# Geohazard Identification, Monitoring and Mitigation Methods Using Soil Nail Technology for Coastal, Riparian, and Hydro Related Infrastructure

By Matthew Reihl PE
October 20, 2022
WEDA

GeoStabilization International®

## OBJECTIVES OF THIS PRESENTATION

- **To introduce and define Geohazards and how they effect our critical assets**
- **Review the approach to assessing geohazards**
- **To provide an overview of infrastructure monitoring methods**
- **Discuss slope mitigation utilizing the soil-nail technology**
- **Review Coastal, Riparian and Hydro related soil nail case studies**

# WHAT IS A GEOHAZARD?



**Geohazards are naturally occurring geological phenomena that pose danger to people's lives, properties, infrastructure and communities. These include landslides, flooding and land subsidence. However, in some cases, geohazards can also be induced by human activities.**

# TYPES OF GEOLOGIC HAZARDS

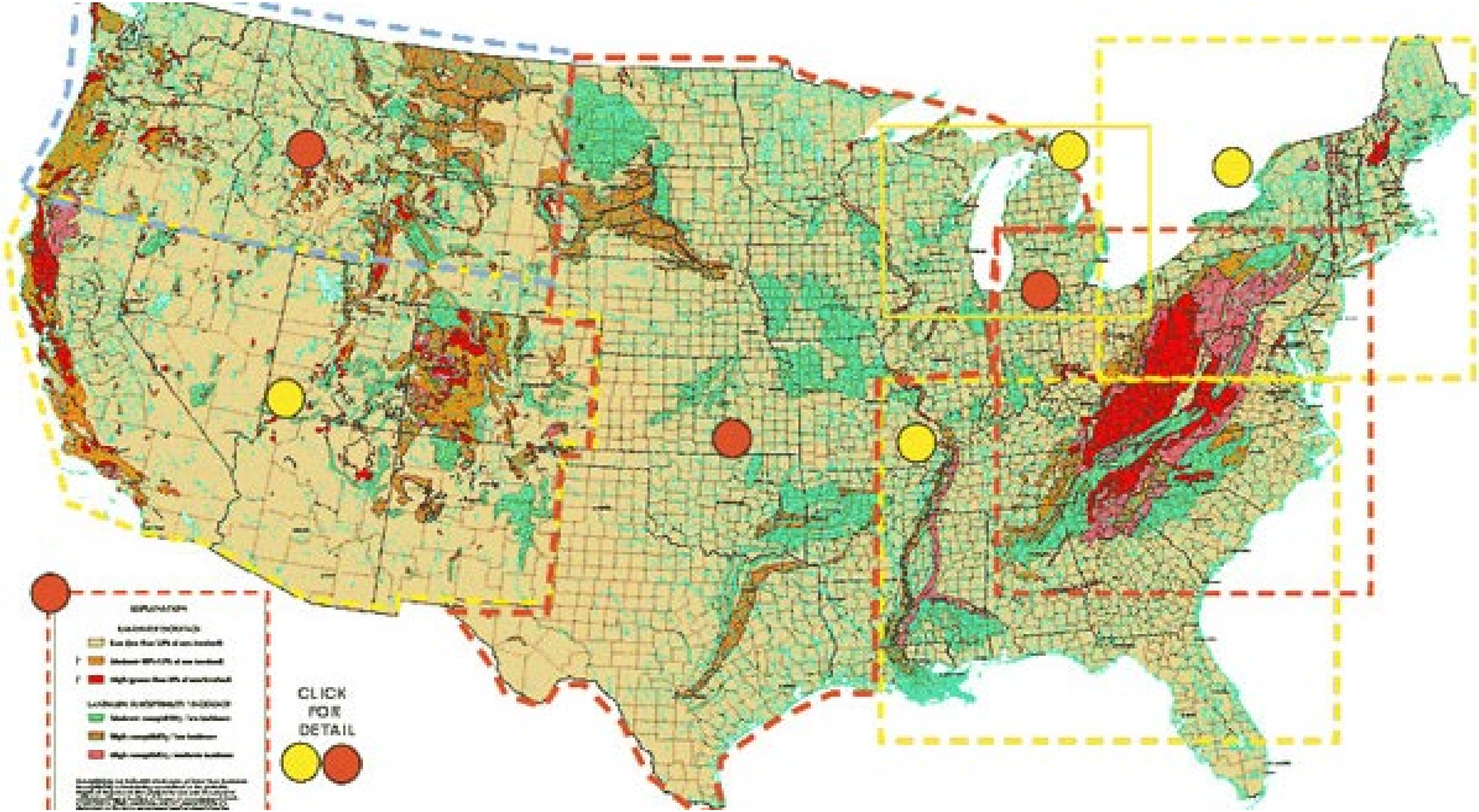
- **Unstable slopes**, such as landslides and rockfall,
  - Including aging infrastructure (end of service life)
- **Seismic** hazards, including surface fault rupture, soil liquefaction, and strong ground shaking
- **Ground subsidence/settlement** associated with underground mines (active and abandoned), surface mines, fluid withdrawal (oil and gas or groundwater), or karst


- **Hydrotechnical** (water erosion – streams

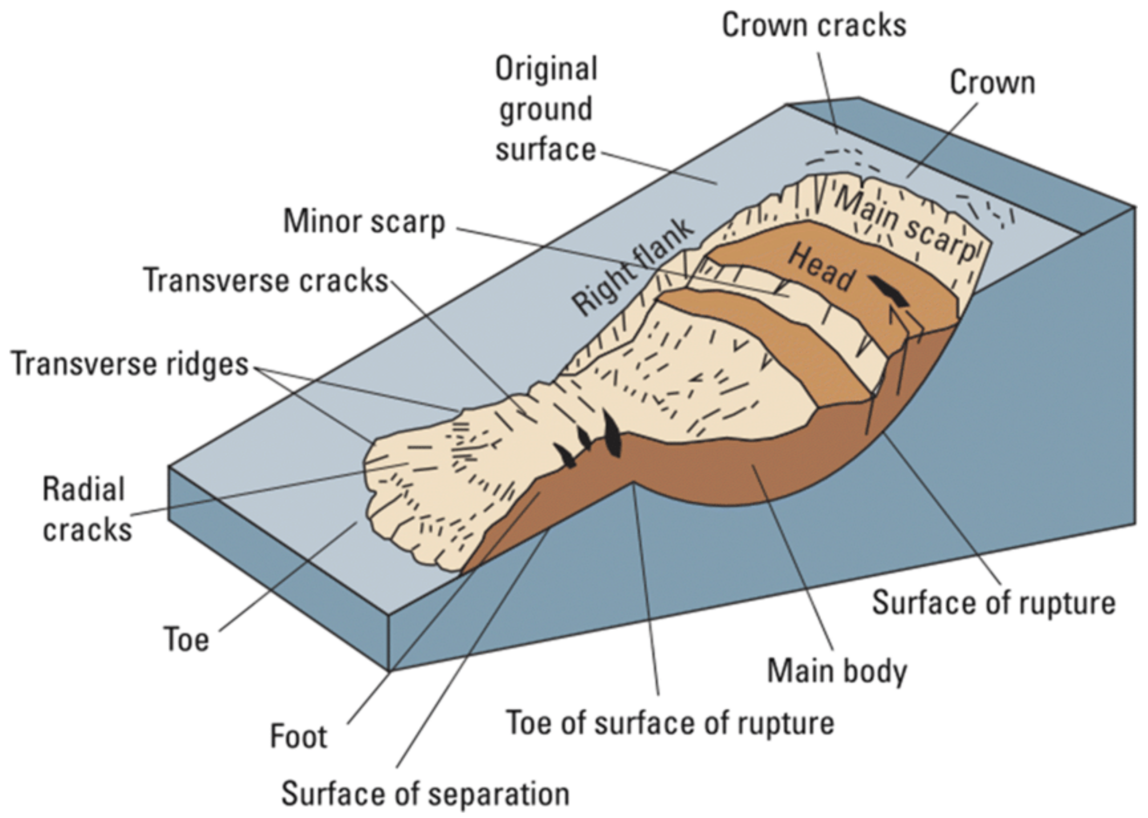
- **Expansive or collapsible soils/rock**
- **Permafrost/Frost heave**
- **Shallow Groundwater**

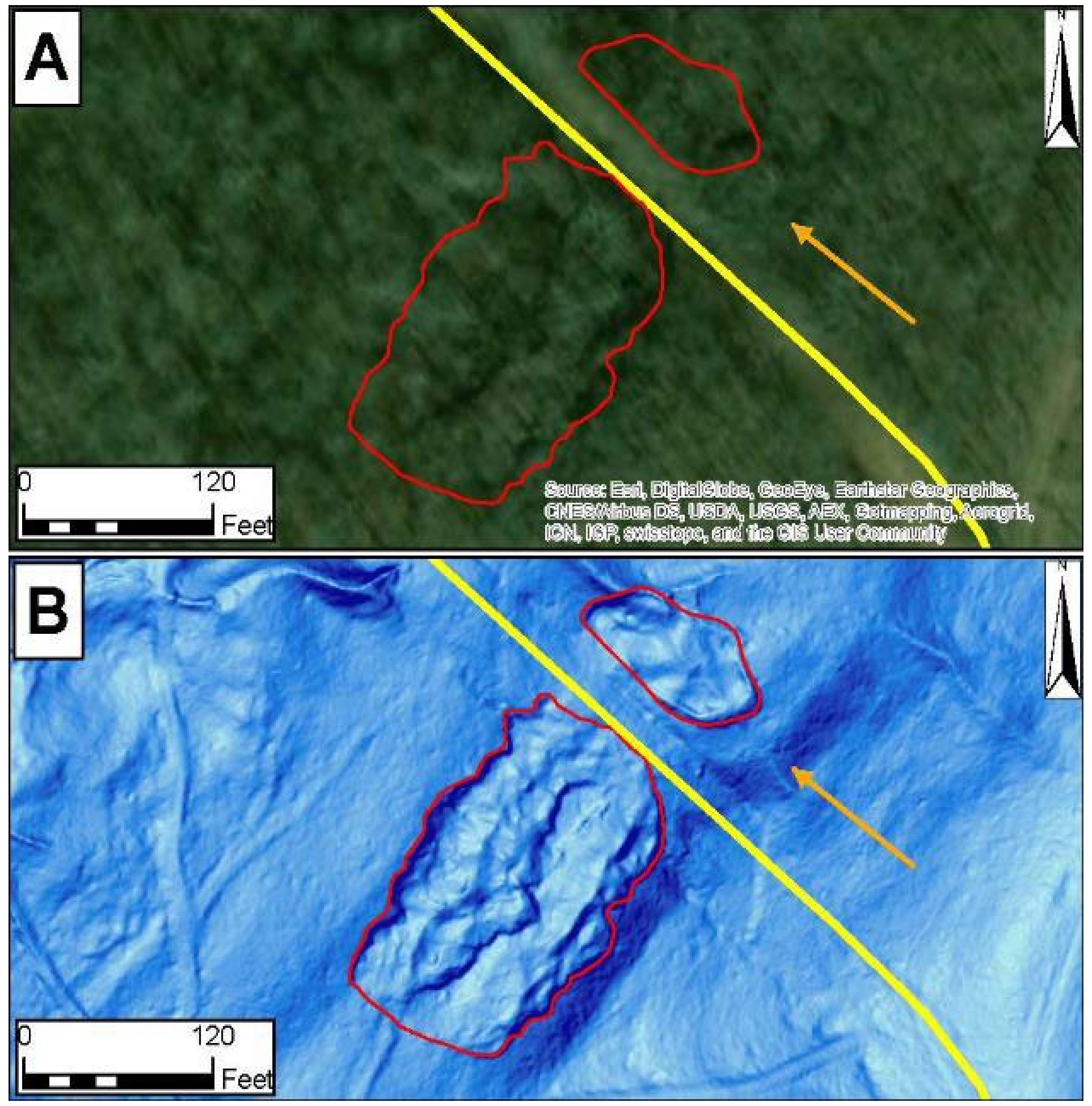

- **Meteorological hazards**, including tornadoes, hurricanes, and lightning strikes
- **Volcanic hazards**

