with the most sensitivities and that are most connected to streams)* | *National Highway Safety Act Fund Requirements (ONF)*<br>*Maintenance Fund Limitations*<br>*Need assessments to refine links between stressors and sensitivities.* |
| | | *Tree Mortality* | | | |
| | | *Wildfire* | | | |
| | *Implementation* | | | | |
| | *Monitoring* | | | | |
| *Road Operations* | *Planning* | | | | |
| | *Design:Water Crossing Fish Passage* | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Table 12. Template for Assessing Adaptation Strategies

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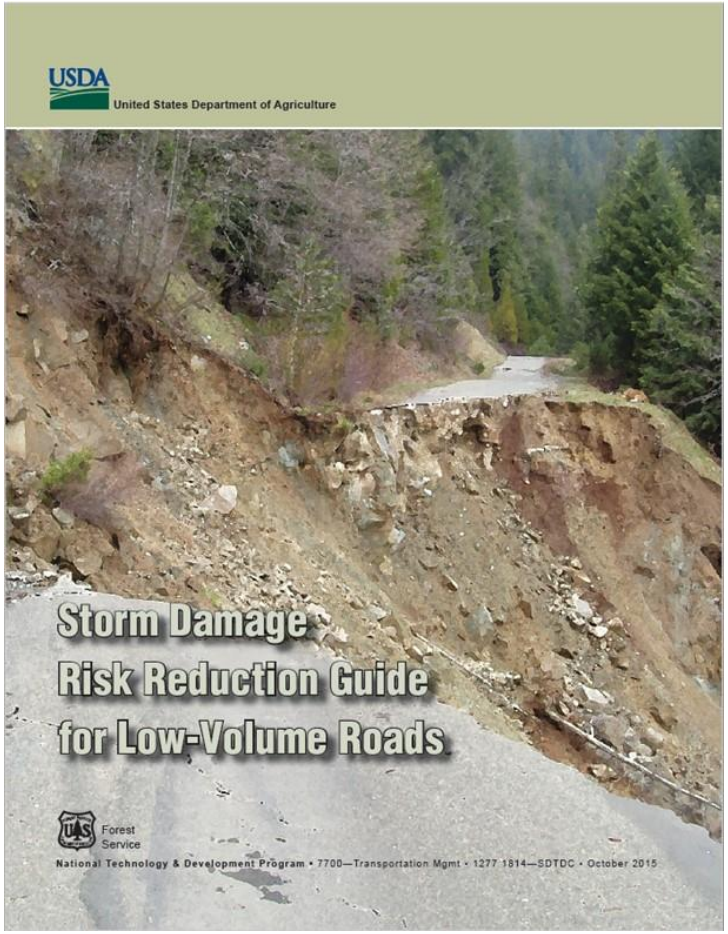
|---|---|---|---|---|---|---|---|
| Asset 2 | Redesign | $A_R$ | Flooding | $a_r$ | | | |
| | | $B_R$ | | $b_r$ | | | |
| | | $C_R$ | | $c_r$ | | | |
| | | $D_R$ | | $d_r$ | | | |
| | Divest | $A_D$ | | $a_d$ | | | |
| | | $B_D$ | | $b_{d1}$ | | | |
| | | | | $b_{d2}$ | | | |
| | | $C_D$ | | $c_d$ | | | |
| Asset 1 | | | | | | | |
| | | | | | | | |

# Tactics

*Table 2—Summary of storm damage risk reduction measures (continued)*

| MOST COMMON TREATMENTS | Effectiveness | | Cost effectiveness | |
|---|---|---|---|---|
| | Short Term | Long Term | Low | High |
| **EASY, LOW COST, OR MOST COST EFFECTIVE** | | | | |
| ***Stream Crossing Structures*** | | | | |
| Culvert maintenance. | * | | | * |
| Minor channel debris removal and clearing. | * | | | * |
| Culvert diversion prevention/armored overflow protection. | | * | | * |
| ***Bridge Protection and Improvement*** | | | | |
| Channel maintenance and debris/sediment clearing around footings. | * | | | * |
| ***Erosion Protection*** | | | | |
| Physical erosion control measures. | * | | * | |
| Vegetating barren areas/deep-rooted native plants. | | * | | * |
| Gully prevention (limiting water concentration). | | * | | * |
| ***Slope Stability Measures*** | | | | |
| Sidecast fill; pull-back/sliver-fill failure prevention. | | * | | * |

