



U.S. Department of Energy  
Office of Civilian Radioactive Waste Management



# Summary of Geotechnical Investigations and Site Conditions at Yucca Mountain

Presented to:

**Nuclear Waste Technical Review Board  
Joint Meeting of the Natural System and  
Engineered System Panels**

Presented by:

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URS Corporation**

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Las Vegas, Nevada**



# Objectives

- **To provide the necessary geological, geophysical, and geotechnical data for development of**
  - **Preclosure seismic design and postclosure performance assessment earthquake ground motions**
  - **Foundation design recommendations for the Surface Facilities**
- **Characterization of the subsurface lithology and stratigraphy, seismic wave velocity structure, and static and dynamic material properties of the repository block and Surface Facilities are required**

# Required for Seismic Design

- **S-wave and P-wave velocity models at surface facilities and repository block**
- **Lithology and stratigraphy beneath surface facilities and repository block**
- **Nonlinear dynamic material properties – shear modulus reduction and damping for fill, alluvium, and tuff**
- **Densities**

# Required for Foundation Design

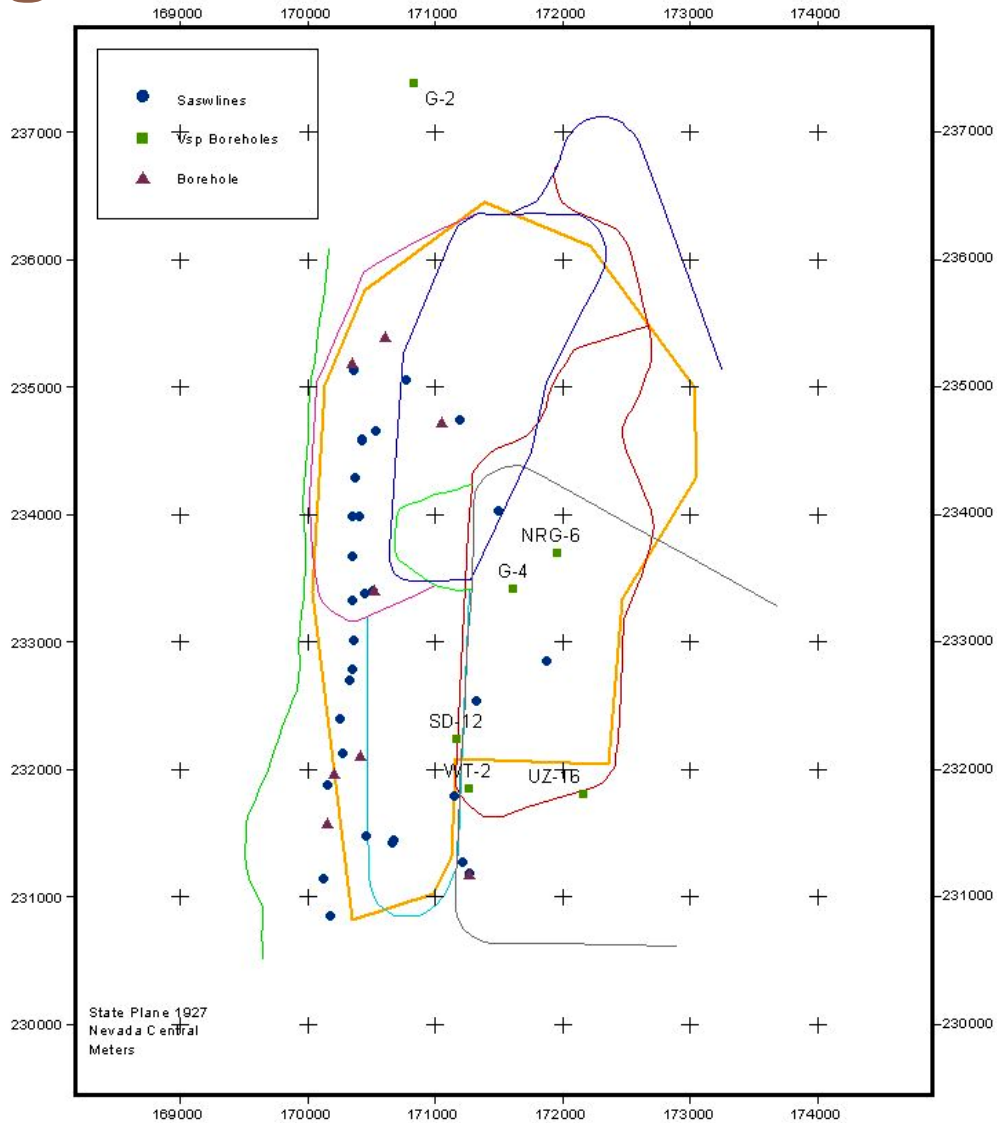
- **Densities, shear strength, and compressibility characteristics of the alluvium, shallow tuff, and potential source of engineered fill**



# Design of Geotechnical Program Above Emplacement Area

- **Program focused on upper block emplacement area**
- **Limited borehole availability and difficult access due to rough topography**
- **Relatively uniform geology across repository block**
- **Program consisted of shallow and deep Spectral-Analysis-of-Surface-Waves (SASW) surveys supplemented by limited shallow borehole measurements**

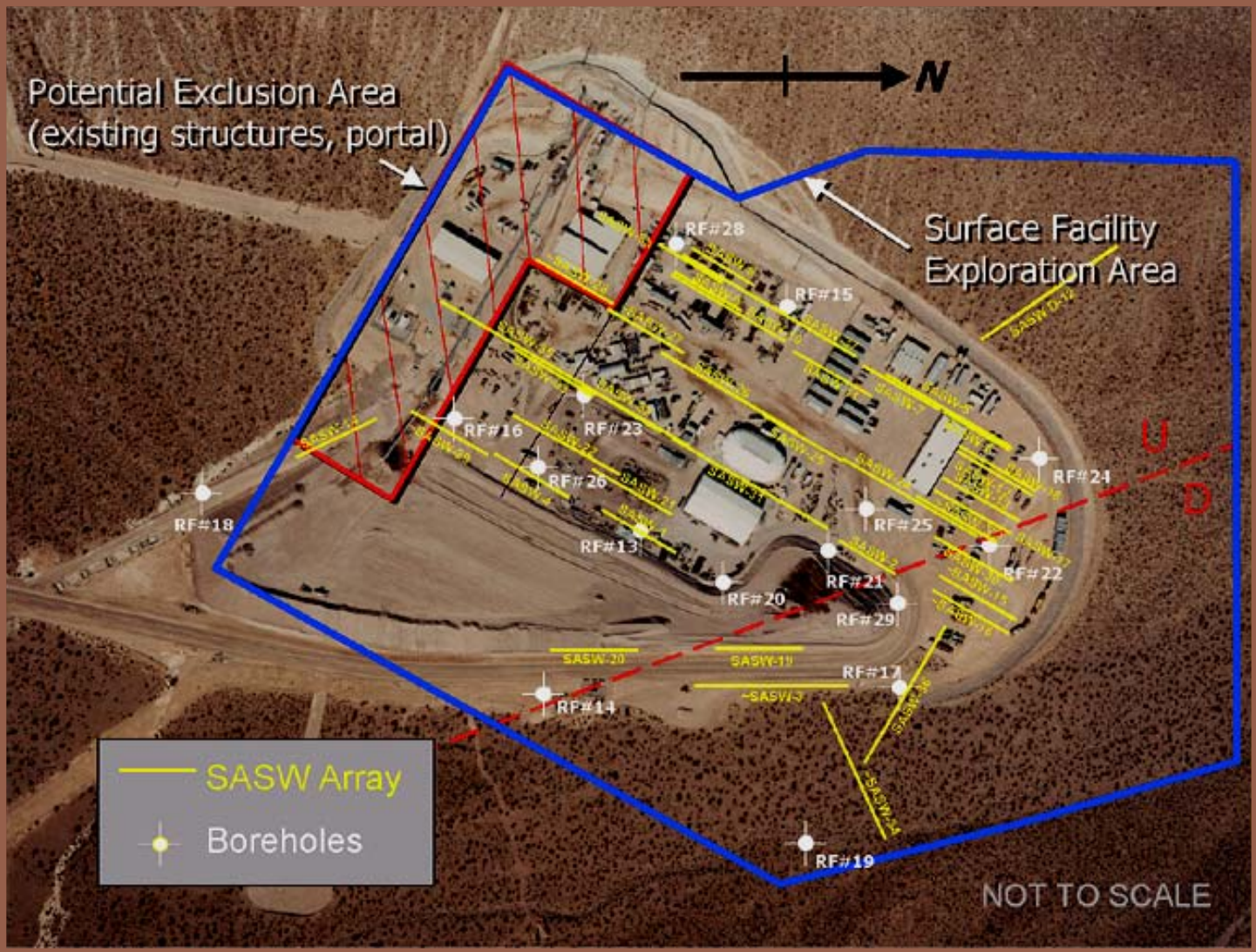
# Emplacement Area (Upper Block) Investigated in Geotechnical Program



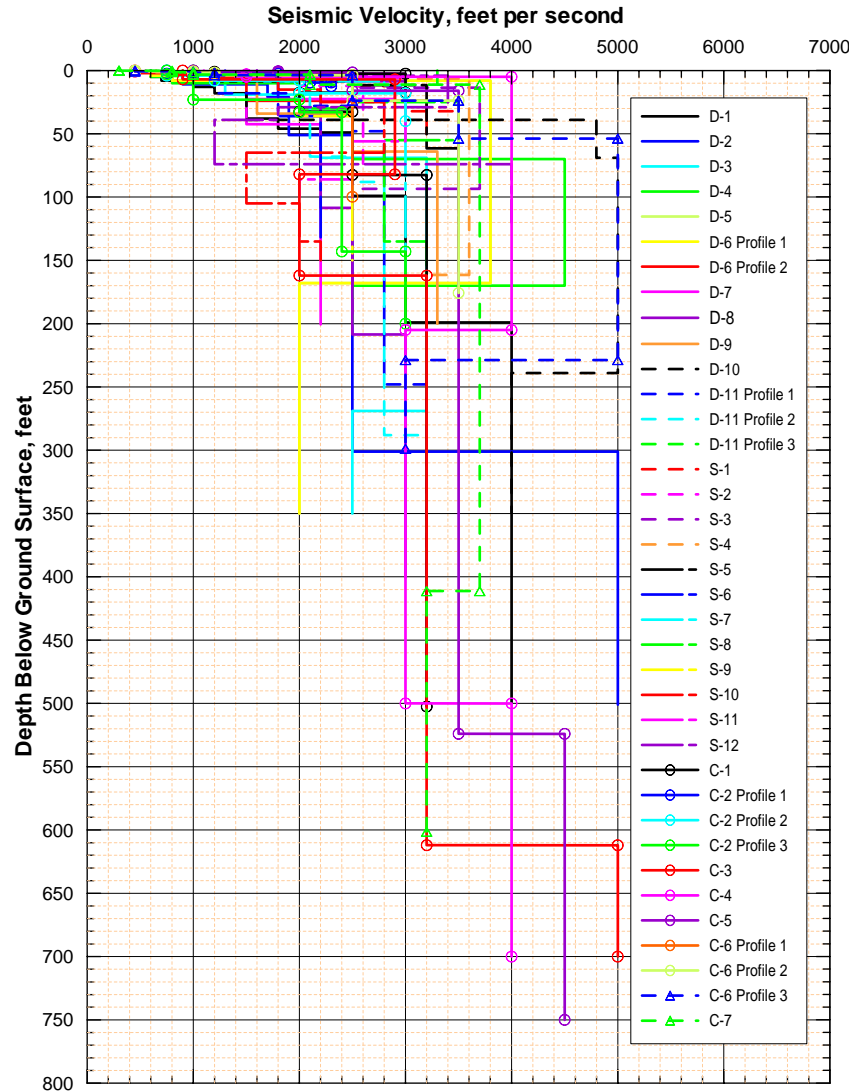
# Design of Geotechnical Program at Surface Facilities

