Validation and Update of the Sinkhole Index
(BED26-977-10)

Jiannan (Nick) Chen, Ph.D.
University of Central Florida

Ryan Shamet, Ph.D., P.E.
University of North Florida

Kelly Shishlova, M.S., P.E. (PM)
Florida Department of Transportation (FDOT)

FDOT GRIP Meeting
August 13th, 2026

Presentation Outline

- Introduction
- Project background
- Project objectives
- Task outline and task findings
- Research conclusions and recommendations
- Example Analysis

Massive sinkholes were found after Hurricane Milton
(example: destruction of infrastructure in Orange City, FL)

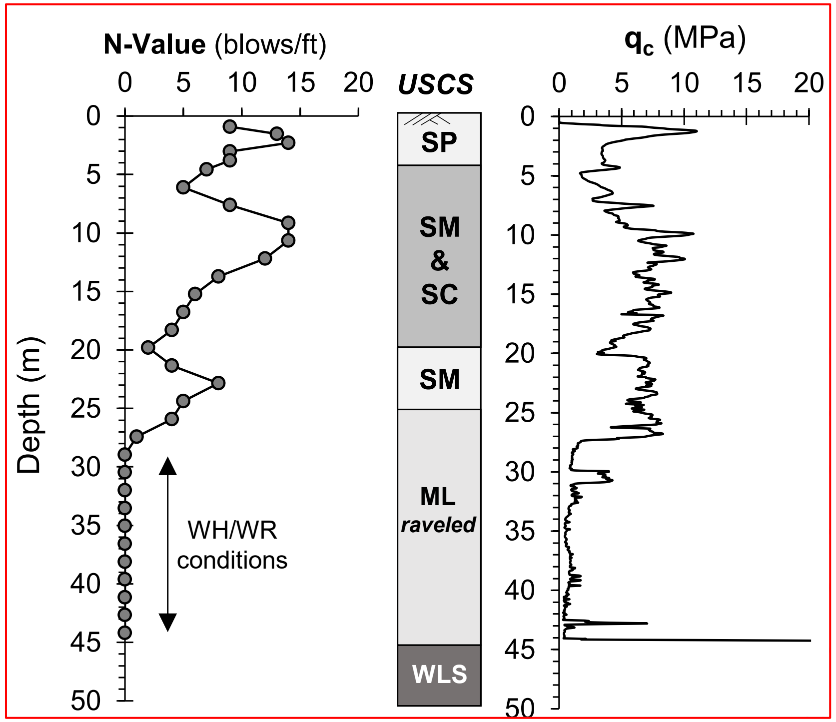
Example: Evolution of Cover-collapse Sinkhole (Soil Arching)

Karst:

Landscape developed by the dissolution of sediment and rocks.

"Eogenetic" karst:

- *youngest* karst (55mya)
- Extensive primary porosity
- "undisturbed" overburden



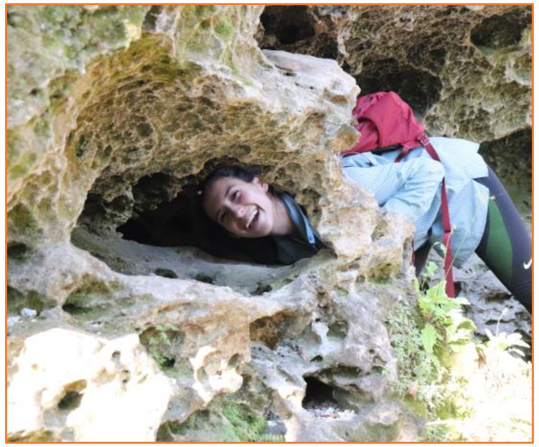


Photo: Exposed Karst near Gainesville, FL.
By: Ryan Shamet (Personal archive)

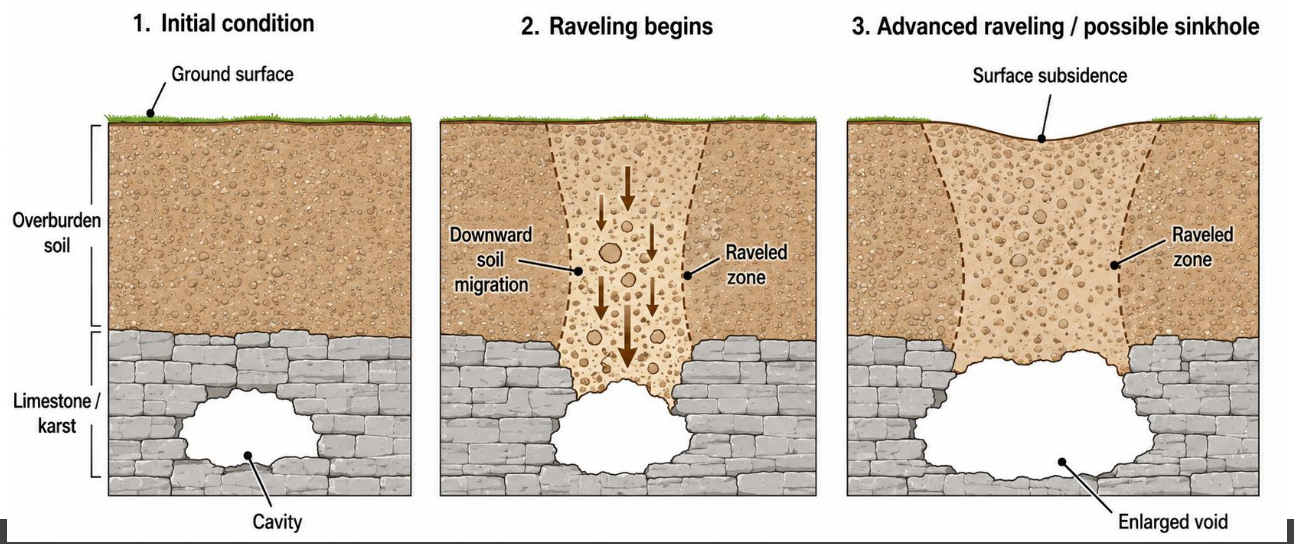
Cone Penetration Test (CPT)

✓ Provides clean drinking water to the state.

✗ Creates a landscape vulnerable to sinkholes.

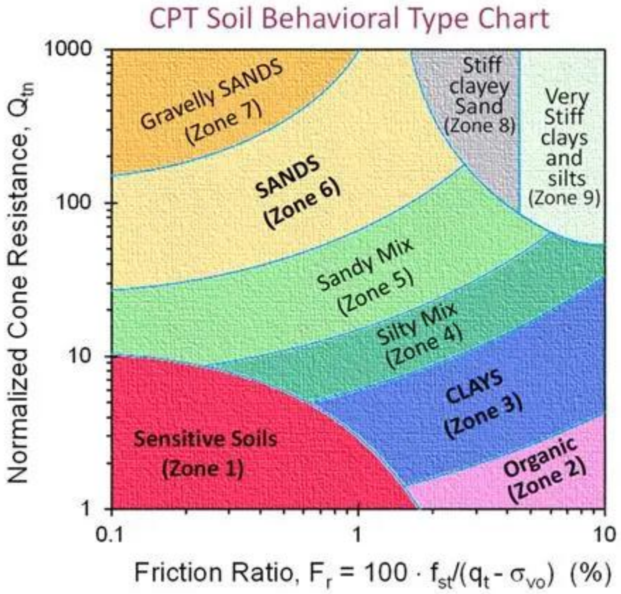
Project Background

- The **<u>sinkhole index (SRR)</u>** and **<u>raveling chart</u>** were developed from the previous FDOT-funded project, entitled "**Development of a Sinkhole Risk Evaluation Program**" (2019).
- Evaluate and validate previously created sinkhole indices using a large database, validate and evaluate the performance of the SRR through the new datasets (different geological formations and geotechnical conditions). In the FDOT-funded project, **Validation and Update of the Sinkhole Index – Phase 1**".
- **Phase 2: Testing and Validation of SRR through Numerical and Physical Testing.** Correlation of Index for Grout Take Estimates (mitigation)

