

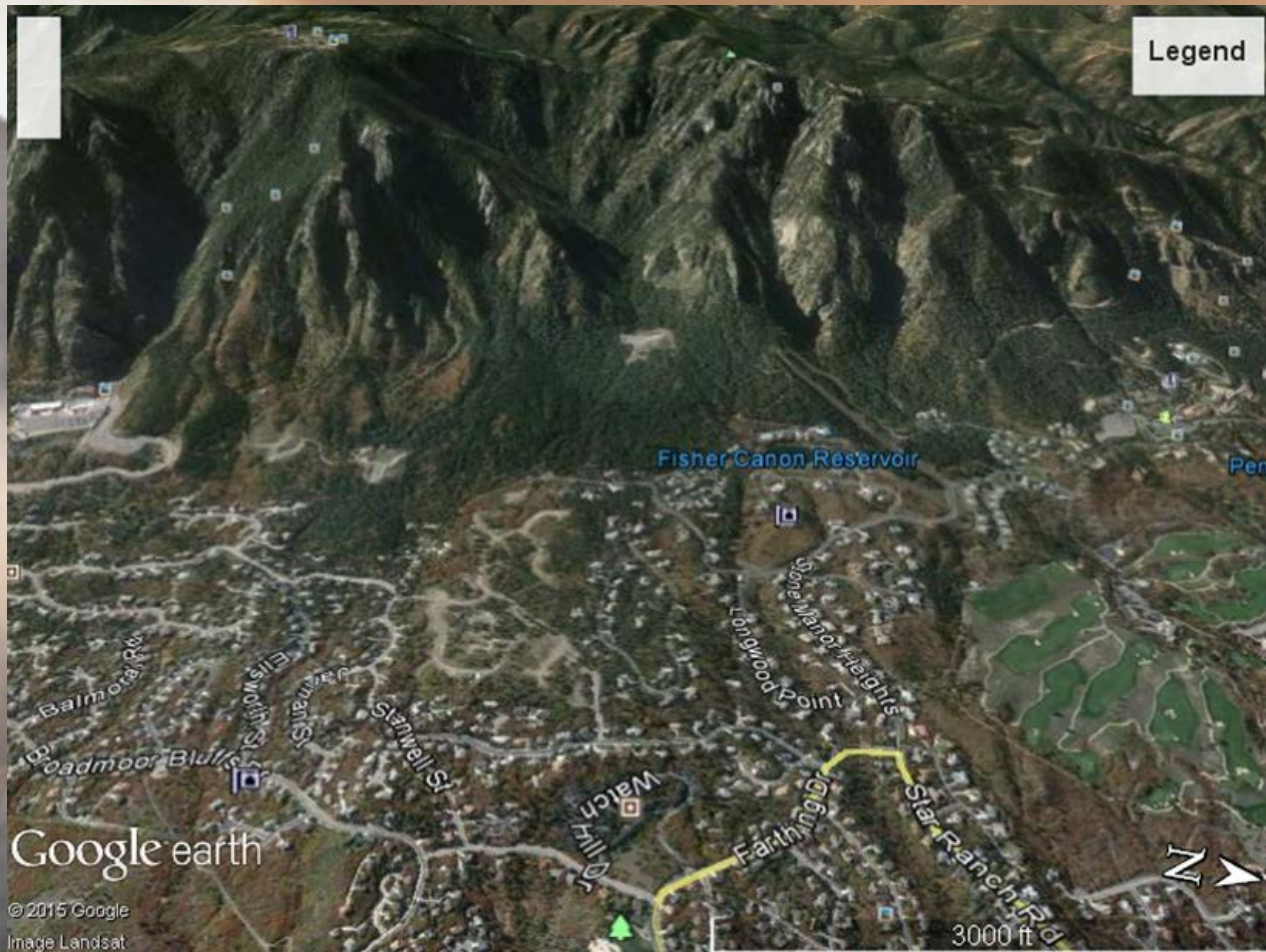
Natural Hazards and the Built Environment: a State of Practice Perspective



*The 18th Annual
George F. Sowers Symposium*

Scott A. Anderson Ph.D., P.E.
Federal Highway Administration
Geotechnical Services Team Manager





FEMA



Waldo Canyon 2012



Gaylon Wamper - AP

Denver Post



Robie Blair - KRDO

Floods follow Fires



Michael Rieger - FEMA

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USGS
science for a changing world

Prepared in cooperation with Colorado Department of Transportation

Probability and Volume of Potential Postwildfire Debris Flows in the 2012 Waldo Canyon Burn Area near Colorado Springs, Colorado



Open-File Report 2012-1158

U.S. Department of the Interior
U.S. Geological Survey

West of Manitou Springs, CO, August 2013

Super-elevated highway curve

K-rail barrier

Rock fall fence

Lower Waldo Canyon
Precipitation Gage

+38.8781°, -104.9333°
EI 6920 ft

Tributary canyon
flow direction

Fountain Creek
flow direction

Steel guard
rail barrier

+38.8784°, -104.9337°, EI 6922 ft

Culvert inlet

US 24 East
US 24 West

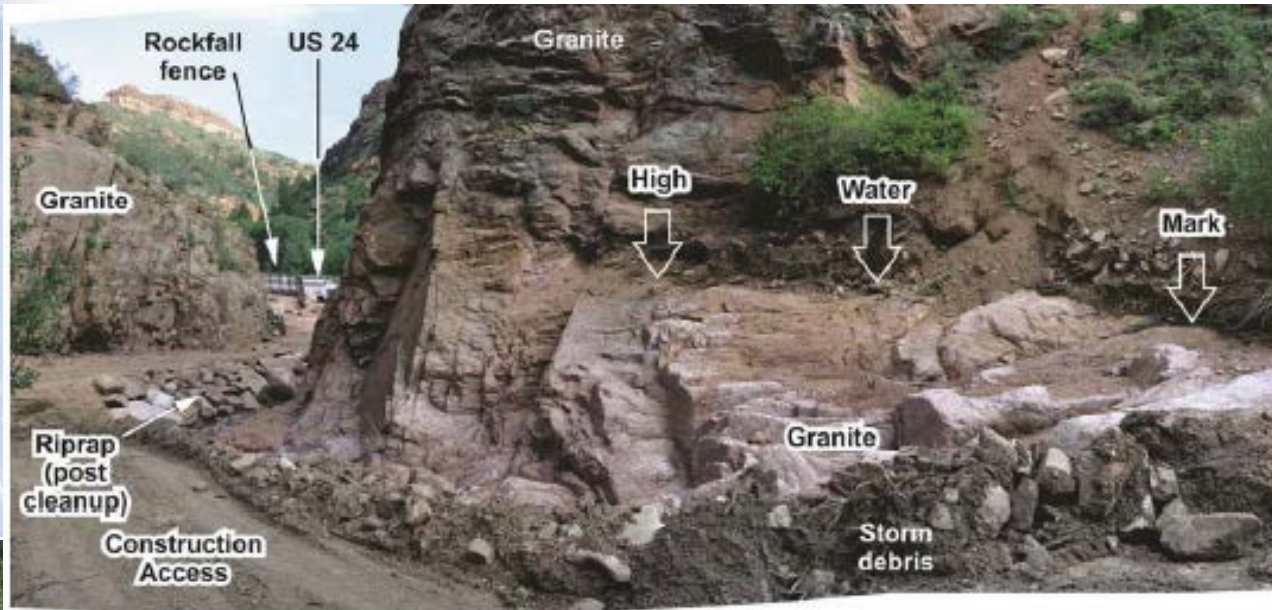
Narrow area

Wide area

Construction
equipment

Waldo Canyon
flow direction

Old School Reconnaissance



New School: YouTube

- Note the Rockfall Fence





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CDOT



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Sallie Clark, Commissioner

In the week before GEER arrived

When GEER arrived





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What now?





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Debris basin



Nets and U.S. 24 Culvert





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Design Considerations

- **Fisher Canyon Debris Dam**
 - Singular hazard design
- **Williams Canyon – Residences**
 - Condemnation
- **Waldo Canyon – 4-lane U.S. Highway 24**
 - Temporary need, risk transfer
- **Downtown Manitou Springs**
 - Partnership and coordination

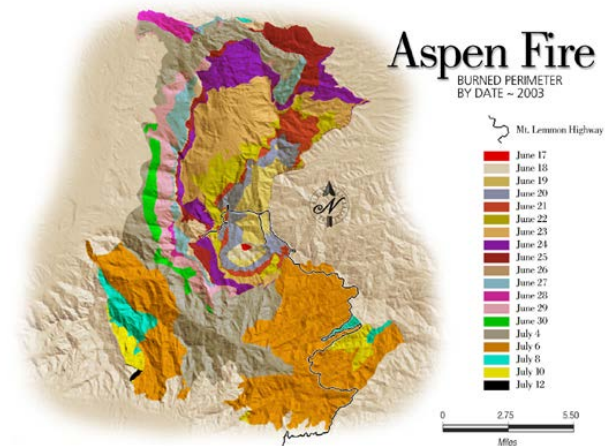
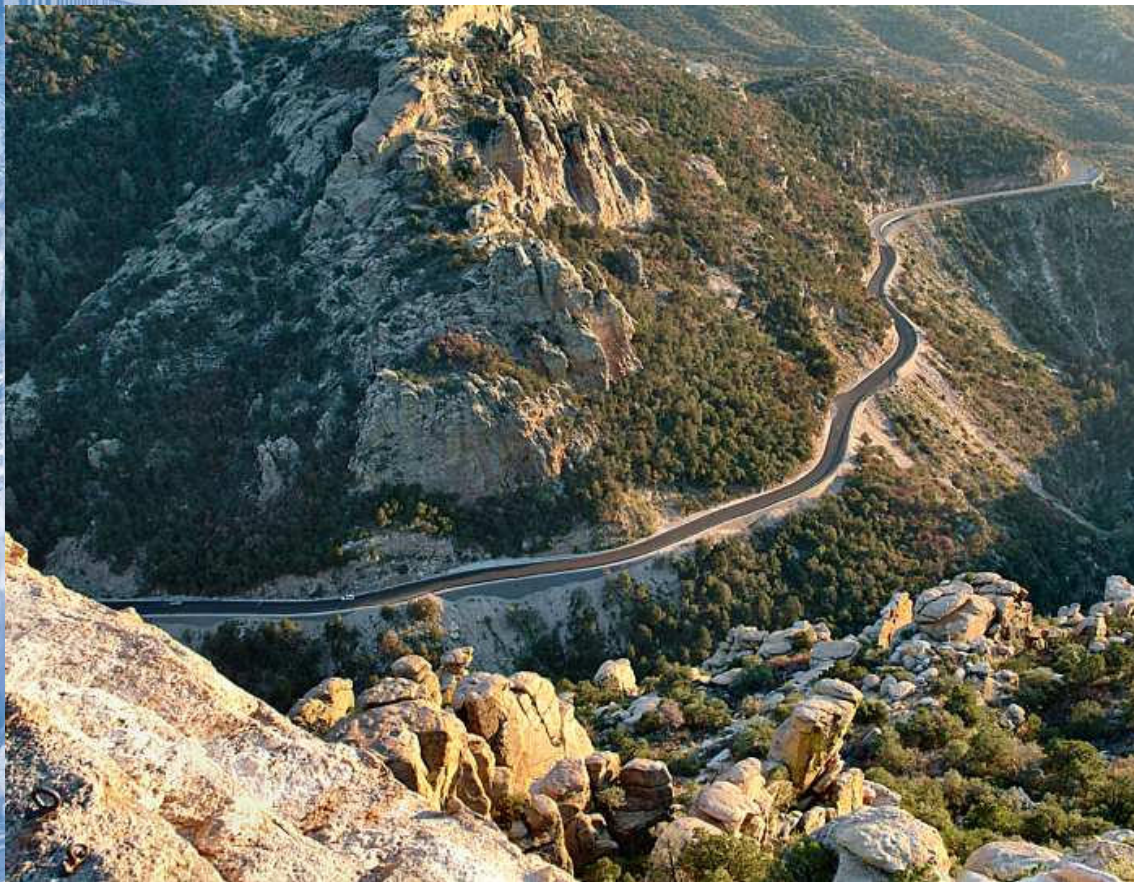