- **Number, locations, and classifications of individual facilities at Surface Facilities Area not finalized at the time of program design**
- **Because of the large area to be investigated and the lack of specific building sites, the program was designed to utilize deep and shallow boreholes supplemented by extensive SASW surveys**

# Surface Facilities Site Characterization Area



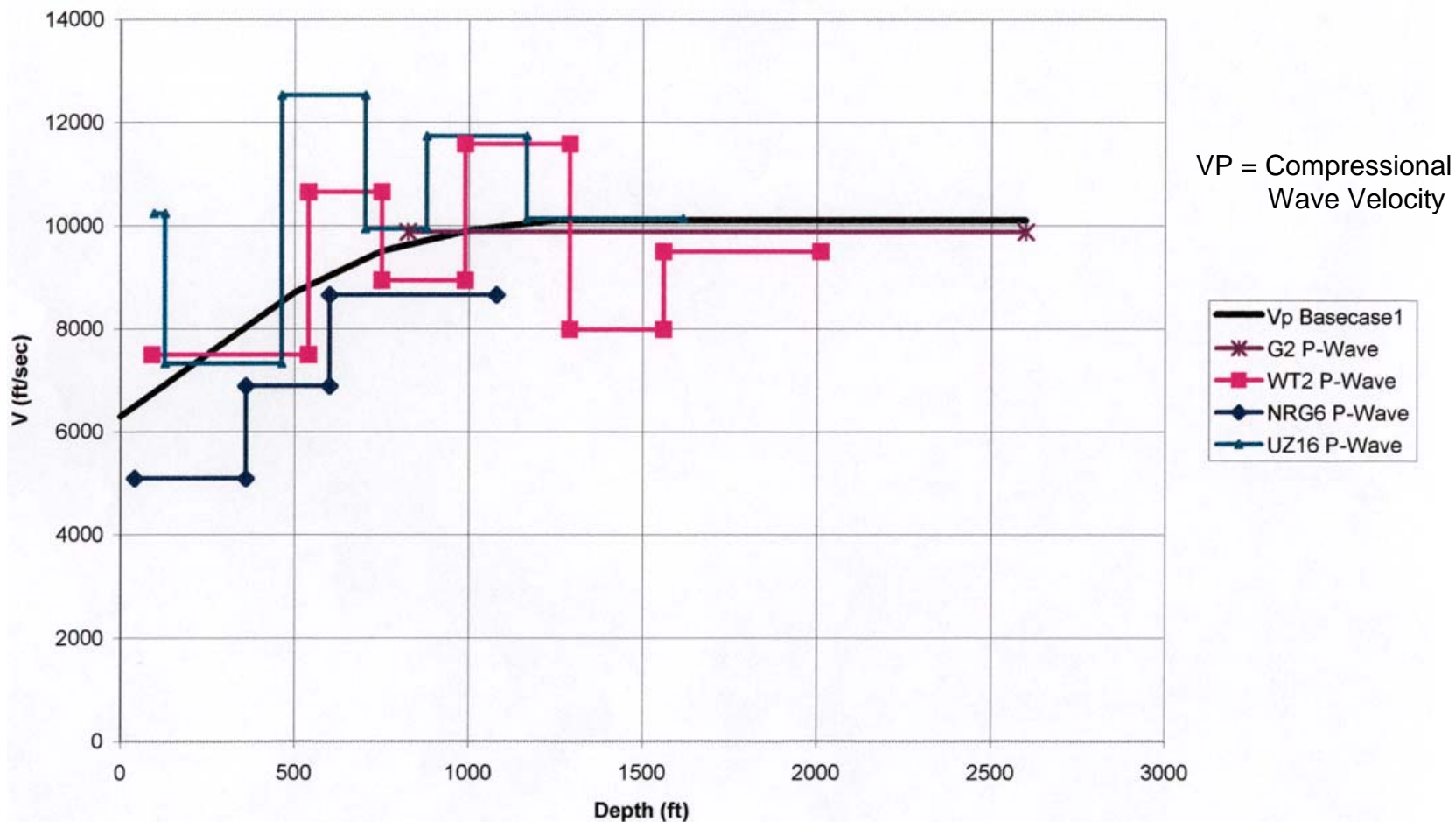
# V<sub>s</sub> Profiles on Top of Yucca Mountain



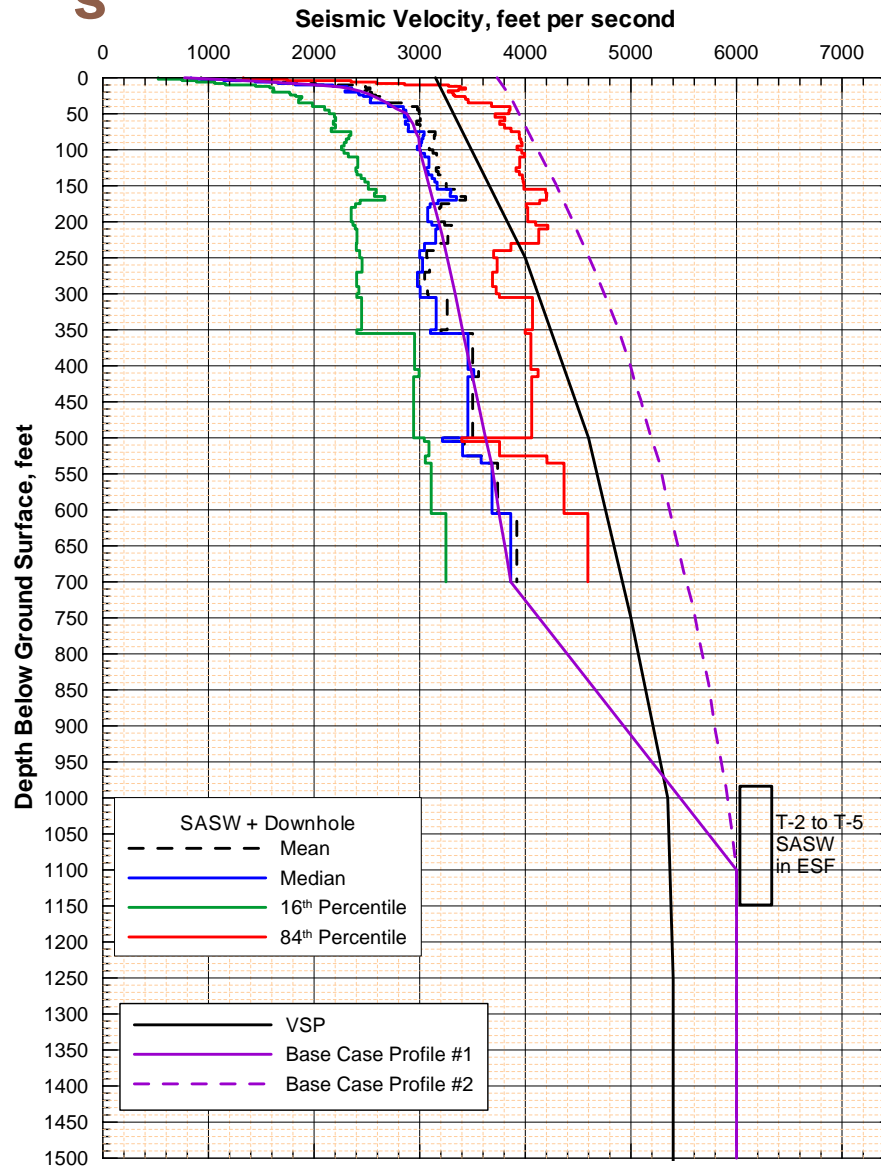
V<sub>s</sub> = Shear Wave Velocity



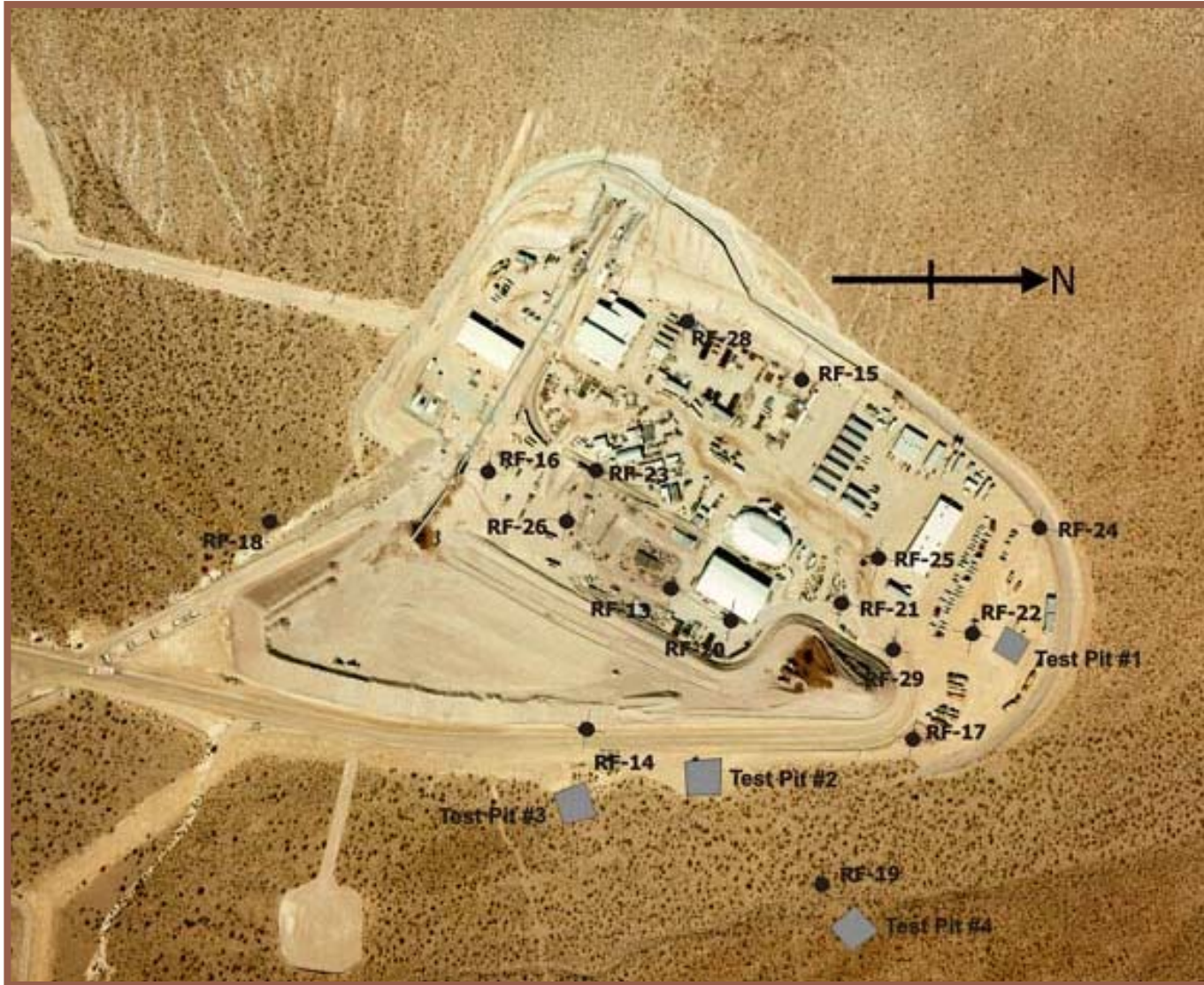
# Comparison of Vertical Seismic Profiling $V_p$ Profiles



