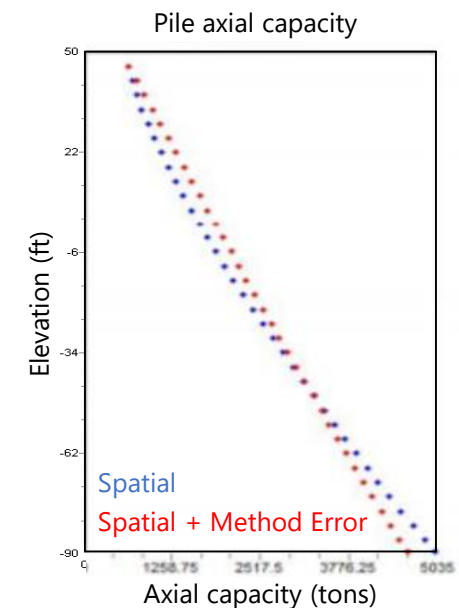
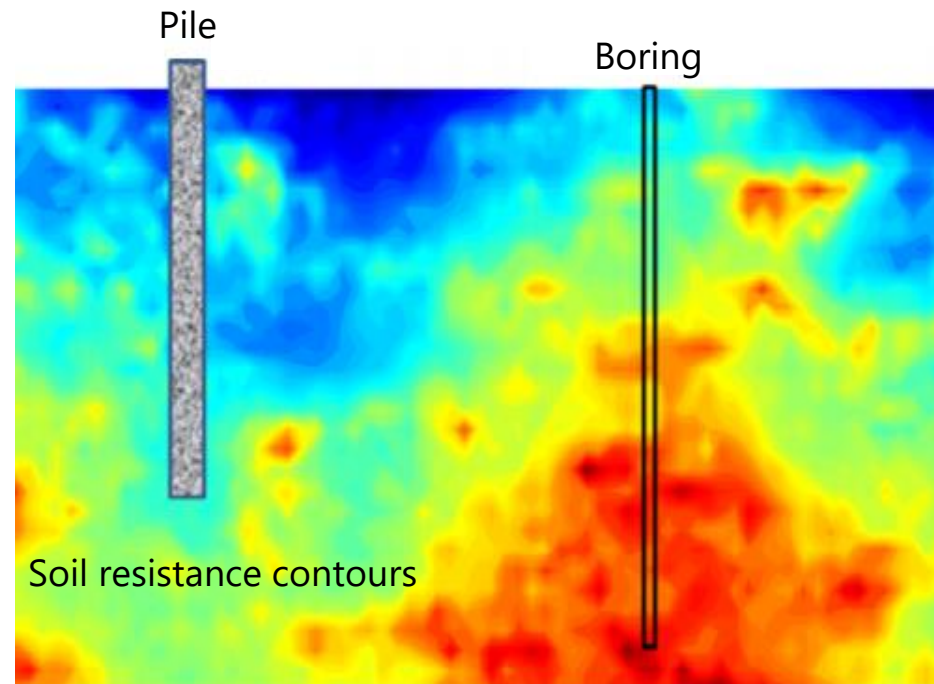
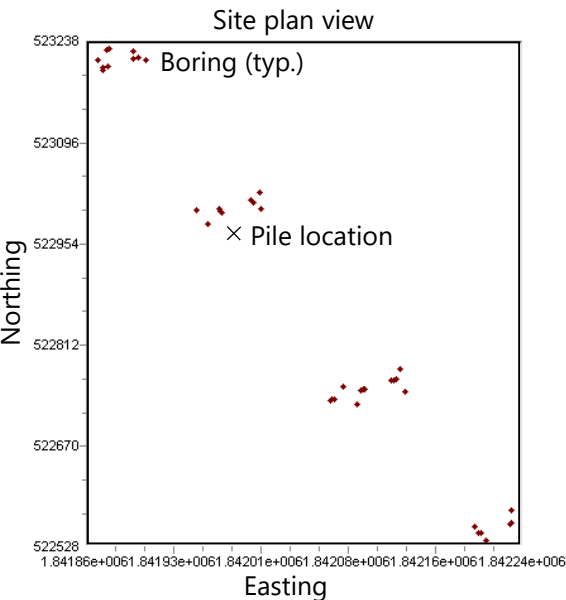


Geo-Statistical Deep Foundation Design Software

GRIP 2019 - Aug. 15, 2019



FDOT project: BDV31 977-108
Project manager: Rodrigo Herrera, P.E.
Institution: University of Florida
PI: Michael Davidson, Ph.D., P.E.
Co-PI: Michael McVay, Ph.D.
Co-PI: Gary Consolazio, Ph.D.
Lead UI Developer: Clinton Monari

Agenda

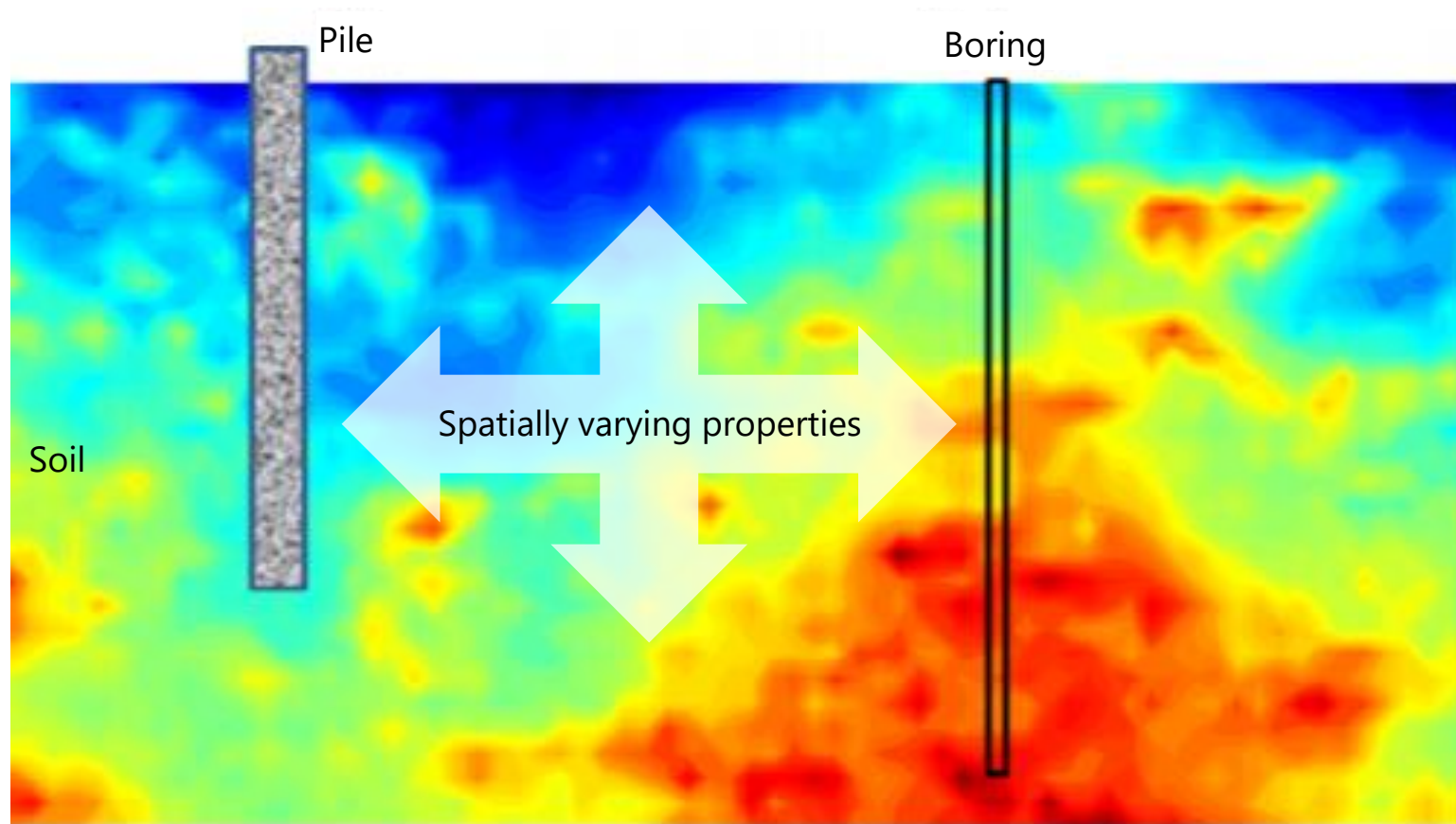
- Introduction
- Project tasks
- Status update: Task 1
- Status update: Task 2
- Next steps

Agenda

- Introduction
- Project tasks
- Status update: Task 1
- Status update: Task 2
- Next steps

Introduction

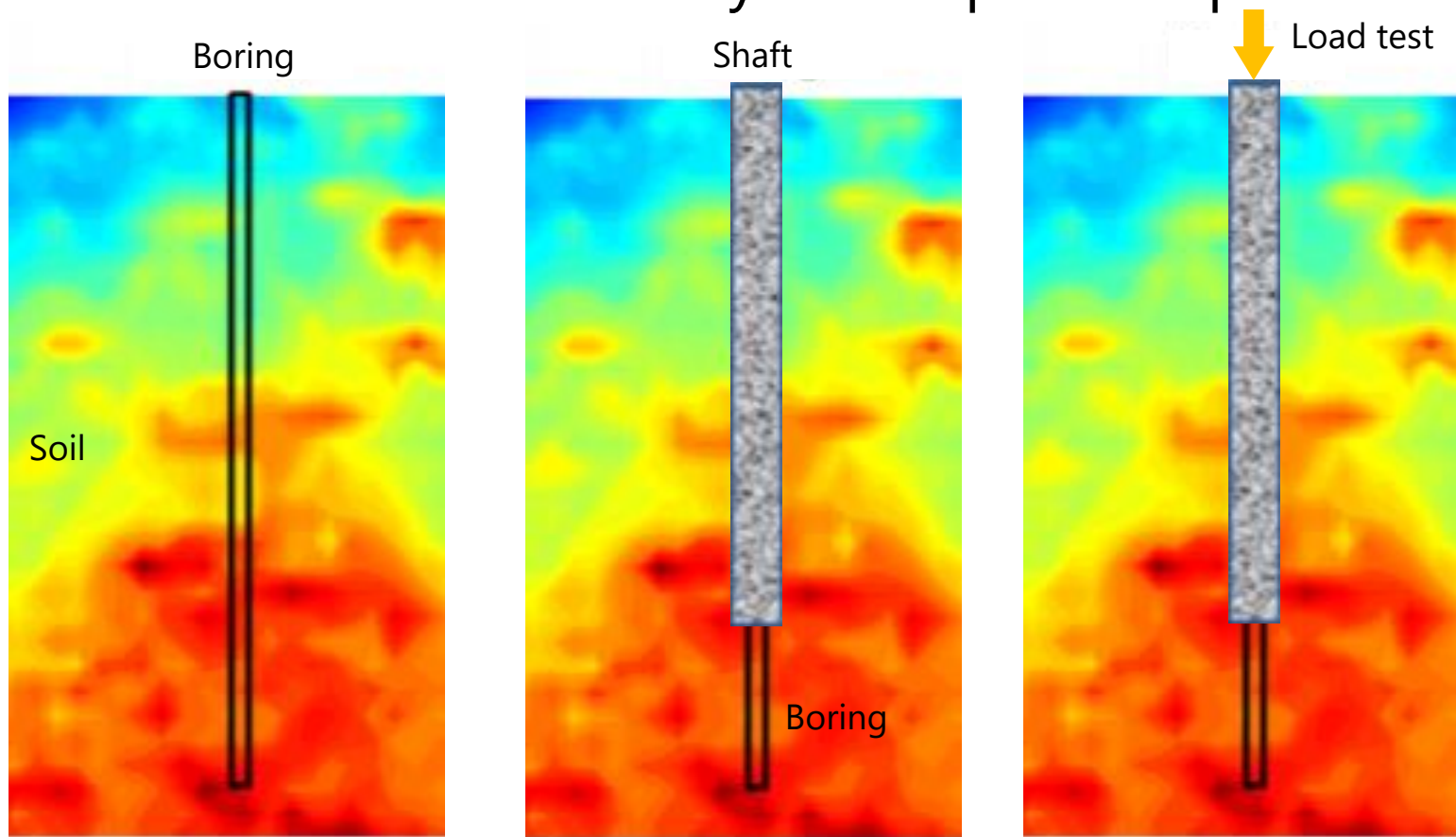
- Soil exhibits spatial variability
 - Vertical and horizontal directions
 - Contributes to uncertainty in computed capacities



