MoDOT Geotechnical Research Thrust

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Partial List of Contributors

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  - MoDOT
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  - University of Missouri
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  - Loadtest, Inc.
  - Drilling Service Co.
  - Hayes Drilling
  - Geokon, Inc.

MoDOT Research Program

- General objective

  Achieve significant and recurring cost savings for MoDOT by developing improved, technically sound geotechnical design guidelines

- Deliverables
  - Improved LRFD guidelines for bridge foundations
  - New LRFD guidelines for earth slopes
  - Commentary documents to support guidelines

Why LRFD for geotechnical applications?

- Because others are doing it
  - Structural codes have adopted LRFD for decades
  - Other countries have adopted (??)
    - Danish Code of Practice
    - Eurocode 7
    - Ontario Bridge Code
    - Canadian Foundation Engineering Manual
    - EPRI TR-105000
- Because "the feds" tell us to do it
  - State DOTs mandated to adopt LRFD for bridge design by 2007
  - Other geotechnical applications in process
- Because it can help us do our jobs better…

Sources of variability/uncertainty

- Variability/uncertainty from site conditions (design parameters)
- Variability/uncertainty from design/analysis methods
- Variability/uncertainty from construction methods

MoDOT Research Program

Task 1
Site
Characterization

Task 2
Foundation
Design Methods

Task 3
Target Reliability

Task 4
LRFD Specifications:
Bridge Foundations
Earth slopes/embankments

Task 4 – Calibration & guidelines

- Conventional calibration (Allen et al., 2005)
  - Lumps sources of variability together
  - Resulting resistance factors produce target reliability in average sense

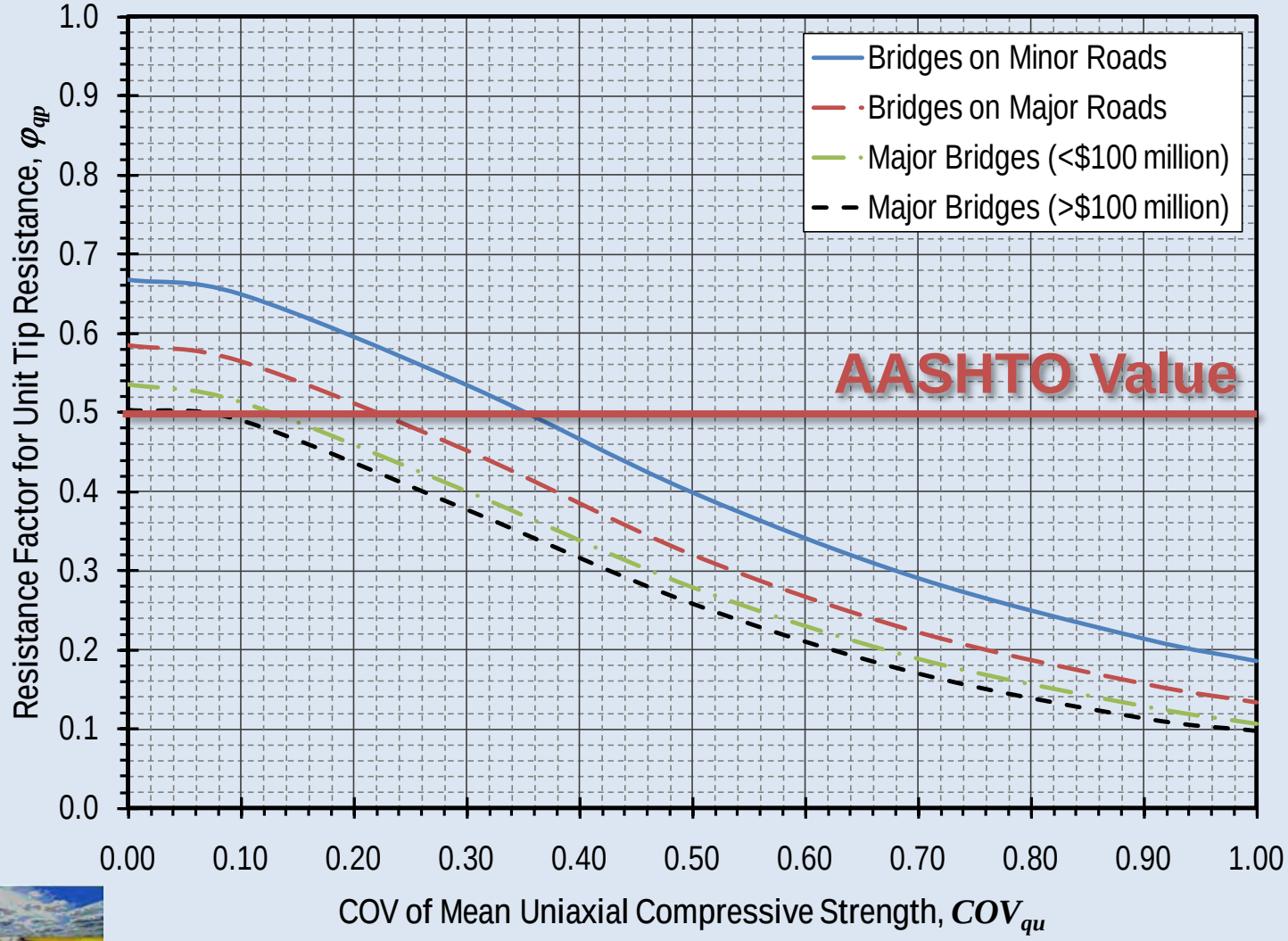
- We chose to use "variability dependent" calibration
  - Separates variability of design methods from variability in design parameters

