Large Excavations in the US

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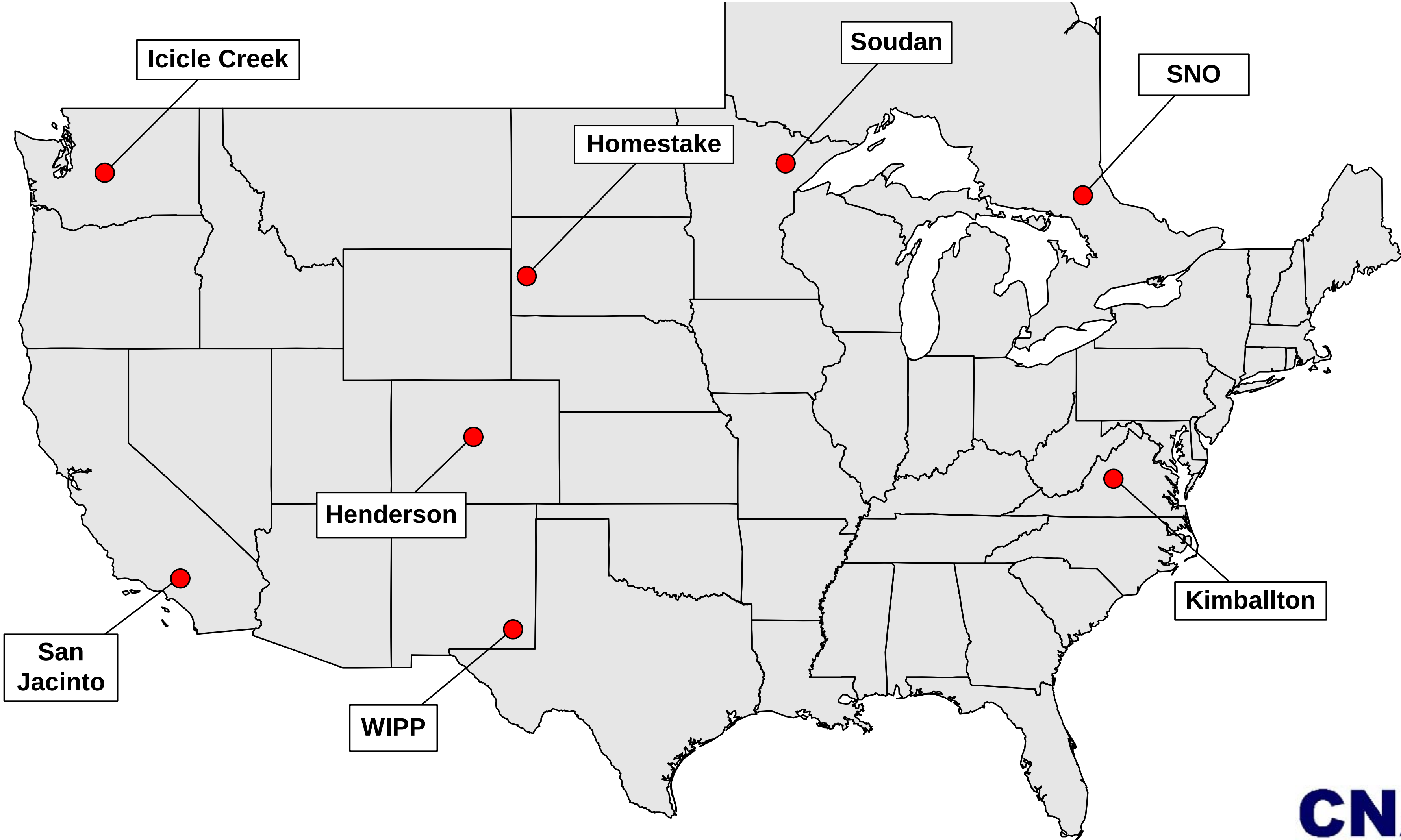
Topics

- DUSEL sites
- Site characteristics important for large excavations
- Rock engineering
- Relative importance of site characteristics
- Megaton detector feasibility

DUSEL Site Locales



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Solicitation 2 Sites

- Cascades-Icicle Creek, WA
  – Greenfield escarpment site & nearby railroad tunnel
- Henderson Mine, Empire, CO
  – Operating molybdenum mine since mid 1970s
- Homestake Mine, Lead, SD
  – Former operating gold mine
- Kimballton Mine, Giles Co., VA
  – Limestone mine & adjacent subsurface

Solicitation 2 Sites

- San Jacinto, CA
  - Greenfield escarpment site
- Soudan Mine, Soudan, MN
  - Operating lab at former iron mine, expansion into adjacent subsurface
- SNOLAB, Sudbury, Ontario
  - Operating lab in operating nickel mine
- WIPP, Carlsbad, NM
  - Operating lab in operating low-level waste facility

