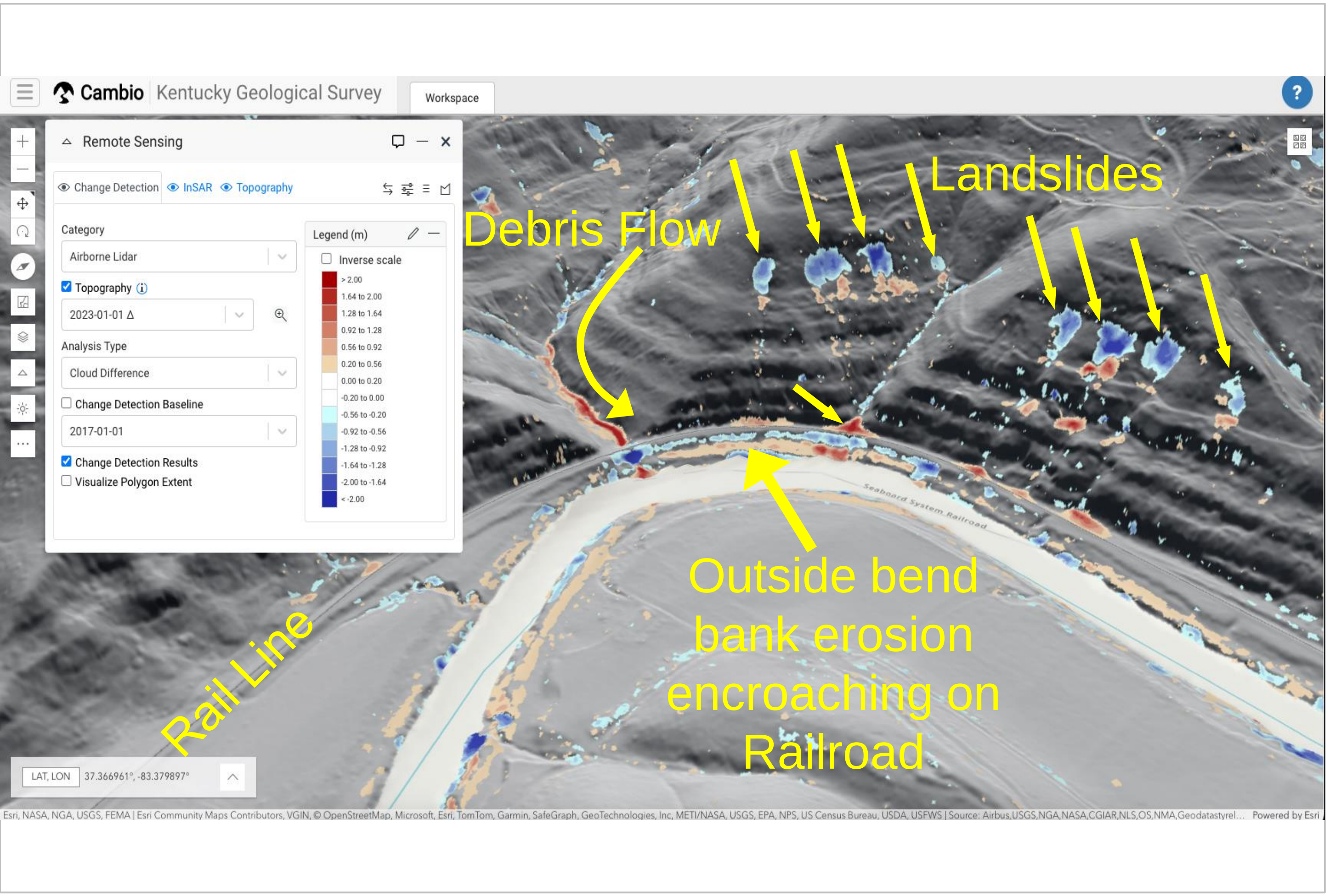


Advances in Network-scale, Risk-Based Geotechnical Asset Management

Presented by:

Nathan Thompson and Mark Vessely,

BGC Engineering

Date:

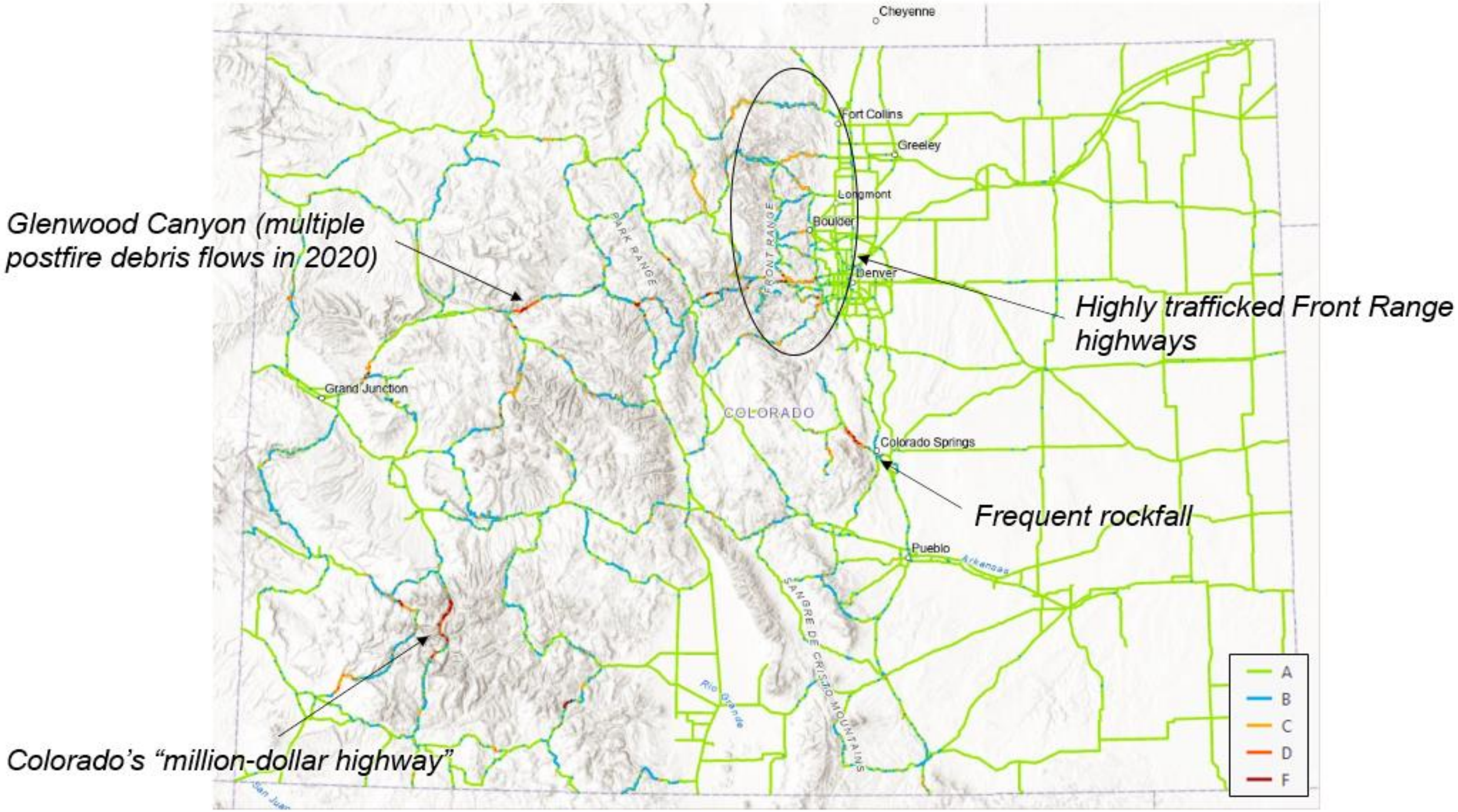
November 19, 2024

Agenda

- In one slide – what are we talking about?
- Advancements in risk and resilience frameworks
- Technology advancements for finding and measuring risk
- Advancing the speed of decisions

GAM tools are quickly advancing that allow you to measure geotechnical risk across your entire network: Where is attention needed? How likely is a failure? How bad might it be?

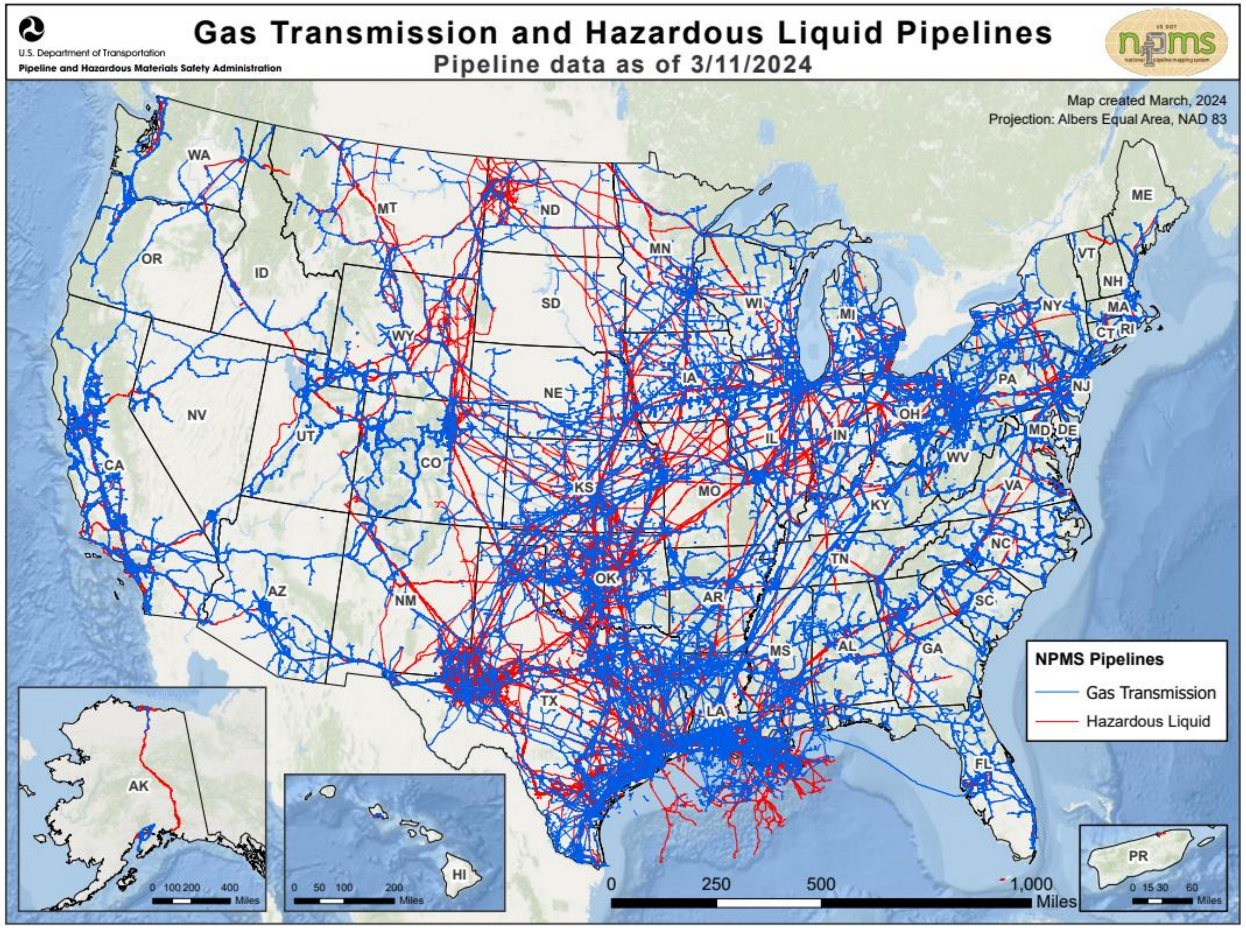
<u>Example:</u>
a complete geohazard threat inventory with baseline risk values for 9,000 centerline miles.