We've had an *implicit* goal of safety

Federal Highway Legislation (MAP-21) has seven *explicit* National Performance Goals

- 1. Safety**
- 2. Infrastructure Conditions: State of Good Repair**
- 3. Congestion Reduction**
- 4. System Reliability- improve efficiency**
- 5. Freight Movement and Economic Vitality**
- 6. Environmental Sustainability**
- 7. Reduced Project Delivery Delays**

Mt. Lemmon, Tucson, AZ



The only road serving Mt. Lemmon



Design and repair considerations here address some other goals:

1. Safety
2. Infrastructure Conditions: State of Good Repair
3. Congestion Reduction
4. System Reliability- improve efficiency
5. Freight Movement and Economic Vitality
6. Environmental Sustainability
7. Reduced Project Delivery Delays

State of Practice: A more explicit discussion of performance goals is expected.

September 2013 Northern Colorado Flood

Sept. 9, 2013

A slow-moving cold front stalled over Colorado.

Sept. 11, 2013

Heavy rains are produced along Colorado's Front Range from Colorado Springs to the Wyoming border.

**Sept. 12 to
Sept. 15, 2013**

Parts of Larimer and Boulder Counties received upwards of 20 inches of rain. Federal emergency declaration is issued in 15 counties.

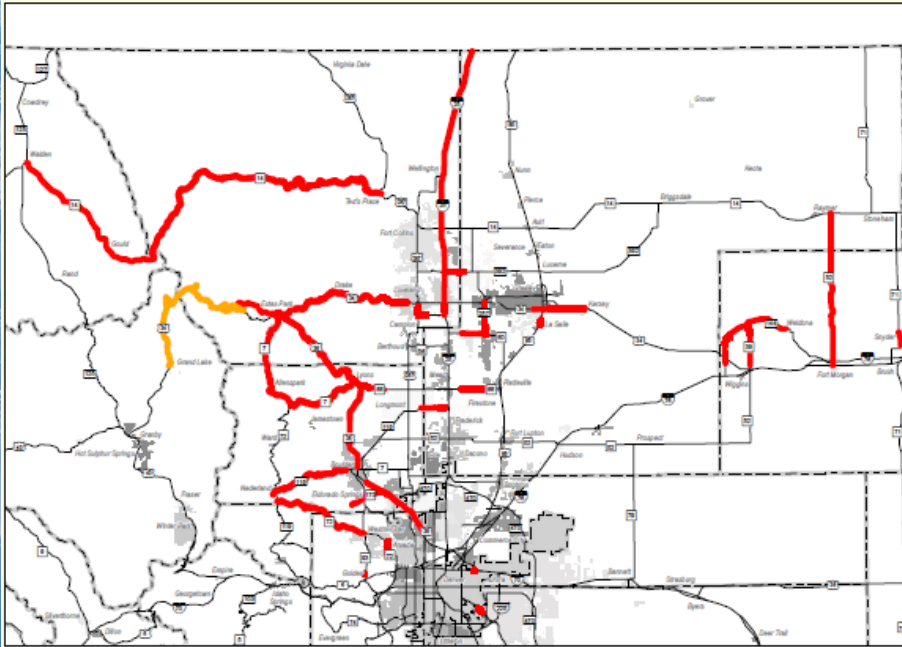
GEER members evaluated social media response

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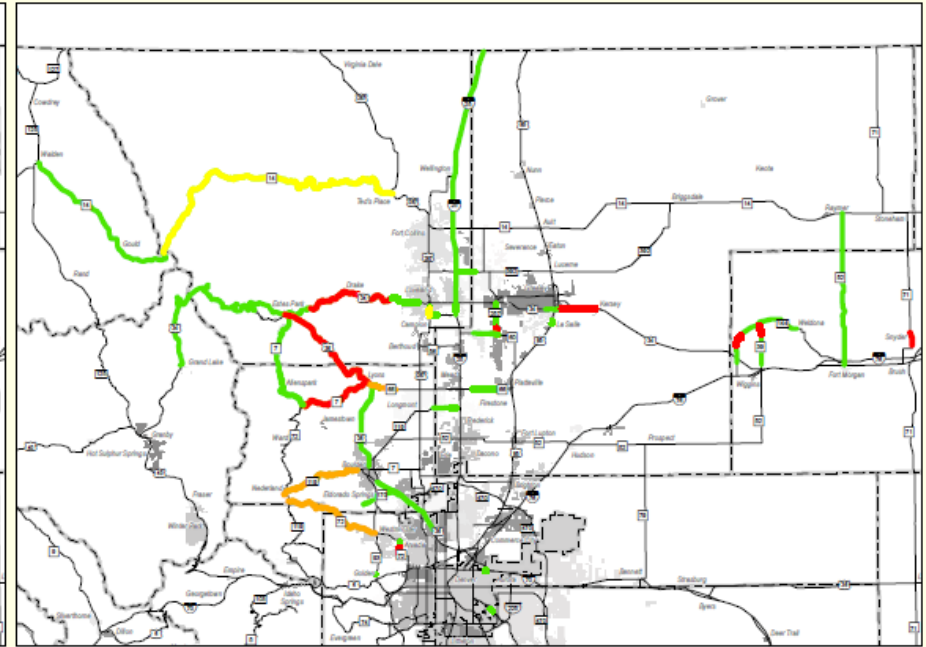


Road Network Impacts







Highway Status
between
September 12 - 16, 2013



Highway Status
as of
September 24, 2013



STATE HIGHWAY CLOSURES

-  Closed to all traffic
-  Closed - Emergency Only
-  Closed - Local Access Only
-  Open with Restrictions
-  Open to All
-  No Reported Damage - Expect Normal Travel



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Other Impacts

- 9-10 deaths
- > 11,000 people evacuated
- 1,750 people rescued by air and ground
- 17,322 damaged homes and businesses
- 2055 destroyed homes and businesses
- 486 miles road damage, 118 miles need permanent repair
- \$2.89 billion impact
- \$450 million FHWA outlay



Denver Post, 09/07/14

Emergency Relief (ER or ERFO) from FHWA

- Catastrophic and from external cause
- Generally within right of way
- In-kind, to standard, or with betterment

What if there is no “standard”?

When is a betterment justified with ER funds?

Application of ER Program is not easy or routine

RISK

Likelihood x Consequence



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RESILIENCE

The capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well being, the economy, and the environment. - USDOT



STANDARDS



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Standards

- **AASHTO “Green book” for geometrics**
- **AASHTO Guide Specs for Bridges and Structures**
- **State Specifications**
- **Rock Slope Standards?**
 - Inside ROW, Outside ROW
 - Global Stability
 - Rockfall Hazard

If they exist at all, they have ‘escape clauses’



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Publication No. FHWA SA-93-057
November 1993