Soil spatial variability (McVay et al. 2012)

Introduction

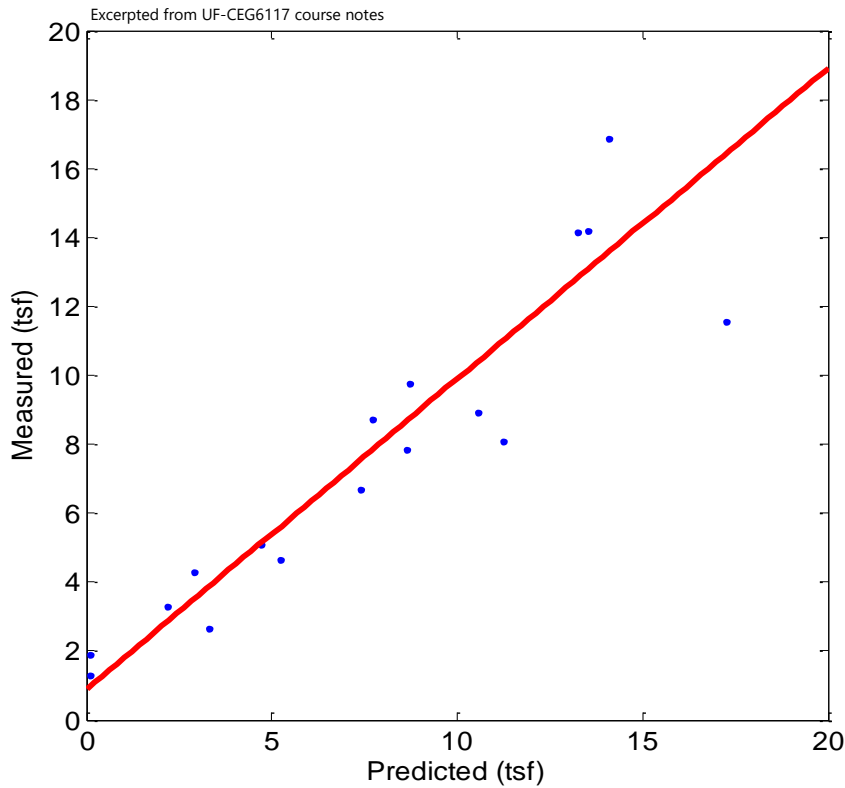
- Method error
 - Underlying assumptions in empirical methods
 - Contributes to uncertainty in computed capacities



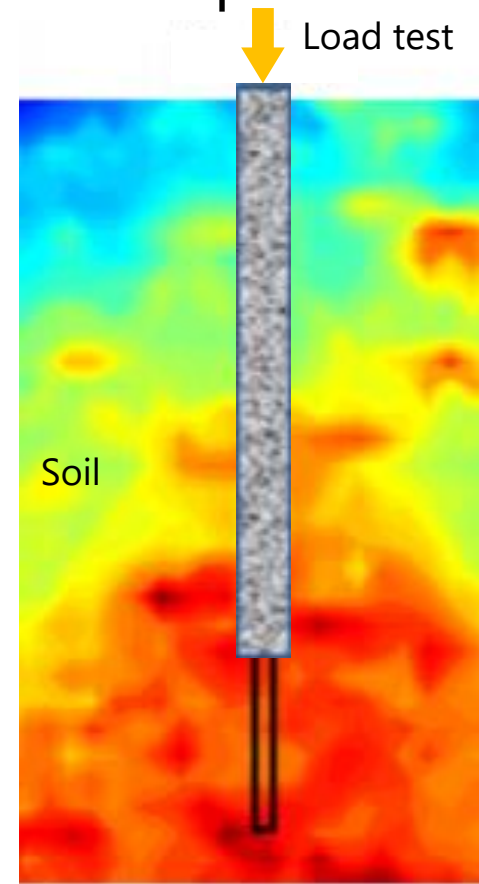
Example: Boring in footprint of non-redundant shaft

Introduction

- Method error
 - Underlying assumptions in empirical methods
 - Contributes to uncertainty in computed capacities



Predicted vs measured resistance



Example: Boring in footprint of non-redundant shaft

Motivation

- How do these affect pile and shaft design?

$$\phi = \frac{\lambda_R \left(\frac{\gamma_D Q_D}{Q_L} + \gamma_L \right) \sqrt{\left[\frac{(1 + COV_{Q_D}^2 + COV_{Q_L}^2)}{(1 + COV_R^2)} \right]}}{\left(\frac{\lambda_{Q_D} Q_D}{Q_L} + \lambda_{Q_L} \right) \exp\left\{ \beta_T \sqrt{\ln\left[(1 + COV_R^2)(1 + COV_{Q_D}^2 + COV_{Q_L}^2) \right]} \right\}}$$

NCHRP 507, Eqn. 10, (Paikowsky et al. 2004)

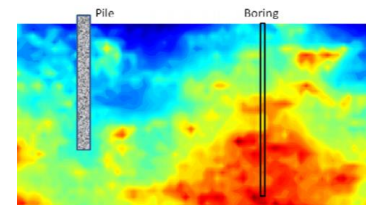
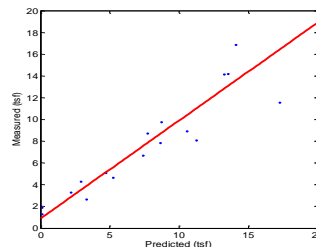
Motivation

- How do these affect pile and shaft design?

$$\phi = \frac{\lambda_R \left(\frac{\gamma_D Q_D}{Q_L} + \gamma_L \right) \sqrt{\left[\frac{(1 + COV_{Q_D}^2 + COV_{Q_L}^2)}{(1 + COV_R^2)} \right]}}{\left(\frac{\lambda_{Q_D} Q_D}{Q_L} + \lambda_{Q_L} \right) \exp\left\{ \beta_T \sqrt{\ln\left[(1 + COV_R^2)(1 + COV_{Q_D}^2 + COV_{Q_L}^2) \right]} \right\}}$$

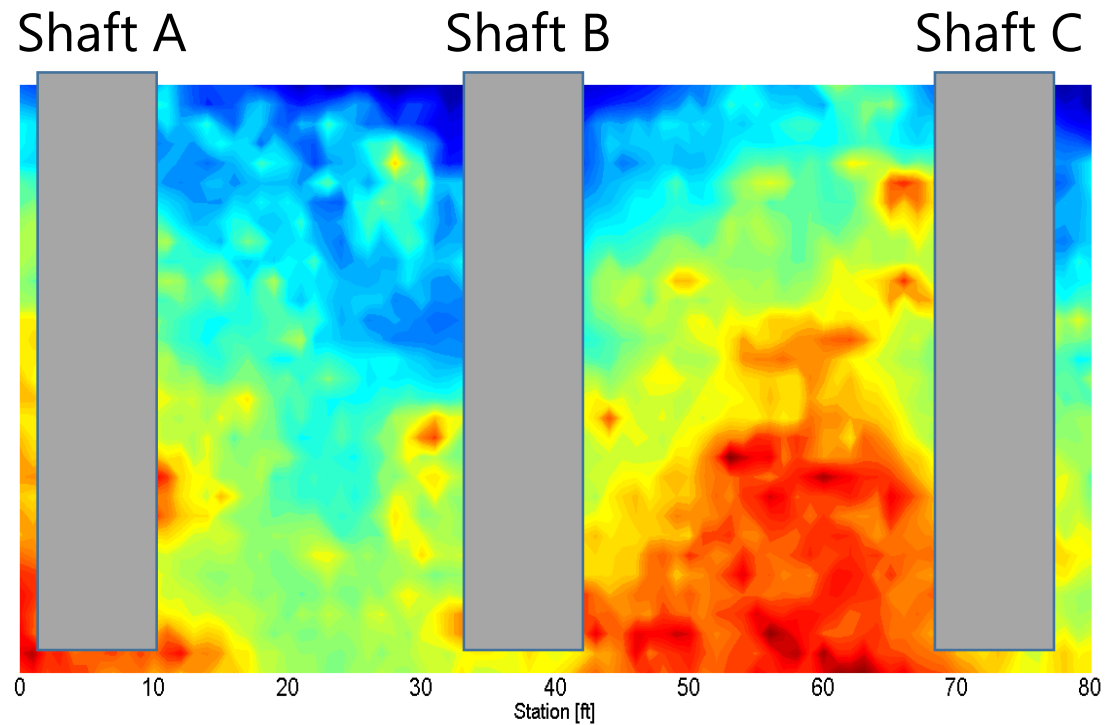
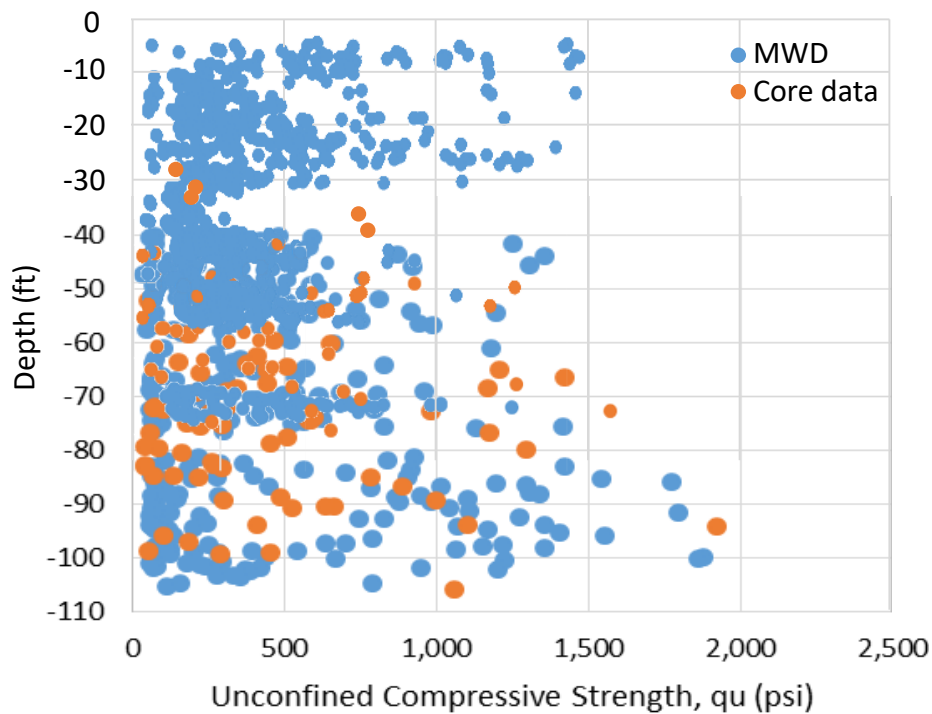
NCHRP 507, Eqn. 10, (Paikowsky et al. 2004)