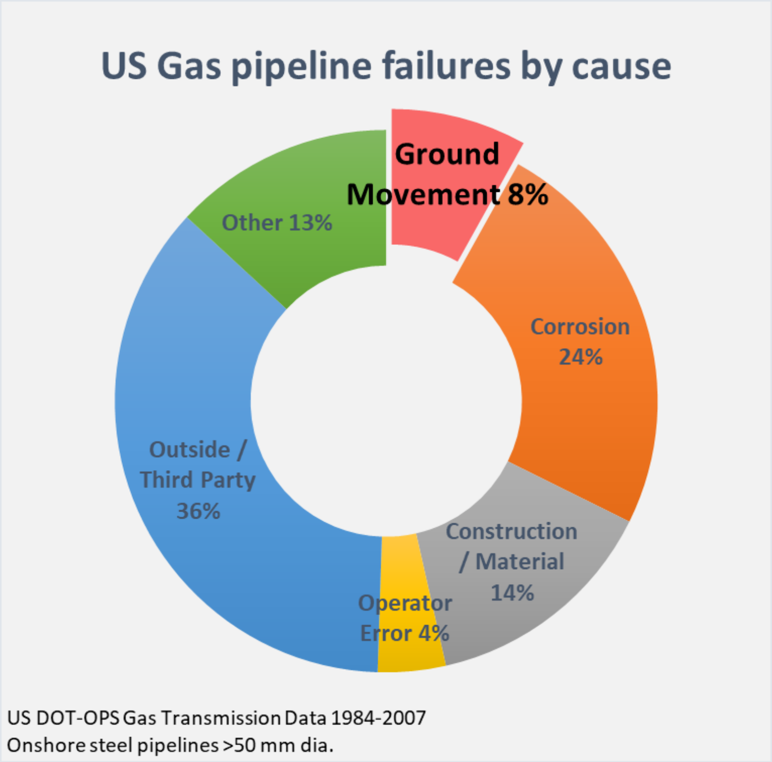
Advancements in Risk and Resiliency Frameworks

The evidence shows the benefits are real

Learning from others: pipeline operators are highly motivated to avoid failure.



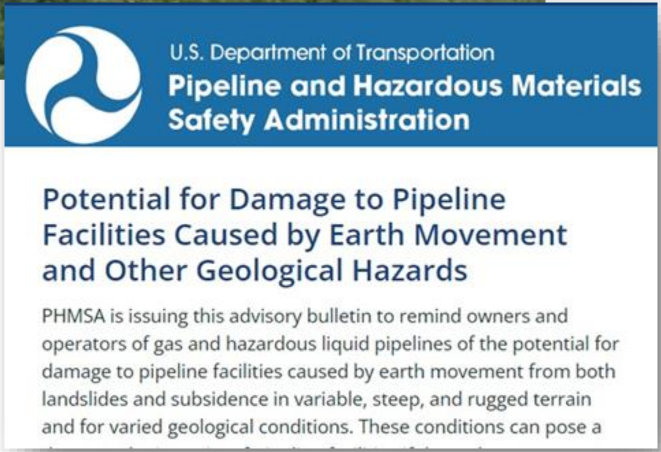
Learning from others: pipeline operators are highly motivated to avoid failure.



Geohazards cause an estimated 74 failures per year globally.

North America annually: ~3 geohazard failures per 100,000 miles, >$750 million USD

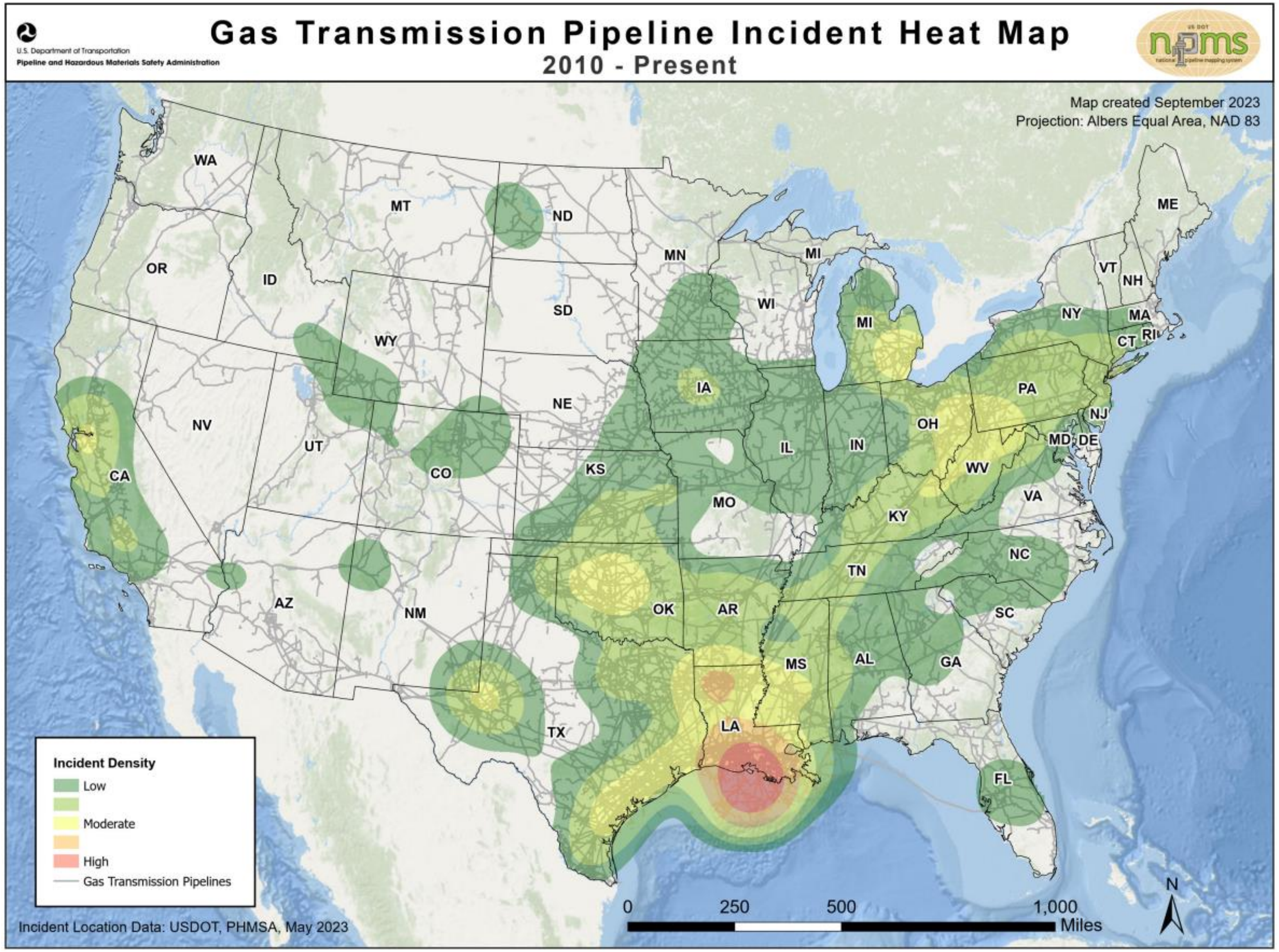
Failures in Kentucky and Ohio in 2020


U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards

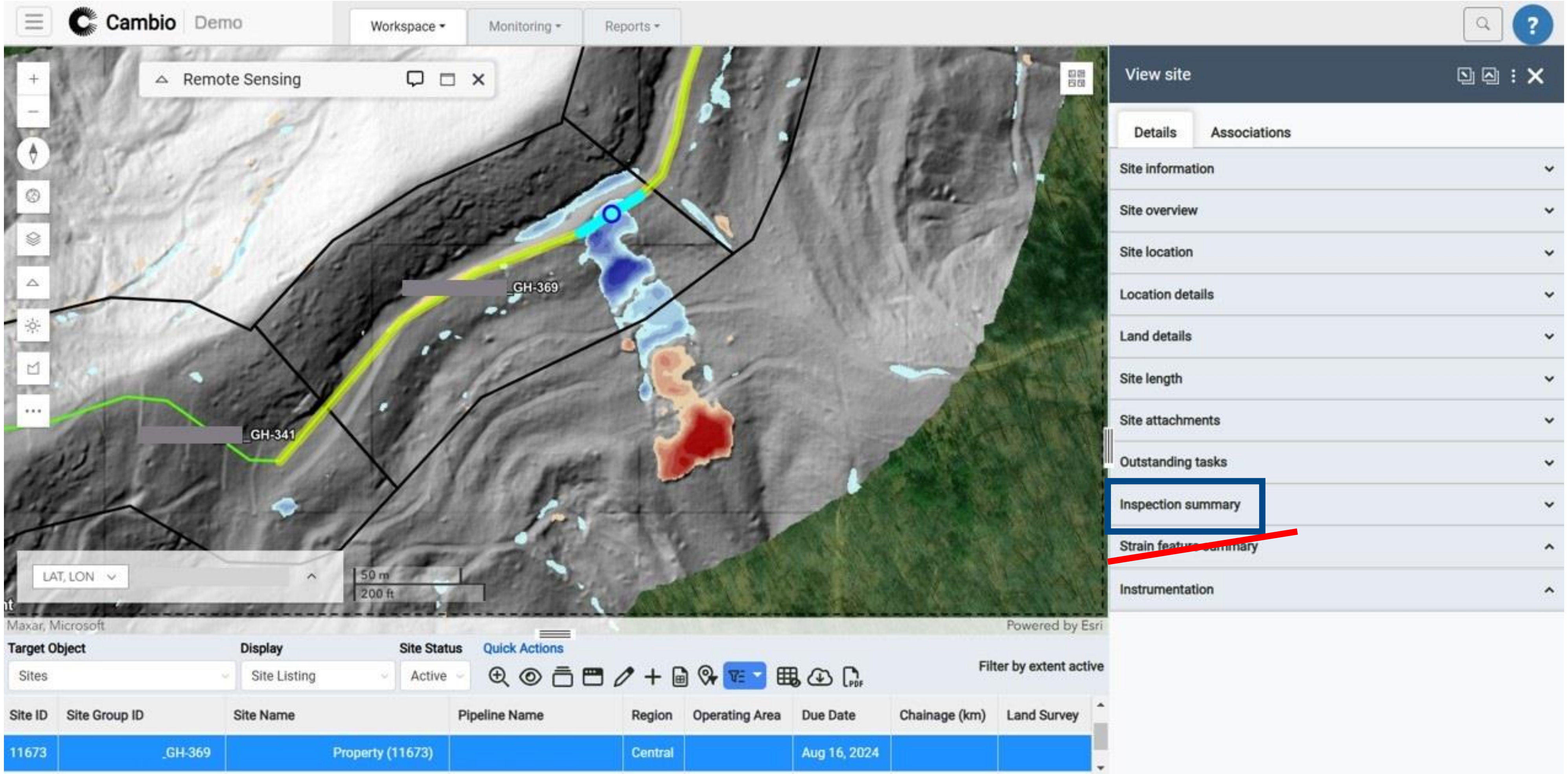
PHMSA is issuing this advisory bulletin to remind owners and operators of gas and hazardous liquid pipelines of the potential for damage to pipeline facilities caused by earth movement from both landslides and subsidence in variable, steep, and rugged terrain and for varied geological conditions. These conditions can pose a

… noted 17 of "some of the more notable events" that occurred over the previous 6 years across 10 different states.