Characteristics for Large Excavations

- What site characteristics are important for large excavations?
  - Depth / shielding capacity
  - Rock type / rock chemistry
  - Rock quality / In situ stress
  - Access / rock removal
- Will review each characteristic for each site
- All comments that follow are for large excavations, not DUSEL in general

Depth / Shielding Capacity

DUSEL Site	Depth / Shielding Capacity
Cascade	Adequate
Henderson mine	Adequate
Homestake mine	Adequate
Kimballton	Adequate
San Jacinto	Adequate
Soudan	Adequate
SNOLAB	Adequate
WIPP	Adequate

Rock Type / Rock Chemistry

DUSEL Site	Rock type / chemistry
Cascade	Igneous, insoluble
Henderson mine	Igneous, insoluble
Homestake mine	Igneous/metamorphic, insoluble
Kimballton	Sedimentary, insoluble
San Jacinto	Igneous/metasediments, insoluble
Soudan	Igneous/metamorphic, insoluble
SNOLAB	Igneous/metamorphic, insoluble
WIPP	Sedimentary, soluble

Rock Quality / In situ Stress

Summary of available information about site rock quality.

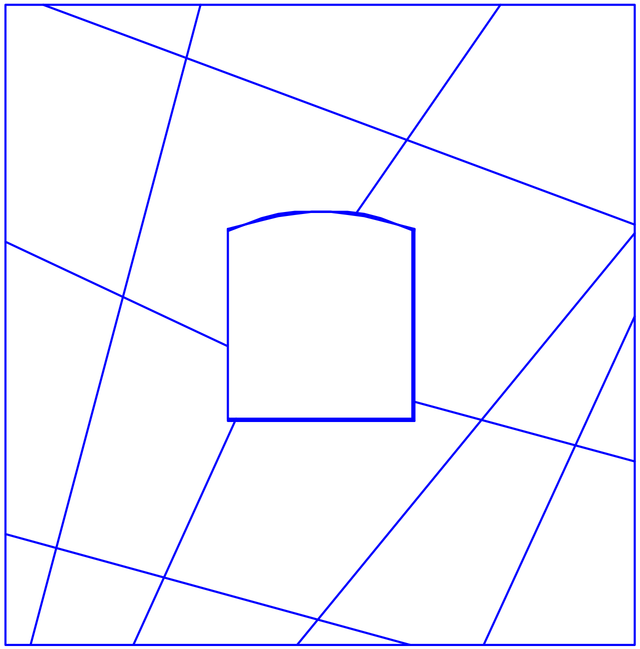
DUSEL Site	Rock quality / In situ Stress
Cascade	Nearby railroad tunnel
Henderson mine	Existing info & nearby mine excavations
Homestake mine	Existing info & nearby mine excavations
Kimballton	Existing info & nearby mine excavations
San Jacinto	Some tunneling nearby
Soudan	Existing info & existing lab caverns (different rock)
SNOLAB	Existing info & existing lab cavern
WIPP	Existing info & existing excavations

No site has sufficient experience to be sure that a megaton detector is feasible!

Rock Engineering 101

- Rock "material" — strong, stiff, brittle
  - Weak rock > Strong concrete
  - Strong in compression, weak in tension
  - Postpeak strength is low unless confined
- Rock "mass" — behavior controlled by discontinuities
  - Rock mass strength is 1/2 to 1/10 of rock material strength
- Discontinuities give rock masses scale effects

Rock Engineering 101



- Massive rock
  - Rock masses with few discontinuities, or
  - Excavation dimension < discontinuity spacing

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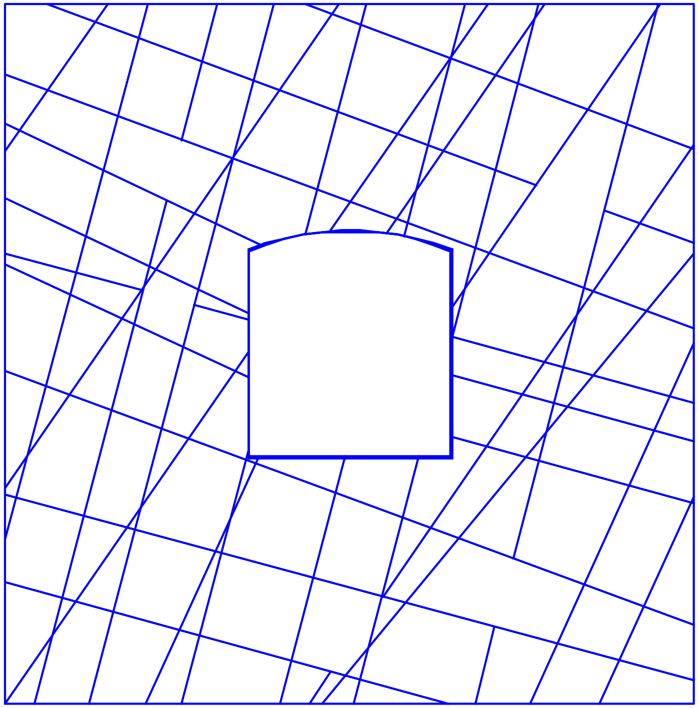
Rock Engineering 101



