Session - Road Building Fundamentals

Topic – Foundation Conditions

Materials & Performance of Facility

Soil/Rock Properties

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November 14, 2013

2013 Arizona Pavements/Materials Conference

Outline of Presentation

- Define need for understanding soil/rock properties
  - Typical problems of soils- resulting in failures
- Geo-hazards
- Characterization methods (example project)
- Key soil parameters associated with design



Need for Determining Foundation Materials Properties

- Certain soils/rocks can contribute to:
  - Poor roadway performance,
  - Foundation failures,
  - Geologic hazards and
  - An elevated risk of safety to the travelling public

Common Problematic Conditions

- Low density, high porosity soils can result in collapsible conditions
  - Common in sheet flow conditions on alluvial fan/flats
- Variable lithologies and associated change in densities/cementation/plasticity/firmness, hardess over short distances can result in differential settlement
  - Common in a lenticular deposits in alluvial/fluvial settings or spanning different geologic units
- High plasticity deposits exposed to variable water conditions can result in heaving conditions
  - Commonly associated with weathered basalts, and lakebed/fluvial clays derived from volcanic ash. Exotic colored clays are typically ash derived.
- Loose finer grained deposits over more open graded deposits can produce piping failures
  - Natural environment
  - Embankment fills

Collapsible Conditions

Collapse/piping feature associated with a low gradient alluvial fan surface where material typically was deposited quickly in a flash flood sheet flood event

Differential Settlement Potential

Sugarloaf Mountain Bridge – Arizona Approach, Hoover Dam Bypass
Founded on combination of rock (rhyolite & dacite) and 130’ of fill, with a MSE embankment at Abutment 2

Sugarloaf Mountain Bridge – Arizona Approach
Multiple-point borehole rod extensometers
Abutment 2 to monitor settlement

Heaving Conditions

Wavy asphalt caused by high plasticity basin-fill claystone subgrade

Piping

Fine grained fill over granular alluvium

Geo-Hazards

- Other geologic conditions that pose a risk to roadway performance and risk to travelling public if unaddressed or not recognized:
  - Slope stability
    - Fill slopes
    - Rock slopes including rock fall
  - Landslides
  - Scour
  - Sinkholes
  - Ground subsidence and earth fissures

Bedrock – Volcanic Tuff Slopes/Foundations

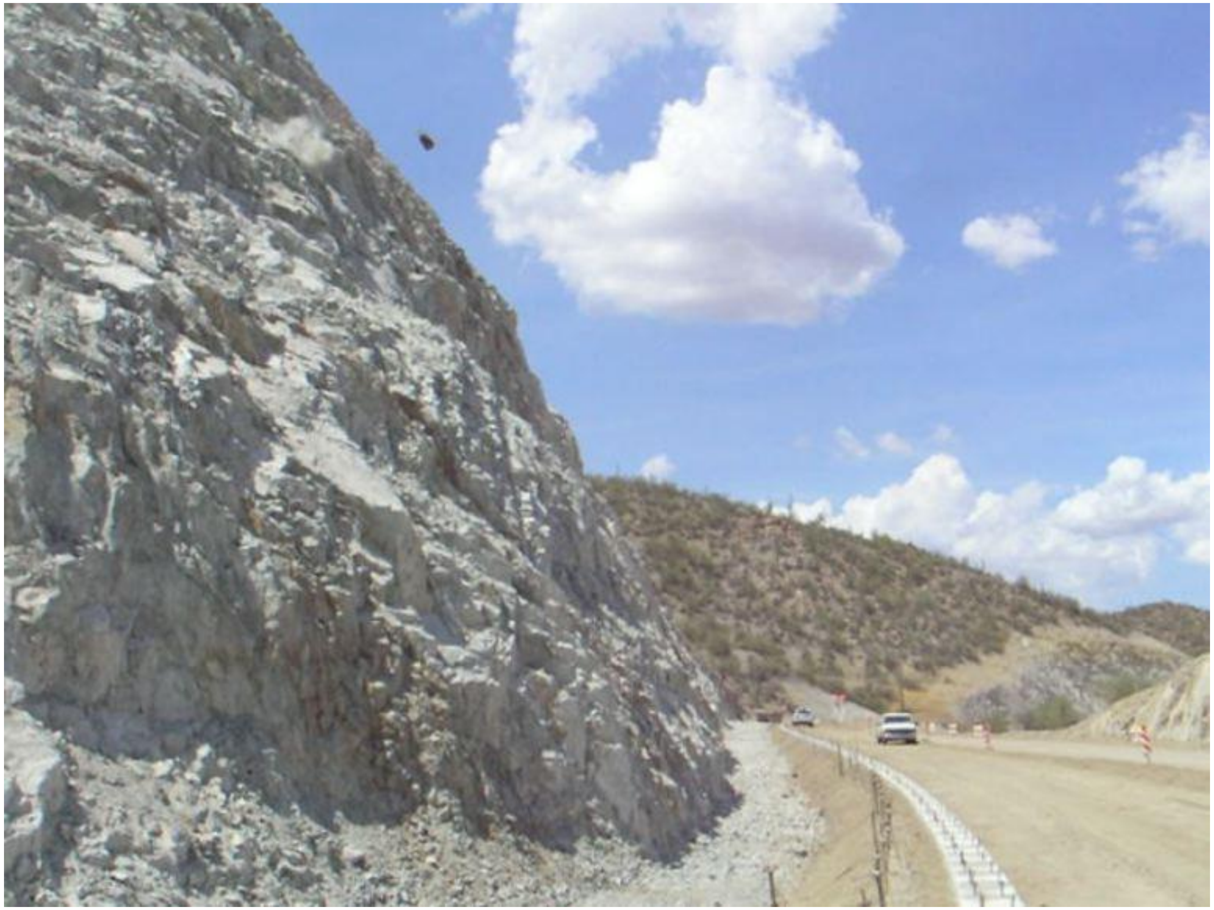
In-situ testing: downhole seismic, goodman jack, RQD & optical televiewer
Lab: Unconfined compression, point load, density, splitting tensile strength, dynamic & static Young's modulus, creep in unconfined compression

Goal: Produce a stable cut slope for Arizona Skewback on Hoover Dam Bypass

Important properties include rock strength of ash tuff to both support the slope and the foundation along the canyon wall. Based on lab and in-situ testing, bearing capacities of the rock was established to be 2000psi for all footings except the Az Skewback which was determined to be 1200psi

Slope stability also dependant upon fractures and faults in and near the walls of the excavation

Geo-Hazards
Rockfall Containment & Slope Geometry Considerations



Rock slope on SR 77, near Winkelman, Az

Stable slope but rockfall can be launched off inclined surfaces sloping toward the roadway

