KY PEM 2021

Remote underground investigation and stability of a historic underground Limestone Mine

Presented By: Daykin schnell

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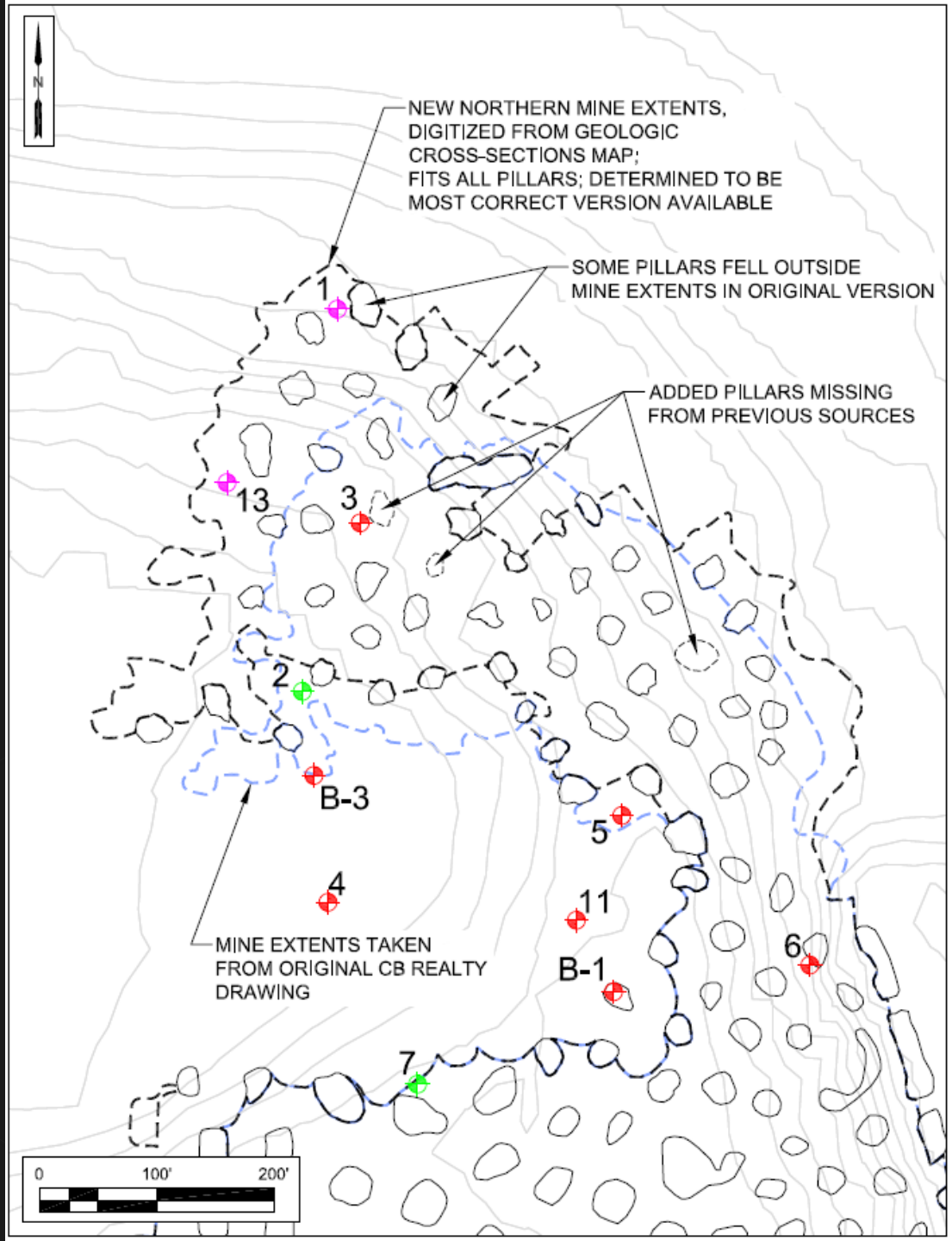
Project Overview

- Historic single-level limestone operation
- Scope of Work:
  - Determine the stability of the general area
  - Identify alternatives for a remediation plan to allow for construction of commercial structures on site
- Background Information:
  - Located in Midwest United States
  - Not actively mined since the 1970's
  - Previous post-mining land use for cold storage
  - No available access to the underground workings

