Geotechnical Asset Management for Transportation Agencies in the United States

Ground Related Risk to Transportation Infrastructure
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- Other GAM advocates in U.S.
    - Dave Stanley, Scott Anderson, Paul Thompson, Darren Beckstrand

Funding for Surface Transportation in U.S.

- Federal government rebates a portion of the federal gas tax revenue each year to each state

- States supplement highway budgets primarily through one or more of the following:
  - More gas taxes, vehicle license fees/taxes, wheel taxes
  - Income, property, and business taxes
  - Mineral and petroleum extraction severance taxes
  - Tolling – limited to high congestion areas with political support

- Railroad
  - Amtrak: federally funded passenger rail system
  - Private: Numerous freight rail owners who also may have occasional passenger operations

Voluntary Implementation Environment

- Currently no regulatory or legislative requirement for geotechnical asset management at Federal or State level

- Recent legislation does require asset management for bridges and pavements and *encourages* management for other assets

- Most work has evolved from rockfall hazard rating systems initiated state by state

Early 1990s: Rockfall Hazards – > **2015**: Risk Based Geotechnical Asset Management

Early Asset Management-Safety Based Rockfall Hazard Rating Systems (RHRS)

Rockfall Hazard Rating Example

- Sum (additive) based hazard score
  - 0, 3, 9, 27, or 81 points assigned for each input category
  - Provides an indication of highest hazard and components can be used for safety risk analysis

			Site 6	Site 7
Slope	Slope Height		50 to 75 feet	75 to 100 feet
	Rockfall Frequency		1 to 2 years	Yearly, Seasonal
	Average Slope Angle		2 to 4	4 to 8
	Launching Features		Minor (<2 ft. surface variation)	Many (2 to 6 ft. surface variation)
	Ditch Catchment		65% to 94% / Class 2	30% to 64% / Class 3
Climate	Annual Precipitation		10 to 20 inches	20 to 35 inches
	Annual Freeze Thaw Cycles		6 to 10	11 to 15
	Seepage/Water		Damp / Wet	Dripping
	Slope Aspect		E, W, NE, NW	SE, SW
	Sed Rock	Degree of Under-Cutting	no value	no value
		Jar Slake	no value	no value
		Degree of Interbedding	no value	no value
	Cryst Rock	Rock Character	Small faults/ Strong Veins	Schist/ Shear Zones < 6 in.
		Degree of Overhang	1 to 2 ft.	2 to 4 ft.
		Weathering Grade	Surface Staining	Slightly Altered/ Softened
	Block in Matrix	Block Size (x3)	no value	no value
		Block Shape (x3)	no value	no value
		Vegetation (x3)	no value	no value
	Discontinuities	Block Size/Volume	1 to 2 ft. / 1 to 3 cy	2 to 5 ft. / 3 to 10 cy
		Number of Sets	1 plus random	2
		Persistance, Orientation	> 10 ft. and dips into slope	< 10 ft. and daylights out of slope
		Aperture	0.1 to 1 mm	1 to 5 mm
		Weatering Condition	Surface staining	Granular infilling
		Friction	Undulating	Planar
Total Hazard Score			162	486
	Site Distance		60 to 80%	40 to 60%
	Average Vehicle Risk		25 to 49%	50 to74%
	No. of Accidents		3 to 5	6 to 8
Total Risk Score			27	81
Combined Score			189	567

History

- 1990-2010: Rockfall Hazard Rating Systems
  - Oregon, Colorado early adoption
  - Numerous states with rockfall hazards adopt and modify RHRS's for state specific needs

- Rockfall systems modified for all unstable slopes
  - Washington (2000's), Alaska 2010

- 2003 - Need for geotechnical asset management first discussed in U.S. literature

History

- Retaining wall inventory and assessment early efforts
  - Cincinnati (1990s-2006) – 1800 walls
    - $170M replacement value
  - National Park Service (2005-2008) – 3,500 walls in 33 parks and monuments
    - $18.5M in deferred maintenance
    - $407M replacement value
  - Oregon, New York