Current AASHTO– Drilled shafts

Method/Soil/Condition				Resistance Factor
Nominal Axial Compressive Resistance of Single Drilled Shafts	φ_{stat}	Side resistance in clay	α-method (O'Neill & Reese, 1999)	0.45
		Tip resistance in clay	Total Stress (O'Neill & Reese, 1999)	0.40
		Side resistance in sand	β-method (O'Neill & Reese, 1999)	0.55
		Tip resistance in sand	O'Neill & Reese (1999)	0.50
		Side Resistance in IGM	O'Neill & Reese (1999)	0.60
		Tip Resistance in IGMs	O'Neill & Reese (1999)	0.55
		Side resistance in rock	Horvath & Kenney (1979) O'Neill & Reese (1999)	0.55
		Side resistance in rock	Carter & Kulhawy (1988)	0.50
		Tip resistance in rock	Canadian Geotechnical Society (1985) Pressuremeter Method (CGS, 1985) O'Neill & Reese (1999)	0.50

AASHTO (2009)

Tip resistance – shafts in weak rock



Summary comparison of guidelines

"Old" MoDOT	"New" MoDOT
• Marginally simpler	• Marginally more complex
• Less consistent reliability	• More consistent reliability
• No explicit benefit to enhanced characterization	• Explicit and quantifiable benefit to enhanced characterization
• Judgment used to avoid "negative consequences"	• Judgment used to produce "positive consequences"

Task 1 – Site characterization

- Objective:

  quantify bias and variability in engineering properties determined using MoDOT's current practices
- Compare variability from current practice with that from "research quality" characterization
  - Four "soil" test sites
  - Five "shale" test sites
- Establish procedure for estimating parameter variability from lab and/or field measurements

Site Characterization

- "Soil" sites
  - UU/CU-type triaxial tests
  - DS/DSS tests
  - Incremental and CRS consolidation tests
  - SPT & CPT tests
  - Hydraulic piston, Shelby tube, & Pitcher samplers
- "Shale" sites
  - UCS/UU-type compression tests
  - Double-tube HQ core barrel
  - "on-site" testing
  - Point Load Index tests
  - SPT, PMT, & TCPT tests
- 76 research borings
- 67 historical borings