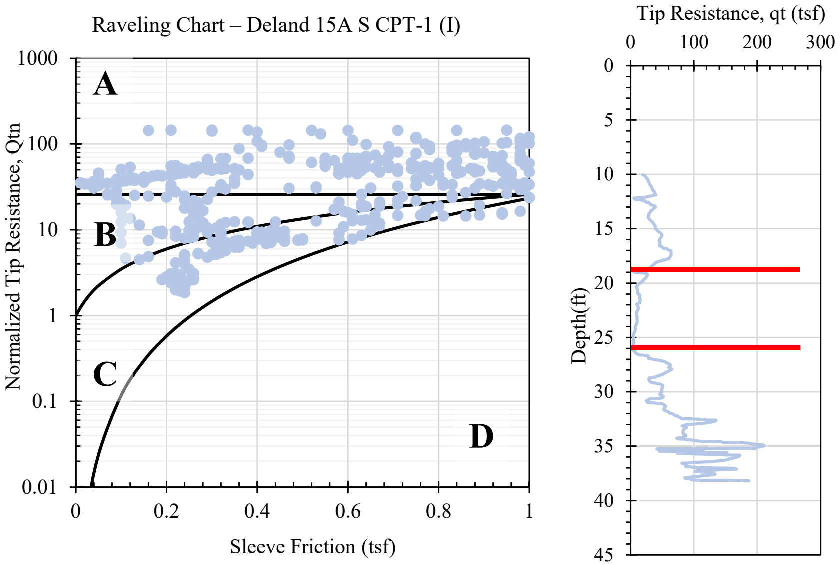


CPT-based Raveling Chart

CPT Soil Behavioral Type Chart (Robertson 2009)

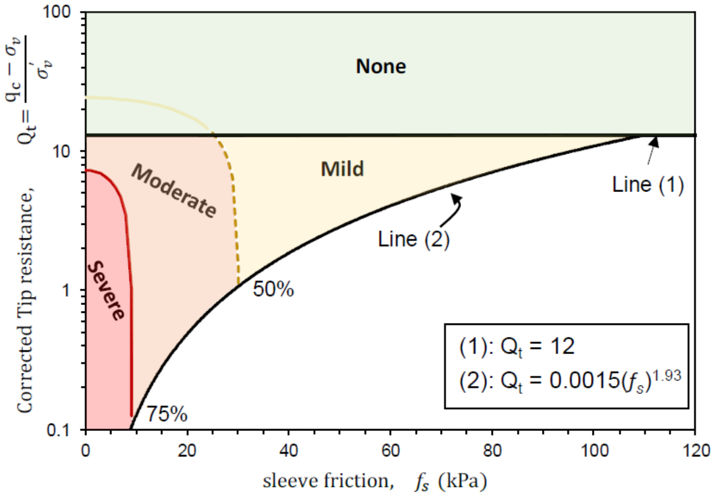


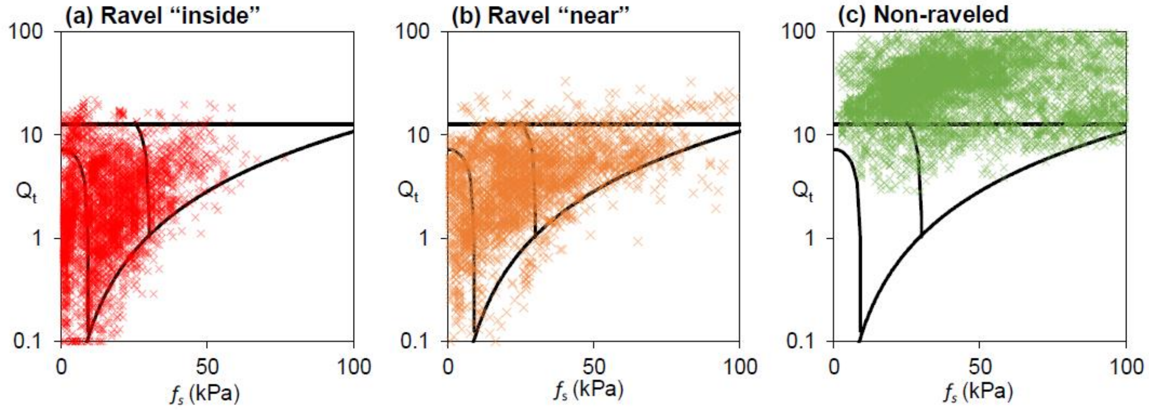
Raveling Chart – Version 1 (Nam 2018)



Zones of Raveling Chart: A – Not Raveled, B- Raveled, C- Severely Raveled, D – Out of Range

Raveling Chart – Version 1 (Nam & Shamet, 2020)





Sinkhole Indices from Cone Penetration Tests

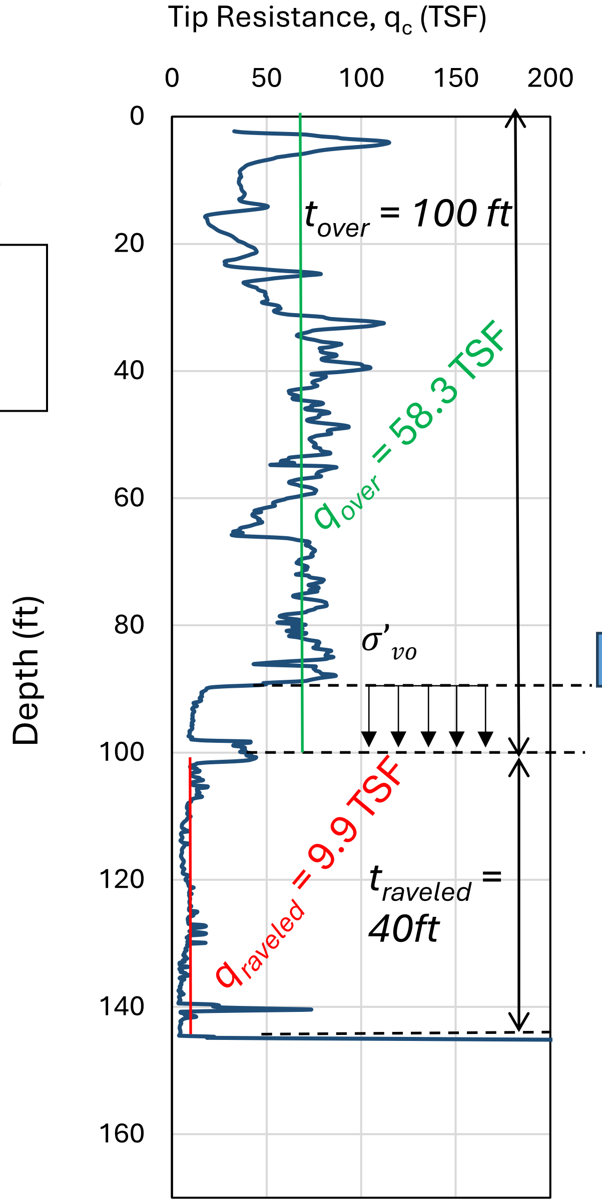
Raveling Index (RI)

$$RI = t_{ravel}/t_{over}$$

$$RI = \mathbf{0.4}$$

Foshee and Bixler (1994)

A simple, dimensionless measure but essentially ignores soil strength



Sinkhole Resistance Ratio (SRR)

