



# Sierra Nevada Climate Change Vulnerability Assessment and Adaptation Strategy for Infrastructure and Recreation

## **CLIMATE CHANGE AND INFRASTRUCTURE**



**Gordon R. Keller, PE, GE**

Geotechnical Engineer

GENESEE GEOTECHNICAL

Retired USDA Forest Service



# Chapter Outline

Gordon Keller, Leslie Boak, Dave Peterson, Mike Furniss, Facilities Engr. ??, et al.

## **Introduction**

- Area of Study (Sierra Nevada)**

- Infrastructure Addressed**

- USFS Climate Change & Transportation Resiliency Guidebook**

## **Climate Change Effects**

- Temperature, Precipitation, Snowpack, Rainfall Intensity, Seasons**

## **Geologic Hazards and Infrastructure**

- Fires, Landslides/Debris Flows, Flooding**

## **Hydrology and Infrastructure Interactions**

## **Vulnerability and Risk Assessment Process & Tools**

- Risk Based Design**

- Watershed Condition Assessments**

- Transportation Analysis**

- Best Management Practices**

- ERFO And FHWA Efforts**

- Other Agency Efforts- WDFW, CalTrans, etc.**



## **Chapter Outline -Continued**

Gordon Keller, Leslie Boak, Dave Peterson, Mike Furniss, Facilities Engr??, et al.