Task 1 – Site characterization

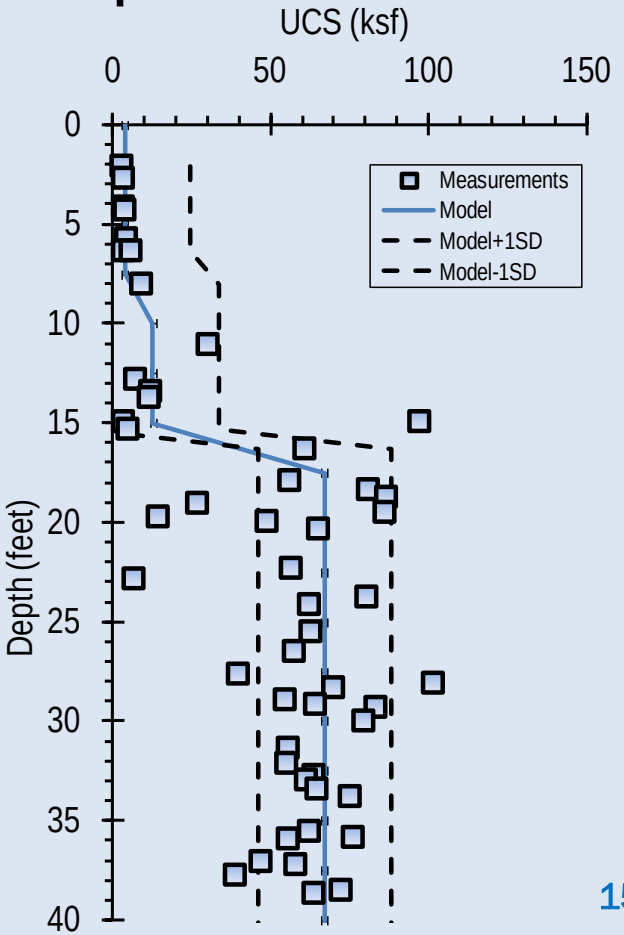
Task 2 – Foundation test program

- Objective:

  quantify variability in foundation capacity and potential design methods
- Re-calibration based on existing load tests with improved measurements of design parameters
- Drilled shaft load test program
  - To enhance available data for end bearing
  - To quantify relationship between site variability and variability in shaft capacity