Nam et. al - FDOT: BDV24-977-17

$$\mathrm{SRR} = \left(\frac{q_{over} + q_{ravel}}{100 * \sigma'_{vo}}\right)\left(\frac{t_{over}}{t_{ravel}}\right)$$

SRR ⇧ = "**safer**" against sinkhole formation

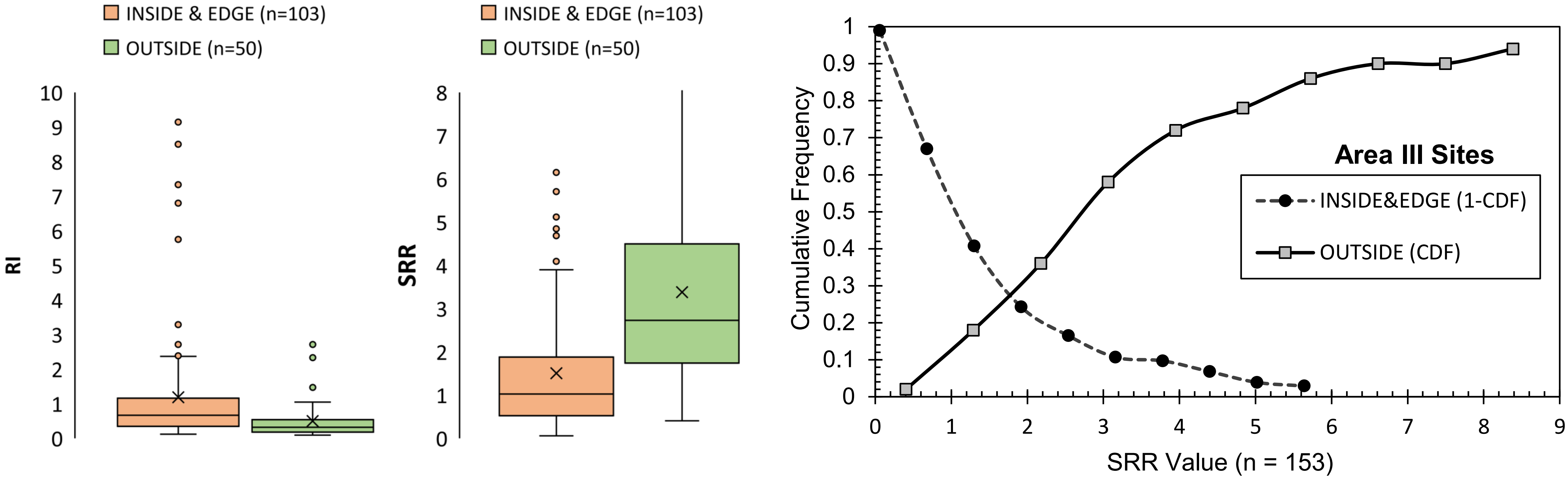
where:

q_{over} = average q_t measured in overburden soils (TSF)
q_{ravel} = average q_t measured in Raveled soils (TSF)
σ'_{vo} = effective vertical stress at depth raveled soils start (TSF)
t_{over} = thickness of overburden (ft)
t_{ravel} = thickness of raveled zone (ft)
q_t = Corrected cone tip resistance (corrected for p.w.p)

$$SRR = \left[\left(\frac{100'}{40'}\right) * \left(\frac{58.3 + 9.9}{2.74 * 100}\right)\right]$$

$$\boldsymbol{SRR = 0.622}$$

SRR Severity Threshold: Area III Sites (Example)



An **SRR value of 2.0** may be a threshold value to be used in better understanding the subsurface vulnerability to sinkhole formation.

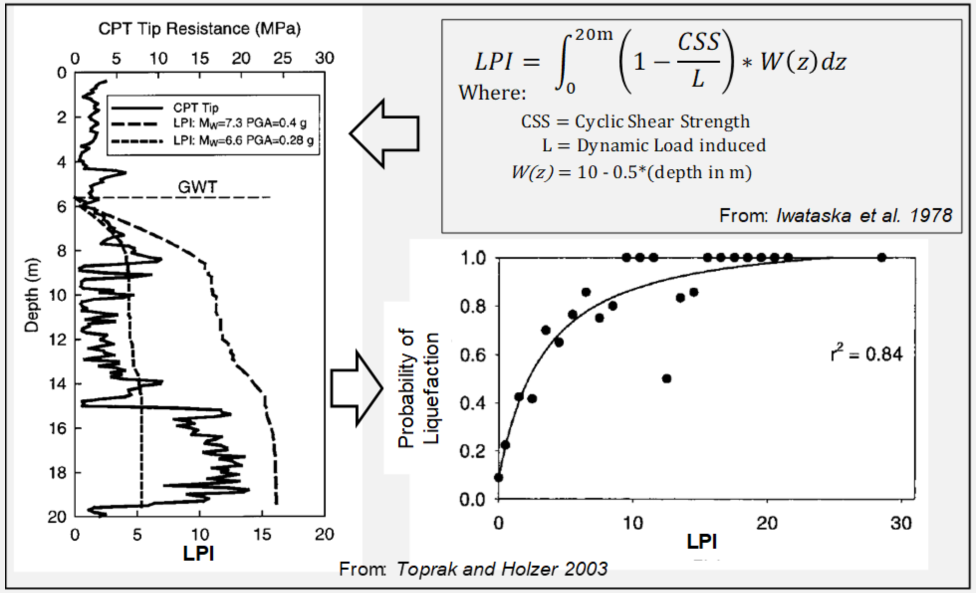
Probabilistic Analysis for Sinkhole Index

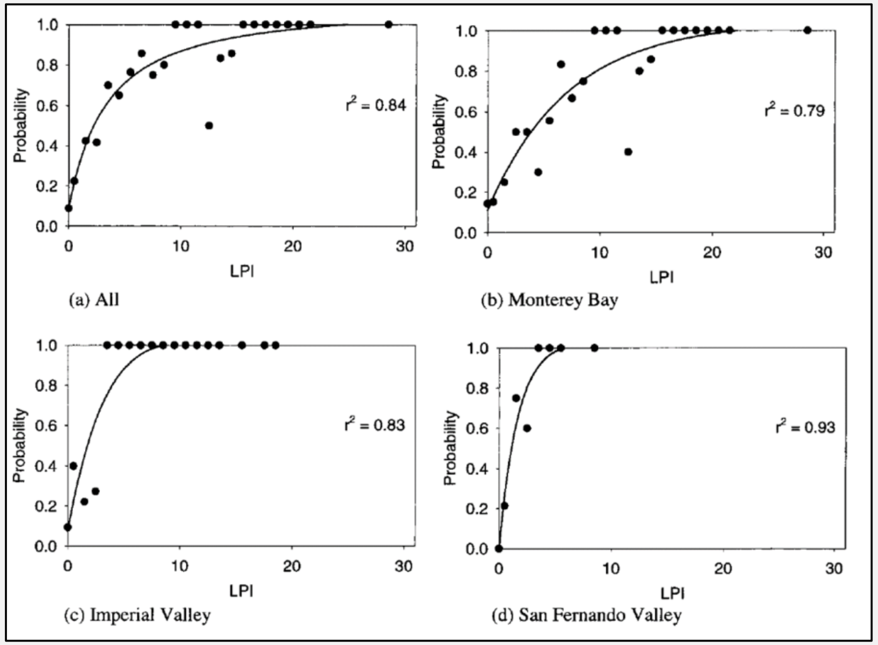
CPTs categorized based on proximity to sinkhole [IN/EDGE vs **OUTSIDE**]

- Raveling Chart used to identify parameters
  - Indices Calculated (SRR & RI)
    - Histograms & Frequency analysis of indices