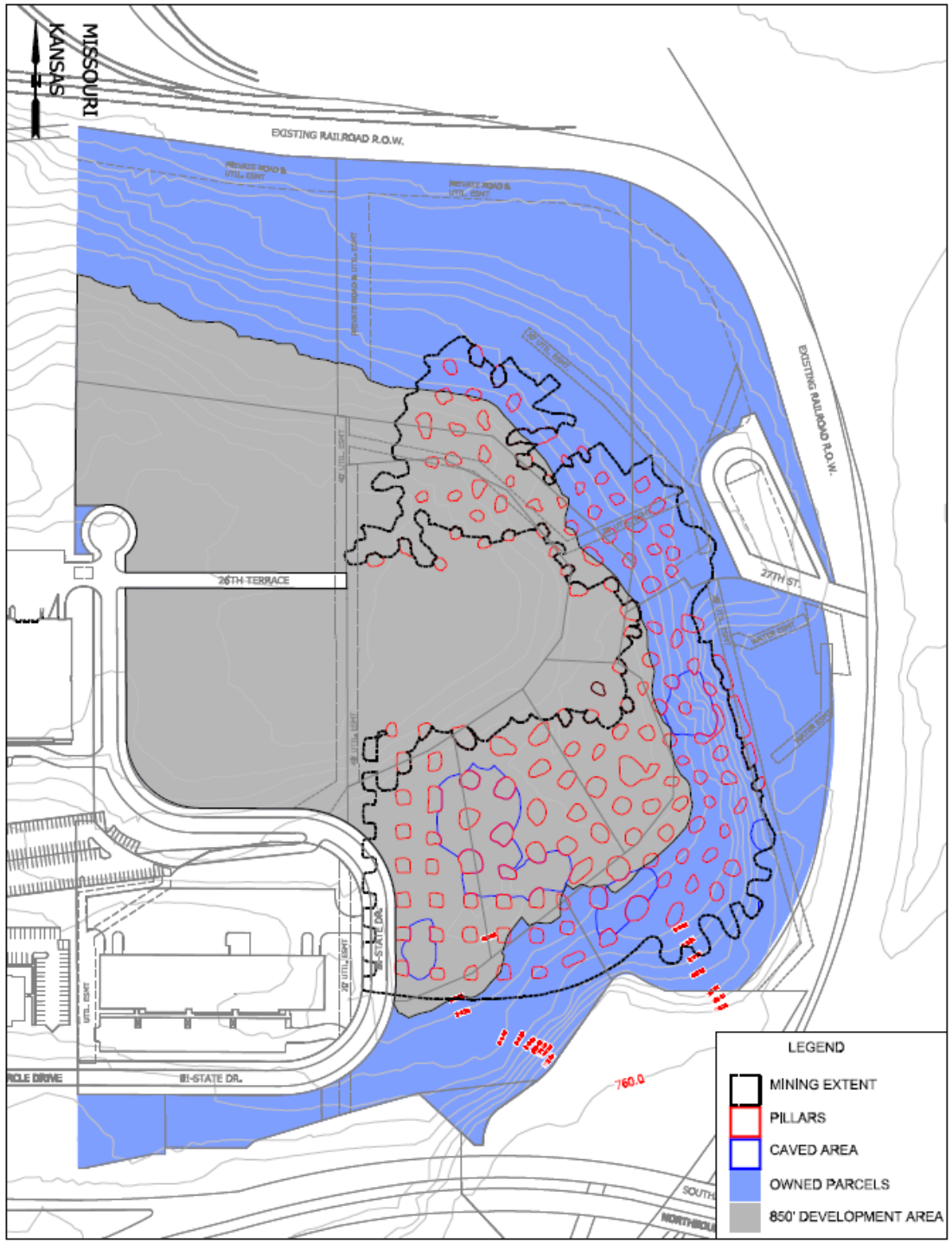
Initial Investigation

- Reviewed Data:
  - Historical data
    - Survey and mine maps
    - Geological cross sections
  - Supporting studies (same geological zones)
  - Had to adjust historic maps to match the most up to date data
- Concerns:
  - Accuracy of the historic maps
    - Extents
    - Mined areas
    - Roof falls / collapsed zones
  - Extents of collapsed zones
  - Overall geotechnical stability of the area



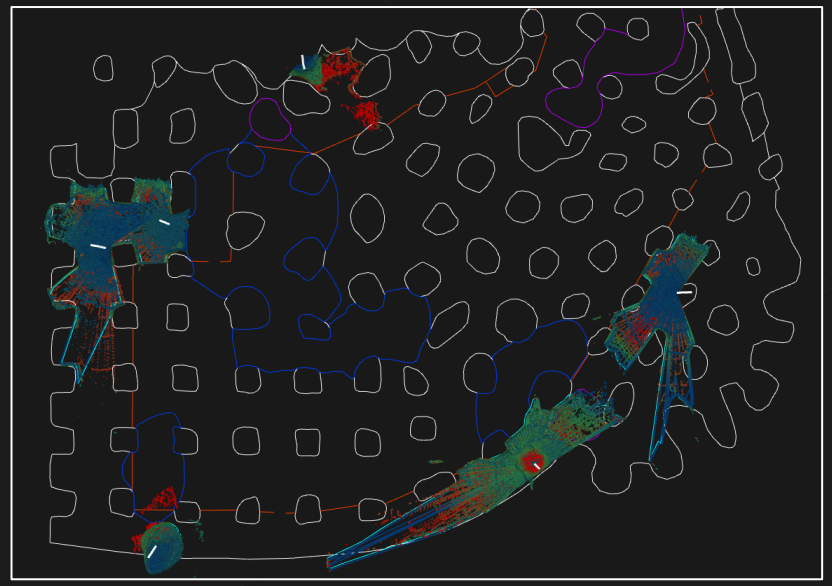
Project Overview

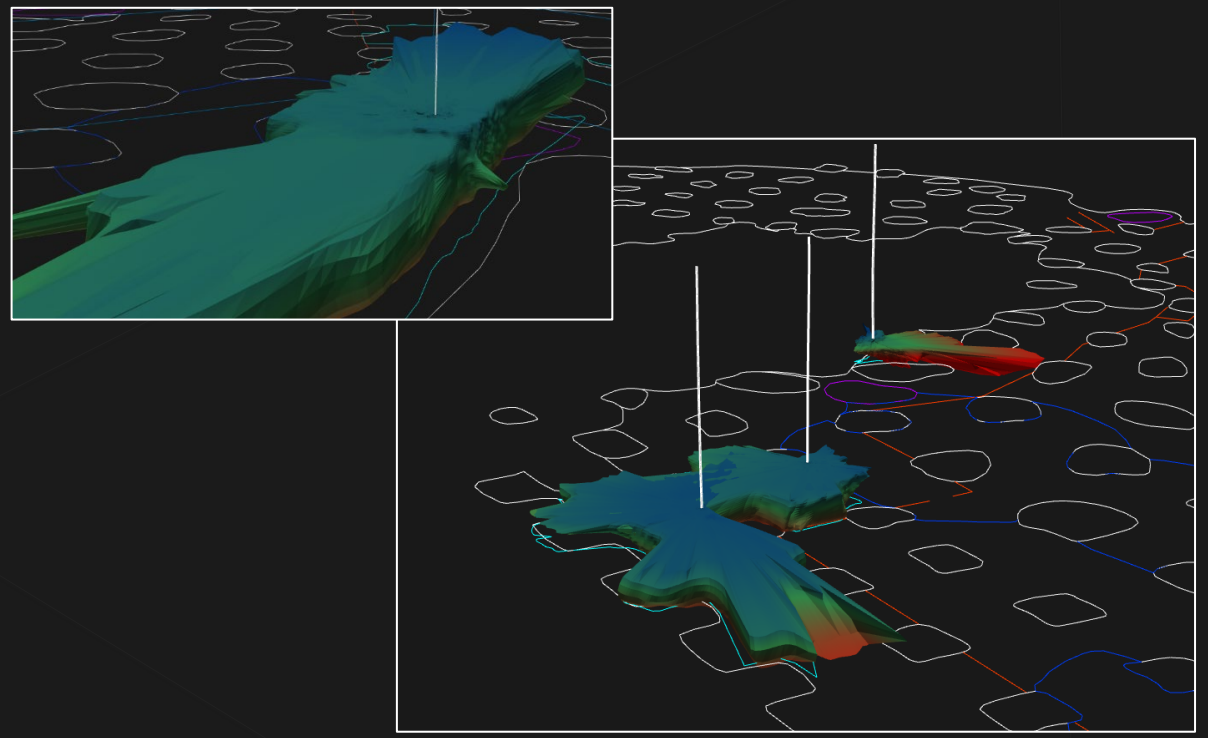
- Develop a Site Investigation Plan
  - Drill holes to remotely access the workings
  - Remotely scan, map, and geolocate underground workings
  - Investigate the extents of the mine
    - Unknown center area
    - North and Northwest extents
  - Adjust historic mine maps to match collected scan data
  - Collect geotechnical information to be used in stability analysis
    - Extent of roof collapse