### **Effects of Climate Change on Transportation Infrastructure and Mitigations**

**Roads and Road Maintenance (Surface Drainage, Freeze/Thaw,  
Decommissioning, Location, Fire Detours)**

**Culverts and Fords (Stream Simulation, Plugging, Diversion Potential )**

**Bridges (Capacity, Freeboard, Scour Potential)**

**Trails (Location, Drainage, Stability, Season of Use)**

### **Effects of Climate Change on Facilities Infrastructure and Mitigations**

**Developed Recreation Sites/Campgrounds**

**Buildings**

**Water Systems**

**Communications Systems**

### **Effects of Climate Change on Other Infrastructure and Mitigations**

**Dams (Capacity, Spillways, FERC Relicensing)**

### **Summary and References**



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

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

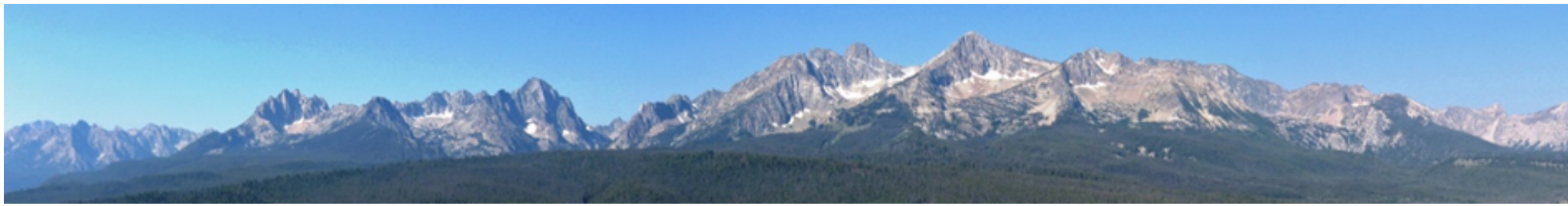


**VOLPE**

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**U.S. Forest Service**





# **Geologic Hazards and Vulnerabilities**

## **Geologic Hazards are Huge–But Some Can be Minimized or Mitigated!!**

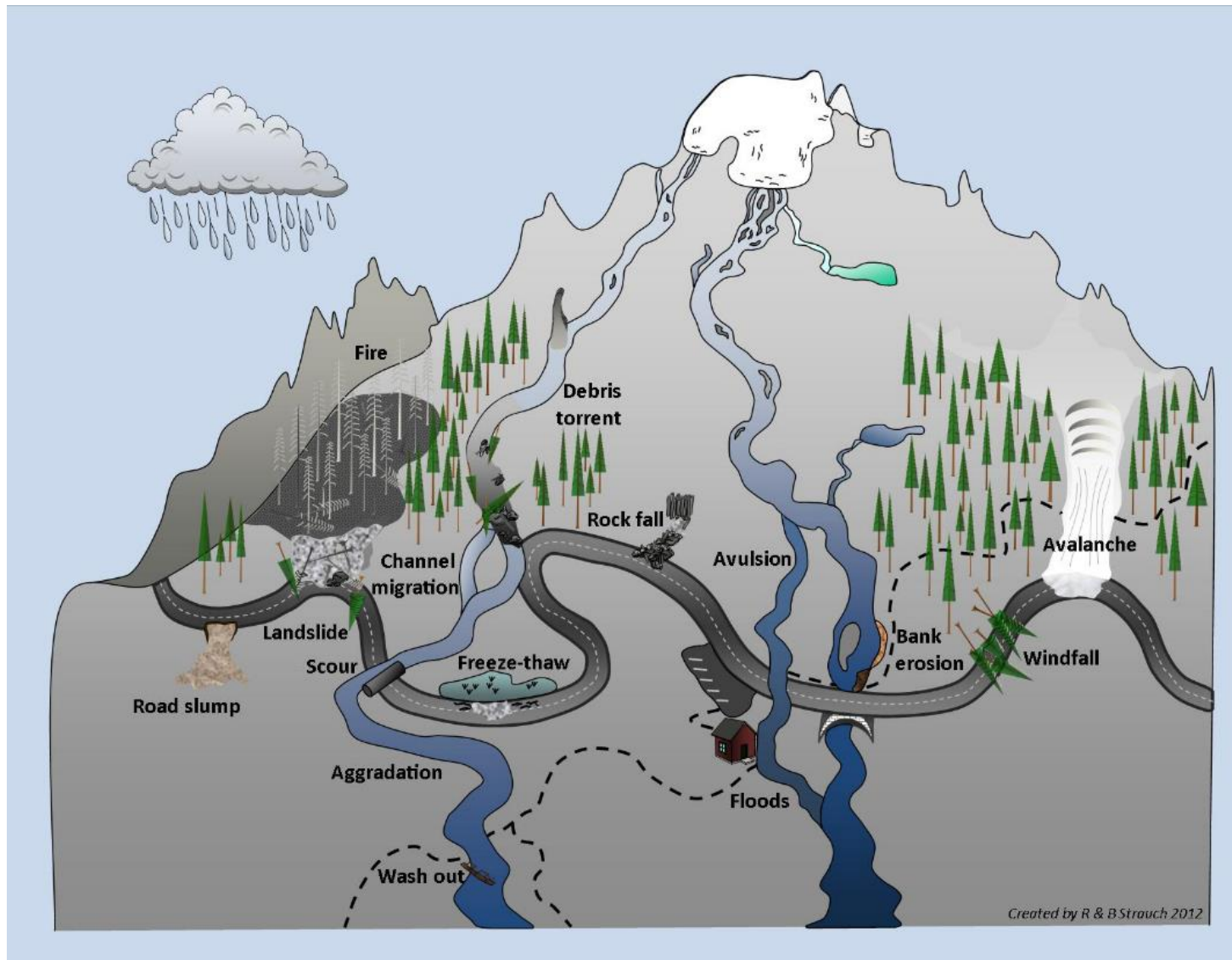
**Droughts & Bug Kill**  **Fires**  **Geologic Hazards**

- Debris Flows and Landslides**

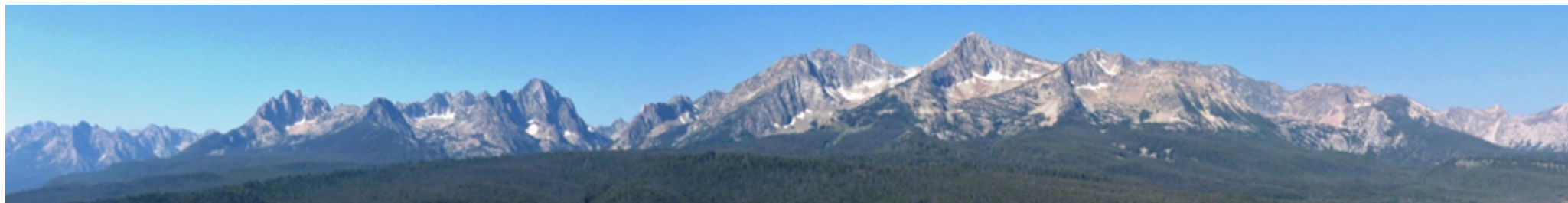
- Flooding**

- Erosion & Gully Formation**

- Stream Channel Instability/Changes**



**Figure 10.1—Many geomorphic, hydrologic, and weather-related disturbances can damage roads and other infrastructure. Figure from Strauch et al. (2014).**



## Risk Assessment

*Table 1—Risk assessment matrix*

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





## **Risk Assessment Tools**

**Measures to Identify Hazards, Minimize Landscape Changes, Reduce Geologic Hazards, and Reduce Infrastructure Damage**

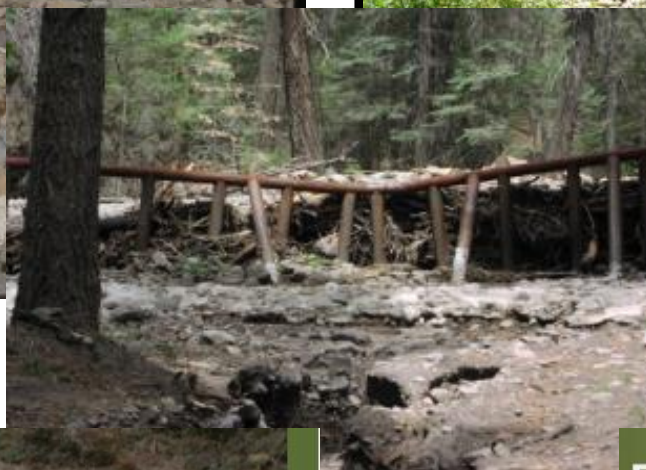
- **WEPP, ERMiT, GRAIP, USGS Slide Risk Maps**
- **Debris Hazard Maps**
- **Road Inventory Maps**
- **Road/Facility Damage History**
- **WIN/WIT**
- **Knowledgeable Folks/Areas to Avoid**
- **Critical Road Maintenance Areas**
- **BAER Efforts**