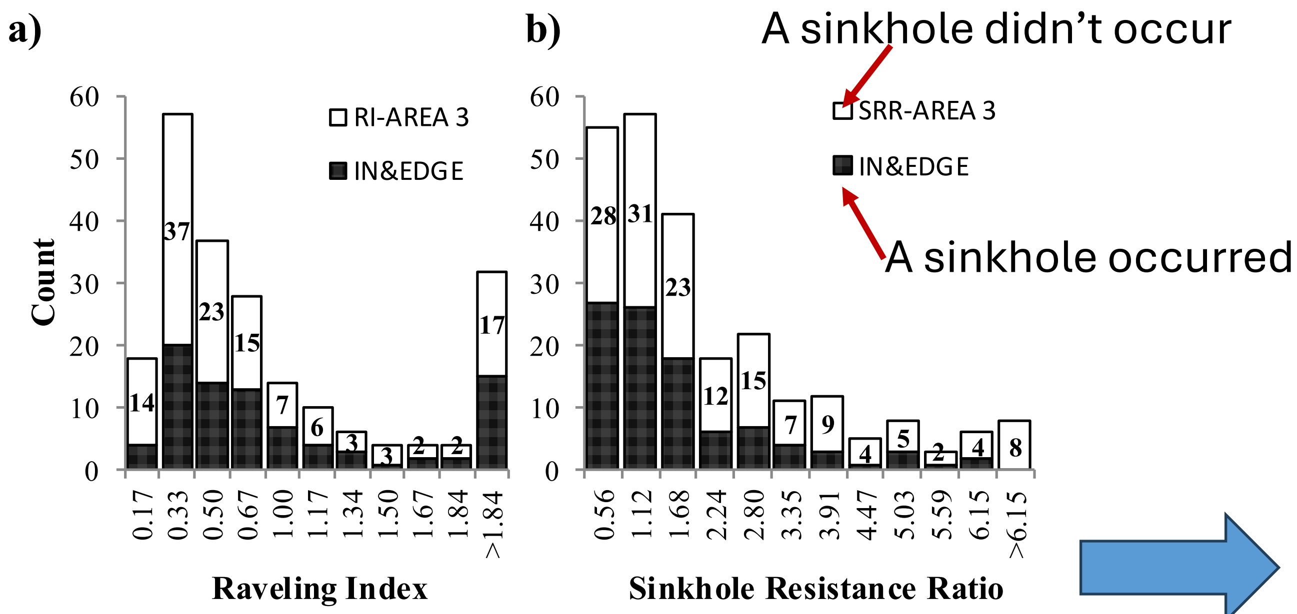
      → Probability = *f* (sinkhole occurrence)

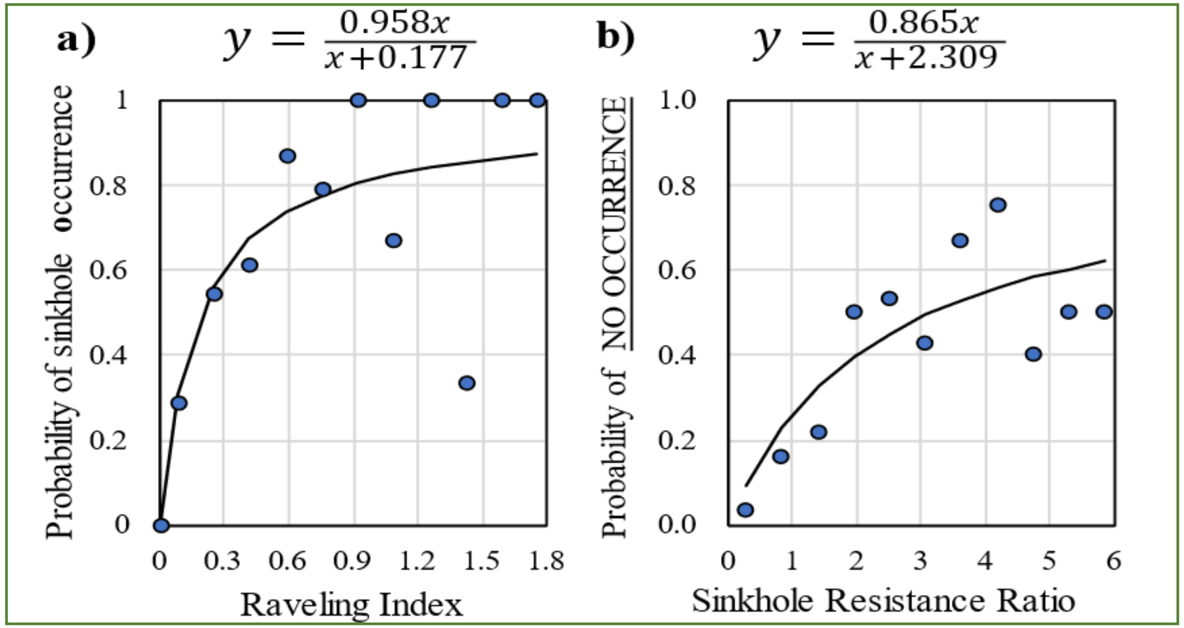
Similar to Liquefaction Potential Index (LPI): ***[Toprak and Holzer 2003]***

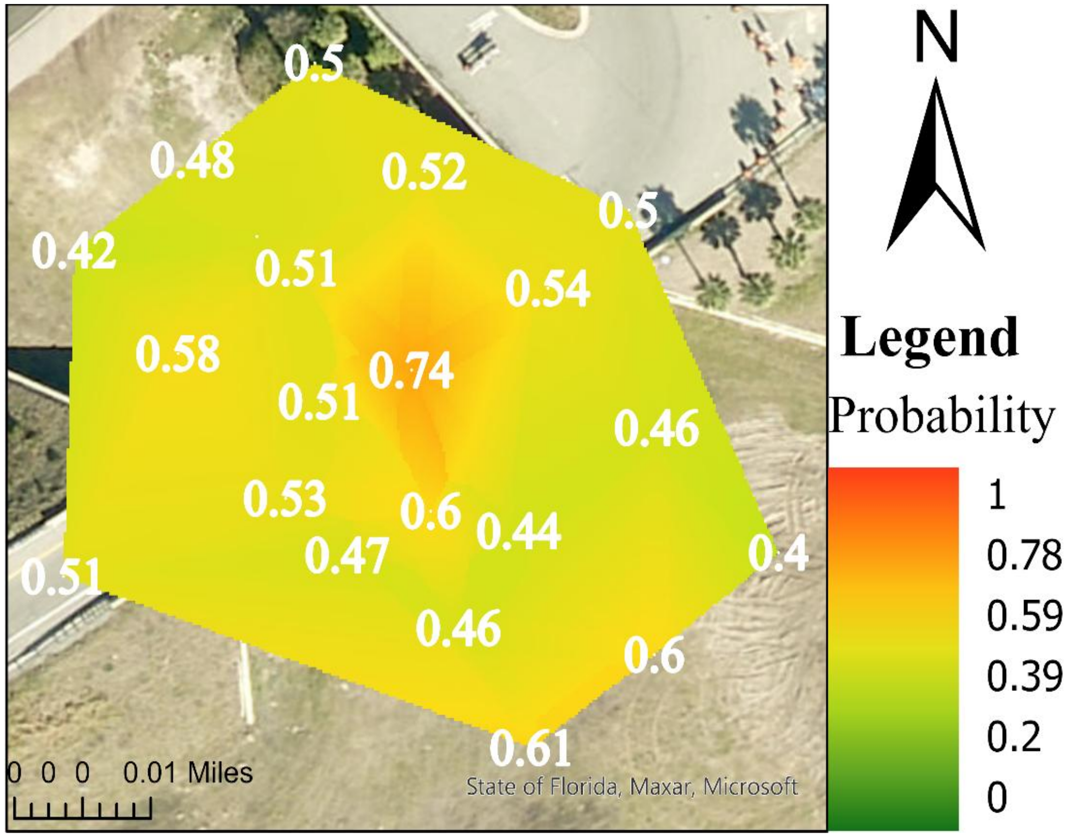




AREA 3: (Cover Collapse)