History

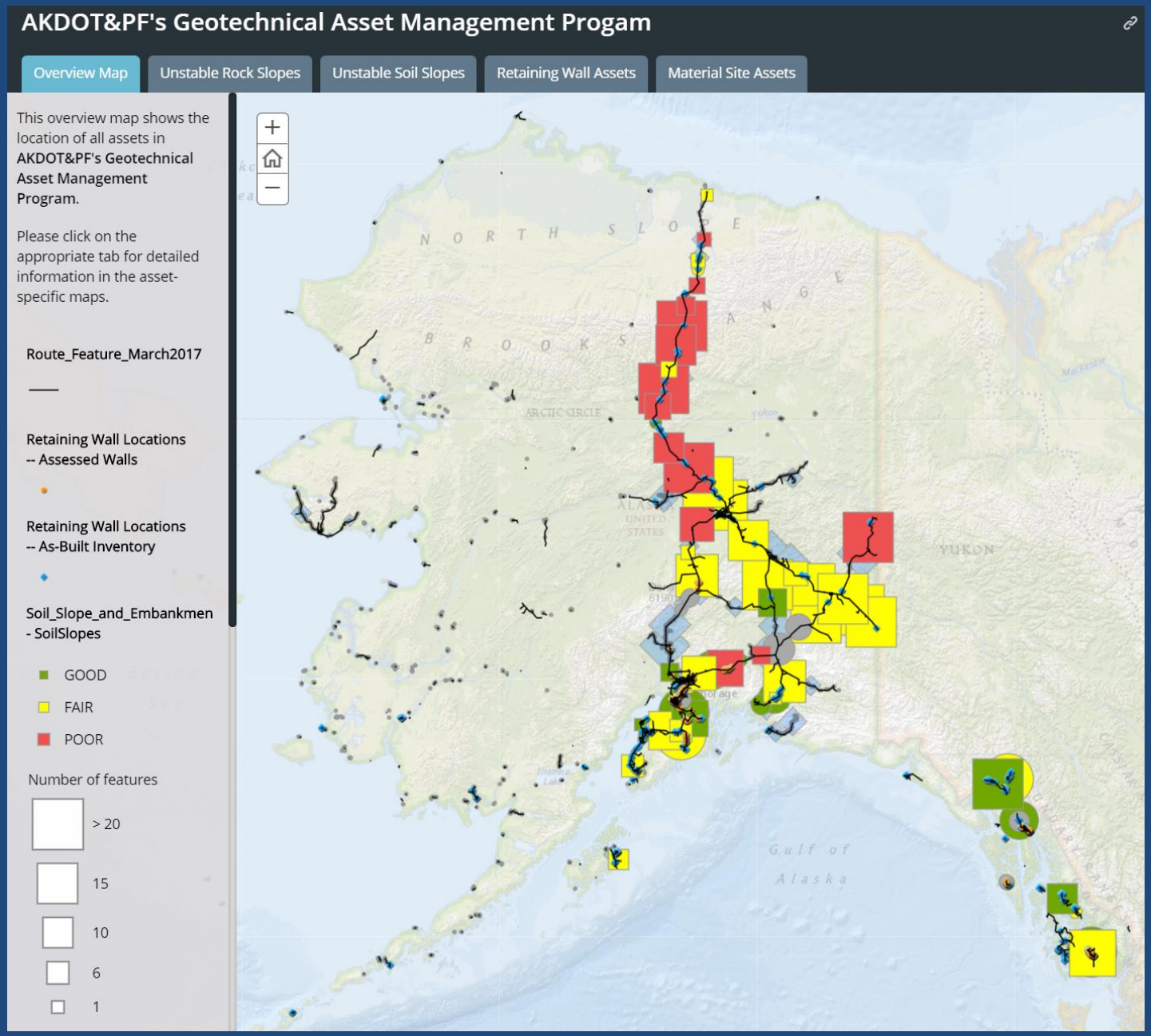
- 2012 – first efforts towards starting geotechnical plans
  - Alaska, Colorado, Vermont
  - Geotechnical Asset Management joint committee formed within Transportation Research Board

- 2016 – Federally funded study to create geotechnical asset management implementation plan for states (current study)

Alaska Department of Transportation

- First state to complete a GAM plan through
  - GAM Champion - David Stanley
- Unstable slopes, rockfall sites, retaining walls, material sites
- Condition based inventory developed from the rockfall hazard rating methodology
- Evaluating risk to safety, mobility, and direct financial costs to department

Alaska Department of Transportation



Alaska Department of Transportation

- Status:
  - Plan document complete
  - Expert judgment for deterioration models
  - Investment not occurring yet
    - Several $M in needs identified but limited funds