- Jointed or “blocky” rock
  - Rock masses with moderate number of discontinuities
  - Excavation dimension > discontinuity spacing

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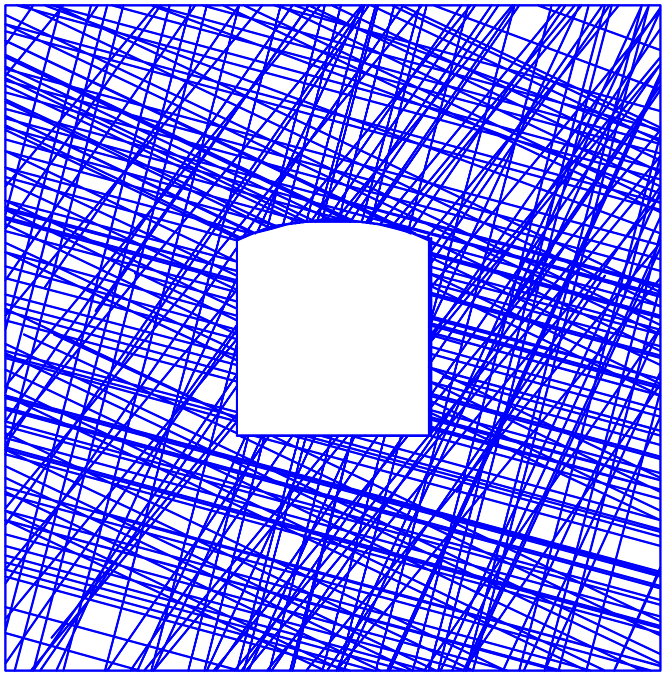
Rock Engineering 101



- Heavily jointed rock
  - Rock masses with a large number of discontinuities
  - Excavation dimension >> discontinuity spacing

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Rock Engineering 101

- Rock stresses in situ
  - Vertical stress ≈ weight of overlying rock
    - ~27 KPa / m ⇒ 35.7 MPa at 1300 m
  - Horizontal stress controlled by tectonic forces (builds stresses) & creep (relaxes stresses)
    - At depth, $\sigma_v \approx \sigma_h$ unless there are active tectonic forces

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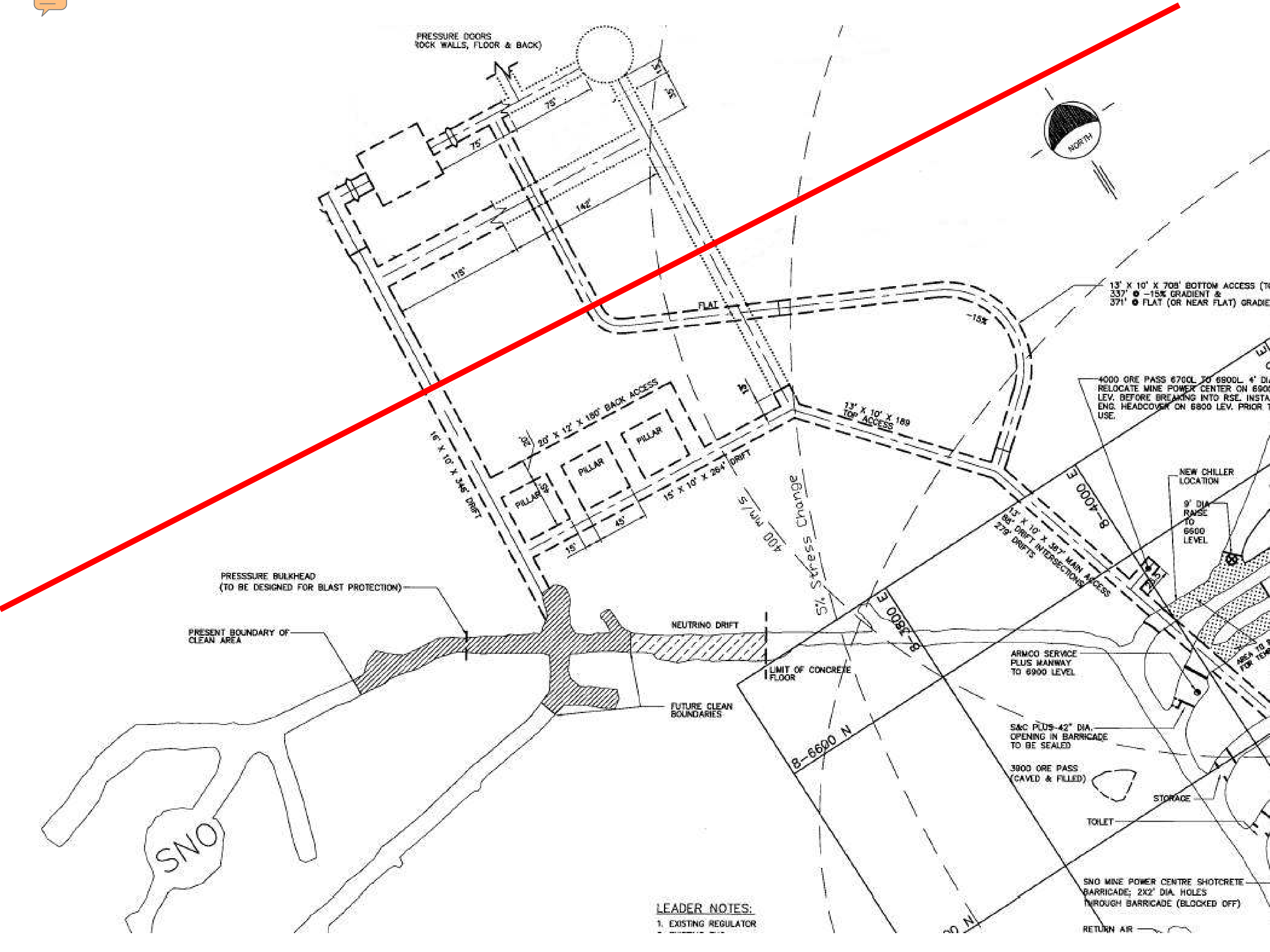
Major Rock Features