Geo-Hazard
SR 87 slide

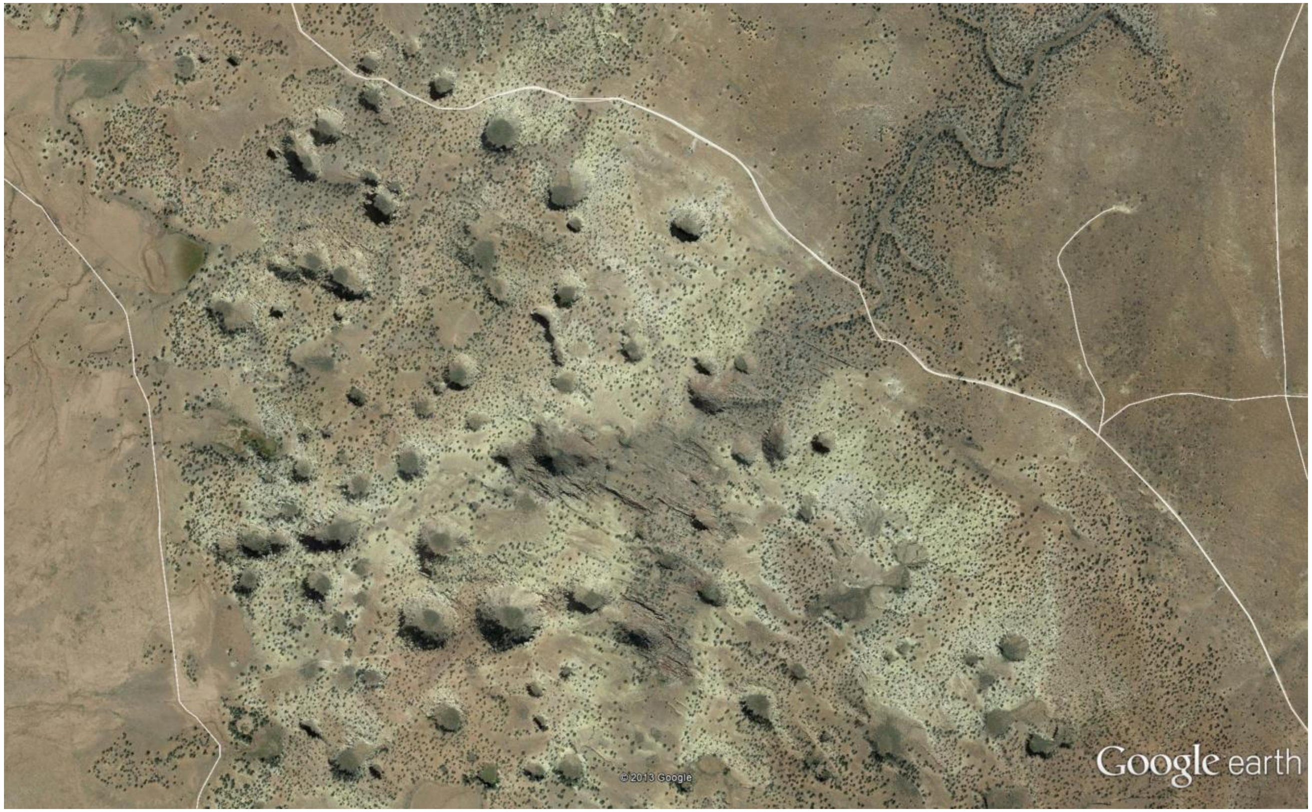
Soil nail wall built on ancient landslide

Scour US 93

Loose fine grained deposits below CMP subject to scour

Geo-Hazards
Sinkholes

Sinkholes near Snowflake, Az

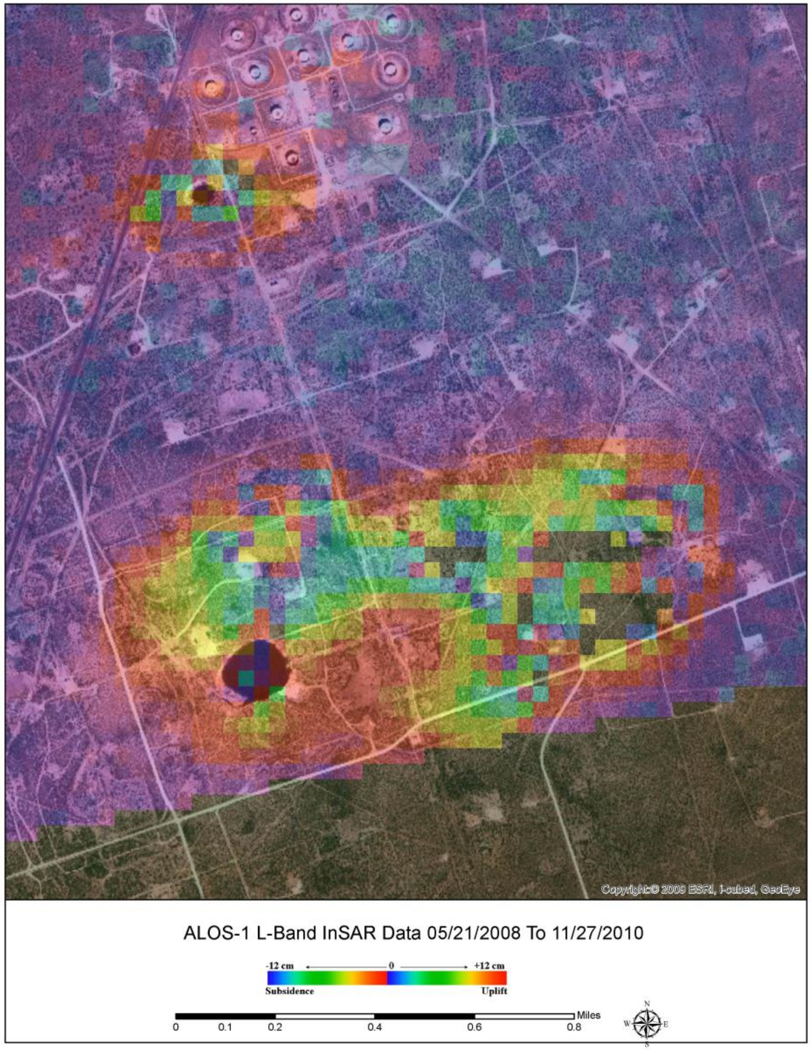


Features result from surface propagation of roof collapse or piping into open solution cavity at depth. Gypsum beds in Supai Fm in this case

More common in areas underlain by sedimentary deposits, including limestone, gypsum, salt. Smaller sinkholes can also form from piping into narrower open fissures.

Sinkholes in Phoenix Valley?

Geo-Hazard
Sinkholes



Sink hole in New Mexico

The upper, smaller sinkhole appeared in 1980, the larger lower sinkhole appeared in 2002, and activity for a future sinkhole is apparent in the InSAR image to the east of the lower sinkhole.

