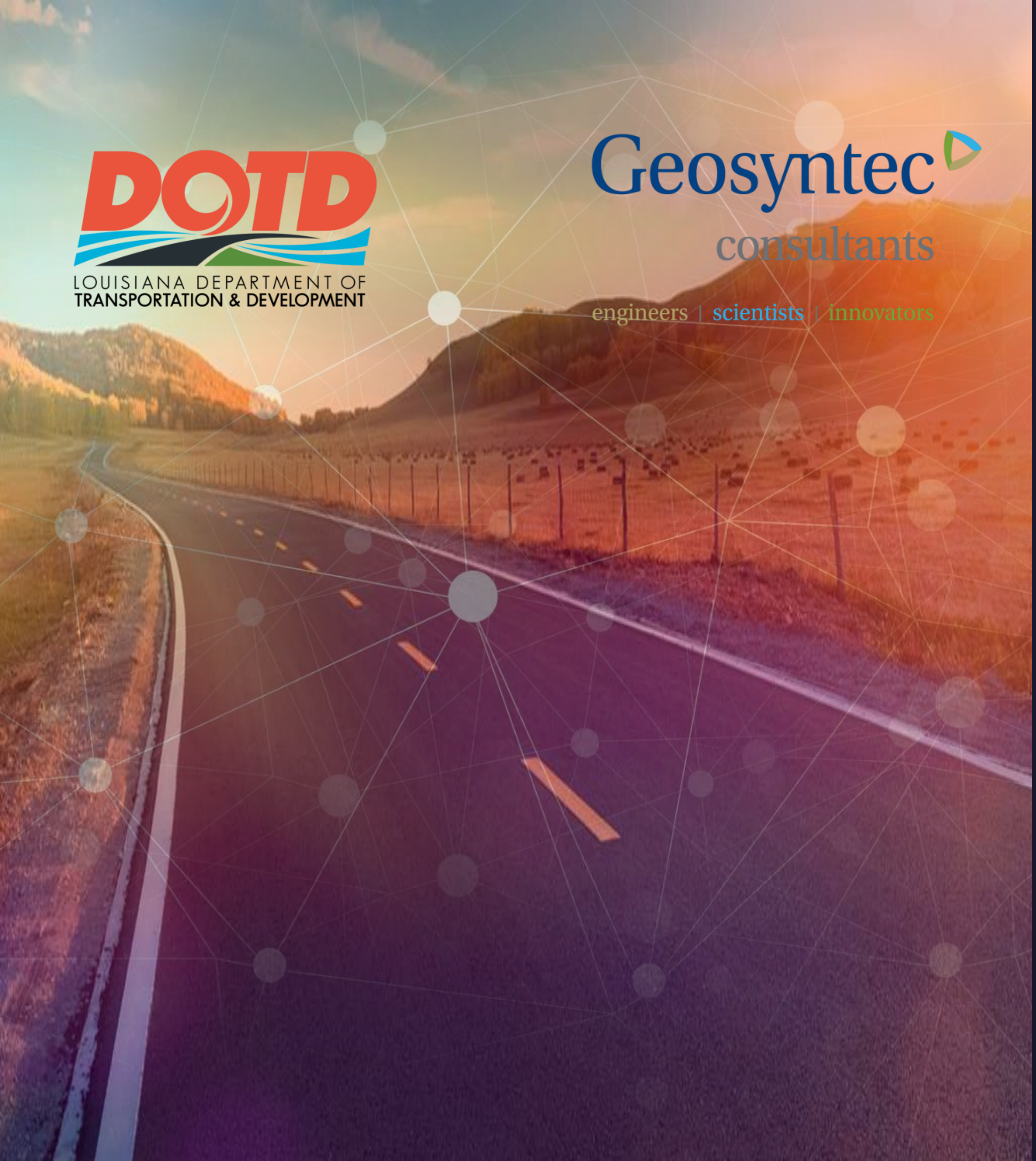

Automated Assessment of Statistic Features to Facilitate Geotechnical Site Characterization and Design in Large Transportation Projects in Louisiana

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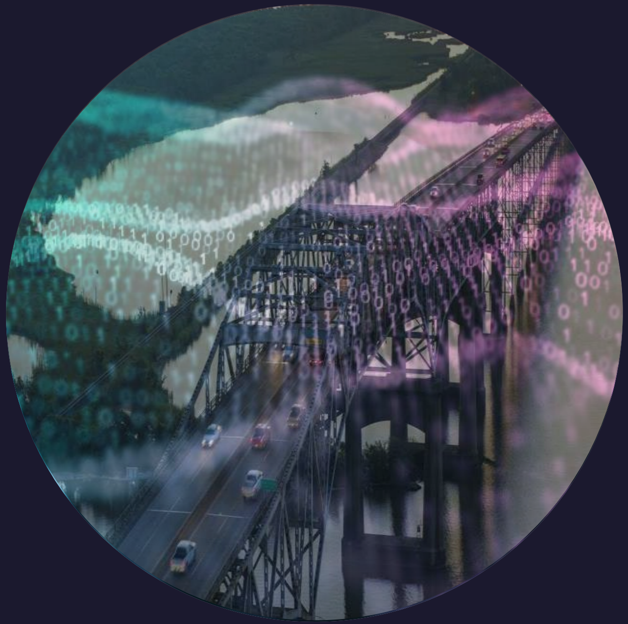
The 51st Annual Southeastern Transportation Geotechnical Engineering Conference (STGEC)

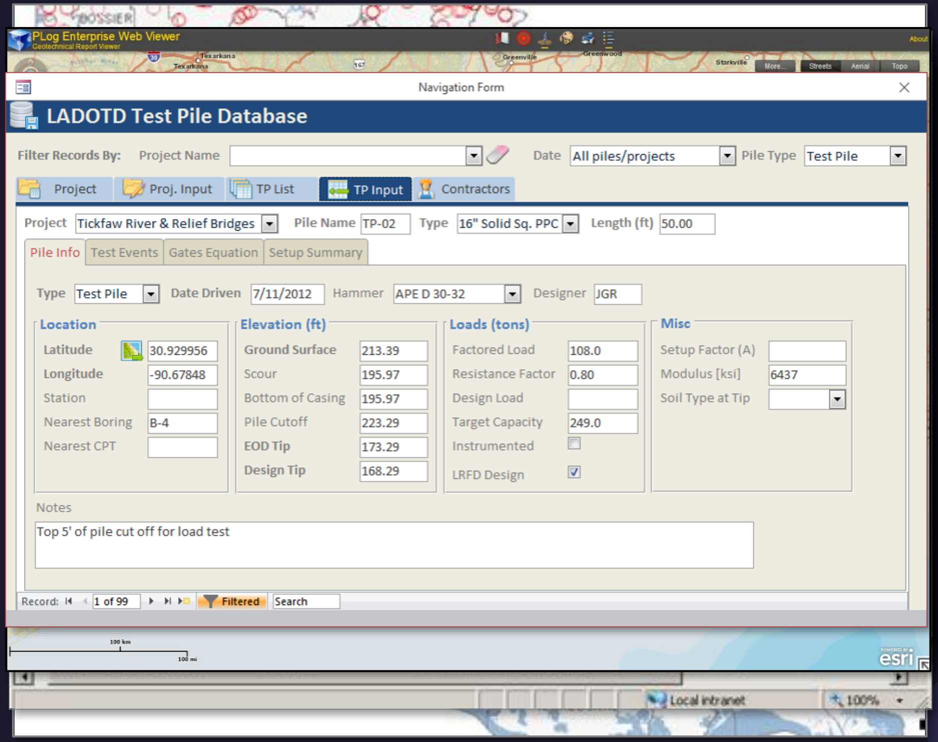
Outline

- LADOTD's Data Management Journey
- A Web-Based Platform to Evolve Geotechnical Site Characterization and Design Practice in Louisiana




LADOTD's
Data
Management
Journey

Research Projects with LA Transportation Research Center



- 03-1GT: Geotechnical Database Phase I (2003-2008)
  - Create database for existing, current, & new records
  - GIS system with scanned images of boring logs
- 10-2GT: Geotechnical Database Phase II (2010-2012)
  - Standardize the LADOTD gINT project format / Boring log format
  - GIS system to create boring logs & plots in real time
- 15-1GT: Geotechnical Database Phase III (2015-2018)
  - Migrate to HoleBase + include test pile database
- 21-2GT: Geotechnical Database Phase IV (2021-present)
  - Migrate as much existing data as possible (in-house/consultant gINT, images)

Data Management Goals

WHERE WE ARE/WERE

- Borehole & lab tests logged on paper: project, boring, sample, etc. re-written multiple times
- Data are received from labs in multiple formats
- Data are stored on a project-by-project basis, not easily retrieved based on proximity to other projects
- Borings, CPTs, load tests, etc. are typically siloed and only looked at together on the project
- For LRFD, "sites" are based on judgement, φ selection based on field verification
- Even when we have data, we often still have to manipulate it excessively

WHERE WE WOULD LIKE TO BE

- Log boring on tablet, begin digital chain of custody that continues throughout lab testing
- Exchange data in standardized format (DIGGS)
- House data in centralized database, reuse as much as possible ($15k per deep boring, 10x that for SLT)
- Get multiple types of data in the same database for easy comparison ➔ automated calibrations?
- Characterize sites based on variability & uncertainty using defensible, repeatable methods
- Develop tools to eliminate tedious plotting & analysis – focus more on decision making