NHI Course No. 130220

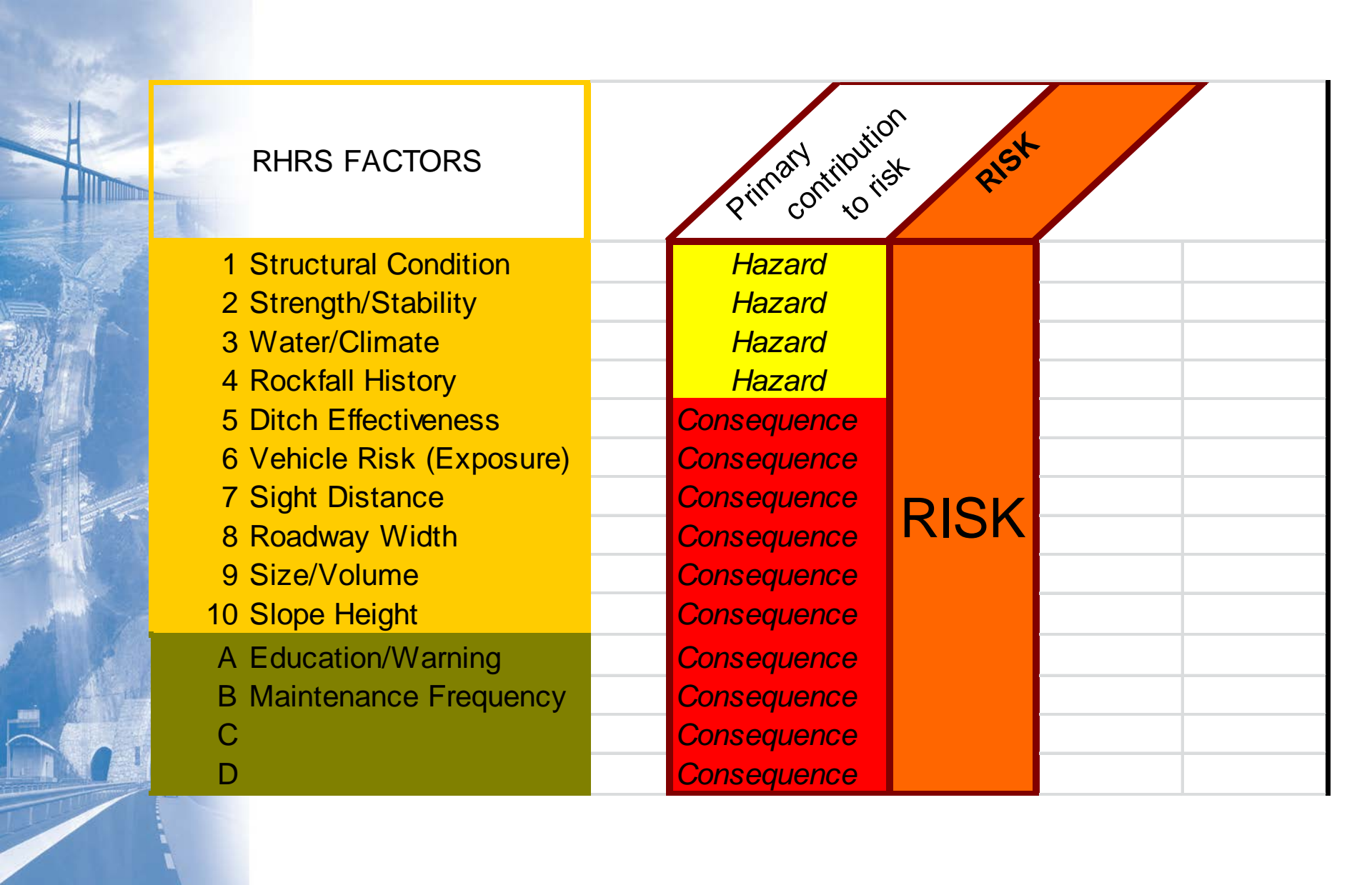
Rockfall Hazard Rating System Participant's Manual



National Highway Institute



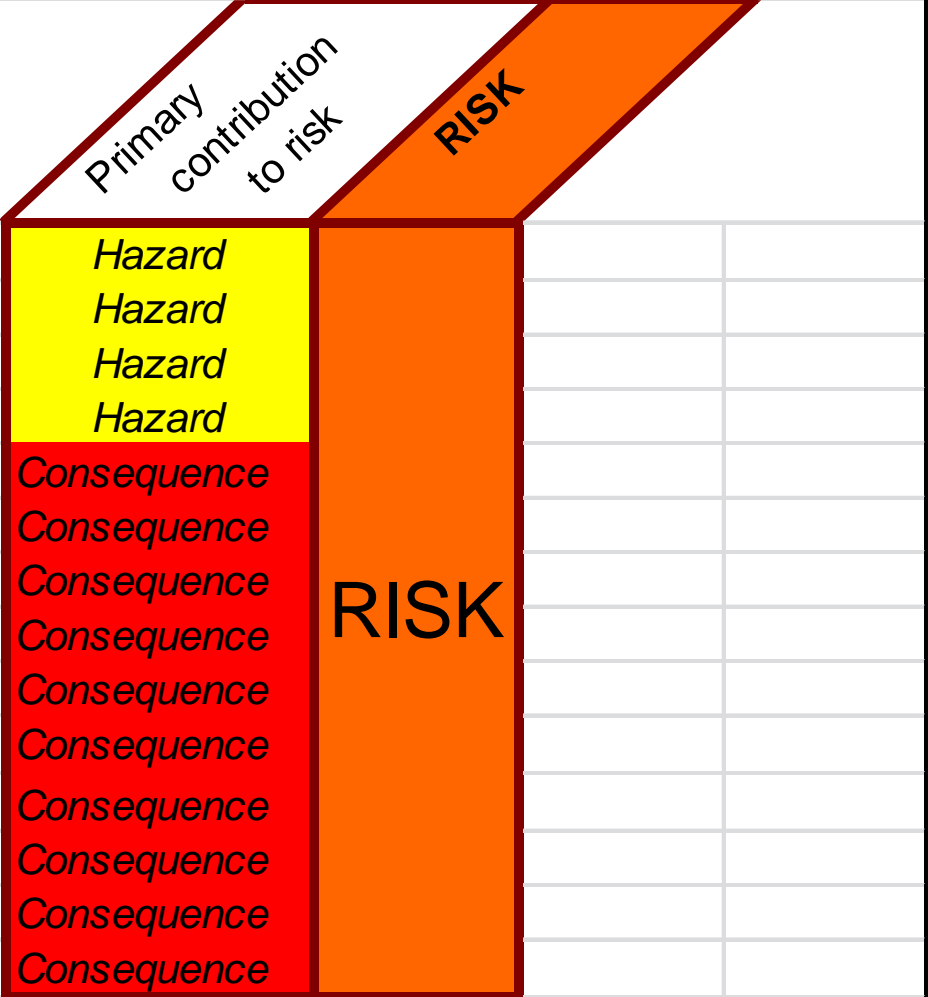
Innovation Through Partnerships



RHRS FACTORS

- 1 Structural Condition
- 2 Strength/Stability
- 3 Water/Climate
- 4 Rockfall History
- 5 Ditch Effectiveness
- 6 Vehicle Risk (Exposure)
- 7 Sight Distance
- 8 Roadway Width
- 9 Size/Volume
- 10 Slope Height

- A Education/Warning
- B Maintenance Frequency
- C
- D



Design Template

Figure 1: Original and Damaged Typical Section

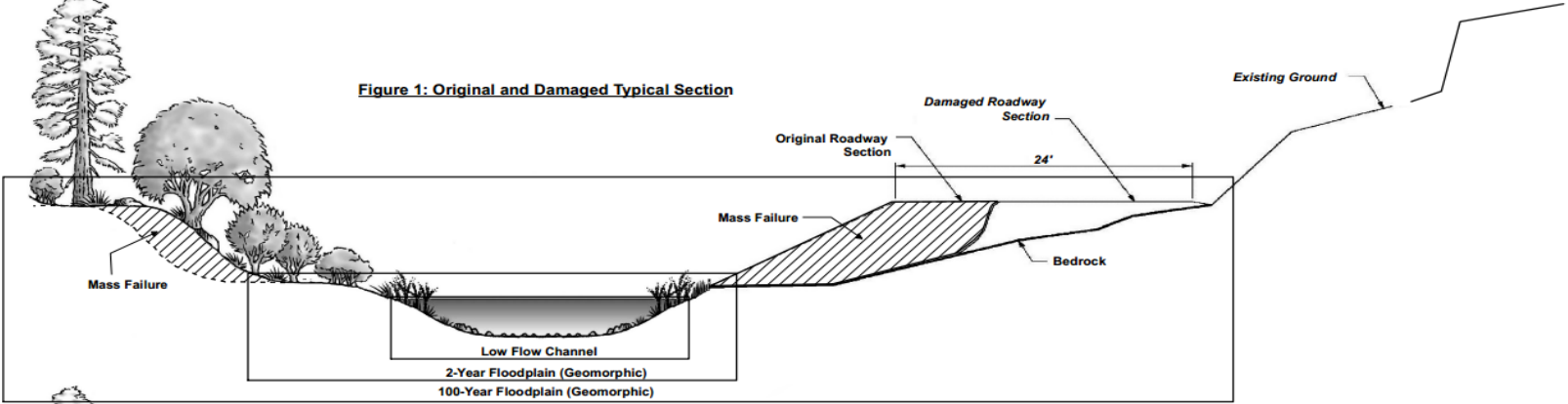
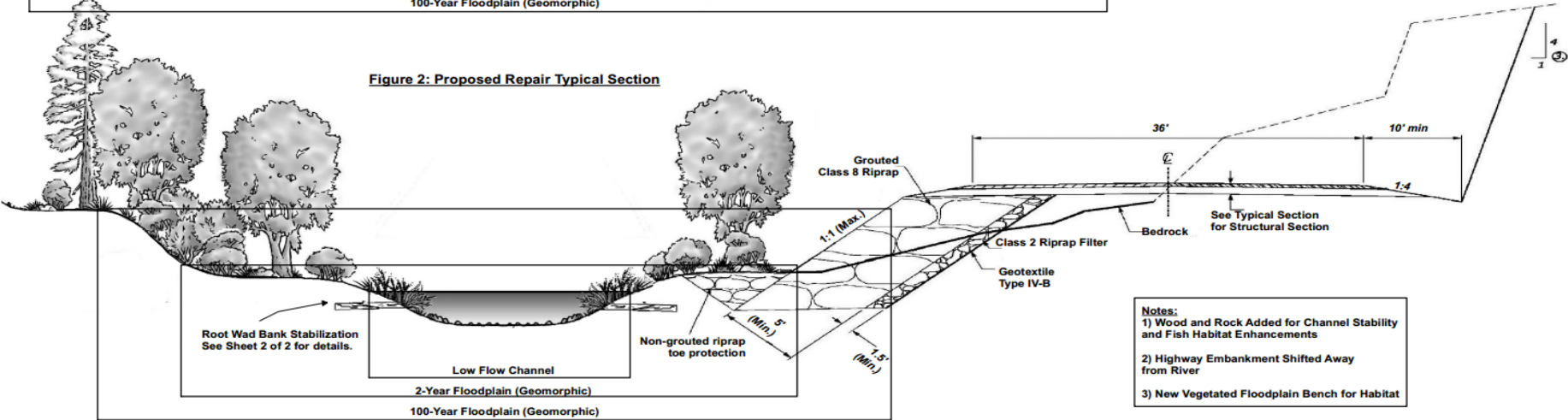


Figure 2: Proposed Repair Typical Section



- Notes:**
- 1) Wood and Rock Added for Channel Stability and Fish Habitat Enhancements
 - 2) Highway Embankment Shifted Away from River
 - 3) New Vegetated Floodplain Bench for Habitat



