Colorado DOT
Risk-Resiliency Model

Johnny Olson, Colorado DOT
Aimee Flannery, Applied Engineering Management

Peer Exchange - Integrating Risk Management in Transportation Asset Management Programs

AASHTO Peer Exchange
Johnny Olson, CDOT Region 4
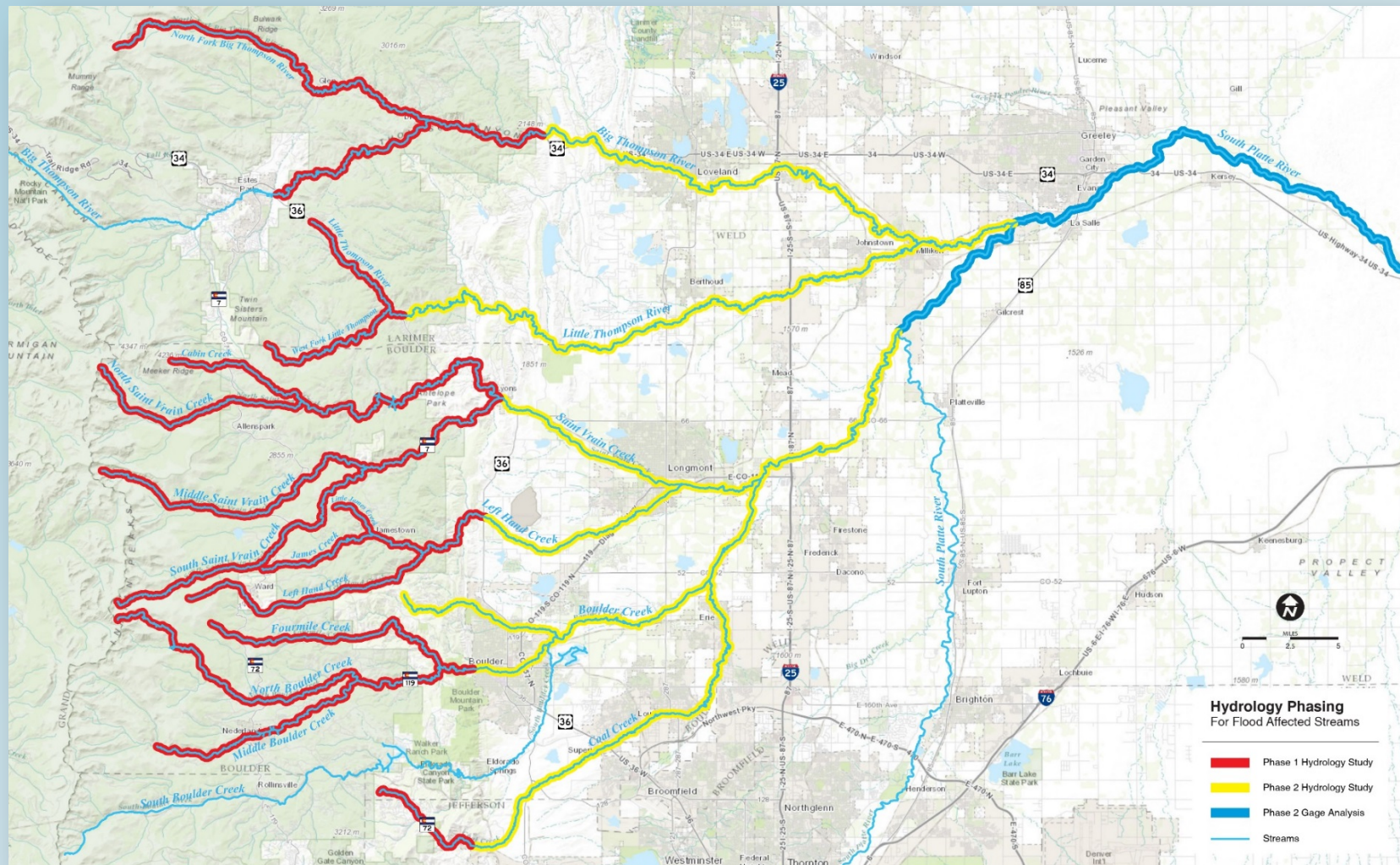**Aimee Flannery, Applied Engineering Management Corp.**

Initial 2013 Flood Impacts

- $480 million estimated damage to facilities
- $153 million estimated local costs
- 486 Miles of state highway closed
- 200+ Bridges and culverts damaged
- 140,000 cubic yards of debris removed

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CDOT and CWCB Hydrology Analysis

Hydrology Phasing
For Flood Affected Streams

- Phase 1 Hydrology Study
- Phase 2 Hydrology Study
- Phase 2 Gage Analysis
- Streams