- Resistance factor (ϕ)
 - COV_R : Coefficient of variation
 - λ_R : Bias factor



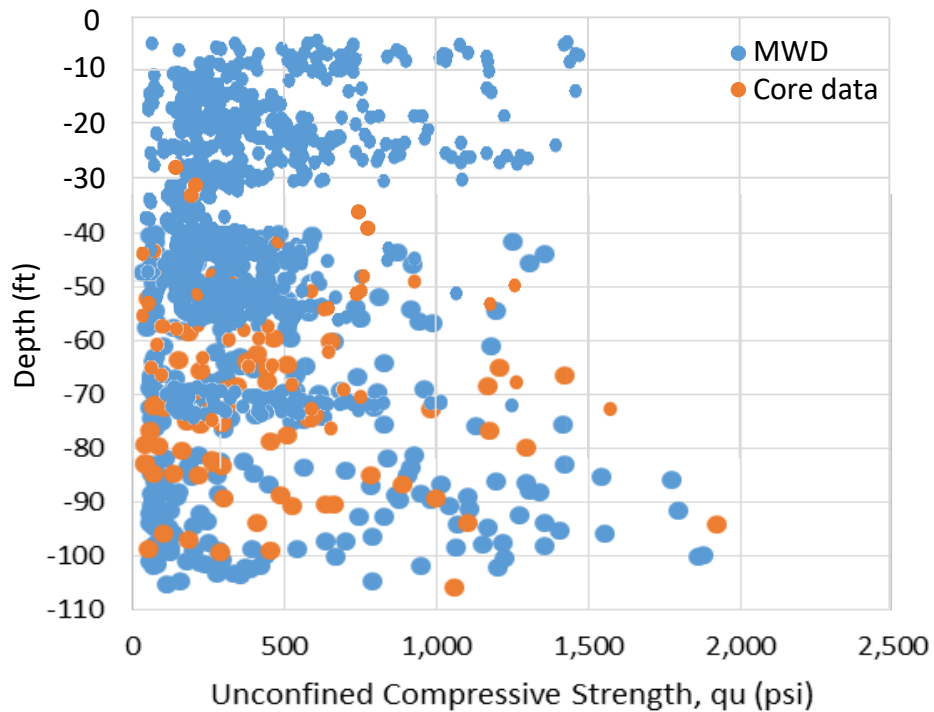
Motivation

- Example: spatial variability
 - Coring and MWD from Test shafts A, B, and C



Motivation

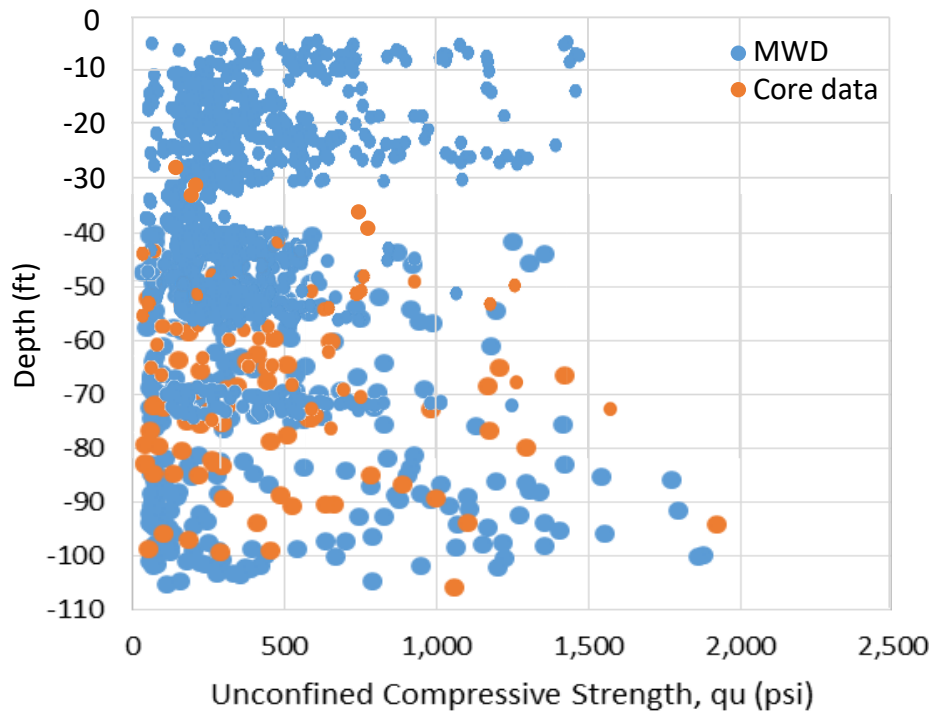
- Example: spatial variability
 - Coring and MWD from Test shafts A, B, and C



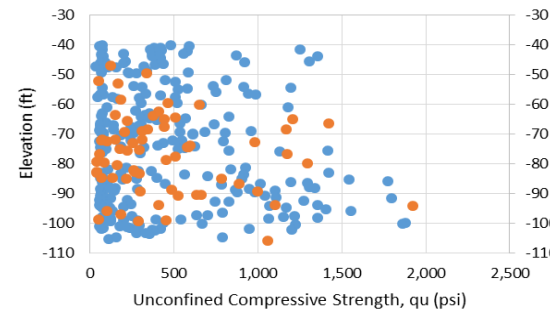
$$\text{COV}_{\text{all}} = 1.7$$

Motivation

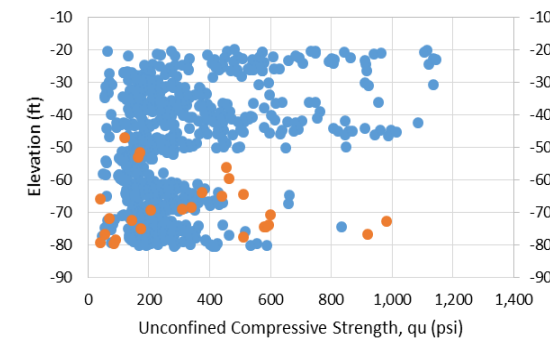
- Example: spatial variability
 - Coring and MWD from Test shafts A, B, and C



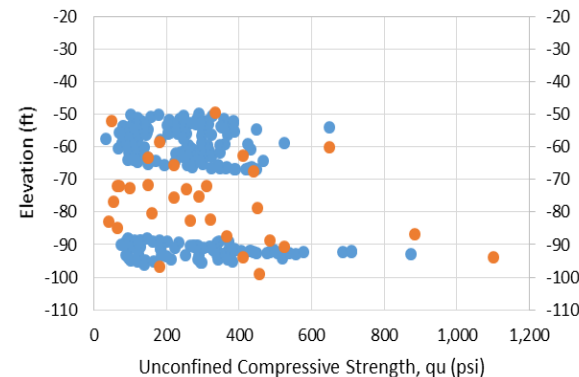
$$COV_{all} = 1.7$$



$$COV_A = 1.03$$



$$COV_B = 0.71$$



$$COV_C = 0.56$$

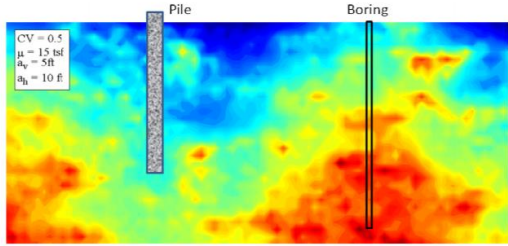
Building on previous FDOT-funded research

- Prototype research software tool: GS-Deep
 - McVay et al. (2012), FDOT BDK75 977-23

Final Report

FDOT Contract No.: BDK75 977-23
UF Contract No.: 00083426

Development of Variable LRFD ϕ Factors for Deep Foundation Design Due to Site Variability




Principal Investigators: Michael C. McVay
Harald Klammier

Graduate Research Assistants: Michael A. Faraone
Krishnarao Dase
Chris Jenneisch

Department of Civil and Coastal Engineering
Engineering School of Sustainable Infrastructure and Environment
University of Florida
P.O. Box 116580
Gainesville, Florida 32611-6580