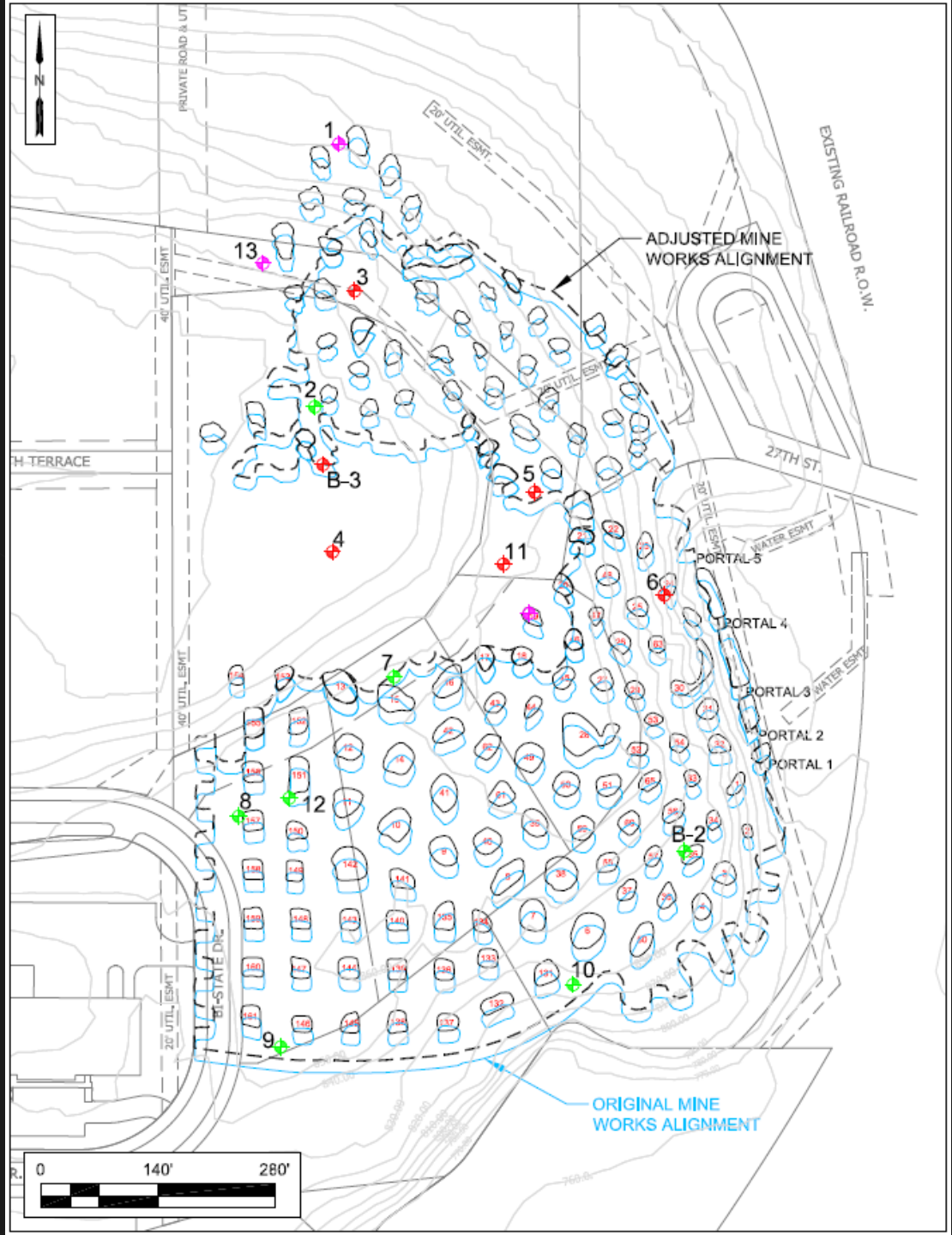
Site Investigation

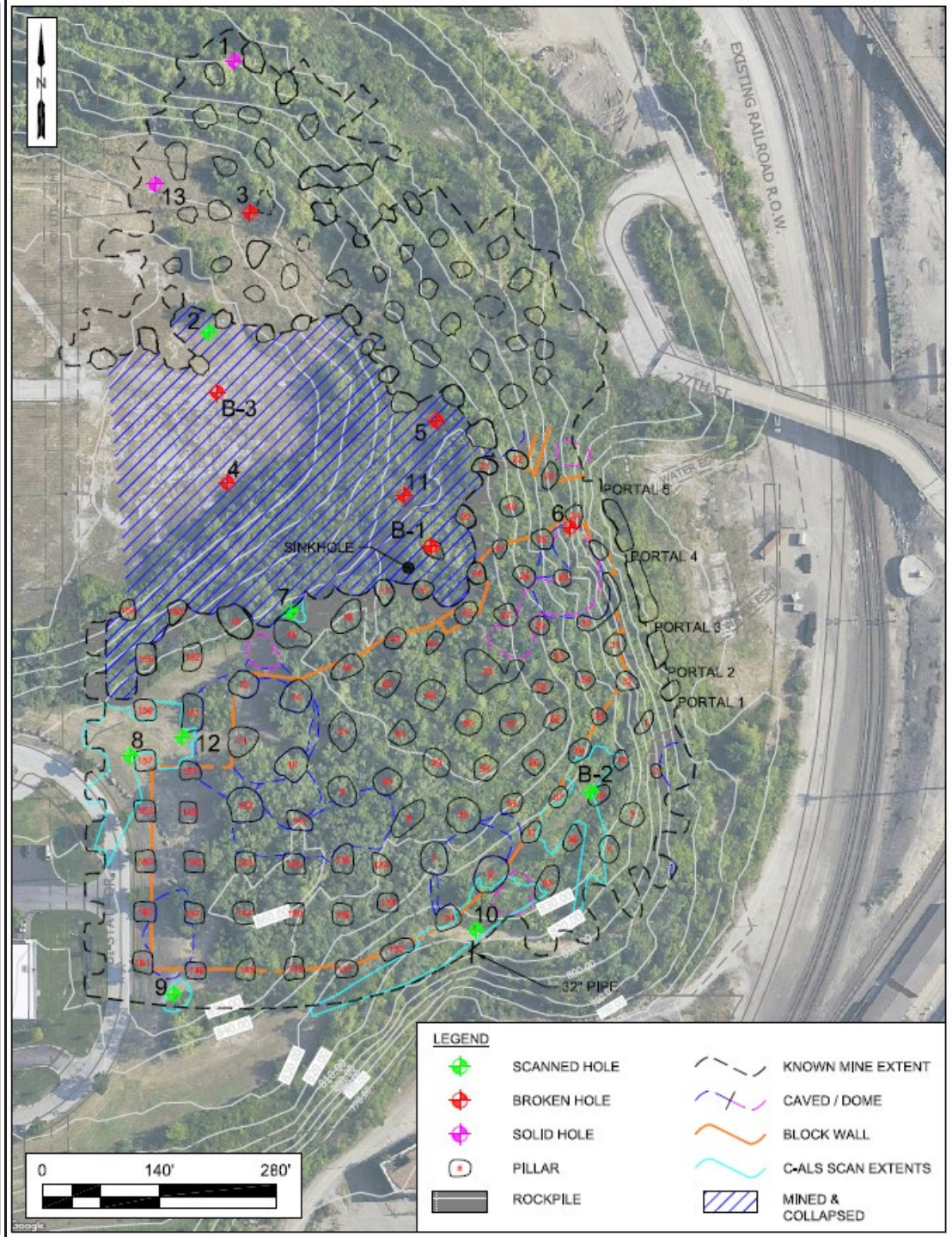
- Remote Scan and Mine Map Correction
  - Drilled 13 Holes
  - Surveyed 15 Holes
  - Geolocate and update maps with scans
    - Plan view
    - Elevation adjustment