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FHWA and CDOT Risk and Resiliency Pilot
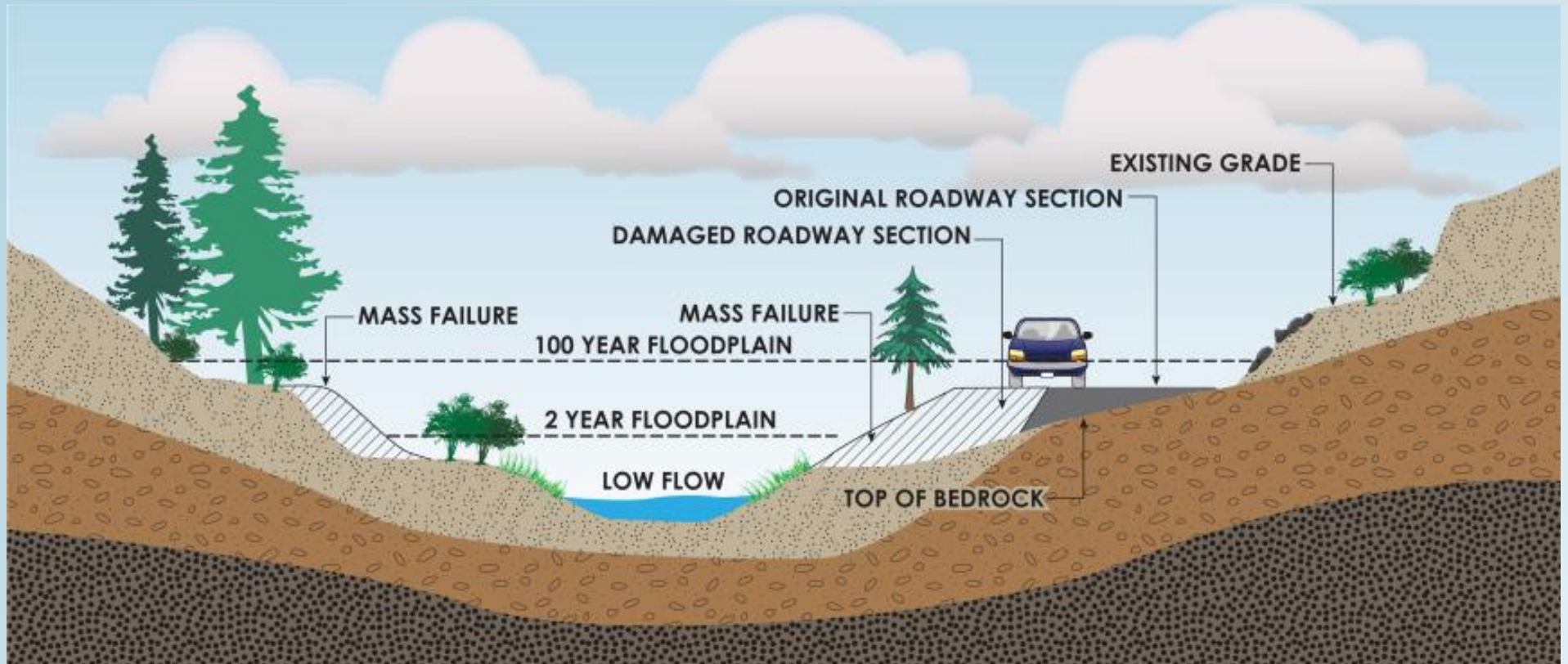
Resiliency Review Process