# GEOHAZARDS – US LANDSLIDE MAP



# GEOHAZARD ASSESSMENT/MITIGATION/MONITORING

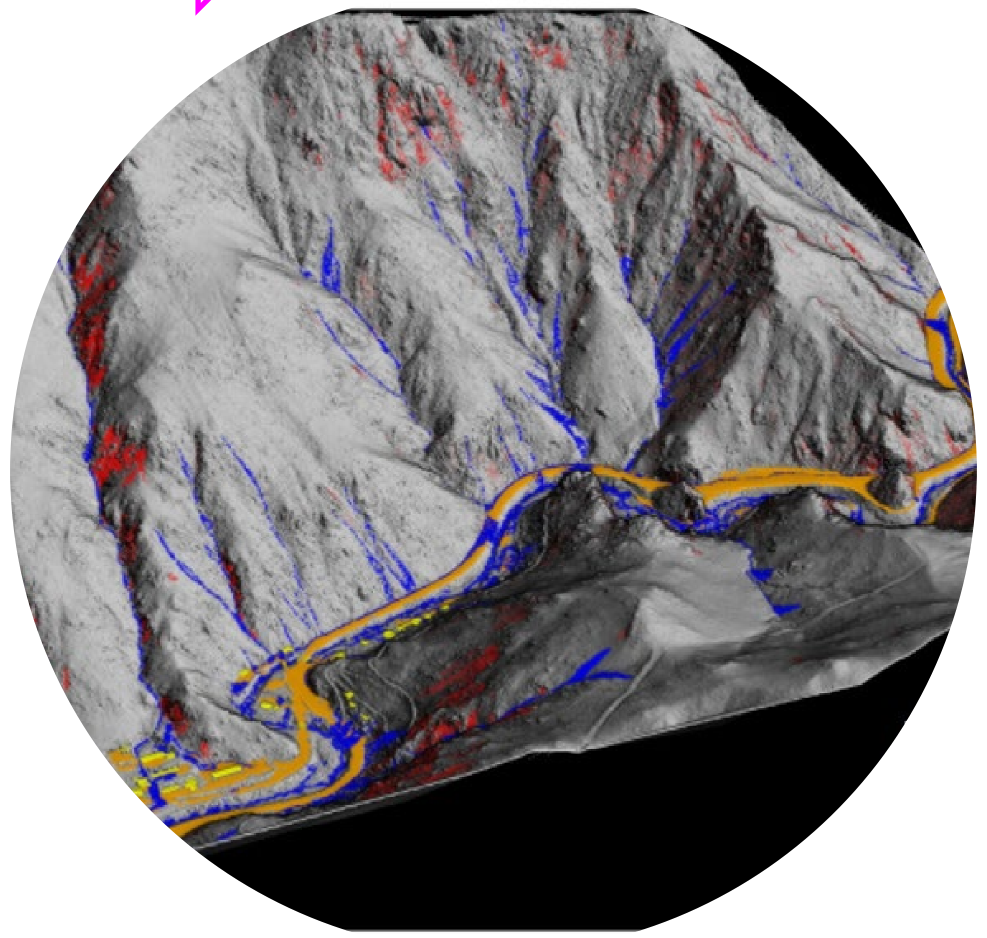



## Geohazard Assessment

## Geohazard Mitigation

## Geohazard Monitoring

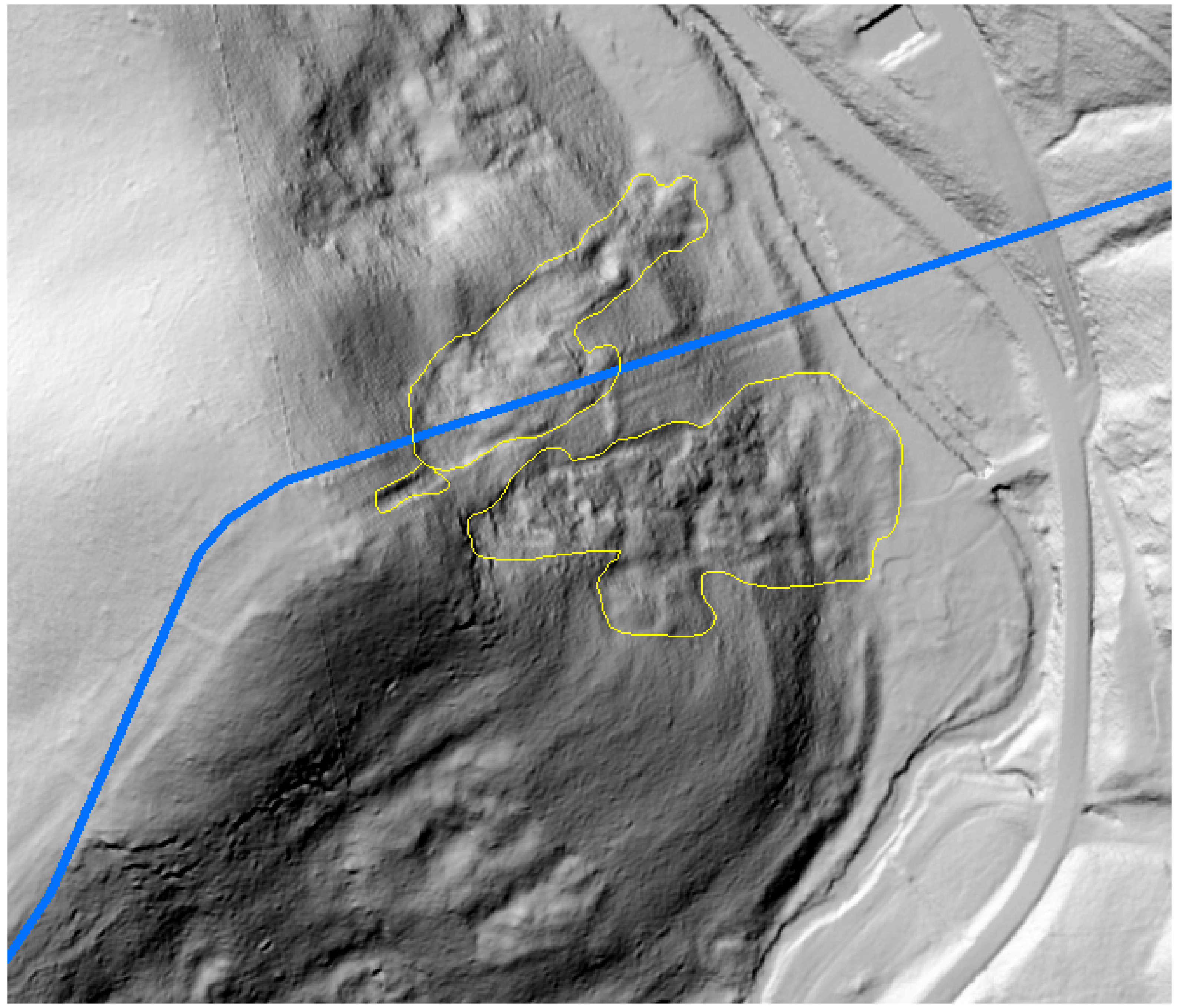


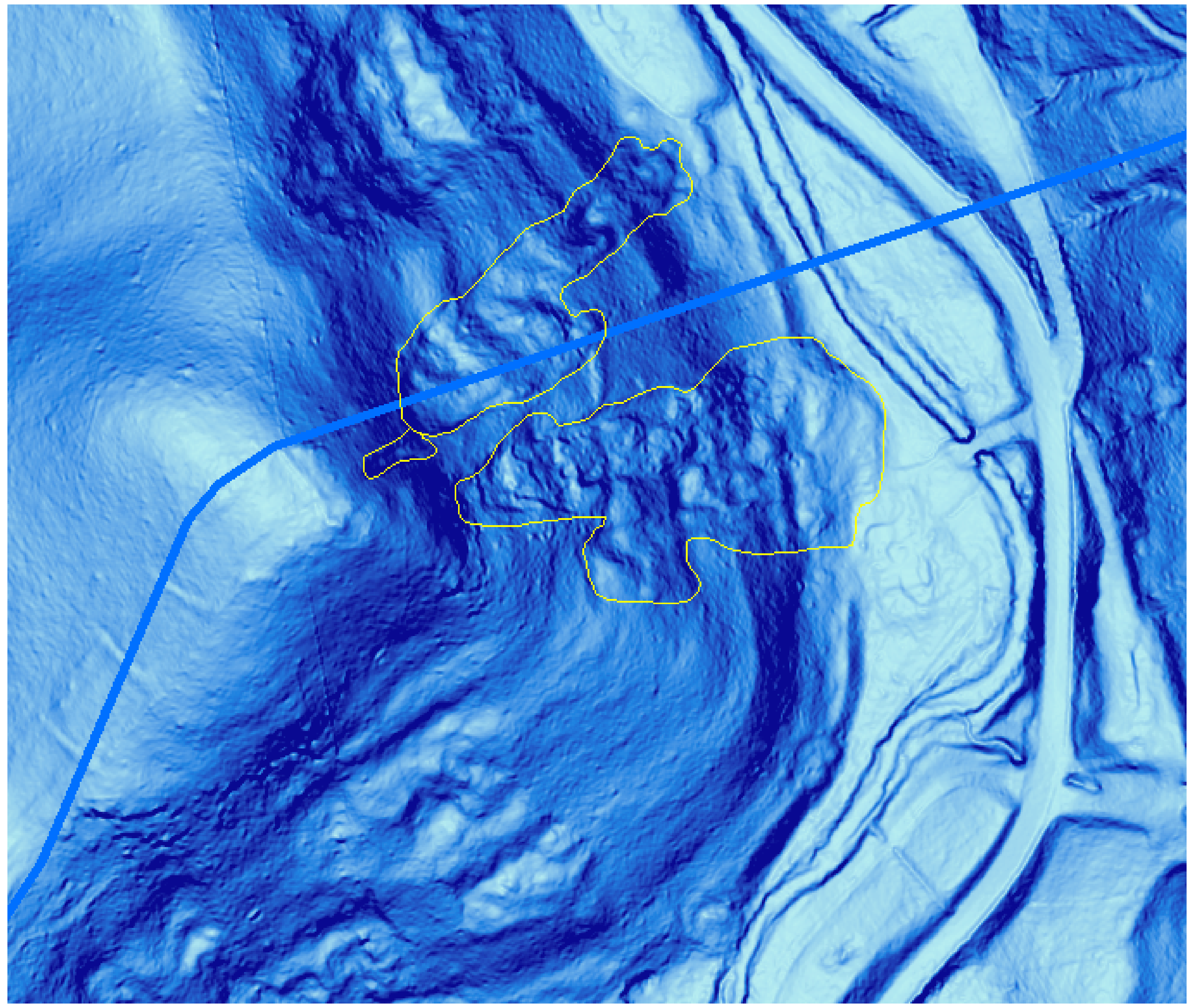
# GEOLOGIC HAZARDS – ASSESSING THE HAZARD

- Qualitative hazard classifications (**low, moderate, or high**) can be assigned
- Based on several criteria:
  - Proximity of the potential hazard to the infrastructure
  - Level of activity of the geologic process (or end of service life) that results in the potential hazard
  - Areal extent of the potential hazard
  - Perceived likelihood of the potential hazard to affect an infrastructure during its service life
  - Types of the potential consequences of the hazard to the respective infrastructure

# GEOLOGIC HAZARDS:  PHASE I ASSESSMENT

- Initial phase in phased approach
- Typical on the Corridor or Regional-scale to preliminarily identify geologic hazards along or near the infrastructure
- Desktop assessment using available data (public lidar) and information (this phase may also include an aerial reconnaissance [e.g., helicopter])