A consortium of pipeline operators agreed to share data and develop best practices. They have reduced geohazard caused failures by up to 80% in the last decade.

Features from a pipeline geohazards workflow can be applied to transportation networks.



***Ground inspection**: site details (<u>risk factors</u>), ground movements, measurements, annotated photos*

***Desktop inspection**: Lidar change detection, IMU strain data, InSAR review*

*Every inspection: **Updated probability of failure (PoF)***

***Hazard** → **Site** → Segment → District → Network*

Typical workflow for a pipeline geohazard manager.

Site Risk Level	Baseline Inspection Frequency
1	Annual
2	3yr
3	5yr
4	As needed (e.g., monitoring alert)

→

Sources of change:

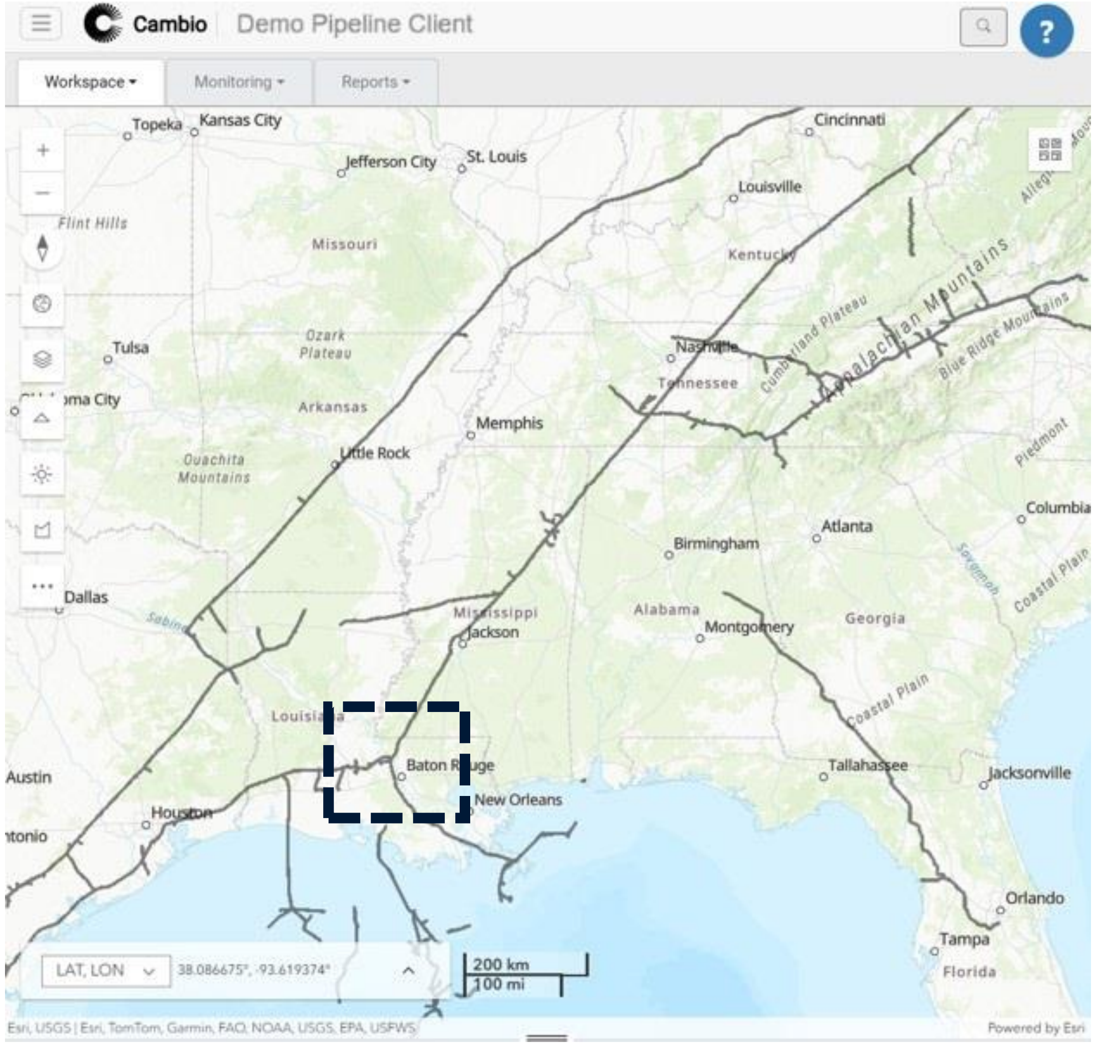
- Ground inspections
- Desktop inspections
- Unplanned, automated alert – geotechnical instrumentation, weather alert (precipitation), seismic alert (USGS ShakeCast)

↓

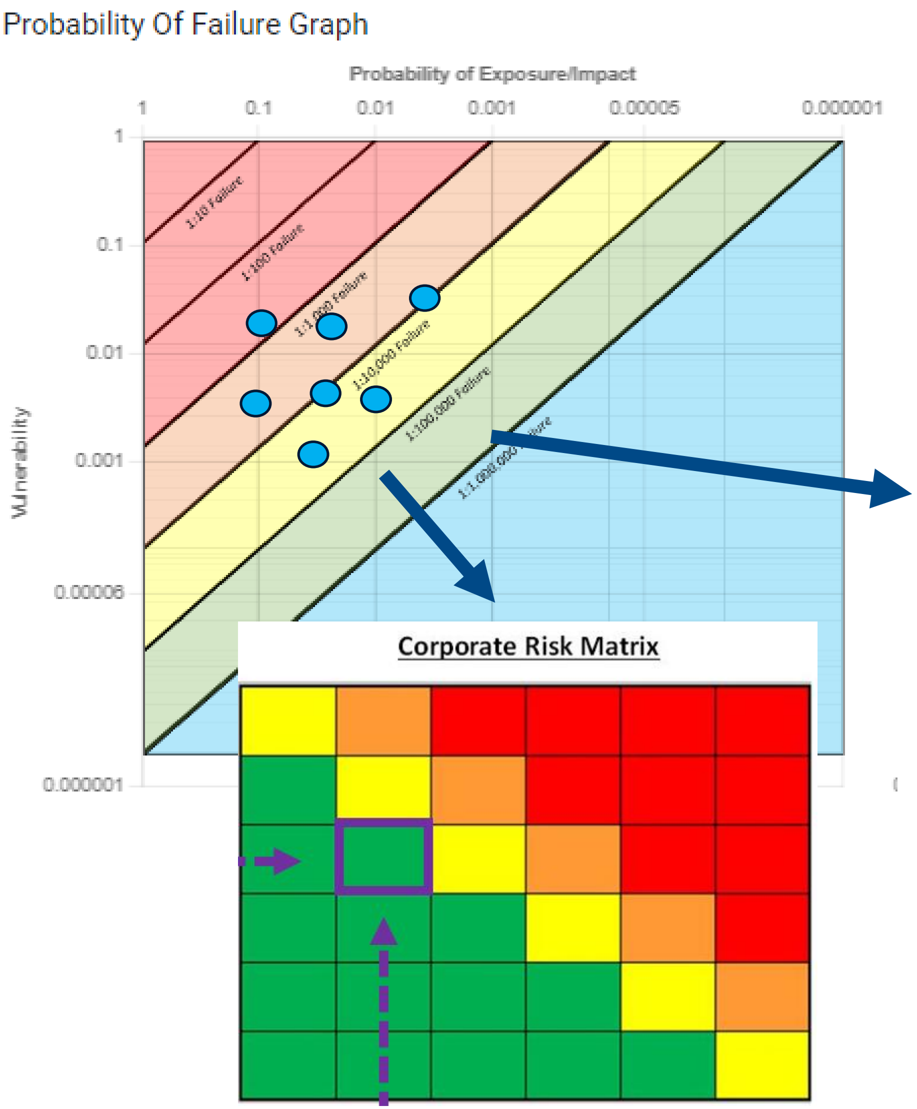
Regular updates focused on changes:

Pipeline ID (System, District, Segment, Line)	Site ID	# GMHs	Max PoF-based Risk Level	GMH Proximity	GMH Activity Level	Next Action
A	A001	3	.02	A	B	MDR
B	B004	1	.004	C	C	Regular inspection

Features from a pipeline geohazards workflow can be applied to transportation networks.



PoF



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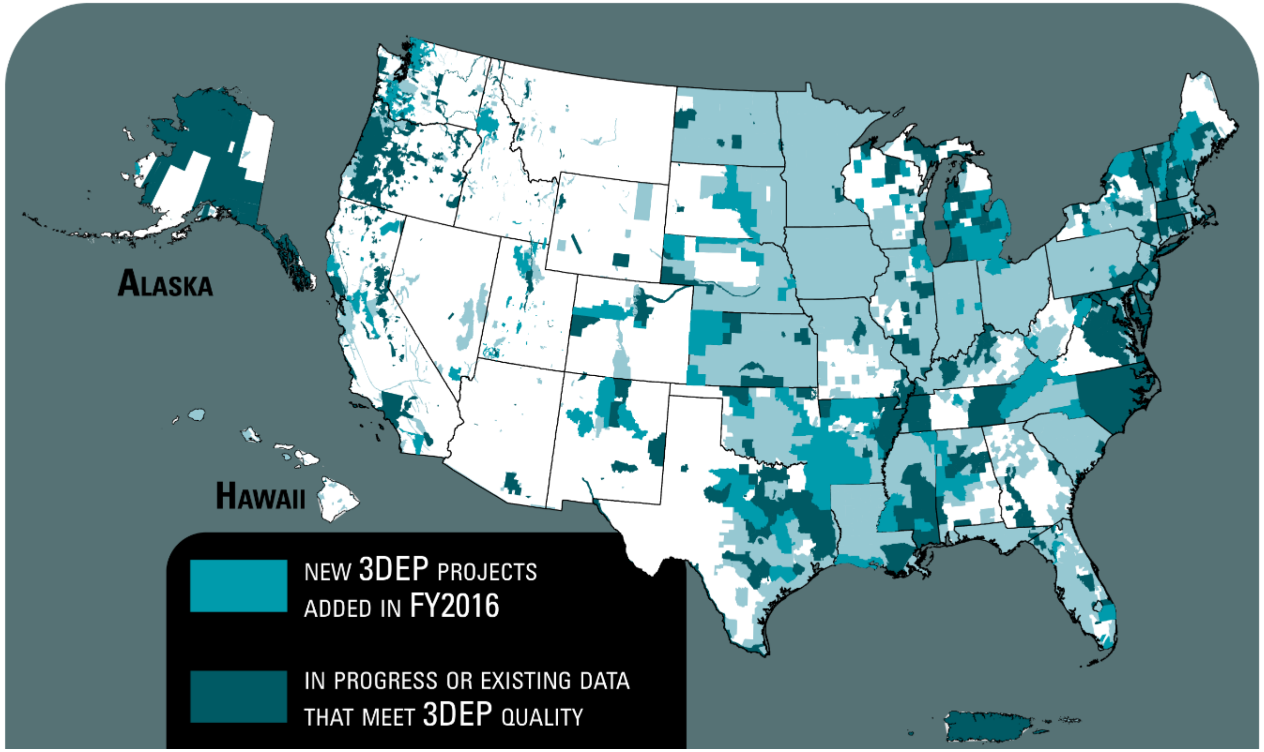
Finding all potential problems from the office