- Assess risk

- Assess vulnerability of assets

- Estimate consequences

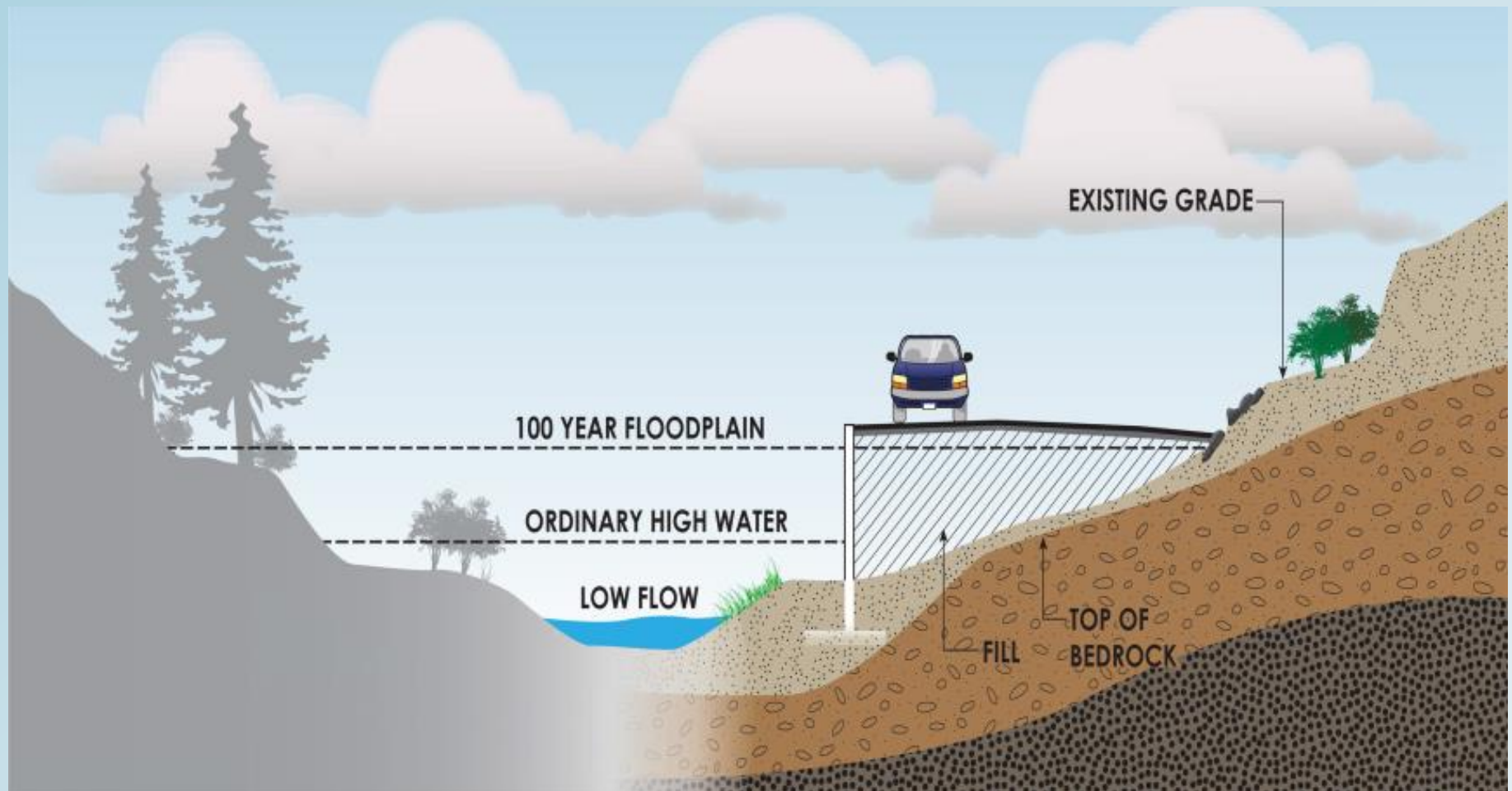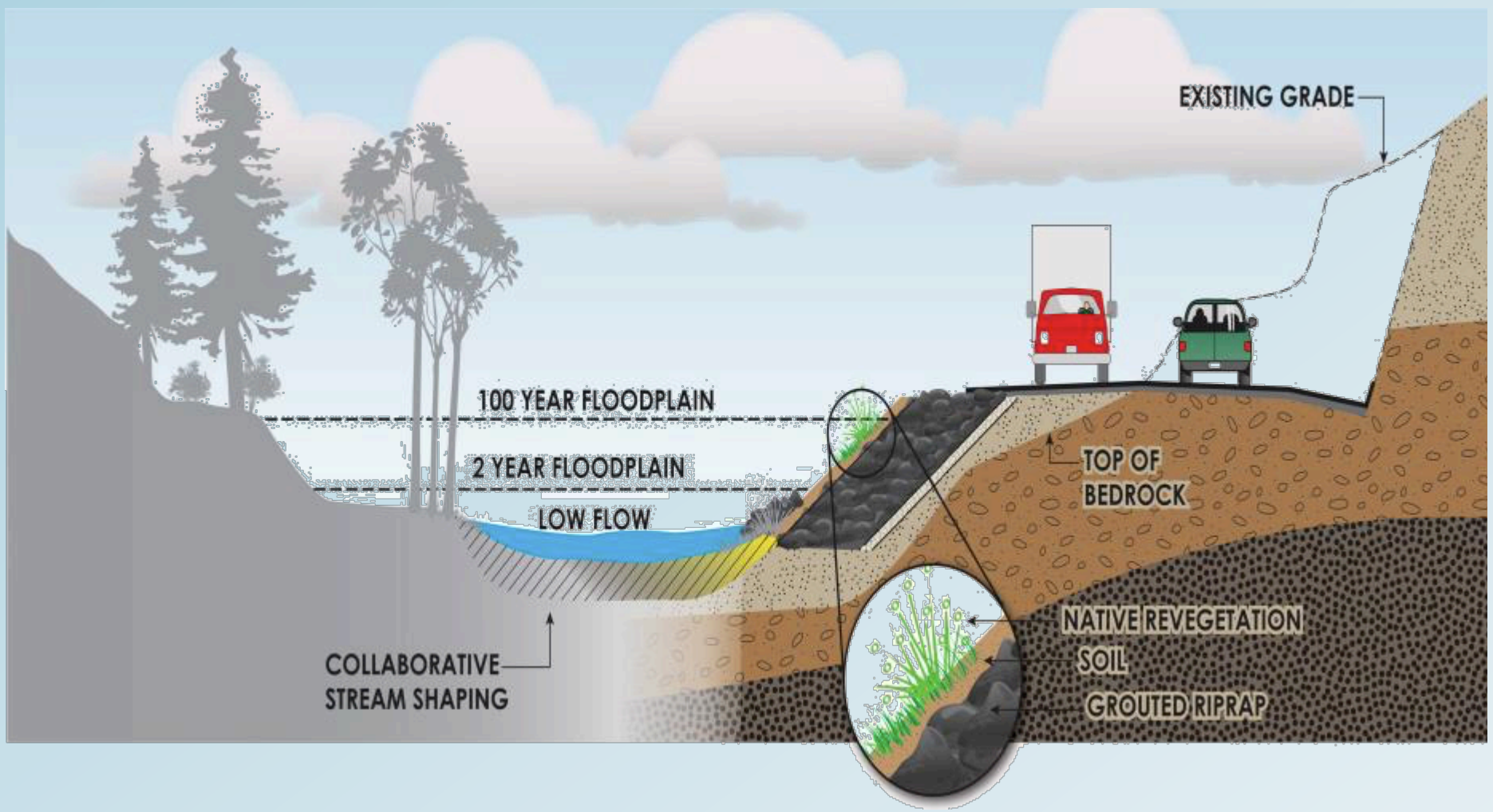- Criticality Score