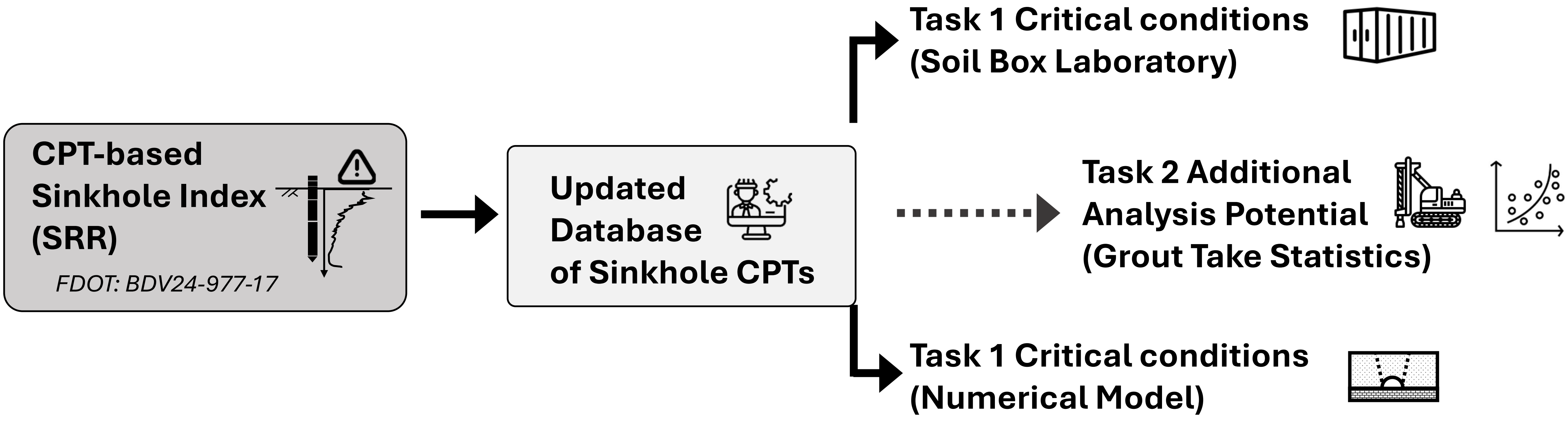




Data for **Area 1** (solution-type sinkhole) were evaluated, but the results were inconclusive due to the limited amount of available data.

Project Objectives (Phase 2)

- Validate the **sinkhole index** via large-scale sinkhole simulation testing
- Validate **sinkhole index thresholds** proposed in Phase 1, using finite element (FE) modeling, and large-scale sinkhole testing using LSSB
- Investigation into Sinkhole Indices’ ability to **estimate grout volume** (empirical)

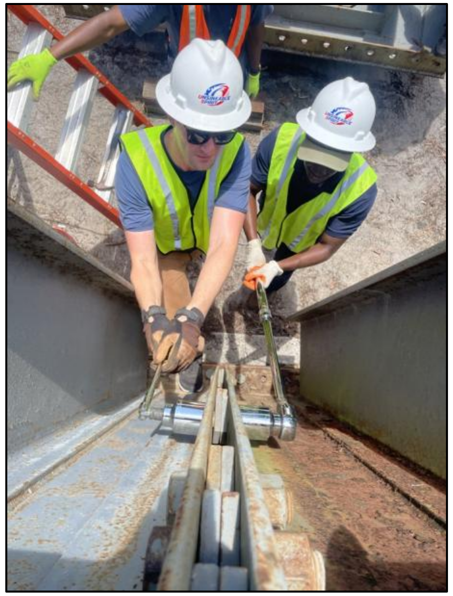


Sinkhole Physical Testing using the LSSB

Large-Scale Soil Box (LSSB) Testing at UNF

- Pressure cell array
  - Density, arching and horizontal stress during collapse.
- Inflatable void options (yacht fender)
- Boundary conditions (plastic liner and waterproof)

Simulation of large-scale sinkhole raveling and collapse to identify the critical ratio of encountered stratigraphy geometry and reduction of soil resistance due to sinkhole formation (SRR parameters).



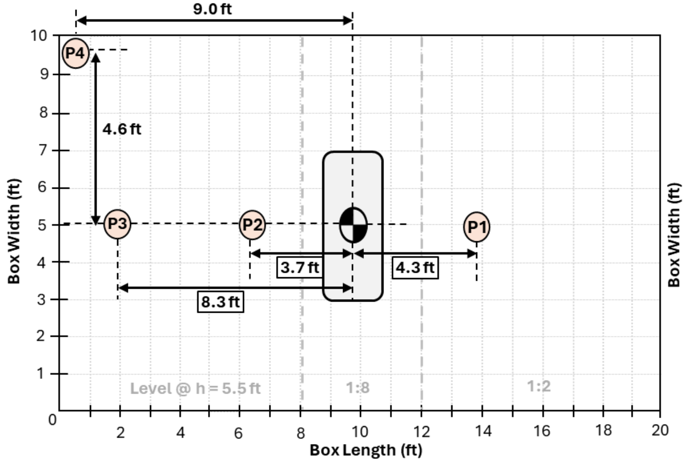
Anchors

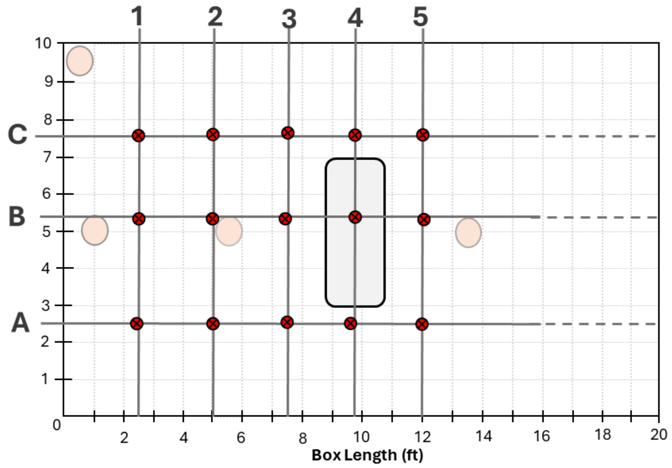
GEOKON

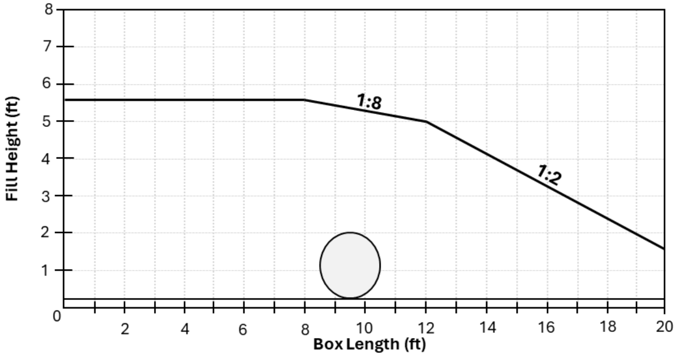
Prior to Testing

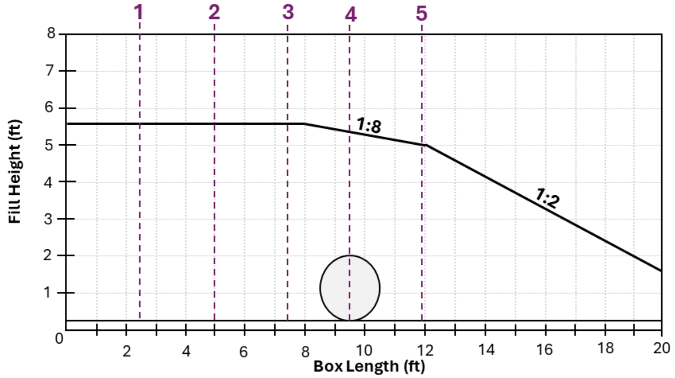
A-3 Soil, medium dense, <u>collapse has yet to occur</u> for <u>**80 days**</u> (Sept 29th to Dec 18th)