Geo-Hazard
Earth Fissures

Occurs in basin fill settings with history of groundwater pumping

InSAR imagery can aid in assessing ground subsidence areas

Steps in Characterizing Soil/Rock Parameters for Design Purposes

- Understand the geologic setting to anticipate general material types and types of deposits
  - Area imagery
  - Topographic relief
  - Geomorpholgy
  - Geologic maps
- Perform a geologic reconnaissance
- Establish a field investigation plan suited for the project and the variability of the geologic units
  - Drill holes, auger, core, rotary, percussion
  - Backhoe pits/trenches – grain size & density testing at grade sections forming subgrade
  - Geologic mapping – correlation of units, predictability (variable methods)
  - Seismic surveys, refraction, ReMi
  - Down hole televiewers
  - Down hole seismic

Steps in Characterizing Soil/Rock Parameters for Design Purposes

- Establish a laboratory testing program to further characterize material properties
  - Typical tests
    - Sieve Analysis
    - Plasticity Index (Atterberg Limits)
    - Moisture Content
    - Density
      - Rings samples - soils, Bulk Density - rock
    - Moisture Density Relations (Proctor)
    - R-value
    - Direct Shear
    - Point Load
    - Unconfined compression
    - pH & Resistivity
    - Chlorides & Sulfates
    - ADOT Nutrient Group Suite

Example - Hoover Dam Bypass
Elements of Investigation

- Laser scanning
- Geologic mapping
  - Conventional surface mapping , where practical with canyon wall photo review
  - Helicopter reconnaissance
  - Canyon wall mapping during rappels in steep near vertical terrain
  - Point cloud image review (structural features)
- Canyon wall drilling
- Oriented Optical Televiewer borehole logging
- In-situ testing
  - NX borehole (Goodman) jack
  - Downhole seismic surveys

Geotechnical Investigation Challenges
Hoover Dam Bypass

Difficult Access

- Rugged terrain with high relief and near vertical canyon walls
- Overhead transmission lines

Site Related Design Features

- Steep cuts (towers, U.S. 83, existing topography)
- Rockfall containment
- Structure foundations

Other Factors

- Variable geologic conditions
  - Rock types
  - Strengths
  - Discontinuities
- Safety during field operations
  - Field crews
  - Public access
- Security associated with Hoover Dam operations
  - Post-9/11 restrictions
  - Restricted air space
  - Daily coordination w/ authorities

Laser Point Cloud-Nevada

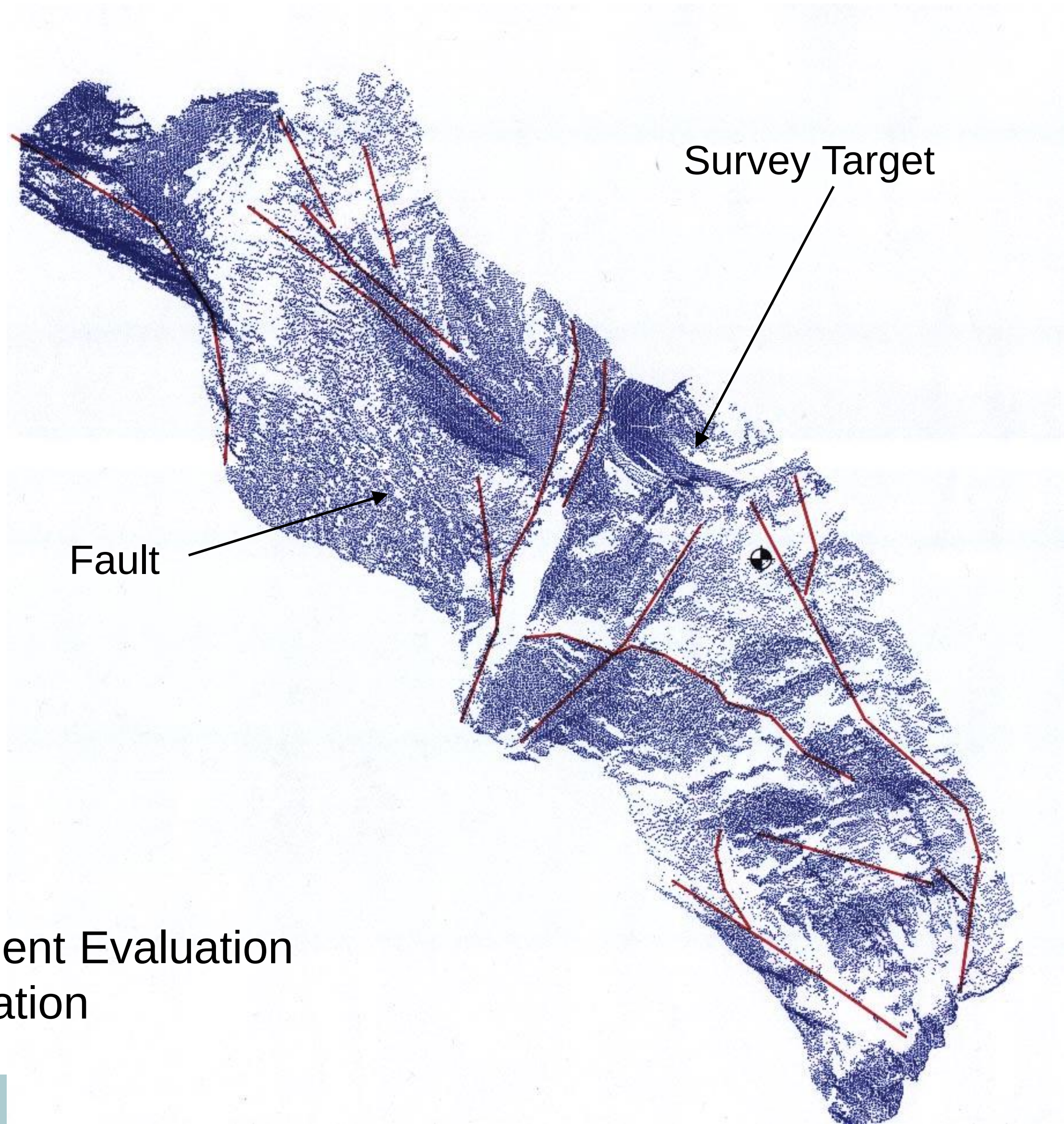
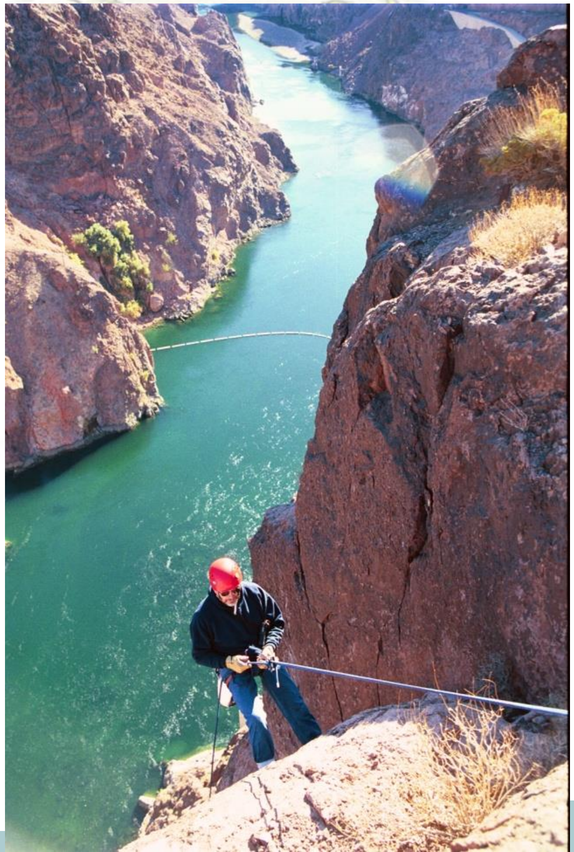
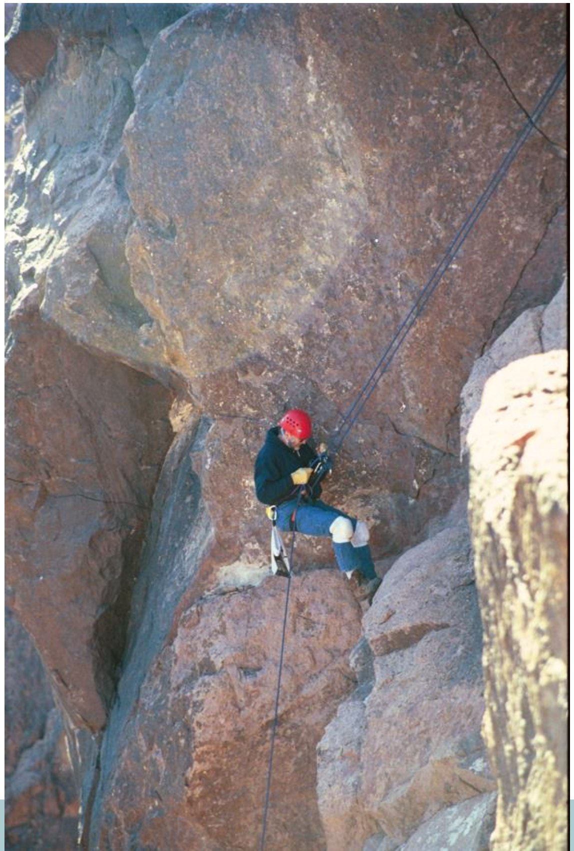