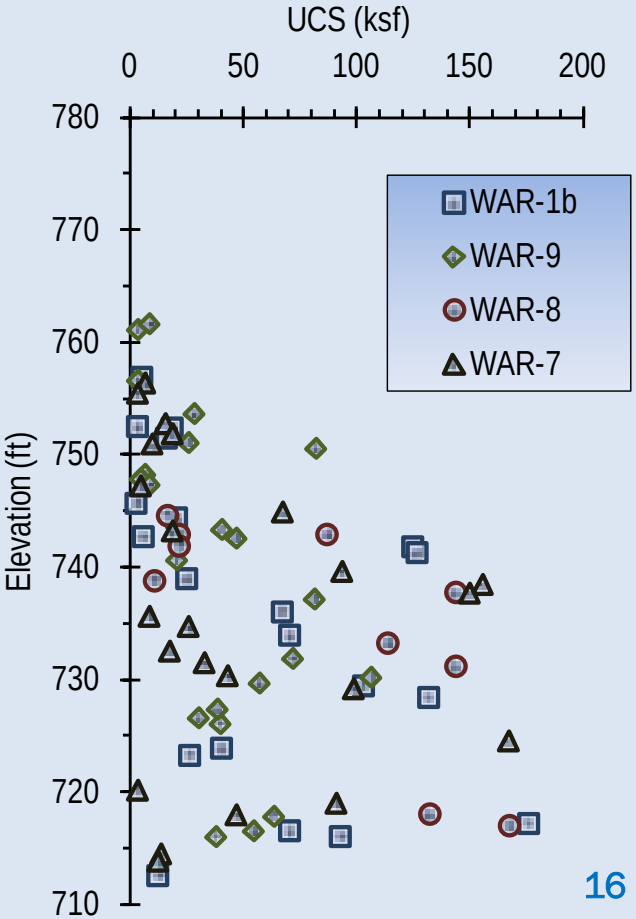
Frankford Load Test Site

- A site with low variability
- Very weak shale overlying competent shale



Warrensburg Load Test Site

- A site with high variability
- Clay overburden over highly variable shale

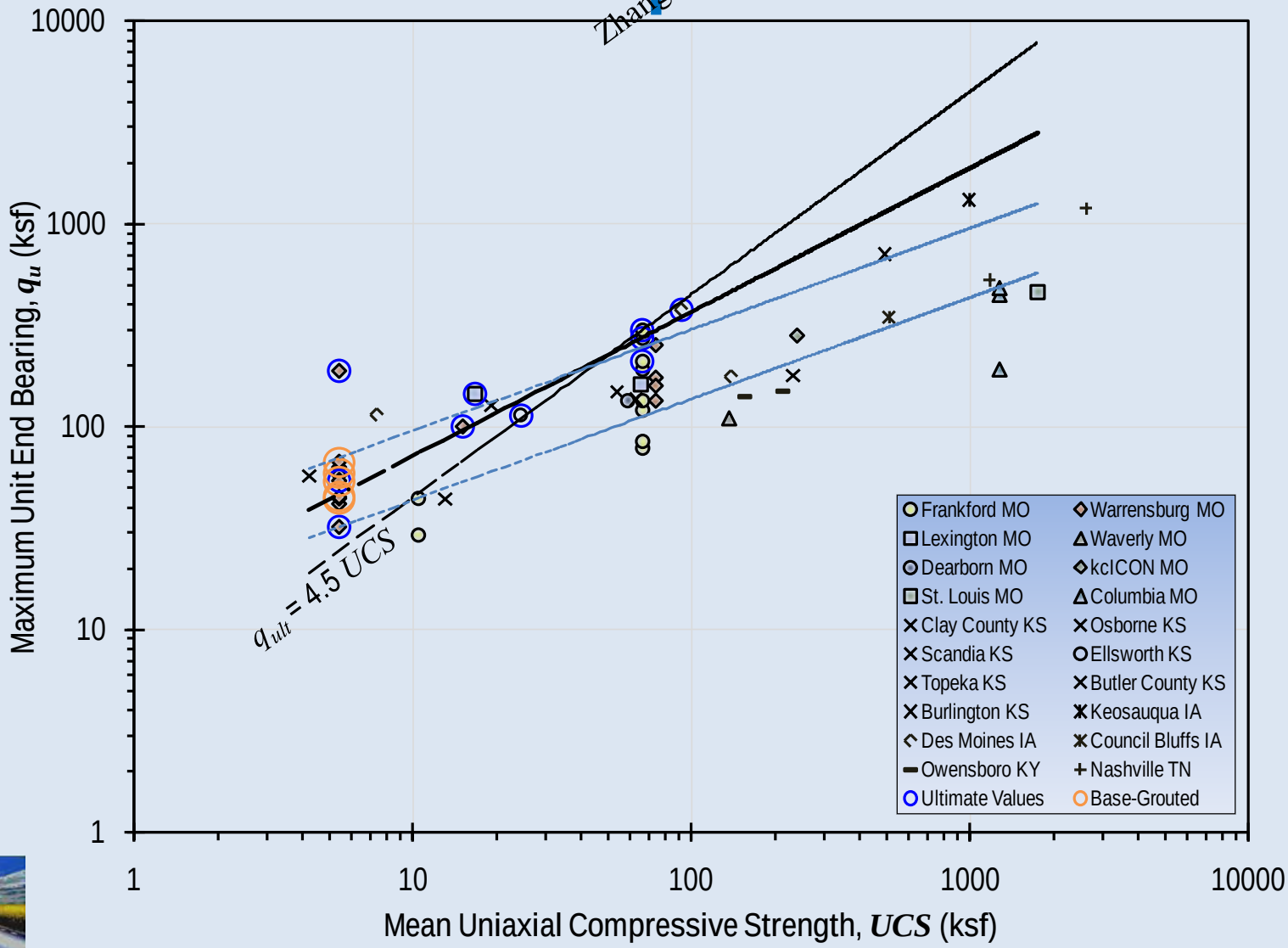


Warrensburg Load Test Site

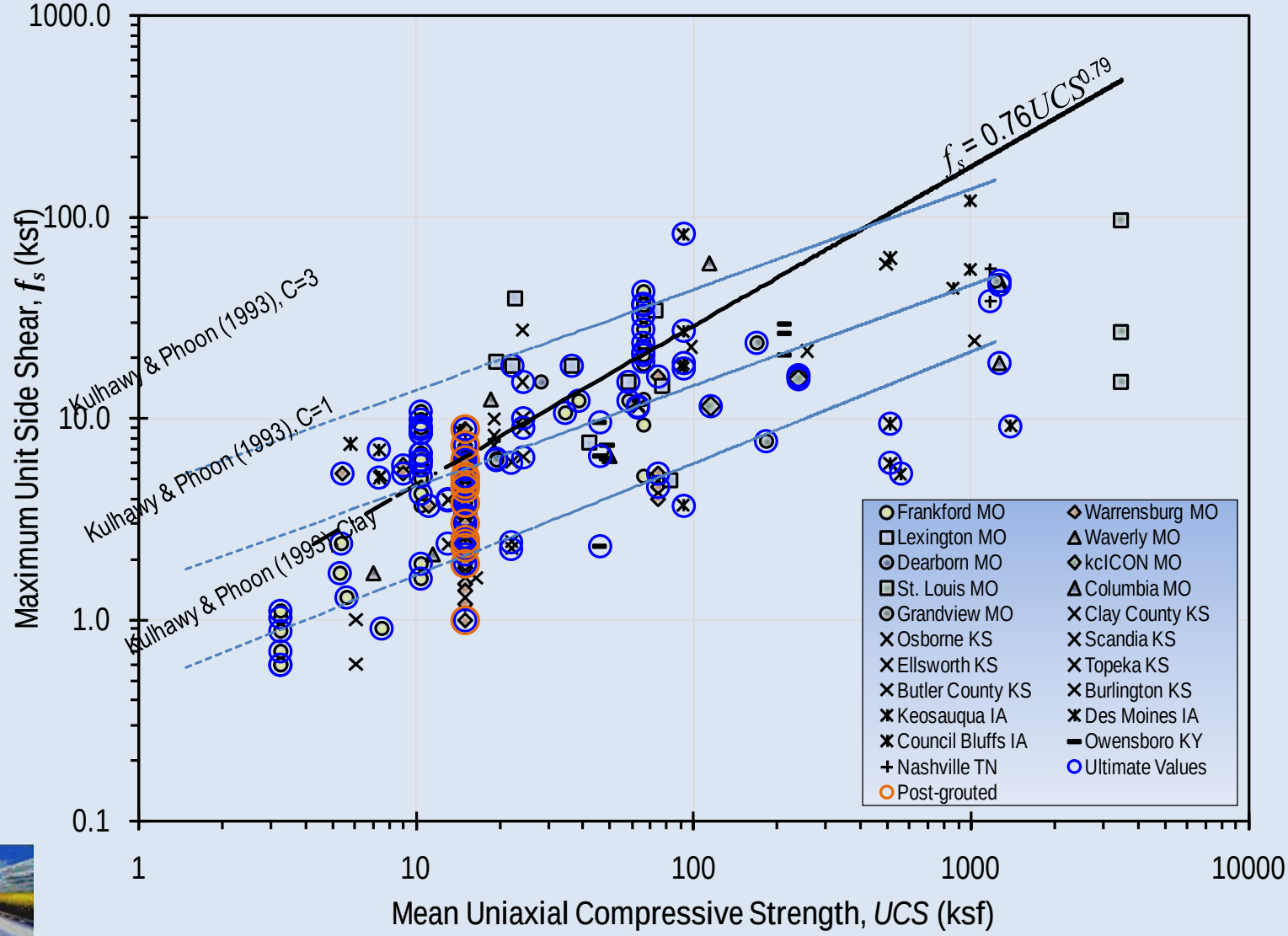
Osterberg Cell

Load Testing at FLTS

Drilled shafts – tip resistance



Drilled shafts – side resistance



Task 3 – Target reliability

- Objective:

  establish target reliability values for use in calibration of design methods

- Current AASHTO specifications generally target probability of failure of about 1 in 1000 ($\beta \approx 3.0$)
- Question is what should we be targeting
  - For strength limit states?
  - For serviceability limit states?

Task 3 – Recommendations

Application	Classification	Recommended Target Probability of Failure	
		Strength	Service A
Foundations	Major Bridges (>$100M)	1 in 10,000	1 in 100
	Major Bridges (<$100M)	1 in 5,000	1 in 75
	Bridges on Major Roads	1 in 1,500	1 in 50
	Bridges on Minor Roads	1 in 300	1 in 25

Example…

- Bridge on major road
- Drilled shaft foundations
- Factored load of 3000 kips
- Used Frankford Load Test site as example
- Compare:
  - o Designs using “old” and “new” guidelines
  - o Designs for two different levels of site characterization

Comparison – “old” and “new”