Post - Construction



Pre - Construction



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Oso Landslide Snohomish County, WA



RISK

RESILIENCE

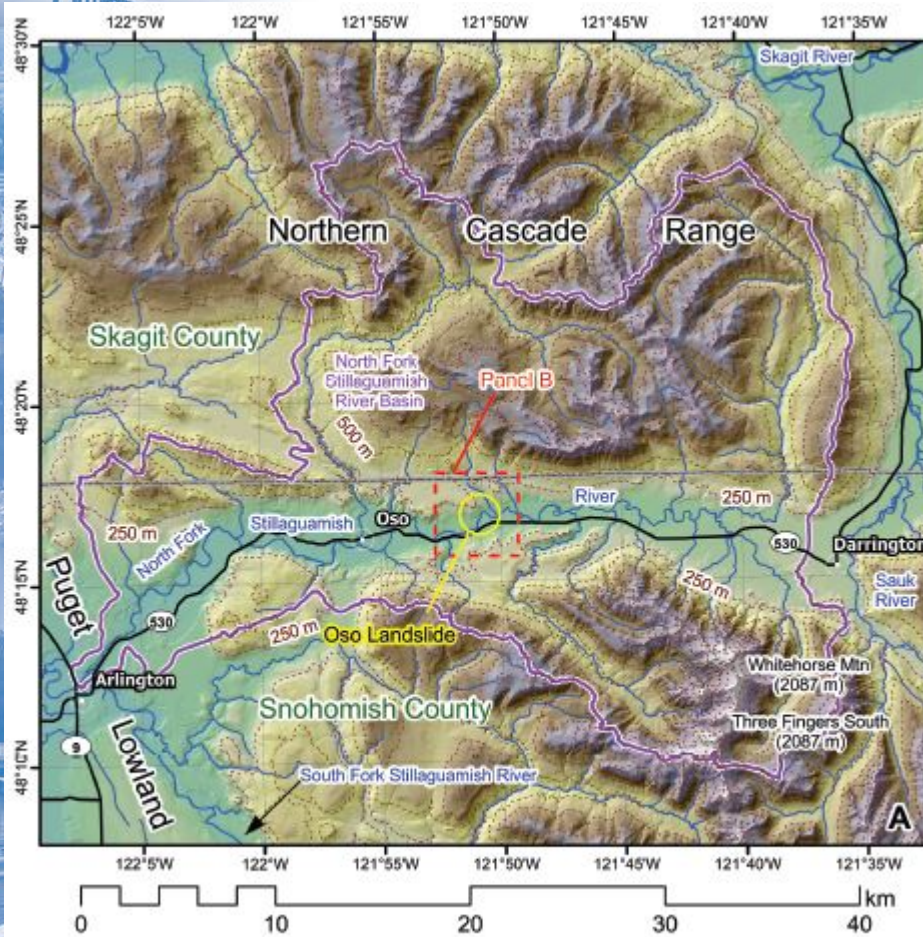
STANDARDS



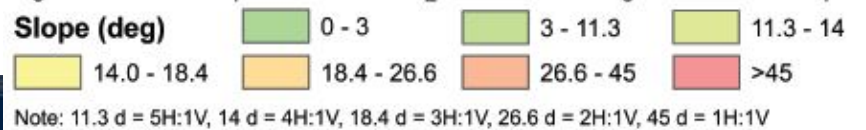
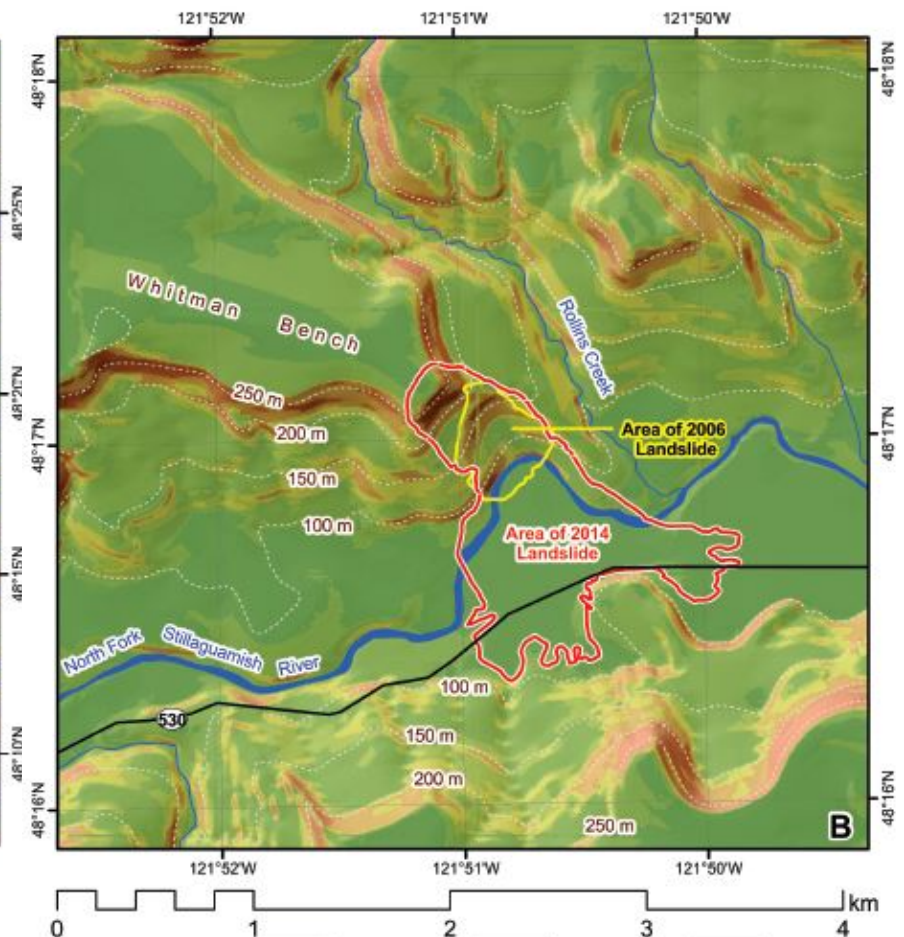
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www.sciencenews.org

Location and General Slope



Projection: NAD_1983_UTM_Zone_10N_m
 Panel A: Contour interval = 250 m
 Panel B: Contour interval = 50 m



22 March 2014 – What happened ?



PHOTO BY TED S. WARREN /THE ASSOCIATED PRESS; GRAPHIC BY THE SEATTLE TIMES

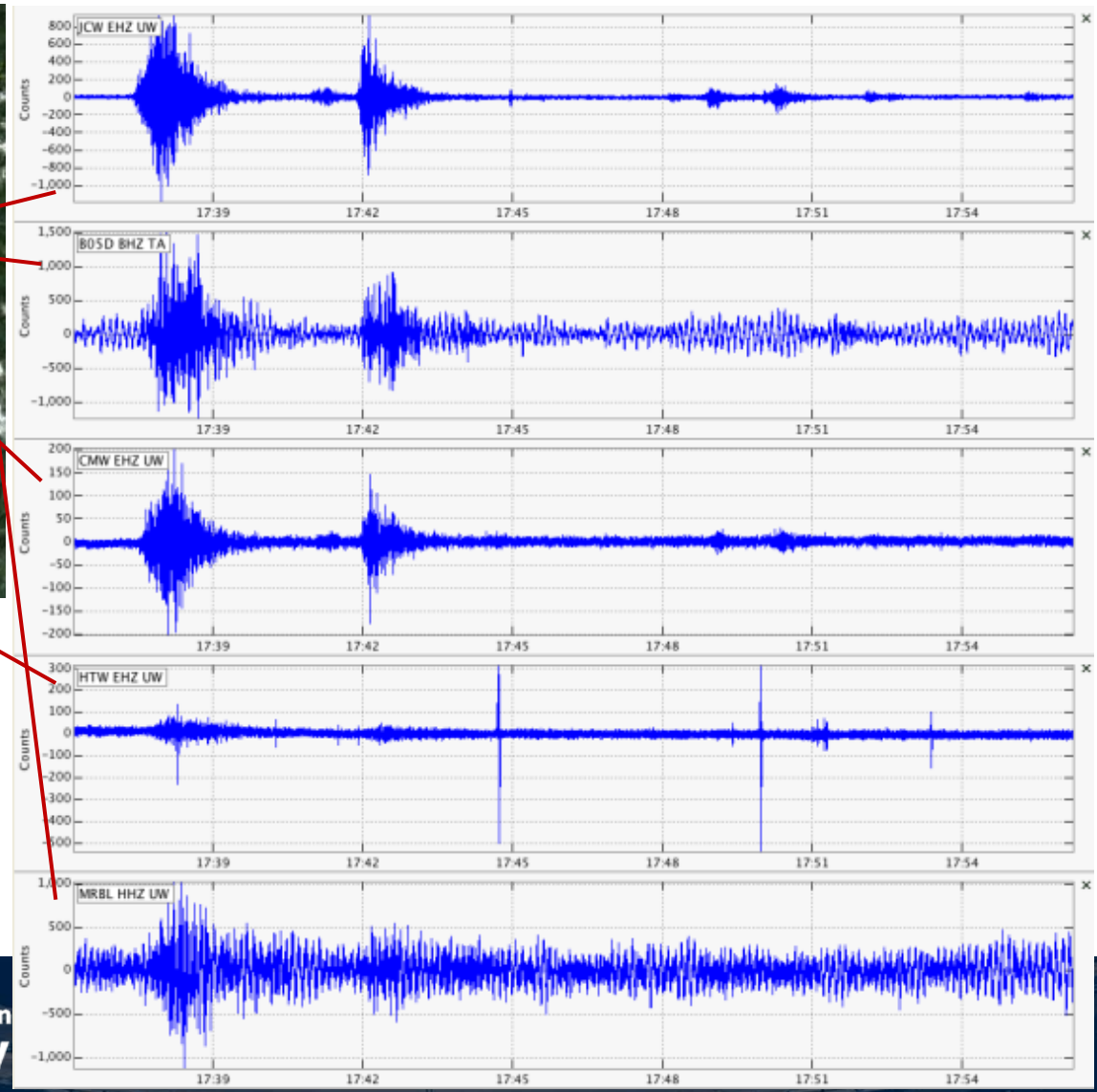
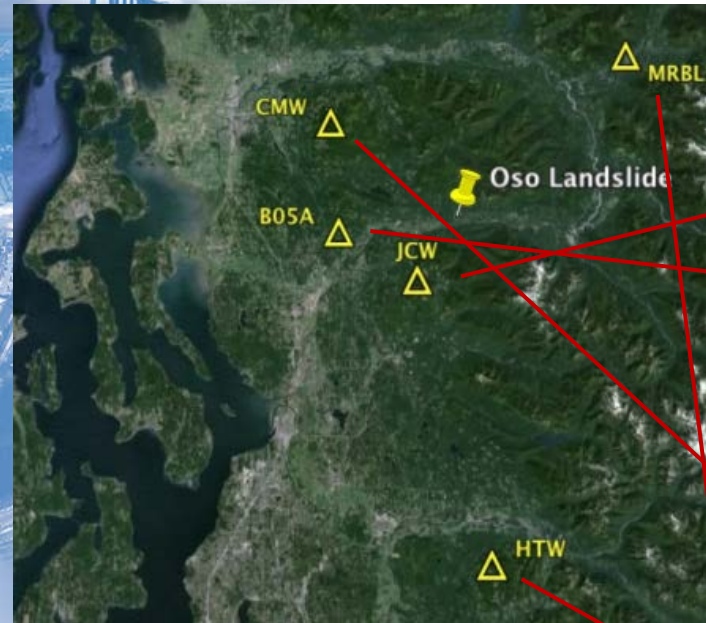
GEER Reconnaissance