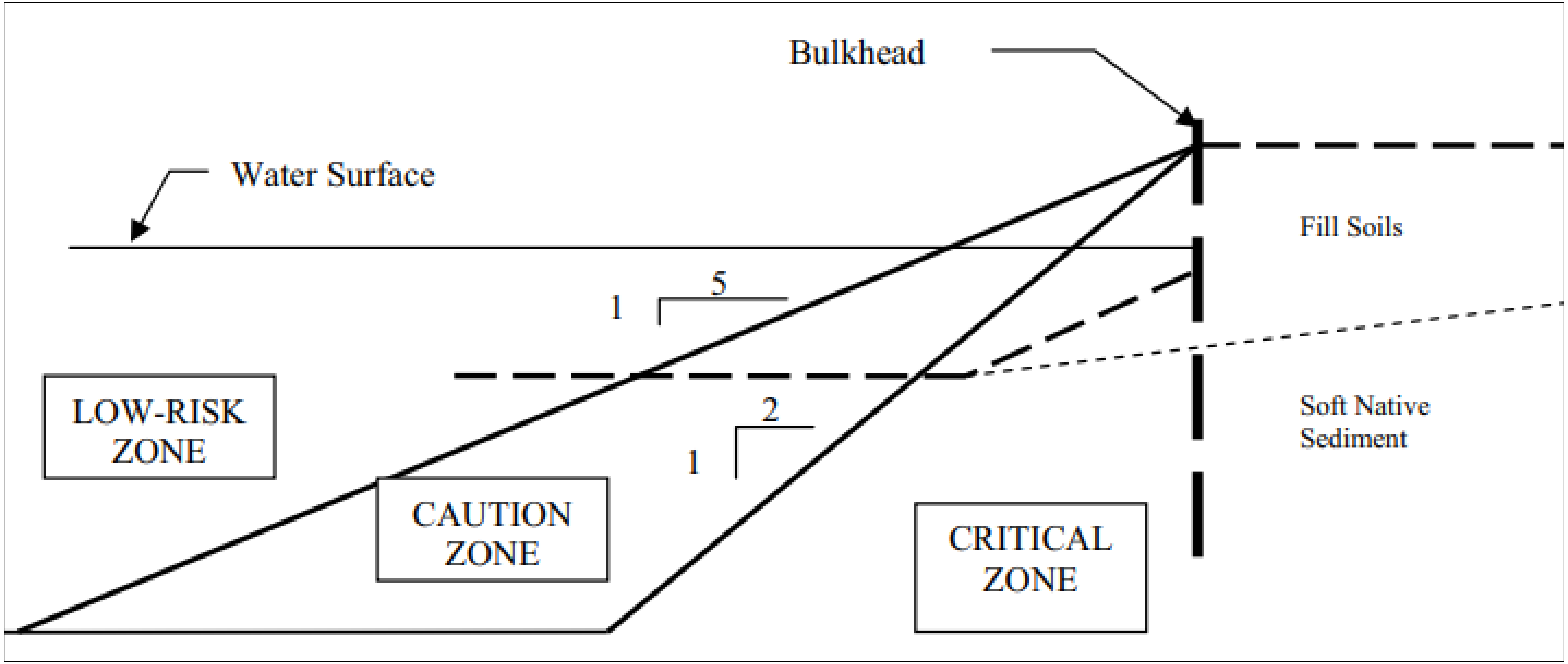




# EXAMPLE PHASE I ASSESSMENT CLASSIFICATION

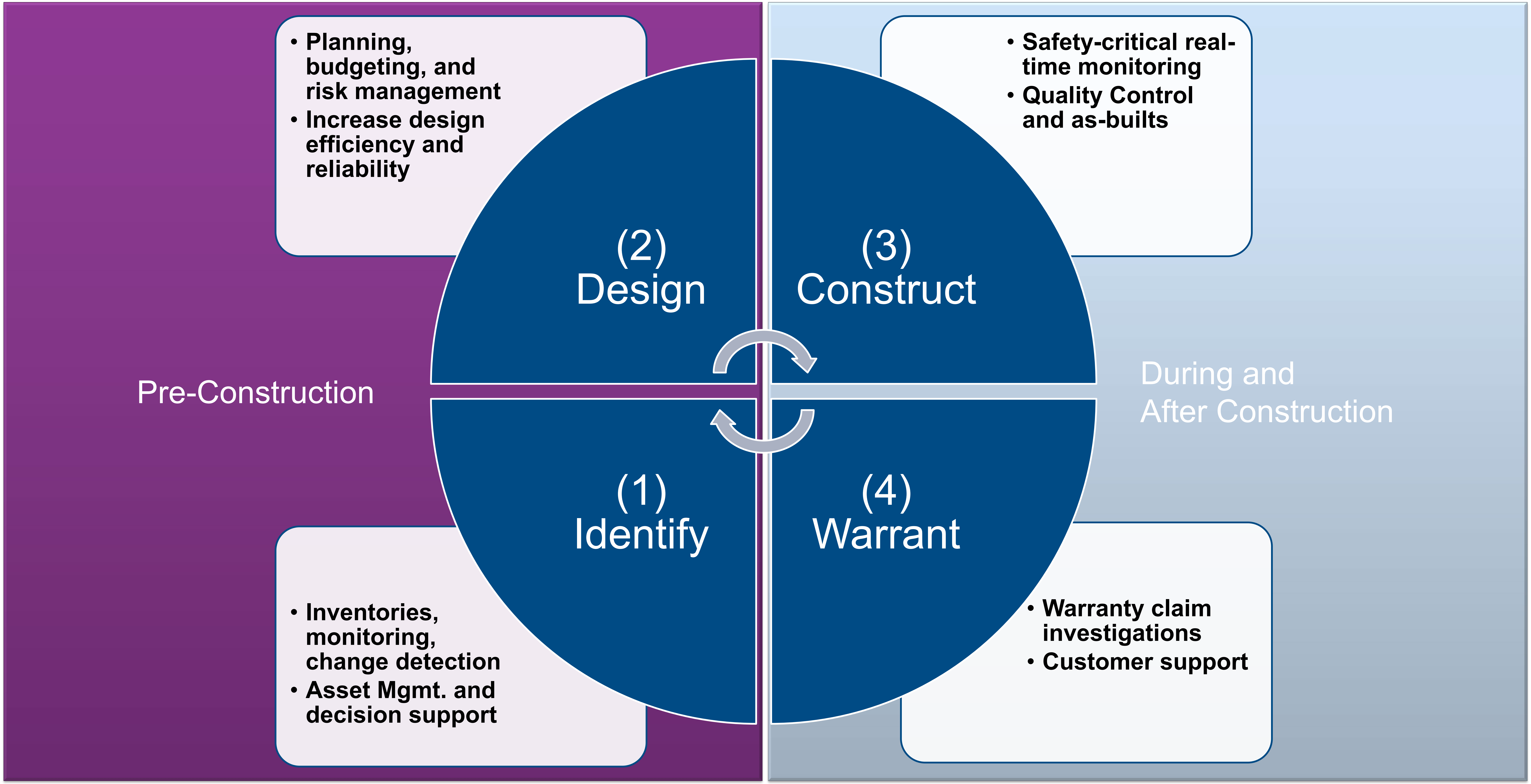
| Low | Moderate | High |
|---|---|---|
| - Dormant or relict landslide (older than a few hundred years) crossed by Channel with low potential for renewed activity.<br>- Shallow, small stream bank slump that is localized and away from other infrastructure on the slopes adjacent to the channel. | - Dormant landslide crossed by Channel with potential for renewed activity.<br>- Active landslide within 30 m of Channel with lateral limits or failure surface that do not intersect a pipeline.<br>- Critical infrastructure above the steepest cross section along a planned dredge. | - Active landslide / instability adjacent to the Channel that may pose a hazard to infrastructure.<br>- Structures reaching end of service life that may be showing signs of excess strain/corrosion.<br>- Historic structures adjacent to the channel |

# EXAMPLE PHASE I ASSESSMENT CLASSIFICATION



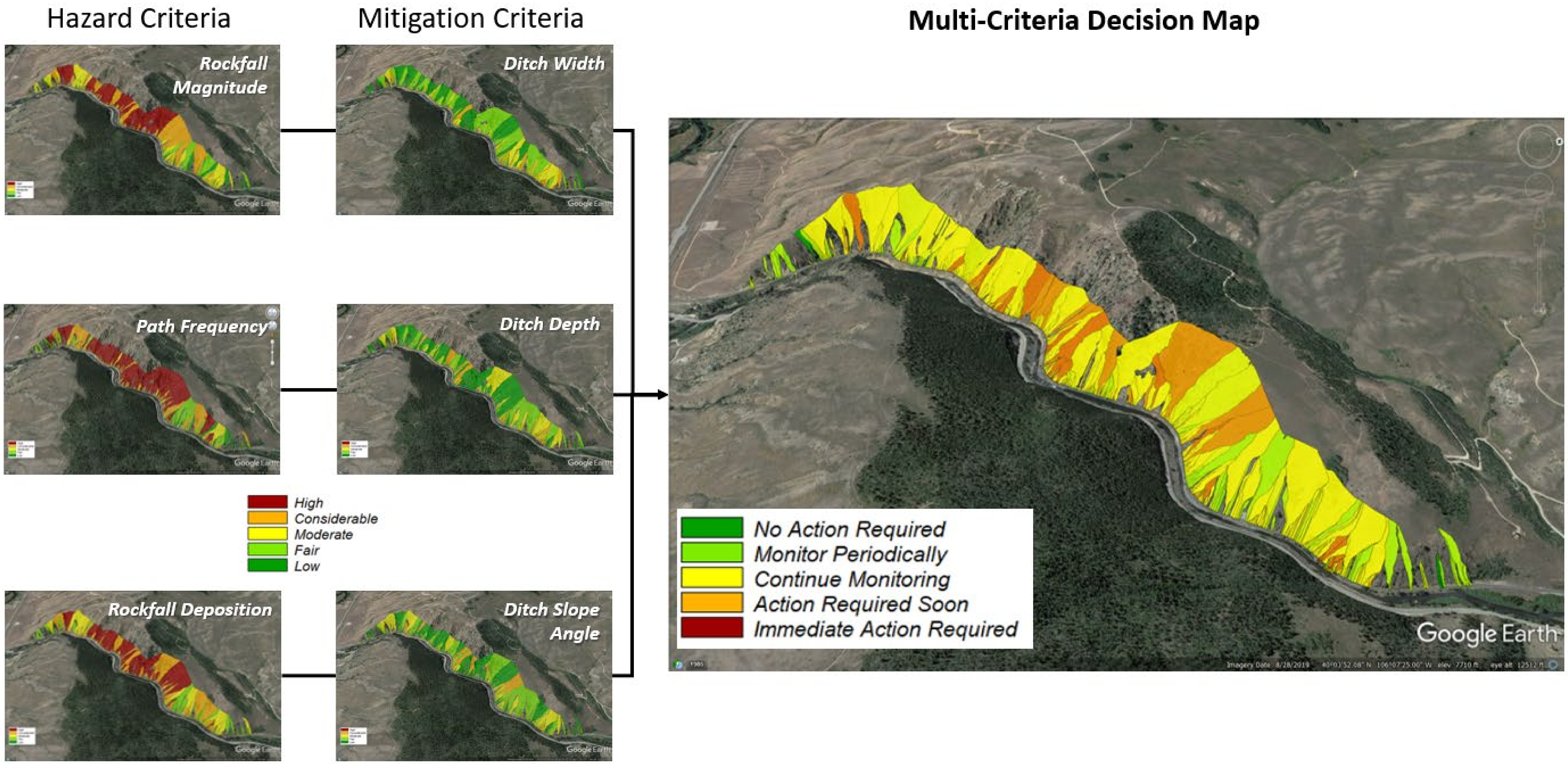

Courtesy of MT Otten "Environmental Dredging versus Shoreline Stability"