Implementation: Site Characterization

- Current resistance factor selection based on field verification
  - This doesn't scale!
  - This tends to leave sources of risk up to "engineering judgement"
  - Is this reproducible and defensible?
- What about variability & uncertainty in the geotechnical properties?
  - See MoDOT drilled shaft research
- GEC No. 5 proposes a rational approach by limiting COV in the geotechnical data

ϕ	Field Verification Requirement
0.80	Static load test + 2% verification
0.75	Dynamic monitoring 100% of piles
0.65	2% verification only
0.50	Static design + LA modified Gates eqn. (local calibration)

Implementation: Site Characterization

- GEC No. 5 recommends $COV_{model} < 0.3$
- Calculations are complicated by the need to combine data from multiple borings and analyze at various depths
    - This is where we usually fall back on "engineering judgment"
- A major obstacle to risk-based geotechnical analysis is a lack of data management
    - If we standardize the data, we can standardize the tools

$$COV_{d-meas} = \frac{\sigma_{d-meas}}{\bar{y}_d} = \frac{\sqrt{\frac{\sum_{i=1}^{n_d}(y_i - \bar{y}_d)^2}{n_d - 1}}}{\bar{y}_d}$$

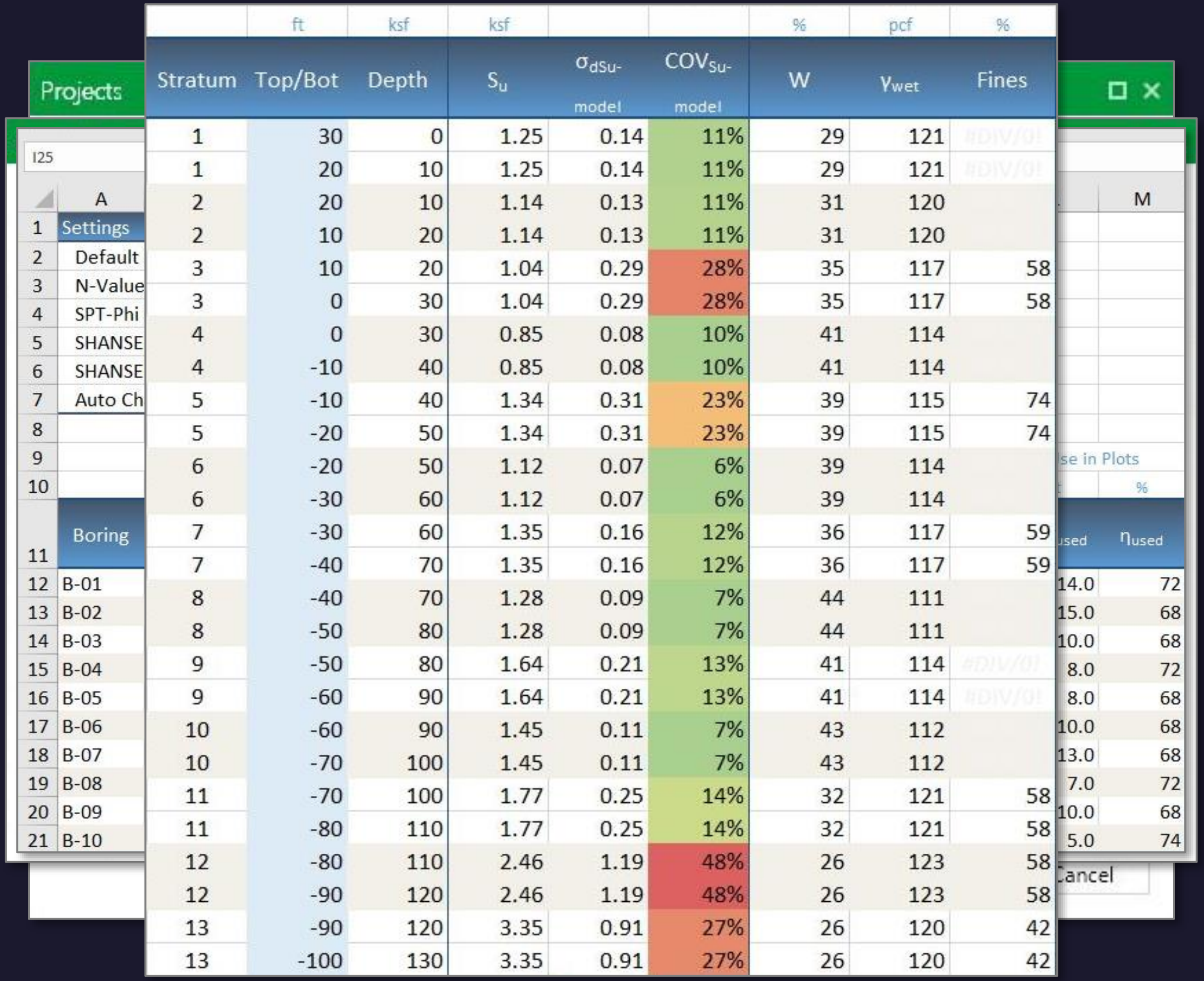
$$COV_{d-model} = \frac{\sigma_{d-model}}{\bar{y}_d} = \frac{\sqrt{\frac{1}{n_d} \cdot \frac{\sum_{i=1}^{n_d}(y_i - \bar{y}_d)^2}{n_d - 1}}}{\bar{y}_d}$$

$$COV_{d-total} = \frac{\sigma_{d-total}}{\bar{y}_d} = \frac{\sqrt{\sigma_{d-meas}^2 + \sigma_{d-model}^2}}{\bar{y}_d}$$

From FHWA NHI-16-072 (GEC No. 5)

Site Characterization

- Query database using Excel plugin
- Once in Excel, we can do conversions, correlations, & other math
  - Since the data are standardized, it works the same way every time
- Let the user select various correlation & plotting options
- Choose soil strata and statistical analyses are automatically updated

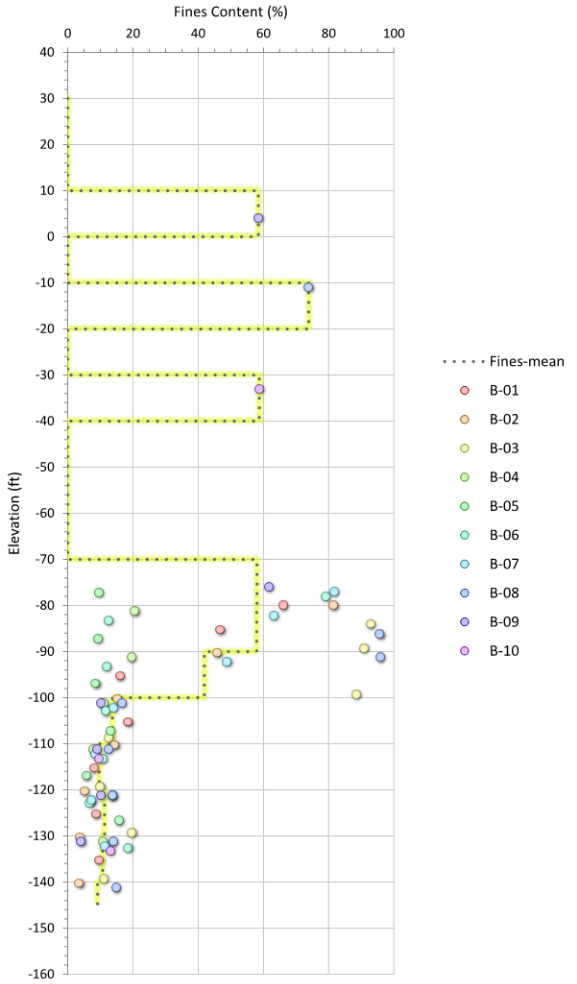


Stratum	Top/Bot	Depth	S_u	$\sigma_{dSu\text{-}model}$	$COV_{Su\text{-}model}$	W	γ_{wet}	Fines
	ft	ksf	ksf			%	pcf	%
1	30	0	1.25	0.14	11%	29	121	#DIV/0!
1	20	10	1.25	0.14	11%	29	121	#DIV/0!
2	20	10	1.14	0.13	11%	31	120	
2	10	20	1.14	0.13	11%	31	120	
3	10	20	1.04	0.29	28%	35	117	58
3	0	30	1.04	0.29	28%	35	117	58
4	0	30	0.85	0.08	10%	41	114	
4	-10	40	0.85	0.08	10%	41	114	
5	-10	40	1.34	0.31	23%	39	115	74
5	-20	50	1.34	0.31	23%	39	115	74
6	-20	50	1.12	0.07	6%	39	114	
6	-30	60	1.12	0.07	6%	39	114	
7	-30	60	1.35	0.16	12%	36	117	59
7	-40	70	1.35	0.16	12%	36	117	59
8	-40	70	1.28	0.09	7%	44	111	
8	-50	80	1.28	0.09	7%	44	111	
9	-50	80	1.64	0.21	13%	41	114	#DIV/0!
9	-60	90	1.64	0.21	13%	41	114	#DIV/0!
10	-60	90	1.45	0.11	7%	43	112	
10	-70	100	1.45	0.11	7%	43	112	
11	-70	100	1.77	0.25	14%	32	121	58
11	-80	110	1.77	0.25	14%	32	121	58
12	-80	110	2.46	1.19	48%	26	123	58
12	-90	120	2.46	1.19	48%	26	123	58
13	-90	120	3.35	0.91	27%	26	120	42
13	-100	130	3.35	0.91	27%	26	120	42