- Two months elapsed
- Last recovery at same time
- Six people, 4 days
- Excellent County support in field
- USGS presence since day one

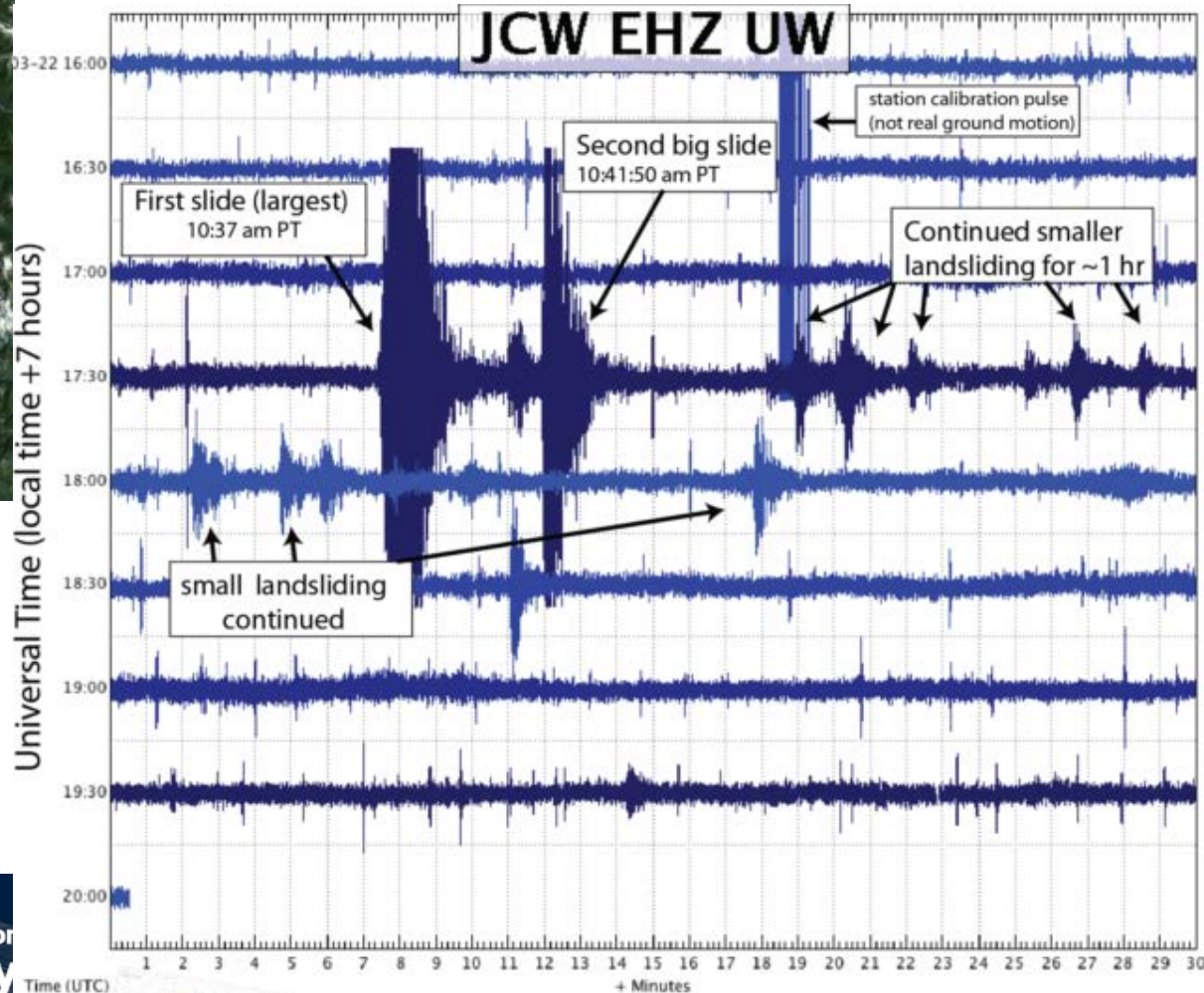
Some remarkable observations reported...

Understanding that can be applied in practice

Seismic Signals



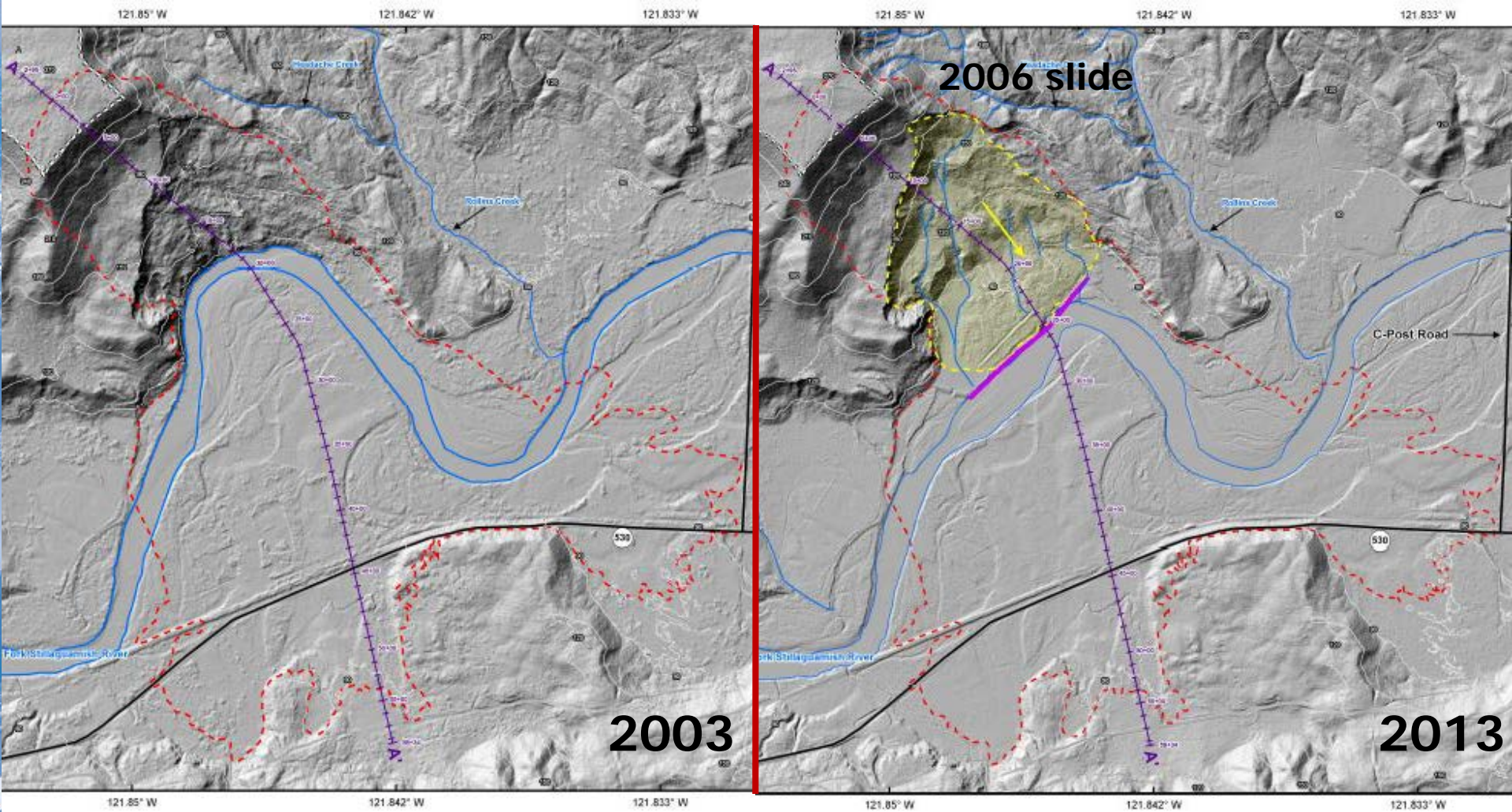
Jim Creek Wilderness Station – 11 km Away