# THE GAMM VALUE CHAIN



# Example – Road Corridor Landslide Activity

## Geohazard Asset Management—Rail Corridor

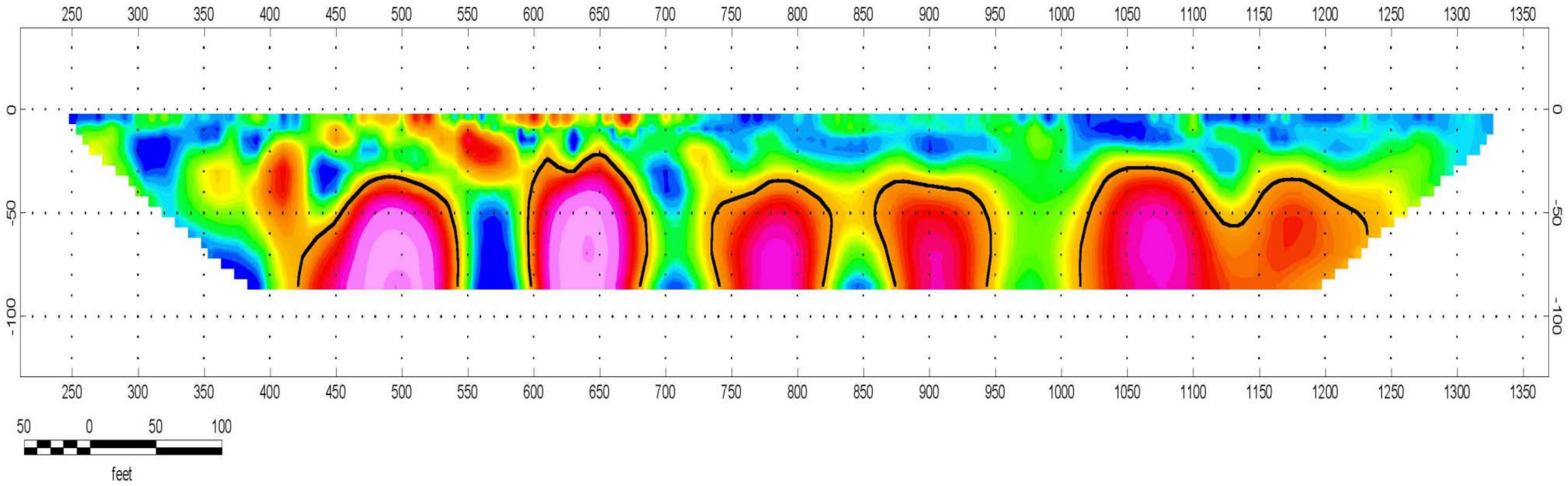


# GEOLOGIC HAZARDS: PHASE II ASSESSMENT

- Site-specific, but non-intrusive study focusing on hazards identified during Phase I
- Typically consists of a geomorphic and geologic ground reconnaissance, and/or more detailed research to gain a better understanding of the location, nature, extent, and potential effect to the infrastructure.

# GEOLOGIC HAZARDS:  PHASE III ASSESSMENT

- Detailed site-specific investigation and analyses to develop monitoring and mitigation designs and support implementation
- May include intrusive investigation techniques (e.g., drilling or test pitting/trenching) or non-intrusive techniques (e.g., geophysics)
- May include detailed engineering analyses and design



# GEOHAZARD MONITORING APPROACH/METHODS

**Monitor the hazard (e.g., the landslide)**

- Observational (visual)
- Surface survey (geodetic)
- Subsurface survey (inclinometers)
- Subsurface survey (extensometers)
- Groundwater (piezometers)
- Repeated LiDAR
- Repeated InSAR

**Monitor the structure (e.g., the stresses on the actual structure)**

- Strain gauges
- Tilt meters
- Inclinometers

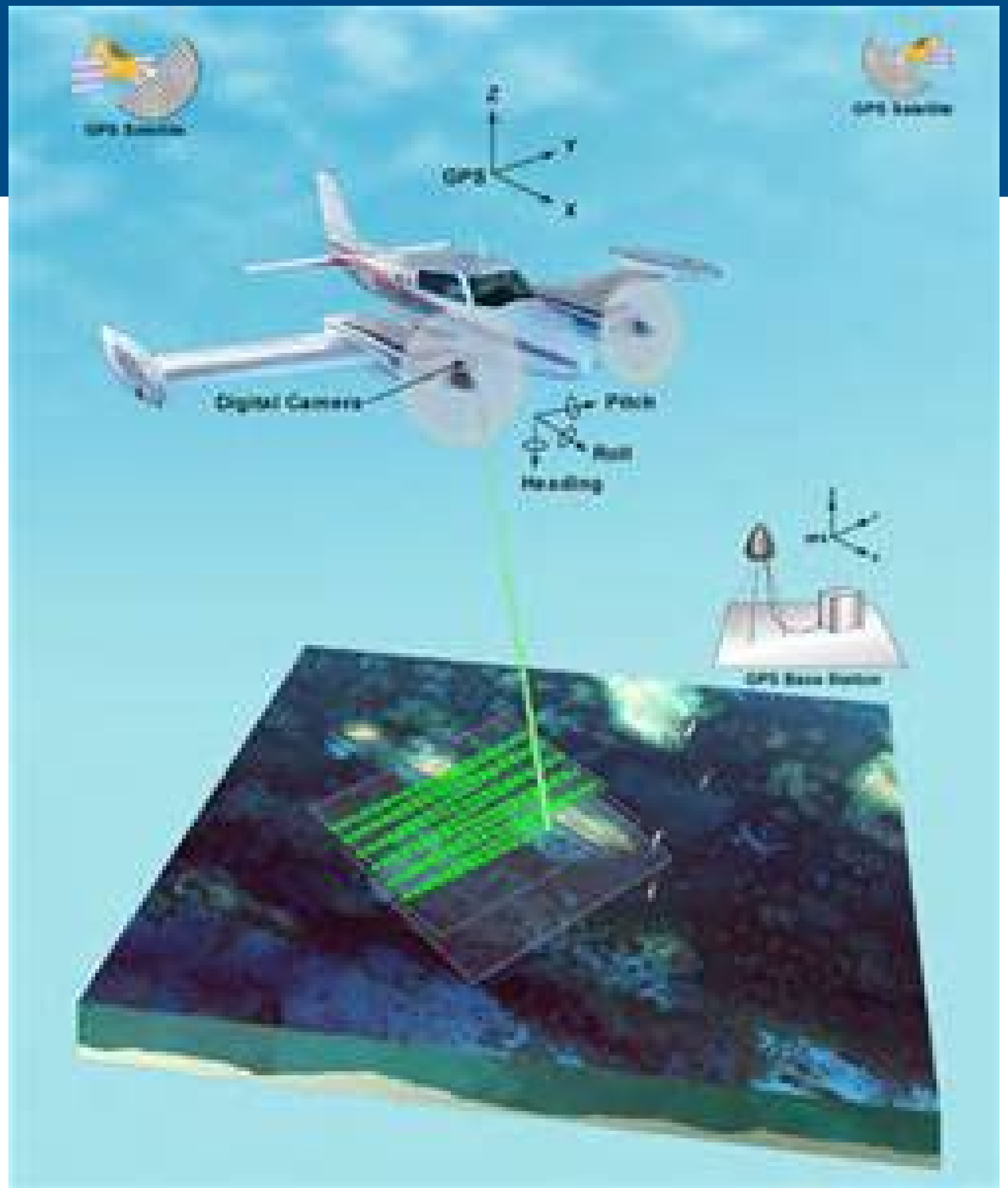
# MONITORING WITH LIDAR

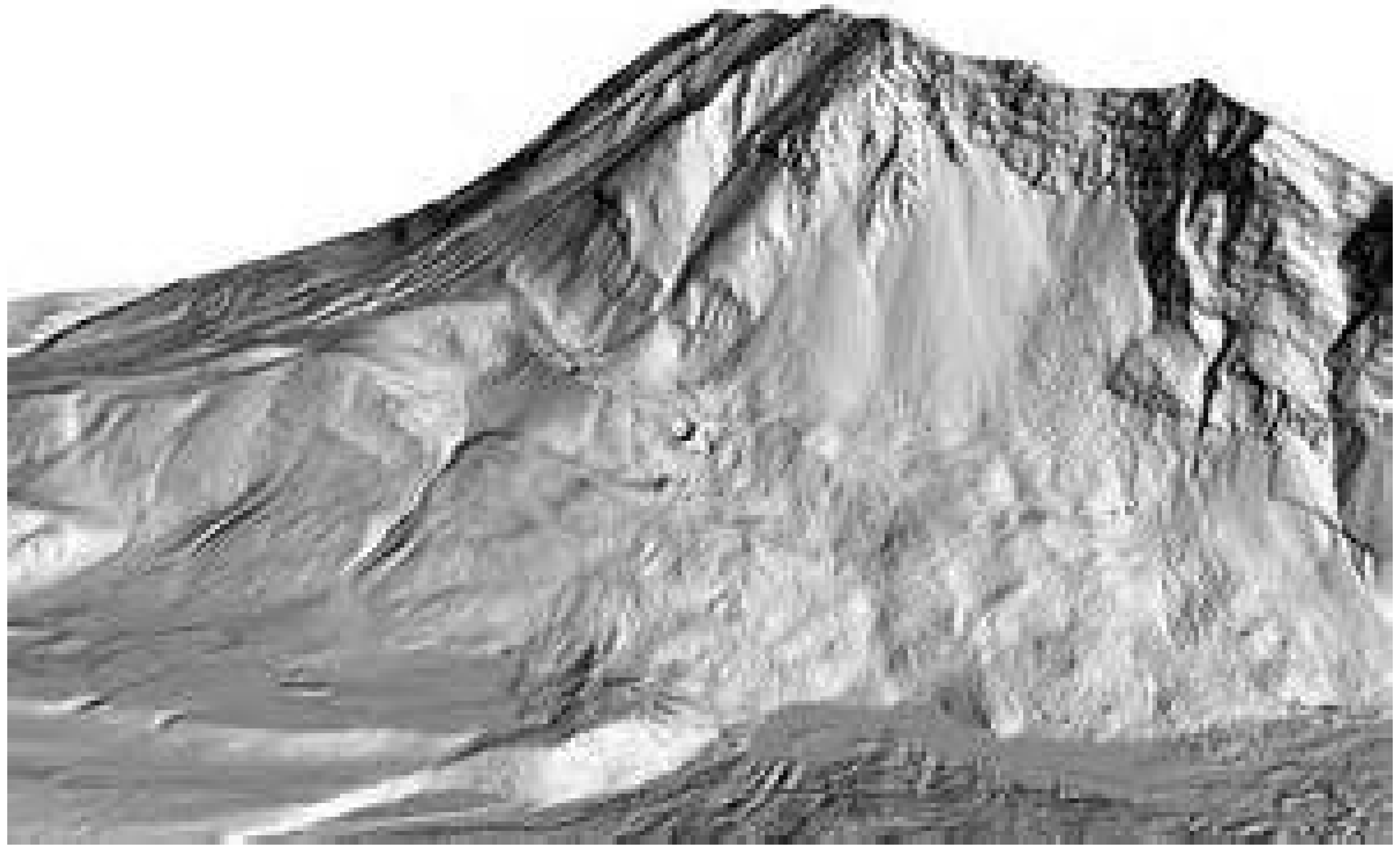
- **Li**ght **d**etection **a**nd **r**anging (LiDAR)
- Active system / Record discrete sample points
- Measures distance by illuminating a target with a laser and analyzing the reflected light

LIDAR allows for high resolution – characterization and monitoring of landslides.