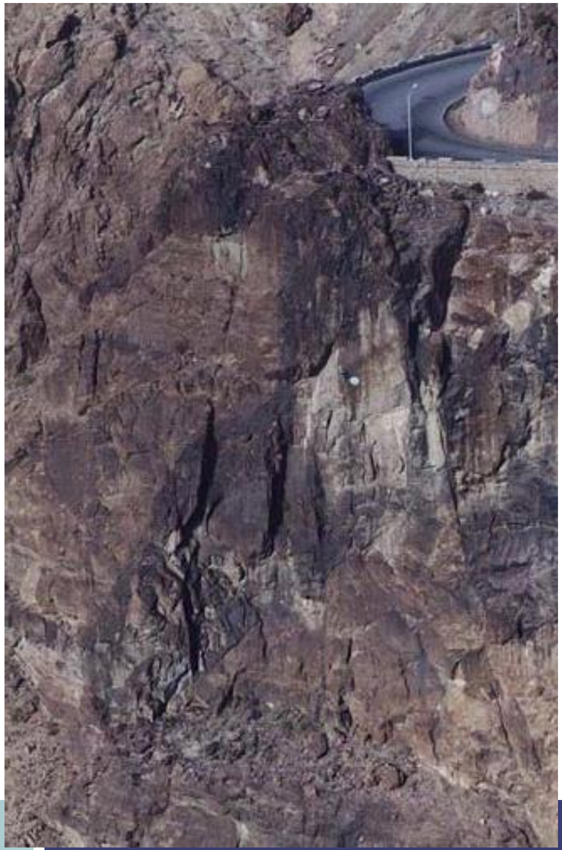
Photo-Lineament Evaluation
Fault Identification

Rappel Mapping
Skewback Location

- Technical skills
  - ➢Geologic Inspections
    - ✓Rock Quality
    - ✓Fracture orientations
    - ✓Fracture conditions
- Rope skills/training
- Safety and security

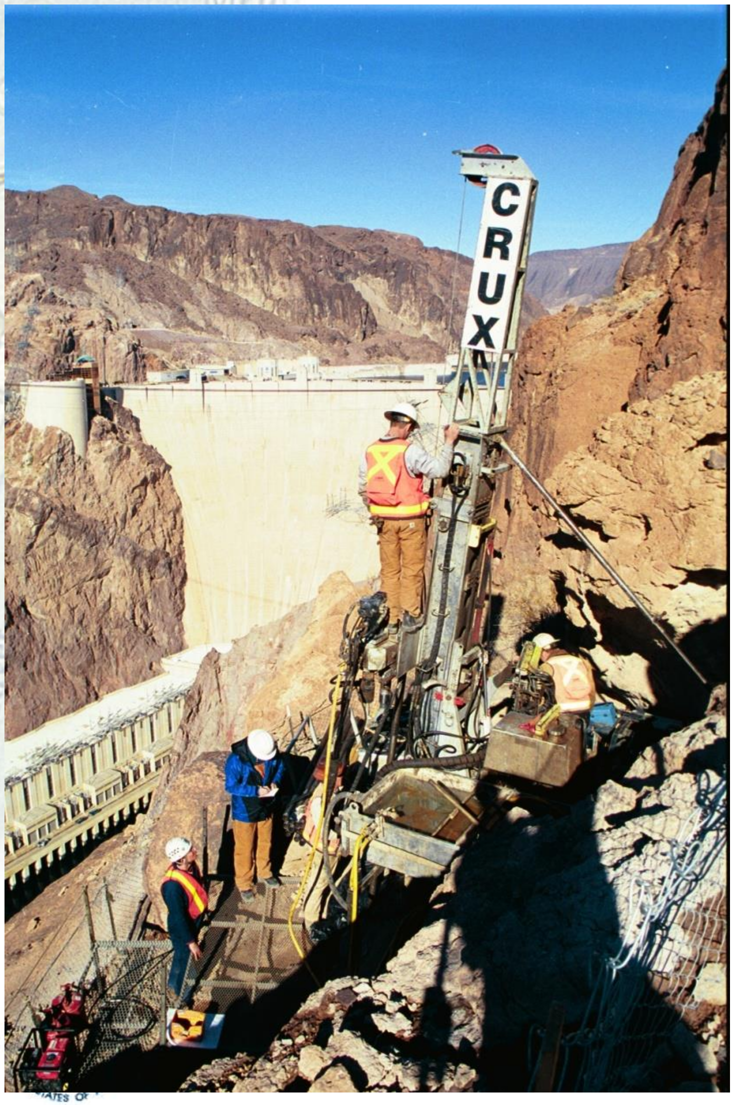






Helicopter Recon
Nevada Skewback

Canyon Wall Drilling

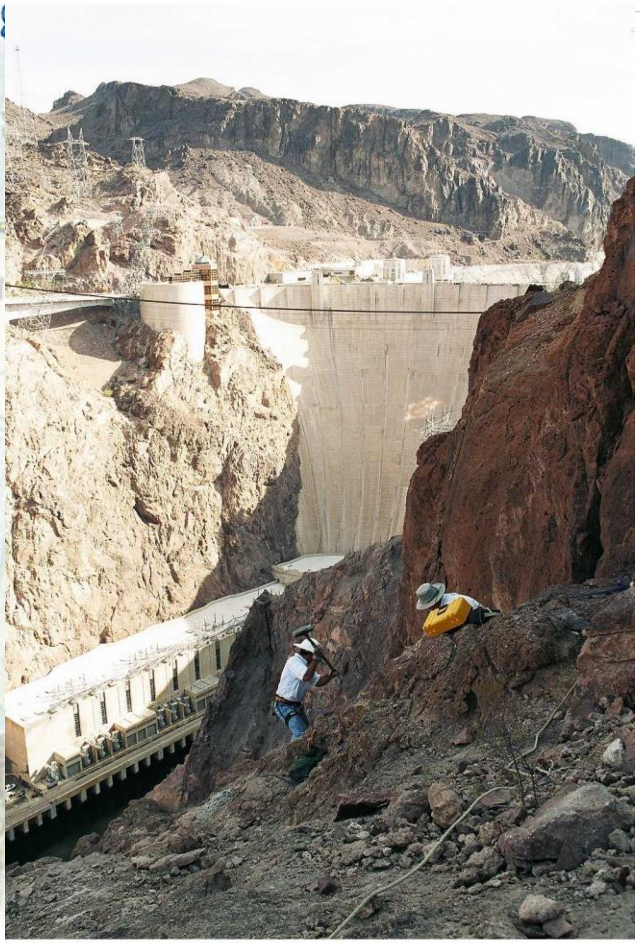


Steep terrain with overhead power lines required portable rigs with access assisted by:

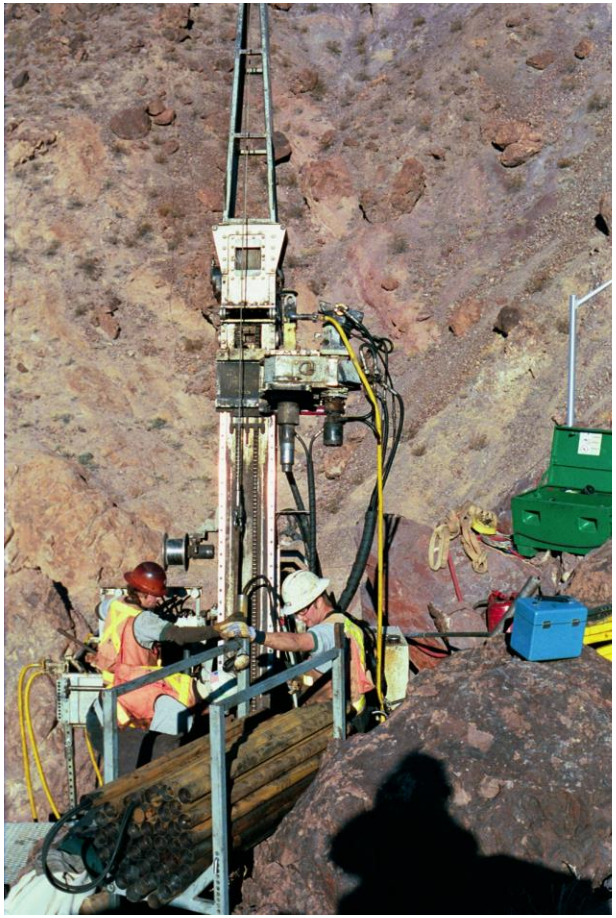
- Helicopter
- Crane
- Track
- Articulated backhoe (Spyder)