- Examples
  - Geologic contacts
  - Joint swarms
  - Shears and faults
- Effects
  - Reduced rock quality
  - Reduced strength
  - Locus for rockburst / seismic activity

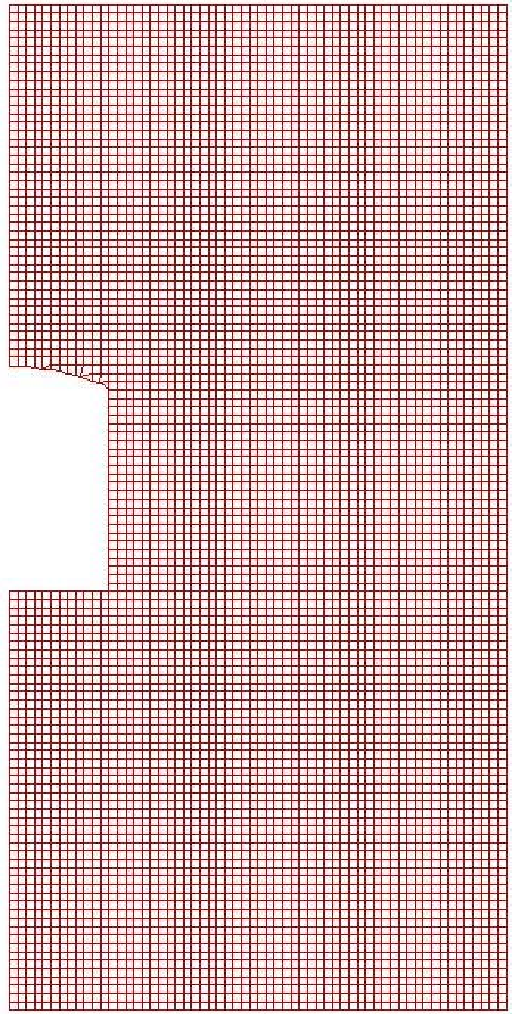

PRESSURE DOORS
ROCK WALLS, FLOOR & BACK)
75'
75'
30'
142'
178'
NORTH
FLAT
-15%
13' X 10' X 708' BOTTOM ACCESS
337' @ -15% GRADIENT &
371' @ FLAT (OR NEAR FLAT) GRADIE
20' X 12' X 180' BACK ACCESS
13' X 10' X 189
TOP ACCESS
PILLAR
PILLAR
PILLAR
15' X 10' X 264' DRIFT
16' X 10' X 346' DRIFT
45'
15'
400 m/s
5% Stress Change
13' X 10' X 387' MAIN ACCESS
88' DRIFT INTERSECTIONS
279' DRIFTS
8-4000 E
8-3800 E
8-6600 N
4000 ORE PASS 6700L TO 6800L. 4' DI
RELOCATE MINE POWER CENTER ON 690
LEV. BEFORE BREAKING INTO RSE. INSTA
ENG. HEADCOVER ON 6800 LEV. PRIOR T
USE.
NEW CHILLER
LOCATION
9' DIA
RAISE
TO
6600
LEVEL
PRESSSURE BULKHEAD
(TO BE DESIGNED FOR BLAST PROTECTION)
PRESENT BOUNDARY OF
CLEAN AREA
NEUTRINO DRIFT
LIMIT OF CONCRETE
FLOOR
FUTURE CLEAN
BOUNDARIES
ARMCO SERVICE
PLUS MANWAY
TO 6900 LEVEL
S&C PLUS 42" DIA.
OPENING IN BARRICADE
TO BE SEALED
3900 ORE PASS
(CAVED & FILLED)
STORAGE
TOILET
SNO MINE POWER CENTRE SHOTCRETE
BARRICADE; 2X2' DIA. HOLES
THROUGH BARRICADE (BLOCKED OFF)
RETURN AIR
SNO
LEADER NOTES:
1. EXISTING REGULATOR