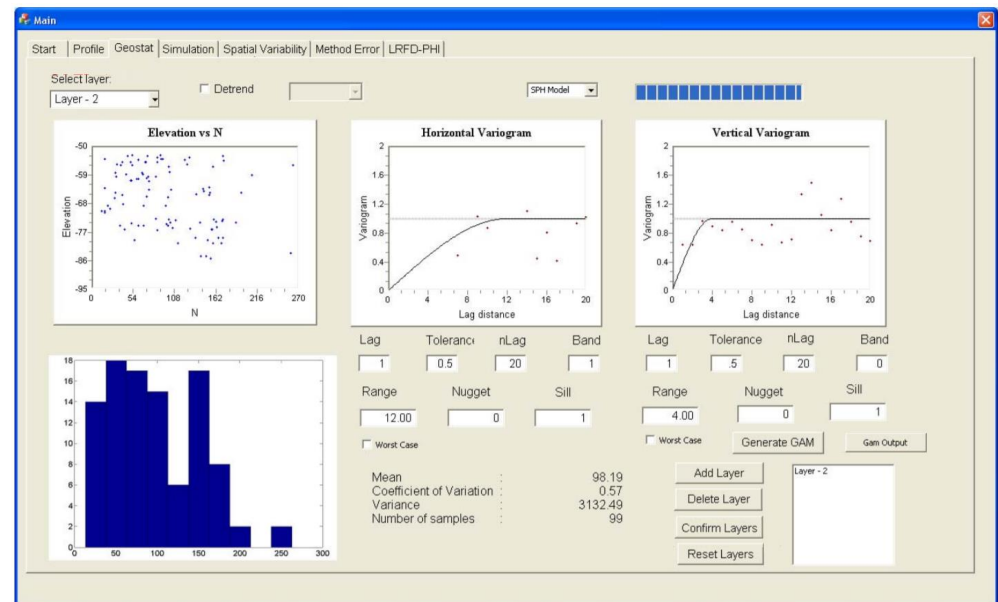
Developed for the



Peter Lai, P.E., and Rodrigo Herrera, P.E., Project Managers

June 2012

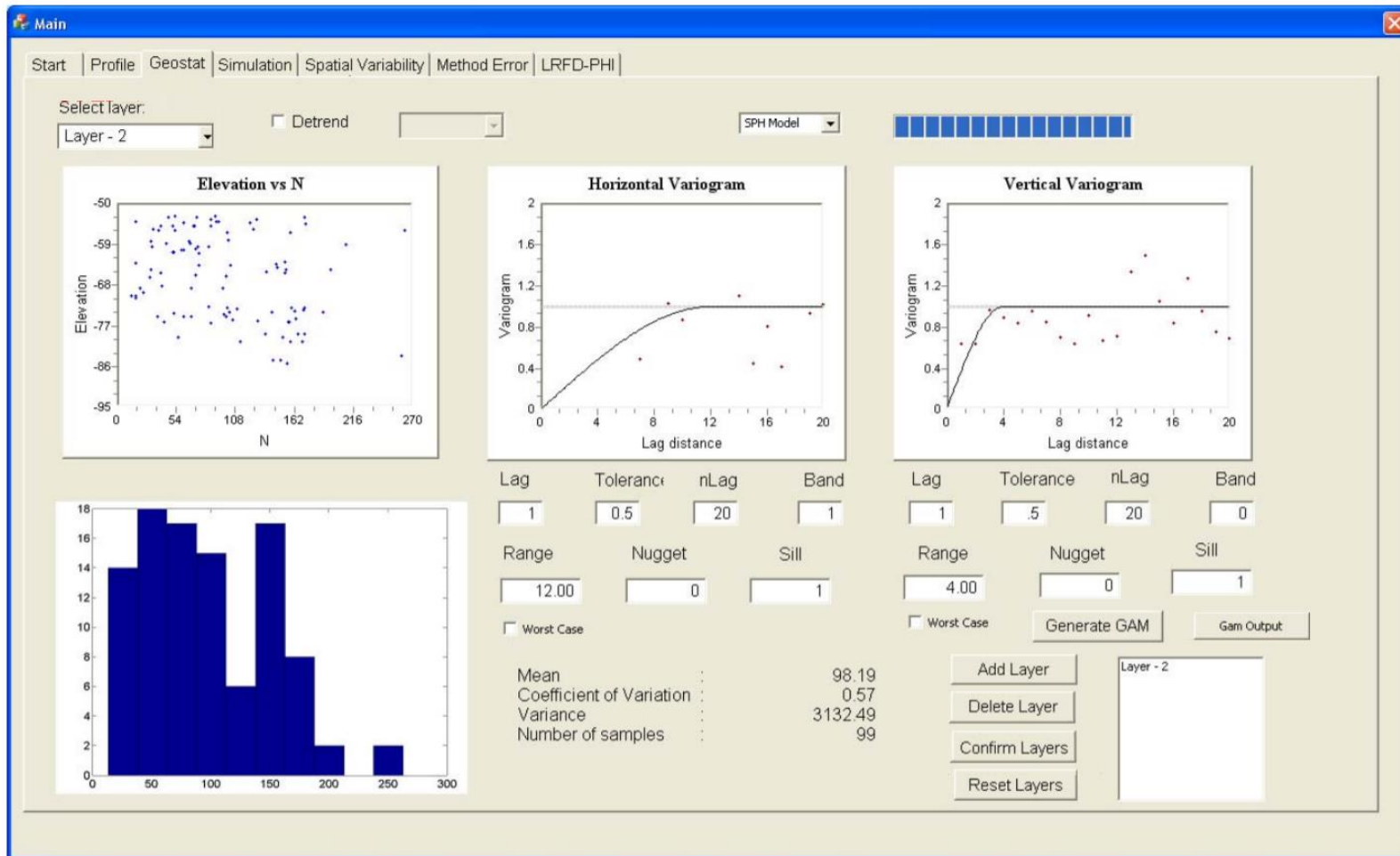
FDOT BDK75 977-23 Project Report



Prototype research tool interface

Project objective

- Transition GS-Deep from research tool to design tool



GS-Deep tabbed interface

Agenda

- Introduction
- Project tasks
- Status update: Task 1
- Status update: Task 2
- Next steps

Project tasks

- Transition GS-Deep from research tool to design tool
 - 1. Establish input file format and data read/write
 - 2. Automate calls to axial capacity software, FB-Deep
 - 3. Conduct quality assurance testing
 - 4. Develop installation package and licensing
 - 5. Develop software user manual
 - 6. Develop software technical manual
 - 7. and 8. Draft-final and final reports

Task 1

- Establish input file format and data read/write

Project Information

Project Number: Based on 47010

Project Name: Based on SR-20 P59

Engineer: MD

Foundation Type

Drilled Shaft

Driven Pile

Plan View of Site

Northing

Easting

Boring	Point Name	Northing	Easting	Ground Surface Elevation	Include
		(ft m)	(ft m)	(ft m)	
1	P59-1	14140.0000	40.0000	17.0000	1
2	P59-2	14170.0000	41.0000	20.0000	1
3	P59-3	14167.0000	42.0000	18.0000	1
4	P59-4	14139.0000	41.0000	14.0000	1

Pre-alpha interface: Start tab

Task 1

- Establish input file format and data read/write

The screenshot displays the GS-Deep software interface. The top menu bar includes 'File', 'Control', and 'Help'. Below the menu, there are icons for file operations (add, folder, save) and a set of tabs: 'Start', 'Profile', 'Geostat', 'Simulation', 'Spatial Variability', 'Method Error', and 'LRFD-Φ'. The 'Start' tab is active, showing a 'Foundation Type' section with radio buttons for 'Drilled Shaft' (selected) and 'Driven Pile'. A data table is visible, listing four borings with their respective coordinates and elevations. A plot in the bottom left shows the spatial distribution of these points on a coordinate system of Easting and Northing. An 'Office Excel' window is overlaid on the plot area.

Boring	Point Name	Northing (ft m)	Easting (ft m)	Ground Surface Elevation (ft m)	Include
1	P59-1	14140.0000	40.0000	17.0000	1
2	P59-2	14170.0000	41.0000	20.0000	1
3	P59-3	14167.0000	42.0000	18.0000	1
4	P59-4	14139.0000	41.0000	14.0000	1

Pre-alpha interface: Start tab

Task 2

- Automate calls to axial capacity software, FB-Deep

GS-Deep

File Control Help

Start Profile Geostat **Simulation** Spatial Variability Method Error LRFD- Φ

General Geometry

Minimum Length (ft)

Maximum Length (ft)

Increment (ft)

Shaft Material

EC (ksi)

Slump (in)

RPercent

Shaft Geometry

Diameter (in)

Casing Length (ft)

Bell Length (ft)

Bell Diameter (in)

Soil

Ground Surface Elevation

Water Table Elevation (ft)

Default RQD and REC to

Layer Separation

Soil Type 1 (Plastic Clay)

Soil Type 2 (Clay and Silty Sand)

Soil Type 5 (Void)

Unit Weight (pcf)

Cu

N (blows/ft)

Pile Geometry

Width (in)

Section

Simulation

Conditional

UnConditional

Number of Simulations:

Boring: ▼

Northing of Foundation:

Easting of Foundation:

Layer	Mean	CV	Variance	Sample Count	av	ah	Sill	Detrend
1	3	0.2	0.36	3	2	2	1	No
2	15	0.3	20.25	15	2	2	1	No
3	35	0.2	49	35	2	2	1	No
4	55	0.6	1089	55	2	2	1	No

Generate FB-Deep Files

Pre-alpha interface: Simulation tab

Task 2

- Automate calls to axial capacity software, FB-Deep

GS-Deep

File Control Help

Start Profile Geostat **Simulation** Spatial Variability Method Error LRFD- Φ

General Geometry

Minimum Length (ft)

Maximum Length (ft)

Increment (ft)

Shaft Material

EC (ksi)

Slump (in)

RPercent

Shaft Geometry

Diameter (in)

Casing Length (ft)

Bell Length (ft)

Bell Diameter (in)

Soil

Ground Surface Elevation

Water Table Elevation (ft)

Simulation

Conditional

UnConditional

Number of Simulations:

Boring

Northing of Foundation

Easting of Foundation

Layer	Mean	CV	Variance	Sample Count	av	ah	Sill	Detrend
1	3	0.2	0.36	3	2	2	1	No
2	15	0.3	20.25	15	2	2	1	No
3	35	0.2	49	35	2	2	1	No
4	55	0.6	1089	55	2	2	1	No