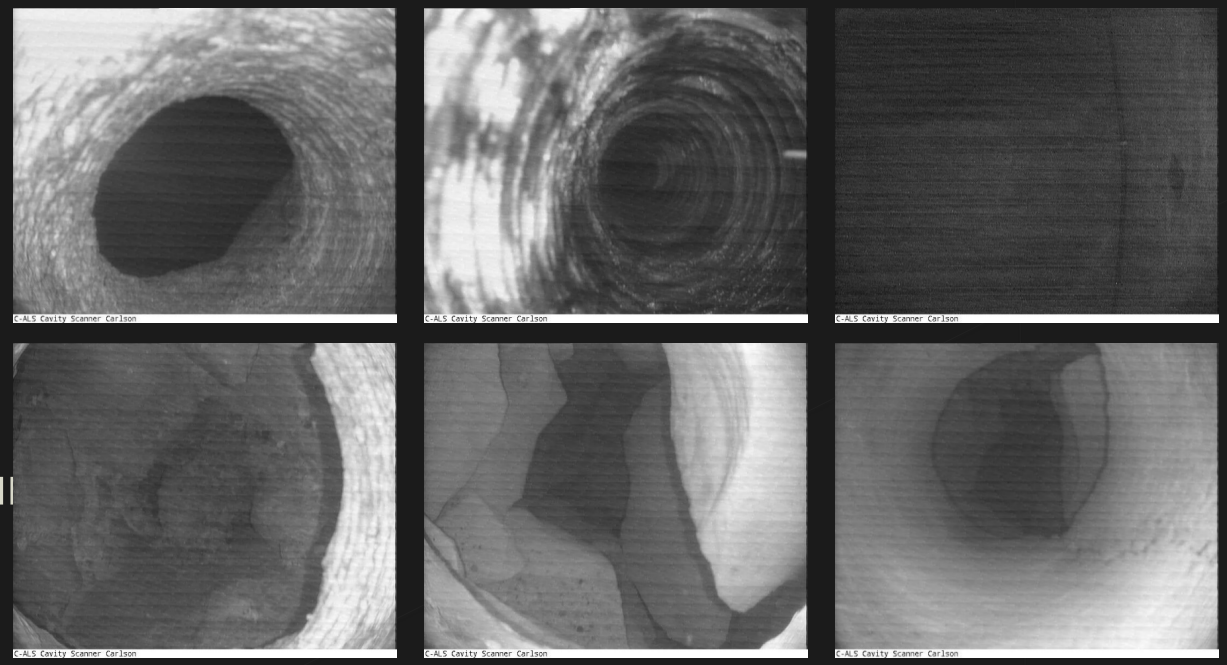
Site Investigation Map Correction

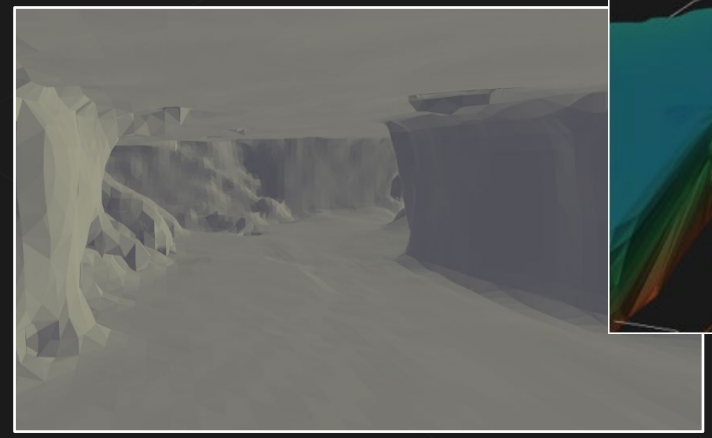


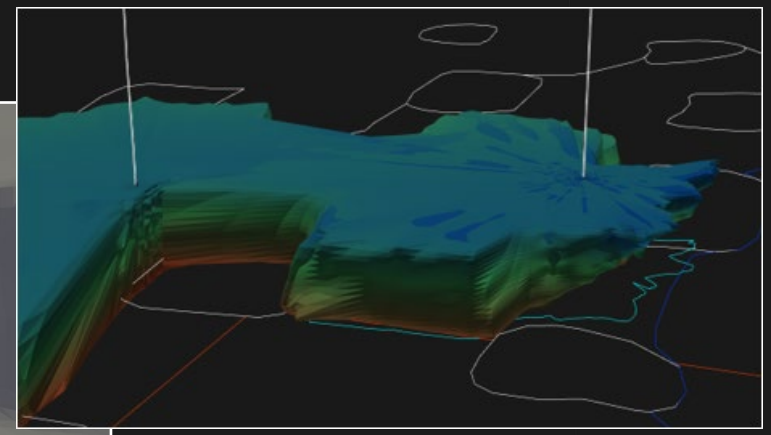


Site Investigation

- Review of Mine Extents and Collapse:
  - Confirm drill logs
  - Photos of geological, hole, and working conditions
    - Identify roof support and utilities undergrou
  - Mapping information geotechnical analysis
    - Approximate depth of geological inconsistencies
    - Pillar dimensions and integrity
    - Roof conditions
      - Stable and collapsed areas
  - Surface Investigation
    - Sinkholes