**Extensive, automated, geometric filtering to remove tree canopy.**

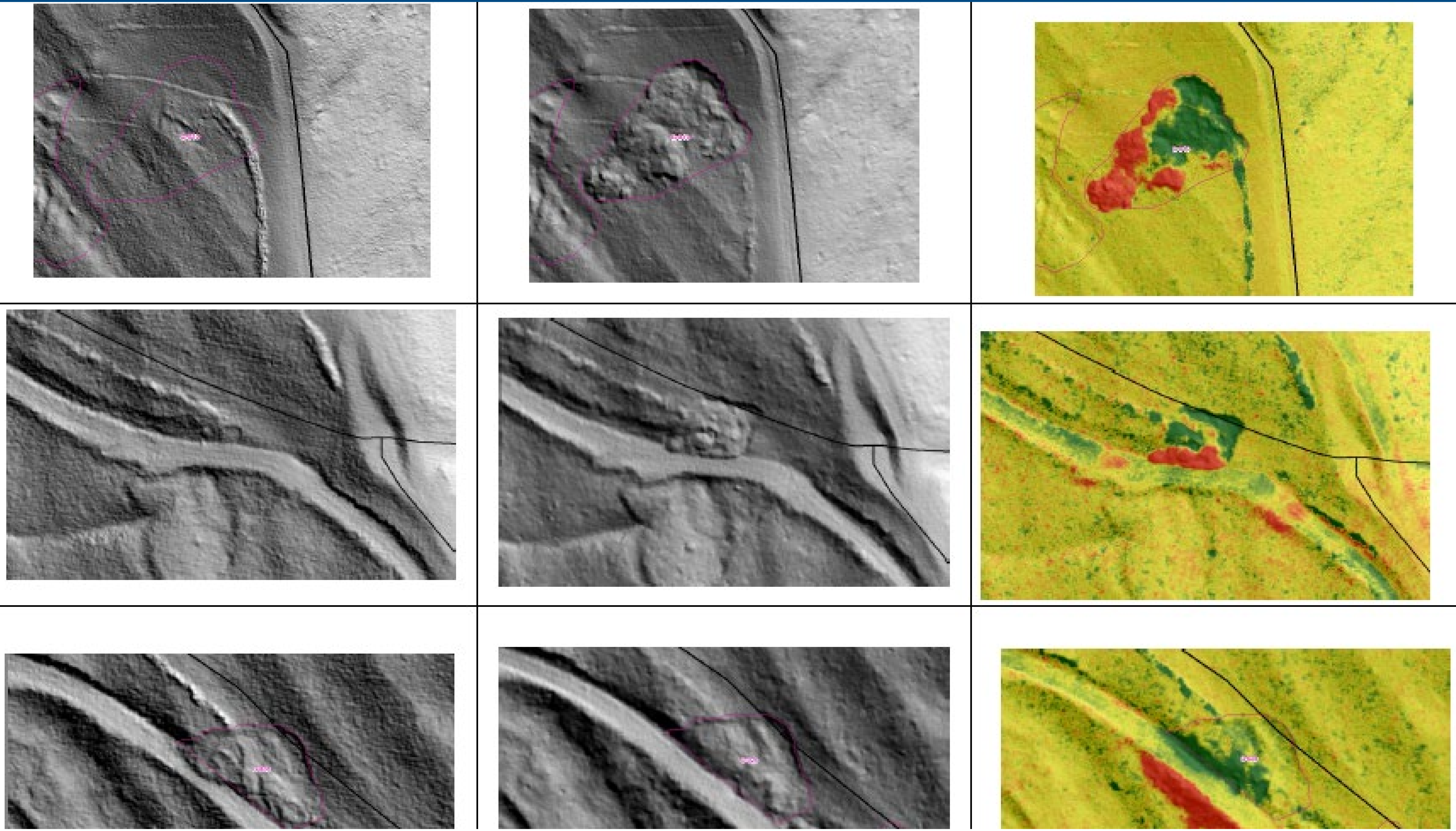
Repeated LiDAR surveys allow documentation of location, distributions, and comparison of amounts/rates of slope change.





(From USGS)

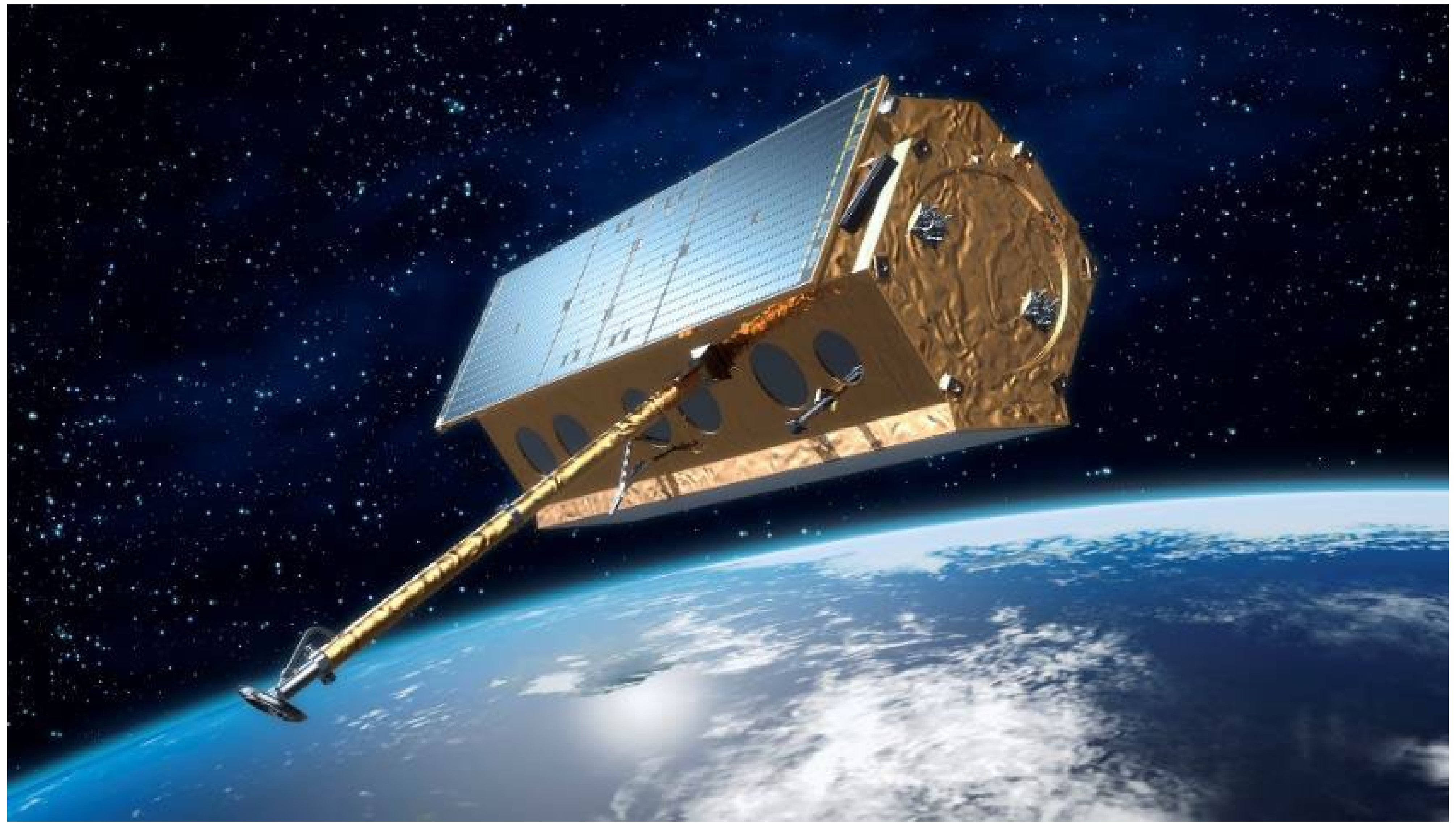
# HAZARD MONITORING – REPEAT LIDAR (CHANGE DETECTION)