- Design alternatives
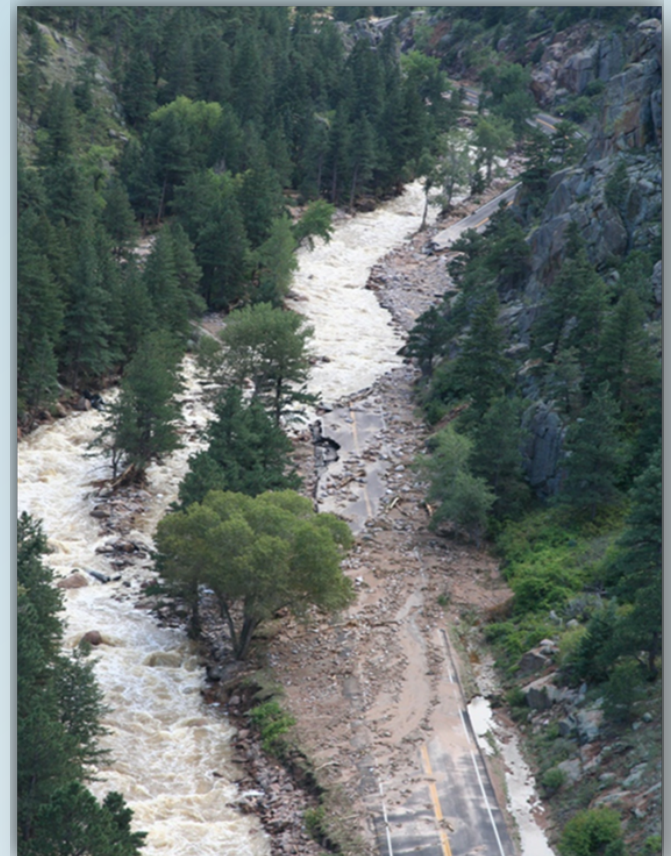
Repair Philosophy

Original & Damaged Section

Typical Repair

Resilient Concept

Three pieces of information provided:

1. <u>Measure of asset criticality</u> to align ER program with typical CDOT investments

2. <u>Annualized monetary risk</u> for each asset from identified threats under current design standards (Restore in Kind) and with design improvements (Betterments)

3. <u>Measure of resilience</u> for each asset from identified threats under current design standards (Restore in Kind) and with design improvements (Betterments)

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Asset Criticality

Criticality Score

- Provides context as to the effect a particular asset or facility has on the public and the agency

- Each asset is scored on a five-point scale (1=Very Low Impact; 5=Very High Impact) for each criterion

	Score				
	1 **Very Low** **Impact**	**2** **Low** **Impact**	**3** **Moderate** **Impact**	**4** **High** **Impact**	**5** **Very High** **Impact**
Road Classification	Rural Major Collector	Urban Collector (Major or Minor)	Minor Arterial	Primary Arterial	Interstate Freeway Expressway
Need for Access by Essential Traffic	Facility Open to Essential Traffic More Than 48 Hours After Event Multiple-Redundant Routes Available with No/Minimal Loss of Capacity	Facility Open to Essential Traffic Within 48 Hours of Event Single Redundant Route Available with No/Minimal Loss of Capacity	Facility Open to Essential Traffic Within 12 Hours of Event Multiple Redundant Routes Available with Some Loss of Capacity	Facility Open to Essential Traffic Within 2 Hours of Event Single Redundant Route Available with Significant Loss of Capacity	Facility Open to Essential Traffic Immediately Following Event Single Point of Failure
Route Designation	Truck % under 10%	HAZMAT Route	Truck % over 10%	Defense Route	Evacuation Route
Capital Cost of Damaged Site (per Lane Mile)	< $5 million/lane mile	$5 - $10 million/lane mile	$10 - $20 million/lane mile	$20 - $30 million/lane mile	> $30 million/lane mile

Resilience Index

Criticality Score	Criticality Level	Resilience Index Score
4 to 10	Low	1.0
11 to 15	Moderate	2.0
16 to 20	High	3.0

Quantifying Risk

$$Risk = C \times V \times T$$

Where:

Risk = annual monetary risk due to applicable threats ($)
C = consequences ($)
V = vulnerability to identified consequences under a specific threat (probability)
T = specific threat likelihood (probability)

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Consequences to Consider

- Human losses (death and/or injury)
- Housing and public services/facilities losses
- Revenue losses
- Economic impacts
- Environmental losses
- Political considerations
- Asset loss ($$)

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Vulnerability

Vulnerability – how vulnerable is an asset to an identified threat?