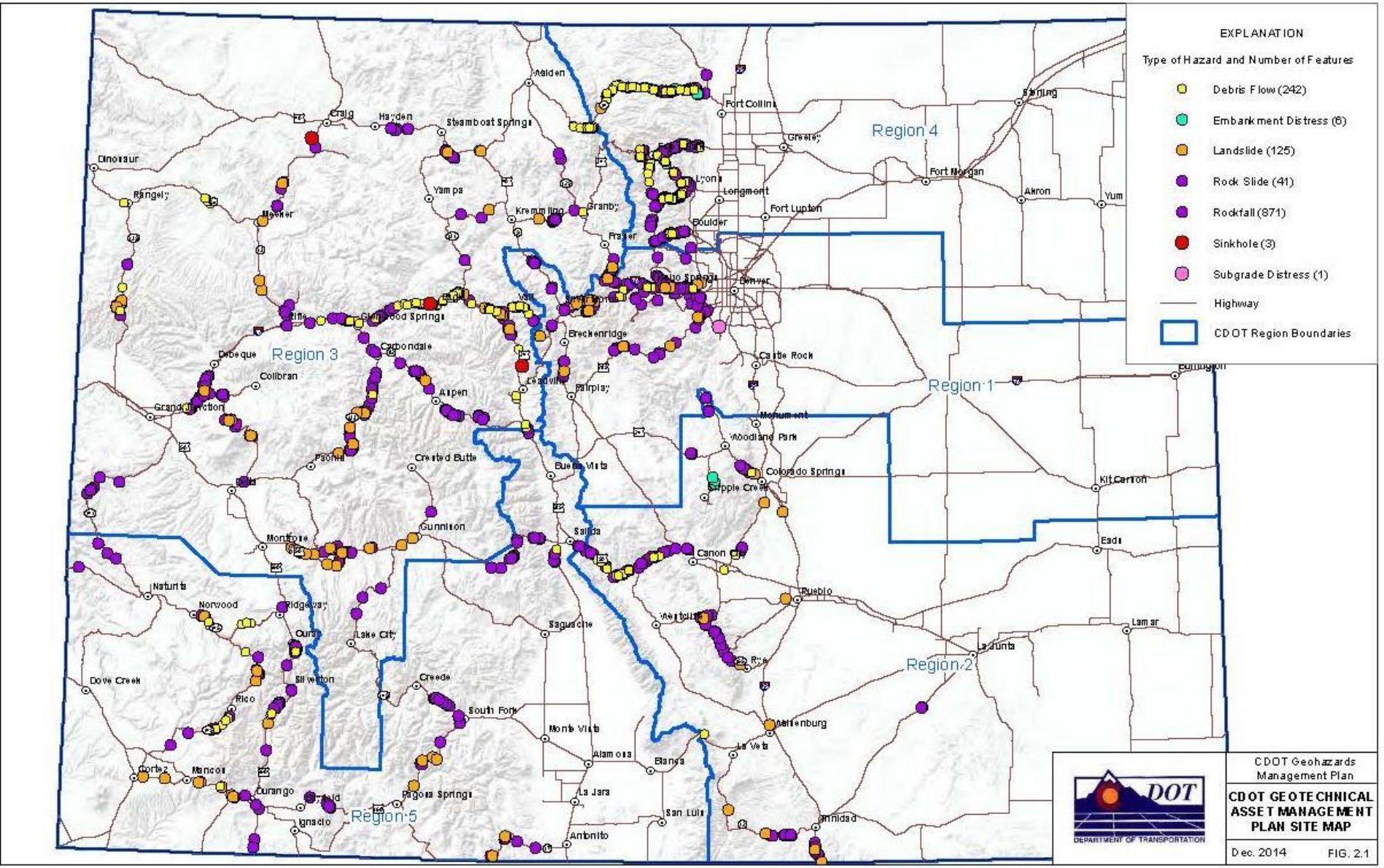
From AKDOT&PF, 2017

Colorado Department of Transportation

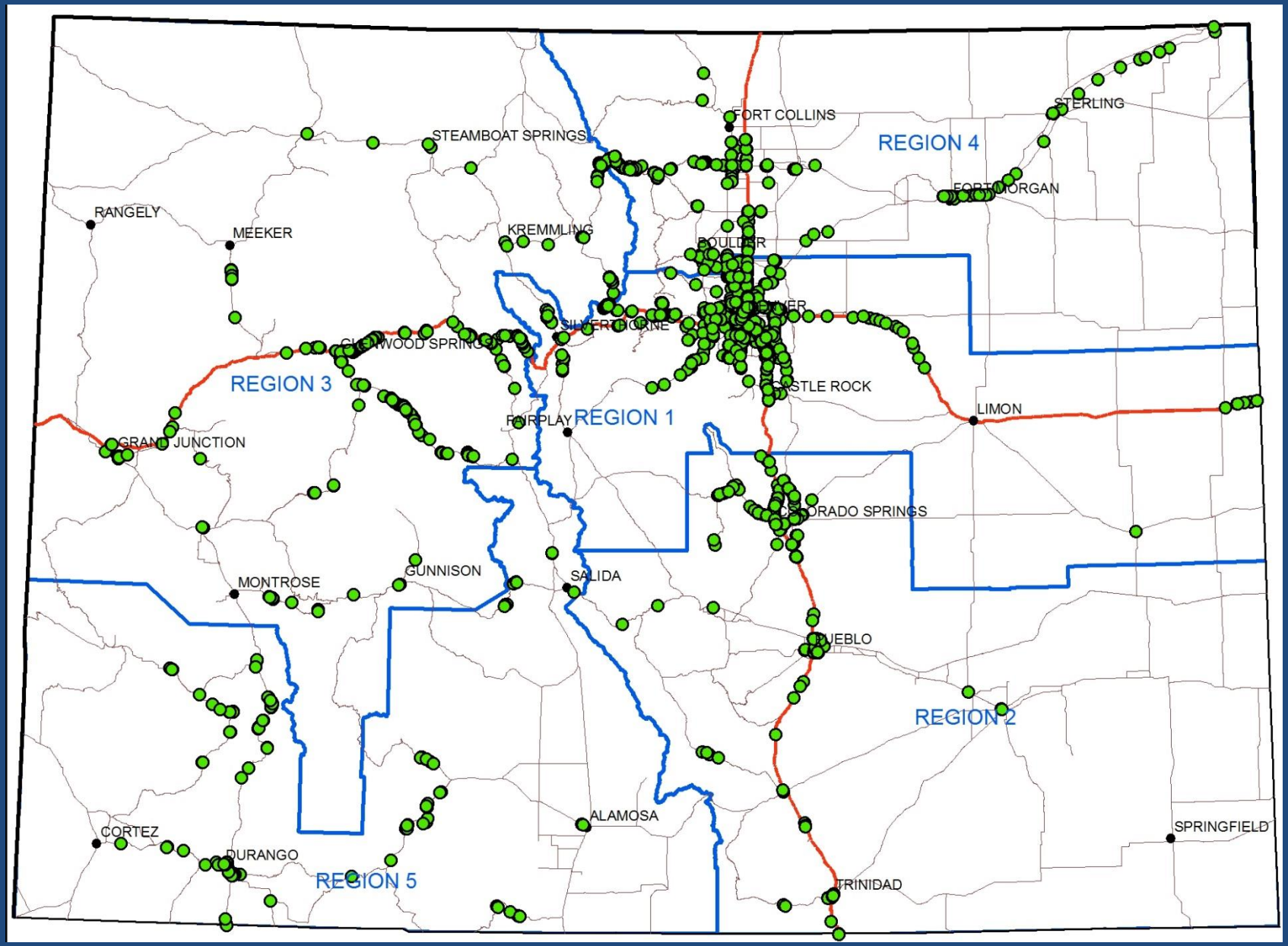
- ~ 3,000 walls: condition based inventory