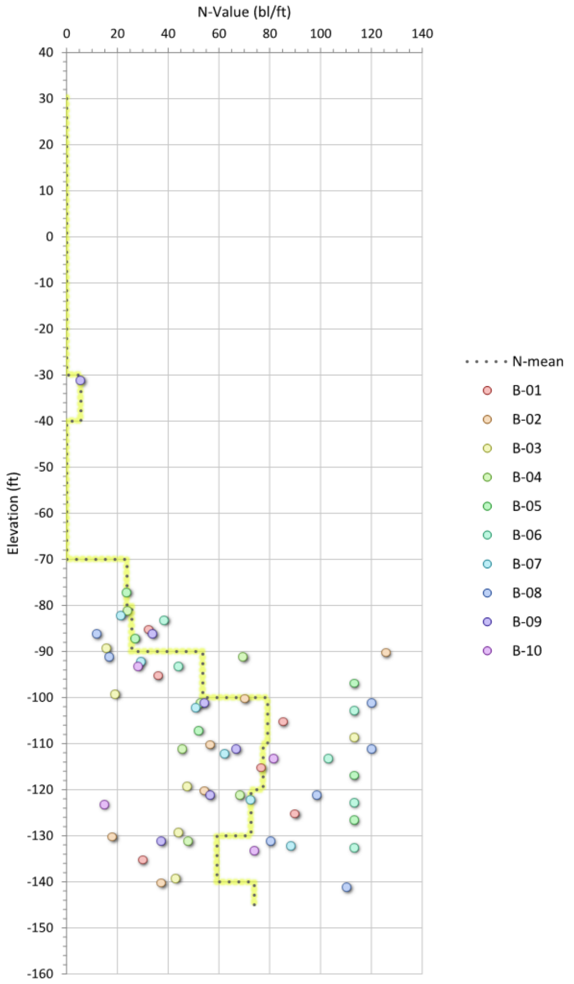
H.001234
LA-1: Port Allen Canal Bridge
LA-1

Geotechnical Data Plots

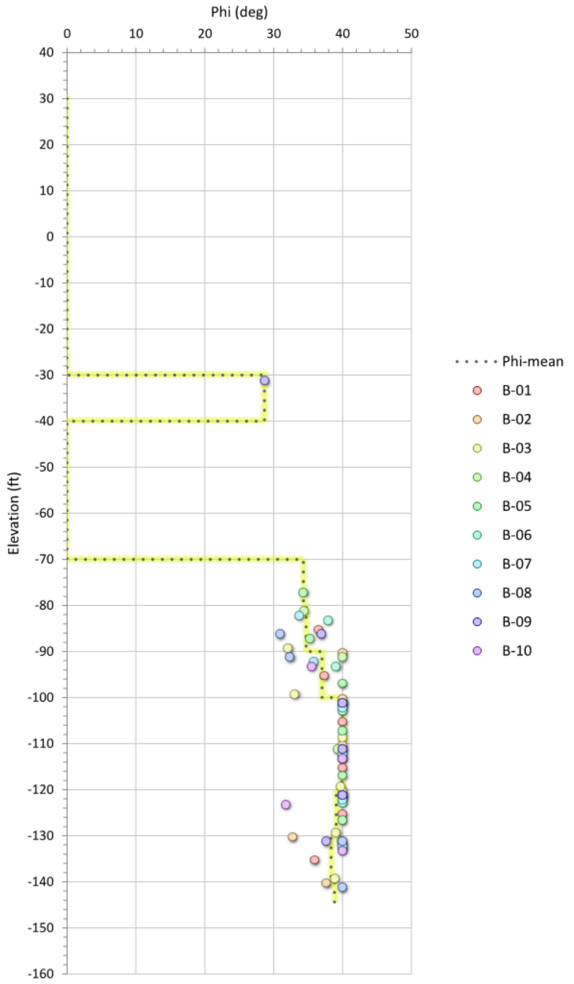
Fines Content vs. Elevation



N-Value vs. Elevation



Correlated Phi Angle vs. Elevation



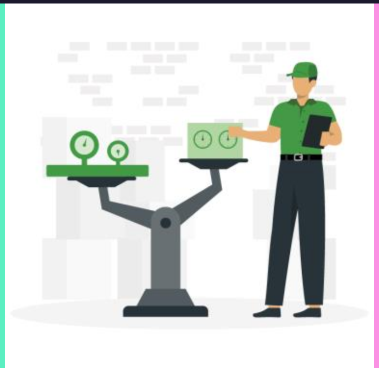
6/21/2022

How about if engineers can efficiently and interactively manipulate, visualize, and interpret different types of geotechnical data from any device with a web browser?