Pacific Northwest
Seismograph Network

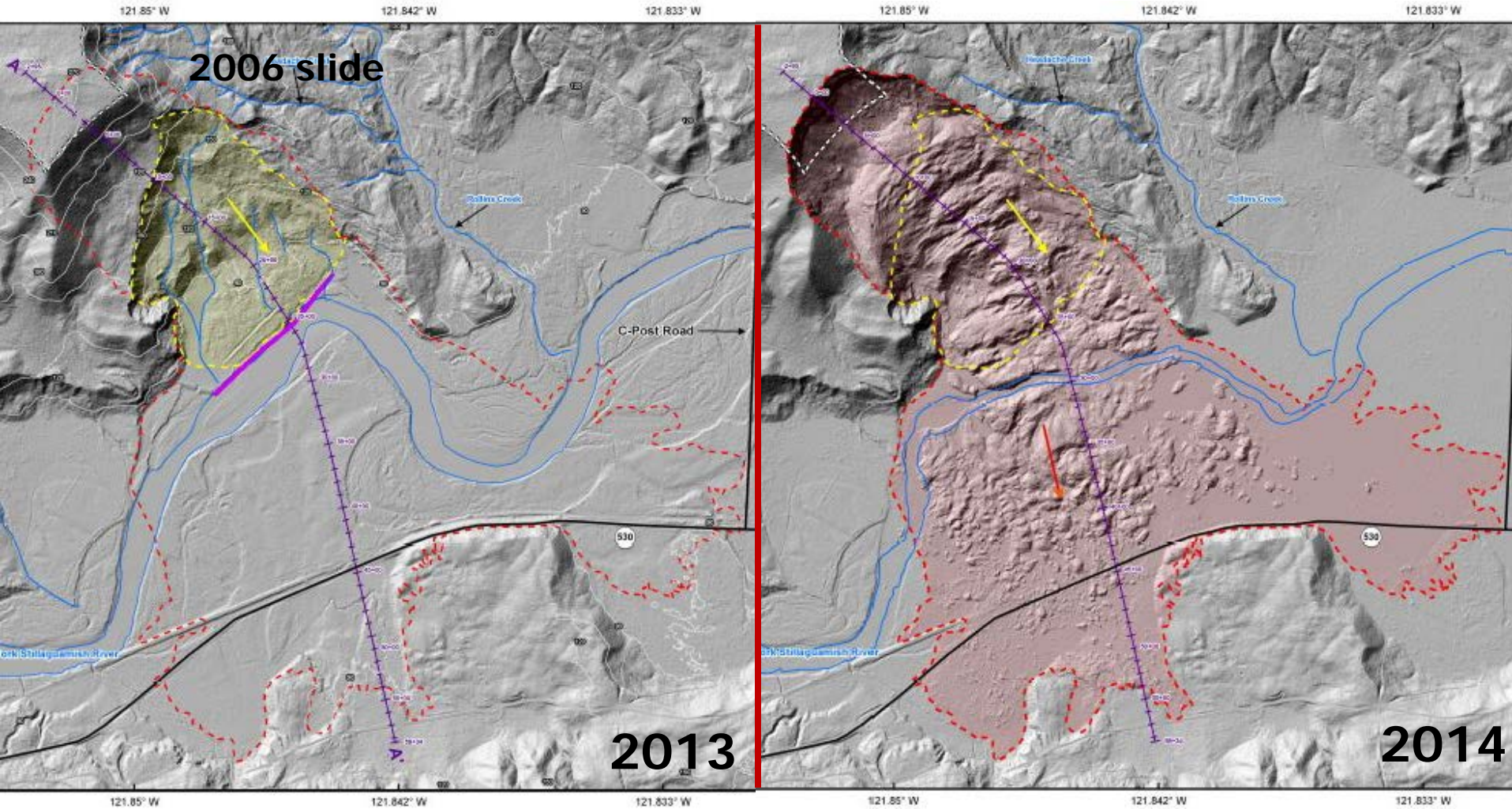
03/22/2014 10:37

Lidar Topography



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Lidar Topography



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Impact



WSDOT High-Resolution Mosaic

24 March 2014





U.S. Dep
Fed
Administration

Record of Extension

WSDOT High-Resolution Mosaic 24 March 2014



Liquefaction



Veneer



Flow



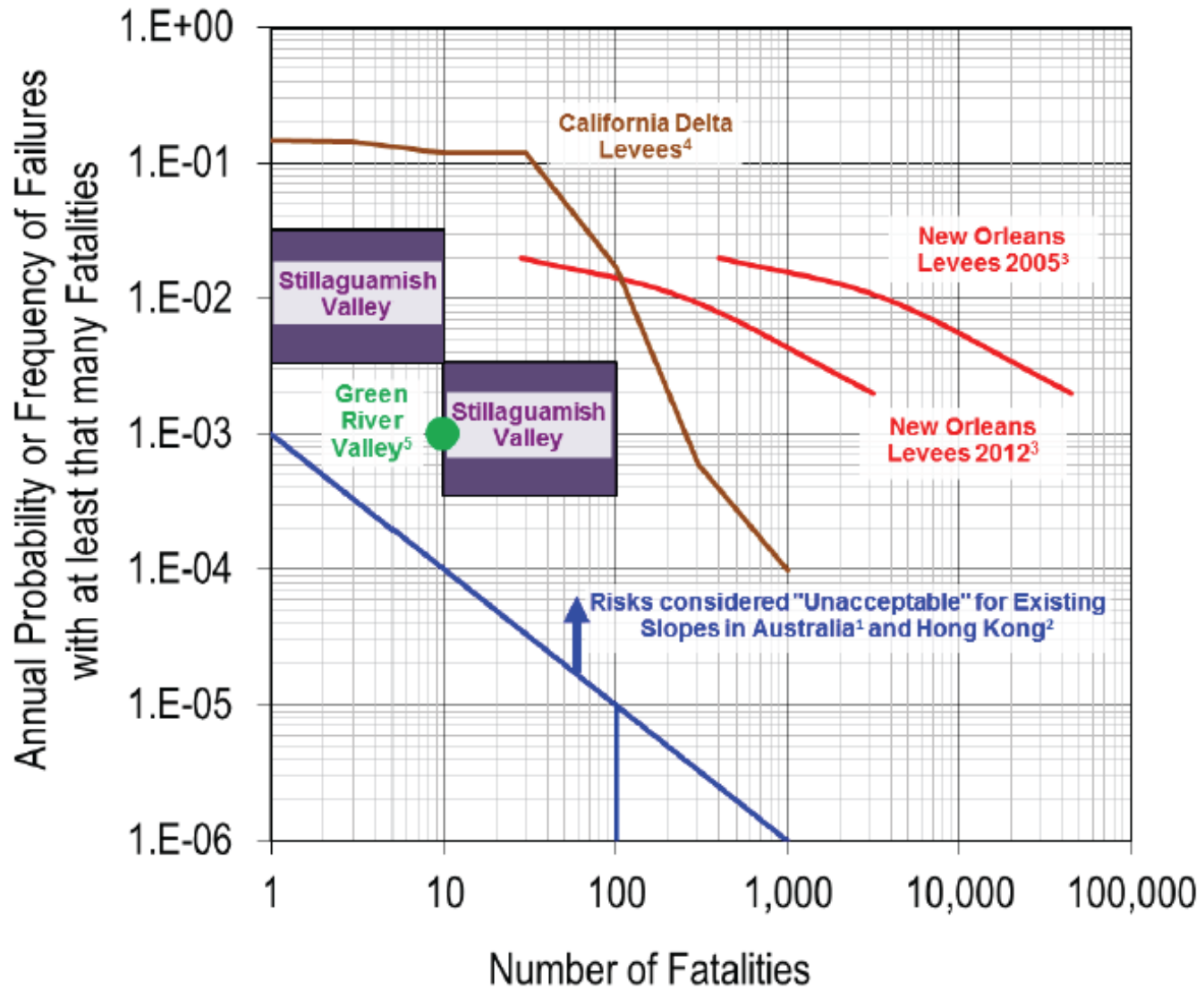
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Prior public view of Risk, Resilience and Standards

- **Steelhead Haven subdivision was platted in 1962**
- **Slide movement every decade since 1950s**
- **A few building permits were issued after 2006**
- **All properties complied with hazard ordinances**
- **Studies were primarily for other purposes**

Basically, there is some of each: risk, resilience and standards

Risk (as understood now)



Approximate risk within 5 km of Oso

SR 530 Reconstruction

- ER eligible: how should it be rebuilt?

Remember:

Risk

Resilience

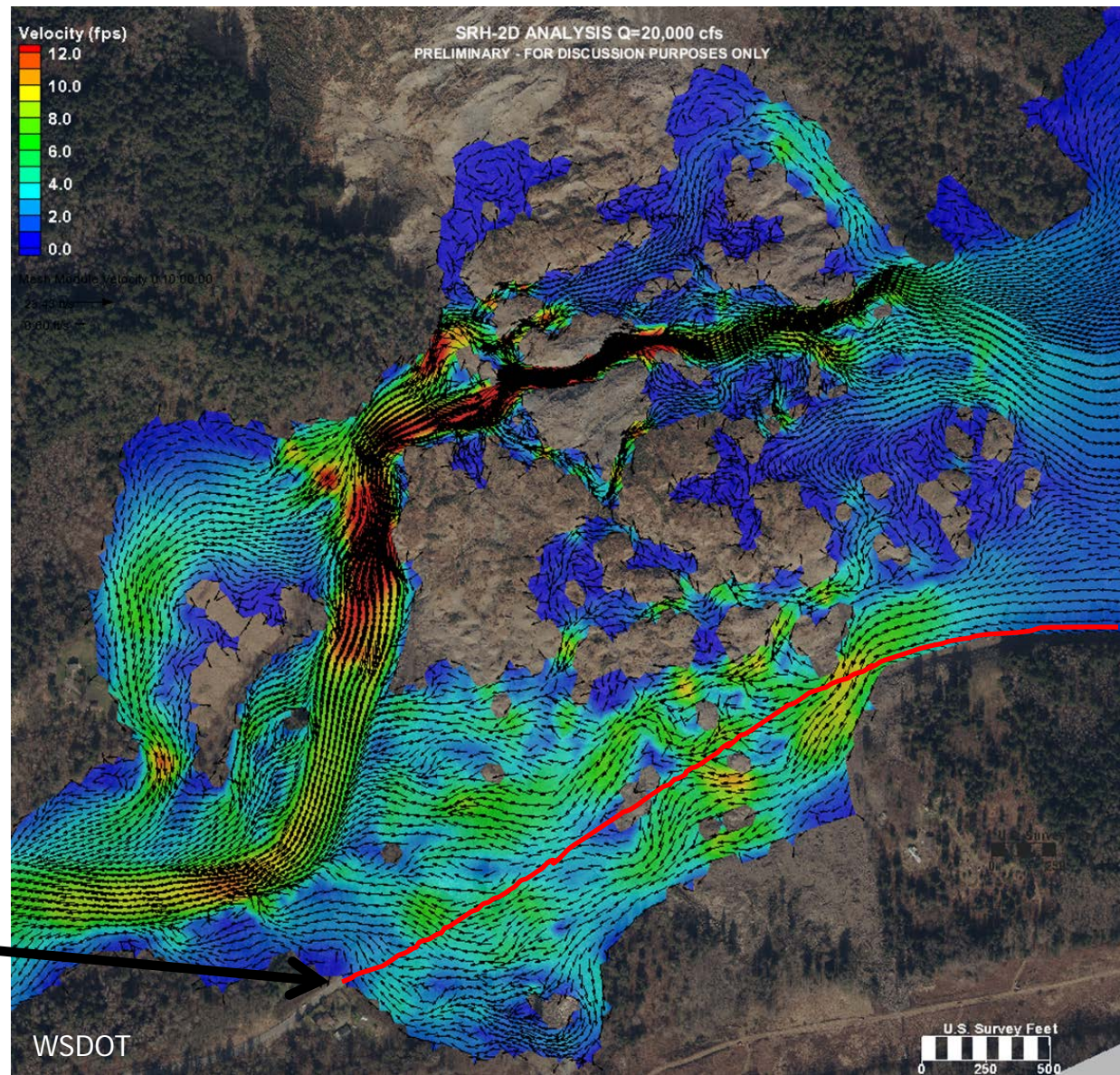
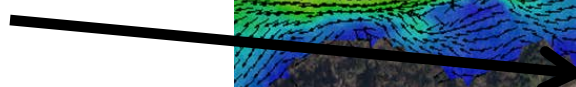
Standards