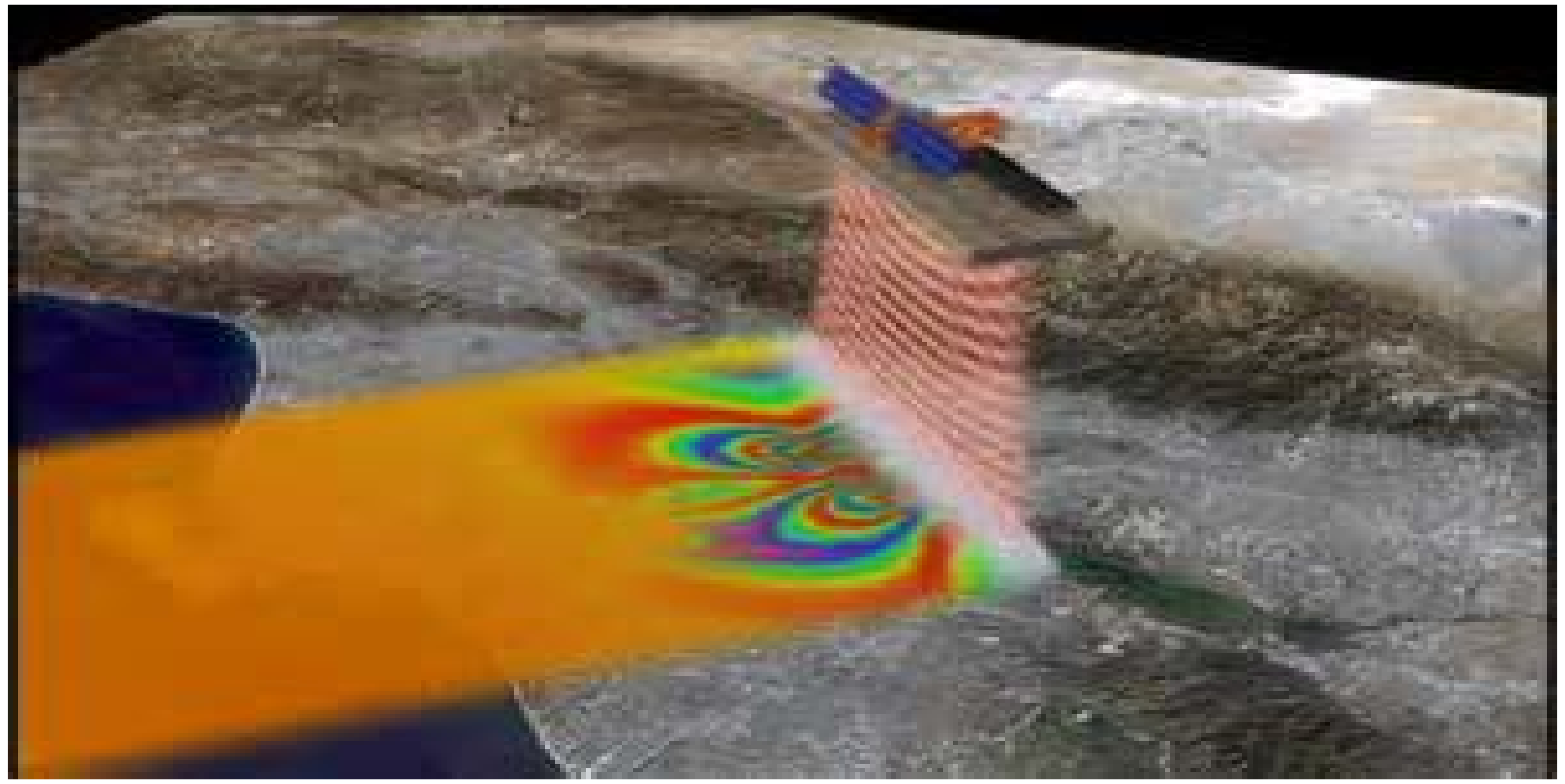


# MONITORING WITH INSAR

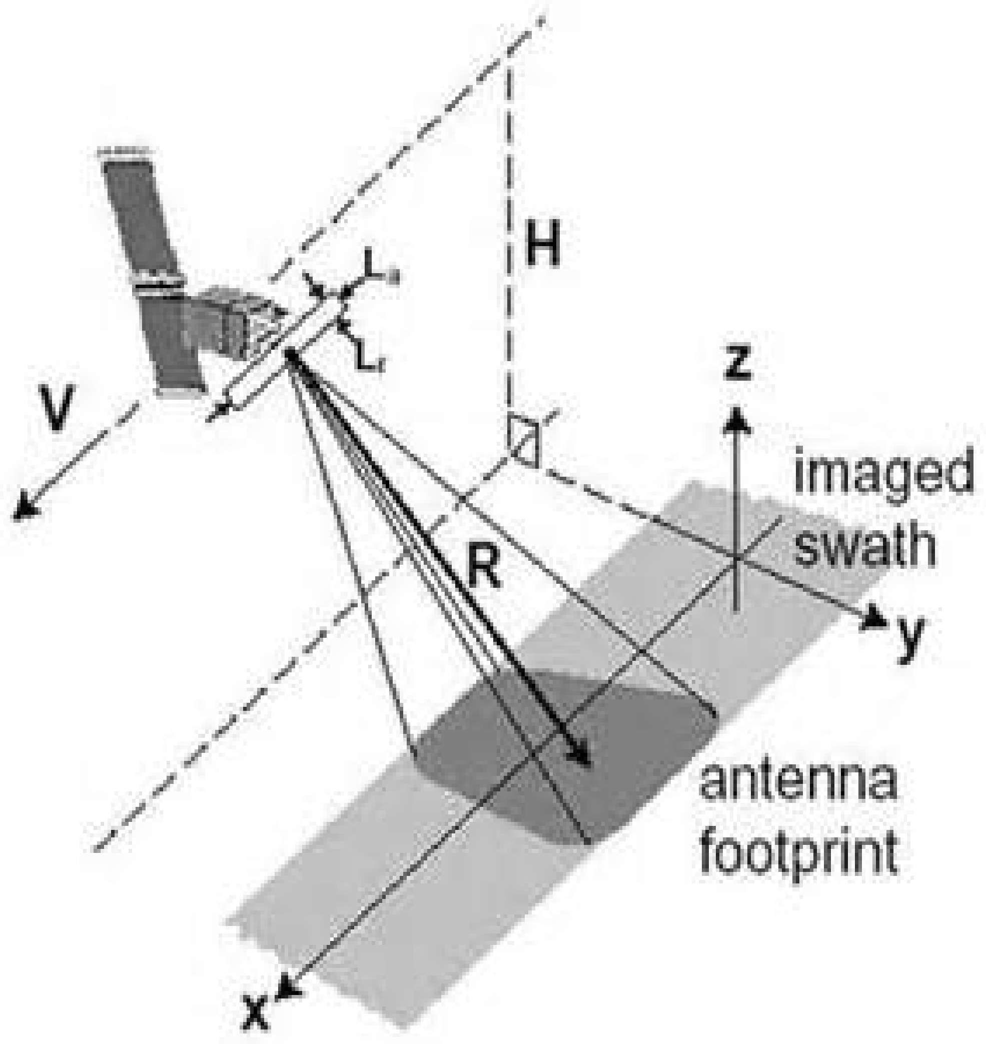
Satellite-based (polar orbiting) and side looking radar - Synthetic Aperture Radar Interferometry (InSAR).

InSAR compares phase variance between two or more successive passes of satellite to detect/monitor differential ground movement.





(from NASA)

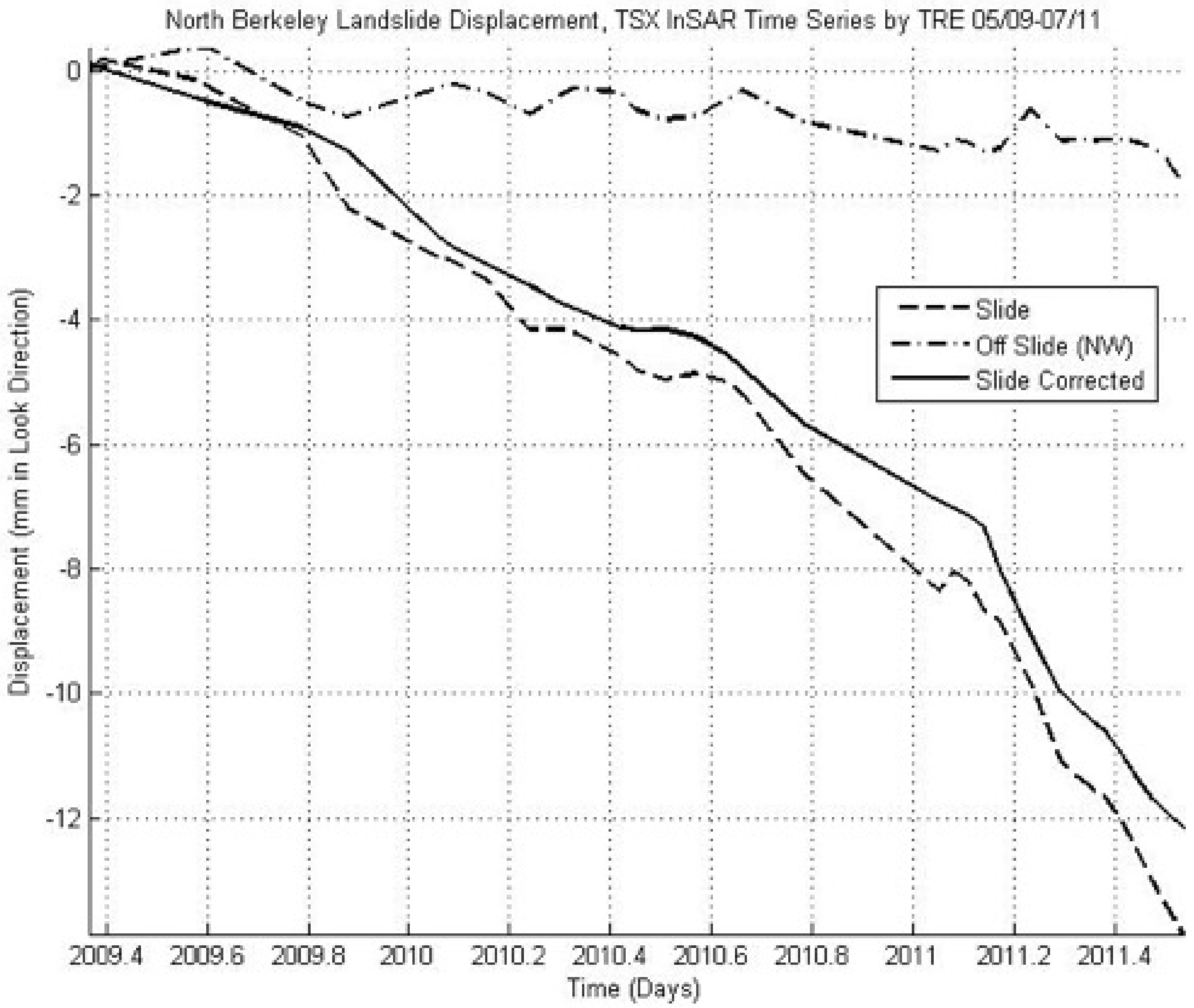



(From USGS)

# BERKELEY SLOW MOVING LANDSLIDES INSAR

- High spatial coverage and high spatial resolution
- Works best in urban areas

- Average displacement time histories in areas of interest
- Actual landslide displacement from differencing background signal




From Dr. Estelle Chaussard, University at Buffalo

# MITIGATION – TYPES

**Slope Stability Options:**

1. Drainage Improvements
2. Grading / Buttress / Shear Keys
   - ✓ Gravity Walls
   - ✓ Replace with Lightweight Fill
3. Soil Treatment / Ground Improvement
4. Mechanical Stabilization
   - ✓ Reinforced Soil Slopes
   - ✓ Shallow Stabilization
     - ▪ (Driven Anchors)
   - ✓ Deep Pinned-Mesh Stabilization
   - ✓ Anchor Blocks w/ Tie Backs
   - ✓ Installations of Piles or Shafts

✓ Combination Systems

**Table 1 – Retaining Wall Properties**

| Wall Category | Wall Sub-Category | Wall Type | Typical Construction Concept | Proprietary |
|---|---|---|---|---|
| Gravity | Mass Gravity | CIP Concrete Gravity | Bottom Up (Fill) | No |
| | Semi-Gravity | CIP Concrete Cantilever | Bottom Up (Fill) | No |
| | Reinforced Earth | MSE Walls:<br>• Precast Panels<br>• Modular Blocks<br>• Geogrid/ Geo-textile/Wire-Faced | Bottom Up (Fill) | Yes |
| | Modular Gravity | Modular Blocks, Gabion, Bin, Crib | Bottom Up (Fill) | Yes |
| Non-Gravity | In-situ Reinforced | Soil Nailing | Top Down (Cut) | No |
| | Cantilever | Sheet Pile, Soldier Pile, Tangent/Secant | Top Down (Cut) /Bottom Up (Fill) | No |
| | Anchored | Anchored Sheet Pile, Soldier Pile, Tangent/Secant | Top Down (Cut) | No |

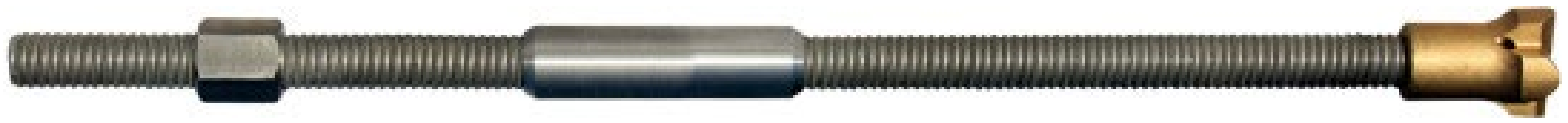
(Courtesy of Wisconsin DOT)

# MITIGATION – FACTORS

**Factors for Selection:**

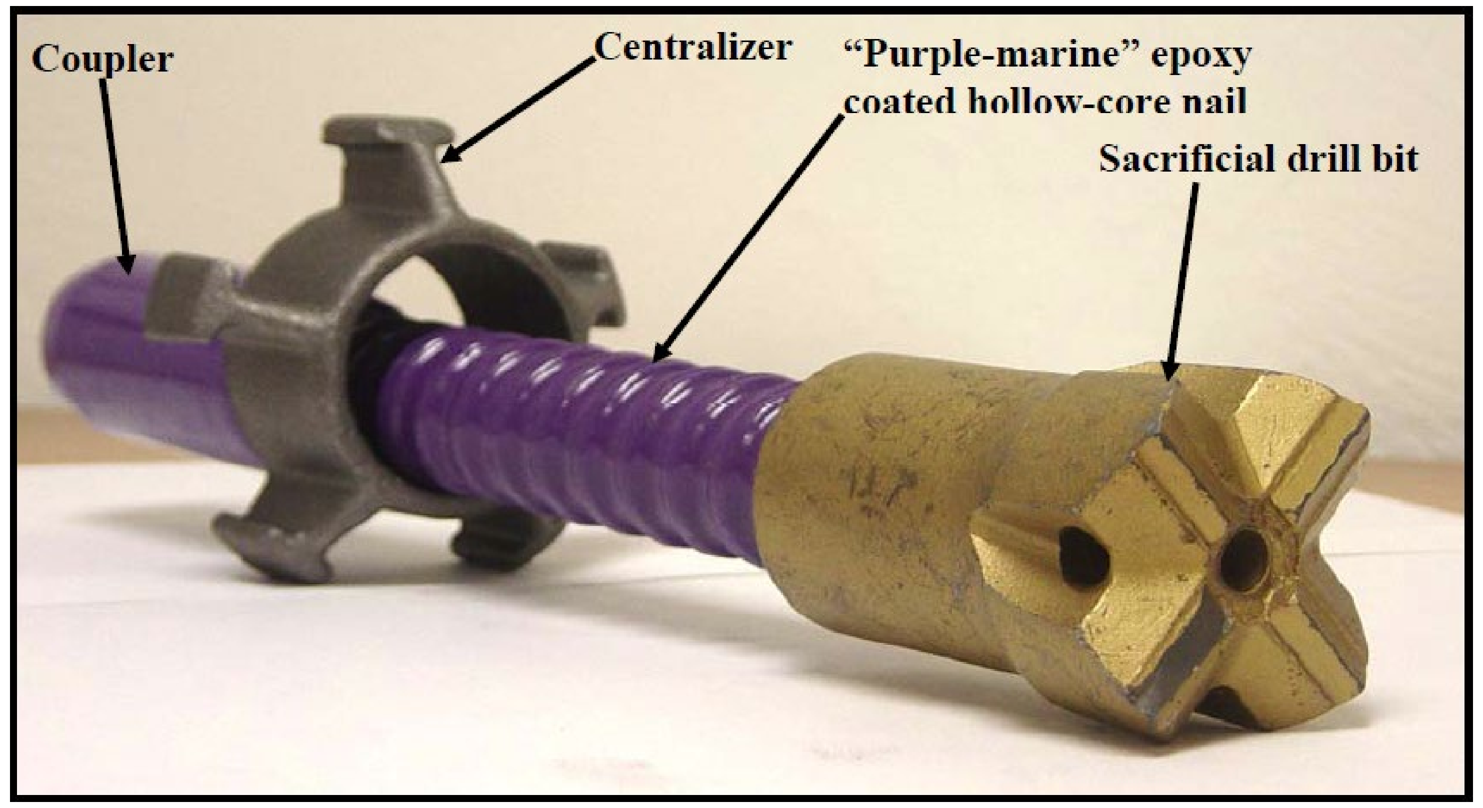
1. Access
2. Capacity Requirements (% improvement)
3. Environmental
4. Right of Way Limits