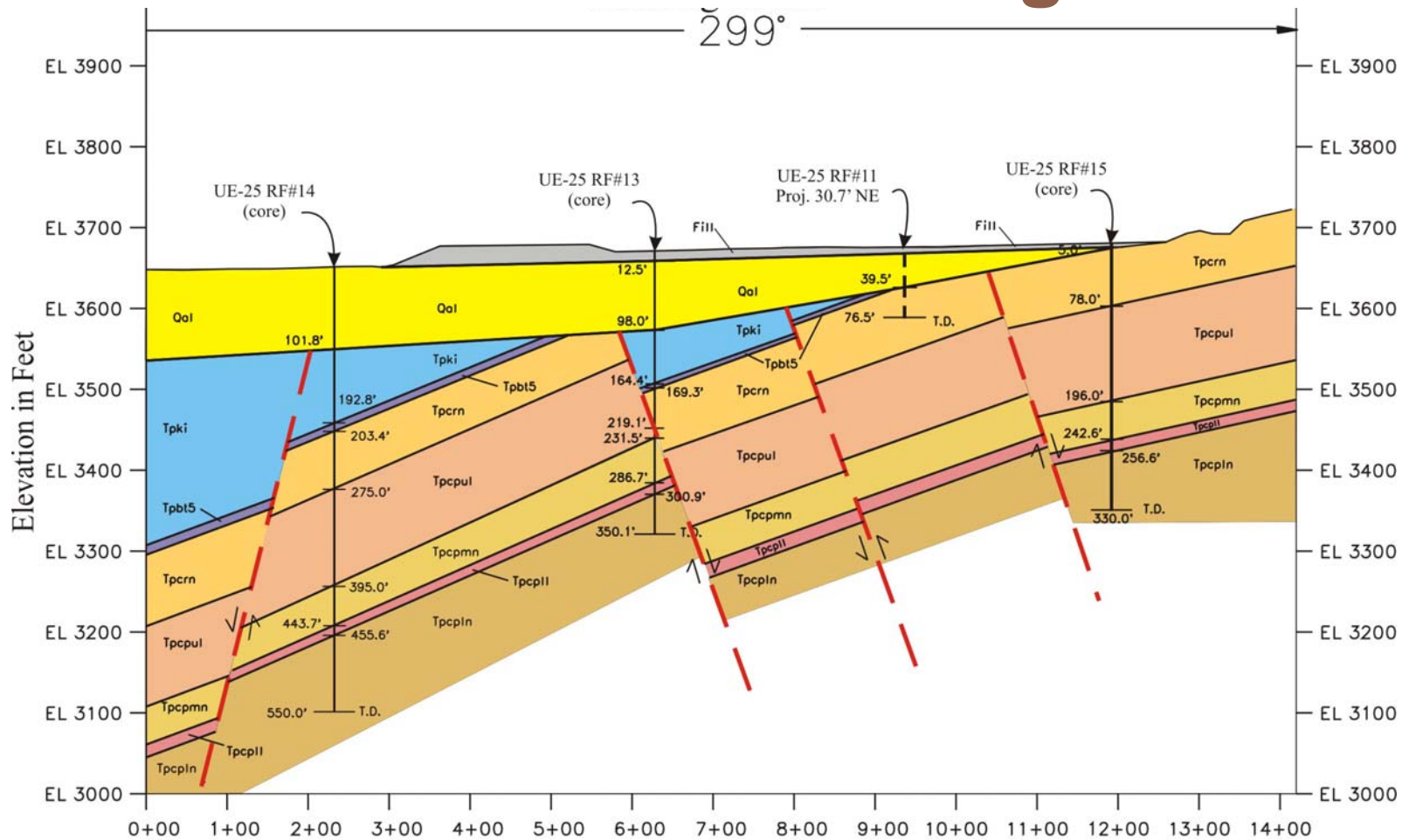
# V<sub>s</sub> Basecase Profiles



# Location of Boreholes and Test Pits



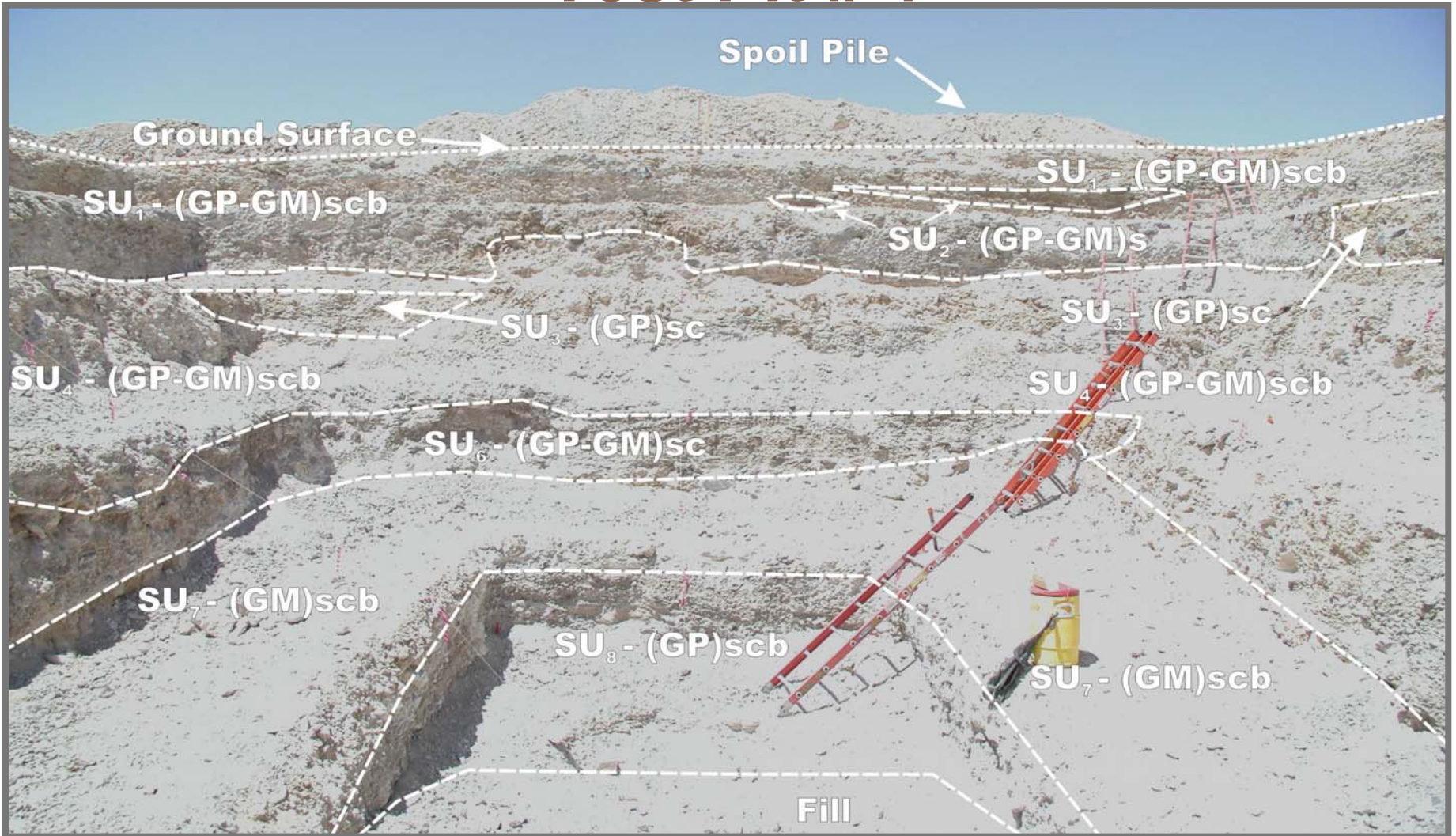
# Surface Facilities Geologic Cross-Section Looking South



- Qal = Quaternary Alluvium
- Tpki = Tuff X
- Tpc\_\_ = Units of Tiva Canyon Tuff



# Test Pit # 1

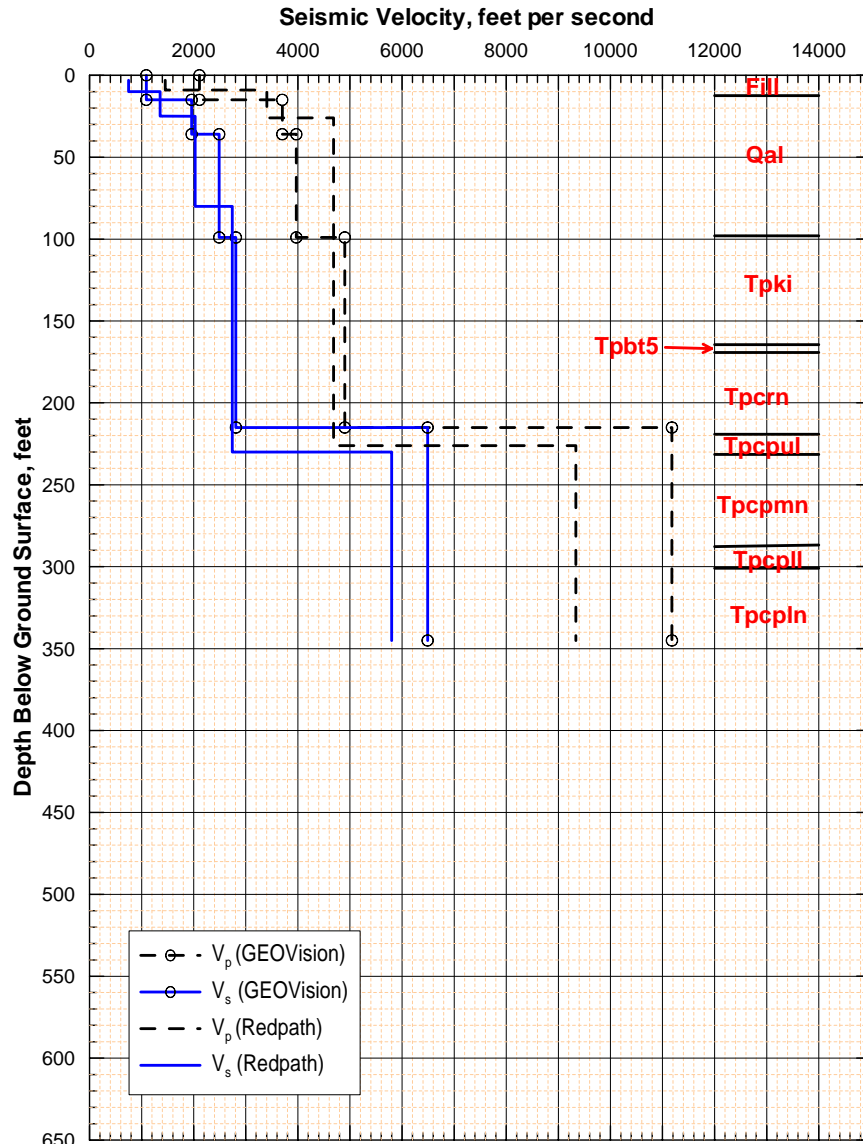


**NOTES:**  
For definition of terms see backup slides

From BSC (2002)