# Fire Impacts on Infrastructure







French Fire, Sierra NF



Rock Mattress 6 Years Later



Newly Installed TRM





**BAER**





# Debris Slide Impacts



Penny Luehring, USFS, BAER



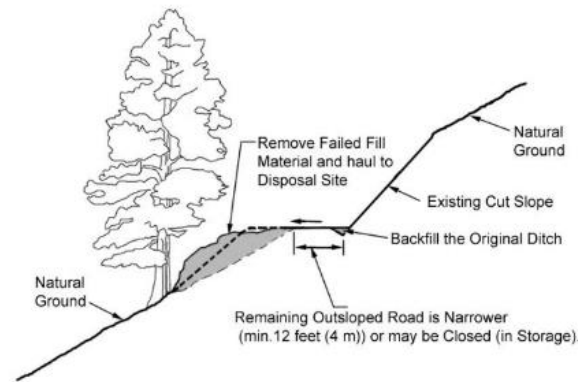
Don Lindsay, CGS





# Debris Slide Prevention and Mitigation

- Preventing Drainage Concentration
- Pulling Back Sliver Fills



- Containment and Deflection Structures





# Landslide Impacts





# Landslide Prevention and Mitigation

- **Biotechnical Slope Stabilization Measures**

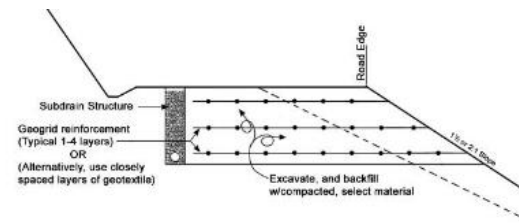
- **Deep Rooted Vegetation**



- **Retaining Structures**



- **Deep Patch**



CROSS-SECTION OF TYPICAL DEEP PATCH  
ROAD EMBANKMENT REPAIR



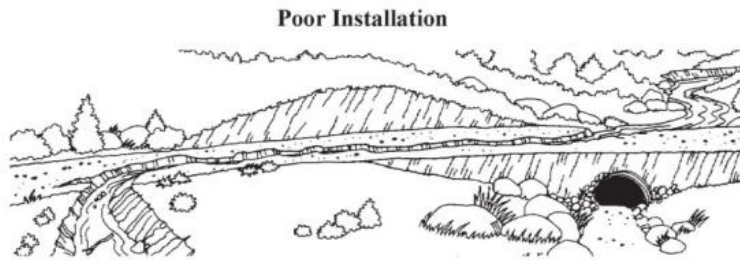


# Flooding and Drainage Issues

- Local Flooding



- Stream Diversion



b. Sketch of a stream diverted down the road, forming a new channel. M. Furniss



- Failed Structures and Washouts



USFS/Volpe





# Surface Drainage Issues

## **WATER CONCENTRATION AND CULVERT DIVERSION**

- **Surface Drainage Problems**



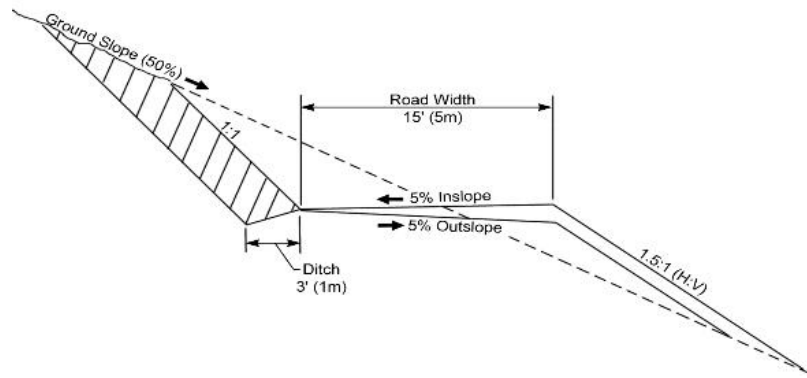
# Surface Drainage Mitigations

## PREVENT WATER CONCENTRATION AND CULVERT FAILURE

- Improved Surface Drainage



- Outslope vs Inslope



- Remove Berms



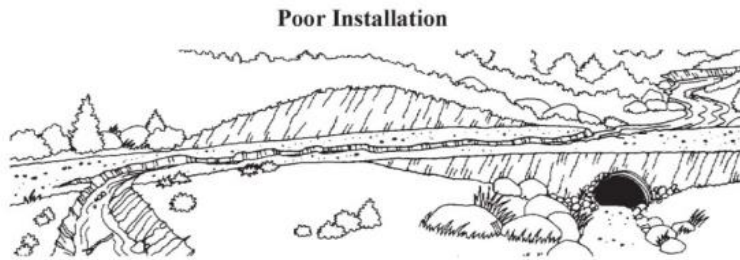


# Culvert Problems

- **Plugging**



- **Stream Diversion**



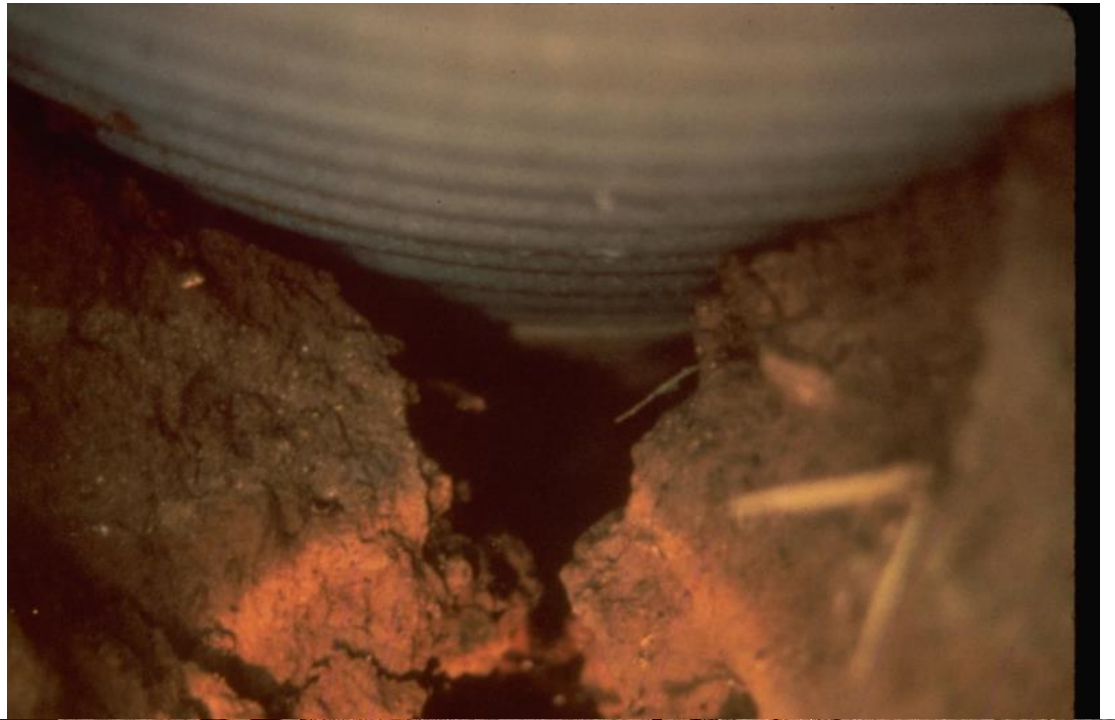
b. Sketch of a stream diverted down the road, forming a new channel. M. Furniss