- Approximately 1600 geologic hazard sites: condition and event based inventory

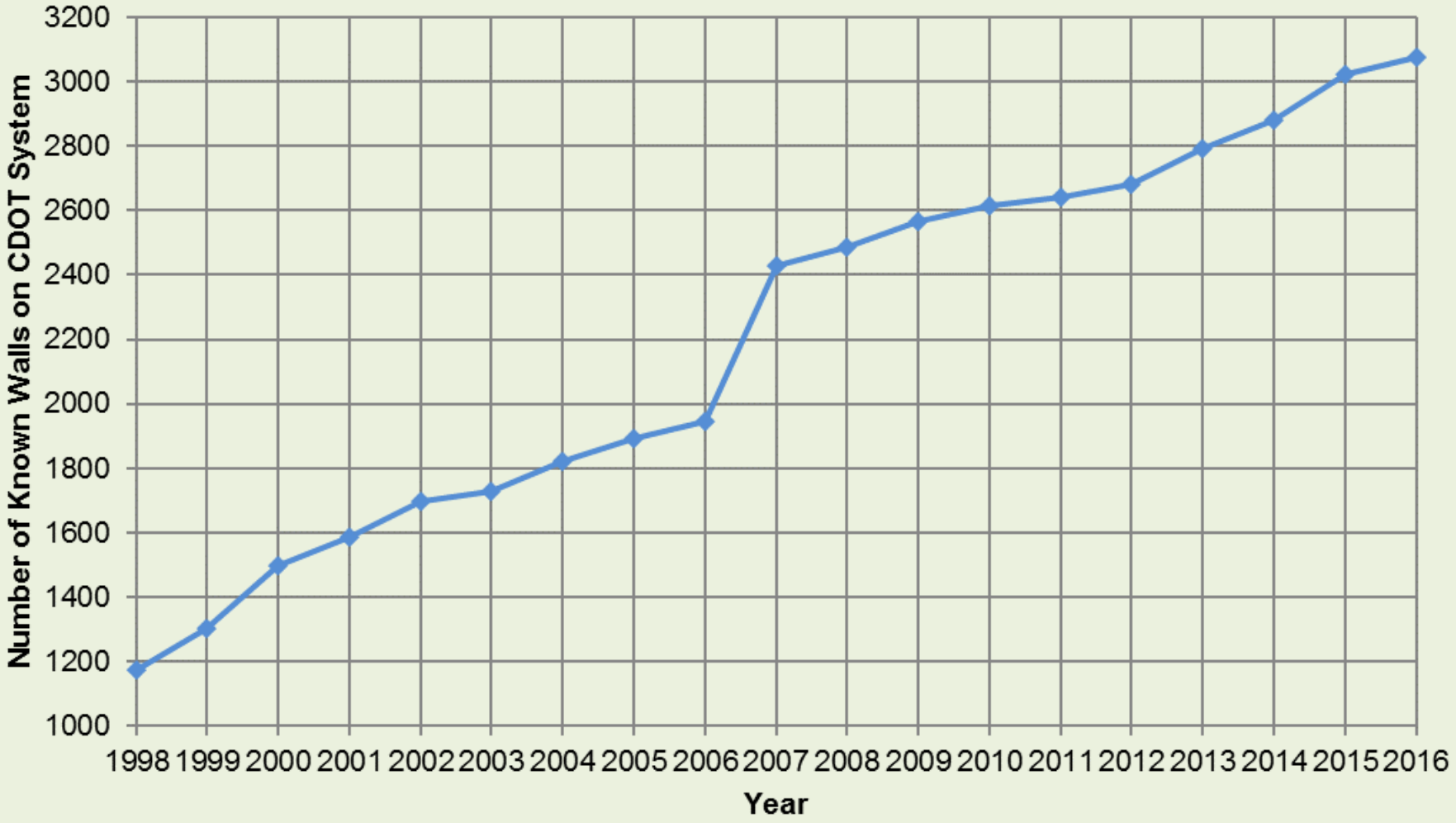
CDOT GeoHazard Site Inventory



CDOT Wall Structure Inventory



CDOT Wall Structure Inventory



Rapidly growing and relatively young asset group

Consequences and Risks

Colorado Department of Transportation

Status:

- Reporting Measures
  - Walls:
    element level and wall condition
  - Walls and Geohazards:
    Level of Risk (LOR)

LOR	Annual Exposure
A	<$1K
B	$1K-$5K
C	$5K-$25K
D	$25K-$50K
F	>$50K

- Draft plans in development