“Old” Guidelines

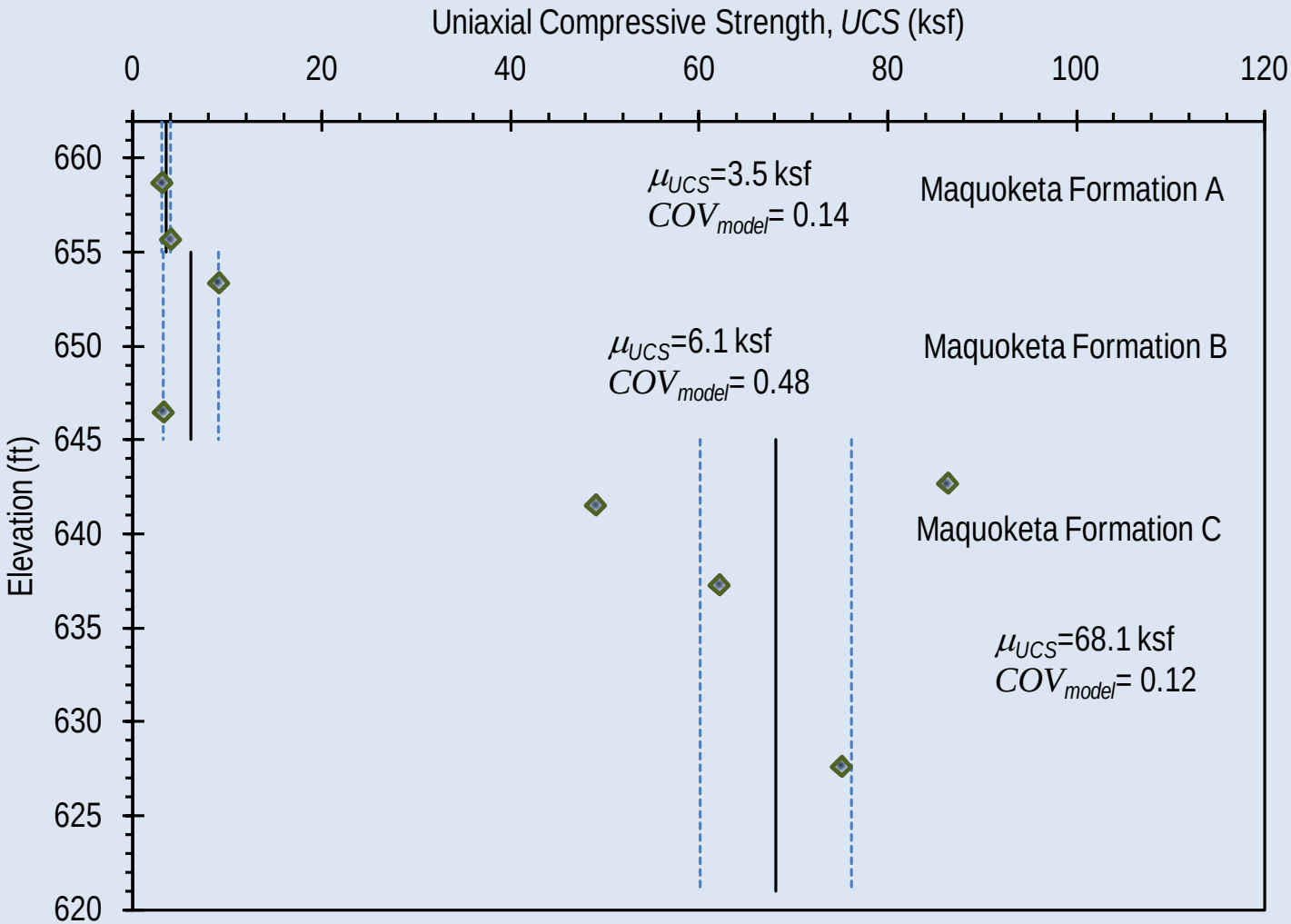
- Required shaft:
  - 4-ft diameter
  - 38-ft length
- Nominal cost:
  $22,500 per shaft