Numerical Modeling

- Rock engineering equivalent of bridge or building structural analysis
- Develop understanding of the critical physical parameters
  - Rock characteristics
  - Rock stresses
  - Cavern shape
  - Rock support & reinforcement
- Common types
  - Continuum
  - Discontinuum

Simple example

- Continuum model FLAC 2D
- 60 x 60 x 180 meters (length not modeled)
- Curved roof & straight walls
- Depth 1300 meters
- Stresses ≈ depth
- Example rock properties
- Sequential excavation
- Rock reinforcement
- Model permits rock failure



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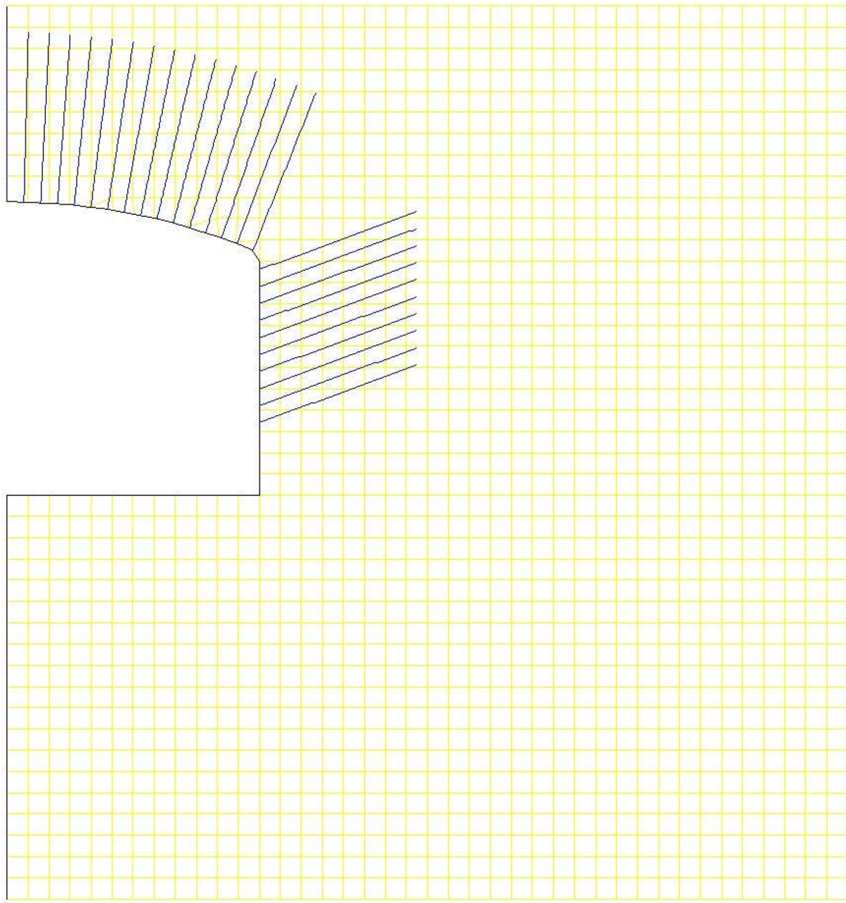
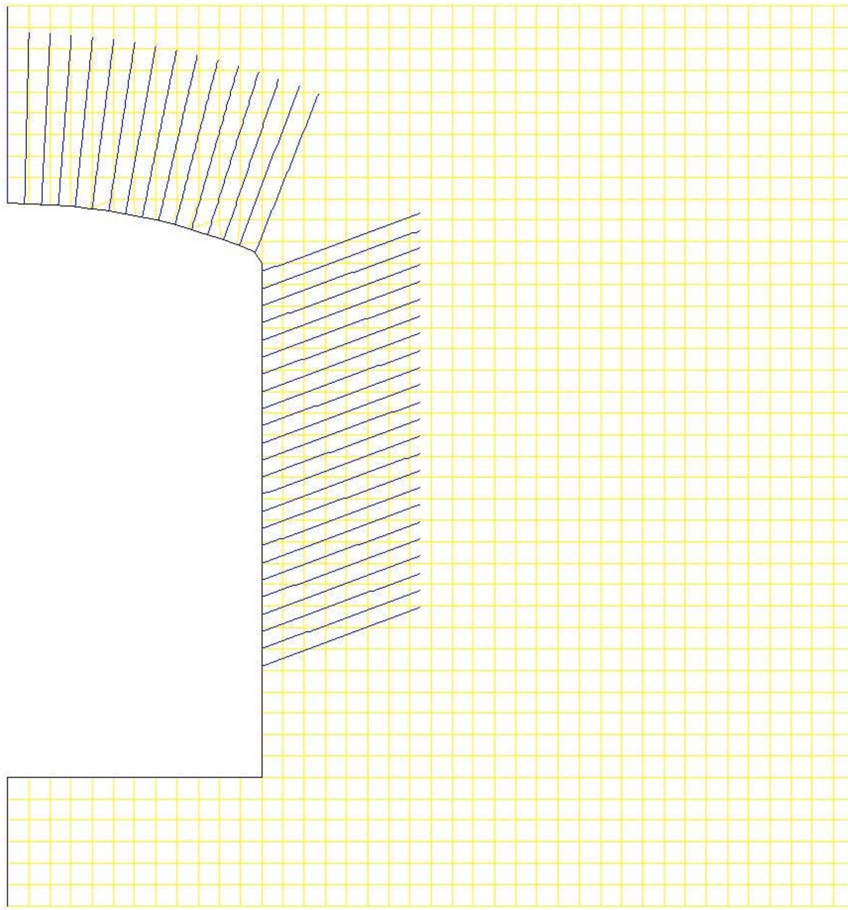
Sequential excavation