- **Failed Structures and Washouts**







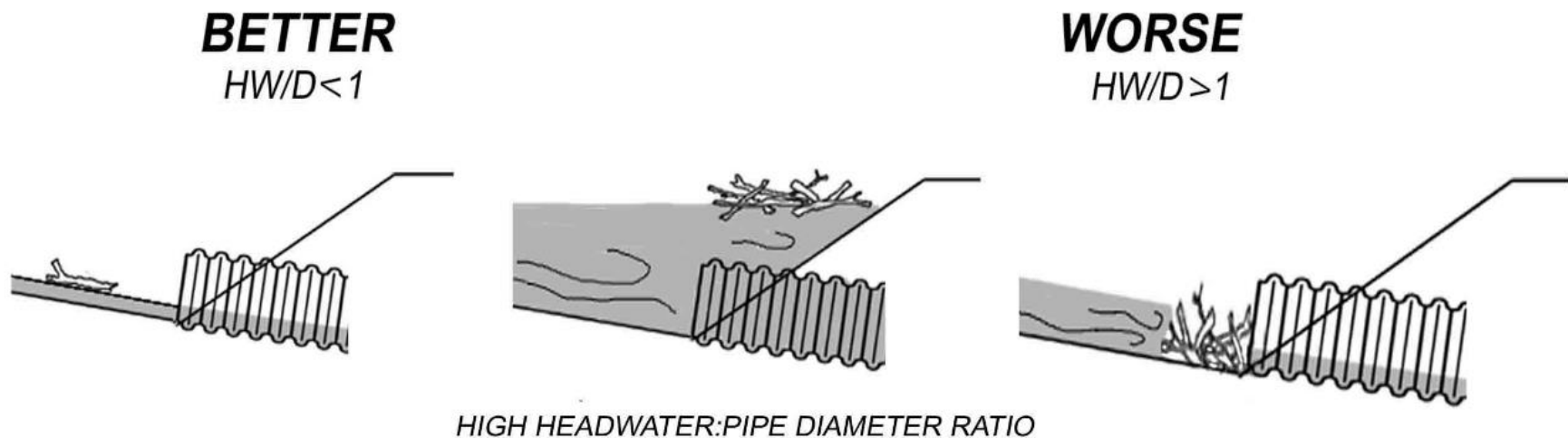


# FLOOD RESISTENT CULVERT DESIGN

-Q50-100 vs Q25

-Use  $\geq$  Bankfull Width

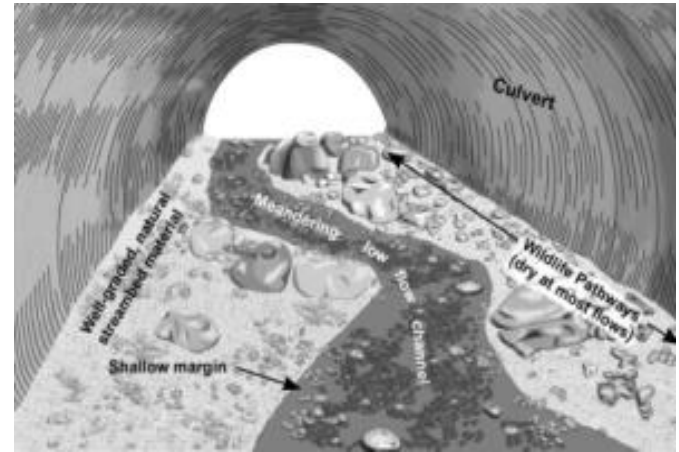
- $HW/D \leq 1.0$



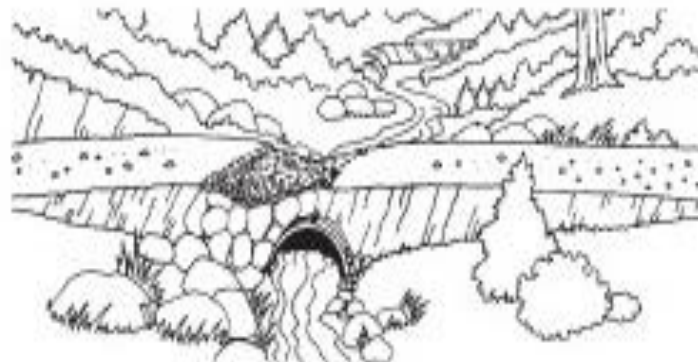


# Flooding and Drainage Mitigations

- **Stream Simulation Structures**



- **Stream Diversion Prevention**





# Flooding and Drainage Mitigations

- **Drainage Structure Plugging Prevention -Trash Racks**



**After Fires**





# Stream Channel Instability

## STAY OUT OF HARM'S WAY

- Evaluate Natural Meander Potential



## MOVE INFRASTRUCTURE AWAY FROM STREAMS

- Armor Stream Channels near Infrastructure





# Bridge Problems

- **Obstructions**



- **Lack of Capacity**



- **Scour Issues**



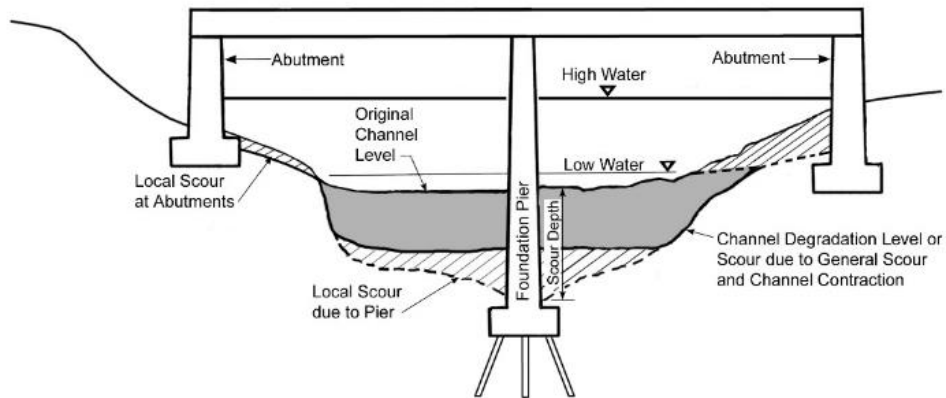


# Bridge Mitigations

## Adequate Capacity



## Scour Prevention





# Dams

- Dam Vulnerability



- FERC Relicensing Issues



# Trails





# Buildings

## Non-Flammable Materials



## Metal Roofs



## Hazard Trees

## “Green” Roofs





# Recreation Facilities & Water Systems



- Penny Luehring, USFS, BAER