https://www.fs.fed.us/t-d/pubs/pdfpubs/pdf12771814/pdf12771814dpi100.pdf



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| | Strategies | Approaches | Stressors | Tactics | Feasibility | Likelihood of Success | Select |
|---|---|---|---|---|---|---|---|
| Asset 2 | Redesign | $A_R$ | Flooding | $a_r$ | + + | + + | |
| | | $B_R$ | | $b_r$ | + | + + | |
| | | $C_R$ | | $c_r$ | + + | + + + | |
| | | $D_R$ | | $d_r$ | + + + | + | |
| | Divest | $A_D$ | | $a_d$ | + + | + | |
| | | $B_D$ | | $b_{d1}$ | + + + | + + + | |
| | | | | $b_{d2}$ | + + + | + + | |
| | | $C_D$ | | $c_d$ | + | + | |
| Asset 1 | | | | | | | |
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|---|---|---|---|---|---|---|---|
| Asset 2 | Redesign | $A_R$ | Flooding | $a_r$ | + + | + + | |
| | | $B_R$ | | $b_r$ | + | + + | |
| | | $C_R$ | | $c_r$ | + + | + + + | |
| | | $D_R$ | | $d_r$ | + + + | + | |
| | Divest | $A_D$ | | $a_d$ | + + | + | |
| | | $B_D$ | | $b_{d1}$ | + + + | + + + | X |
| | | | | $b_{d2}$ | + + + | + + | |
| | | $C_D$ | | $c_d$ | + | + | |
| Asset 1 | | | | | | | |
| | | | | | | | |

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| | | $B_R$ | | $b_r$ | + | + + | |
| | | $C_R$ | | $c_r$ | + + | + + + | |
| | | $D_R$ | | $d_r$ | + + + | + | |
| | Divest | $A_D$ | | $a_d$ | + + | + | |
| | | $B_D$ | | $b_{d1}$ | + + + | + + + | X |
| | | | | $b_{d2}$ | + + + | + + | |
| | | $C_D$ | | $c_d$ | + | + | |
| Asset 1 | | | | | | | |
| | | | | | | | |

# Section 3: Implementation Opportunities

- Broadly:
  - New construction
  - Reconstruction
  - Maintenance (inc. CMRD)
- Specifically:
  - AOP projects (CMLG)
  - ERFO betterments
  - Divestment

# Example Strategies and Approaches

| Stressors | Options | | | Strategies | Sample Approaches |
|---|---|---|---|---|---|
| | Resistance | Resilience | Response | | |
|  | | • | • | Adjust operations and maintenance practices | More frequent maintenance of drainage (culverts, grates, catch basings) and roadway (base, shoulder, pavement) assets |
|  | | | • | Divest in asset | Place asset in storage |
| | | | | | Obliterate asset |
| | | | | | Decommission asset |
| | | | | | Change maintenance level |
|  | | • | • | Retrofit existing assets and engineer new assets to withstand future environmental conditions | Use construction materials better suited to changing climatic conditions |
| | | | | | Add barriers to prevent water incursion into tunnels |
| | | | | | Elevate roads and bridges to reduce exposure to flooding |
| | | | | | To prevent embankment / side slope erosion and possible failure, add robust slope protection such as matting riprap vegetation or possibly a closed drainage system around bridges |
| | | | | | Provide protections to roadway embankments (i.e. armoring, retaining walls, additional culverts, etc.) |
| | | | | | Increase the capacity of existing culverts to accommodate future increased precipitation and flooding events |
| | | | | | Replace the subgrades with materials so that the pavement structure will function during inundation and for multiply inundations |
| | | | | | Construct sea walls/bulkheads to protect assets from exposure to flooding |
| | | | | | Construct storm gates to shield assets from flooding |
| | | | | | Strengthen and stabilize assets (e.g., install approach plates at bridge approaches, enhance resistance to saturation of roadway base) |

# Example Strategies and Approaches

| Stressors | Options | | | Strategies | Sample Approaches |
|---|---|---|---|---|---|
| | Resistance | Resilience | Response | | |
|  | | • | • | Incorporate climate change considerations into systems planning | Site new facilities outside of expanded flood plains and high wildfire risk areas |
| | | | | | Raise profile of new facilities to reduce exposure to flooding |
| | | | | | Attenuate flooding velocities to reduce impacts of flooding (e.g., through constructed wetlands) |
| | | | | | Increase drainage capacity to increase the capacity of the network to recover functionality |
|  | | • | • | Improve operations and post disaster response planning for weather emergencies | Plan for and develop emergency detours |
| | | | | | Ensure redundant critical connectors |
|  | • | • | • | Sustain fundamental ecological functions of forests to mitigate risk of wildfire and tree mortality | Maintain or restore soil quality and nutrient cycling |
| | | | | | Maintain or restore hydrology |
| | | | | | Maintain or restore riparian areas |
|  | • | • | • | Reduce the impact of existing biological stressors causing tree mortality. | Maintain or improve the ability of forests to resist pests and pathogens |
| | | | | | Prevent the introduction and establishment of invasive plant species and remove existing invasives |
| | | | | | Manage herbivory to protect or promote regeneration |
|  | • | • | | Protect forests from severe fire and wind disturbance. | Alter forest structure or composition to reduce risk or severity of fire |
| | | | | | Establish fuelbreaks to slow the spread of catastrophic fire |
| | | | | | Alter forest structure to reduce severity or extent of wind and ice damage |

# What questions do you have about the transportation guidebook?

# How do you think this tool could be used?

# What is the best way to share it with key staff in engineering?

# How could we apply this framework to R9?

# What are some limitations to using a guidebook like this?