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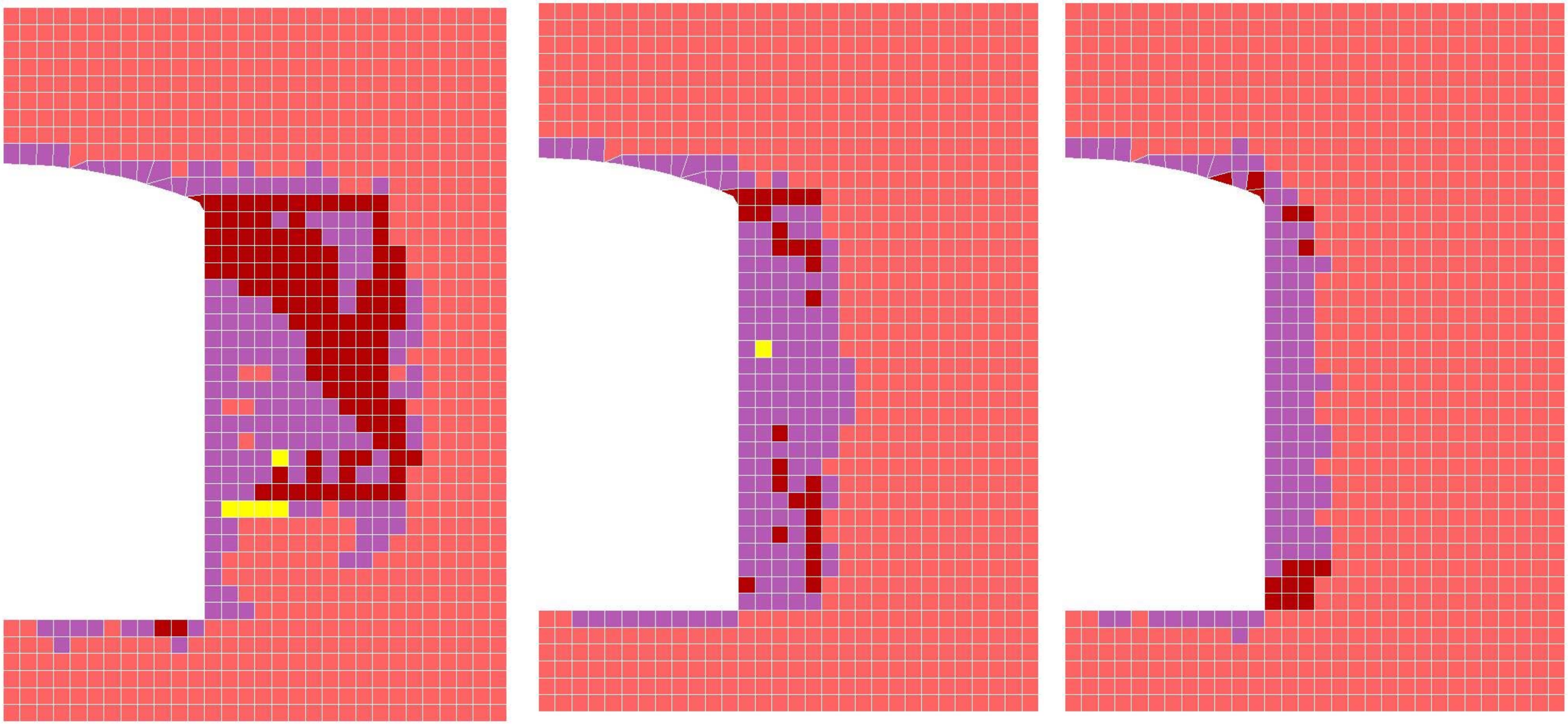