Limited access required variably inclined boreholes to reach foundation depths

In-Situ Testing



Downhole Seismic



Borehole Jack

Means of estimating rock mass modulus from field data

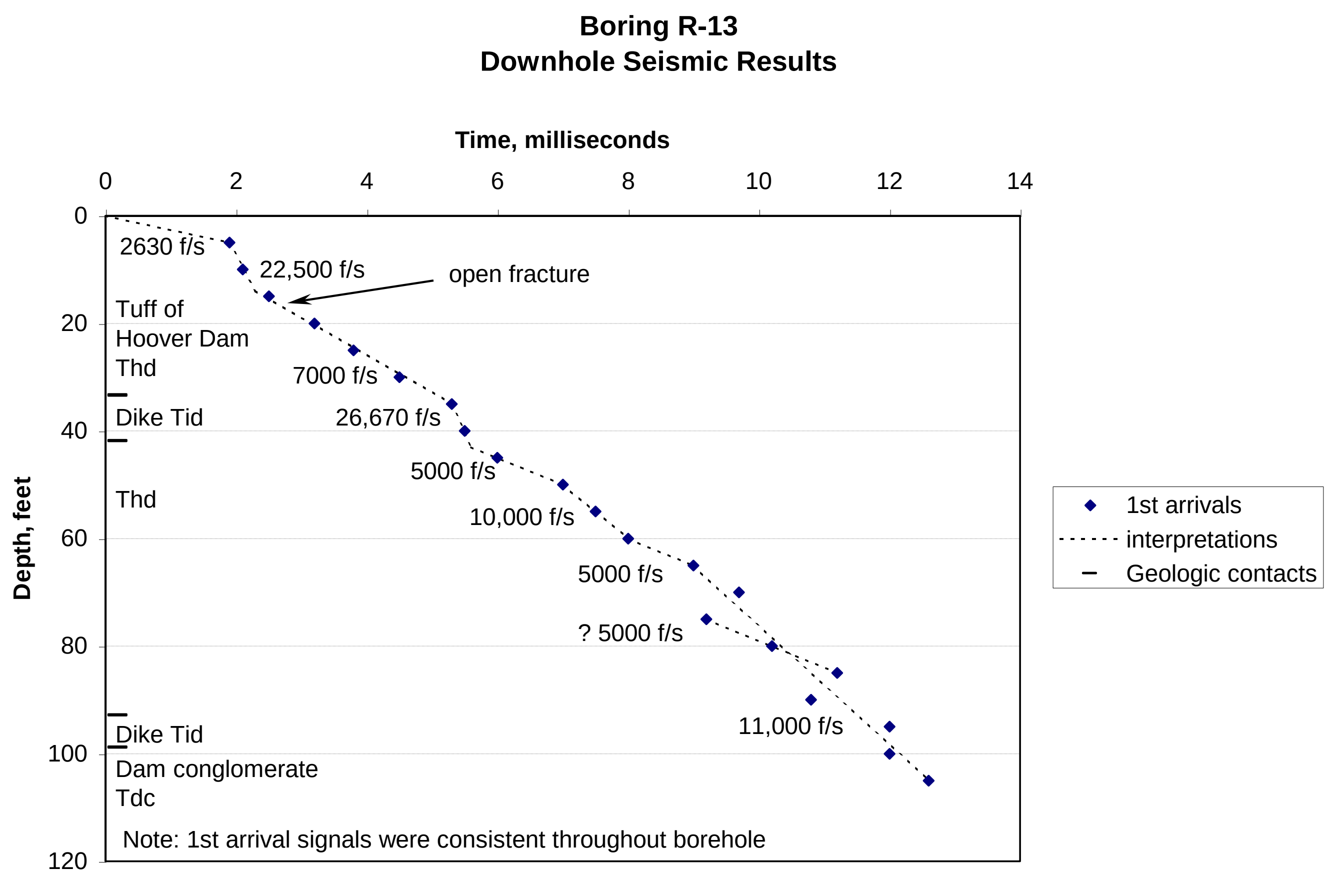
Downhole Seismic Testing

amec

Arizona Skewback