# Communication Systems/ Towers



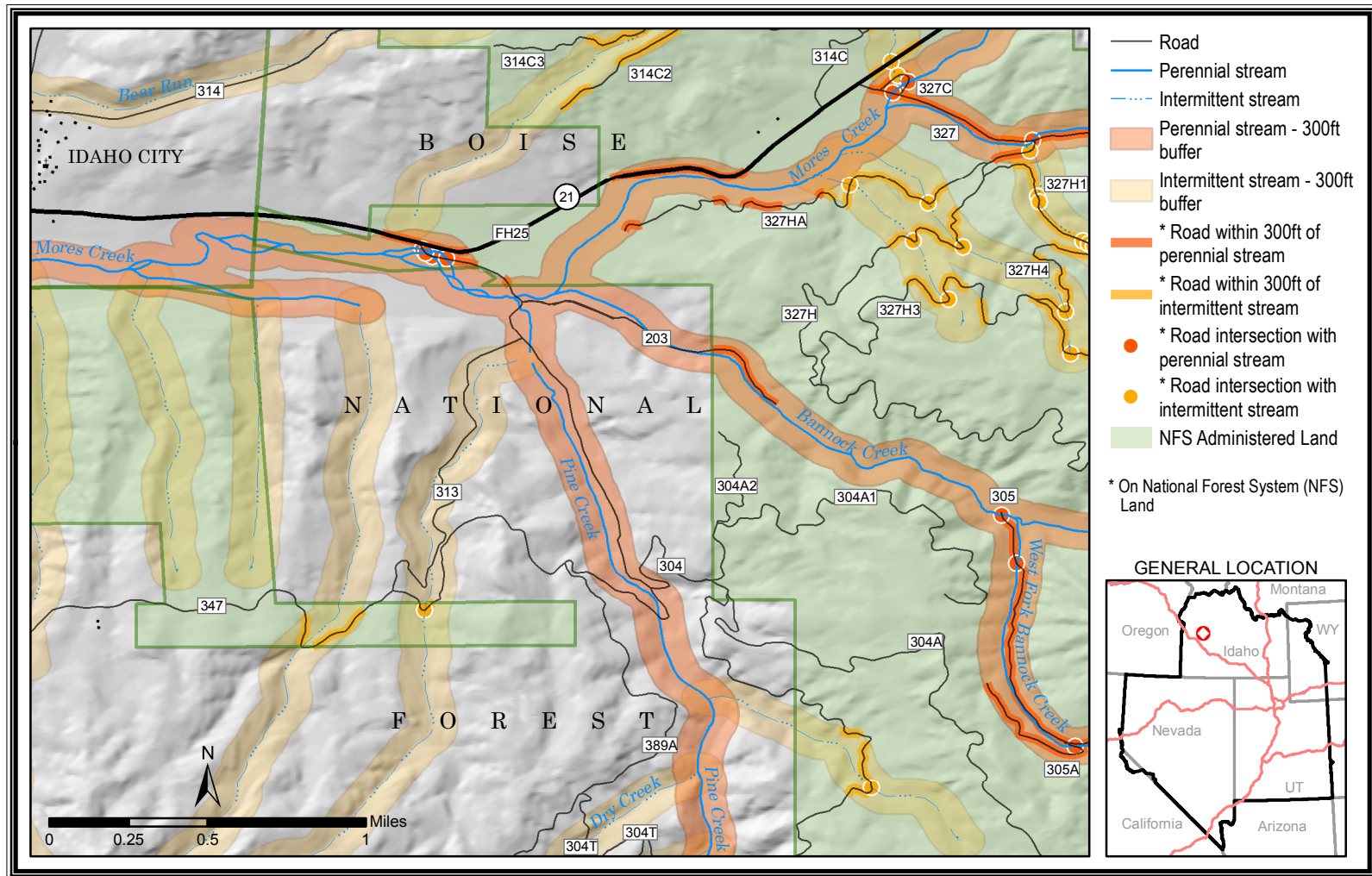


# Tools and Products

**Table 10.1—Road length for different maintenance levels in national forests in the U.S. Forest Service Intermountain Region. From the U.S. Forest Service Infrastructure database**

	<u>Operational maintenance level</u>						
National Forest	Basic custodial care (closed) <sup>a</sup>	High clearance Vehicles <sup>b</sup>	Suitable for passenger cars <sup>c</sup>	Moderate degree of user comfort <sup>d</sup>	High degree of user comfort <sup>e</sup>	Total	
	-----Miles-----						
Ashley	23	974	339	157	88	1,581	
Boise	1,527	2,503	542	14	--	4,587	
Bridger-Teton	572	983	385	214	--	2,154	
Caribou-Targhee	461	1,529	577	177	23	2,767	
Dixie	992	2,075	460	49	15	3,592	
Fishlake	43	1,710	168	12	7	1,941	
Humboldt-Toiyabe	493	4,351	626	69	17	5,556	
Manti-La Sal	302	1,616	290	9	--	2,217	
Payette	842	1,649	428	36	4	2,959	
Salmon-Challis	1,198	2,345	342	41	2	3,928	
Sawtooth	268	1,341	270	17	21	1,916	
Uinta-Wasatch-Cache	182	1,689	96	141	125	2,570	
Total	6,903	22,764	4,863	936	302	35,768	