Public high resolution lidar is a game changer

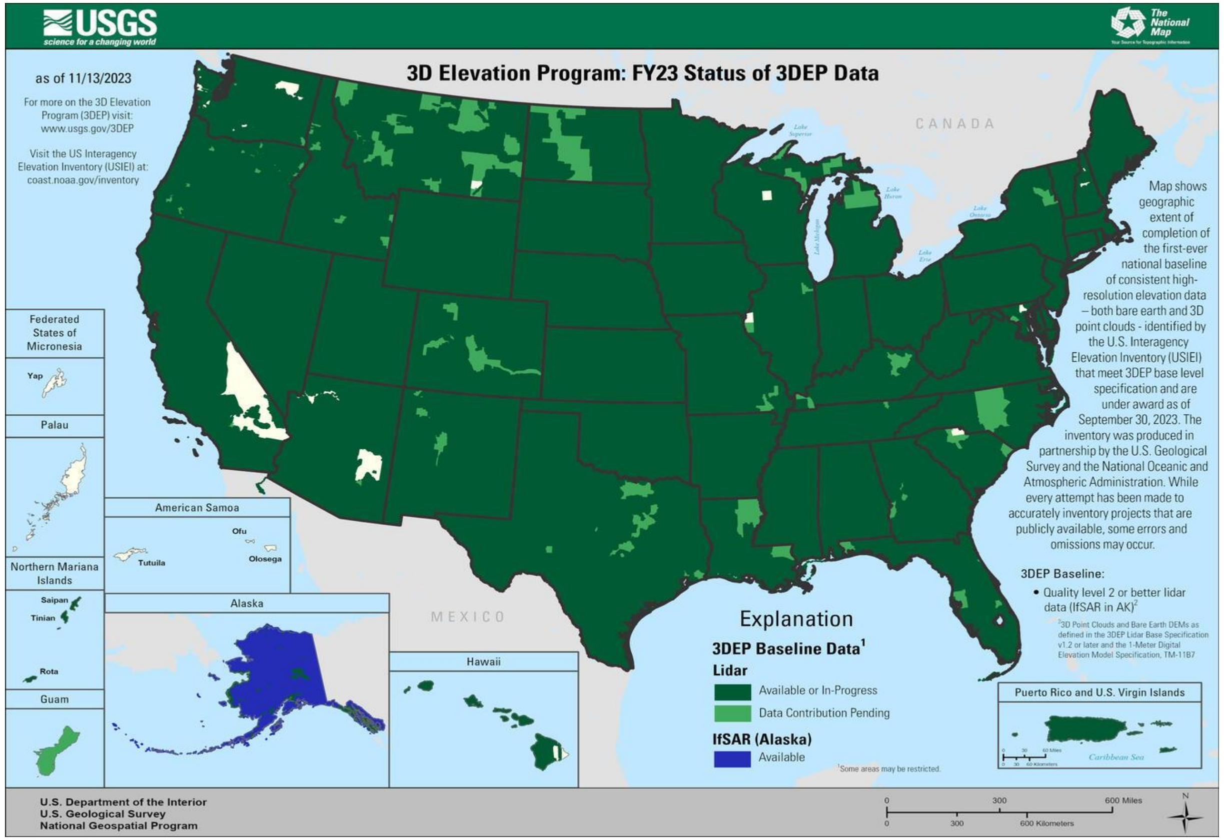
It's different now

Near complete country-wide high resolution lidar coverage evolution from USGS, regional efforts, and agency projects

Public high-resolution lidar 2016



Public high-resolution lidar 2023



USGS 3DEP Status

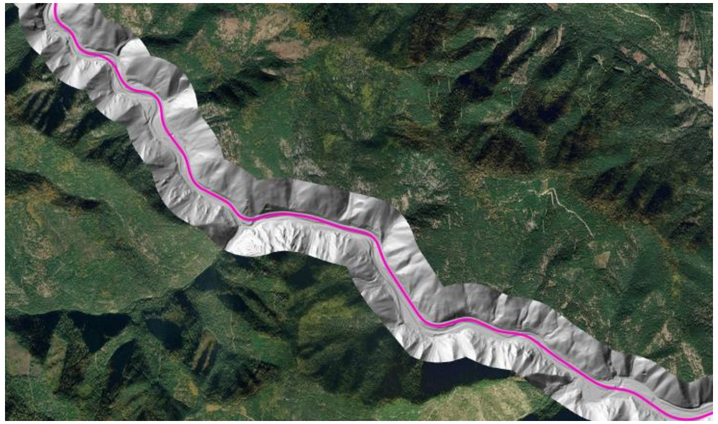
Aerial imagery
vs.
Bare Earth Lidar

Automated Screening to find Assets and Geohazards

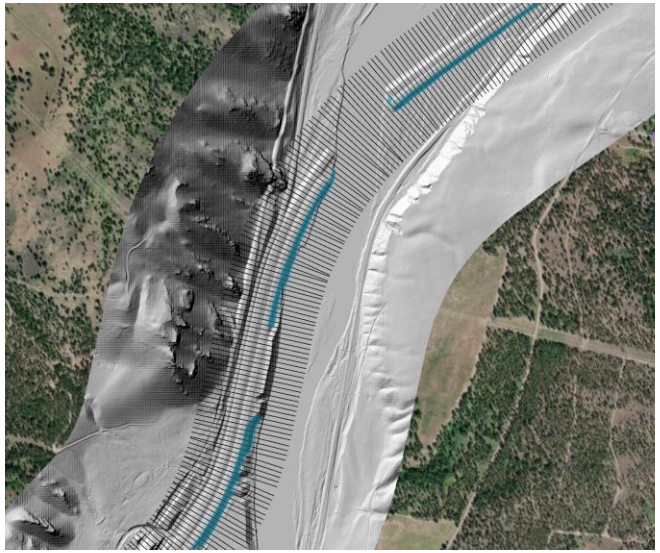
Lidar based Digital Elevation Model (DEM), Highway Line

Extract a series of elevation profiles along the highway line

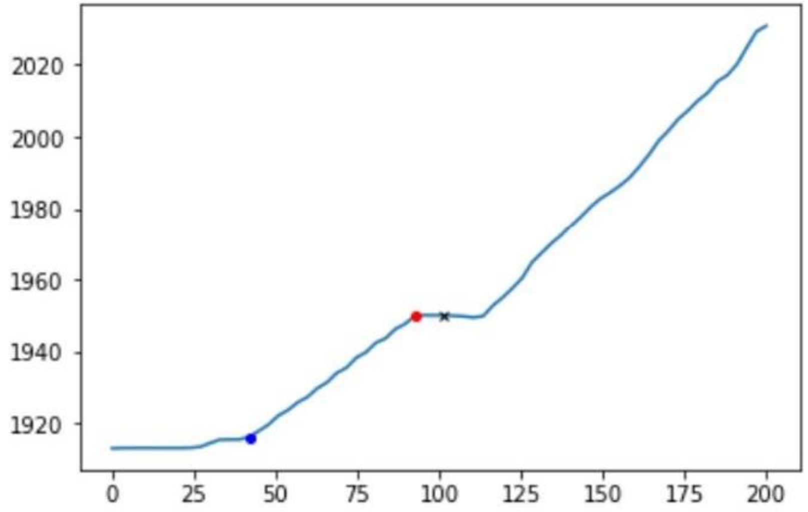
Flag slopes over a specified height and slope threshold



- Inputs are elevation data and a line representing the highway(s) of interest



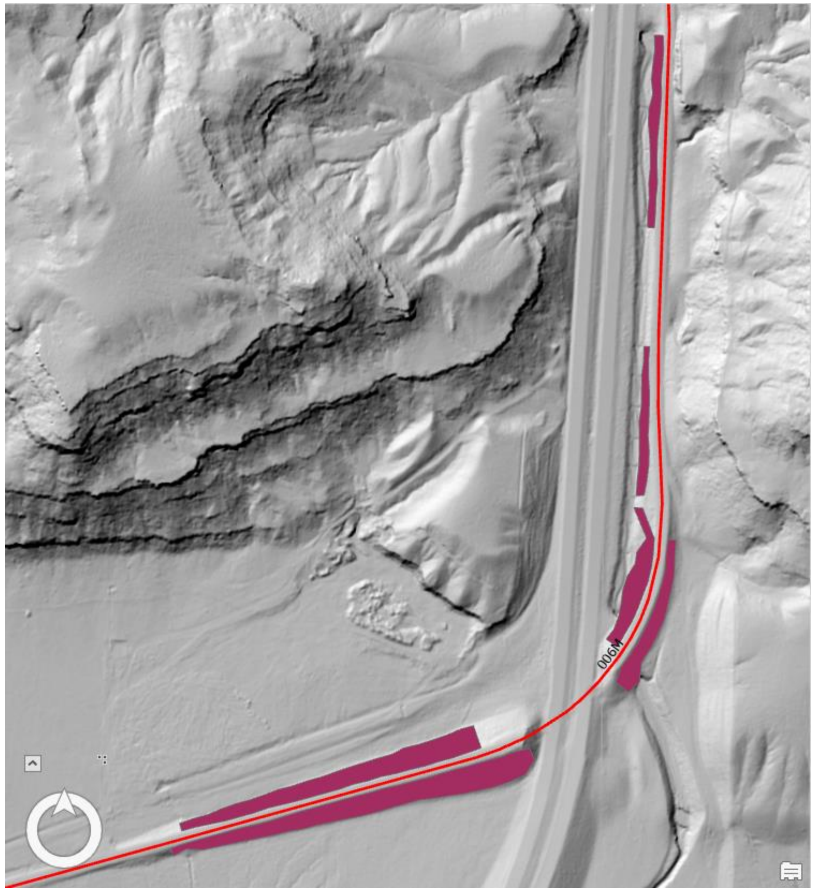
- Generate a series of perpendicular profiles



- For each profile, software identifies probable cuts, embankments, and retaining walls using lidar-derived slope and height