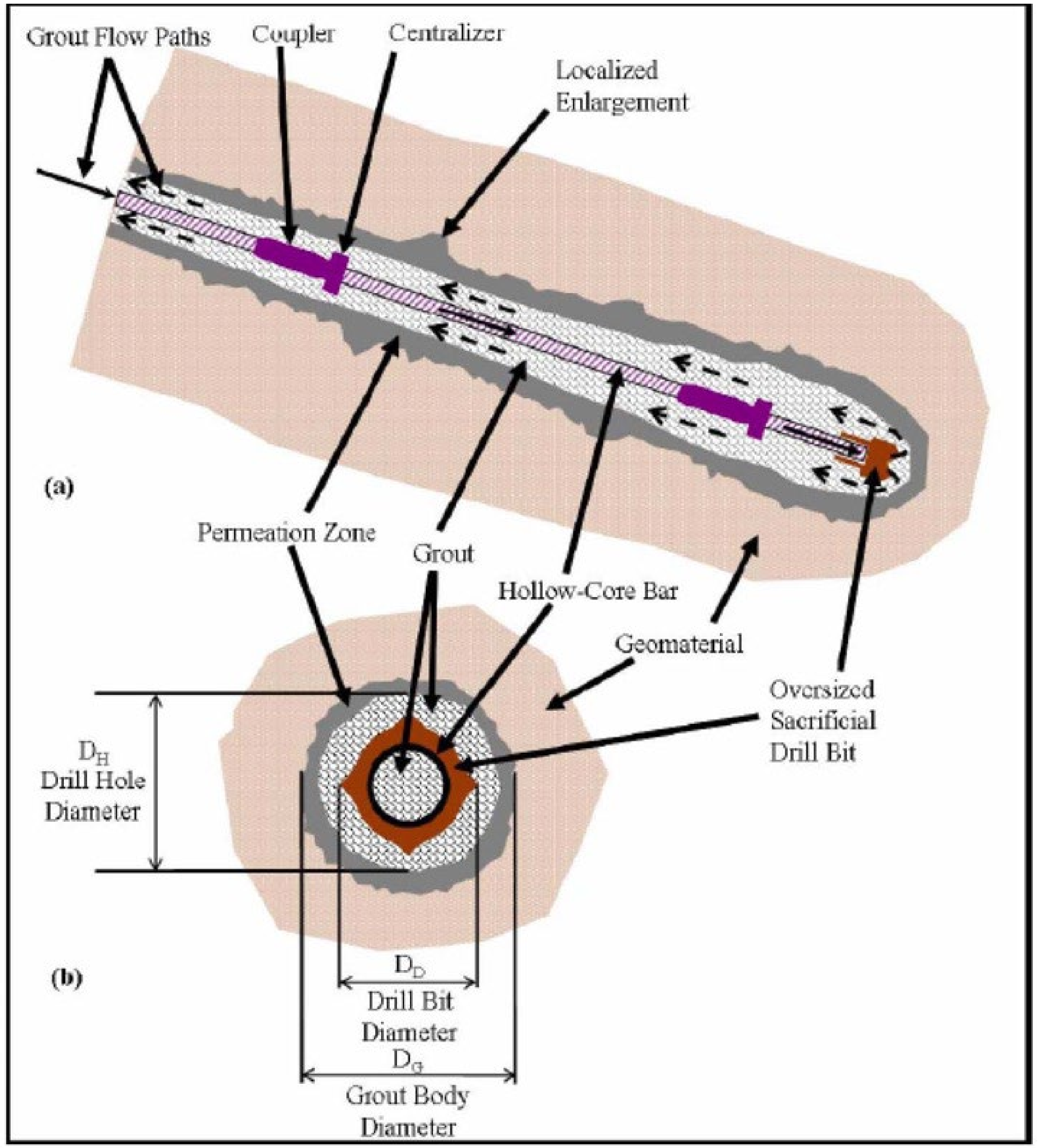
# MITIGATION - TYPES OF SOIL - NAIL DRILLING METHODS

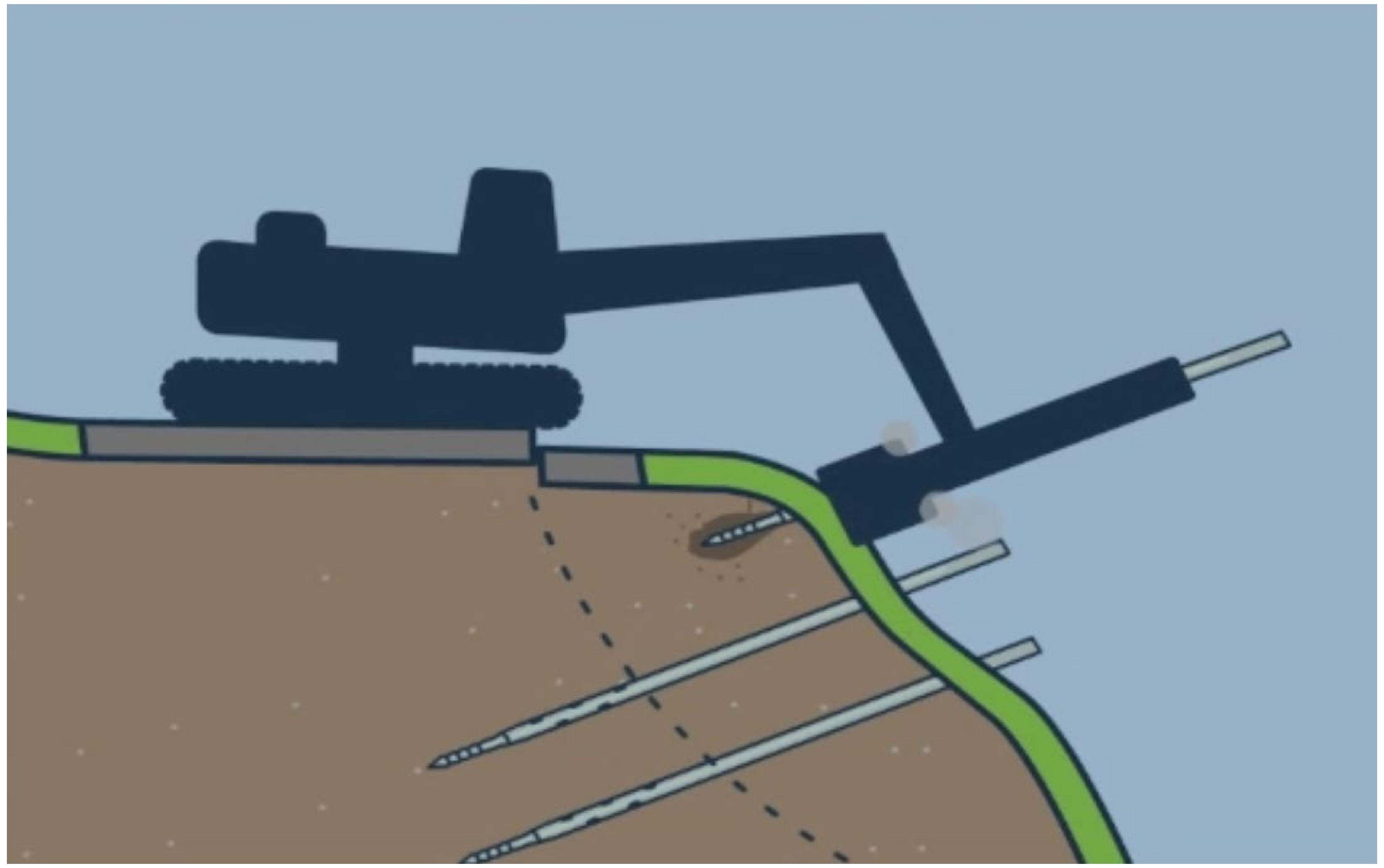


***Soil-Nail Drilling Methods***

- Self Drilling Nails
- Nails Installed by a Soil Nail Launcher



# SOIL NAIL LAUNCHER

- The soil nail launcher technology was originally developed by the British military to launch chemical weapons.
- The soil nail launcher is a compressed air cannon that has been repurposed to accelerate a 1.5-inch diameter, 20-foot-long steel or fiberglass tube to over 200 miles per hour in a single shot.
- The soil nail launcher works well in sands, gravels silts and clays and can be installed rapidly (200+ nails per shift).

# Shoreline – Slope Mitigation

- Slope Mitigation – using Soil Nail technology along stream, rivers and coastal areas.
- Failed Slope



- Slope being mitigated during a flood event

- Slope mitigated with soil nails adjacent to a streambed

# RIPARIAN CASE STUDY - NORTH CENTRAL PA

***Background***

- Project located in north central PA
- Long existing failure near the shoulder of the road causing roadway settlement and extensive cracking.
- Old timber and lagging wall that supported roadway above the stream was deteriorated and failing
- Township had to place jersey barriers for safety to divert traffic away from the side of the road, on an already narrow roadway that was utilized by the water utility.