Factors affecting vulnerability:

- Asset age and condition
- Countermeasures implemented to reduce vulnerability
- Interdependence between on and off-system assets

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US-34A MP 73.5 Damage (September 2013)

Local Access Bridge

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US-34A MP 73.5 Damage (September 2013)

Downstream
Local
Access Bridge

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Threats

- Threats can range from political to natural
- Efforts to date focused on natural threats within context of asset geographic location
- Typical threats analyzed in risk assessment:
  - Flooding
  - Wind
  - Earthquakes
  - Avalanche
  - Tornados
  - Fire
  - Storm surge/Hurricanes
  - Cascading effects of threats – example burn/flooding

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Measure of Resilience

Resilience = AADT × % AADT Not Serviced ×
Days Out of Service × V × T

Resilience = potential number of vehicles affected by threats in a given year (veh)

% AADT Not Serviced = based on expected number of lanes closed

V = vulnerability to identified consequences under a specific threat (probability)

T = specific threat likelihood (probability)

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Example Application of Risk and Resilience Process

US 34 MP 66.61 – MP 78.63

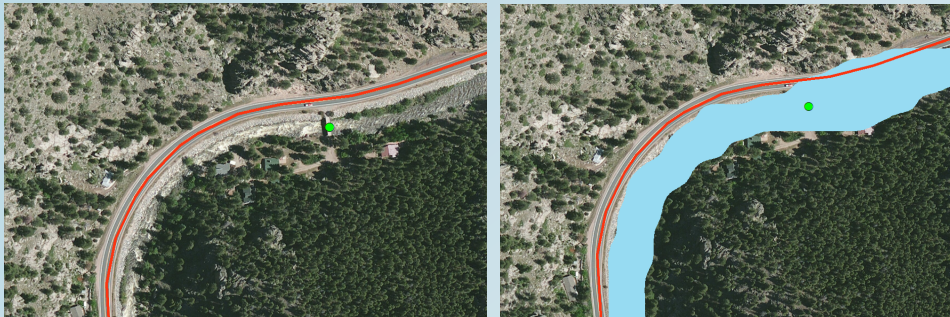# Flood Zone for I-34 Corridor for 100yr event (HAZUS-MH)
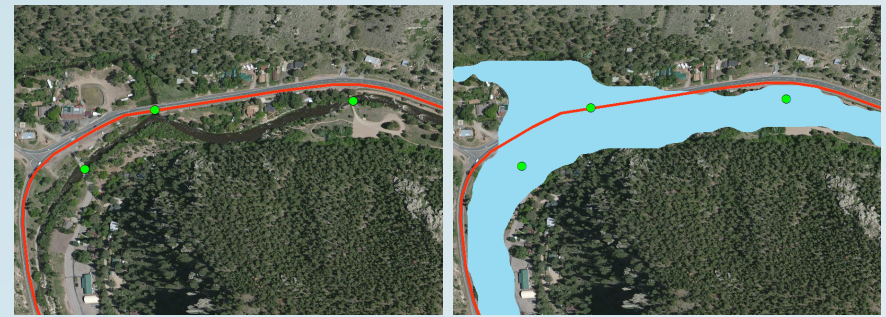
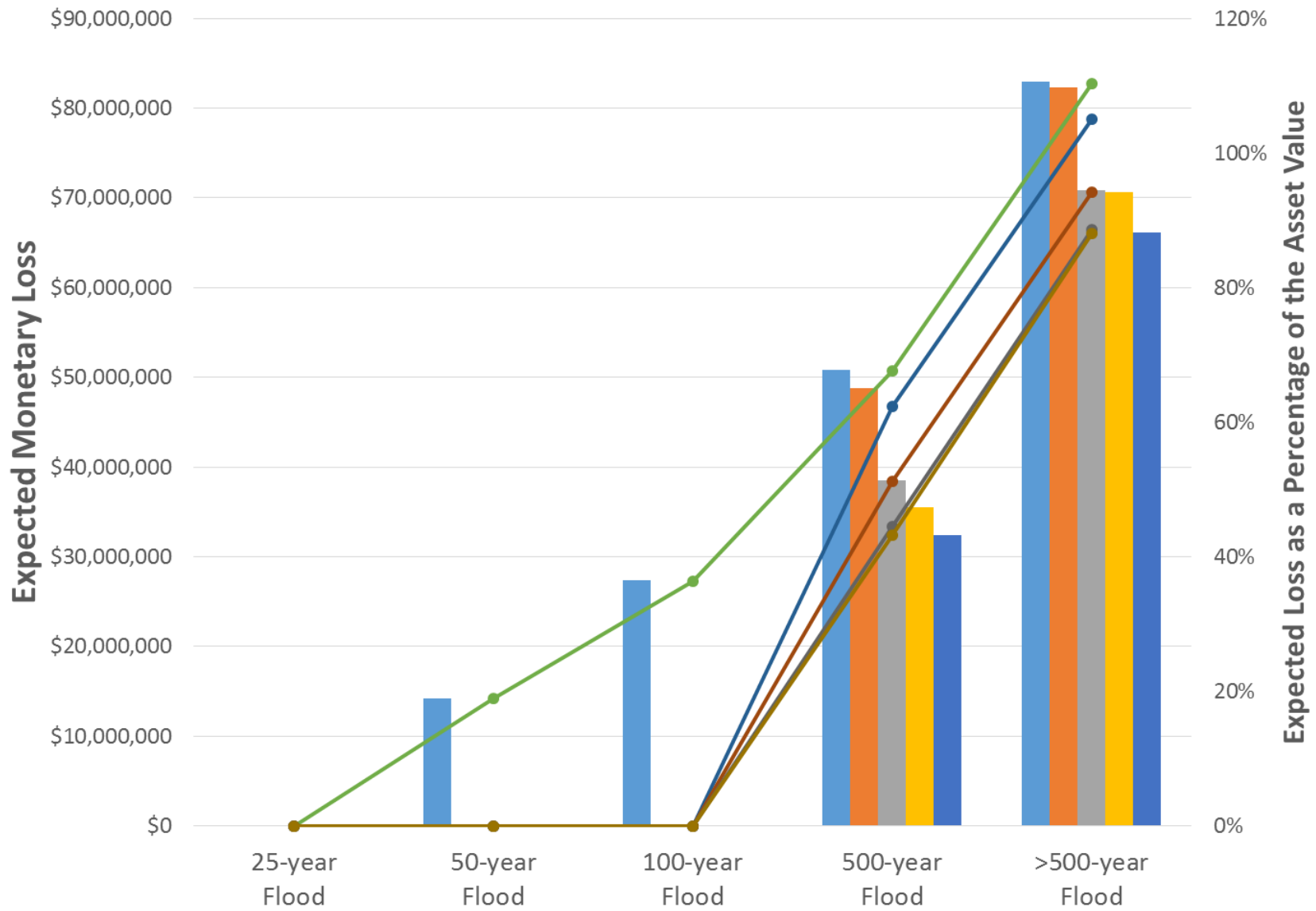Local Access Point (LAC) at MP 67