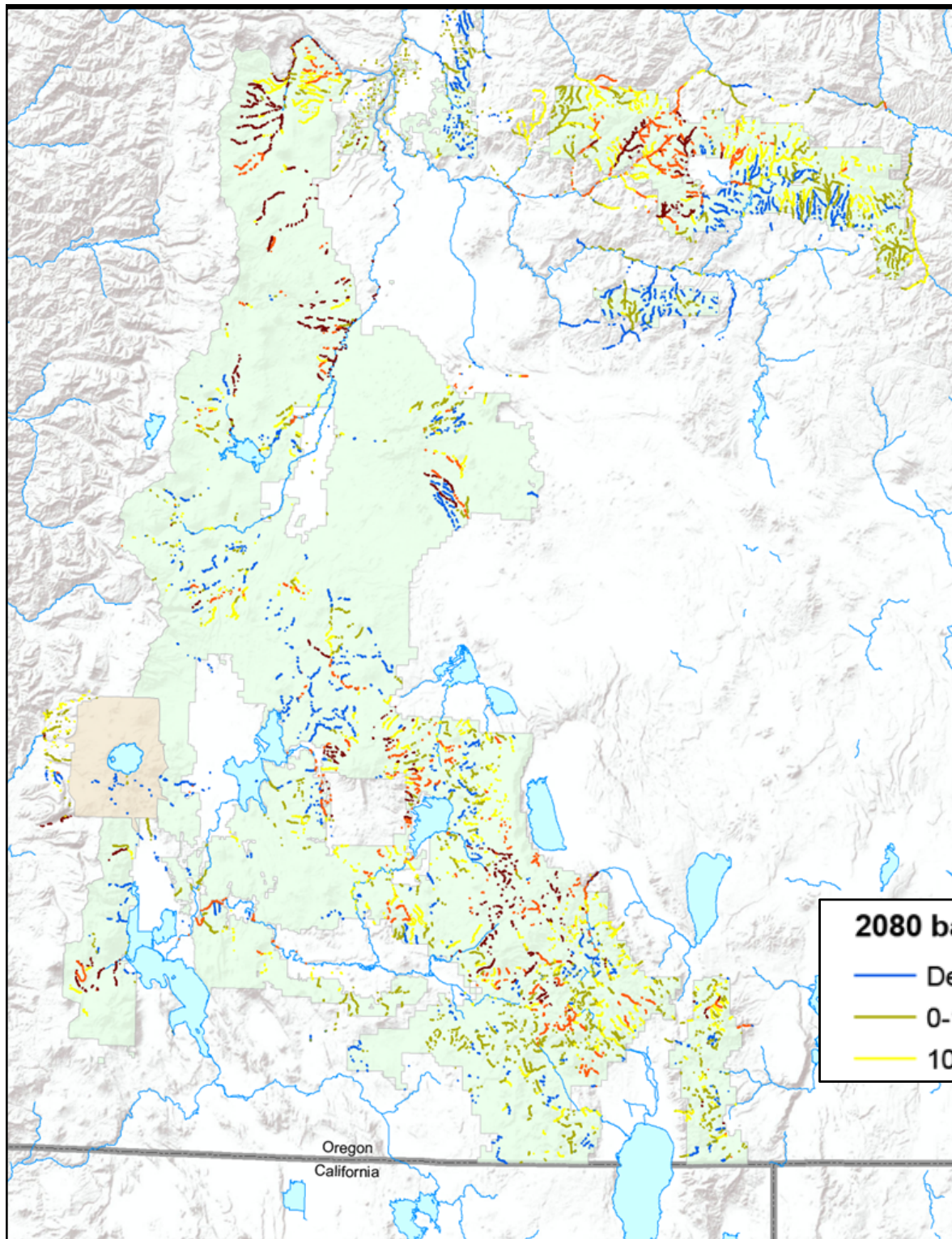




**Figure 10.6—Mapping buffers around streams can be used to identify current roads that are potentially at risk from flooding, and to preclude the placement of new roads in vulnerable locations.**



**Percent change in  
bankfull flow  