FB-Deep

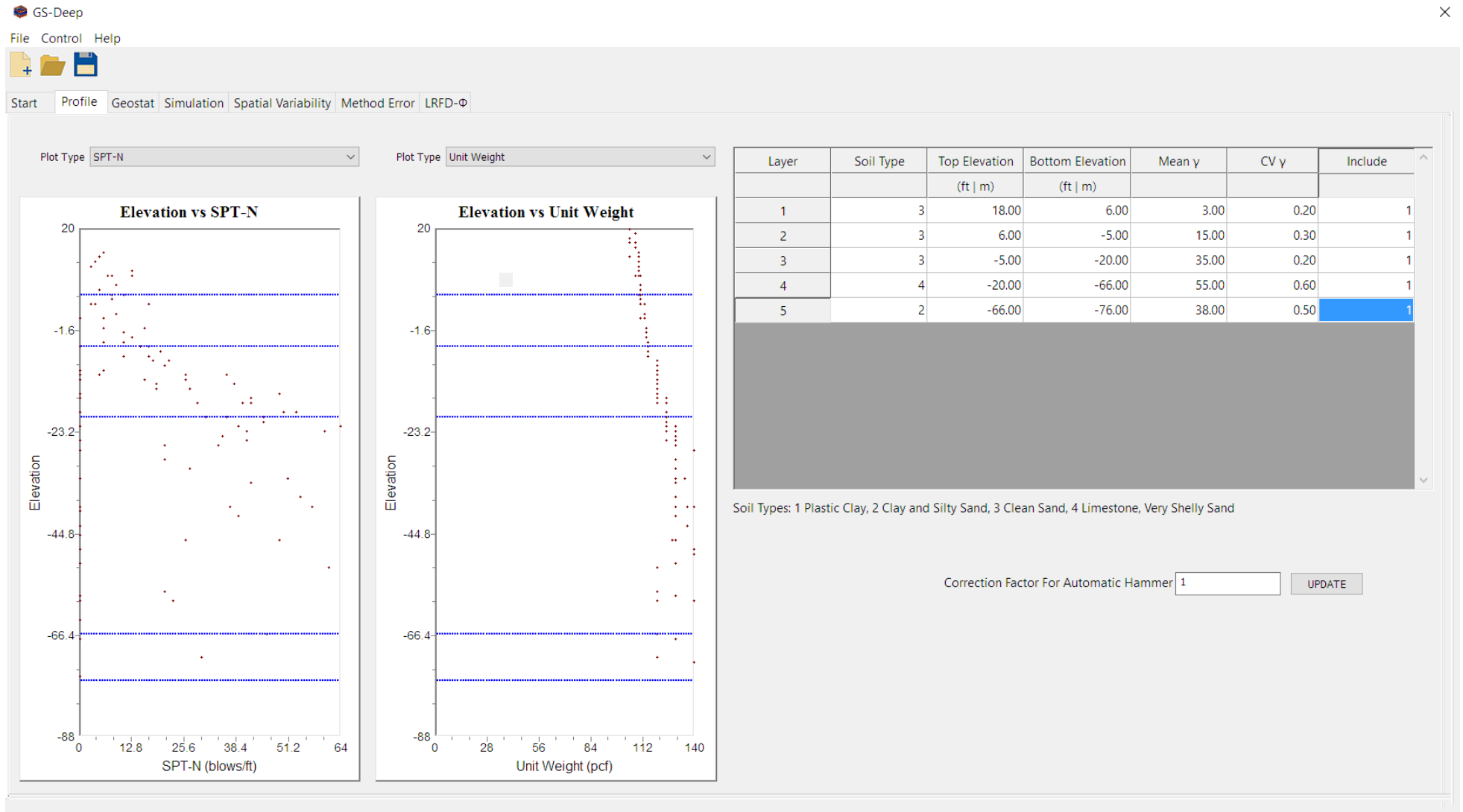
Version 2.06

Generate FB-Deep Files

Pre-alpha interface: Simulation tab

Task 3

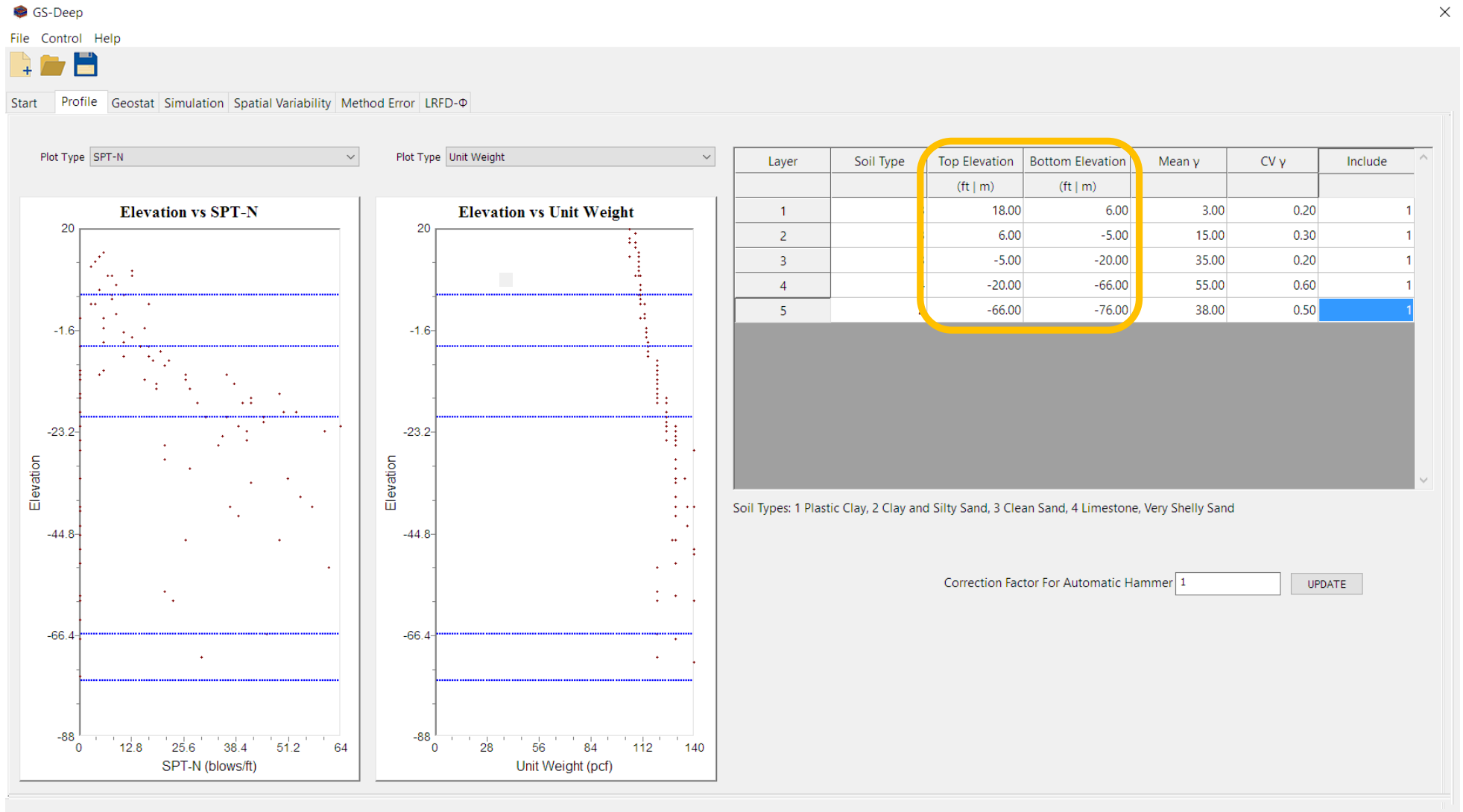
- Conduct quality assurance testing



Pre-alpha interface: Profile tab

Task 3

- Conduct quality assurance testing



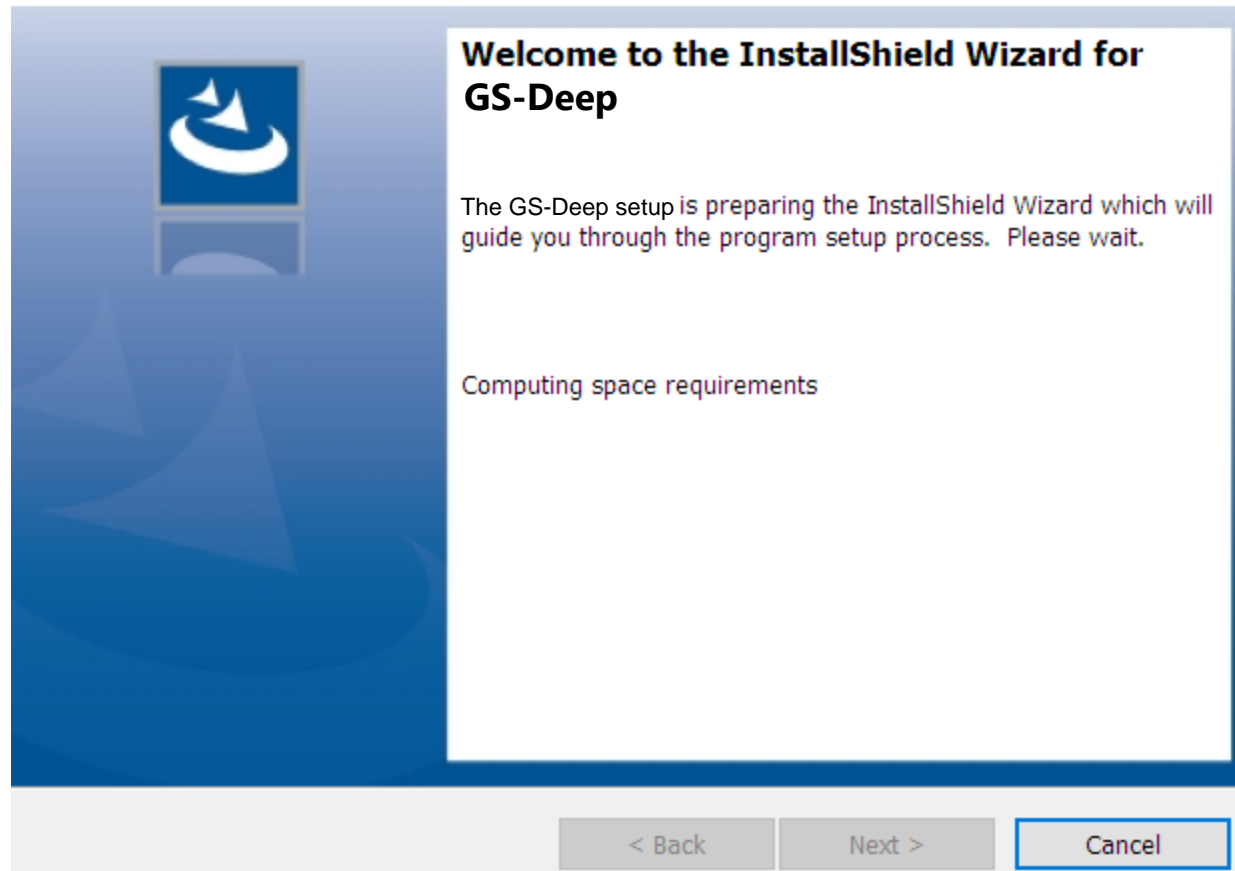
Pre-alpha interface: Profile tab

Task 3

- Conduct quality assurance testing
 - C++ engine routines (imported from MATLAB)
 - Random number generation (normal, log)
 - Descriptive statistics (mean, COV, normal score)
 - Regression (linear, log-lin, polynomial)
 - Interpolation (linear)
 - Matrix operations (factorization, covariance)
 - Ordinary kriging
 - Simulation (unconditional, conditional)