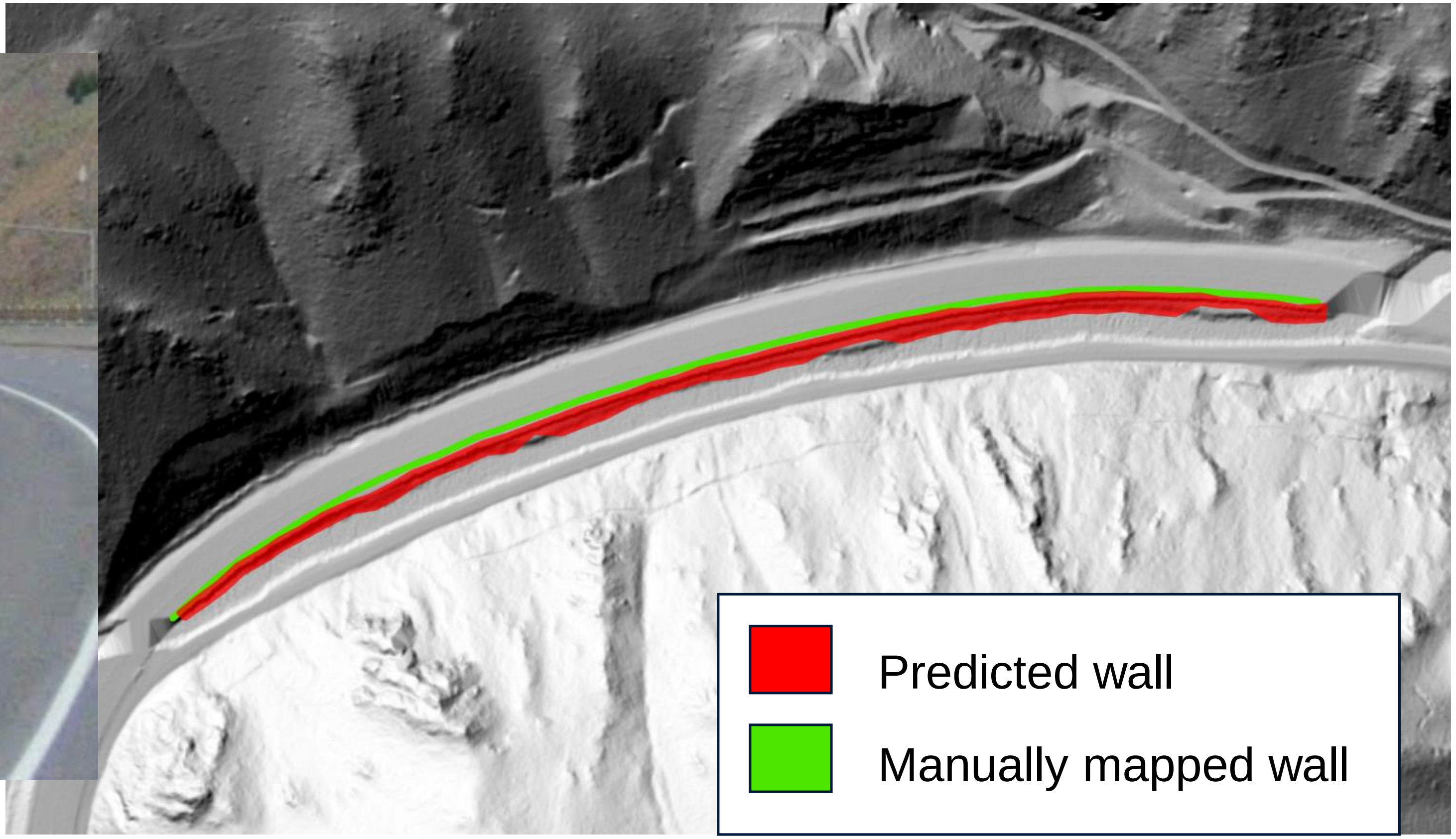
Lidar Analysis

Example output – embankment assets across Colorado



Lidar Analysis

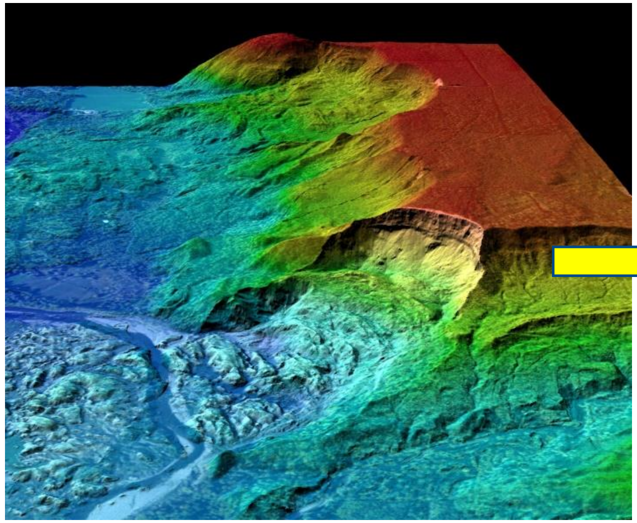
Slopes and walls in Montana

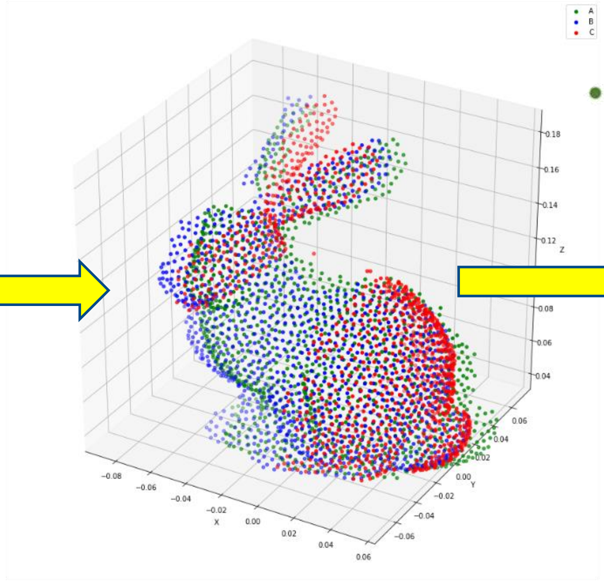


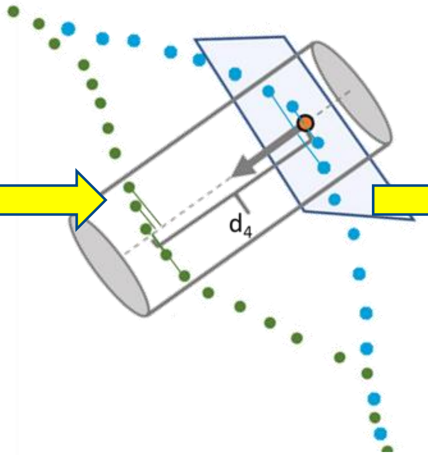
Advancing with Lidar Change Analysis at Large Scale

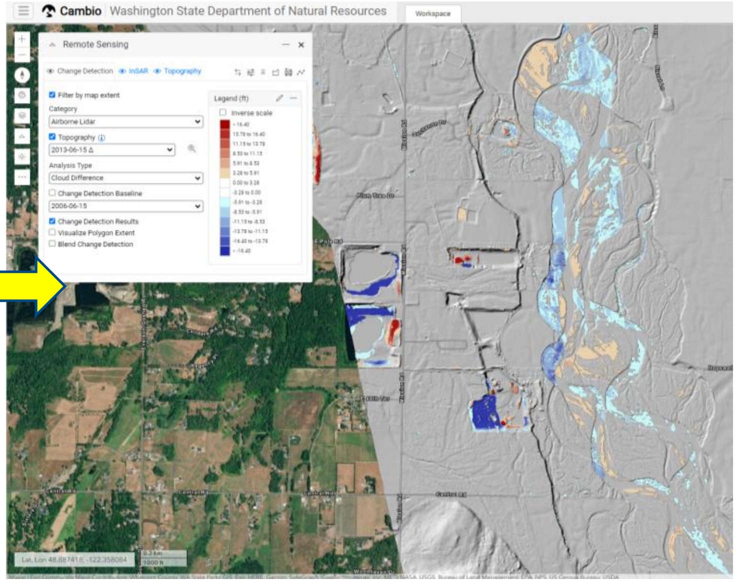
Extracting value from multiple lidar generations

Point Clouds -> Iterative Closest Point Method -> Model-to-Model Cloud Comparison -> Change TIF









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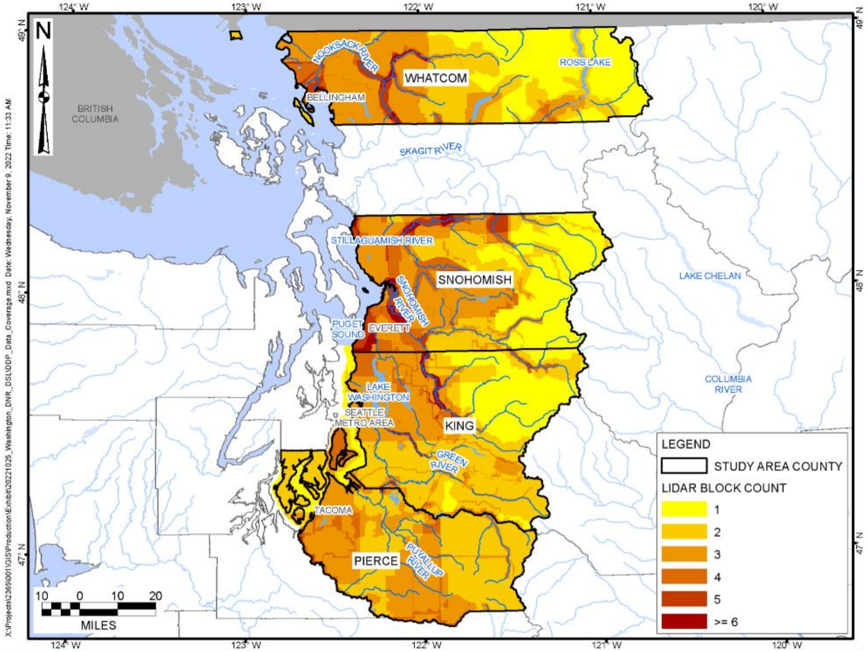
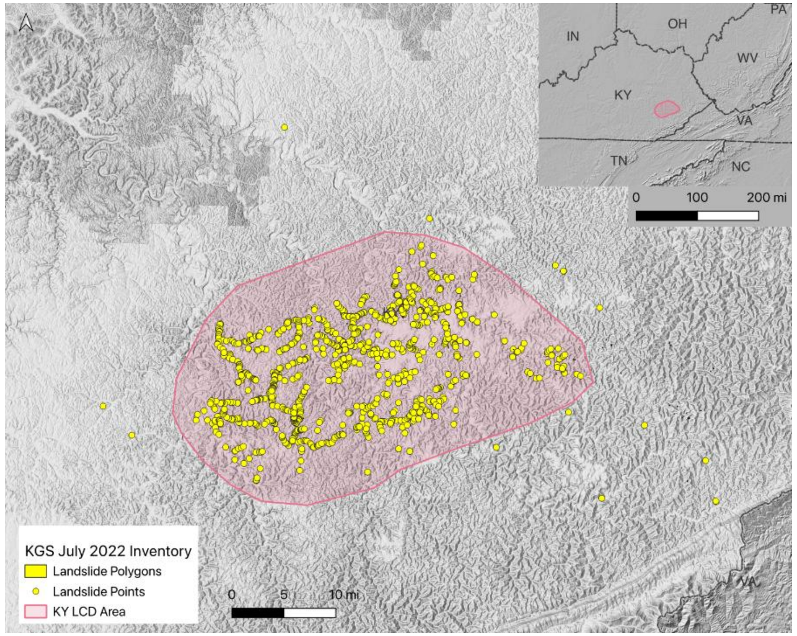
Where is network scale LCD occurring now

- At BGC – over 38,000 sq miles processed (all of Ohio is 44,000 sq mi)
  - **Pipelines:** Mostly in Canada and US
  - **Highways**: Colorado DOT, Caltrans, Western Federal Lands (Yellowstone and Denali)
  - **Regional**: Washington DNR, Kentucky Geological Survey