between historical  
and future (2080s)  
time periods for  
road segments  
within 90 m (200  
feet) of streams.**





# Burn Severity and Debris Slide Risk Mapping

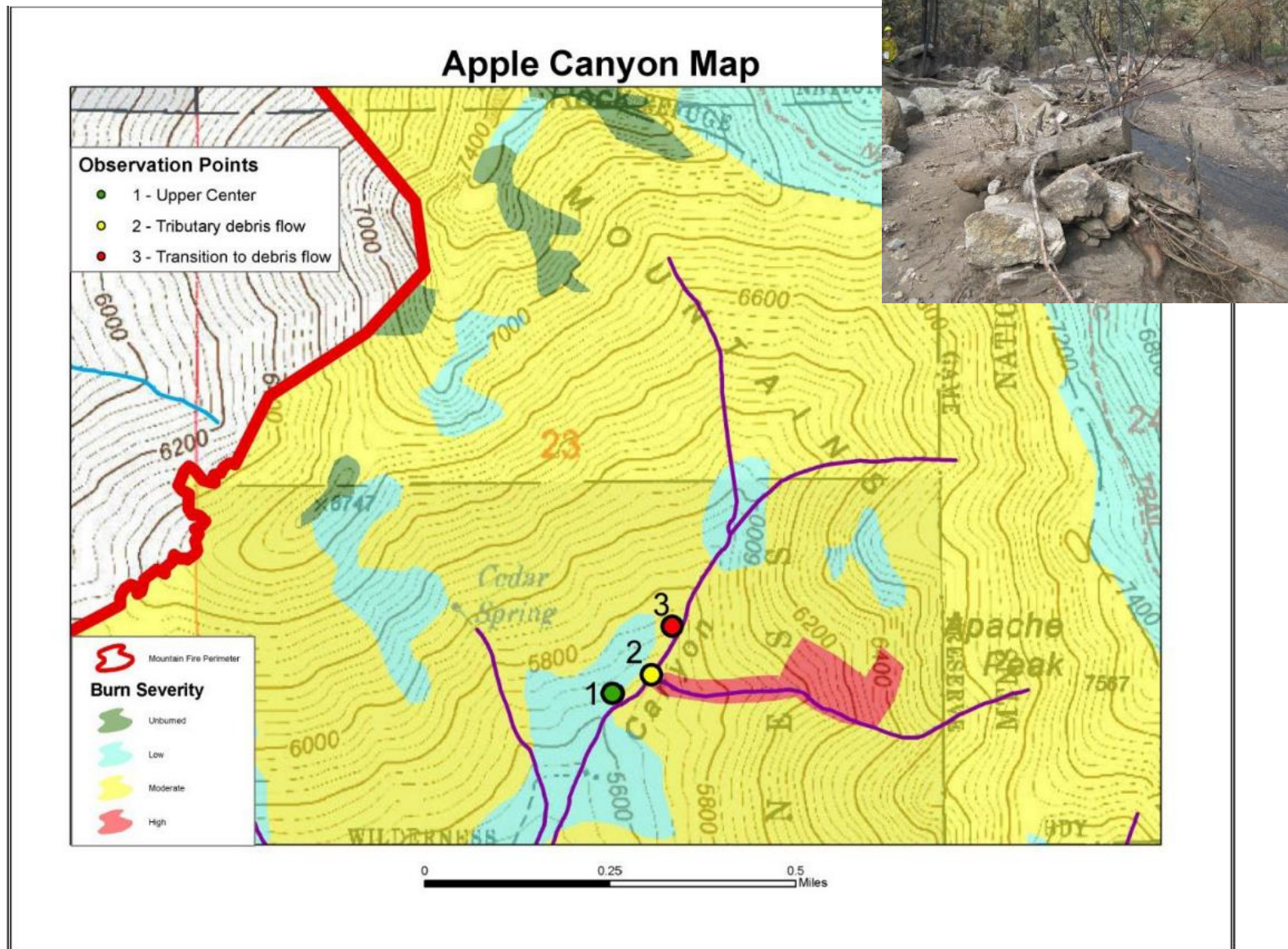
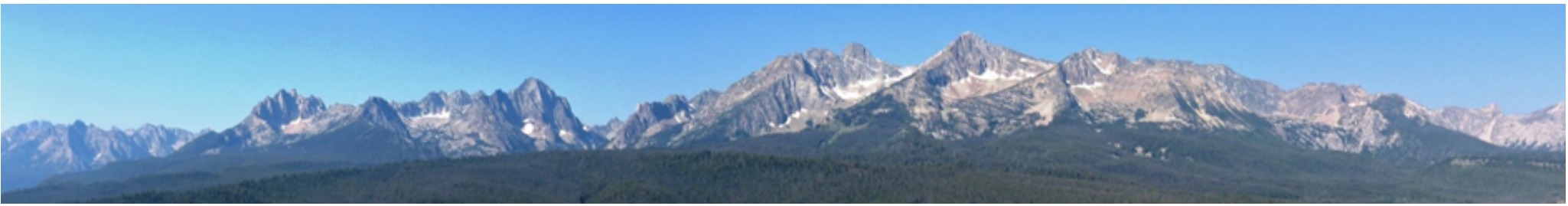