“New” Guidelines

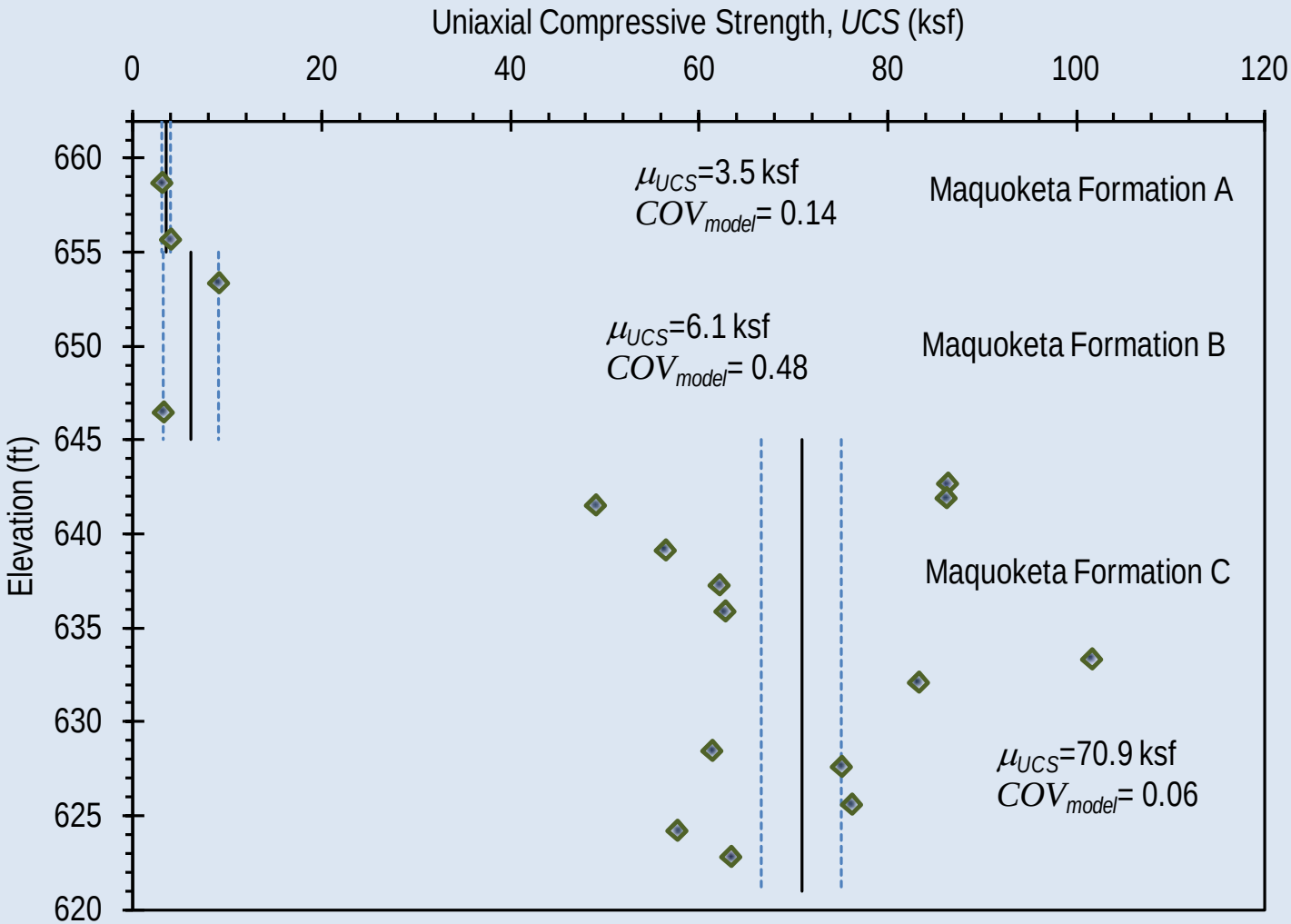
- Required shaft:
  - 4-ft diameter
  - 25-ft length
- Nominal cost:
  $15,000 per shaft

New guidelines result in savings of approximately $7500 per shaft

Example: minimal characterization



Example: expanded characterization



Comparison – “minimal” & “expanded”

Minimal

- Required shaft:
  - 4-ft diameter
  - 25-ft length
- Nominal cost:
  $15,000 per shaft

Expanded

- Required shaft:
  - 4-ft diameter
  - 17-ft length
- Nominal cost:
  $10,000 per shaft

Benefit of added characterization is approximately $5000 per shaft

Conclusion - Keys to success

- Comprehensive nature of research program
  - o Cost savings produced were combined results from all tasks
- Establishing appropriate objectives and metrics for research from outset
  - o maintained focus throughout work
- Meaningful collaboration
  - o considerable contributions from all parties

A few of the players…