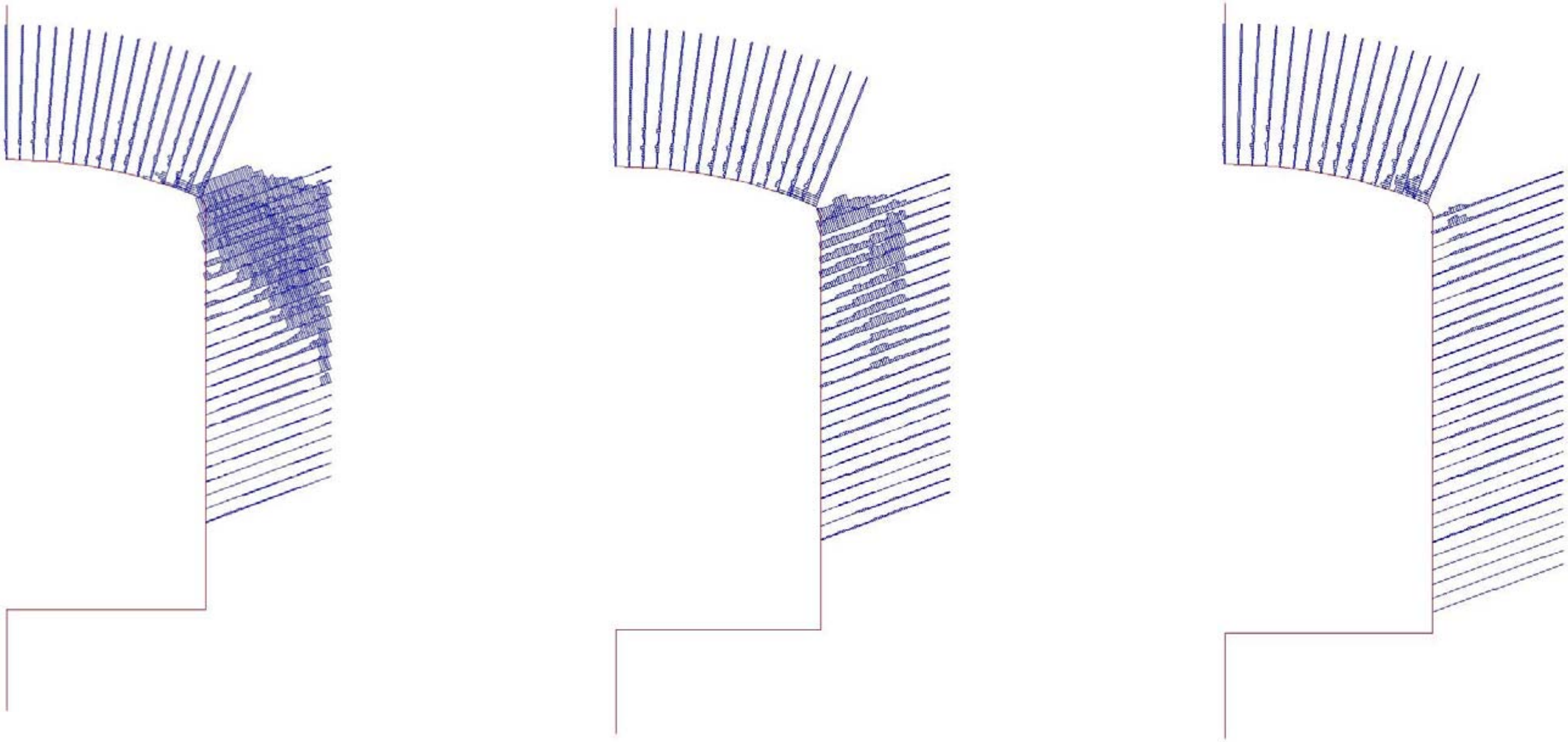
Effect of Rock Strength