The Implementation of a web-based platform for …

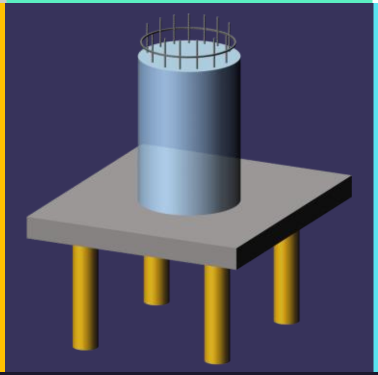
Borehole

CPT



Construction Testing & Support

Site Characterization



Reliability Based Design

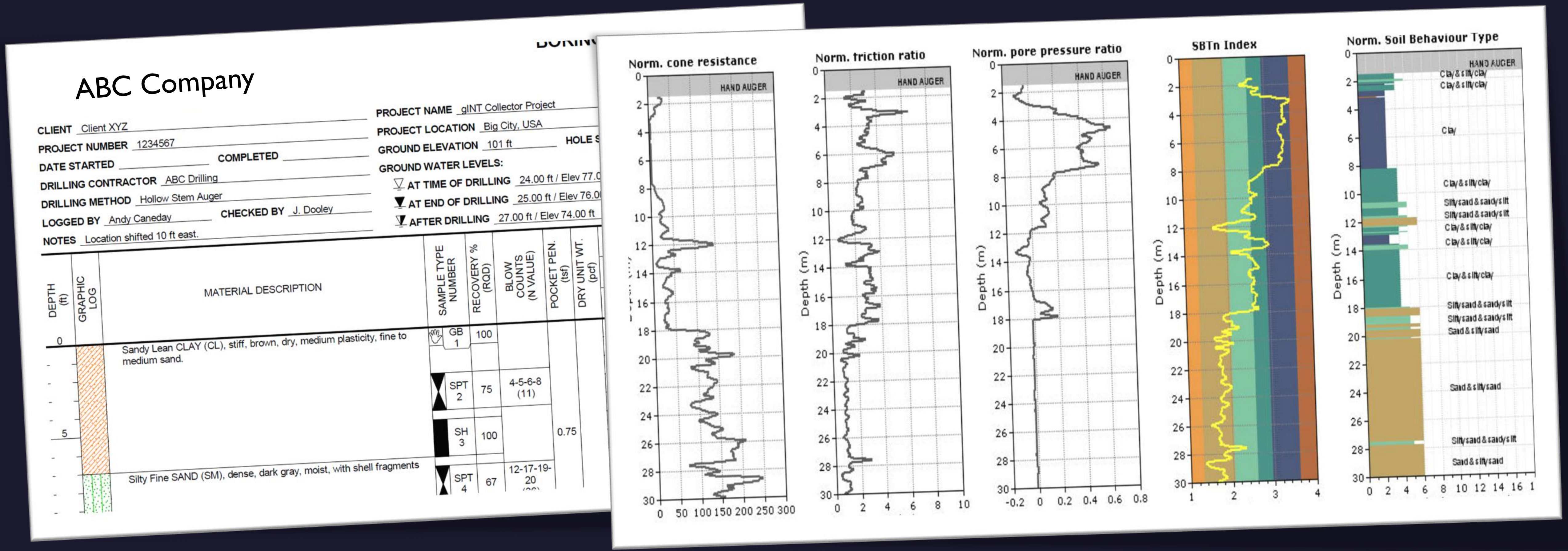
Key Objectives

Identify Variability and Uncertainty

Reduce Design Costs

Increase Design Efficiency

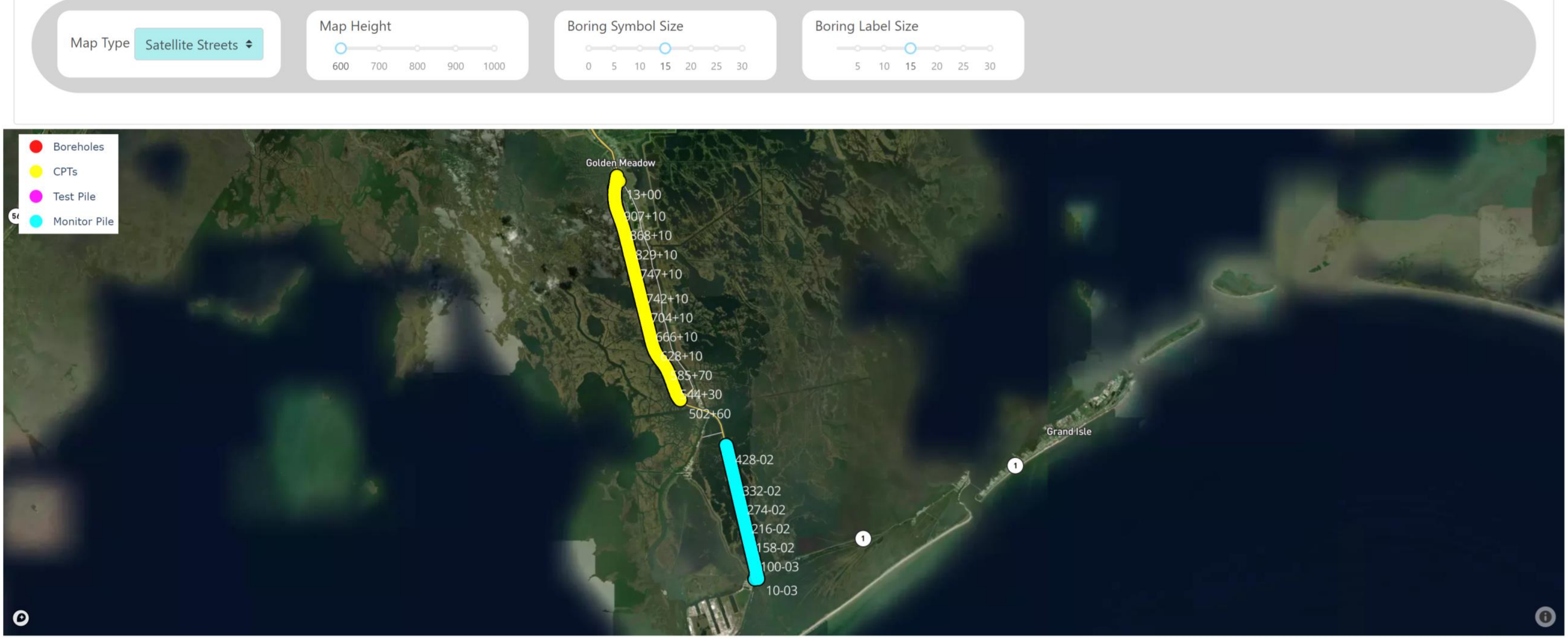
Improve Design Quality



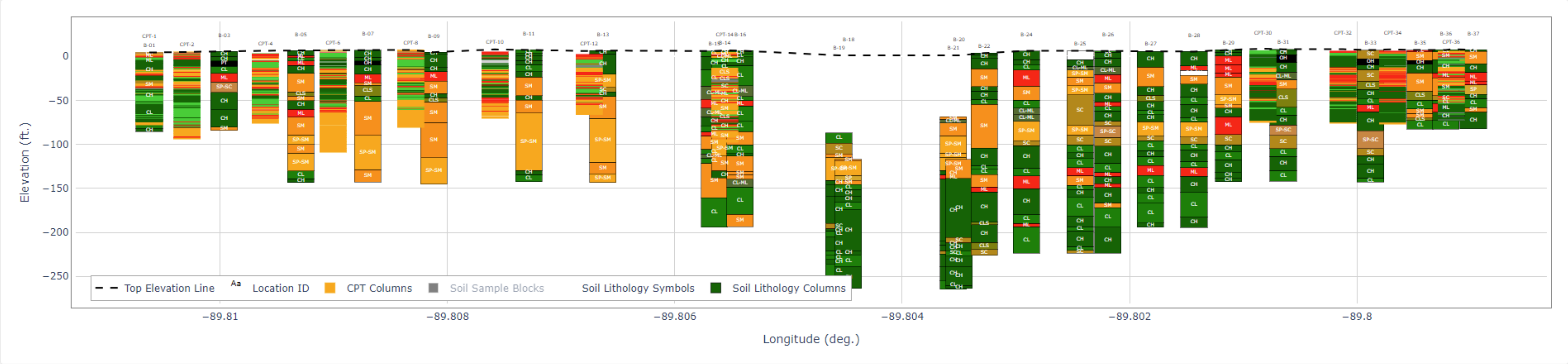
Typical Borehole and CPT Deliverables

- Good for archive, but no digital data embedded;
- Cannot be reused efficiently for engineering design analysis.

Interactive web-based map for borehole, CPT, and construction testing locations



Select point locations in the web-based map to interactively visualize any borehole cross sections



Point List

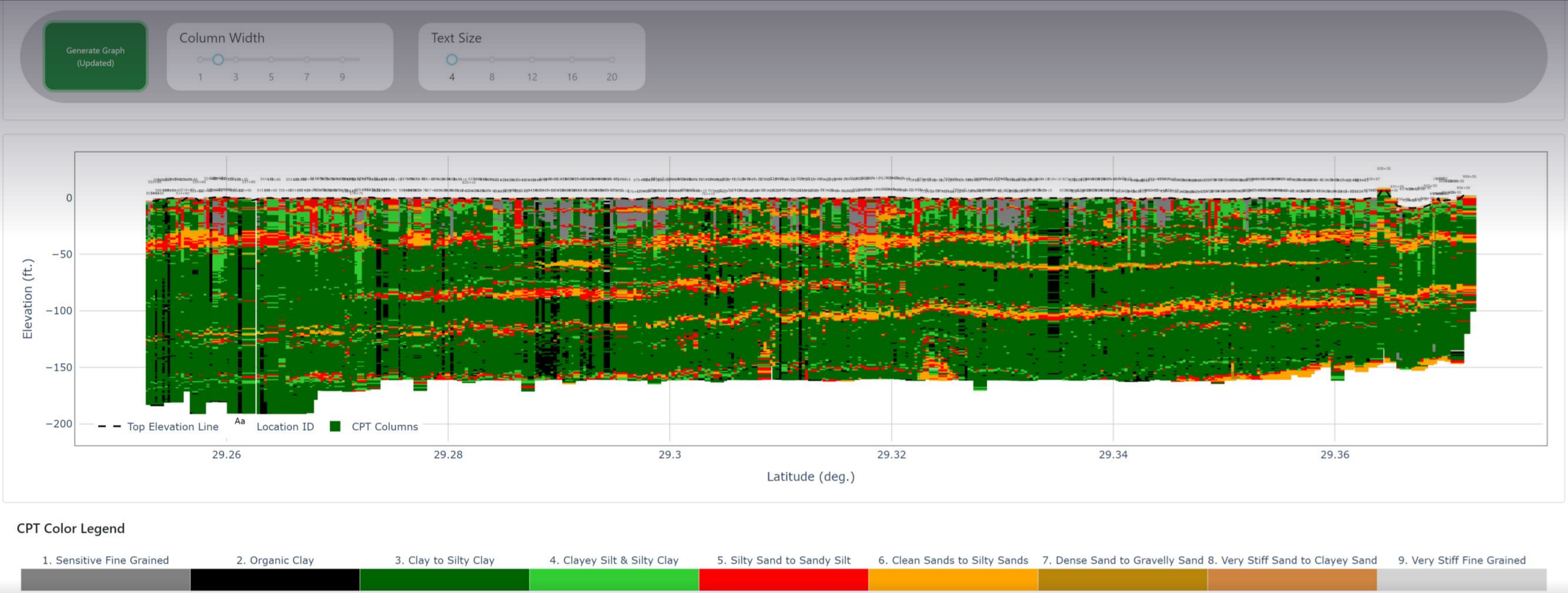
B-01 B-03 B-05 B-07 B-09 B-11 B-13 B-14 B-15 B-16 B-18 B-19 B-20 B-21 B-22 B-24 B-25 B-26 B-27 B-28 B-29 B-31 B-33 B-35 B-36 B-37 CPT-1 CPT-10 CPT-12 CPT-14
CPT-2 CPT-30 CPT-32 CPT-34 CPT-36 CPT-4 CPT-6 CPT-8

CPT Color Legend 1 (SBTn, after 1990 & SBT, 2010)

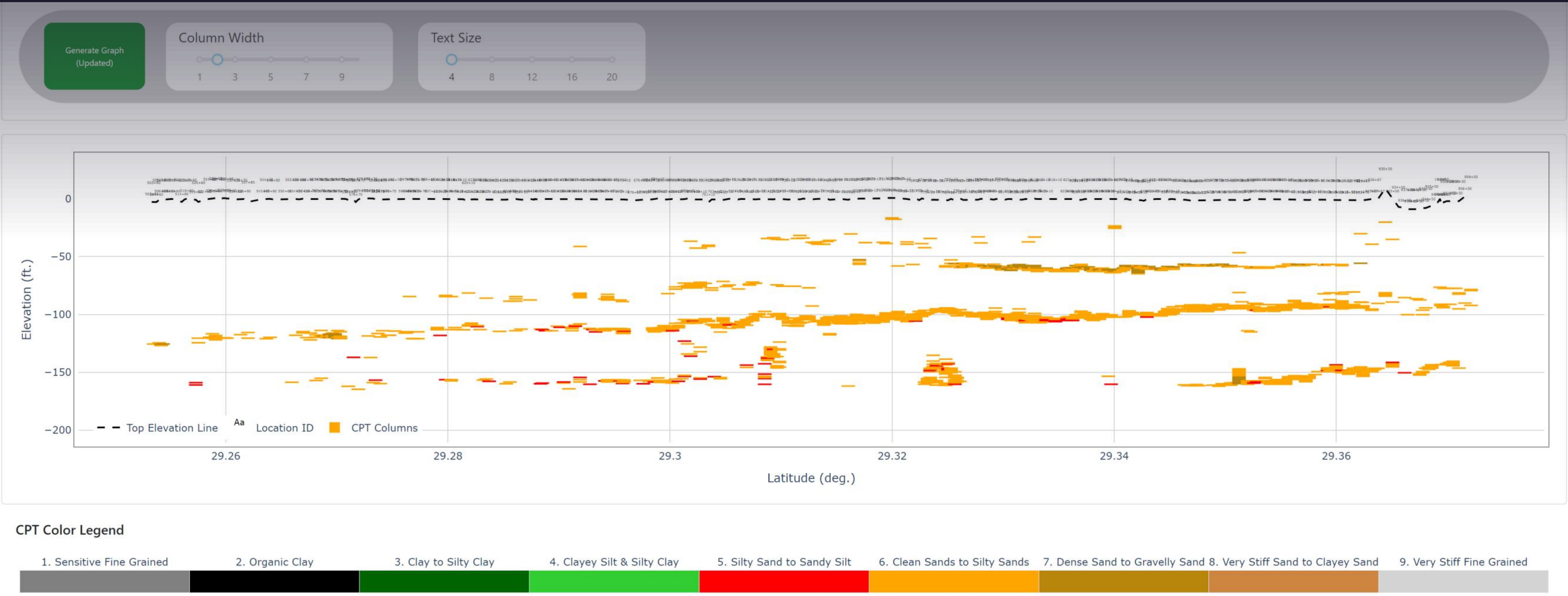
1. Sensitive Fine Grained
2. Organic Clay
3. Clay to Silty Clay
4. Clayey Silt & Silty Clay
5. Silty Sand to Sandy Silt
6. Clean Sands to Silty Sands
7. Dense Sand to Gravelly Sand
8. Very Stiff Sand to Clayey Sand
9. Very Stiff Fine Grained