LAC at MP 75

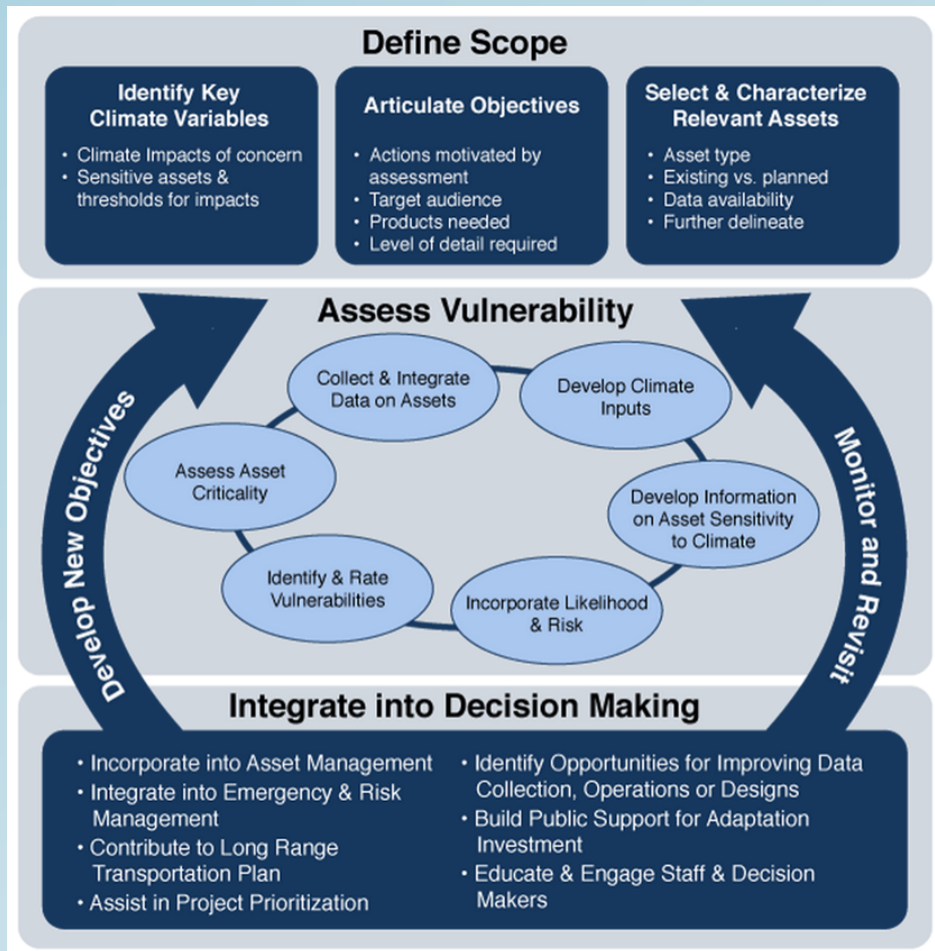
LAC at MP 74

C-17K & LAC at MP 76

Example Application of RnR for US 34

Design Alternative	Hydraulic Design (year)	Total Project Cost	Cost Above PR	Annualized Cost Above PR, C	Annualized Benefit, B	B/C$_{Risk}$	B/C$_{RnR}$
Restore-in-Kind (ER+PR)	25	Total =$50,848,500 ER=$17,347,300 PR=$33,501,200	$0	$0	$0	N/A	N/A
Replace to Standard	25	$55,562,500	$22,061,300	$757,491	$629,086	0.83	1.66
Design Alternative A	50	$54,115,300	$20,614,100	$707,800	$693,313	0.98	1.96
Design Alternative B	100	$58,622,700	$25,121,500	$862,565	$705,585	0.82	1.64
Design Alternative C	50	$54,602,000	$21,100,800	$724,511	$726,730	1.00	2.01

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Risk Analysis and Management for Critical Asset Protection (RAMCAP)

RnR Analysis → Asset Management

Step 1.
Use existing databases, services & models

RAMCAP Evaluation

Quantitative & Probabilistic

Prioritized high-risk, critical assets

CDOT Regions I & III

Step 2.
Engineering Analysis

Step 3.
Benefit/Cost Design Alternatives:
- Maintain
- Repair
- Upgrade

Step 4.
Asset Management Plan

Step 5.
STIP

Step 6.
Projects

Connects $$$ spent on projects to decreased risk and increased resilience

8/26/2015