Cablebolt Forces



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Rock Mass Characterization

- Stages
  - Choose the best site
  - Find best location at the chosen site
  - Prove rock conditions at chosen location
- Volume of rock necessary
- Technical objectives
  - Provide design basis
  - Choose proper design and construction techniques
  - Reduce risk of differing site conditions
  - Basis for cost estimating
  - Basis for defining baseline, i.e. contractor bidding

Access / Rock Removal

DUSEL Site	Access / Rock Removal
Cascade	Horizontal access & nearby railroad tunnel
Henderson mine	10-mile ore conveyor
Homestake mine	Existing shaft ore handling equipment
Kimballton	Inclined tunnel to surface
San Jacinto	Horizontal access
Soudan	Shaft
SNOLAB	Shaft & underground use
WIPP	Shaft

Conclusions about important features

- Depth / shielding capacity
  - All sites appear adequate
- Rock type / rock chemistry
  - All sites appear adequate, but salt at WIPP may be problematic (due to creep & solubility)
- Rock quality / In situ stress
  - All sites are potentially suitable, but none are guaranteed feasible
- Access / rock removal
  - All sites are potentially suitable, but horizontal access is beneficial

What is MOST important?

- Rock type / rock chemistry
  - Creep & solubility are the principal issues
- Rock quality / In situ stress
  - Commonly influences costs by a factor of 2 to 4, could make a site unfeasible
- Access / rock removal
  - Can influence costs significantly, but is very site dependent

Rock Engineering 101

- What are the implications for large cavern construction?
  - Find a site with excellent rock
  - Characterizing the rock mass is JOB ONE
  - Avoid tectonic zones & characterize in situ stresses
  - Select size, shape & orientation to minimize rock support, stress concentrations, etc.
    - Soudan 2 & MINOS caverns

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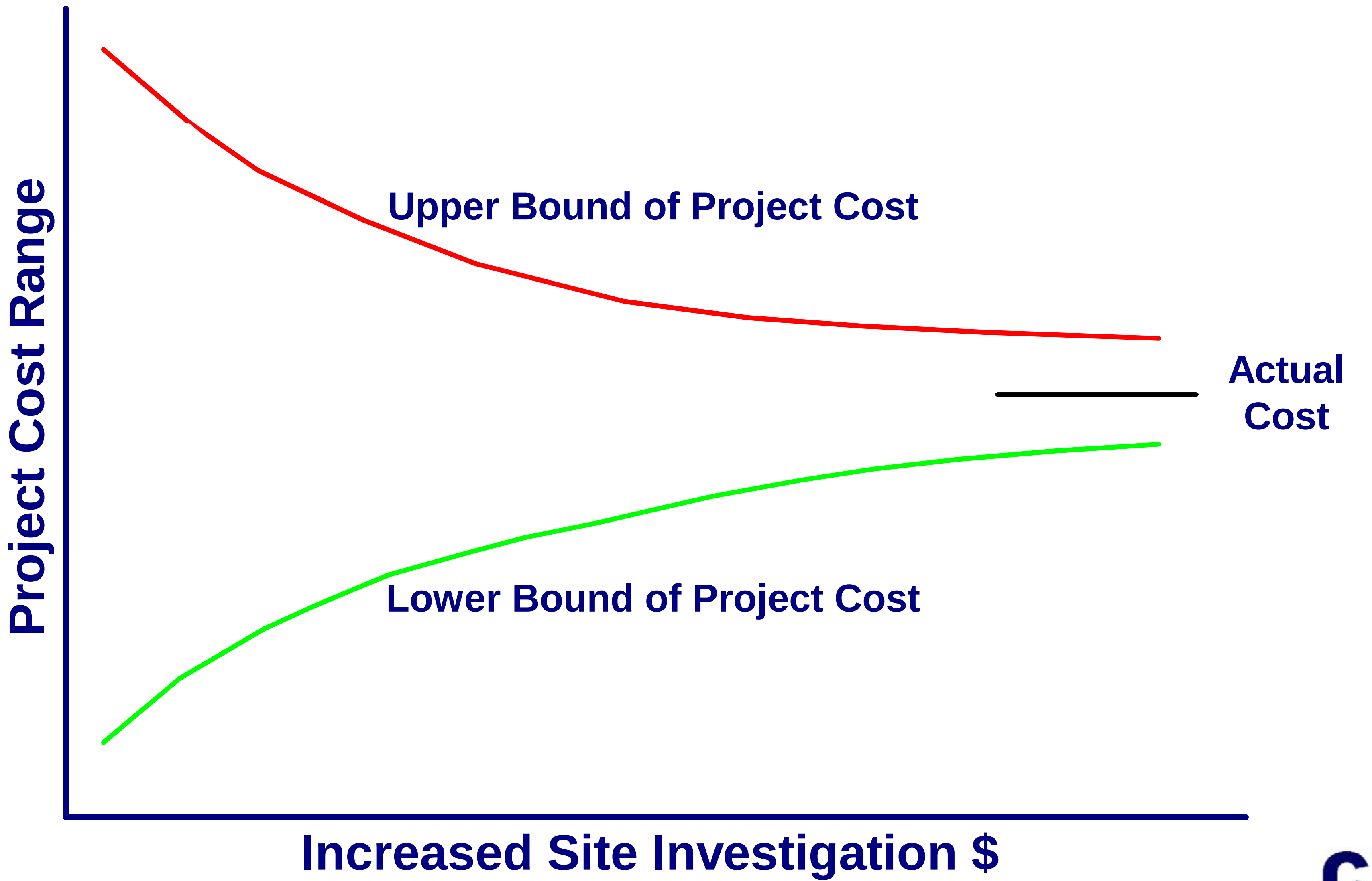
Cost & Risk vs. Site Investigation



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Questions?

Concluding Remarks

- Is a megadetector feasible?   Qualified yes
- What are the qualifications?
  - Rock conditions & depth
    - Best location at the best site, not too deep
  - Enlightened funding agencies
    - Understand & manage the risks, cost uncertainties
  - Site factors
    - Rock removal, competing demands for resources
  - Contractor
    - Chosen on cost & qualifications