- Annual funding of around $5M-$10M
  for investment in both geohazards and walls

Vermont Transportation Department

- 3,600 rock cuts in risk based program
  - 4% (121) identified as high hazard
  - Risk evaluated based on degree of customer (traffic)

		Customer Service Level *(Exposure)*				
		1	**2**	**3**	**4**	**5**
Rockfall Hazard Ranking Score	**500+** *(High Hazard)*	7	2	1	9	0
	300 to 500 *(Medium Hazard)*	32	6	12	24	0
	300– *(Low Hazard)*	9	6	4	9	0

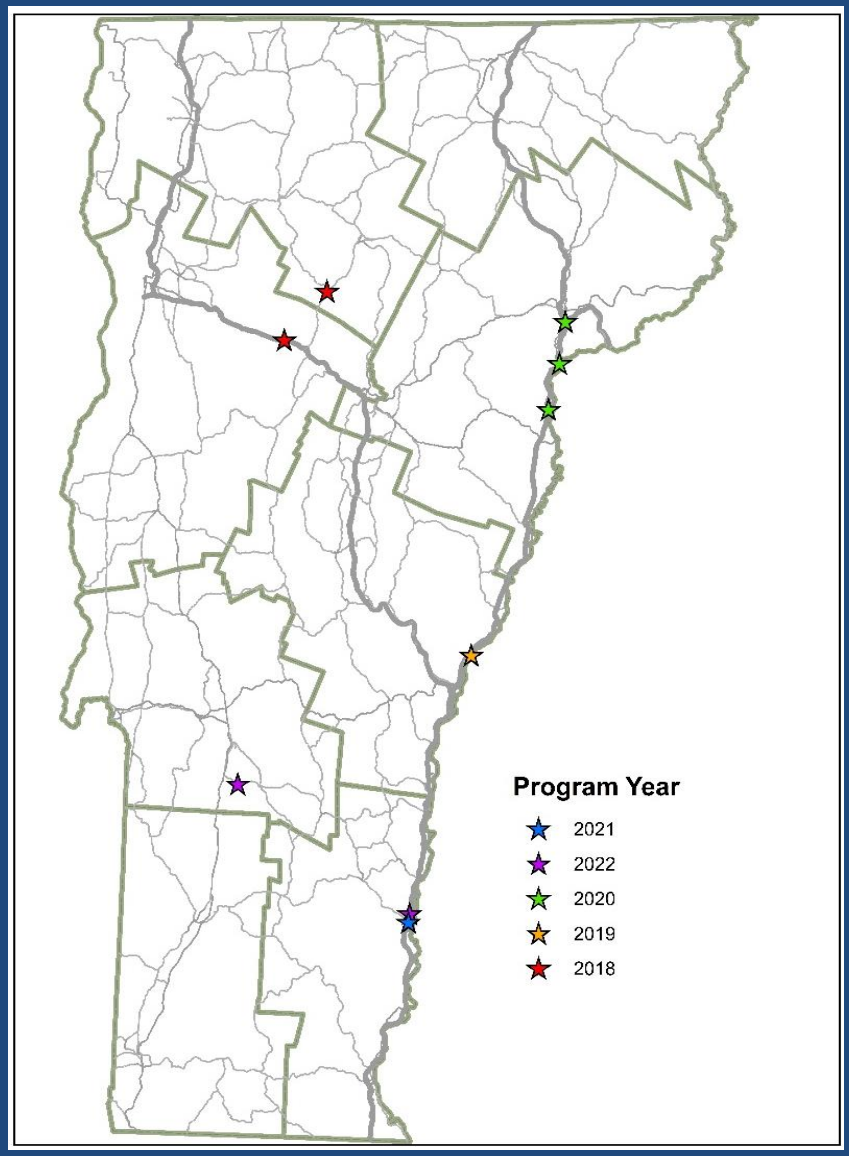
High Priority
Medium Priority
Low Priority