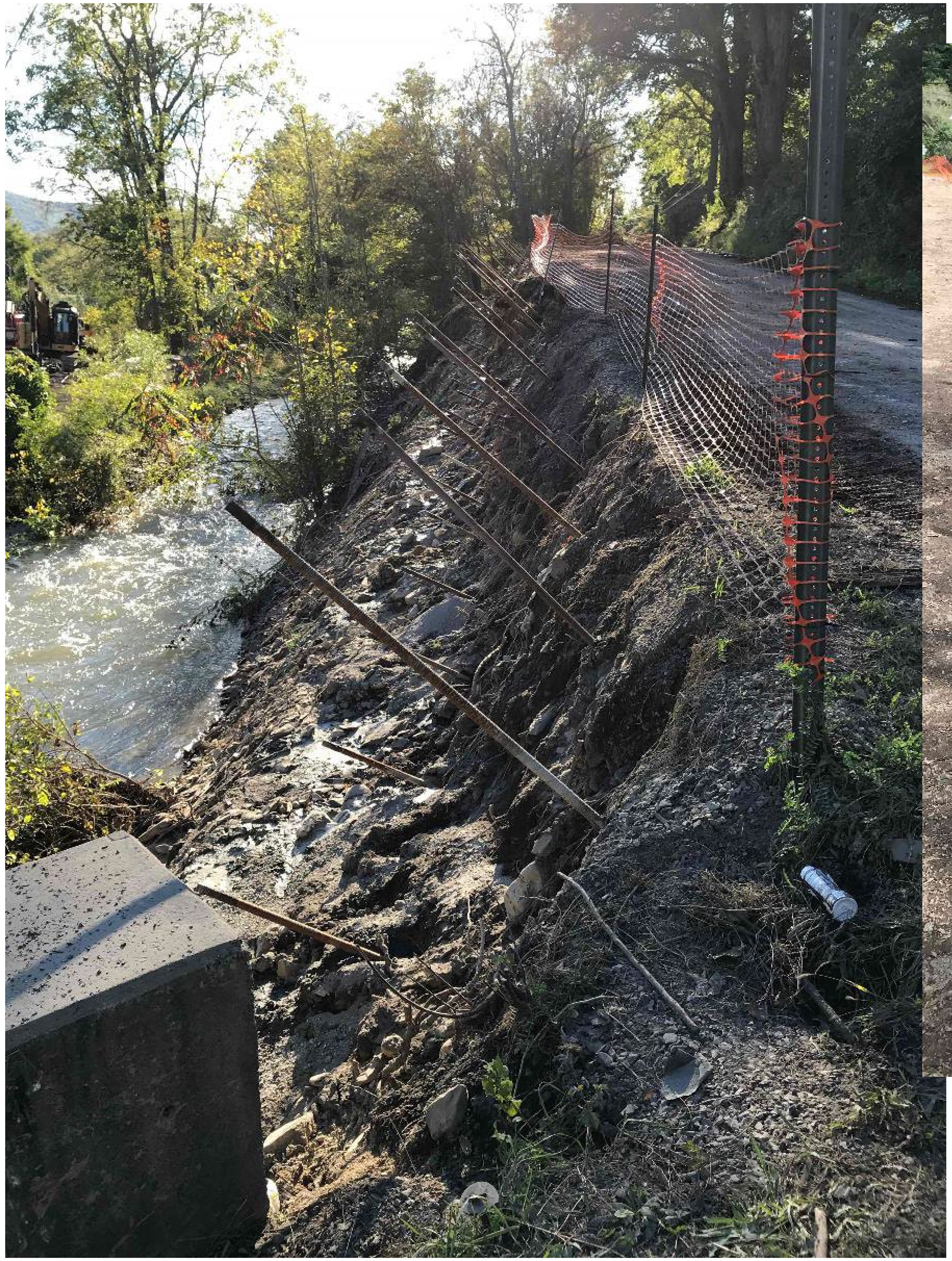
Waterdale Road Project, Williamsport, PA

# RIPARIAN CASE STUDY - NORTH CENTRAL PA

***Background con't***

- Large existing pipeline (36") below the roadway. Provided water to town and middle-sized city – Williamsport, PA.

- Site conditions (shallow, weak rock, limited roadway width, erosion susceptible toe in stream) – not conducive to piling wall, earthwork solution and other stabilization methods.



# RIPARIAN CASE STUDY - NORTH CENTRAL PA

***Basic Engineering Design***

- Using lateral supports (self drilling nails/hollow bar nails) to hold up erosion resistant facing and uploaded the lower slope by material to improve overall stability.
- Hollow bar soil nails to avoid cave-in/collapse susceptible soils when drilling through.
- Soil nails drilled at angles to avoid conflict of the water main
- Lateral supports isolate the roadway from downslope movements.

# RIPARIAN CASE STUDY – LANDRY PARISH LA

***Background***

- Project located in Landry Parish LA
- Rapid Drawdown failure of slope affecting LA-745.
- Rock buttress installed (no engineering)
- State had to place jersey barriers for safety to divert traffic away from the side of the road, on an already narrow roadway affected by the slope issues.

LA 745 Landry Parish LA

# RIPARIAN CASE STUDY – LANDRY PARISH, LA

***Background con't***

- Buttress Fails during Installation
- Client proceeded with buttress – only approach to find equilibrium

# RIPARIAN CASE STUDY – LANDRY PARISH, LA

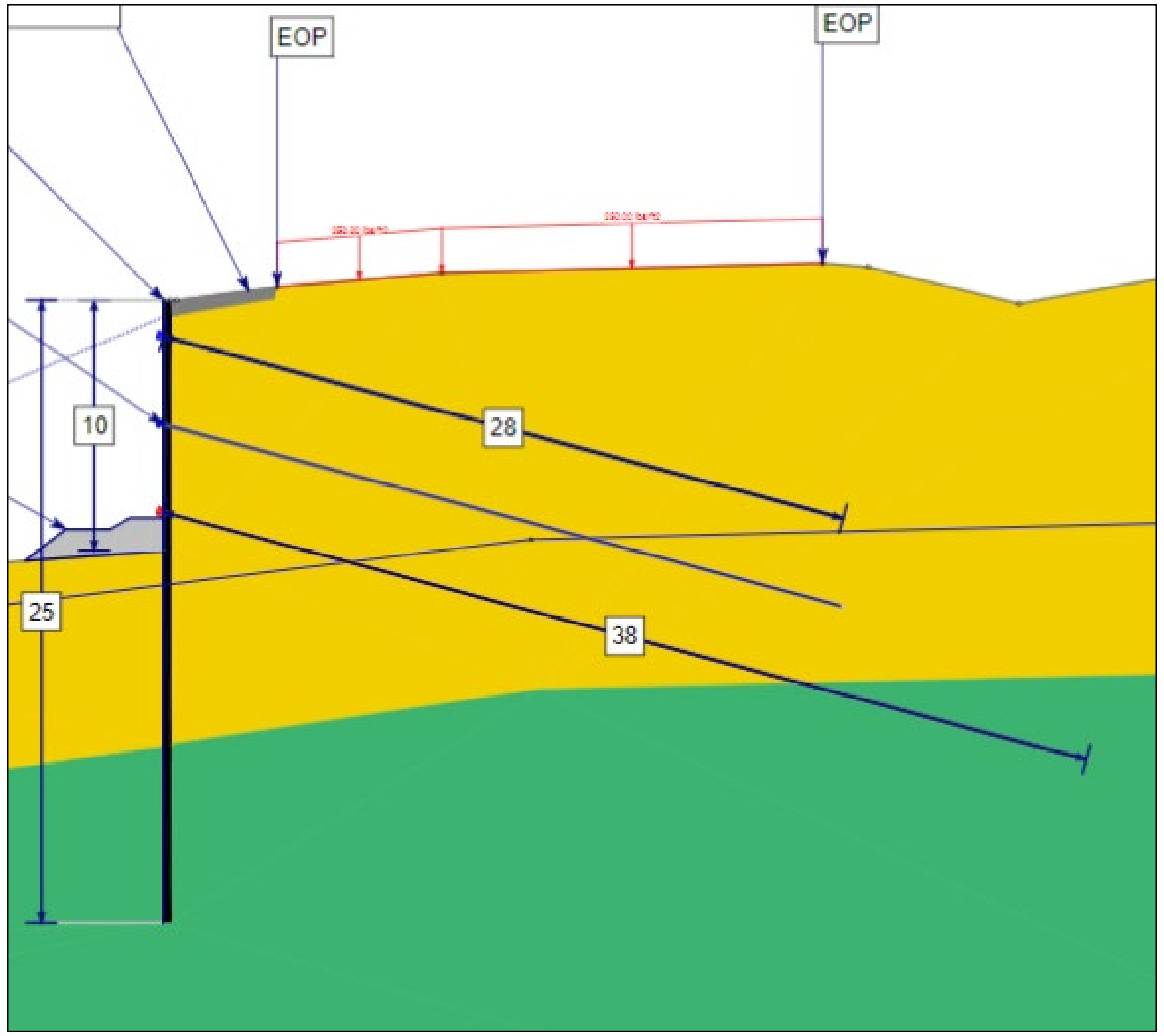
***Background con't***

- Buttress Fails 6 months later

# RIPARIAN CASE STUDY - NORTH CENTRAL PA

***Background con't***

- Installation of an engineered tied-back sheetpile wall




# Coastal Project – Del Norte, California

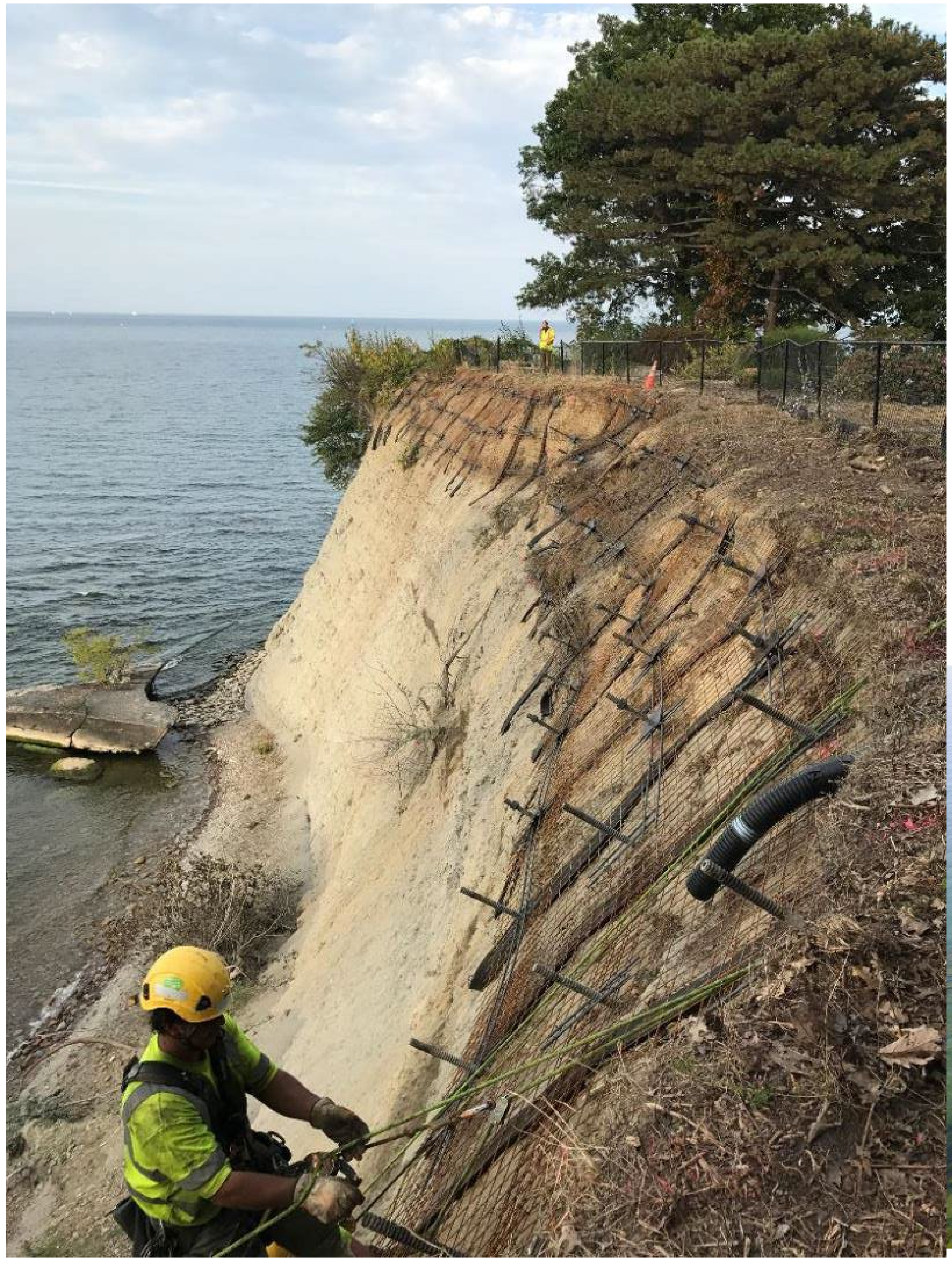
› **Coastal Slope Mitigation** – located in Del Norte, California and on the edge of the Pacific Ocean

# Hydro Project – Lake Mead (Dam/Reservoir)

- **Lake Mead, Nevada –** largest reservoir in the US.
- Rock Slope Mitigation adjacent to scenic view

# Shoreline/Bluff Project – Lake Erie, near Cleveland, Ohio

- **Lake Erie, near Cleveland, Ohio –** slope mitigation to stabilize an eroding slope - Great Lakes region.

# CONTACT INFORMATION

# Thank You

**Matthew Reihl PE**
**201-317-6505**
**Matthew.Reihl@gsi.us**