Interactively add and visualize any nearby CPT data on top of the borehole cross sections

Generate a cross section with more than 300 CPTs in a few minutes



Implement user-defined rules to identify critical soil layers to design decisions



Develop Soil Design Models and Select Soil Design Parameters

UNNECESSARILY HIGH CONSTRUCTION COSTS

If selections are substantially less than actual values.

INADEQUATE DESIGN RELIABILITY AGAINST FAILURE

If selected values of design parameters are far greater than actual in-situ values

Interpretation of Variability and Uncertainty for Design Parameters

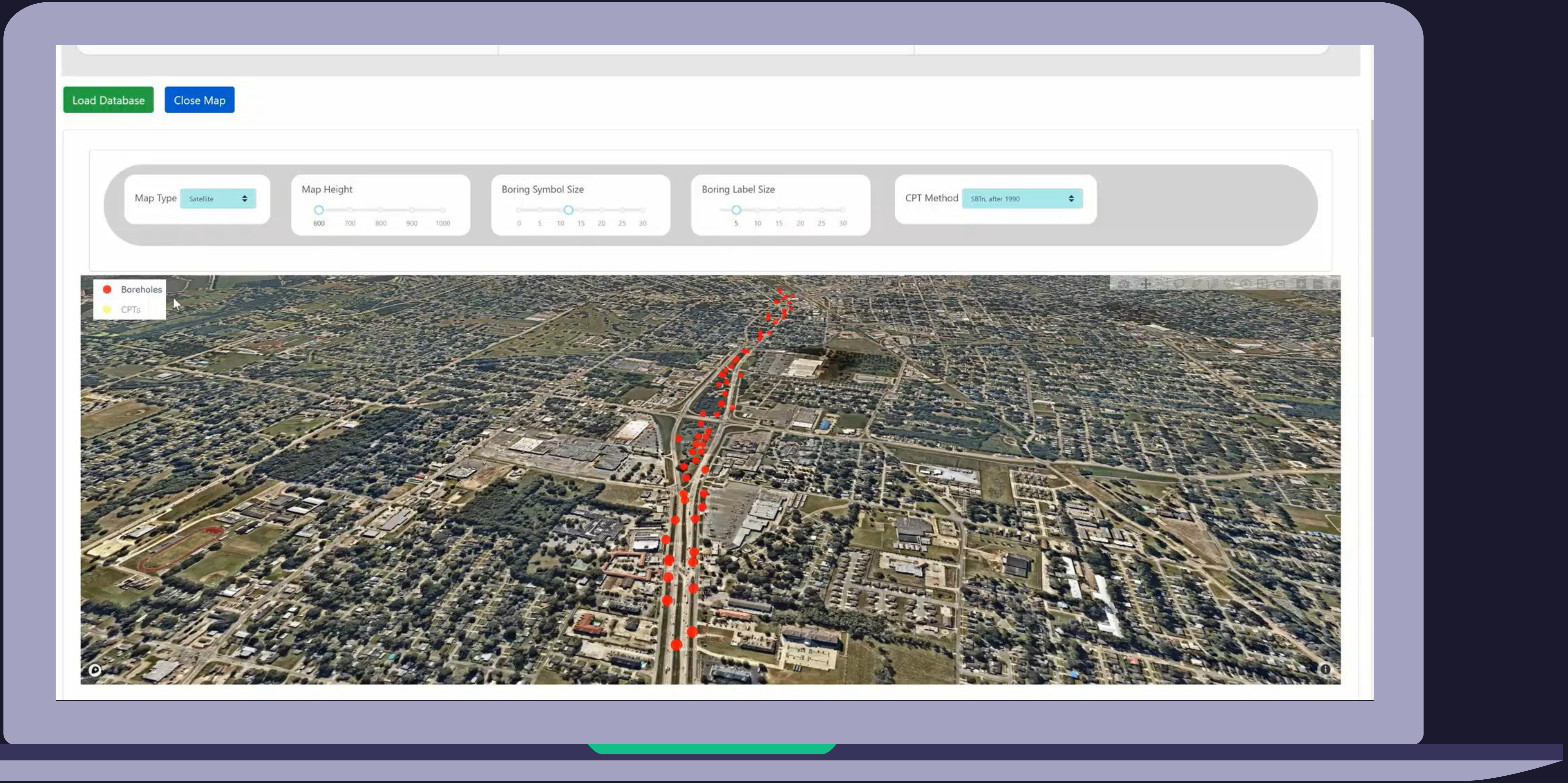
Variability:

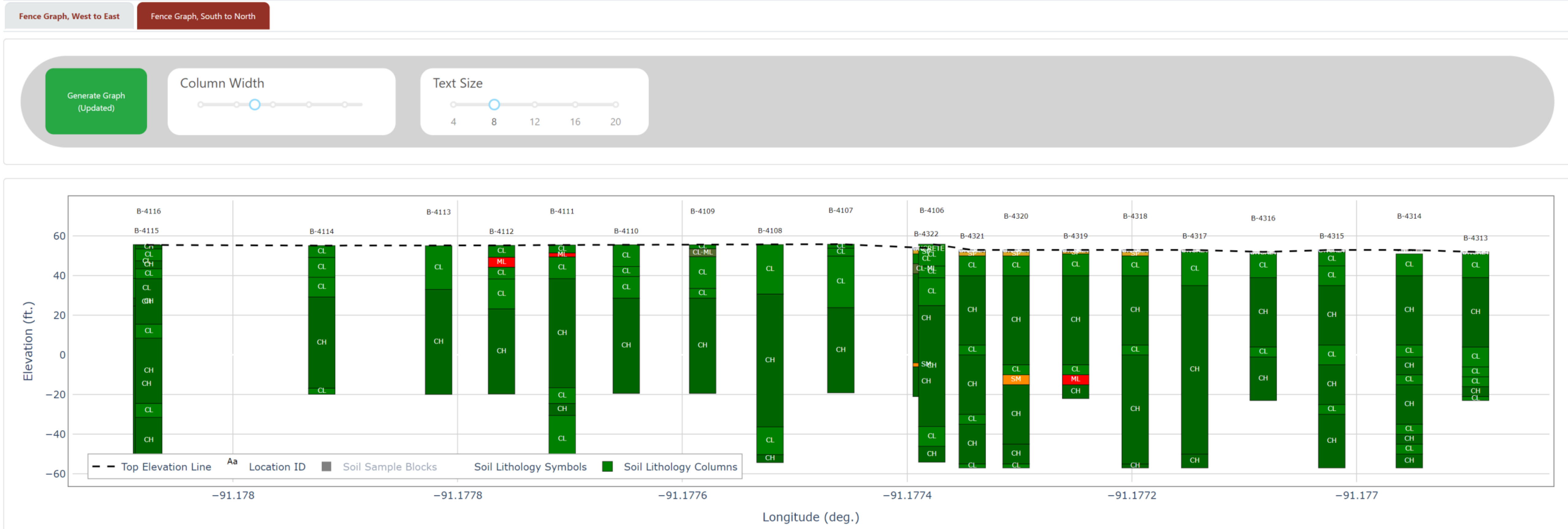
$$COV_{measure} = \frac{\sigma_{measure}}{\bar{y}} = \frac{\sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y})^2}{n-1}}}{\bar{y}}$$

Uncertainty:

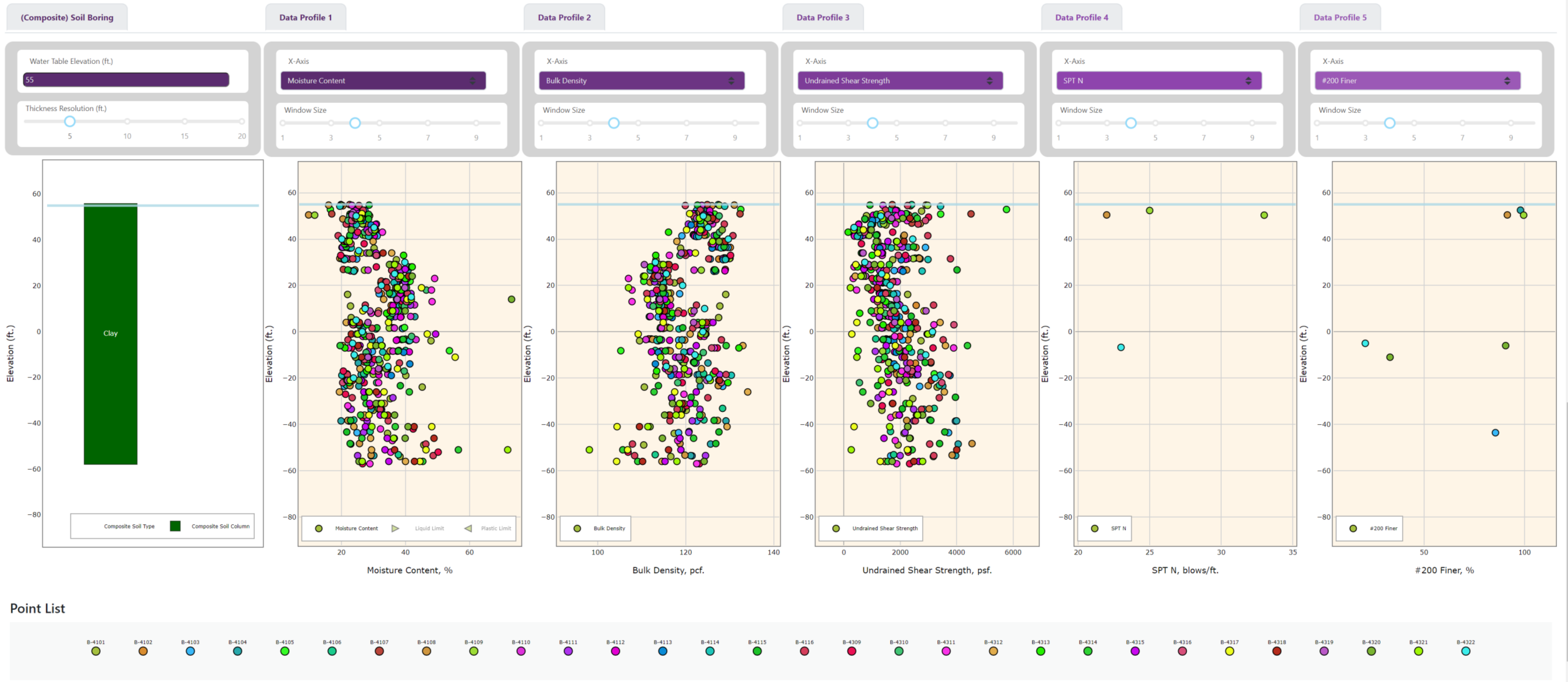
$$COV_{model} = \frac{\sigma_{model}}{\bar{y}} = \frac{\sqrt{\frac{1}{n} \cdot \frac{\sum_{i=1}^{n}(y_i - \hat{y})^2}{n-1}}}{\bar{y}}$$

“Geotechnical design performed using soil parameters established from mean values with $COV_{model} \leq 0.3$ are likely to have reliability that practically equals or exceeds the target reliability for design.”

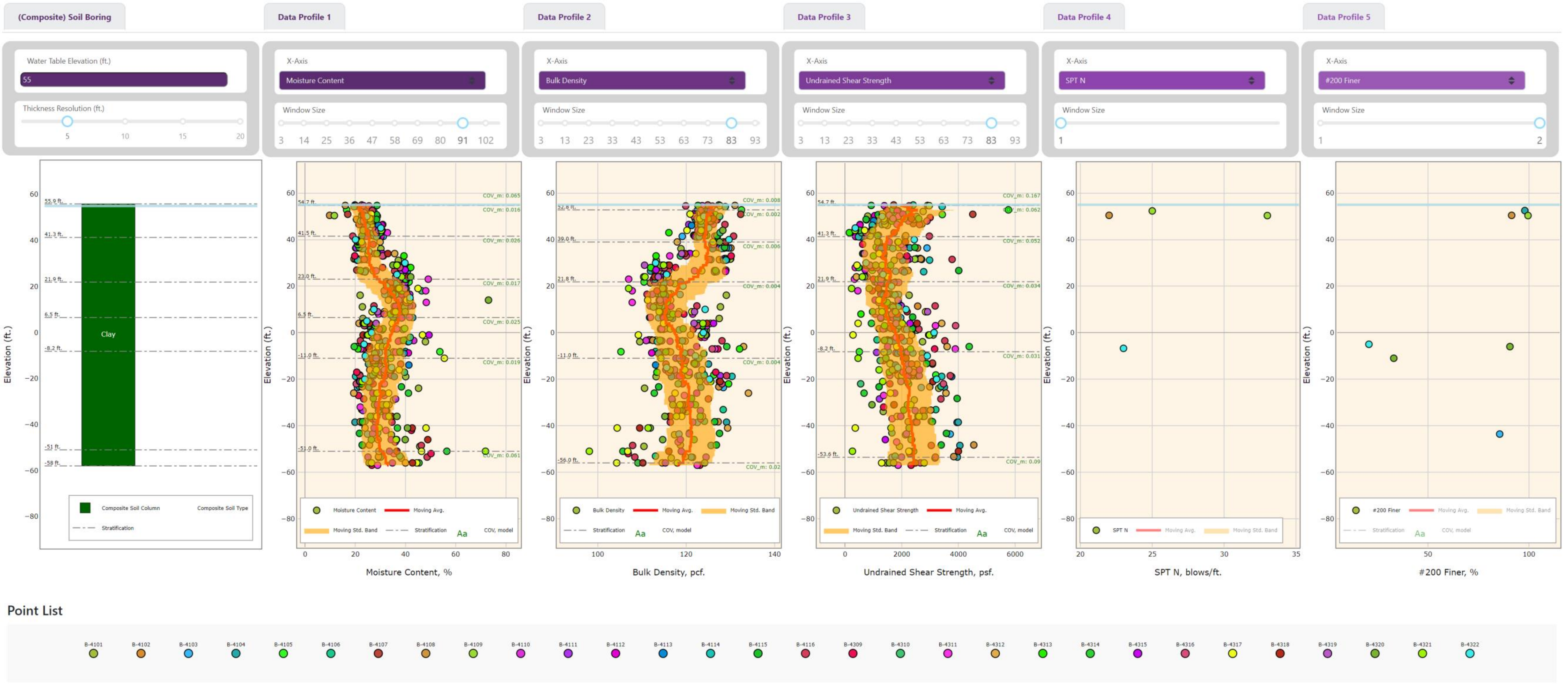

Load Database
Close Map
Map Type
Satellite
Map Height
600
700
800
900
1000
Boring Symbol Size
0
5
10
15
20
25
30
Boring Label Size
5
10
15
20
25
30
CPT Method
SBTn, after 1990
Boreholes
CPTs



Showcase: An interactive soil boring cross-section profile for a design section of a highway and bridge design and construction project