Task 4

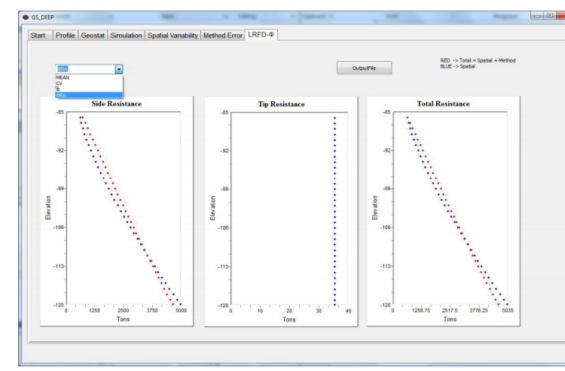
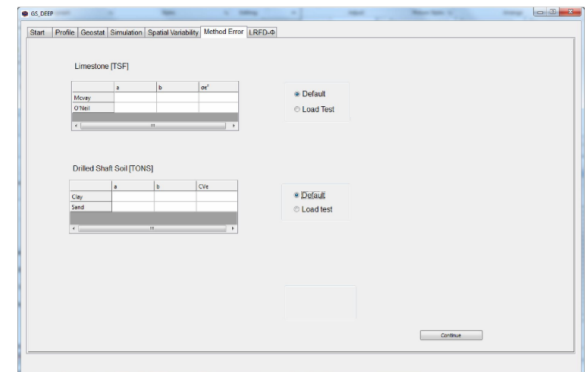
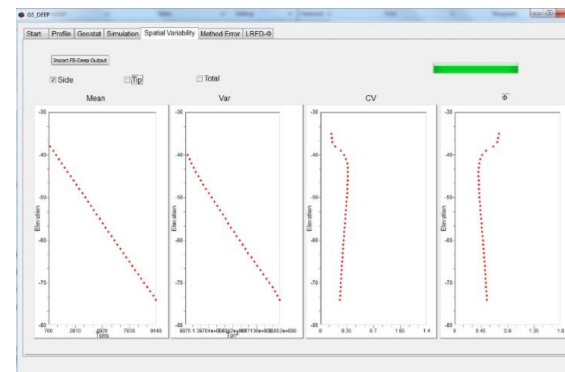
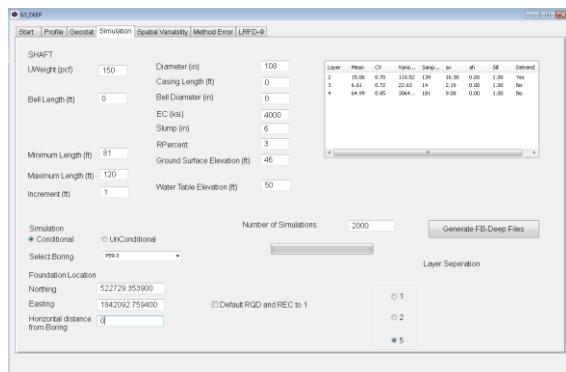
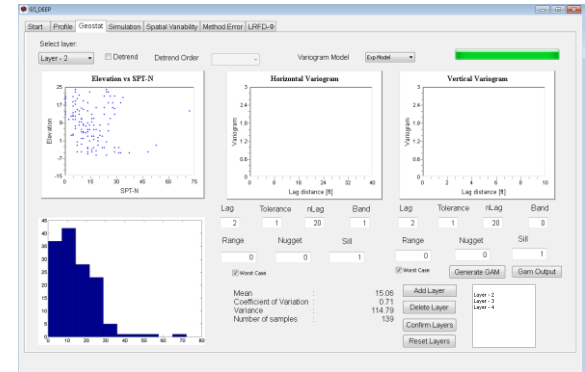
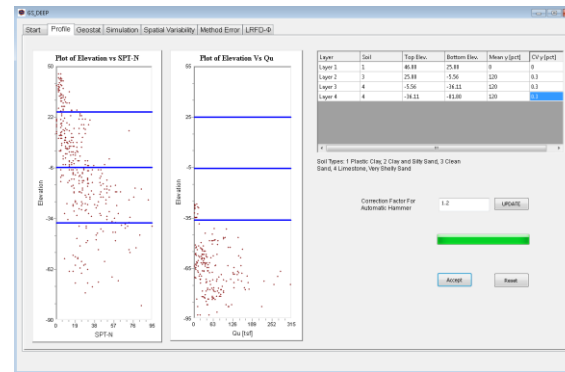
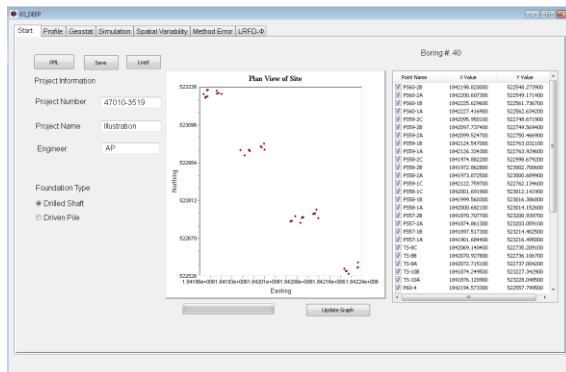
- Develop installation package and licensing
 - Requires use of FB-Deep



Example GS-Deep installation dialog

Task 5

- Develop software user manual



Program tabs

Task 5

- Develop software user manual

The image displays a central user manual cover for 'GS-Deep' by Bridge Software Institute. The cover features the BSI logo and the text 'Help Manual'. Surrounding the cover are several screenshots of the software's interface, showing various simulation and analysis tools. The screenshots include:

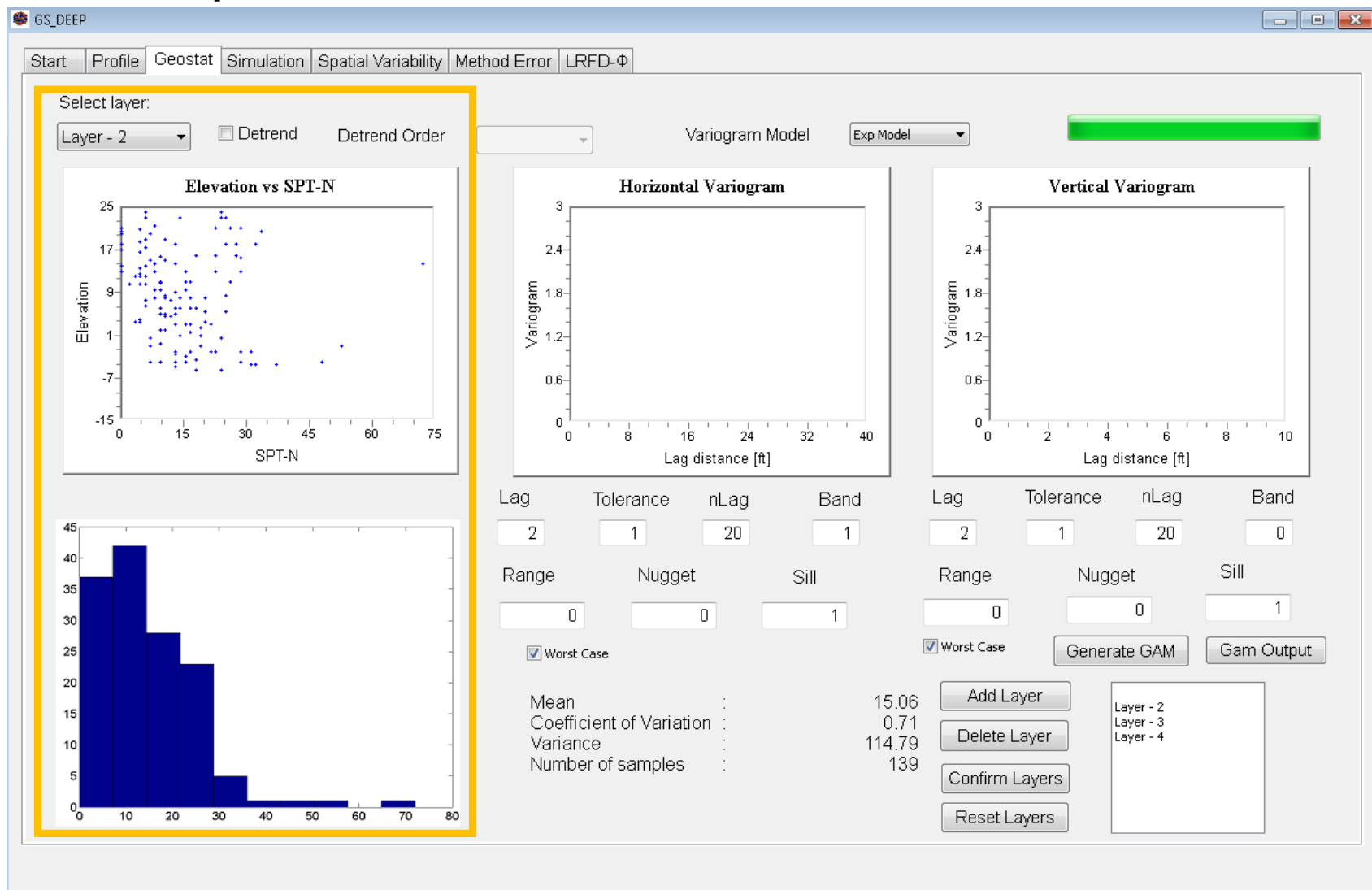
- Plot of Elevation vs SPT-N**: A scatter plot showing the relationship between SPT-N and Elevation.
- Plot of Elevation vs Qu**: A scatter plot showing the relationship between Qu and Elevation.
- Horizontal Variogram**: A plot showing the horizontal variability of the data.
- Vertical Variogram**: A plot showing the vertical variability of the data.
- Simulation Parameters**: A window for setting simulation parameters such as Shaft Weight, Diameter, Casing Length, and Simulation Type.
- Simulation Results**: A window displaying simulation results, including a table of parameters and a histogram of the results.

At the bottom of the collage, there are three small plots showing the results of a simulation, likely related to the 'Program tabs' mentioned in the caption.