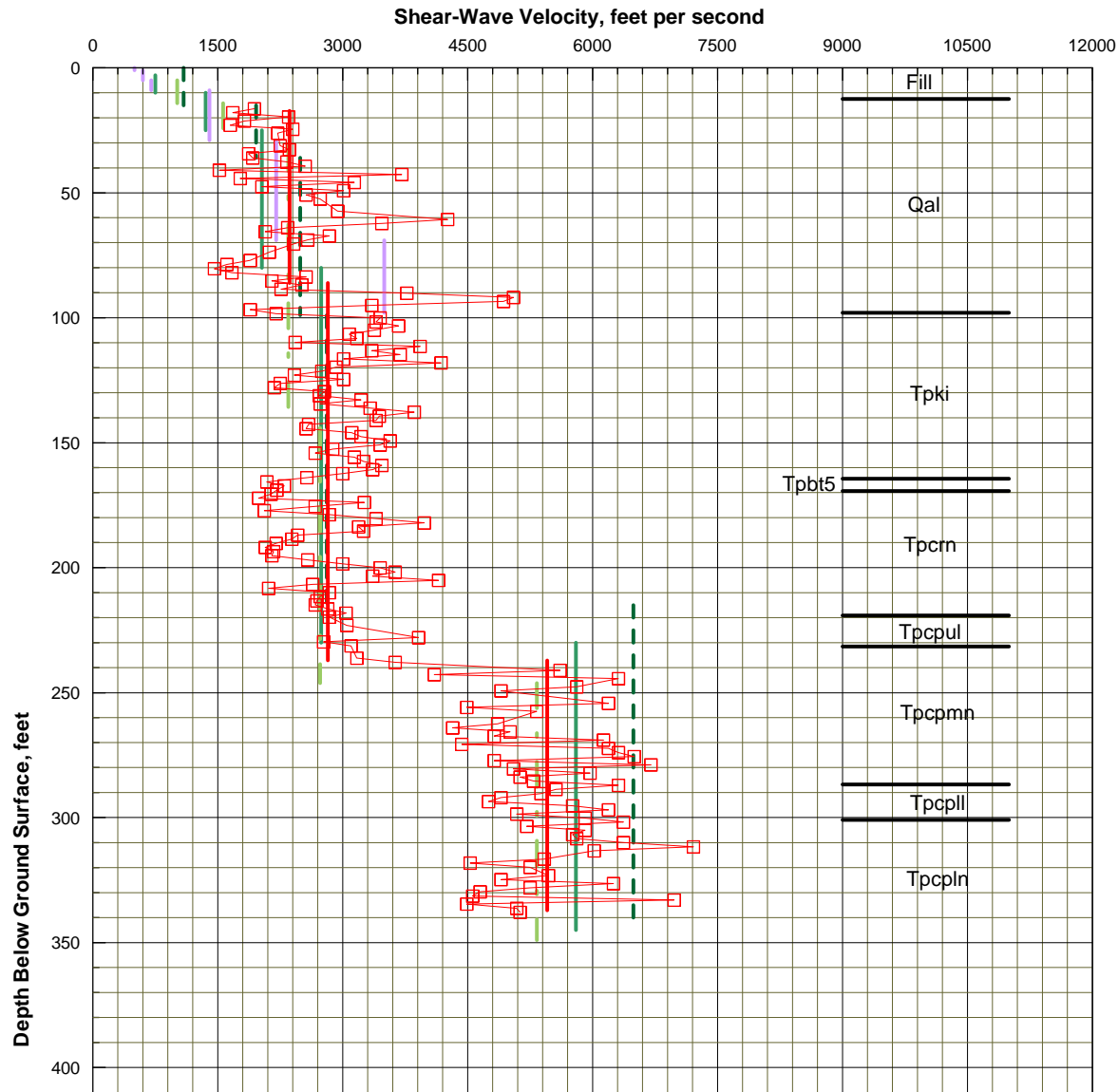


# Borehole RF #13 Downhole $V_p$ and $V_s$ Measurements and Generalized Lithology

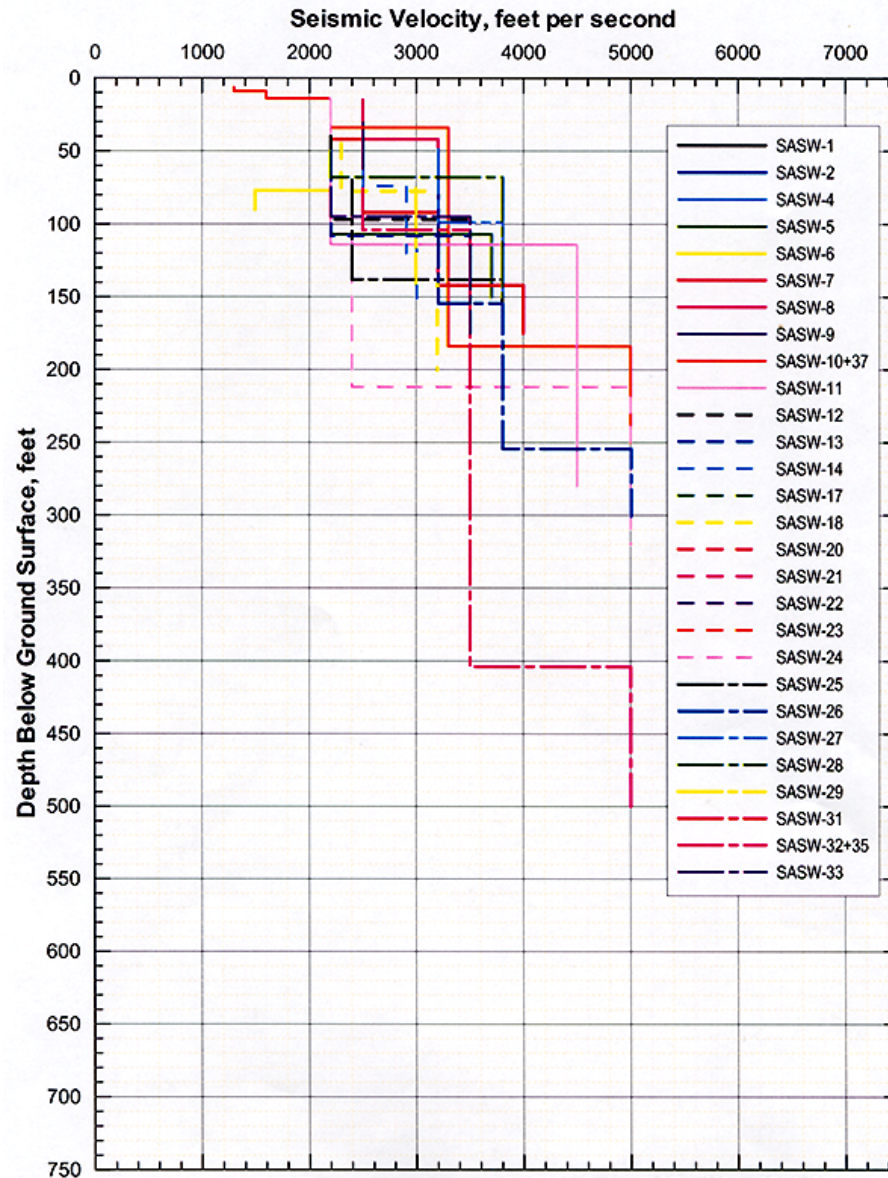


Qal = Quaternary Alluvium  
 Tpc\_\_ = Units of Tiva Canyon Tuff

# V<sub>s</sub> Suspension Data at Borehole RF #13

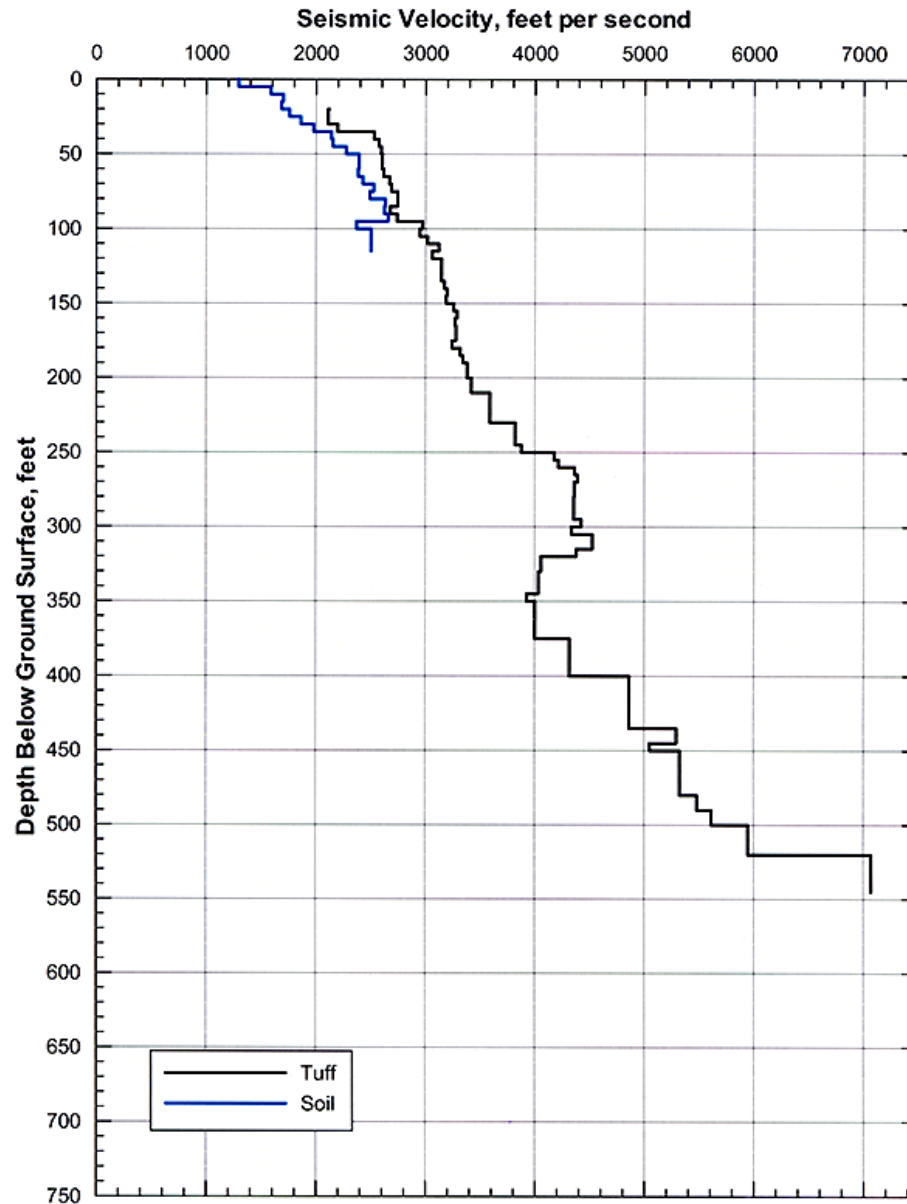


# SASW $V_s$ Measurements in Tuff at Surface Facilities





# V<sub>S</sub> Profiles at Surface Facilities



# Probabilistic Representation of Velocity Models

- **Objective: Characterize variability in shear-wave velocity profiles at one location**

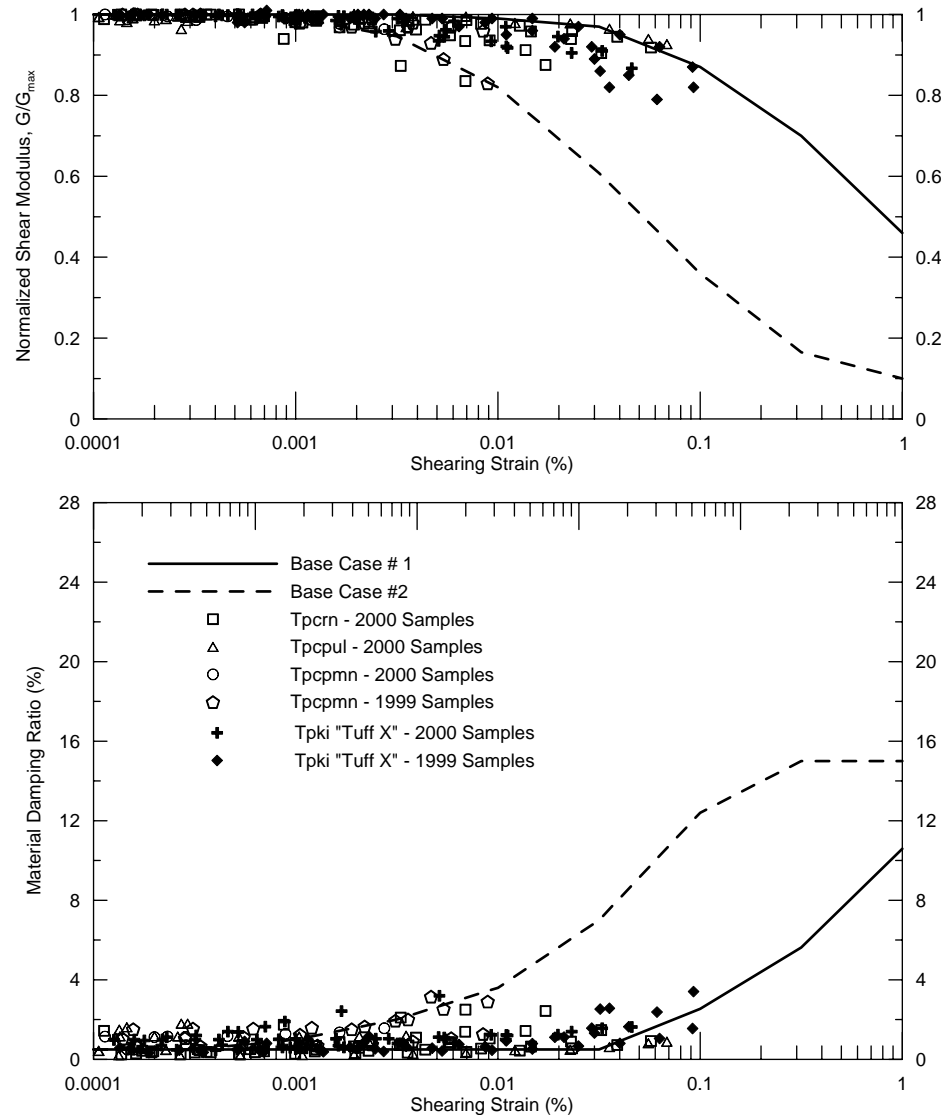
- Borehole to borehole variation within one location (repository block or waste-handling building)
- Vertical variation at one borehole (central tendency, roughness)