Pipeline ROW and LCD extent example in Ohio



Washington DNR county scale LCD extent



Eastern Kentucky Landslides LCD extent

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Example output from Kentucky

Example transportation application

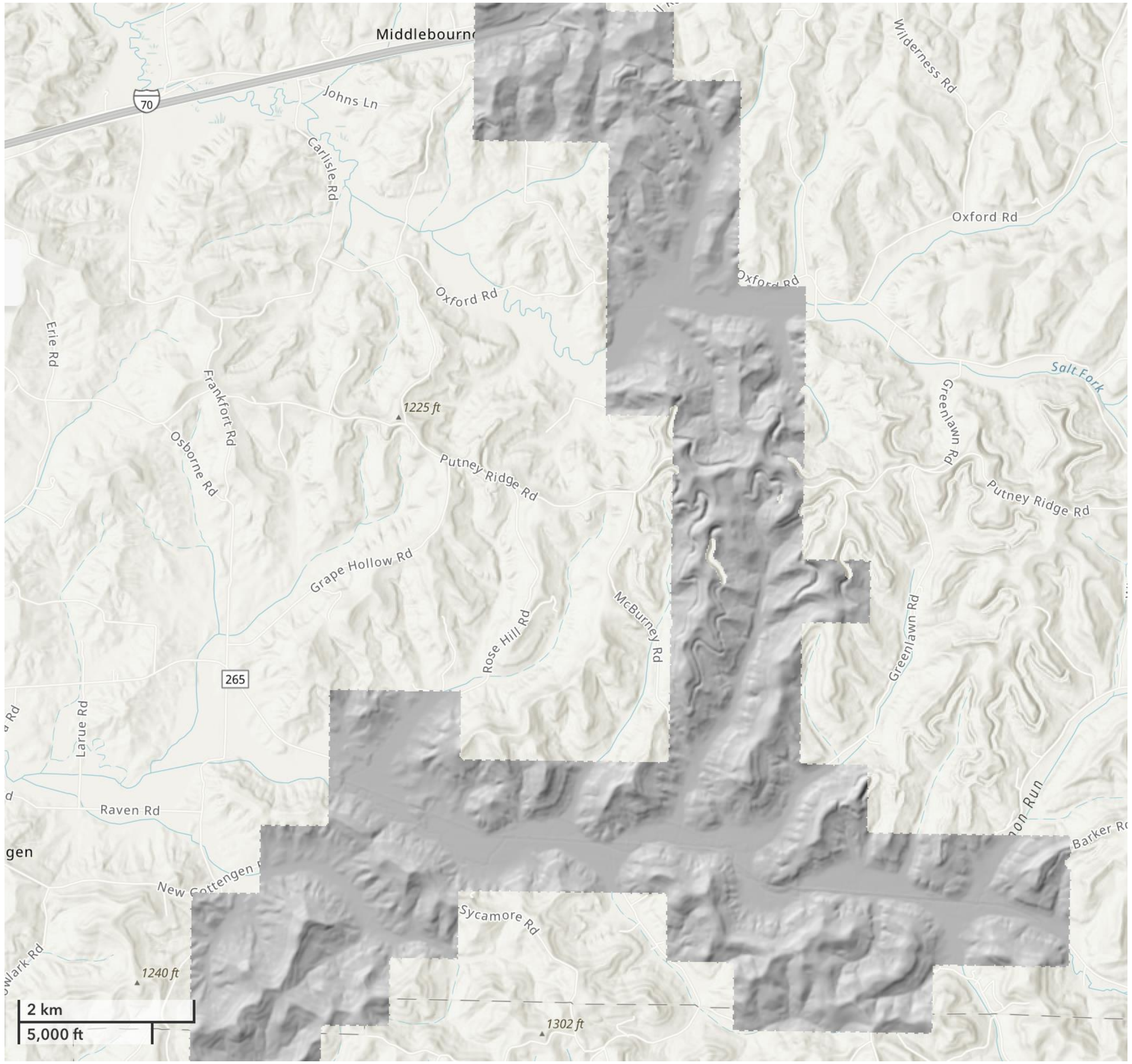
Example of lidar use in combination with prior asset inventory

Note: Lidar change detection => LCD

Embankments hunting and looking for change

What was done?

- Embankment hunting along SR-513
- Lidar Change Detection in entire area

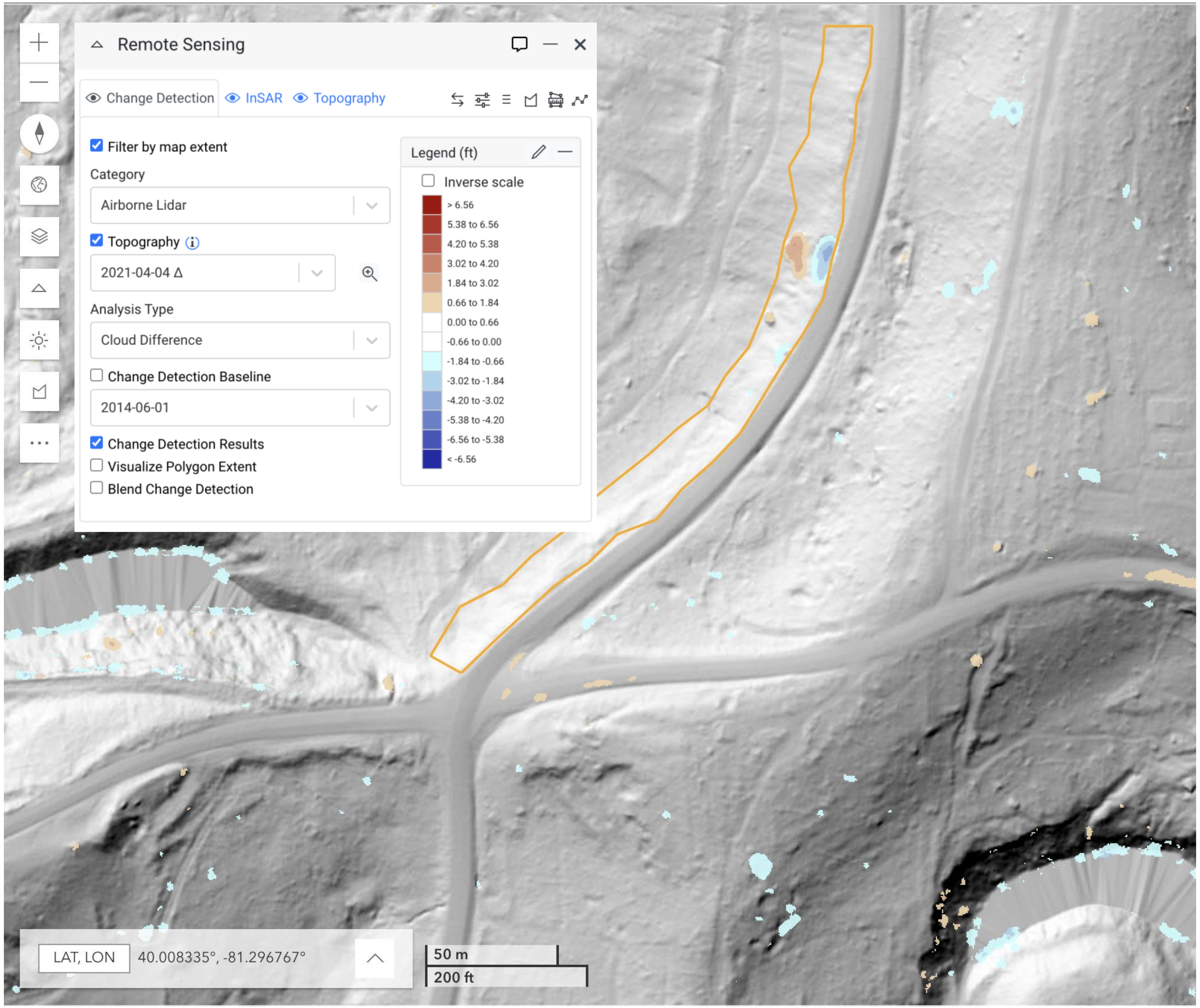


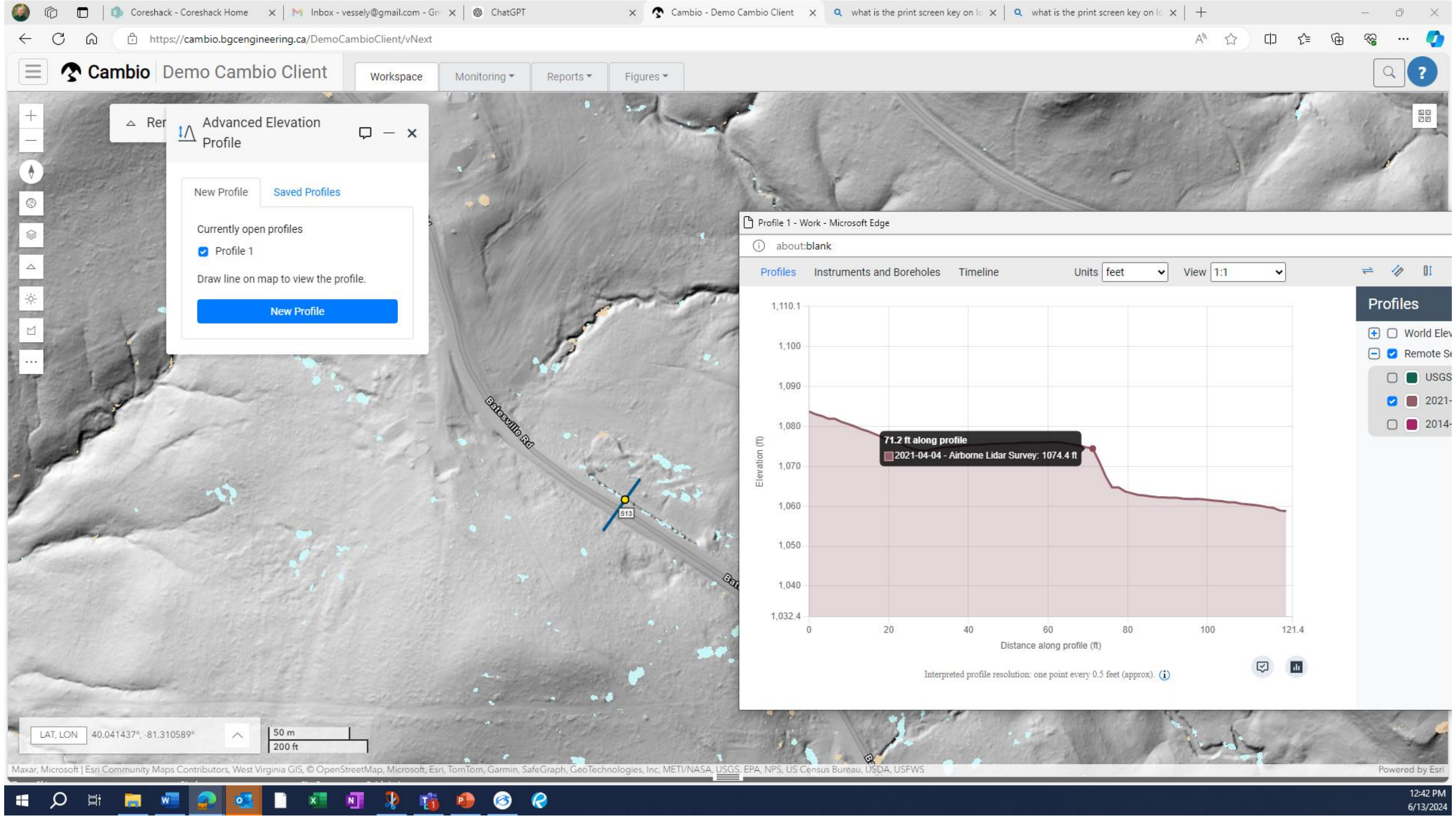
Example Findings

There is a landslide that slipped sometime between 2014-2021 on a embankment

Findings should be field verified, but we did this with:

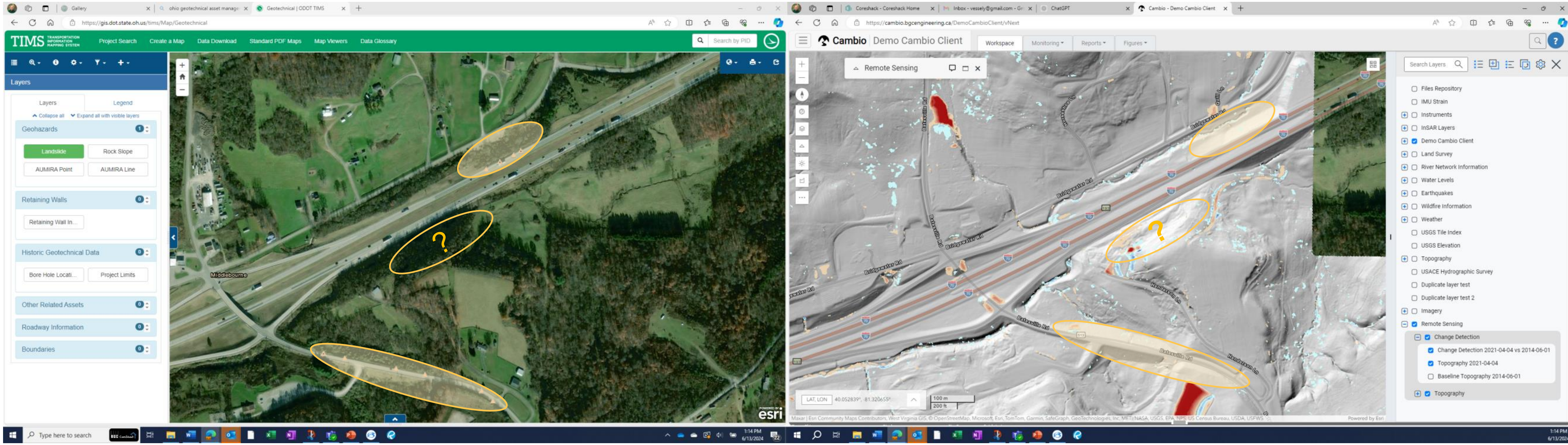
- In minutes and with no field work
- Existing data
- Can be scaled across entire state





Other uses for lidar in GAM:
Inform retaining wall inventory and tracking

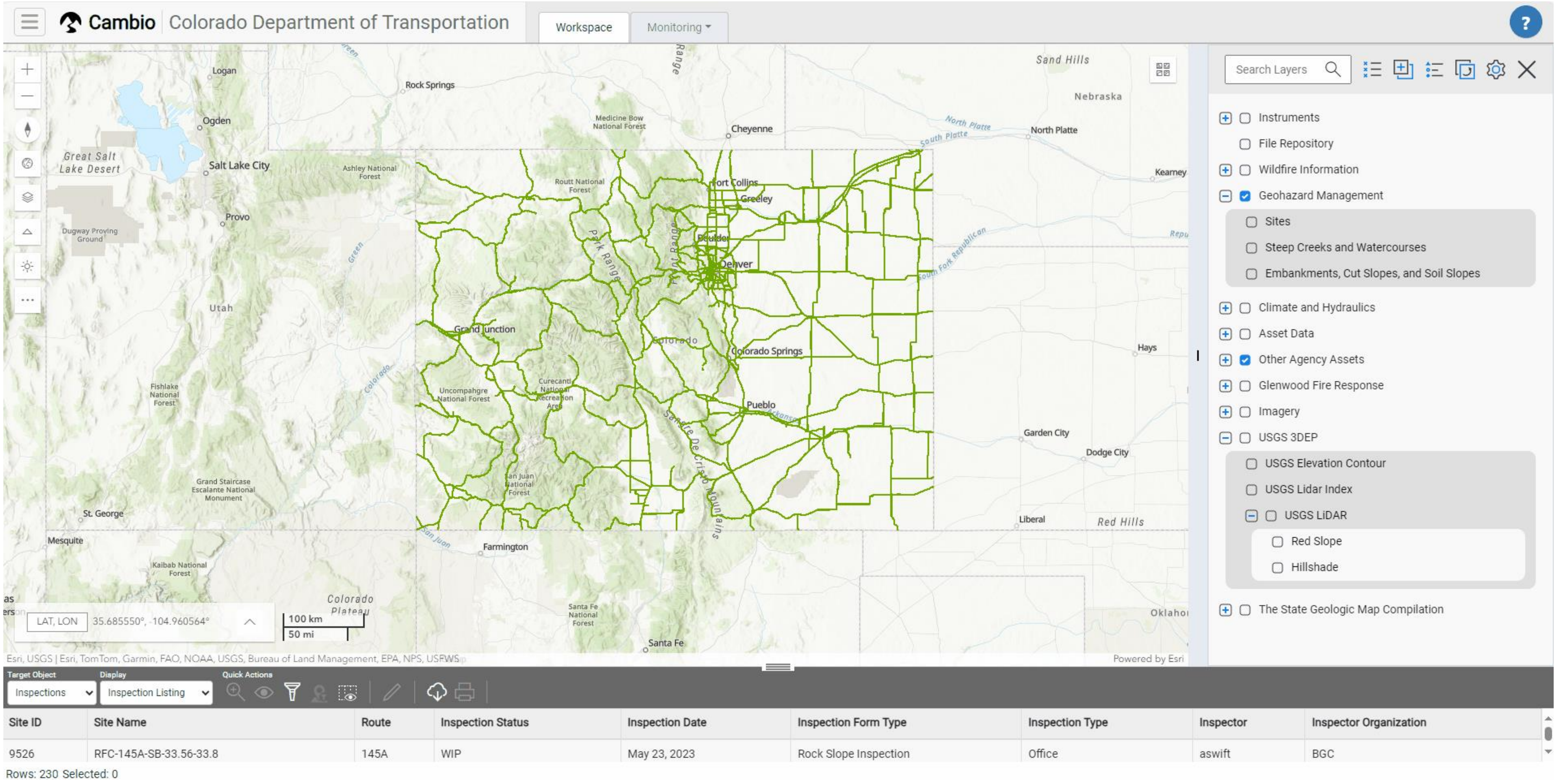
Closing knowledge gaps and saving time



10 landslide sites in the inventory view on the left, yet only 1 has measurably moved in the last 7 years? *How would this inform the inspection program in the future?*

Also, there is a site not in the inventory but showing change. *How does that inform the future plans?*

Statewide scale example



The speed advantage to resiliency

Technology brings the resourcefulness and rapidity to resiliency before and after disaster

How do geo-professionals influence resiliency

- Resiliency is treated through four options
    - **Robustness**
    - **Redundancy**
    - **Resourcefulness**
    - **Rapidity**

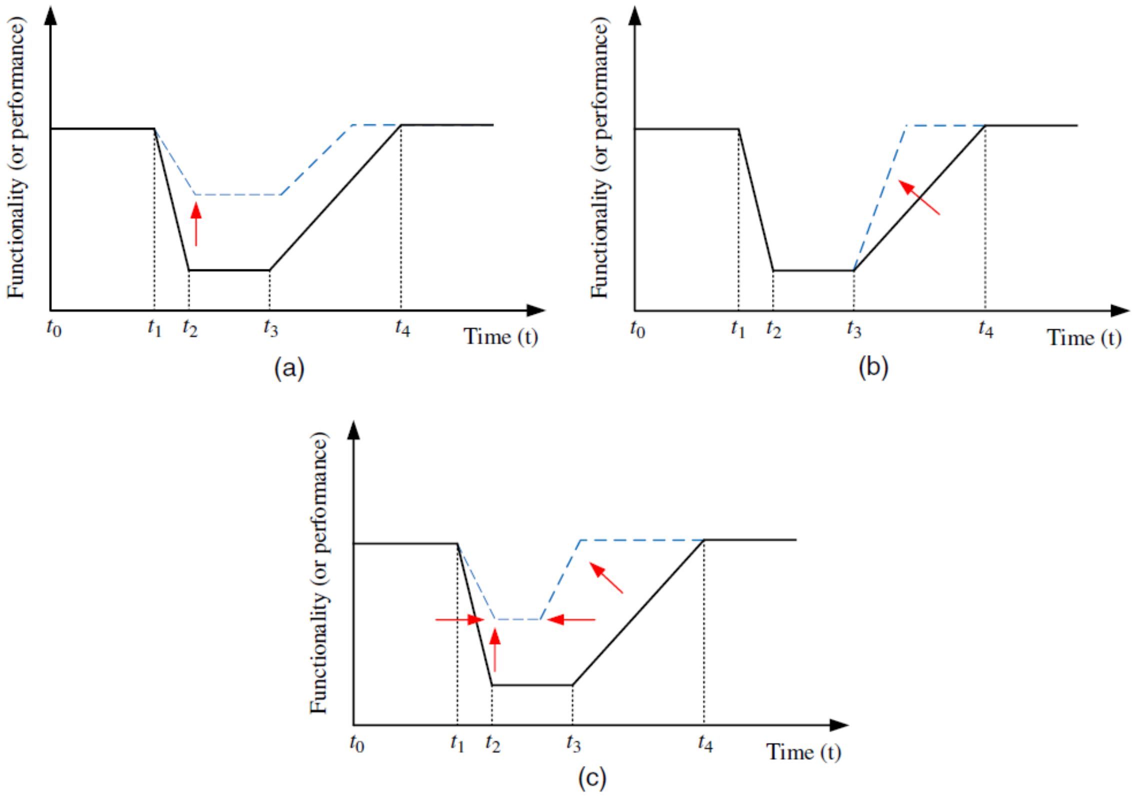
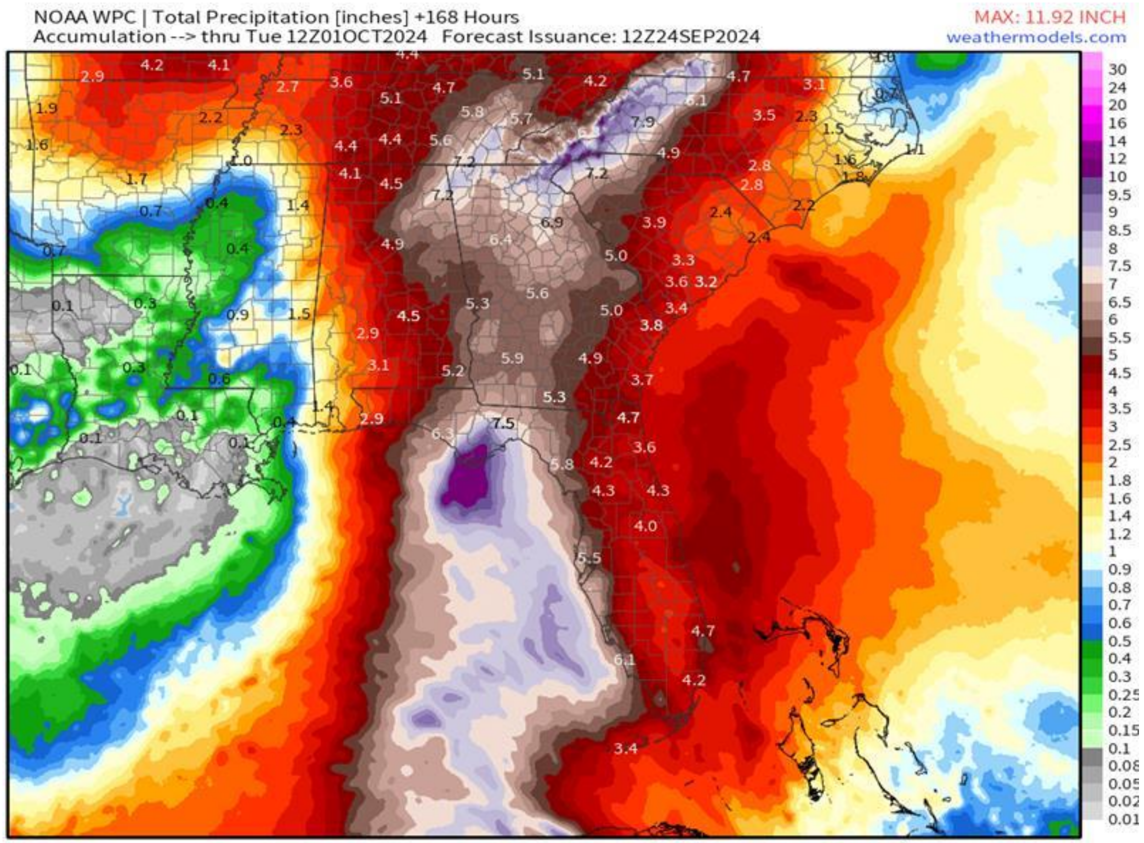