Program tabs

Task 6

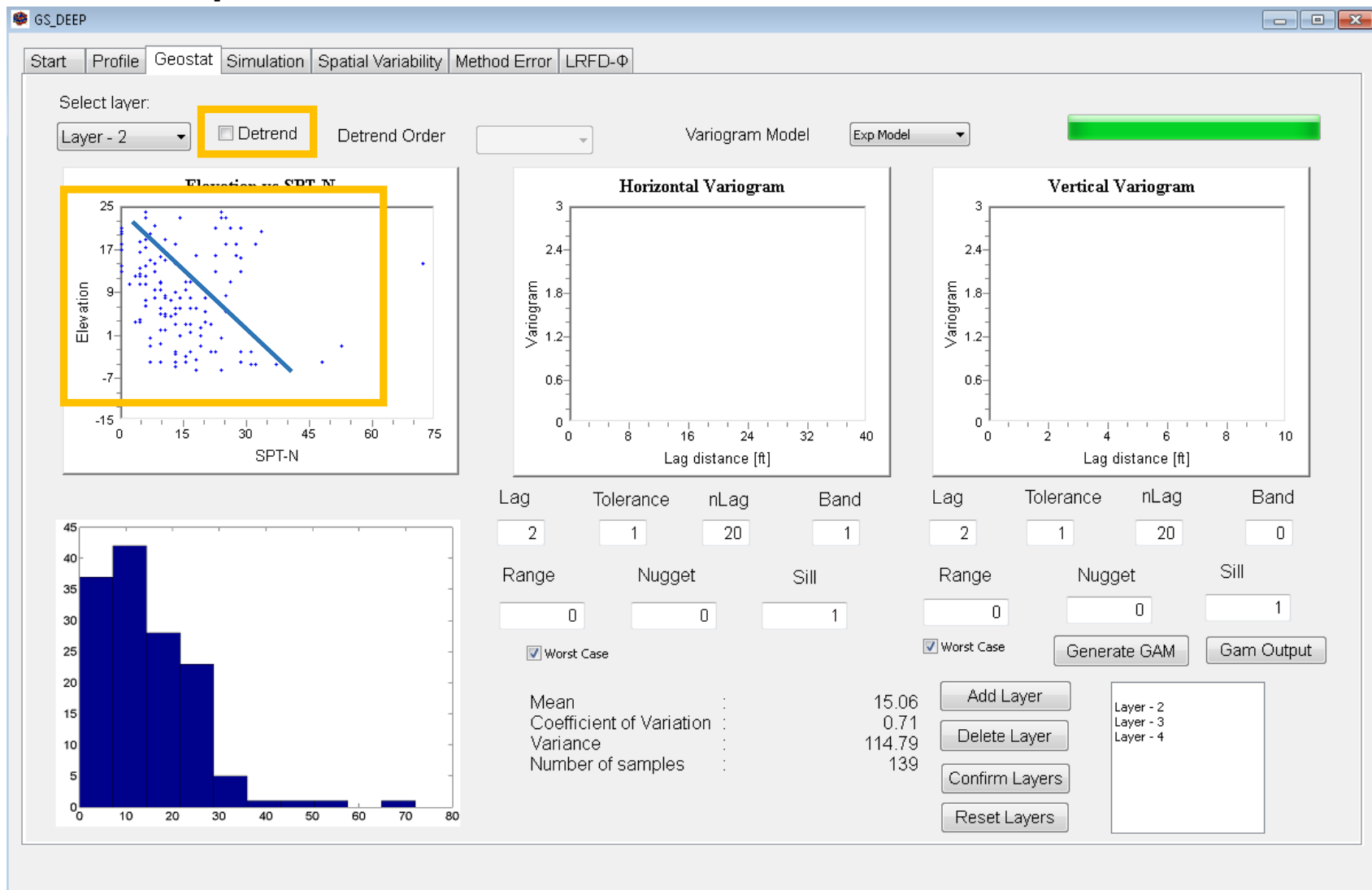
- Develop software technical manual



Geostatistics tab

Task 6

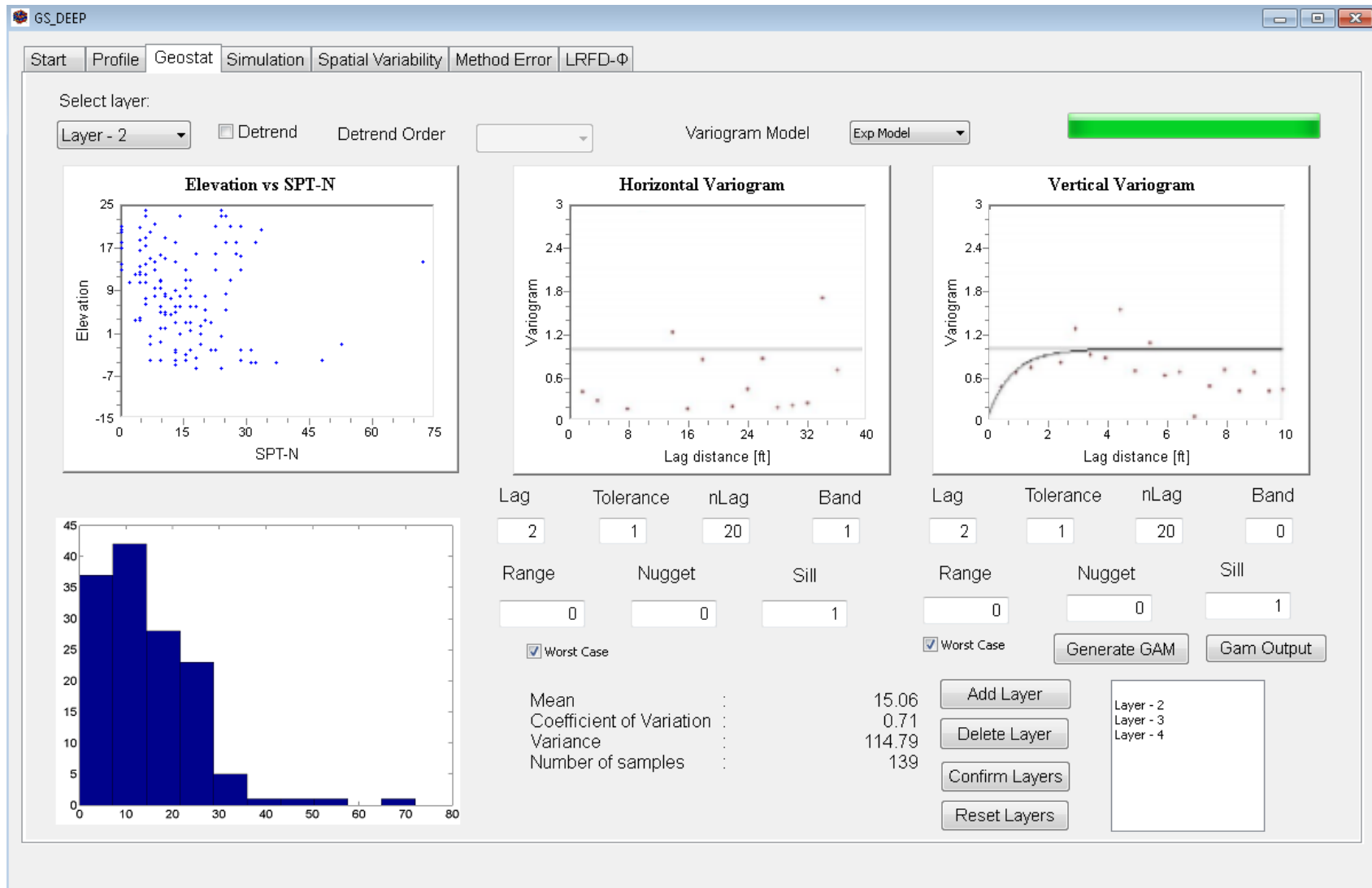
- Develop software technical manual



Geostatistics tab

Task 6

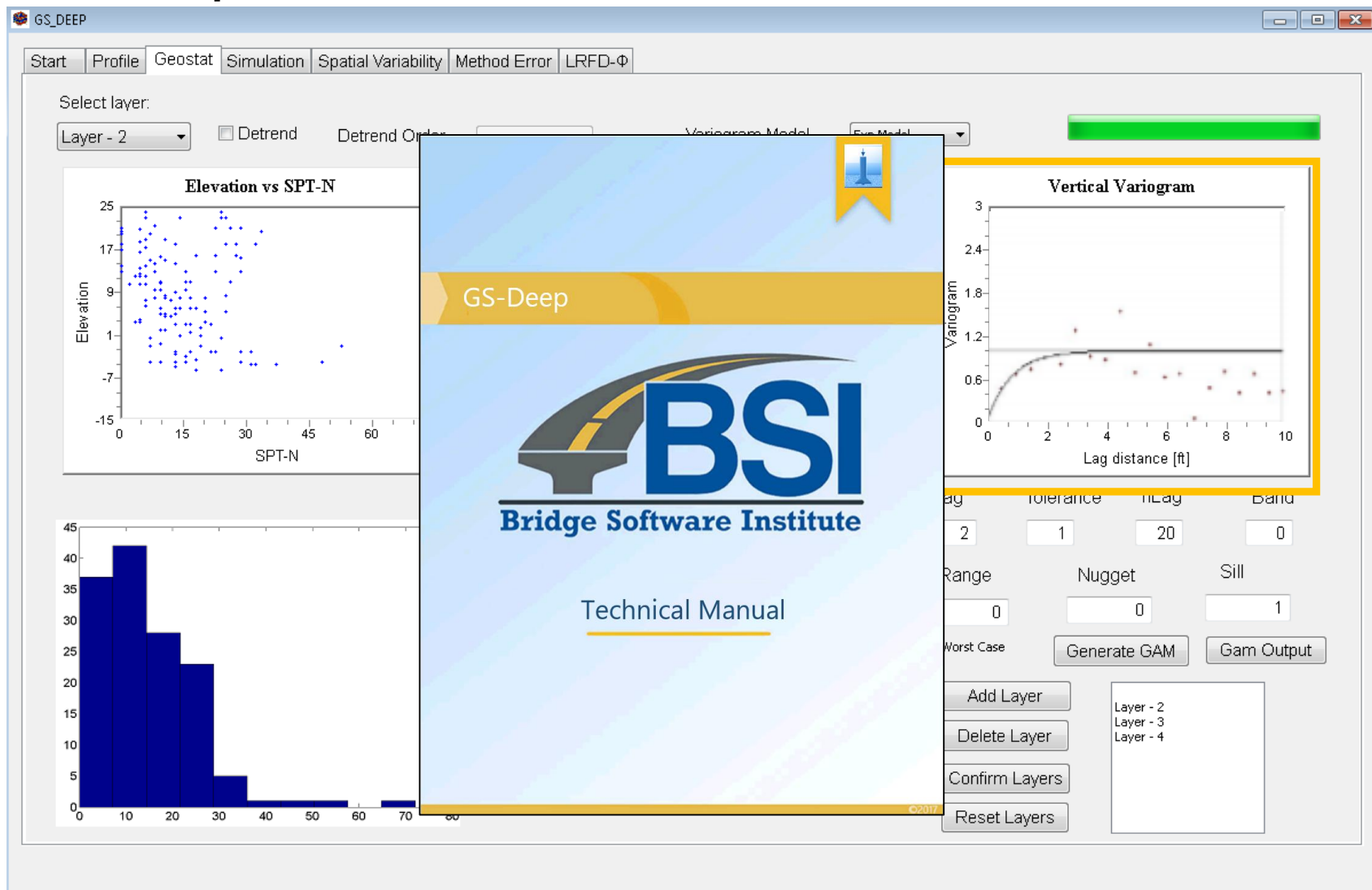
- Develop software technical manual



Geostatistics tab

Task 6

- Develop software technical manual



Geostatistics tab

Agenda

- Introduction
- Project tasks
- Status update: Task 1
- Status update: Task 2
- Next steps

Status update: Task 1

- Establish input file format and data read/write

	A	B	C	D	E
1	This tab must be populated with data prior to loading GS-Deep.				
2					
3	Program Data	Input Options	Units	Value	
4	Version			0.01	
5	Time			11:17 AM	
6	Date			7/23/2019	
7	Random Seed			1	
8					
9	Project Item	Input Options	Units	Value	
10	Project Number			Based on 47010	
11	Project Name			Based on SR-20 P59	
12	Engineer			MD	
13	Unit System	[English SI]		English	
14	Foundation Type	[Drilled Driven]		Drilled	
15					
16	Point Name	Include	Northing	Easting	Ground Surface Elevation
17		[Yes No]			
18			ft m	ft m	ft m
19	P59-1	Yes	14140	40	17
20	P59-2	Yes	14170	41	20
21	P59-3	Yes	14167	42	18
22	P59-4	Yes	14139	41	14

Input set for Start tab

Status update: Task 1

- Establish input file format and data read/write

	A	B	C	D	E	F	G	H	I	J	K	L
1	This tab must be populated with data prior to loading GS-Deep.											
2												
3	Depth	Soil Type	N. Blows	Unit Weight	Cu	qu	qt	qb	Em	RQD	Socket Roughness	Rock Recovery
4		[1 2 3 4 5]								[0.0 to 1.0]	[0 1]	[0.0 to 1.0]
5	ft m		blows /ft blows/30 cm	pcf kN/m^3	tsf kPa	tsf kPa	tsf kPa	tsf kPa	ksi kPa			
6	0	3	0	105								
7	1	3	0	108								
8	4.5	3	4	110								
9	7.5	3	8	110								
10	10.5	3	5	111								
11	13.5	3	4	111								
12	16.5	3	6	113								
13	20	3	13	114								
14	22.5	3	17	115								
15	23	3	20	115								
16	25.5	3	18	120								
17	26	3	21	120								
18	28.5	3	26	120								
19	31.5	3	19	120								
20	34	3	29	120								
21	34.5	3	40	125								
22	37.5	3	31	125								
23	38	3	45	125								
24	40.5	4	60	130								
25	43.5	4	34	130		2	0.4	1.2	255	0.37	1	0.65
26	50	4	51	130						0.17	1	0.23
27	56	4	57	130								
28	56.5	4		140						0	1	0.17
29	63	4	26	130								
30	65	4		140						0.9	1	0.4
31	71	4		140		9.7	2.6	1.5	300	0.23	1	0.4
32	77	4		140		11.8	2.3	2	310	0.5	1	1
33	83.5	4		140						0.73	1	0.85
34	89.5	4		140						0	1	0.3
35	94.5	4		140						0.23	1	0.8
36	100	4		140						0.33	1	1
37	105.5	4		140		150.7	15.07	48	600	0.88	1	1