Flood Stage



SR 530



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Design Solution



WSDOT



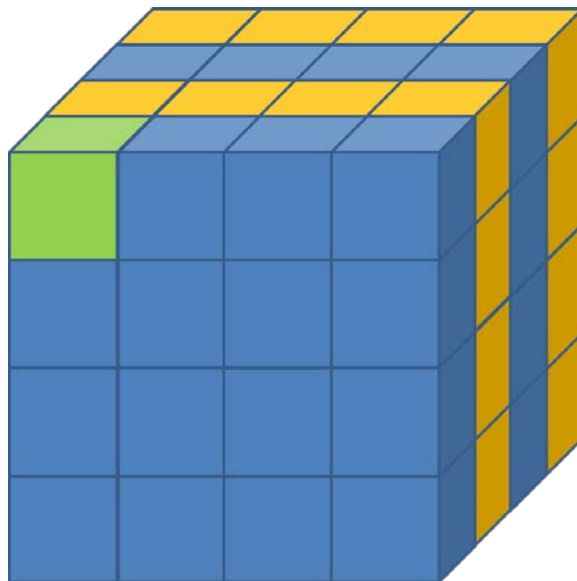
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A final concept

Highway departments (and others) are using risk based plans to manage their assets and to achieve performance goals.

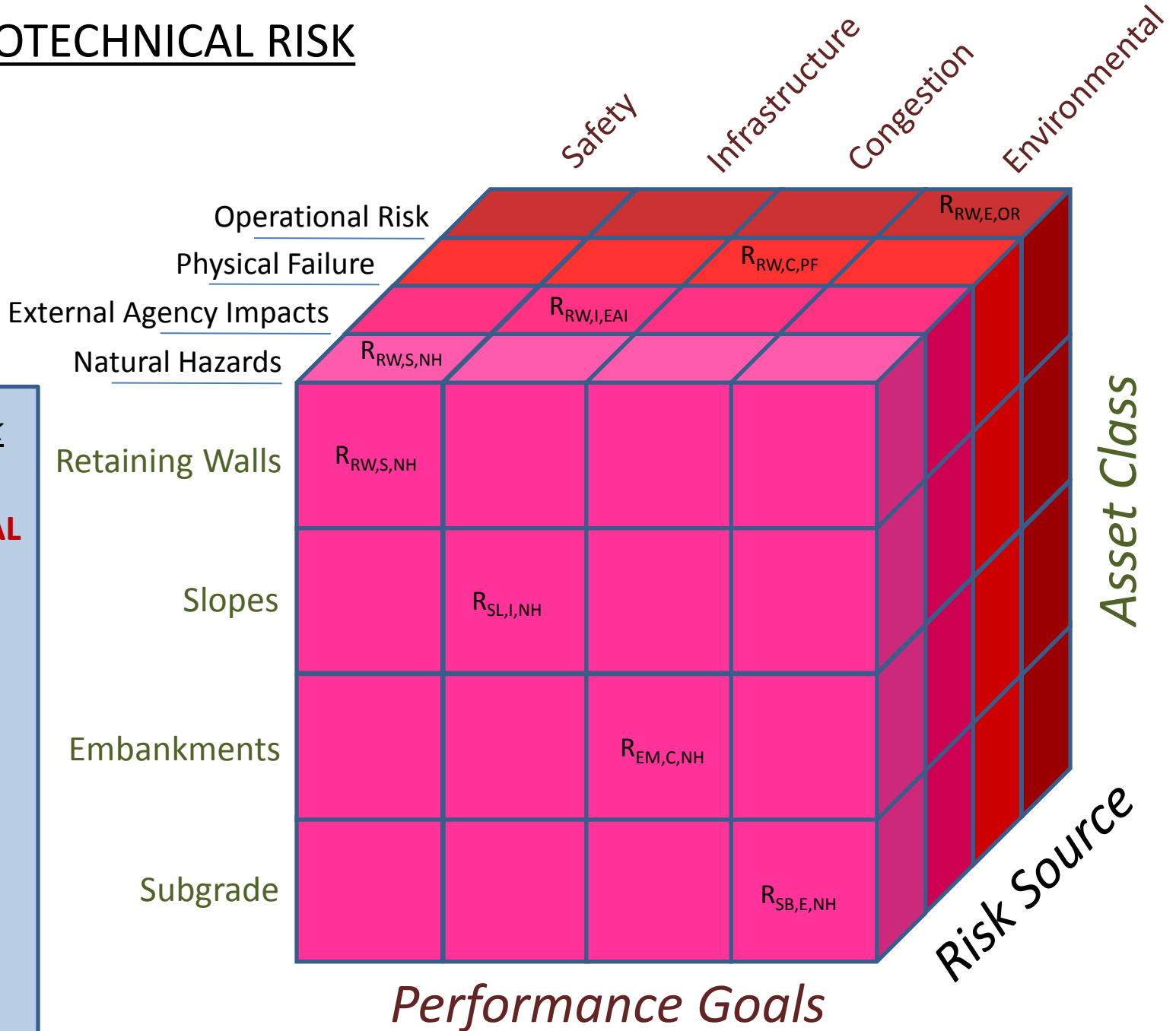
The SR 530 embankment on the Oso landslide is now an asset subjected to risks.

Consider a “Risk Cube”



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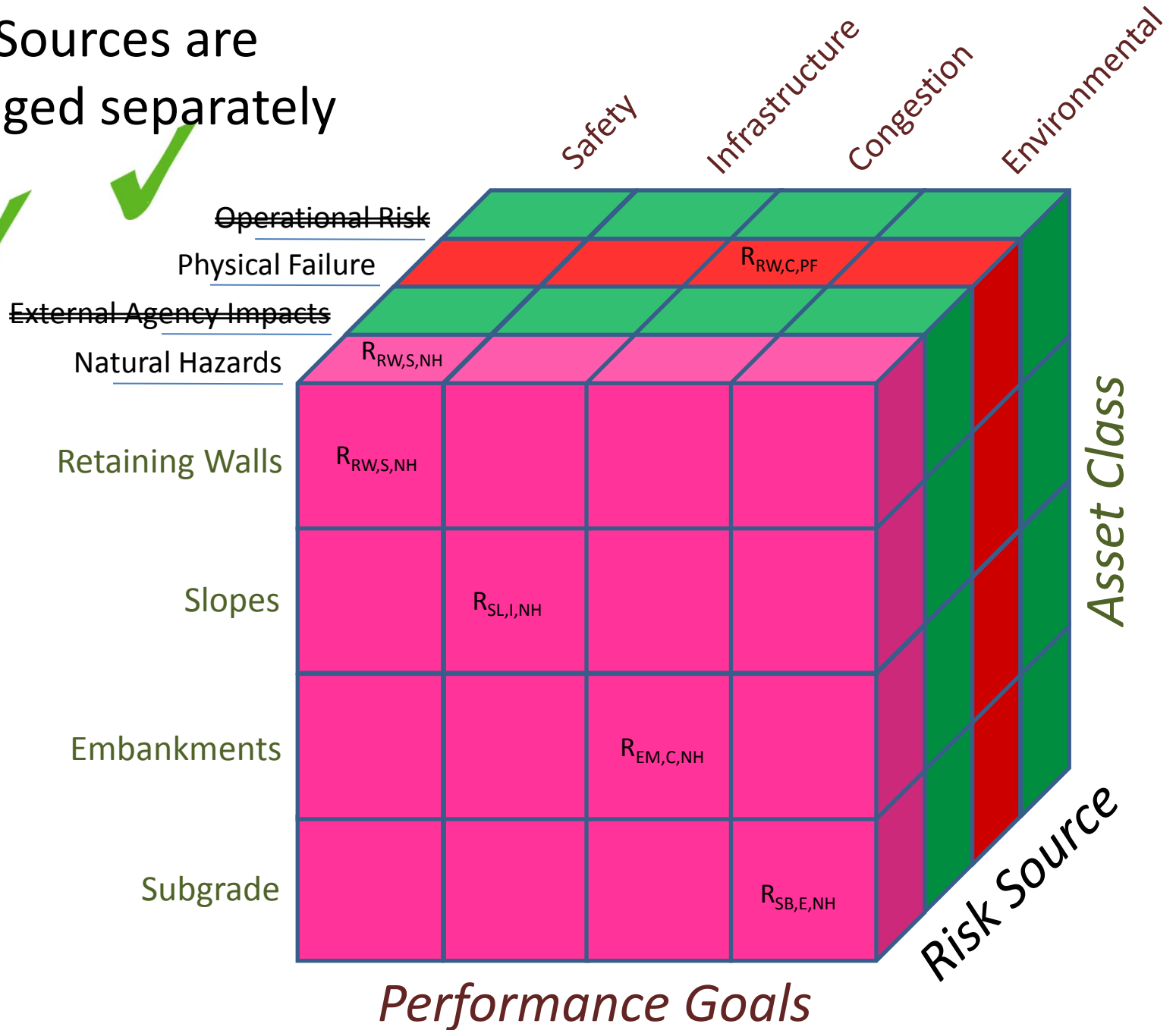
ALL GEOTECHNICAL RISK