- **Purpose: Generate artificial velocity profiles that are statistically similar to observed profiles for use in site-response calculations**

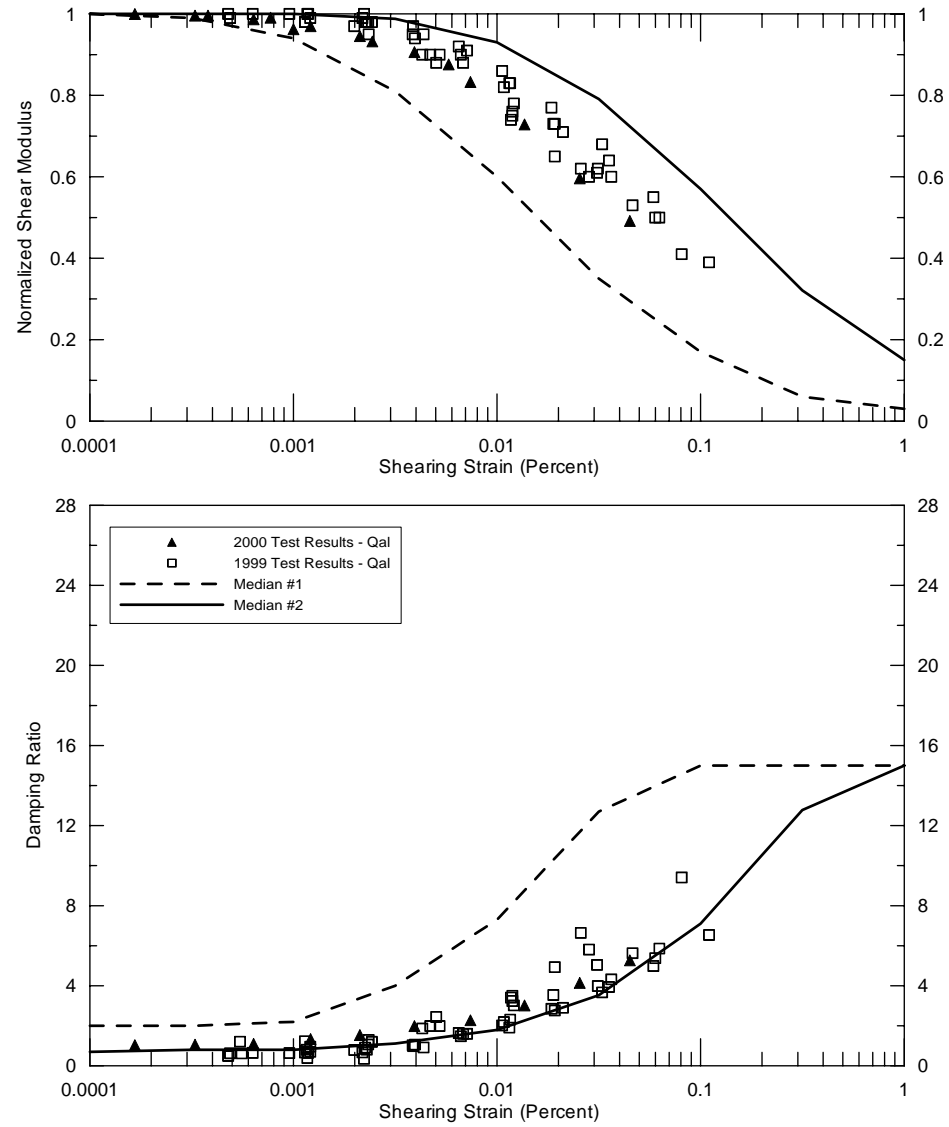
# Samples Tested

- **24 intact tuff specimens from Surface Facilities**
- **5 reconstituted alluvial specimen from Surface Facilities Area**
- **10 compacted granular fill specimens from material from Fran Ridge Borrow Area**
- **5 intact tuff specimens from north portal area of Exploratory Study Facility (ESF)**

# Variation in Normalized Shear Modulus and Damping Ratio with Shearing Strain (Tuff)



# Variation in Normalized Shear Modulus and Damping Ratio with Shearing Strain (Alluvium)



# Summary

- **Based on the seismic velocity surveys (SASW, vertical seismic profile (VSP), and shallow downhole) performed above the emplacement area and in the ESF, two basecase velocity profiles have been developed for  $V_S$  and  $V_P$  for the repository block**
- **Based on SASW, downhole, and suspension data, single basecase profiles for  $V_S$  and  $V_P$  have been developed for the surface facilities**
- **A probabilistic representation of the velocity profiles has been developed to characterize the variability at the emplacement area and WHB**

# Summary

(Continued)

- **Shear modulus reduction and damping curves have been developed for the tuff and alluvium**
- **Uncertainties in the velocity structure and dynamic properties in the emplacement area and to a lesser extent, the WHB are being incorporated into the design ground motions to a greater degree than if more site-specific data were available. This results in more conservative ground motions**

# Backup





# Soil Terms and Acronyms

- **Abbreviations and Terms used for soil units (SU)**

**SU<sub>x</sub> = Soil unit, number (x)**

**GM = Silty-gravel [gravel with significant sand/silt content]**

**GP = Poorly-graded gravel with a small amount of sand/silt**

**GP-GM = Poorly-graded gravel with a small to significant amount of sand and silt**

**scb = Soil includes cobbles and boulders**

**sc = Soil includes cobbles**

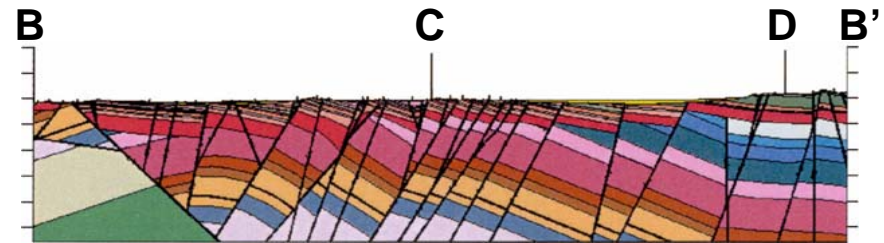
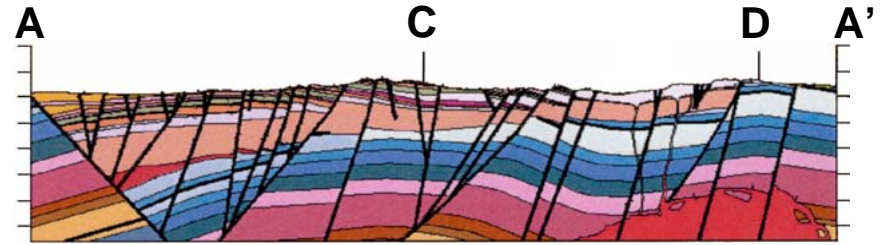
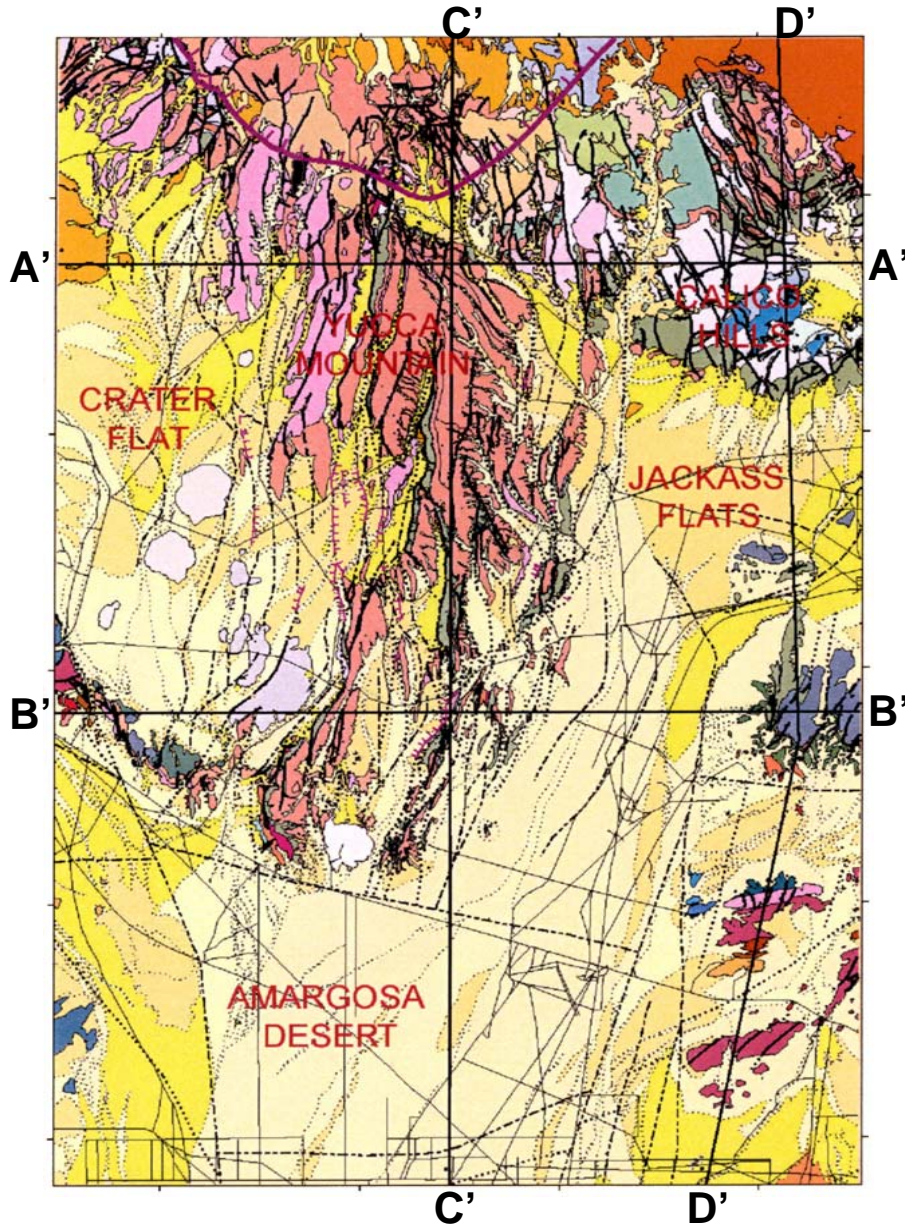
**s = Soil**