Input set for Locations of Interest

Status update: Task 1

- Establish input file format and data read/write

This tab must be populated with data prior to loading GS-Deep.												
Depth	Soil Type	N. Blows		Unit Weight	Cu	qu	qt	qb	Em	RQD	Socket Roughness	Rock Recovery
ft m	[1 2 3 4 5]	blows/ft	blows/30 cm	pcf kN/m ³	tsf kPa	tsf kPa	tsf kPa	tsf kPa	ksi kPa	[0.0 to 1.0]	[0 1]	[0.0 to 1.0]
0	3		0	105								
1	3		0	108								
4.5	3		4	110								
7.5	3		8	110								
10.5	3		5	111								
13.5	3		4	111								
16.5	3		6	113								
20	3		13	114								
22.5	3		17	115								
23	3		20	115								
25.5	3		18	120								
26	3		21	120								
28.5	3		26	120								
31.5	3		19	120								
34												
34.5												
37.5												
38												
40.5												
43.5												
50												
56												
56.5												
63												
65												
71												
77												
83.5												
89.5												
94.5												
100												
105.5												



Boring Log

Boring Identification
 Boring Date:
 Boring Number:
 Station Number:
 Offset: ?

Additional Options
 Ground Surface Elevation: (ft)
 Blow count is obtained using automatic hammer
 Correction Factor:

Cu Calculation Method
 Direct
 CPT

Strength Reduction Factor
 Side friction (= < 1.0):
 End bearing (= < 1.0):

Rock Side Friction Calculation Method
 William's McVay's A qu^B
 A: B:

Boring Data

No.	Depth (ft)	Soil Type	Soil Description	N. Blows (blow/ft)	Unit Weight (pcf)	Cu-Dir (tsf)	qu (tsf)	qt (tsf)	qb (tsf)	Em (ksi)	RQD	Socket Roughness	Rock Recovery
1	0.000	3	Clean Sand	0.000	108.000								
2	1.000	3	Clean Sand	4.000	110.000								
3	4.500	3	Clean Sand	8.000	111.000								
4	13.500	3	Clean Sand	5.000	114.000								
5	40.500	4	Limestone, very shelly sand		120.000		2.000	0.400	1.200	255.000	0.370	1	0.650
6	43.500	4	Limestone, very shelly sand		120.000		9.700	2.600	1.500	300.000	0.230	1	0.400
7	50.000	4	Limestone, very shelly sand		125.000		11.800	2.300	2.000	310.000	0.500	1	1.000
8	56.000	4	Limestone, very shelly sand		125.000		150.700	15.070	48.000	600.000	0.880	1	1.000

Notes
 1. Soil Types are as follows: 1. Plastic clay; 2. Clay and silty sand; 3. Clean sand; 4. Limestone, very shelly sand; 5. Void, final layer, no capacity.
 2. Depths are relative to ground surface elevation. The first layer must have a depth of 0.
 4. Socket Roughness: 0=Smooth, 1=Rough. For Smooth sockets, the A qu^B method will be automatically selected.

Input set for Locations of Interest: consistent with FD-Deep

Status update: Task 2

- Automate calls to axial capacity software, FB-Deep

GS-Deep

File Control Help

Start Profile Geostat **Simulation** Spatial Variability Method Error LRFD- Φ

General Geometry
Minimum Length (ft) 50
Maximum Length (ft) 80
Increment (ft) 1

Shaft Material
EC (ksi) 4500
Slump (in) 6
RPercent 2

Shaft Geometry
Diameter (in) 60
Casing Length (ft) 45
Bell Length (ft) 0
Bell Diameter (in) 0

Soil
Ground Surface Elevation
Water Table Elevation (ft) 42

Table:

Layer	Mean	CV	Variance	Sample Count	av	ah	Sill	Detrend
1	3	0.2	0.36	3	2	2	1	No
2	15	0.3	20.25	15	2	2	1	No
3	35	0.2	49	35	2	2	1	No
4	55	0.6	1089	55	2	2	1	No

Simulation
 Conditional
 UnConditional
Number of Simulations: 2000
Boring P59-1
Northing of Foundation 0
Easting of Foundation 0


FB-Deep
Version 2.06

Generate FB-Deep Files

Pre-alpha interface: Simulation tab

Status update: Task 2

- Automate calls to axial capacity software, FB-Deep
 - Stage 1: Implement batch mode in FB-Deep



FB-Deep

-2.06

- Engine » Enhancements: Updated the pile skin friction and end bearing capacity calculations for unplugged conditions, in accordance with the API method.
- Engine » Enhancements: For steel pipe piles and concrete cylindrical piles, added flag that indicates open or closed end conditions.
- Interface » Enhancements: For steel pipe and concrete cylindrical piles, restored the option to select open or closed end conditions.
- Interface » Enhancements: Updated the input file format from binary (.SPC) to ASCII (.IN). For backwards compatibility, all .SPC files loaded into the program will be automatically converted to .IN format. Option to convert multiple .SPC files to .IN format was also added to the Control Menu.
- Interface » Enhancements: Added a "Batch Mode" option in the Control Menu to allow for streamlined analysis of multiple input files.
- Interface » Enhancements: Added an option for engineers to input the End Area of H-piles when using CPT analysis.

- Stage 2: Automation in GS-Deep
 - "Run Simulation" button on Simulation tab
 - FB-Deep batch called in background
 - "Load Simulation Results" on Spatial Variability tab

Agenda

- Introduction
- Project tasks
- Status update: Task 1
- Status update: Task 2
- Next steps

Anticipated project timeline

- Total duration: 18 months
 - Task 1 (Deliverable 1: September 2019)
 - Task 2 (Deliverable 2: December 2019)
 - Task 3 (Deliverables 3.1, 3.2: March 2020, March 2020)
 - Task 4 (Deliverable 4: May 2020)
 - Task 5 (Deliverable 5: May 2020)
 - Task 6 (Deliverables 6.1, 6.2: June 2020, June 2020)
 - Task 7 (Deliverables 7.1, 7.2: June 2020, August 2020)
 - Task 8 (Deliverable 8: September 2020)

Task 1 items

- 'Wiring up' read-in input data to engine routines
- Task 1 report
 - Documentation of GS-Deep input file format

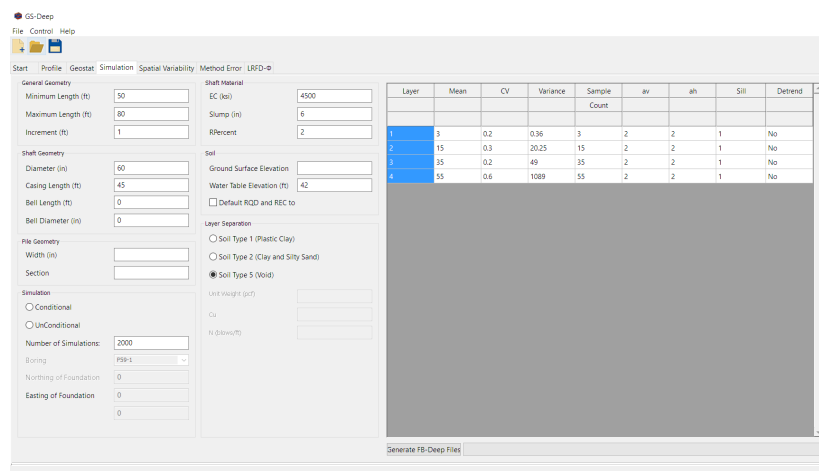
	A	B	C	D	E
1	This tab must be populated with data prior to loading GS-Deep.				
2					
3	Program Data	Input Options	Units	Value	
4	Version			0.01	
5	Time			11:17 AM	
6	Date			7/23/2019	
7	Random Seed			1	
8					
9	Project Item	Input Options	Units	Value	
10	Project Number			Based on 47010	
11	Project Name			Based on SR-20 P59	
12	Engineer			MD	
13	Unit System	[English SI]		English	
14	Foundation Type	[Drilled Driven]		Drilled	
15					
16	Point Name	Include	Northing	Easting	Ground Surface Elevation
17		[Yes No]			
18			ft m	ft m	ft m
19	P59-1	Yes	14140	40	17
20	P59-2	Yes	14170	41	20
21	P59-3	Yes	14167	42	18
22	P59-4	Yes	14139	41	14

	A	B	C	D	E	F	G	H	I	J	K	L
1	This tab must be populated with data prior to loading GS-Deep.											
2												
3	Depth	Soil Type	N. Blows	Unit Weight	Cu	qu	qt	qb	Em	RQD	Socket Roughness	Rock Recovery
4		[1 2 3 4 5]								[0.0 to 1.0]	[0 1]	[0.0 to 1.0]
5	ft m		blows/ft blows/30 cm	pcf kN/m ³	tsf kPa	tsf kPa	tsf kPa	tsf kPa	ksi kPa			
6	0	3		0	105							
7	1	3		0	108							
8	4.5	3		4	110							
9	7.5	3		8	110							
10	10.5	3		5	111							
11	13.5	3		4	111							
12	16.5	3		6	113							
13	20	3		13	114							
14	22.5	3		17	115							
15	23	3		20	115							
16	25.5	3		18	120							
17	26	3		21	120							
18	28.5	3		26	120							
19	31.5	3		19	120							
20	34	3		29	120							
21	34.5	3		40	125							
22	37.5	3		31	125							
23	38	3		45	125							
24	40.5	4		60	130							
25	43.5	4		34	130		2	0.4	1.2	255	0.37	1
26	50	4		51	130						0.17	1
27	56	4		57	130							0.23
28	56.5	4			140						0	1
29	63	4		26	130							0.17
30	65	4			140							
31	71	4			140		9.7	2.6	1.5	300	0.9	1
32	77	4			140		11.8	2.3	2	310	0.23	1
33	83.5	4			140						0.5	1
34	89.5	4			140						0.73	1
35	94.5	4			140						0	1
36	100	4			140						0.23	1
37	105.5	4			140		150.7	15.07	48	600	0.33	1
											0.88	1

Example Excel input tabs

Task 2 items

- Automated calls to FB-Deep
 - “Run Simulation” button on Simulation tab
 - FB-Deep batch called in background
 - “Load Simulation Results” on Spatial Var. tab



- Task 2 report
 - Documentation of automated calls to FB-Deep
 - Documentation of process of building up FB-Deep files

Thank you