Vermont Transportation Department

- Reporting measure
  - Access Sustainability Index (ASI)
    - ratio of available funds/needed funds
    - Communicates funding need of program to deliver improvements

Vermont Transportation Department

- Status
  - Planning a 5 year, $4.2M investment program for 9 rock slopes with State funds
  - Mitigation selected based optimized financial analysis over life-cycle
  - Starting wall inventory

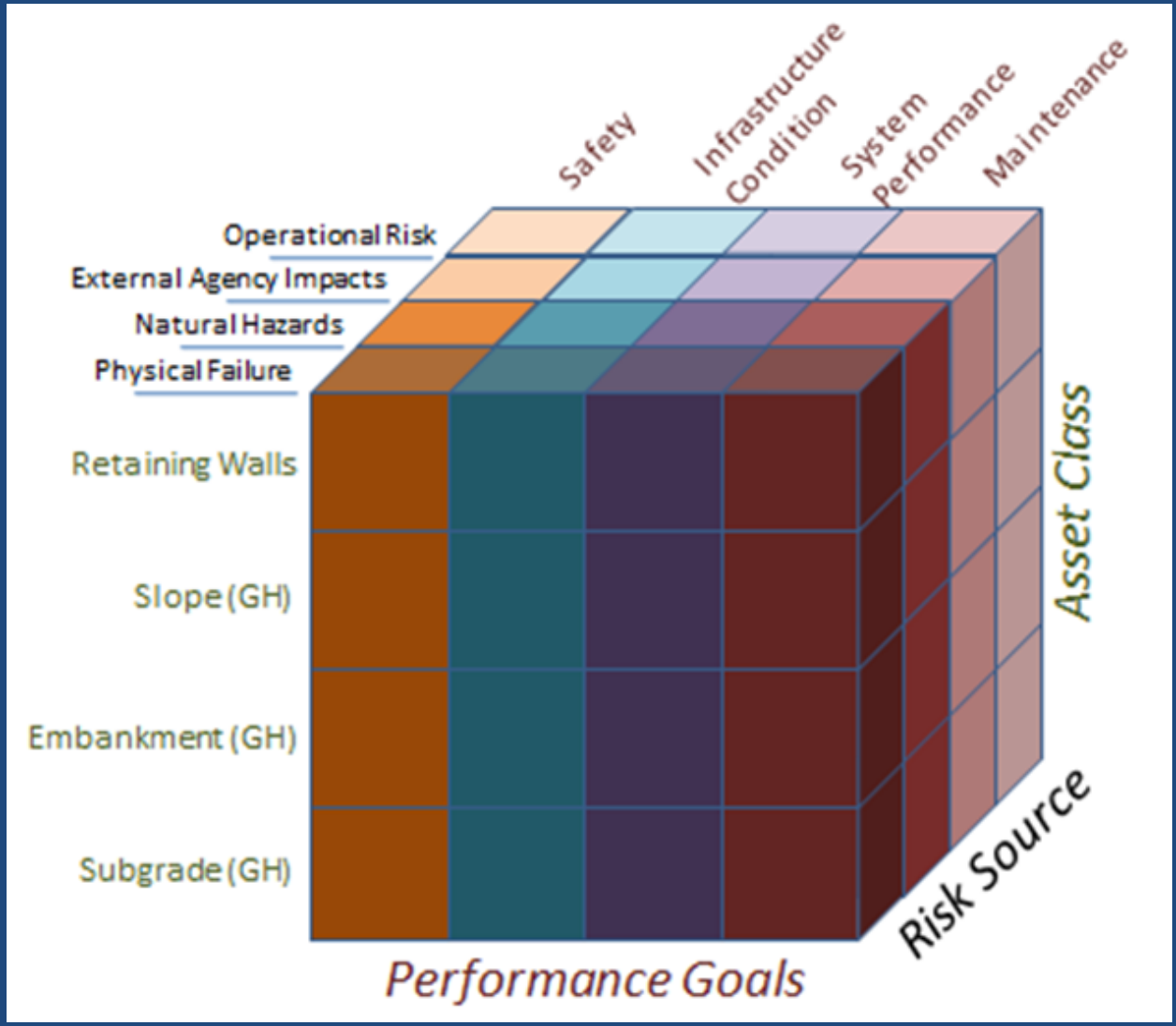


What has enabled Geotechnical Asset Management in U.S. (so far)

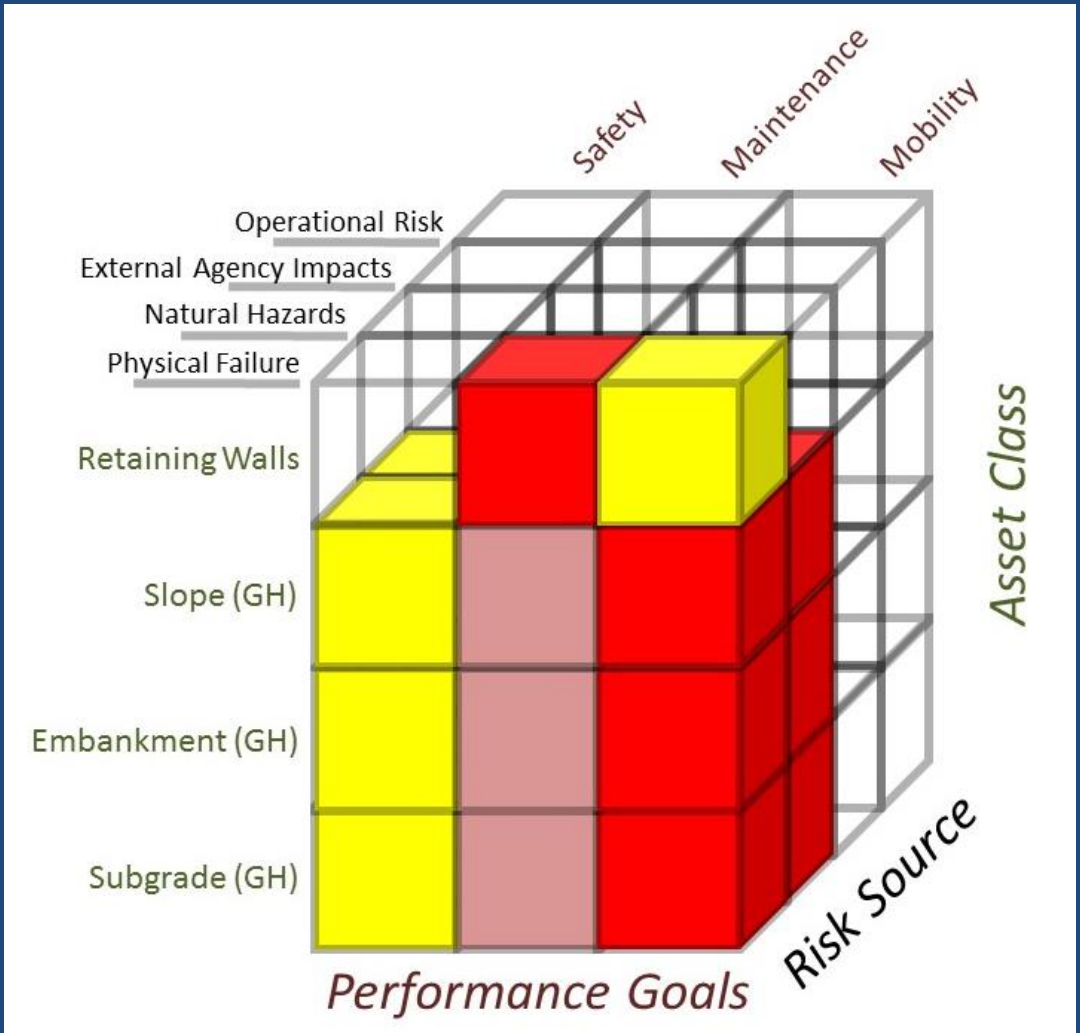
- Dedicated state funds, not waiting for outside funding/direction
- Recent major natural hazard event that highlighted need
- Personnel changes
  - Geotechnical staff interested in asset management
  - Planning and management staff who understand value
- Change management programs for implementing new efforts in a large agency
- Staff that can assume a proactive role versus solely being assigned to design and construction support duties
- Prior experience with early GAM (e.g. rockfall sites)
- Executive leadership that understand risk, asset management, and performance measurement