Layout in the Large-Scale Soil Box (LSSB) Testing





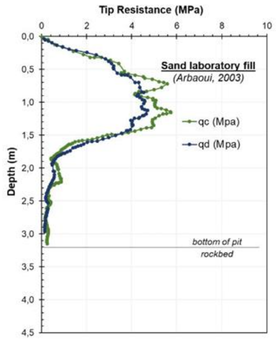




Deflate-able Fender

GEOKON

(DCPT PANDA®)



SRR = *f*(cone tip resistance) → q_c

Dynamic CPT → q_d

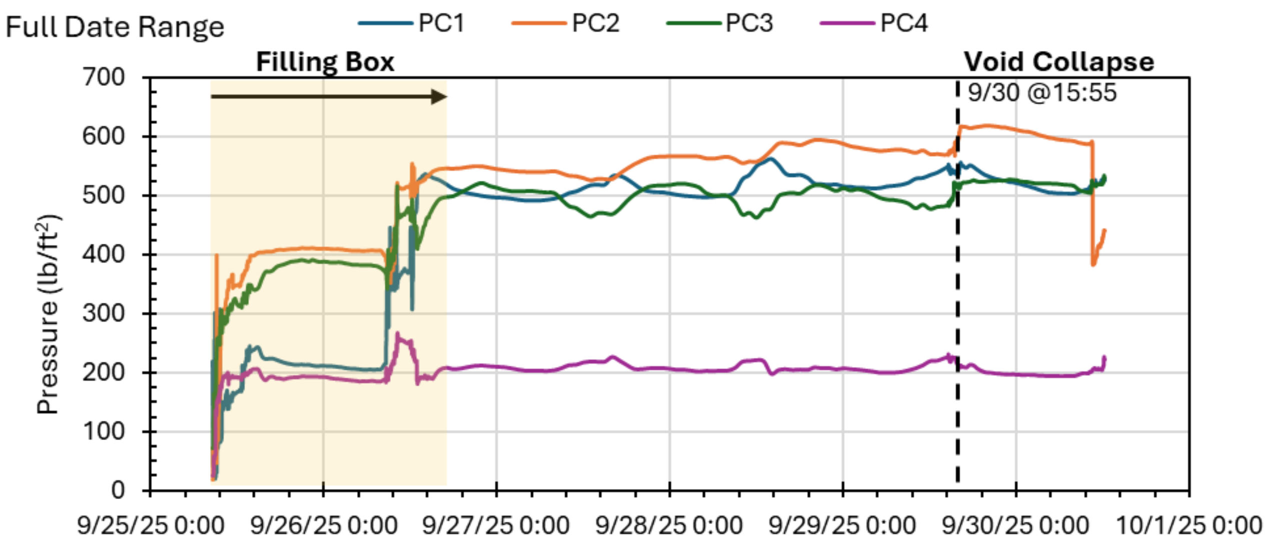
$$q_c = 0.87 q_d \text{ to } 1.11\, q_d$$

Benz-Navarrete et. al (2020)

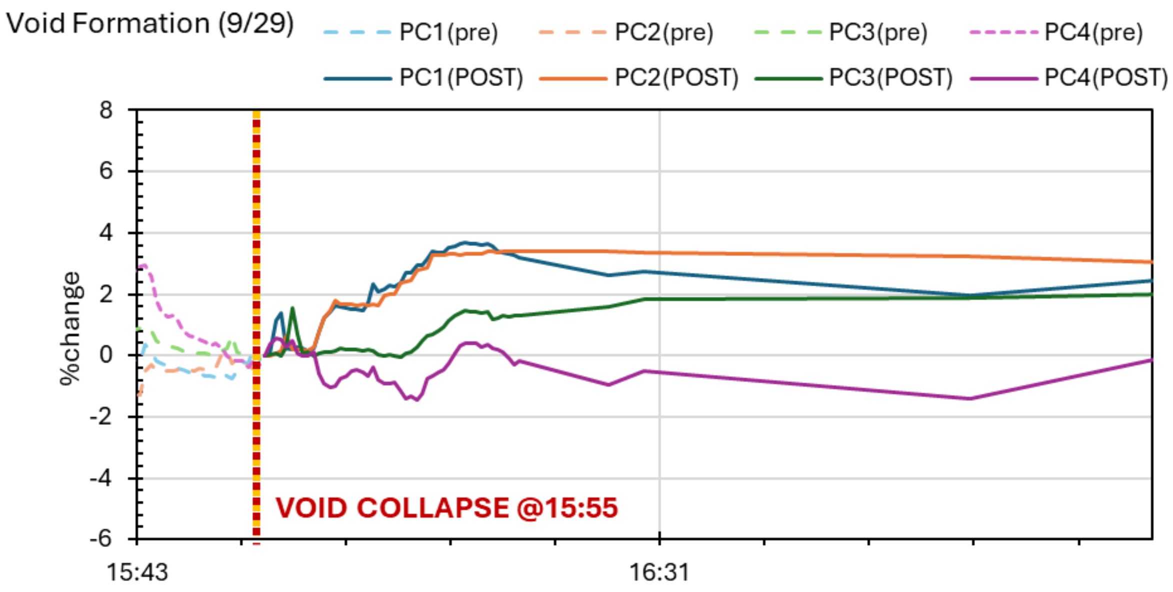
Steps:

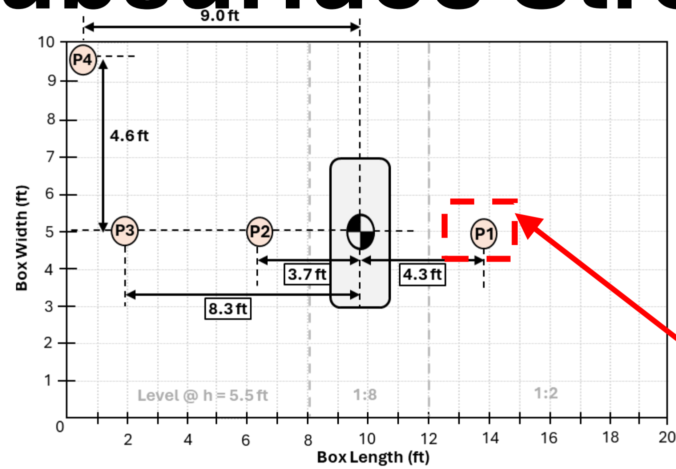
1. Subsurface void: installation of in situ (controllable) volume
2. Sandy Soil fill and density check (baseline)
3. reference q_c profiling (DCPT PANDA®)
4. Post-collapse forensics → **Sinkhole Indexing**