**Fill = Undefined soil type, manually placed**

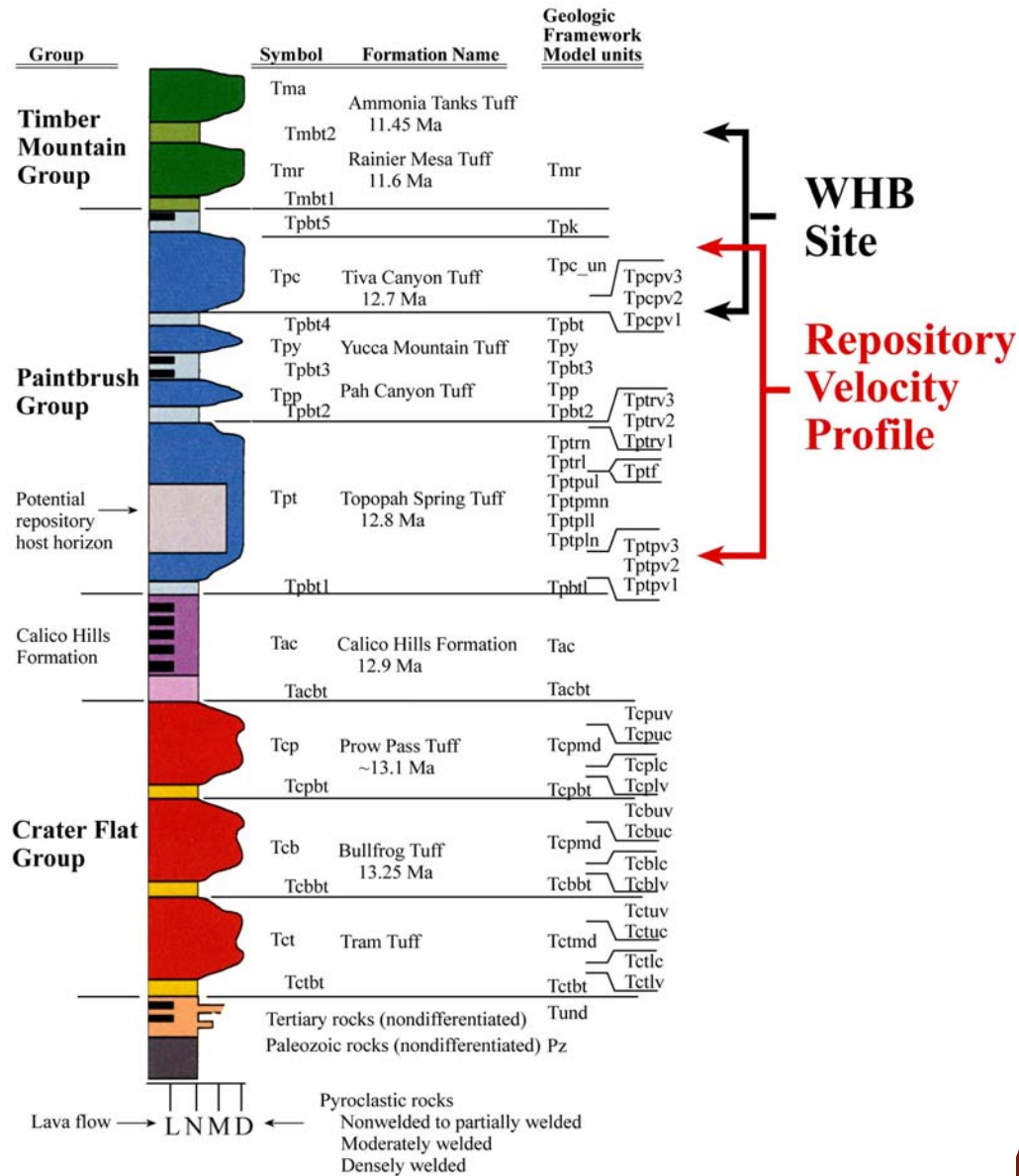
**Spoil pile = Excavated soil/rock pile**

*BSC (Bechtel SAIC Company) 2002. Geotechnical Data for a Potential Waste Handling Building and for Ground Motion Analyses for the Yucca Mountain Site Characterization Project. ANL-MGR-GE-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20021004.0078.*

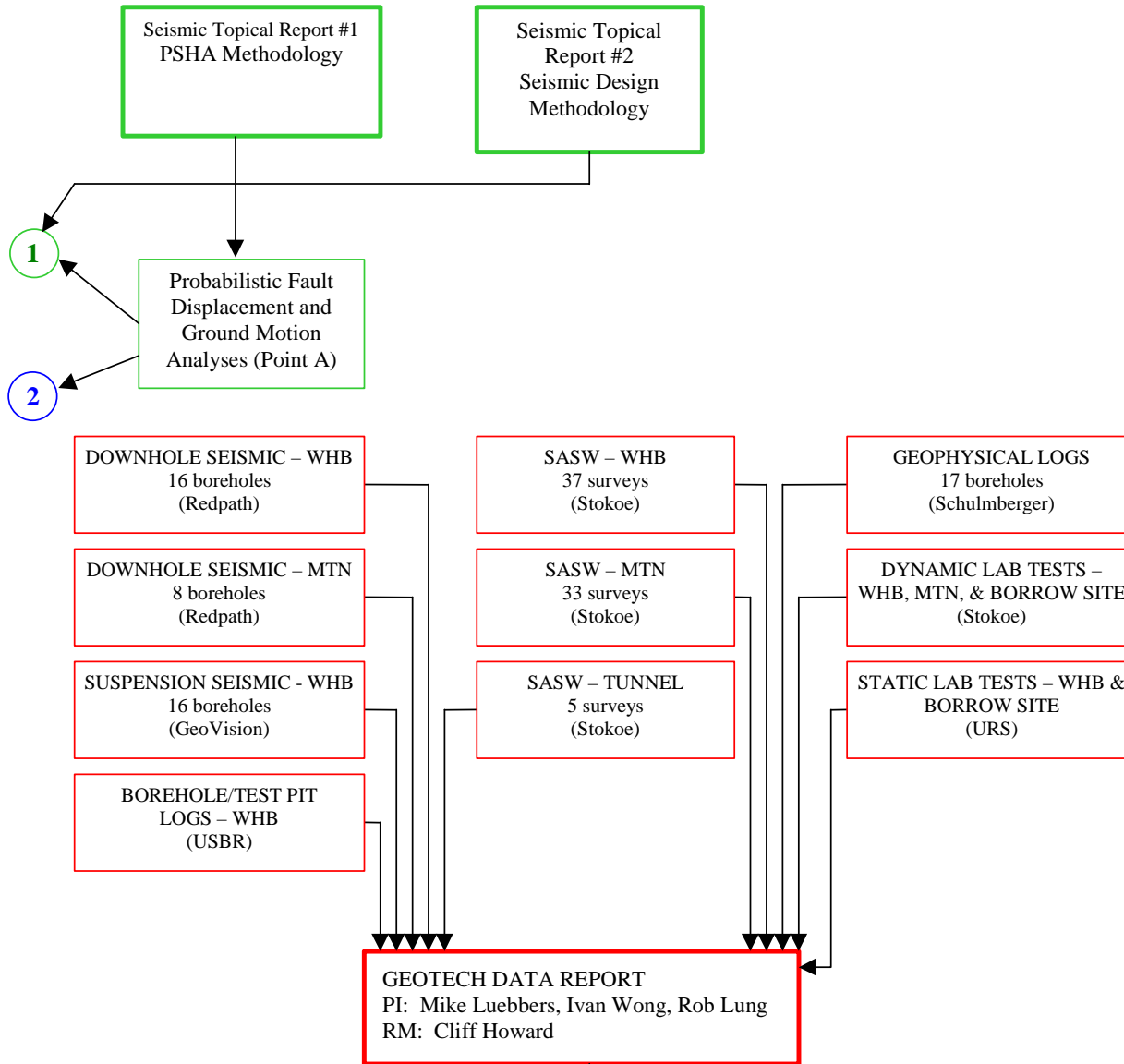
# Geologic Map of the Yucca Mountain Region



# Lithostratigraphy



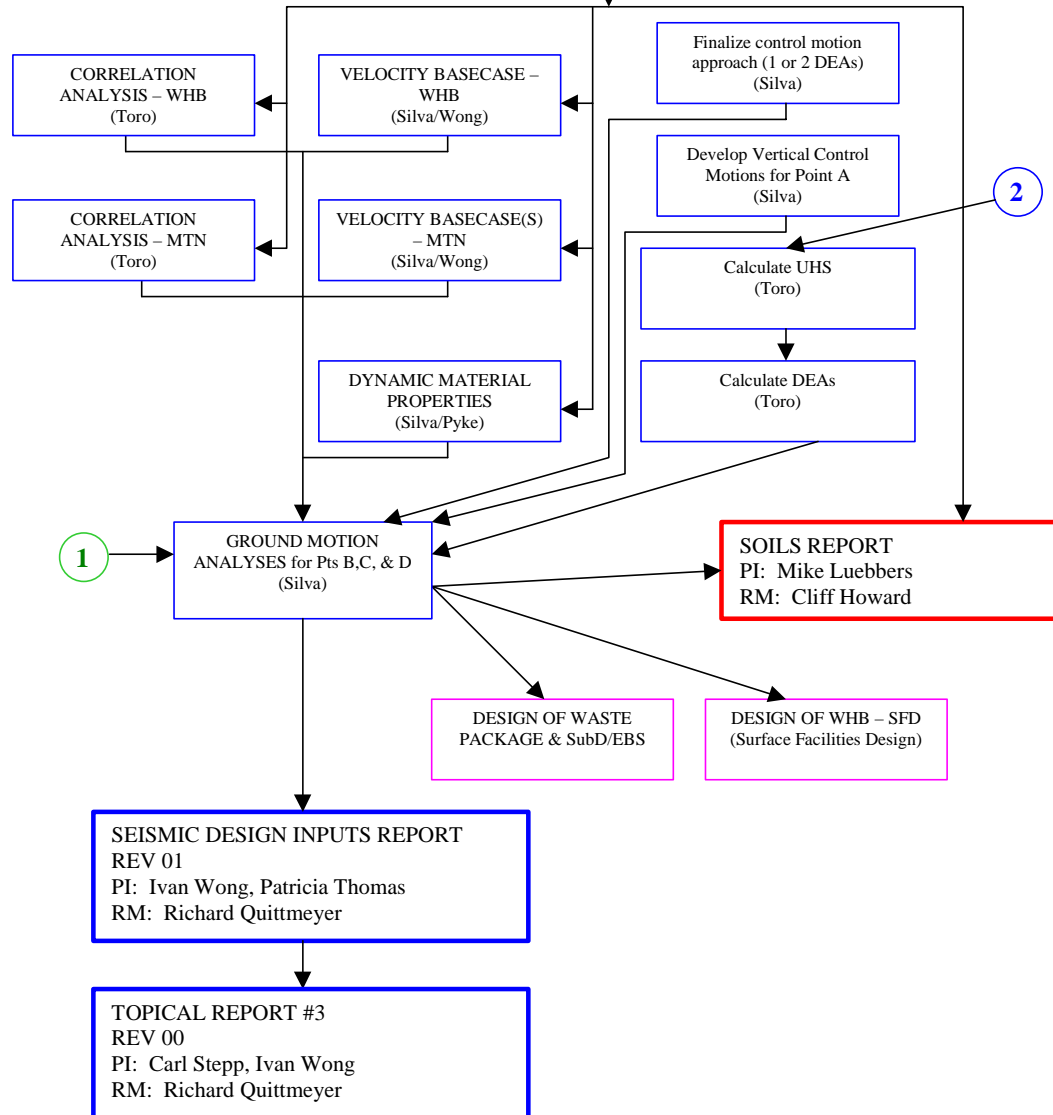
# Flow Chart for Geotechnical Investigations