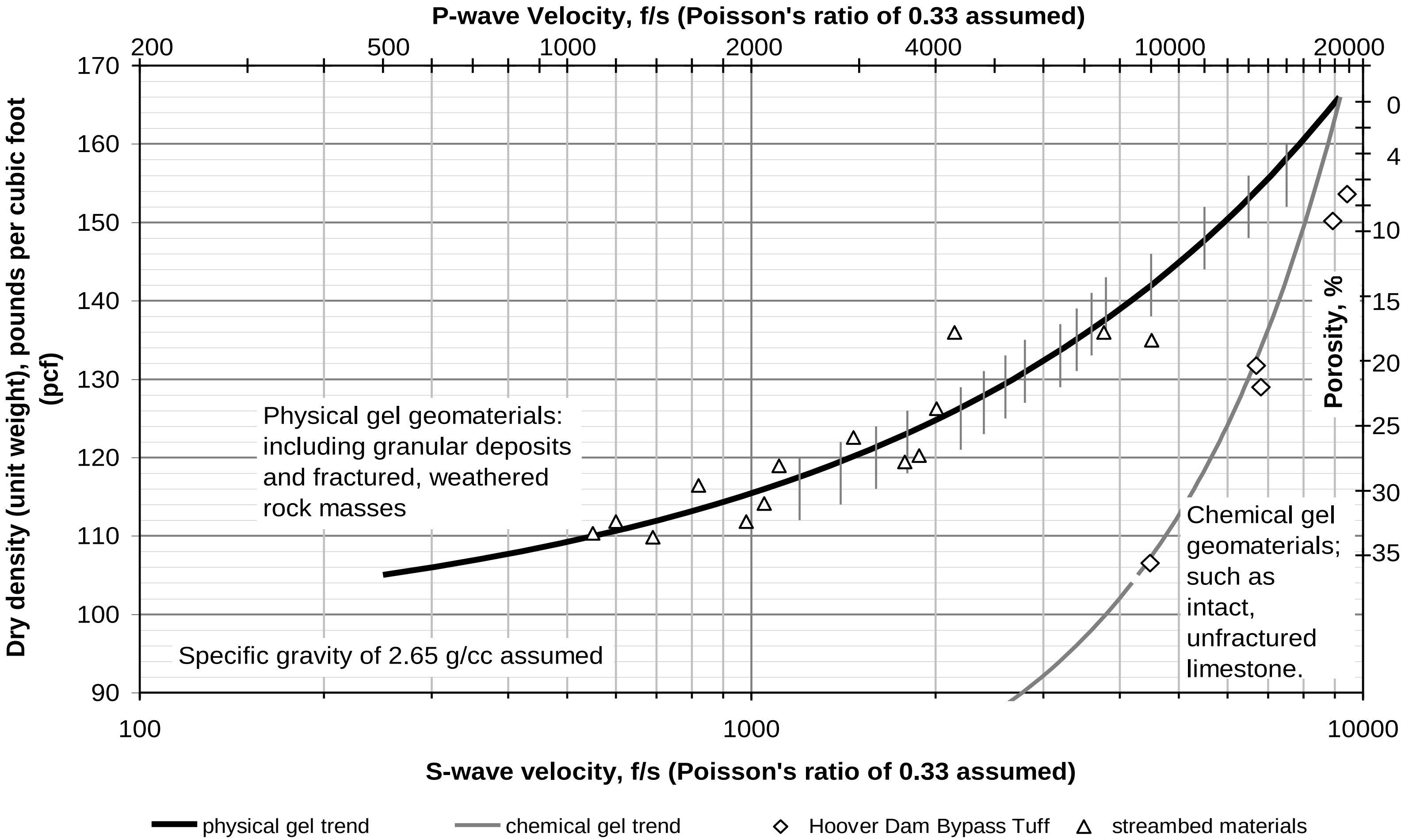
Nevada Skewback

Seismic Results - Hoover Dam Bypass

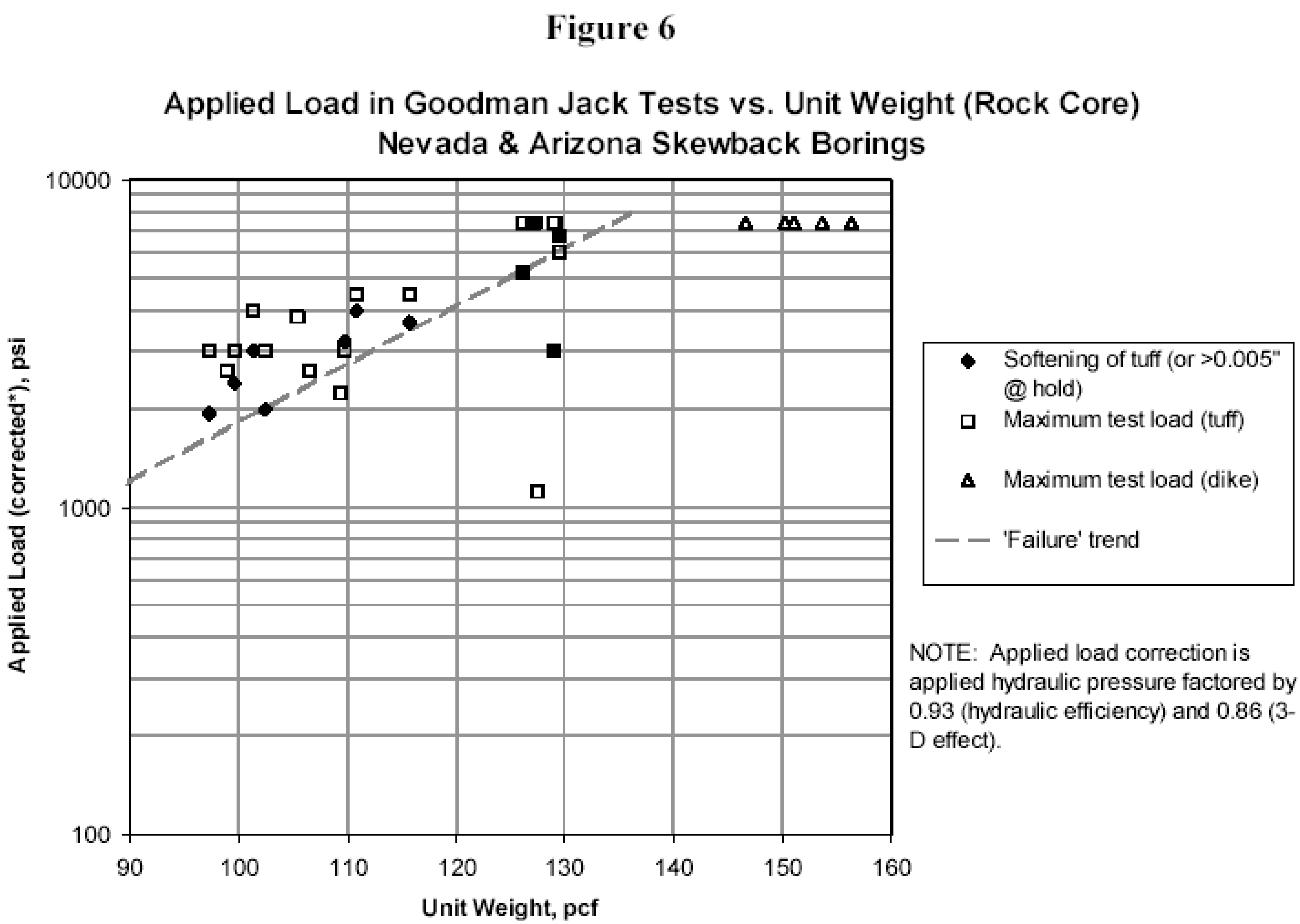


SUBSURFACE INVESTIGATION – Surface Seismic Investigations

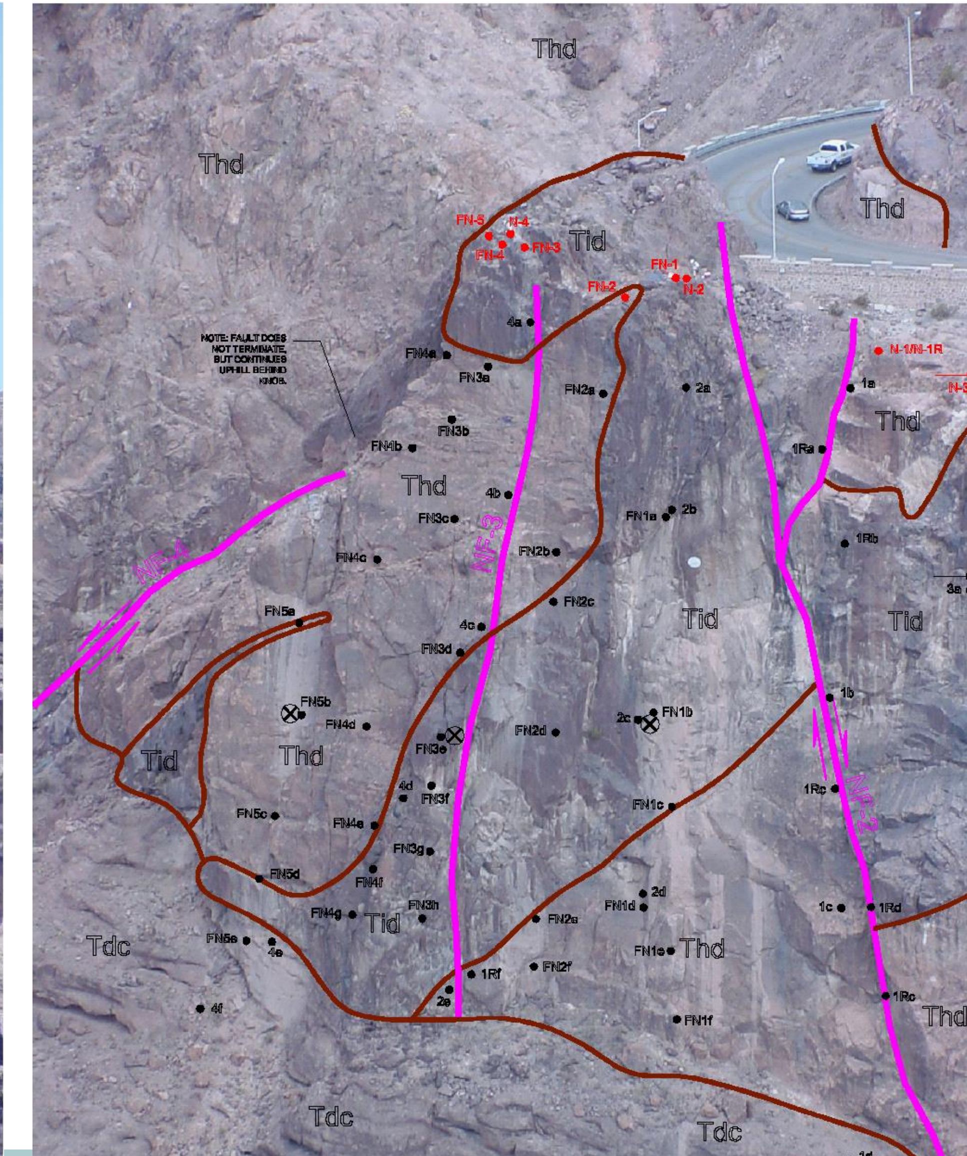
Relationship between Seismic Velocity and Dry Density