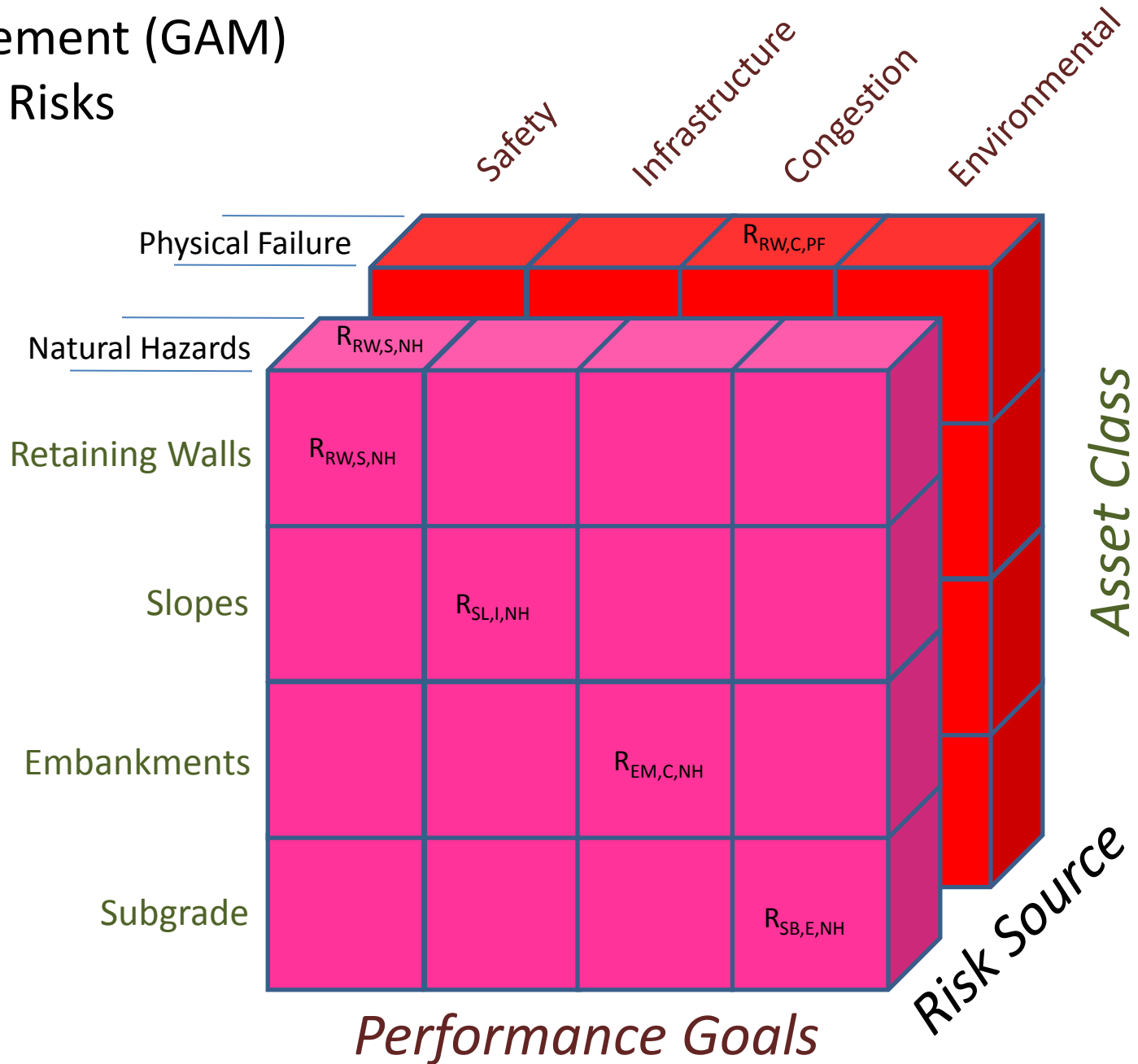
Σ of **ALL Risk**
Sources on
GEOTECHNICAL
Assets with
 respect to **ALL**
Performance
Goals

 Can be done
 for GAM
 Section,
 Corridor or
 entire
 inventory

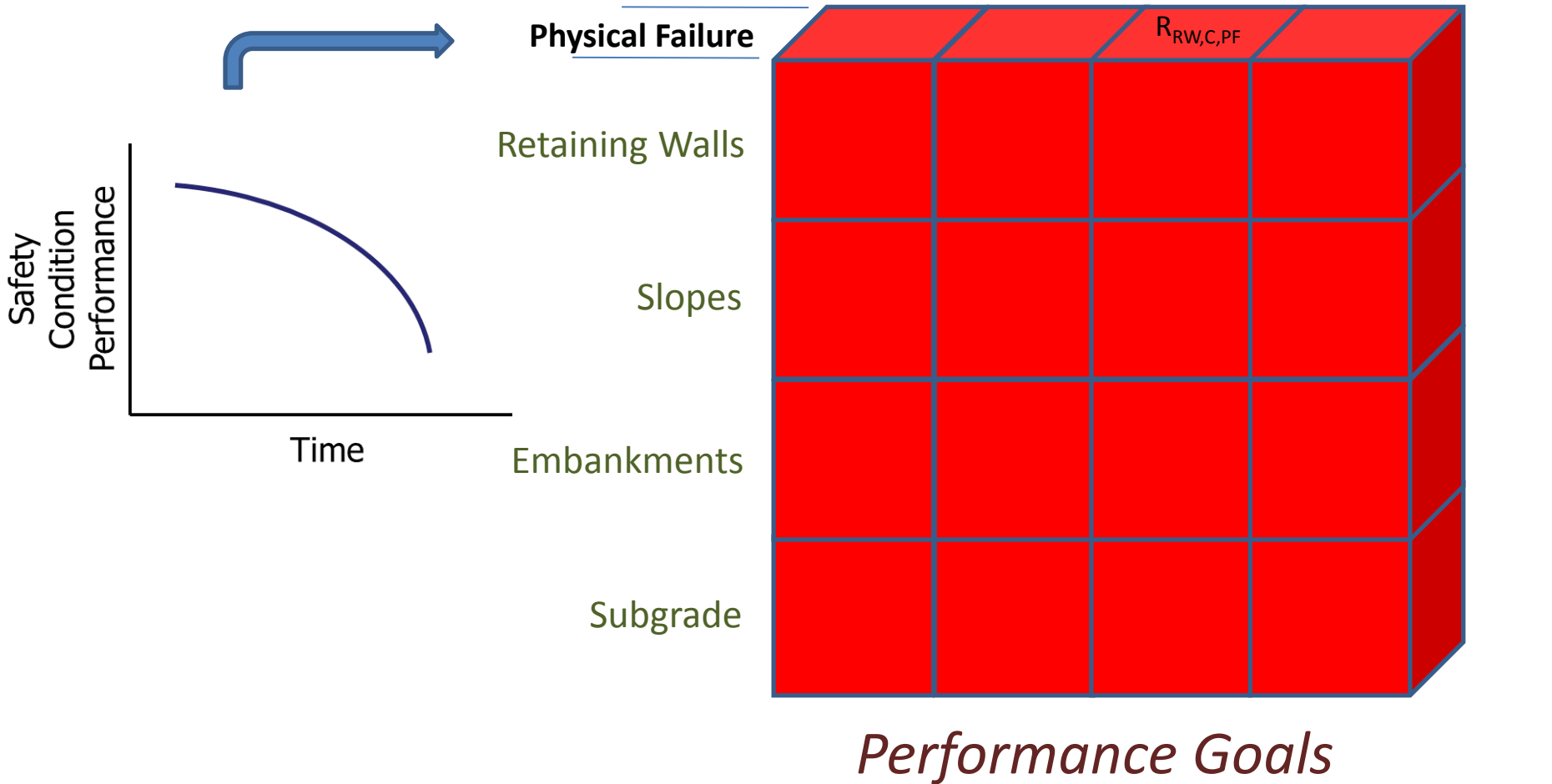
2 Sources are managed separately



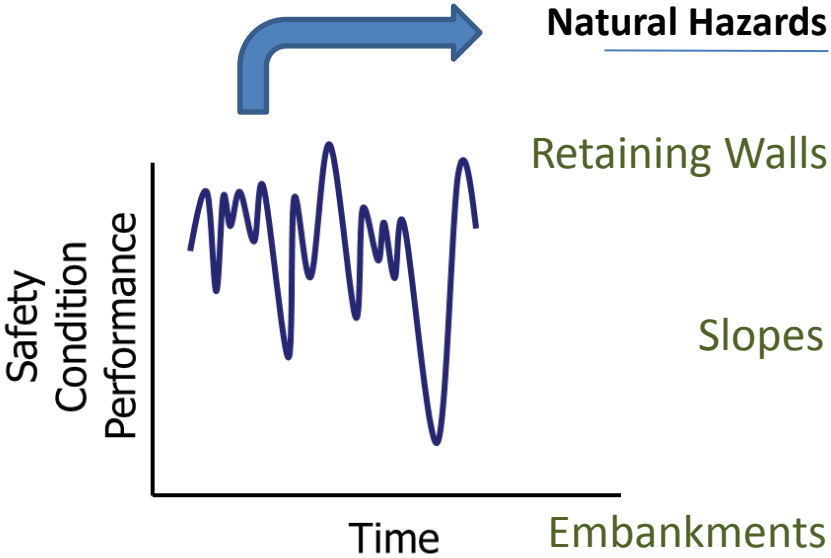
Geotechnical Asset Management (GAM) Risks



Physical Failure Risk Source



Natural Hazard Risk Source



Natural Hazards

Retaining Walls

Slopes

Embankments

Subgrade

Safety

Infrastructure

Congestion

Environmental

	$R_{RW,S,NH}$			
$R_{RW,S,NH}$				
	$R_{SL,I,NH}$			
		$R_{EM,C,NH}$		
			$R_{SB,E,NH}$	

Performance Goals

My Question for you:

The risk of what? Let's be clear.



Your Questions for me?



Patricia Brach - FEMA