Figure 1. Map of the watershed which was the source of the debris flow impacting the Yokoji-Zen Mountain Center. The point locations (1-3) are referred to in the text.





# **“Storm Damage Risk Reduction Guide for Low-Volume Roads”**

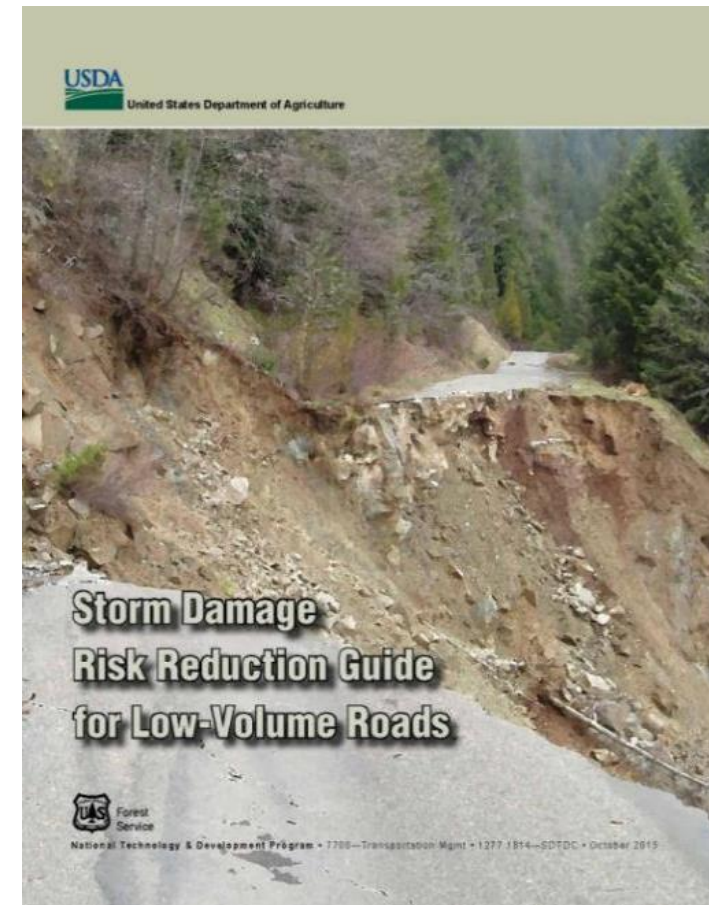
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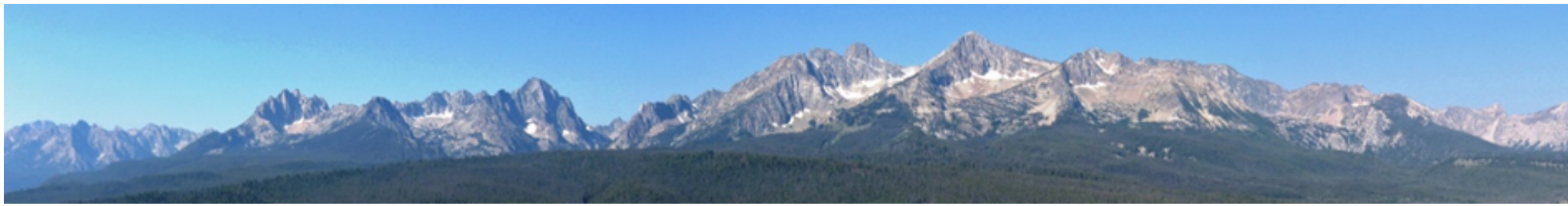
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**-US Forest Service Climate Change & Transportation Resiliency Guidebook**

**-RMRS-GTR 375, Chapter 11: Effects of Climate Change on Infrastructure**







**Gordon R. Keller, PE, GE**  
Consulting Geotechnical Engineer  
Quincy, California  
[gordonrkeller@gmail.com](mailto:gordonrkeller@gmail.com)  
530-284-6441