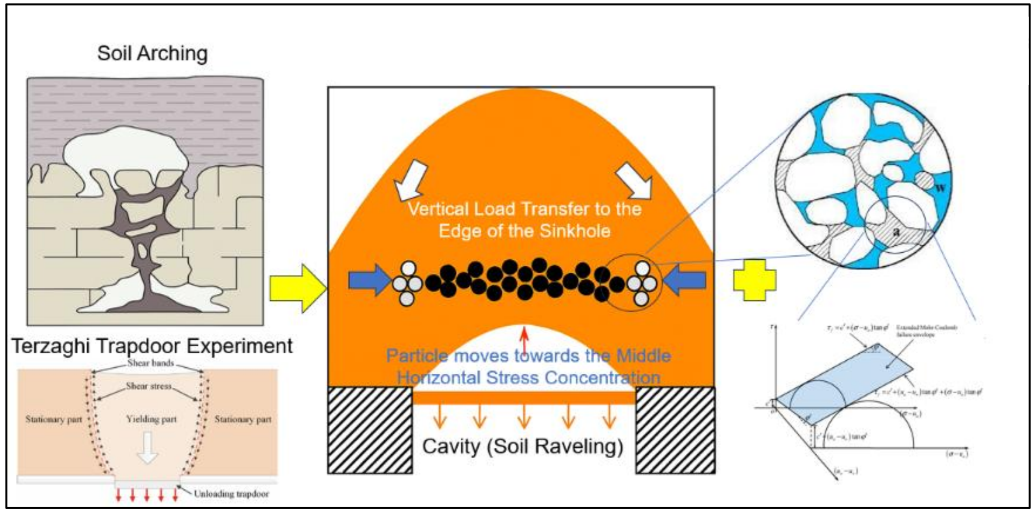
Measurement of the Subsurface Stresses



Full range of results from pressure sensors

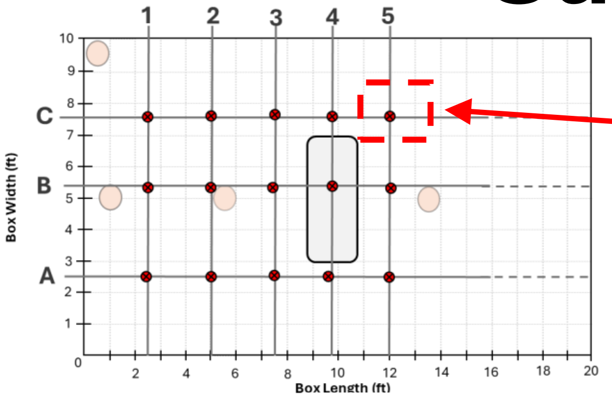


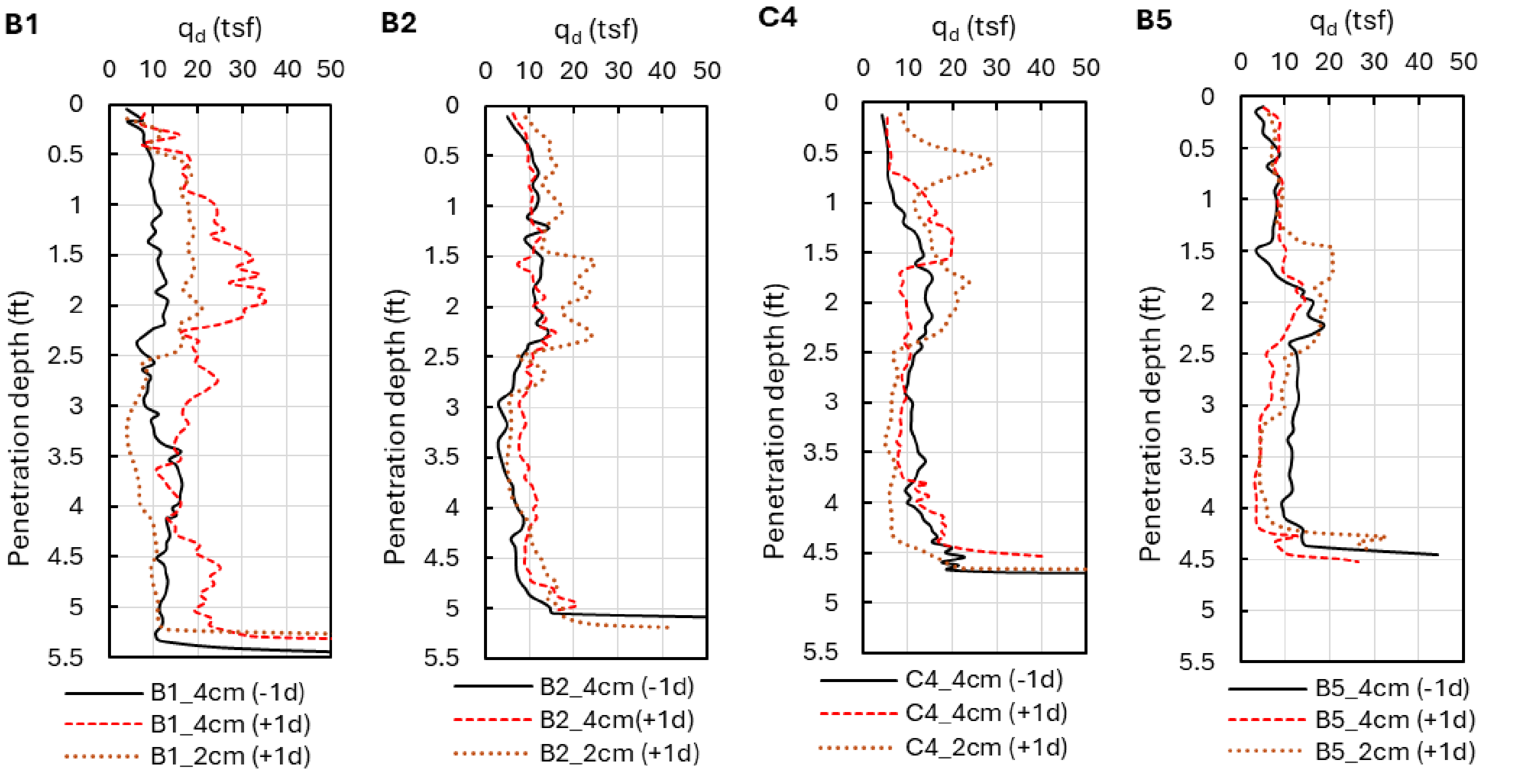




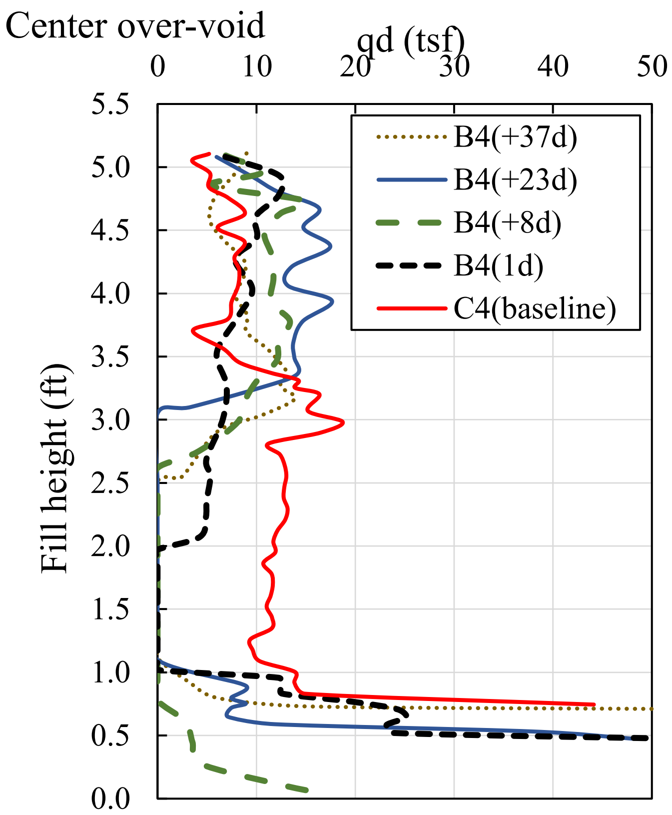
Normalized pressure sensor reading collapse of void, showing %change in sensor reading with baseline when void was collapsed. *Stress redistribution in the overburden soil*