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25

Colorado Resiliency Project

Why now:
- Major impacts from hazards in the last five years
- Continued expectation that hazards will occur and potentially increase due to changing climate patterns
- Opportunity to learn lessons from past disasters
- Opportunity to build back in a way that makes us stronger
- Opportunity to integrate Resiliency into future community development and our every-day lives

Colorado Resiliency Project

The Colorado Resiliency Project
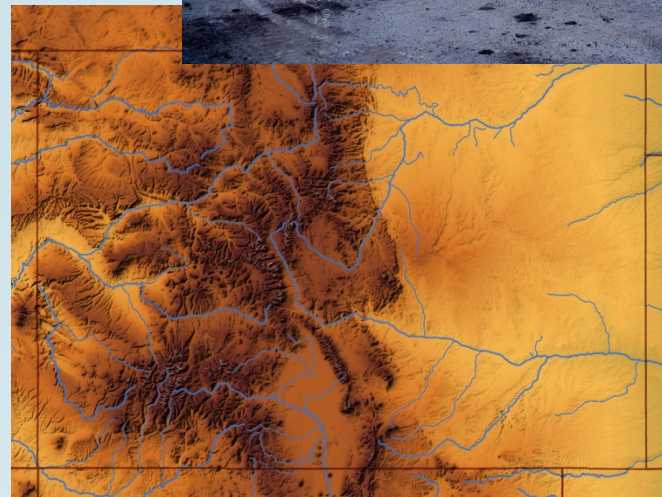
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Recovery Office
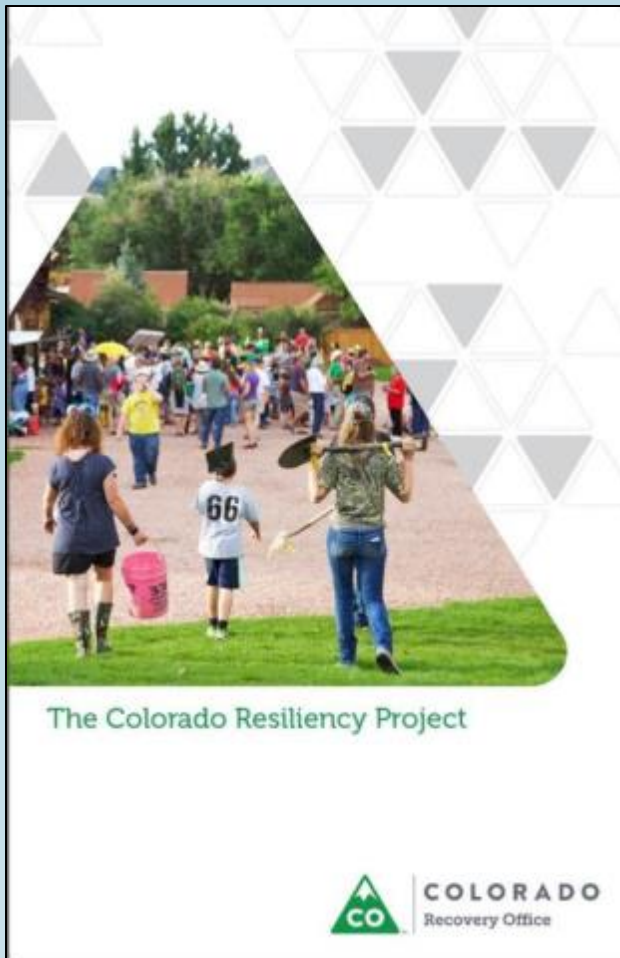
- One-Year Report

- Engagement and Community Outreach

- Colorado Resiliency Working Group

- Peer Review

- Resilience Heroes

- NDRC Application

- CDBG-DR

Resiliency Framework

www.coloradounited.com/resilient

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Colorado Resiliency Framework

- **Resource** for local governments, businesses, non-profits and individuals

- **Support and cultivate** a culture of resilience at the state and local level

- **Empower** the whole community and tap into a sense of personal responsibility that defines us as Coloradans.