Rock Mass Strength – Hoover Dam Bypass

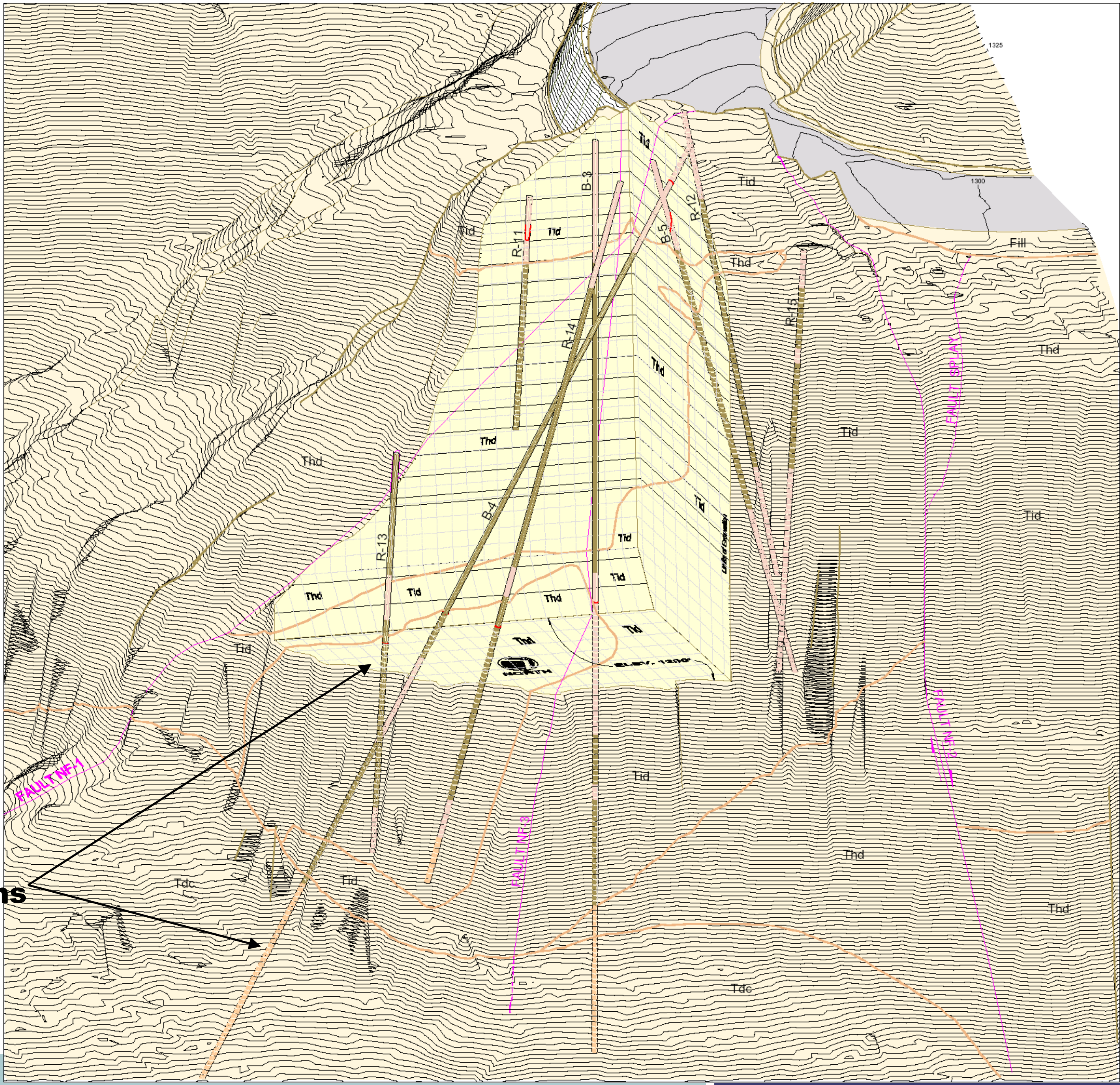


Geology-Nevada Skewback



Nevada Skewback Excavation

3-D rendering with projected geology



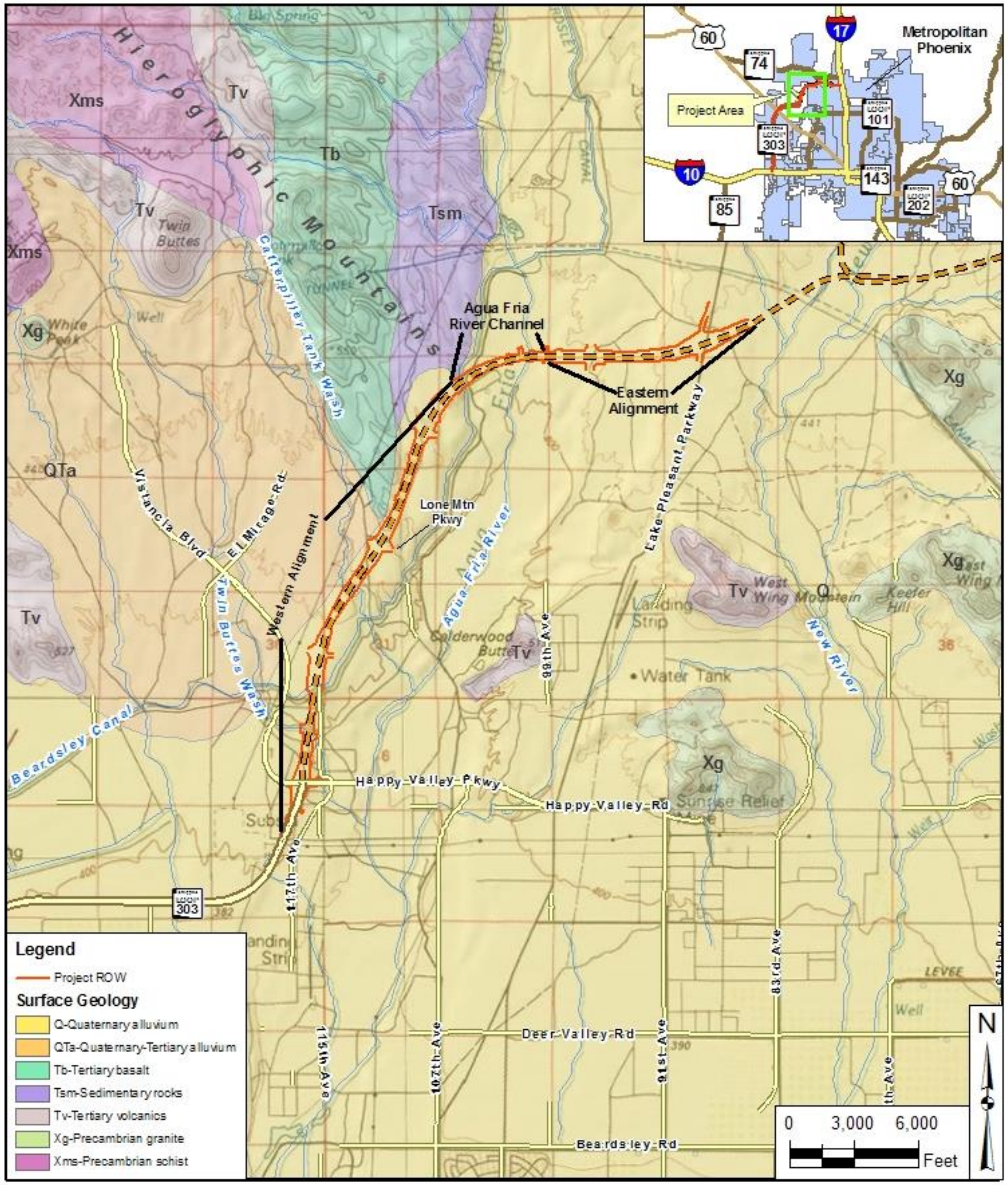
Borehole projections

ASU ADOT
Arizona State University

GEOLOGIC SETTING - REGIONAL

- Regional Setting
  - Basin and Range
  - Hieroglyphic Mtns.
  - Quarternary Alluvium

- Local Setting
  - Western Alignment
  - Agua Fria River Channel
  - Eastern Alignment



Key Parameters Required for Roadway/Pavement projects

- Subgrade conditions and performance factors
  - Continuity of deposits and suitable geologic units
  - Gradation
  - Plasticity
  - Moisture content & groundwater
  - Density of in-situ soils
  - R-values,
    - tested & correlated to establish a minimum construction value
  - Proctor values
    - establish compaction requirement for embankment fill forming the new subgrade
  - Seismic wave velocities
    - existing profile characterization
    - earthwork factors fro using material as embankment fill
  - Corrosivity of soils
    - pH & resistivity to establish type of metal piping required
      - including thickness, type of metal or coating types
    - Sulfate & Chloride content of soils
      - evaluate reaction with concrete
      - type of cement to resist
      - gypsiferous soils require type V cement

Unified Soil Classification System

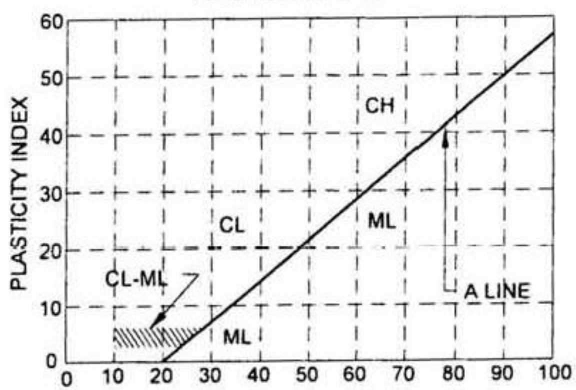
UNIFIED CLASSIFICATION SYSTEM FOR SOILS

Soils are visually classified by the United Soil Classification System on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see " The Unified Soil Classification System " ASTM Designation: D2487

MAJOR DIVISION			GRAPH SYMBOL	GROUP SYMBOL	TYPICAL DESCRIPTION
	rse sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)		GW	Well graded gravels, gravel-sized mixtures or sand-gravel-cobble mixture.

NOTE: Coarse-grained soils with between 5 % to 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone on the plasticity chart to have dual symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Boulders	Above 300mm (12in.)
Cobbles	300mm to 75mm (12in. to 3in.)
Gravel	75mm (3in.) to No. 4 sieve
Coarse gravel	75mm to 19mm (3in to 3/4in.)
Fine gravel	19mm (3/4in.) to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt or clay)	Below No. 200 sieve

LIMI	HI PL	(Liquid limit more than 50)		silty and sandy clays of high plasticity.

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