Communicating the Risk to Others

- Risk Cube



Communicating the Risk to Others



- Illustrating outcome Colorado DOT outcomes

Going Forward in U.S.

- Implementation Manual Completion in 2018
  - Apply lessons learned from state interviews and established asset management programs
  - Propose simple maturity approach with options for more complexity if desired

What do State DOTs Suggest for Enabling

- Training on implementation for geotechnical staff
  - data awareness and management
  - financial planning
  - and life-cycle analysis
- Training on applying risk management in financial and life-cycle scenarios
- Dedicated staff resources to implement and maintain the program

Concepts and Frameworks for U.S. Implementation

- Models to emulate
  - Network Rail
    - Mature risk-based GAM program
  - Switzerland PLANAT program
    - Functioning life-cycle cost-benefit process for natural hazard mitigation among multiple funding partners
  - Infrastructure Maintenance Management Manual
  - USACE Water Infrastructure
    - Aggregation of risk and conventional software usage
  - Vermont, Colorado, Alaska DOTs
    - Lessons learned in early GAM implementation experience

Challenges for U.S. Implementation

- No regulatory requirement expected in near term
  - States must fund and Federal funds are limited
- Geotechnical asset management will need to compete on measurable risk and cost benefit
  - Improve performance for the same cost; or,
  - maintain current performance at a lower cost
- While most see need, there is reluctance due to:
  - Absence of Federal or other requirement for GAM; or
  - Potential liability associated with adverse reporting to public or FHWA (may do GAM but not report)

Challenges for U.S. Implementation

- Staffing for implementation
  - Geo-professionals and resources to develop plans (e.g. Executives and TAM staff aren't going to start)
- Data for tracking and measurement
  - Department costs
  - Delay and safety performance
- Differentiating between natural hazard and physical failure – not a routine process or data point yet

Important Distinction for GAM: Physical Failure vs. Natural Hazards

Important Distinction for GAM: Physical Failure vs. Natural Hazards

Funding opportunity?

Assets Beyond Right-of-Way (ROW)

- Current U.S. practice
  - DOTs often include hazardous assets beyond ROW in inventory
  - Typically responsible for first (and only) response and funding
    - More likely to recover costs from private owners
    - Adjacent public lands usually don't have funds for assistance

Funding opportunity?

U.S. Implementation Guidance

- Overcoming barriers
  - Communicate performance/exposure to executives in absence of top down objectives. Inform the level of risk acceptance.
  - Make the business case for voluntary investment
    - Slope sites and walls have done well in inventory and assessment steps, but difficult to complete the management cycle
  - Start simple with continuous improvement
  - Common definitions and terminology between agencies

U.S. Implementation Guidance

- Measuring Performance
  - Performance measures need to connect to broader agency goals such as investment, risk exposure, and performance (Outward Measures)
  - Condition data more applicable internal to program (Inward Measures)
  - Need flexibility to connect to variable strategic goals

- Risk and Risk Management
  - Direct risk analysis at performance of asset rather than value

U.S. Implementation Guidance

- Return on Investment
  - Tools to show benefit from reduction in future adverse situations/events
  - Adaptable ROI analysis frameworks for a geo-professional

	Annual Risk Exposures			Expected Annual Risk Exposure
	Safety	Mobility	Maintenance	
Existing/Baseline GAM Risk Exposure	$ 5,000	$ 50,000	$ 25,000	$ 80,000

Proposed Risk Management Treatment Option 1 (e.g. Instrumentation)	Probability of Improvement to Safety Exposure	Probability of Improvement to Mobility Exposure	Probability of Improvement to Maintenance Exposure		Option Initial Investment Cost	Option Annual Cost	Net Benefit/ Year	5 Year Expected Net Present Value	5 Year Expected Present Value Ratio
	0.05	0.25	0	$ 67,250	$ 50,000	$ 2,500	$ 10,250	$ (1,827)	-0.04
Proposed Risk Management Treatment Option 2 (e.g. scaling)									
	0.25	0.5	0.5	$ 41,250	$ 50,000	$ 1,000	$ 37,750	$ 127,418	2.55

Assumes 2.1% annual inflation rate