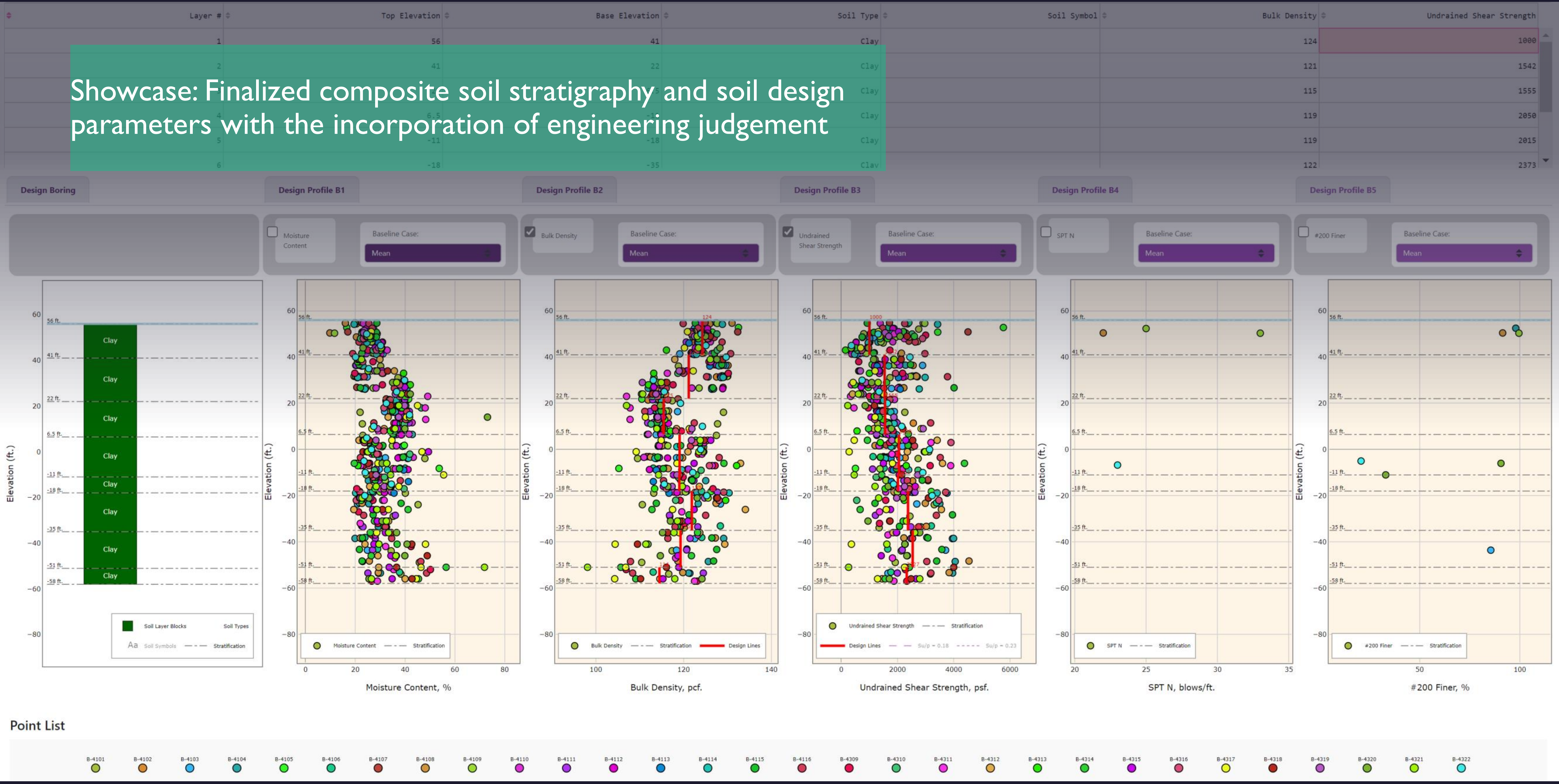


Showcase: Data profiles for the design section

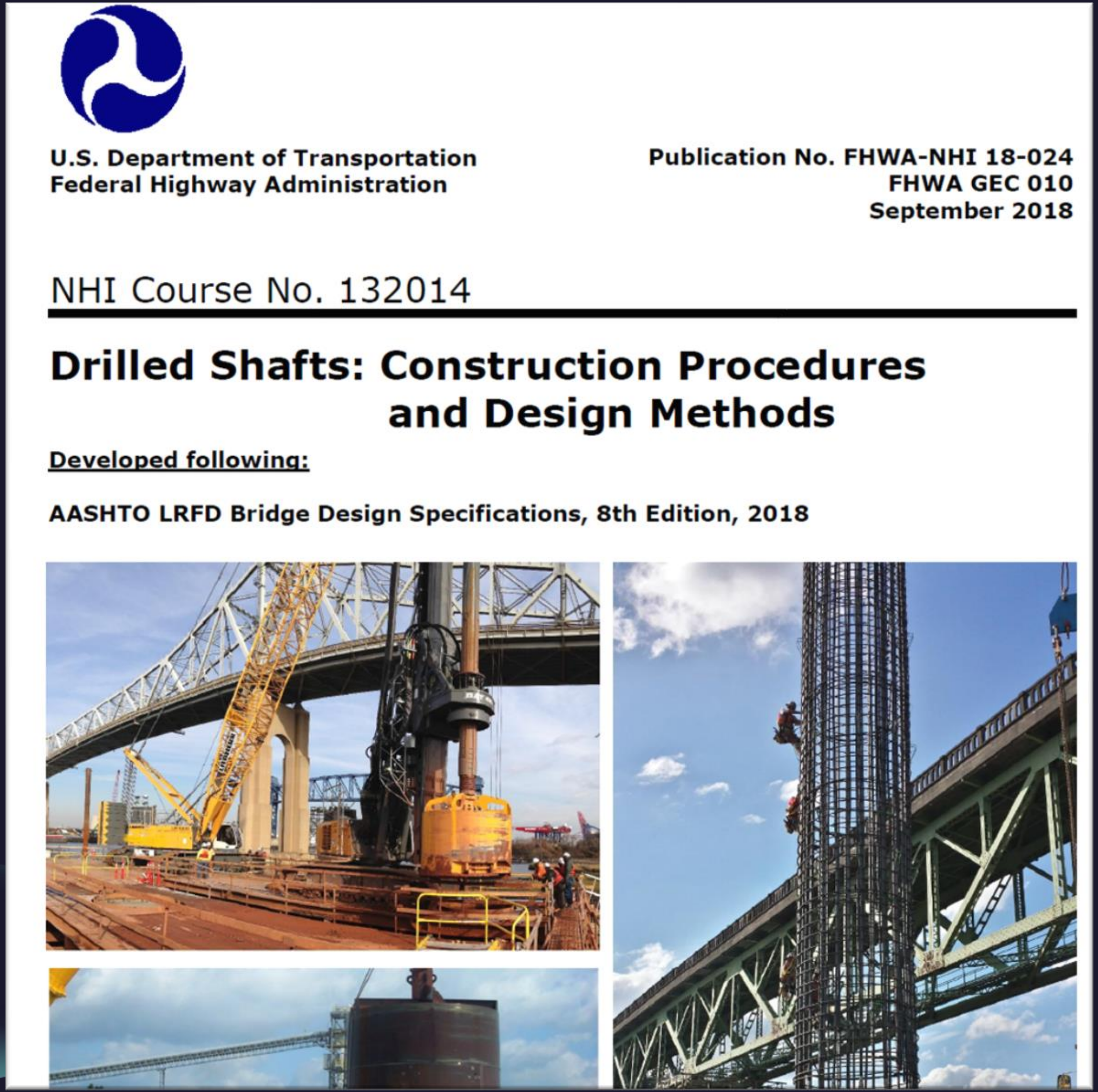


Showcase: Data profiles with dynamically generated data statistical features and the independently generated soil stratigraphy boundary lines

Showcase: Finalized composite soil stratigraphy and soil design parameters with the incorporation of engineering judgement



Parametric Analysis Deep for Foundation Design using the same web-based platform


U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI 18-024
FHWA GEC 010
September 2018

NHI Course No. 132014

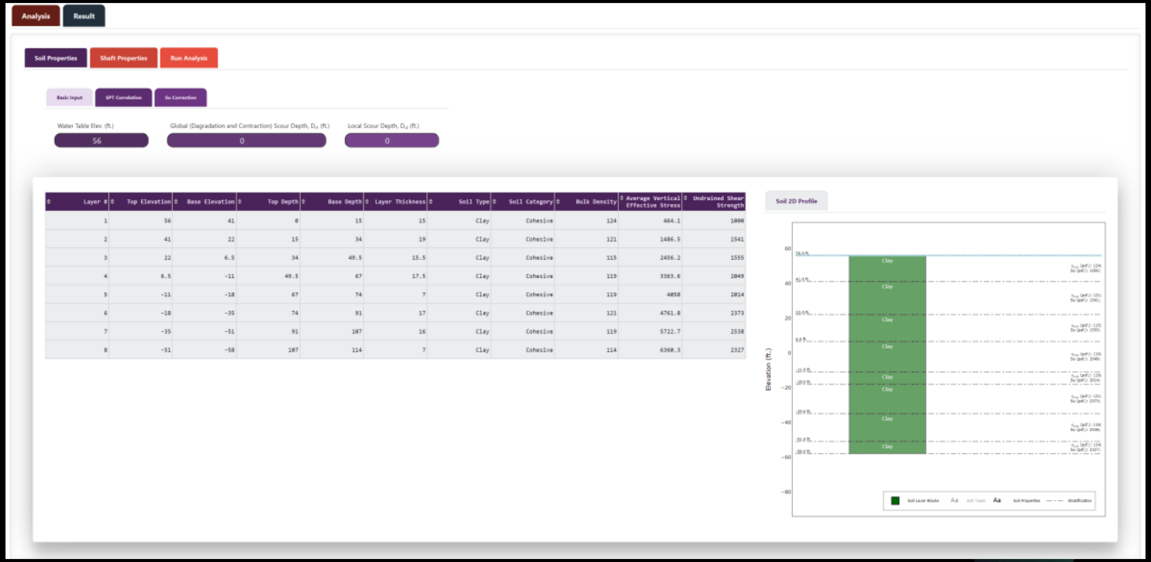
Drilled Shafts: Construction Procedures and Design Methods

Developed following:

AASHTO LRFD Bridge Design Specifications, 8th Edition, 2018

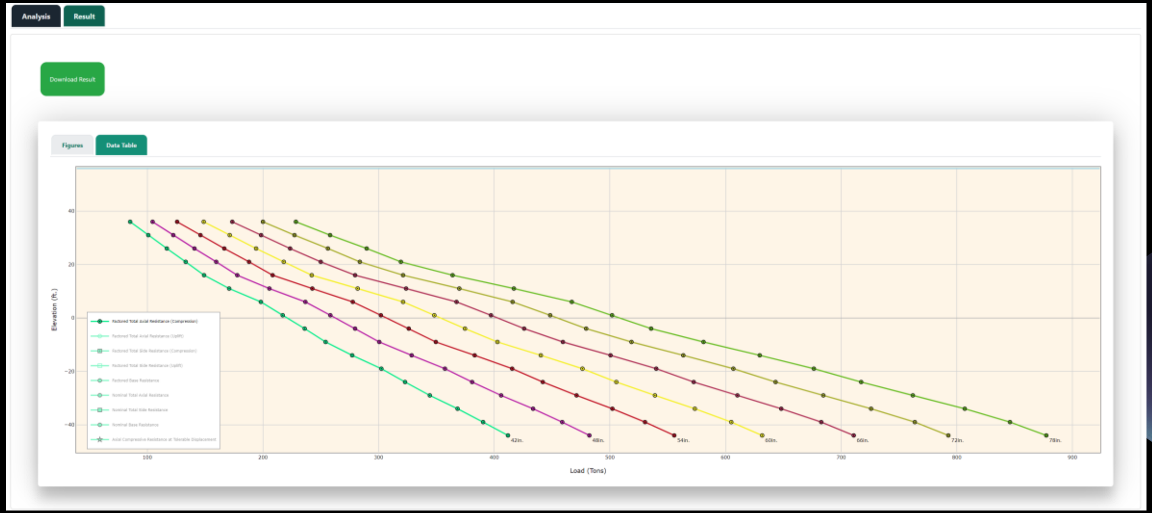
Step 2: define geometry of drilled shafts