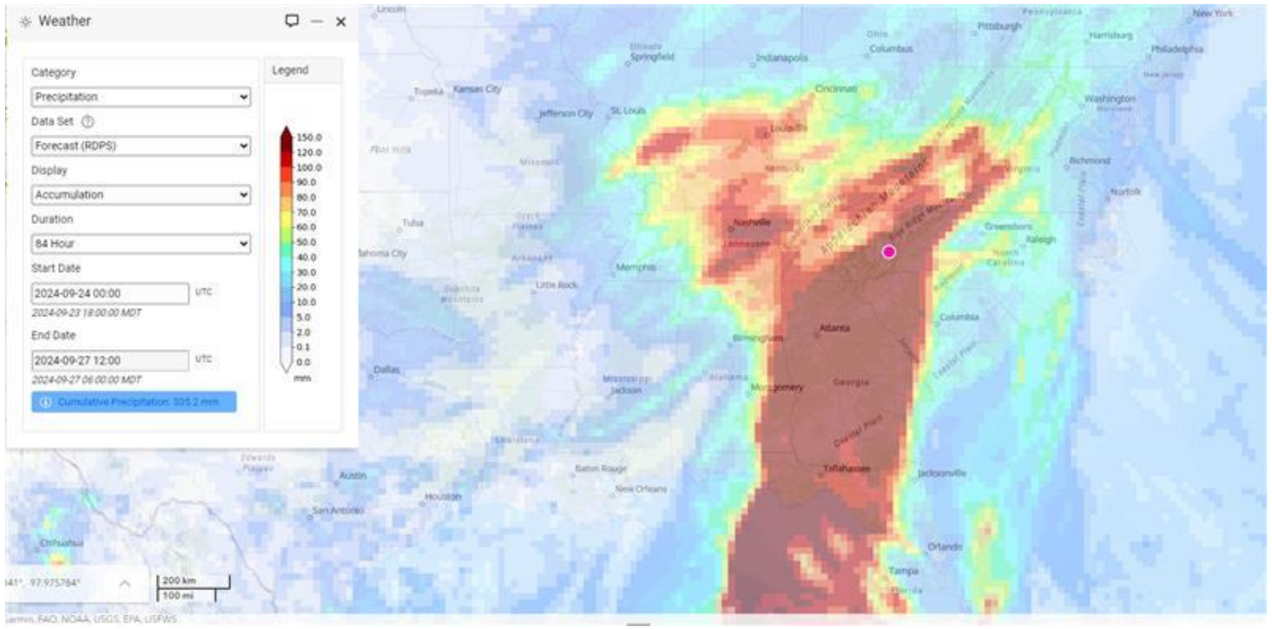
Fig. 3. Effect of resilience properties on system performance: (a) case with enhanced robustness and redundancy; (b) case with enhanced rapidity; and (c) case with enhanced resourcefulness.

 03121004-3 ASCE-ASME J. Risk Uncertainty Eng. Syst., Part A: Civ. Eng.

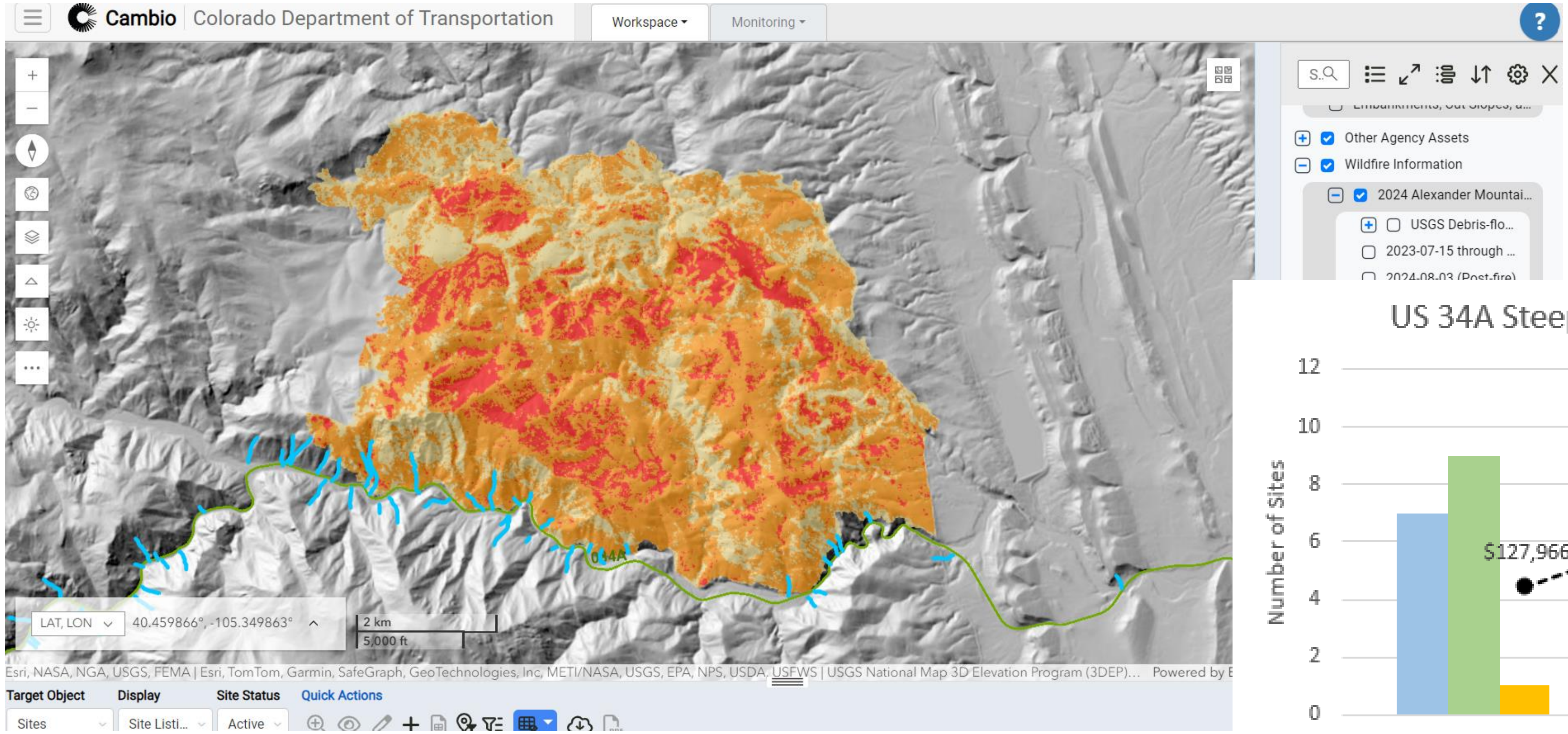
ASCE-ASME J. Risk Uncertainty Eng. Syst., Part A: Civ. Eng., 2022, 8(1): 03121004

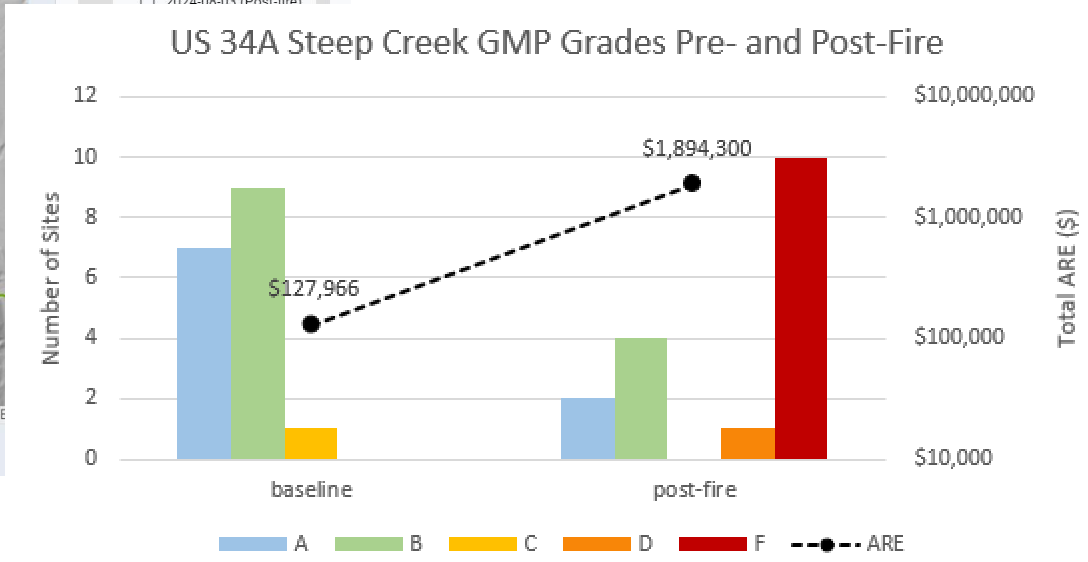
Rapid analytics: pipeline operator response workflow





Rapid analytics: post-fire debris flow risk change





August 2024 – measuring change in risk from pre-fire to post-fire conditions

Rapid Response after the event

- Lidar and other regional remote sensing data are easy to obtain
    - Not quite Uber quick but close when parts are in place

- What does lidar quickly after an event enable?
    - **Data for decisions in days instead if months**
    - **Quickly map changes - remotely**
    - **Quantify scour, sliding, erosion - remotely**
    - **3D terrain files for other disciplines – roadway, hydraulics**
    - **Communication and showing action – social license**

Contact us

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