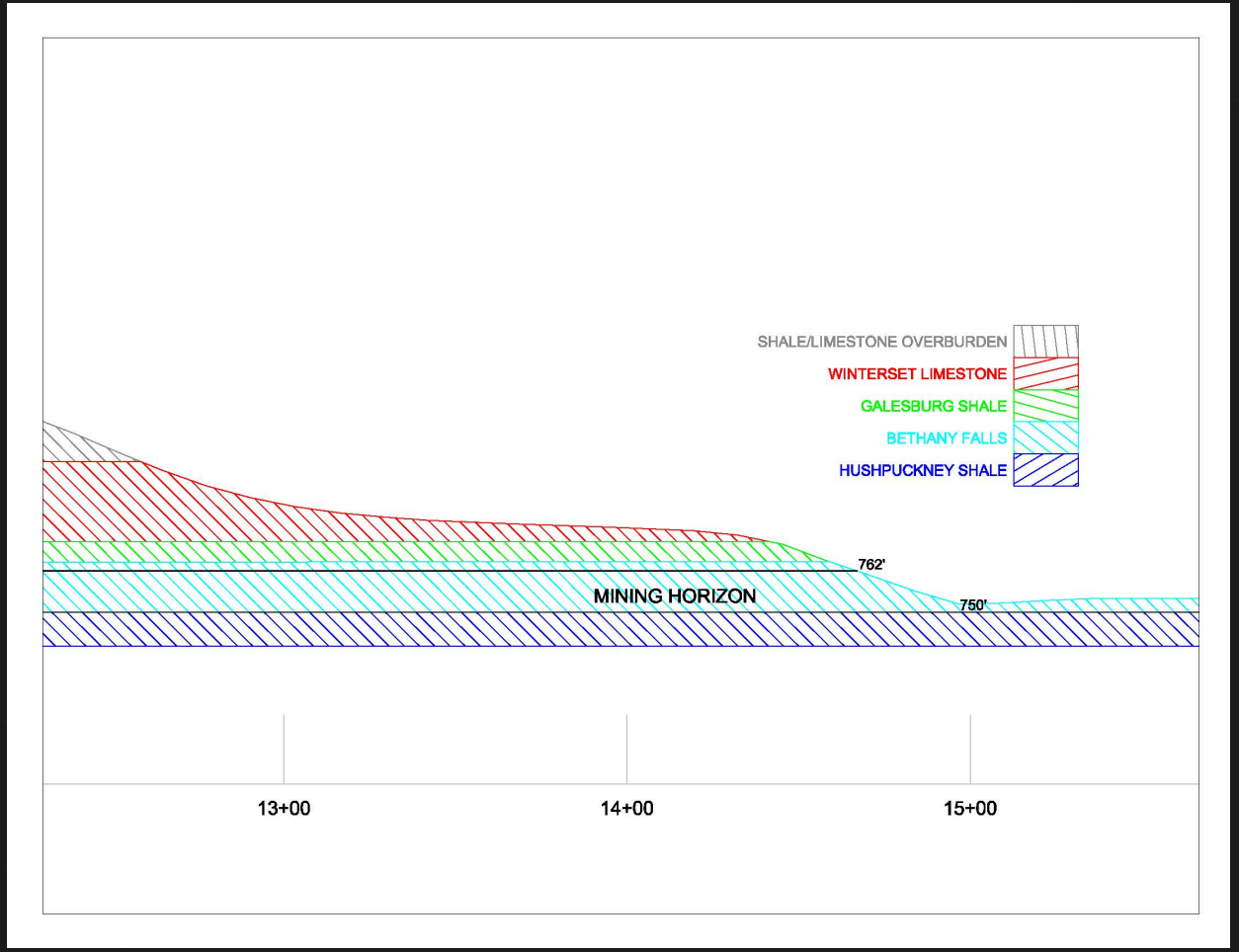






Data Analysis

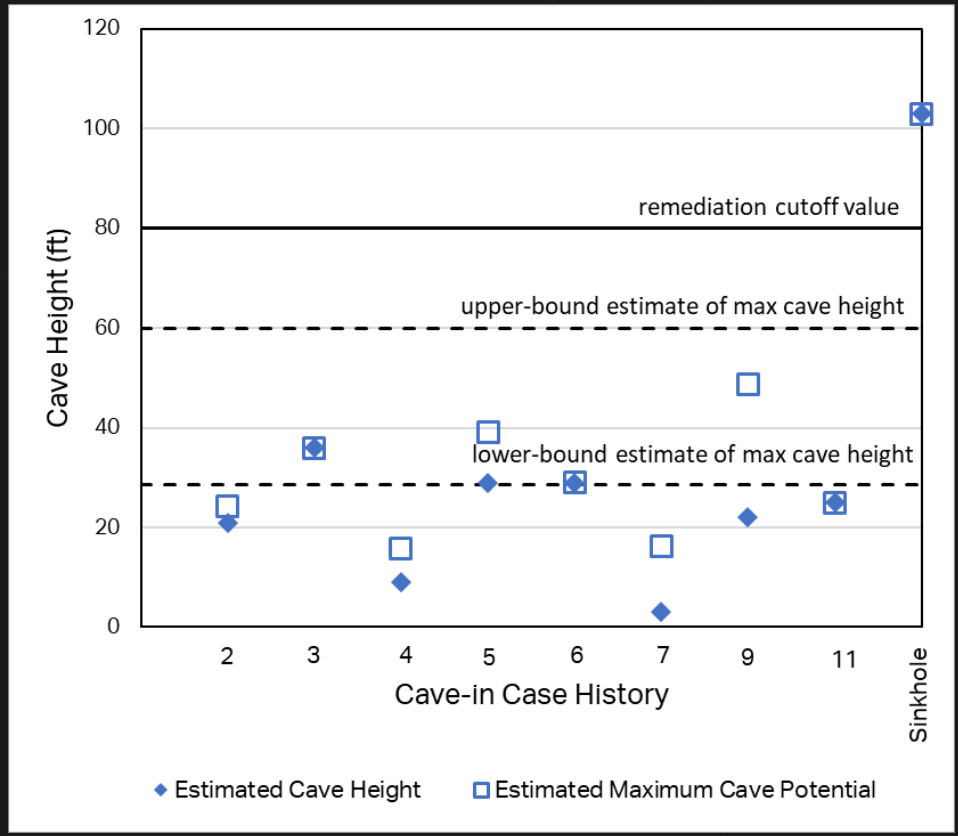
- Review of Mine Extents and Collapse:
  - Collapse extent determined using BF and size of historic workings
  - Volumetric analysis separated into 4 horizons



Data Analysis

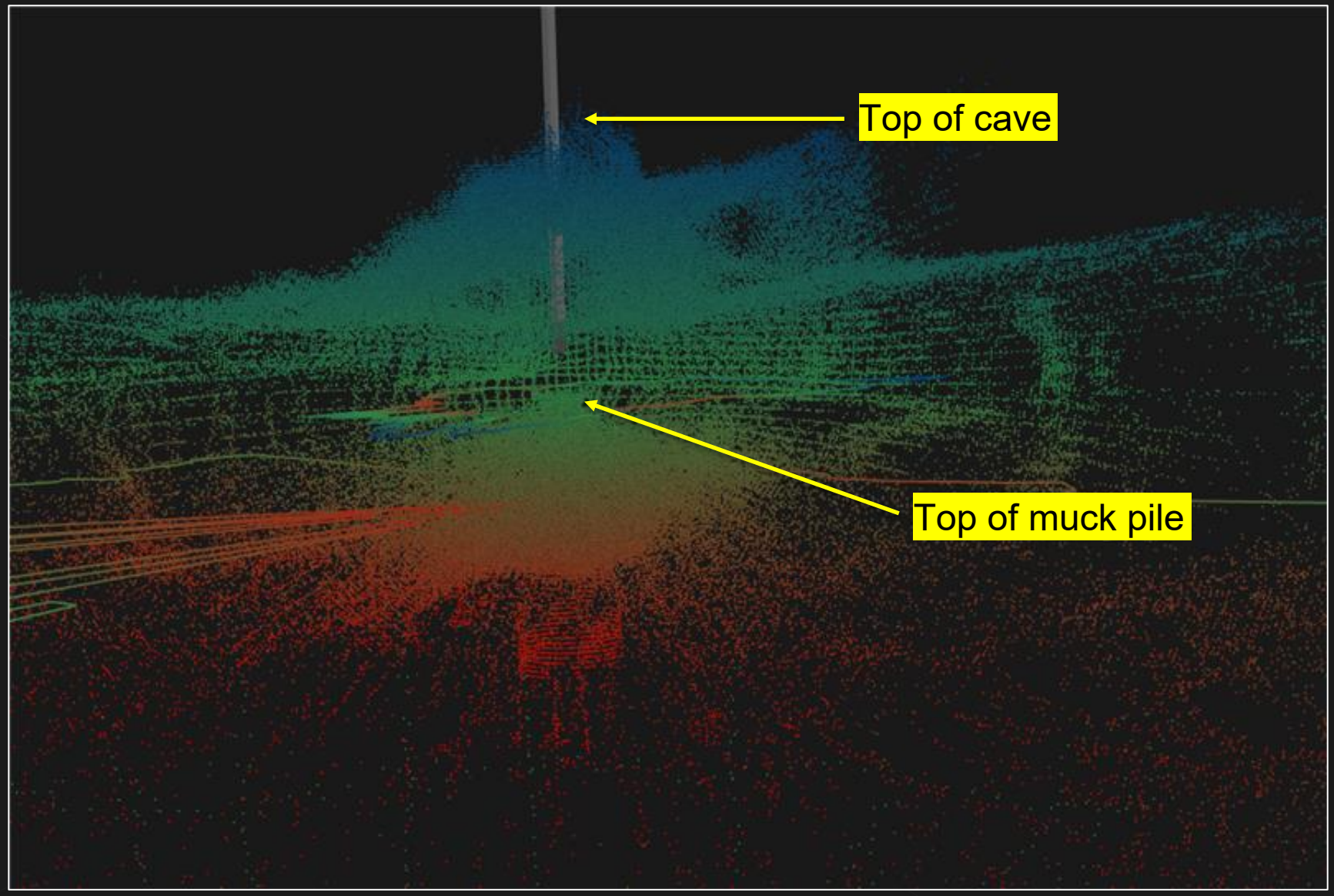
- Roof Collapse Review:
  - Reviewed all holes with caving above designed roof height
    - 8 of 15 holes investigated
  - Estimated Bulking Factor (BF)
    - Range of cave height using an assumed floor elevation based on scan data
  - Collapse potential calculated based on remaining void and a conservative BF of 1.3
  - Sinkhole is an outlier – most likely related to local geology