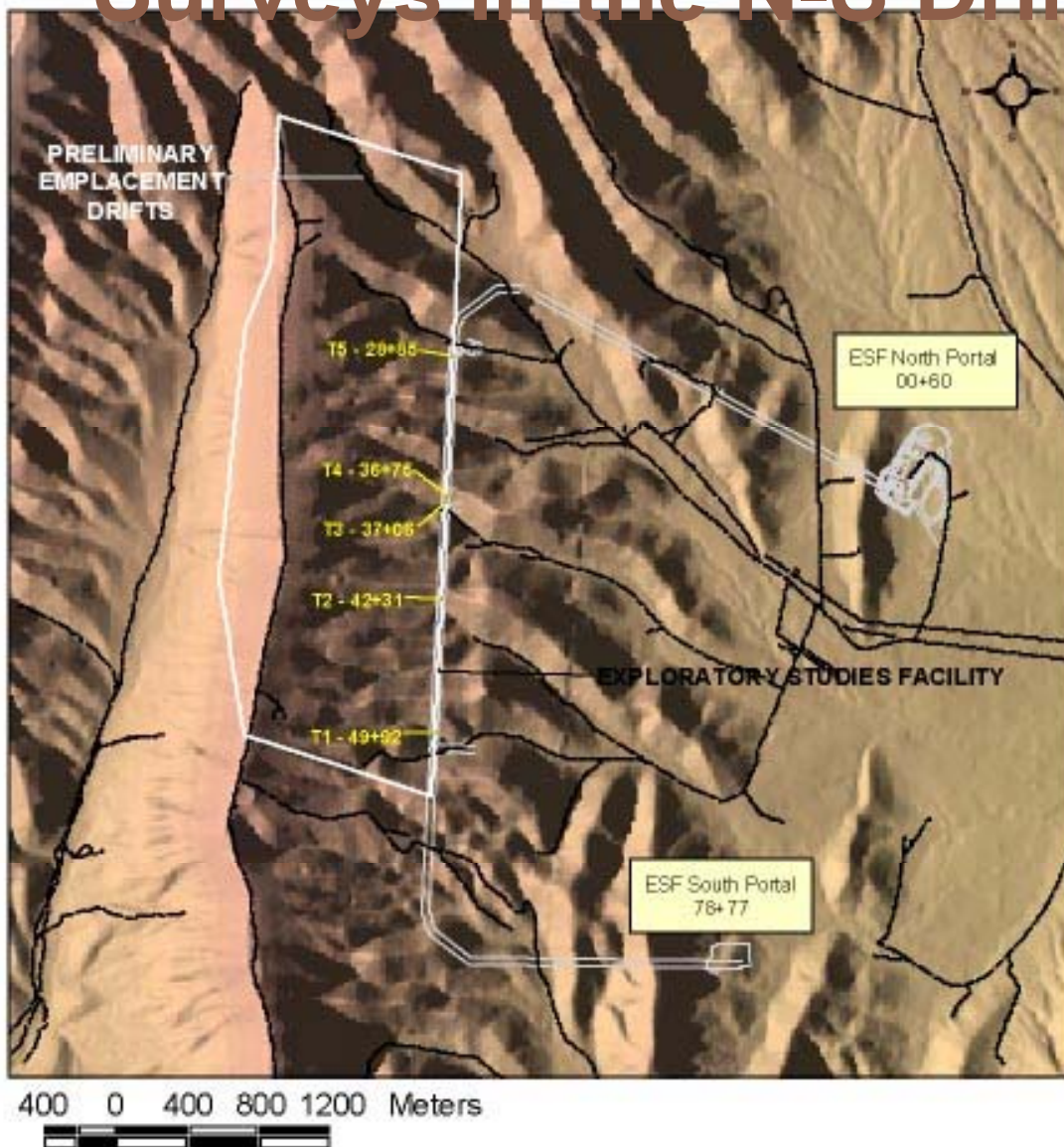
Receive data via input transmittal 1-Oct-01

# Flow Chart for Geotechnical Investigations

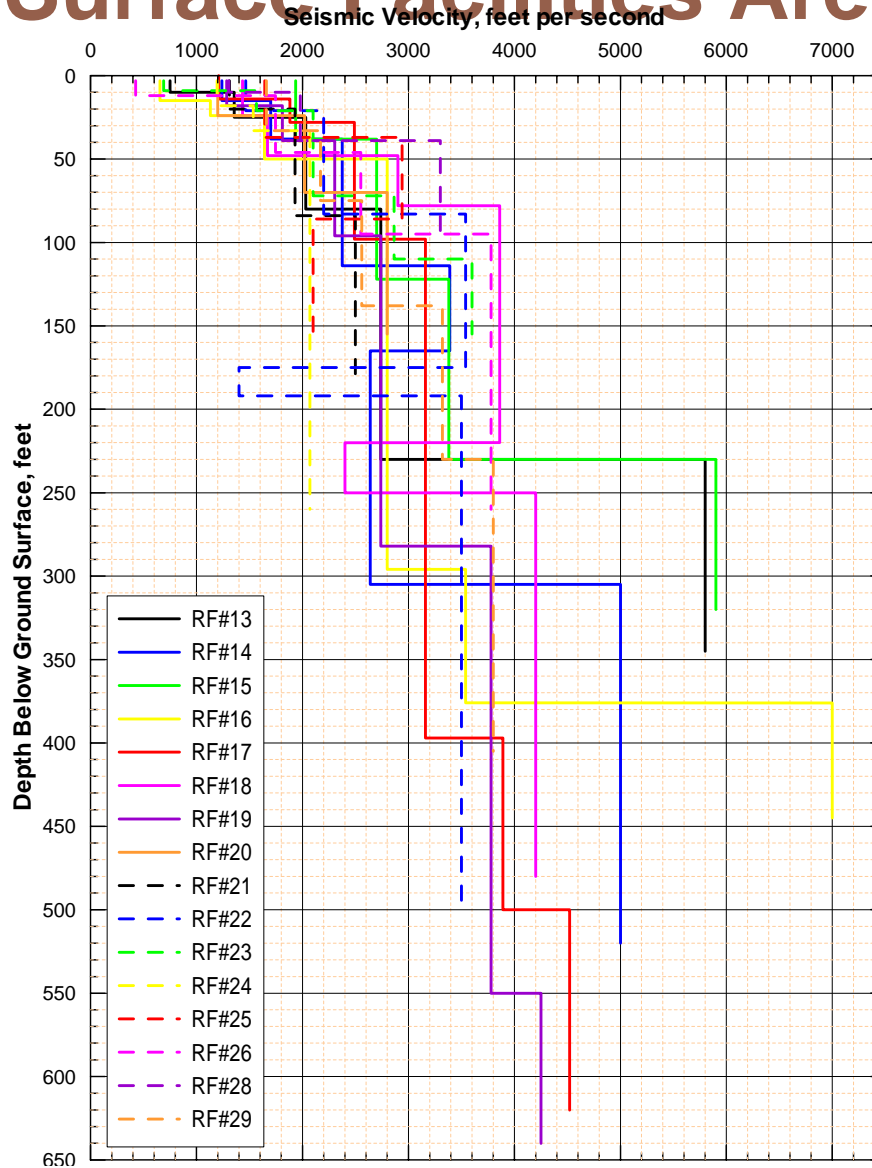
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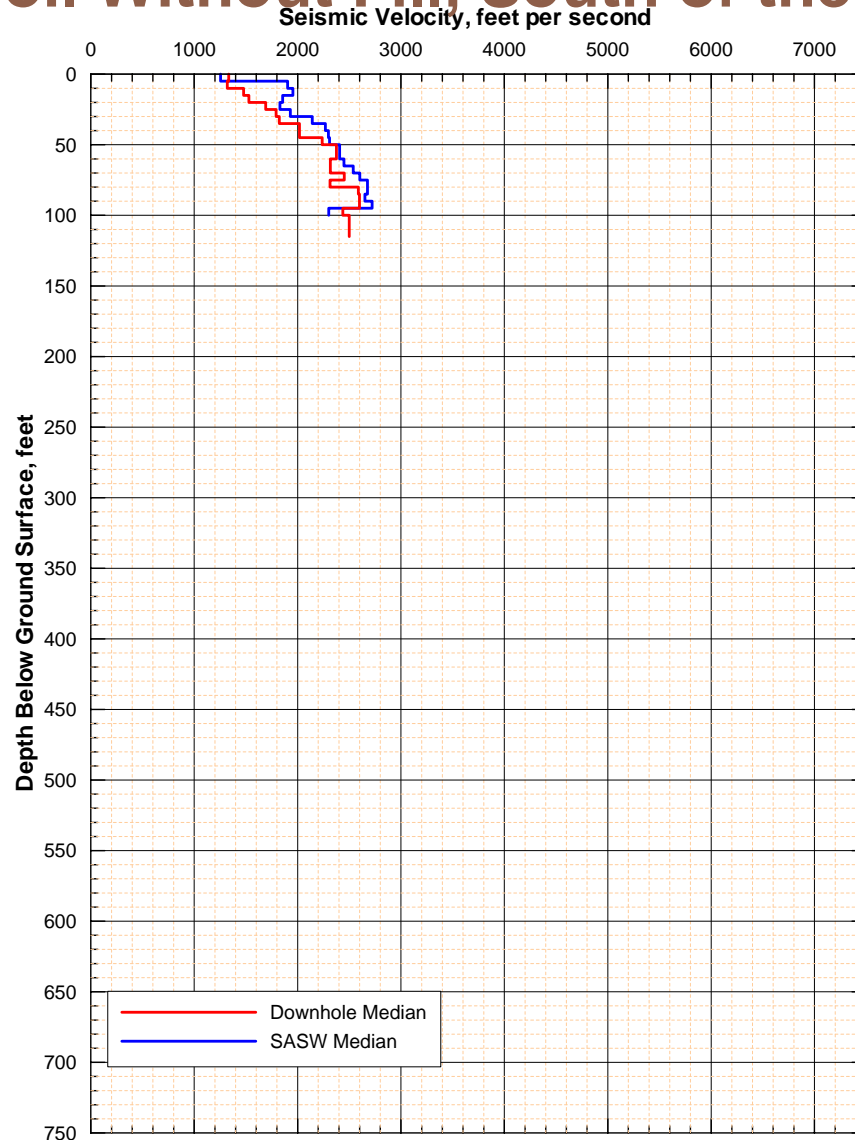
# Spectral Analysis of Surface Waves Surveys in the N-S Drift



# Downhole $V_s$ Measurements in the Surface Facilities Area

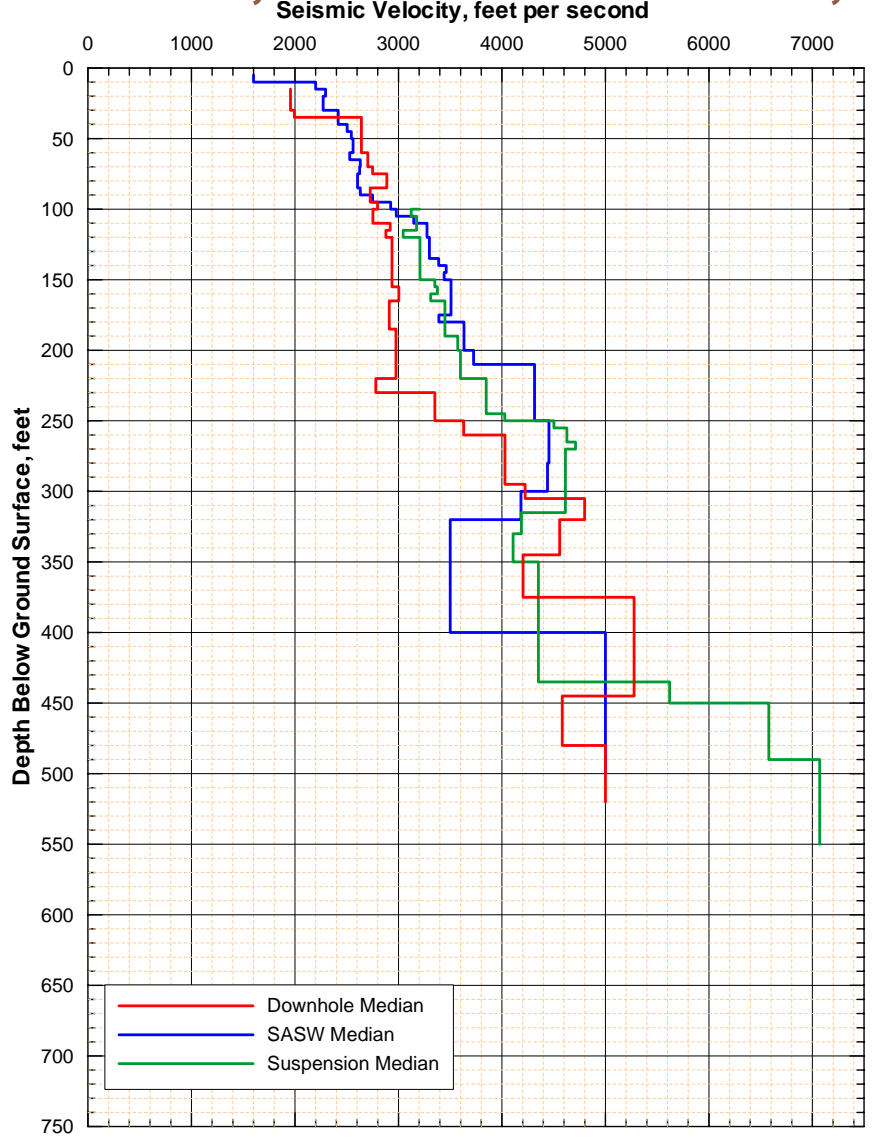


# Comparison of Spectral Analysis of Surface Waves and Downhole Measurements at Surface Facilities, Soil Without Fill, South of the Fault