- **Integrate** resiliency into our every-day way of life.

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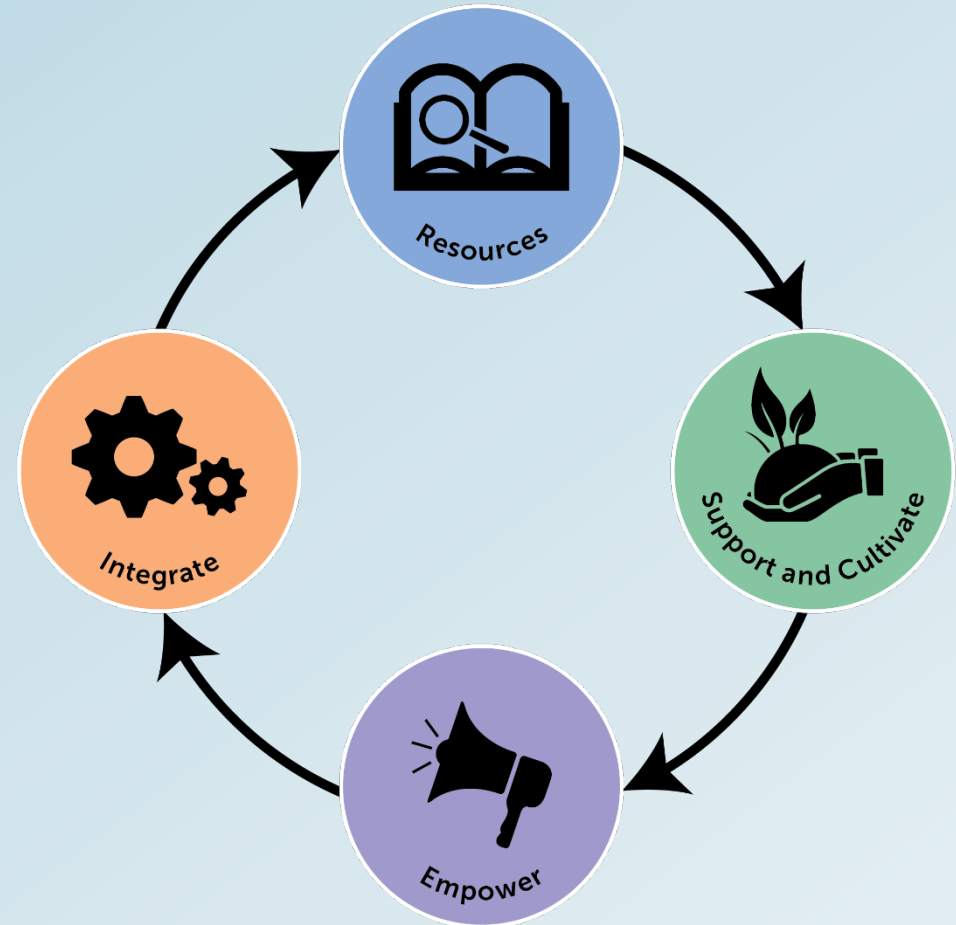
Colorado Resiliency Framework

- Sector Overview

- Shocks and Stresses

- Problem Statements

- Strategies and Goals

- Cross-Sector Integration

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Colorado Resiliency Framework
Example Sector Overview

Shocks
- Damaged or destroyed infrastructure
- Inaccessible infrastructure

Stresses
- Increased demand
- Long term wear and tear on infrastructure
- Changing climate conditions

Example Strategies
- Evaluate Infrastructure risks to determine comprehensive approach to hazards
- Develop policies that a stakeholder / interagency approach should be taken for infrastructure design and construction projects to ensure that all interested parties are involved

Infrastructure
Transportation
Green Infrastructure
Water
Wastewater
Solid Waste
Energy
Communications
Public Facilities

CDOT Risk and Resiliency

How is CDOT going to incorporate resiliency into day to day operations?

- Risk and Resiliency Analysis Tool

- Asset Management

- Project Management

CDOT and Relevant Risk Efforts and Tools May 2015

Outstanding Concerns

- Why doesn't transportation have an industry standard for analyzing risk and resilience of highway assets?

- An industry standard would help:
    - standardize definitions of key terms (resilience, hazard, risk, etc.)
    - provide agencies with a series of lookup tables to assess anticipated losses from identified threats to specific assets

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Questions?

Thank you!