	No. of Cases	Max	Min	Average
Cave Height Above Roof (ft)	8	29 - 36	3 - 9	20 - 22
Cave Distance Into Winterset (ft)	5	23	3	14
Cave to Top of Winterset	1	CH3, 75-ft Unsupported Span		
Cave Above Winterset	1	Sinkhole, Cave to Surface		
Bulking Factor	8	1.52 – 1.93	1.18 – 1.25	1.45 – 1.57



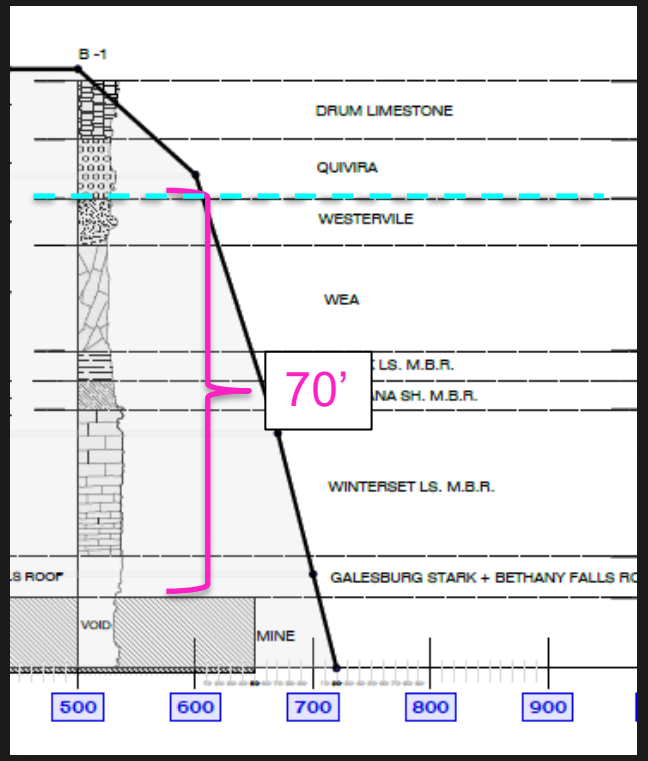
Data Analysis

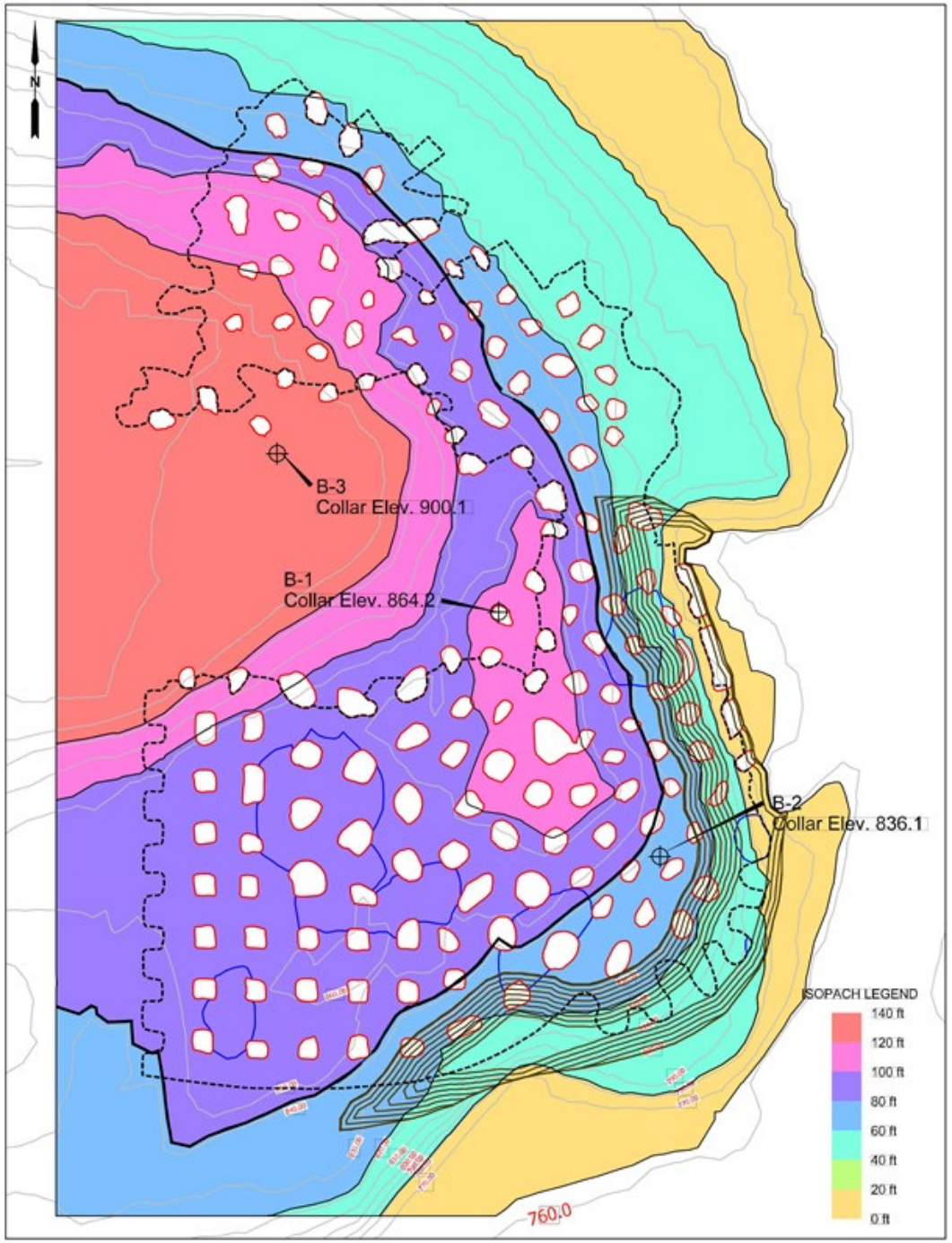
› Roof Collapse Review Example:



Recommendations

- Reclamation Requirements and Limitations
  - 70 ft cover requirement
    - Anything less will need to be excavated and back f
  - 70 ft to 80 ft will require grout columns

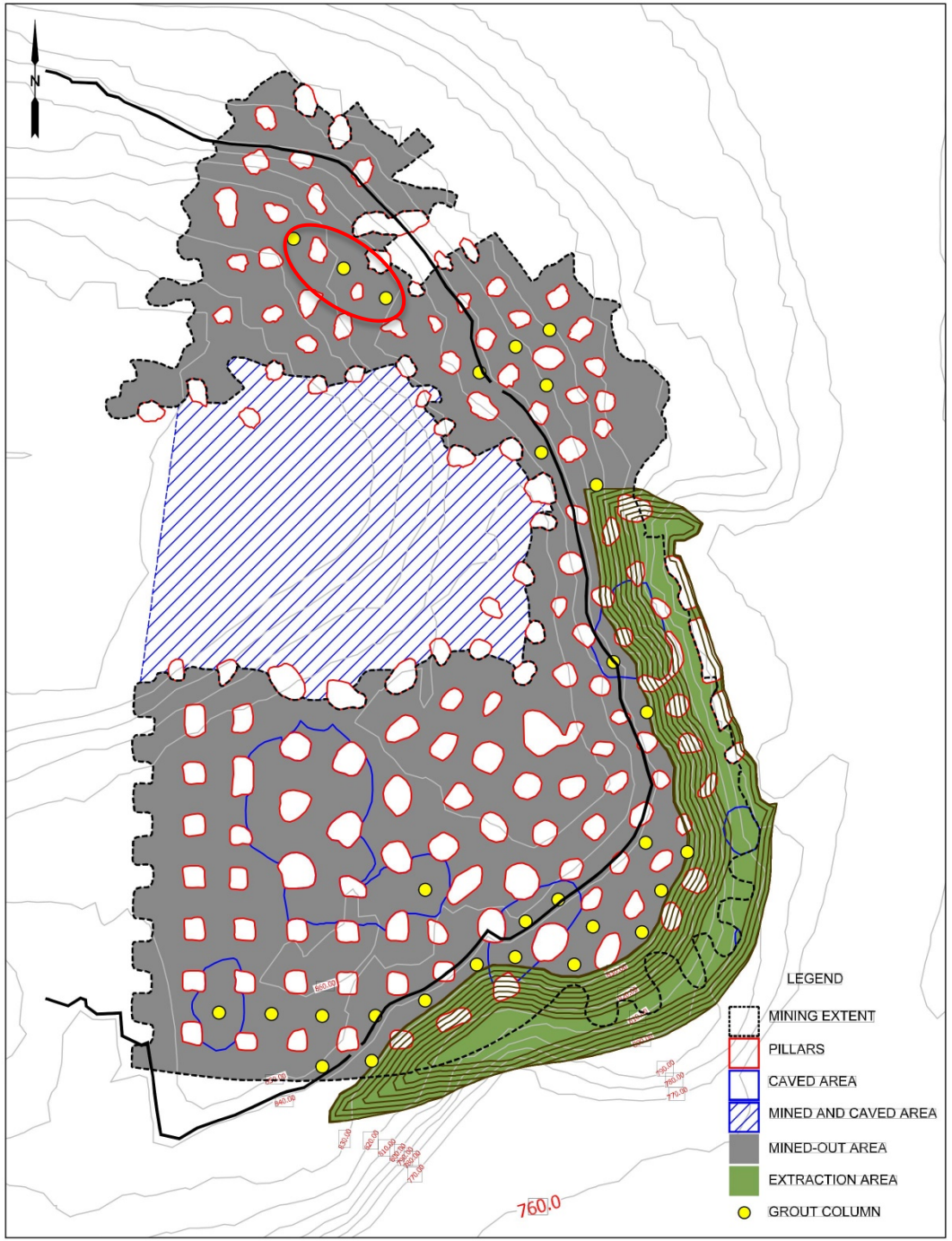




Recommendations

- Recommended Approach for Site Development
  - Prepare site for commercial construction
  - Shallow cover extraction with grout columns
  - Backfill with material on-site
    - Regrade and put in roads as needed
  - Work possible year-round with consideration of the effects of wet and cold weather
  - Provided estimated cost summary

Extraction Area Volumetric Analysis			
Horizon	Strata	Volume (CY)	Avg. Thickness (ft)
Overburden	Shale/Limestone	38,000	21
	Winterset Limestone	43,800	23
	Galesburg Shale	10,700	6
	Bethany Falls	7,200	4
	Sub-Total	**99,700**	**53**
Remaining Pillars	Bethany Falls	1,800	12
Extraction Total		**101,500**	**65**



Questions?