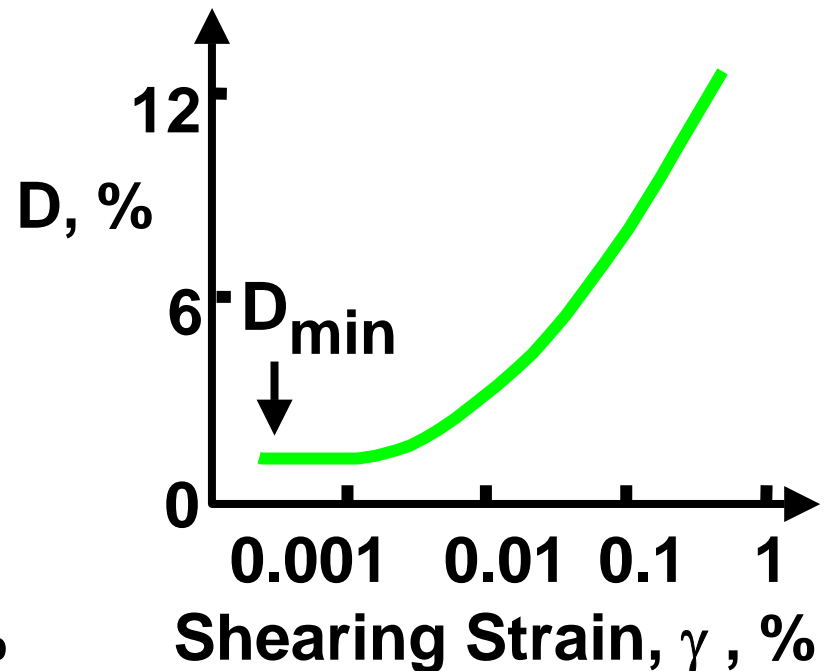
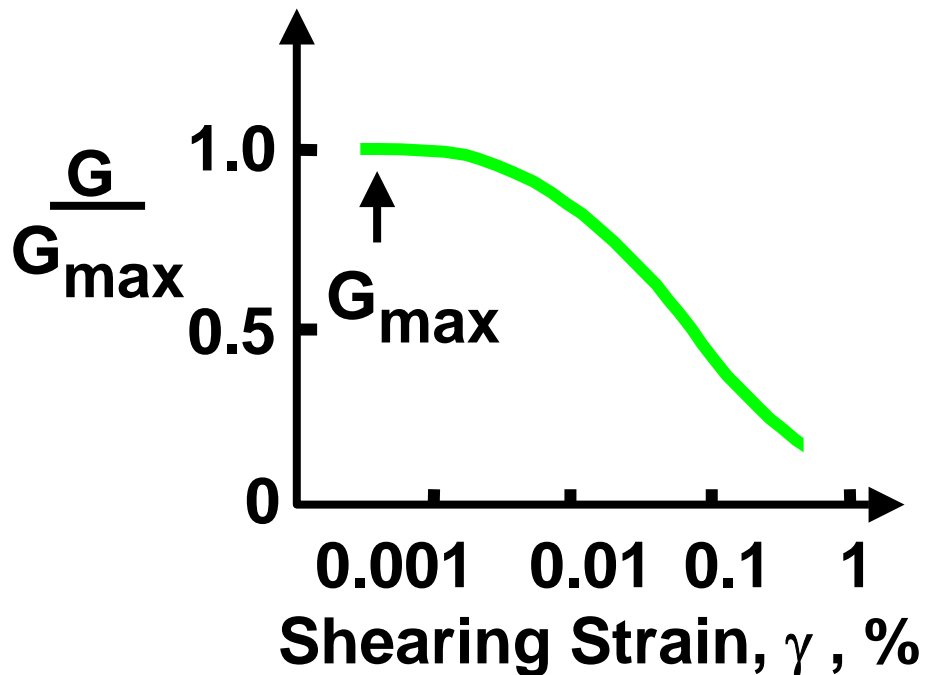


# Shear-Wave Velocities for Downhole, Suspension and Spectral Analysis of Surface Waves Measurements at Surface Facilities, South of the Fault, Tuff

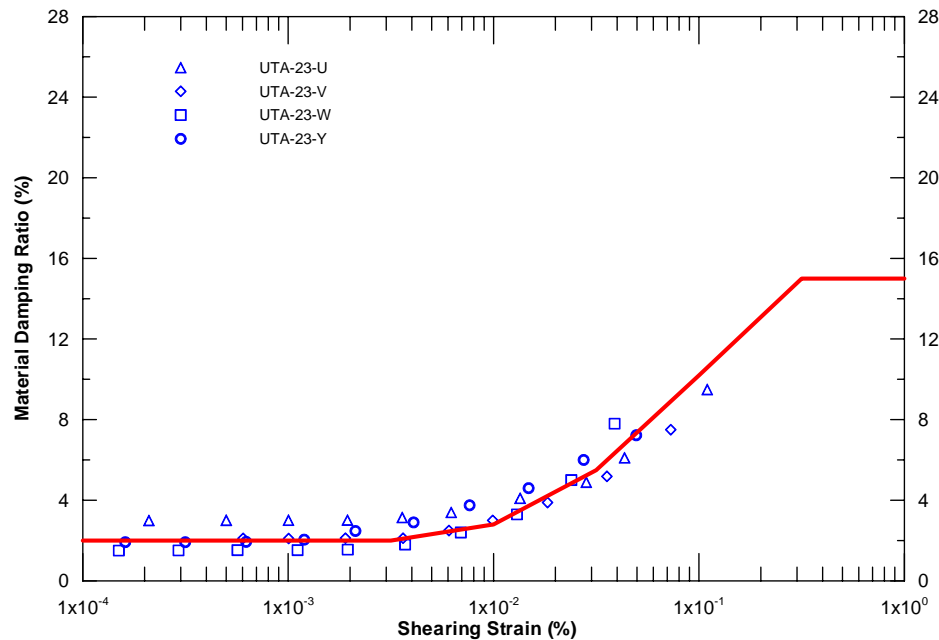
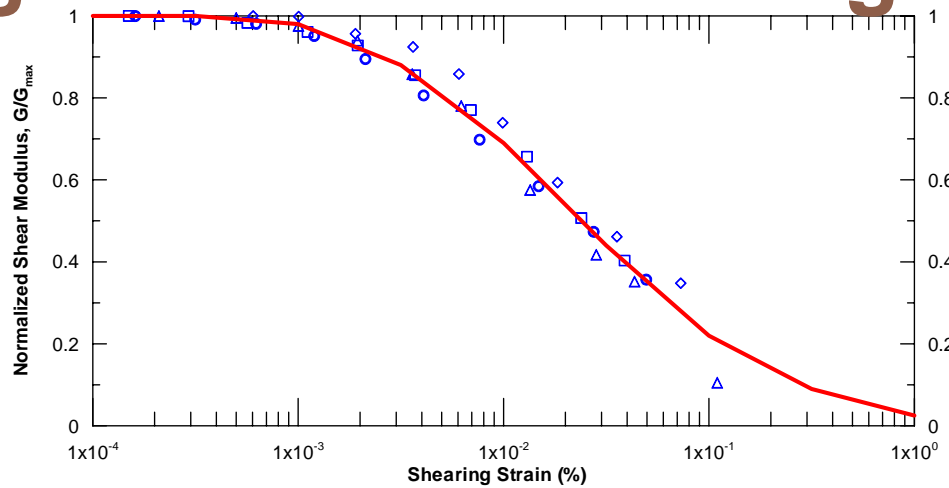


# Dynamic Laboratory Testing

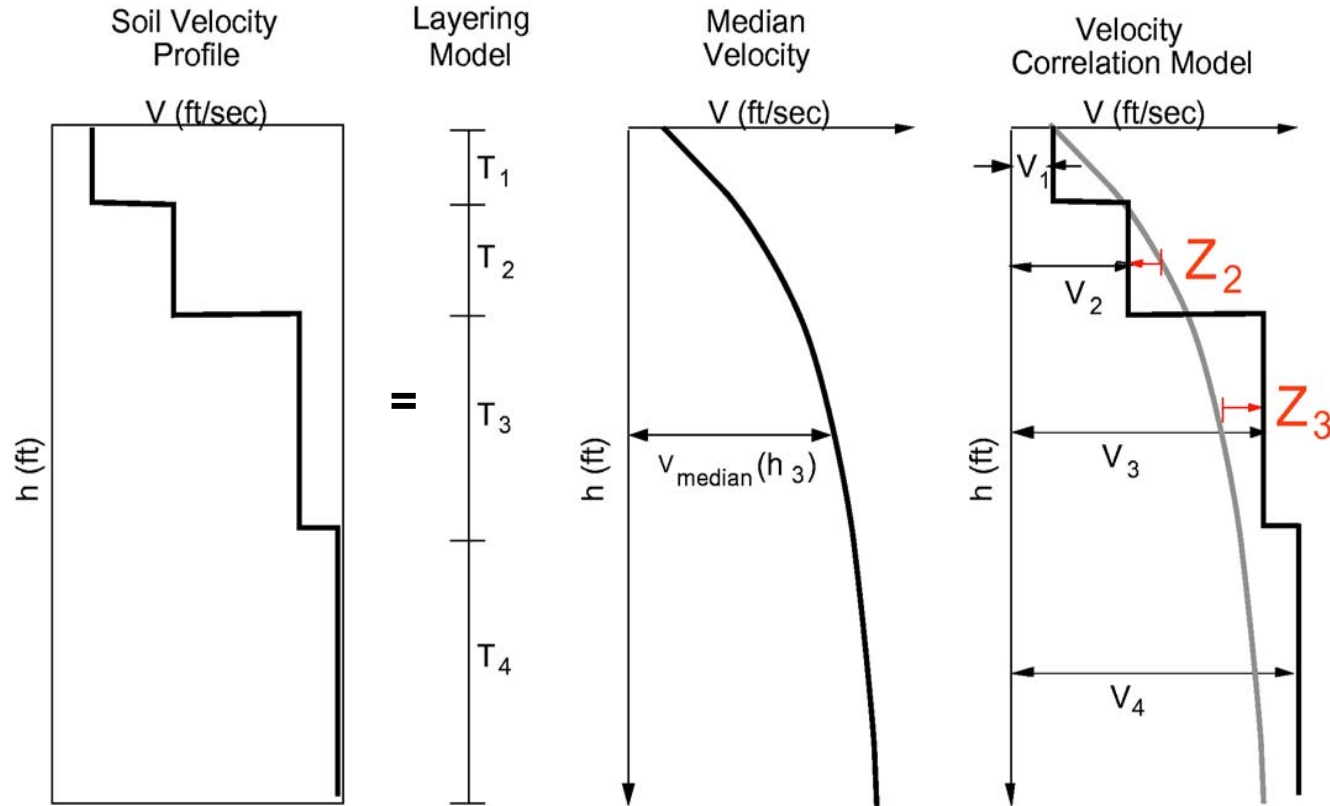
To provide dynamic property data to aid in the development of material/site specific normalized shear modulus and hysteretic damping versus shearing strain curves for use in seismic analyses.



# Variation in Normalized Shear Modulus and Damping Ratio with Shearing Strain (Fill)



# Formulation



$T_i$  is the thickness of layer  $i$

Actually, formulation works with  $\ln(\text{Velocity})$ , not with velocity as shown here

# Specimens UTA-23-A to 23-J