Step 1: Apply the finalized soil design model

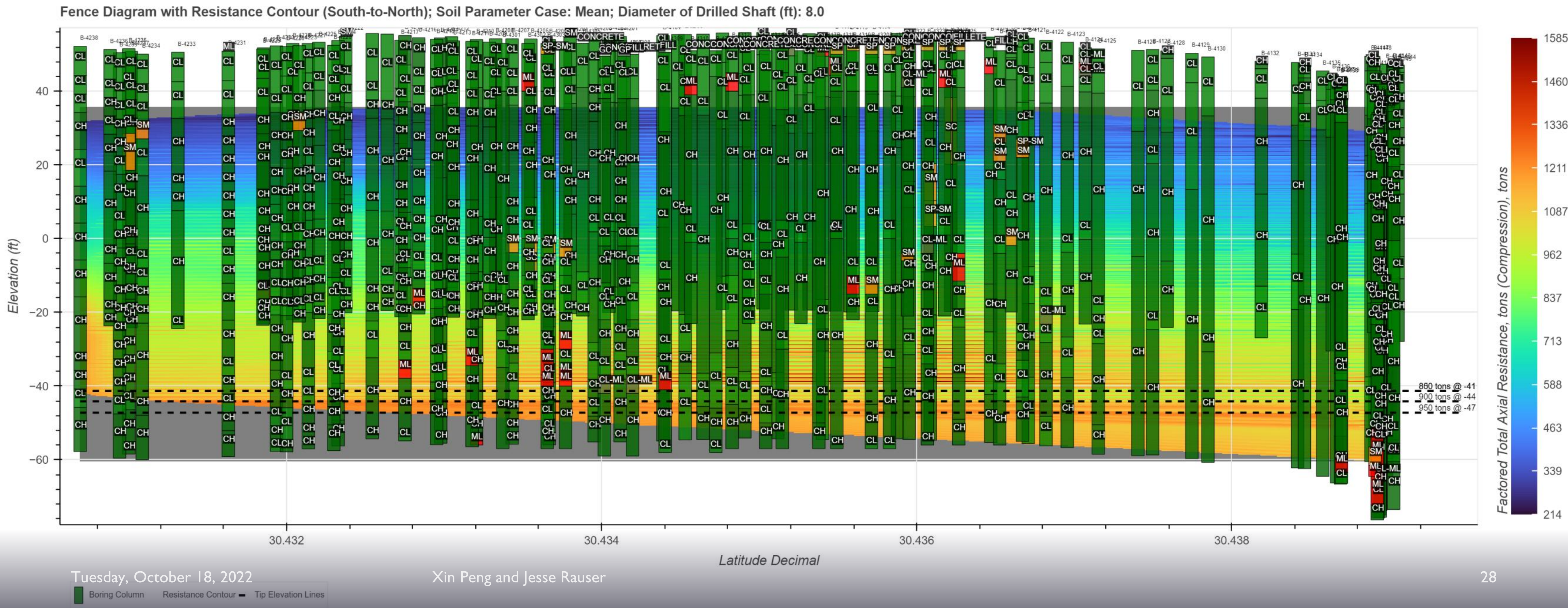


Layer #	Top Elevation	Base Elevation	Top Depth	Base Depth	Layer Thickness	Soil Type	Soil Category	Bulk Density	Average Vertical Effective Stress	Undrained Shear Strength
1	56	41	0	15	15	Clay	Cohesive	124	464.1	1000
2	41	22	15	34	19	Clay	Cohesive	121	1486.5	1541
3	22	6.5	34	49.5	15.5	Clay	Cohesive	115	2456.2	1555
4	6.5	-11	49.5	67	17.5	Clay	Cohesive	119	3363.6	2049
5	-11	-18	67	74	7	Clay	Cohesive	119	4058	2014
6	-18	-35	74	91	17	Clay	Cohesive	121	4761.8	2373
7	-35	-51	91	107	16	Clay	Cohesive	119	5722.7	2538
8	-51	-58	107	114	7	Clay	Cohesive	114	6360.3	2327

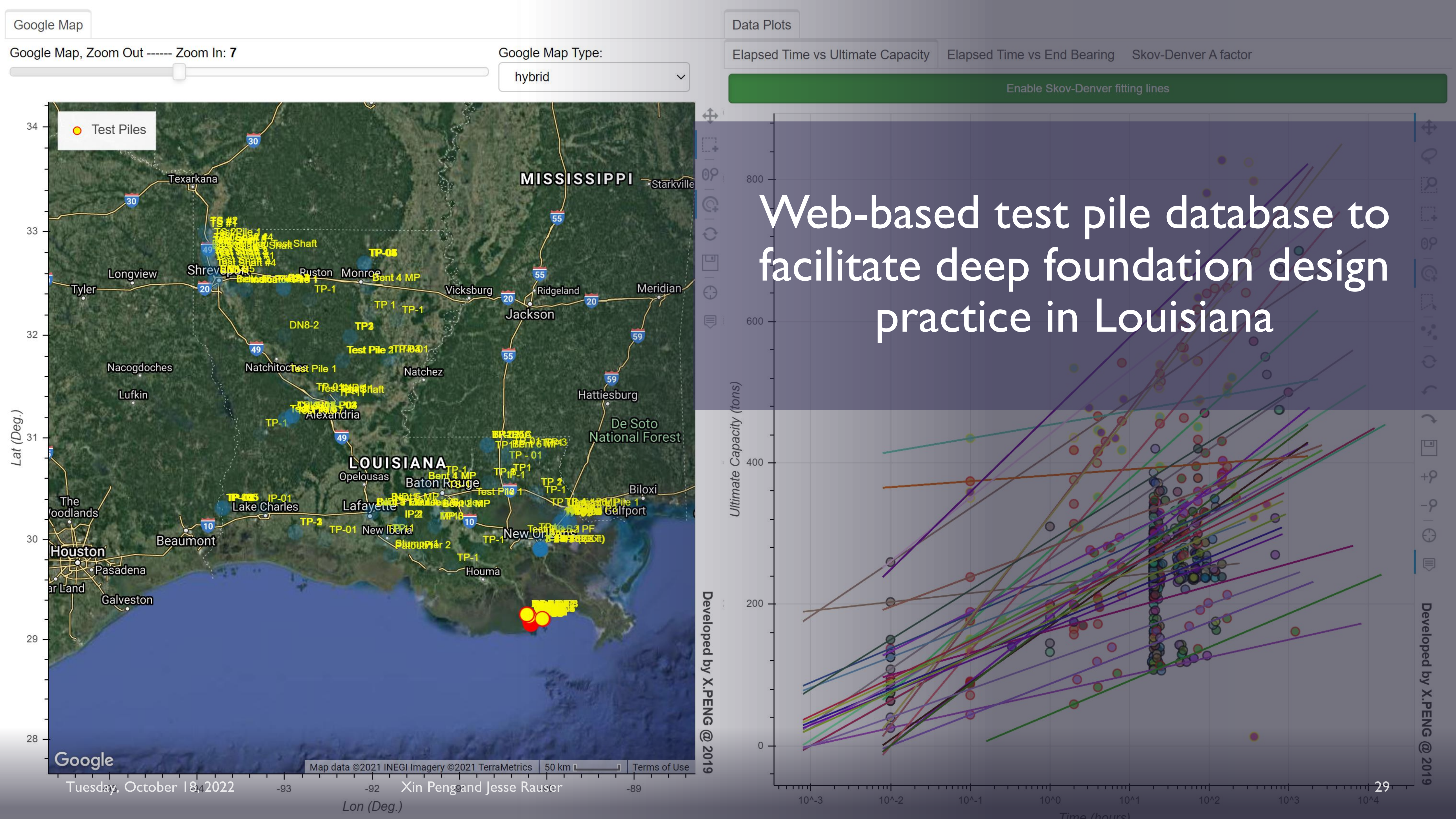
Step 3: Perform analysis and visualize results



Batch analysis to estimate the axial resistance of the drilled shaft at each borehole location



Web-based test pile database to facilitate deep foundation design practice in Louisiana



Summary

Boreholes and CPTs

Digital data can be interactively visualized and interpreted based on project needs.

Site Characterization

Geotechnical design models and soil design parameters can be efficiently developed based on data statistics and specifications from FHWA GEC-05.

Reliability Based Design

The variability and uncertainty of the developed soil design models can be automatically assessed, which can potentially be implemented into the following deep foundation engineering analysis with site-specific resistance factors.

Construction Testing & Support

A preliminary framework of a web-based test pile database has been initiated to visualize and interpret historical data, which also provides a potential to integrate with reliability-based design workflows to automatically calibrate the site-specific resistance factors for different design methods

Data Interoperability

Data from gINT and DIGGS, or any other SQL (including Bentley's holebase and Openground) and NoSQL databases can be imported into the web-based platform to facilitate site characterization and design practice. No data re-entry is necessary.

Thank You

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