Subsurface Raveling (dCPT)





Array of dCPT profile comparison of pre-collapse (-1 day) and post-collapse (+1 day) using both 4-cm^2 sacrificial cone and 2-cm^2 standard cone



dCPT profiles over time performed over the formed void

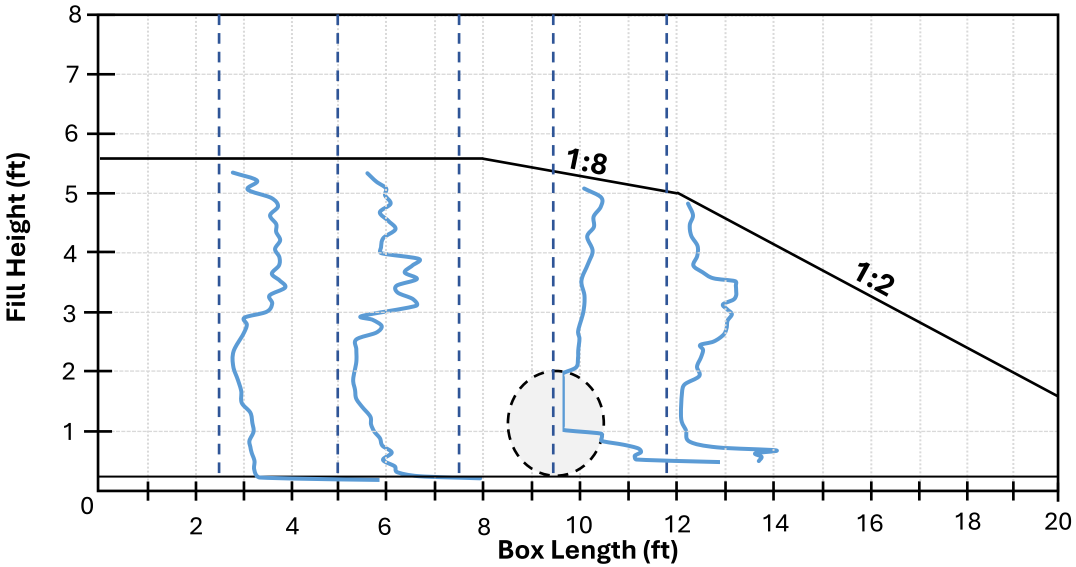
Raveling occurs over time.

Calculated SRR from Large-scale Soil Box Test

- Simulated SRR values still show "critical" (i.e., SRR < 2.0) values around the void, even with no collapse at the surface. SRR also changes with time.

Day	$q_{d,over}$(tsf)	$q_{d,ravel}$ (tsf)	γ_m (pcf)	H_{over} (ft)	H_{ravel} (ft)	σ'(psf)	SRR^{dCPT}
+1	7.55	0.00	95	3.13	0.95	297.2	1.7
+8	10.25	0.48	95	2.59	2.05	246.1	1.1
+23	13.40	0.33	95	2.05	2.05	194.8	1.4
+37	8.87	0.78	95	2.59	1.50	246.1	**1.4**

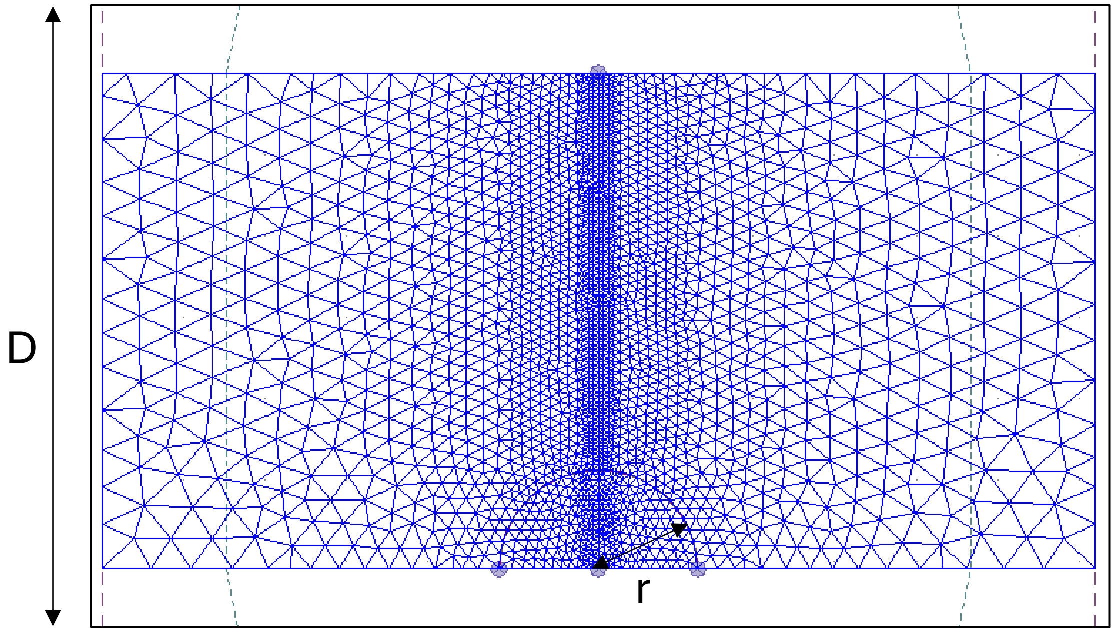
$$\mathrm{SRR} = \left(\frac{q_{over} + q_{ravel}}{100 * \sigma'_{vo}}\right)\left(\frac{t_{over}}{t_{ravel}}\right)$$



Questions still need to be answered:

- What is the threshold or range of confidence for safe or vulnerable?

Numerical Modeling of Sinkhole Resistance Ratio



Model Domain and Meshes

Model Details – Geometry and Material Properties

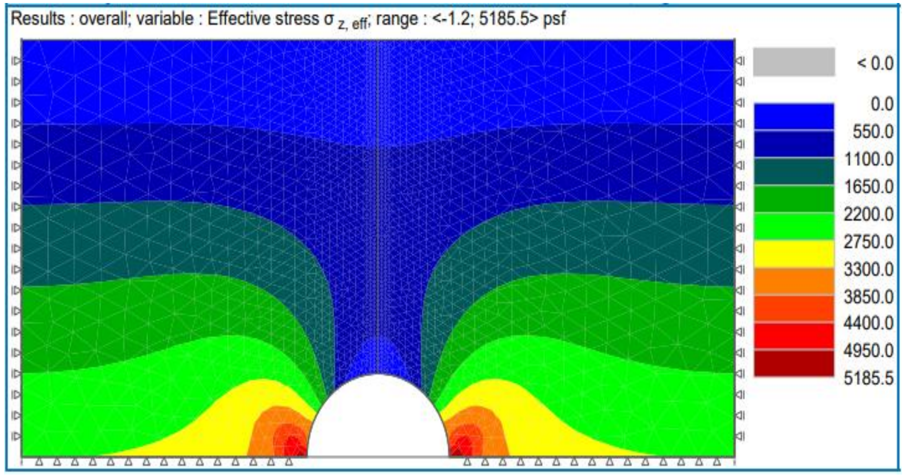
Parameter	Unit	Value	Condition
Soil behavior model	-	Mohr-Coulomb	Constant
Depth (D)	ft	10, 20, 30	Varies
Void radius (r)	ft	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Varies
Friction angle (ϕ)	Degrees (°)	0, 16, 32	Varies
Cohesion (c)	psf (lb/ft^2)	2000	Constant
Unit weight (γ)	pcf (lb/ft^3)	130	Constant
Poisson's ratio (υ)	Dimensionless	0.42	Constant
Elastic modulus (E)	psi (lb/in^2)	1200	Constant
Dilation angle (ψ)	Degrees (°)	0	Constant

Boundary Conditions

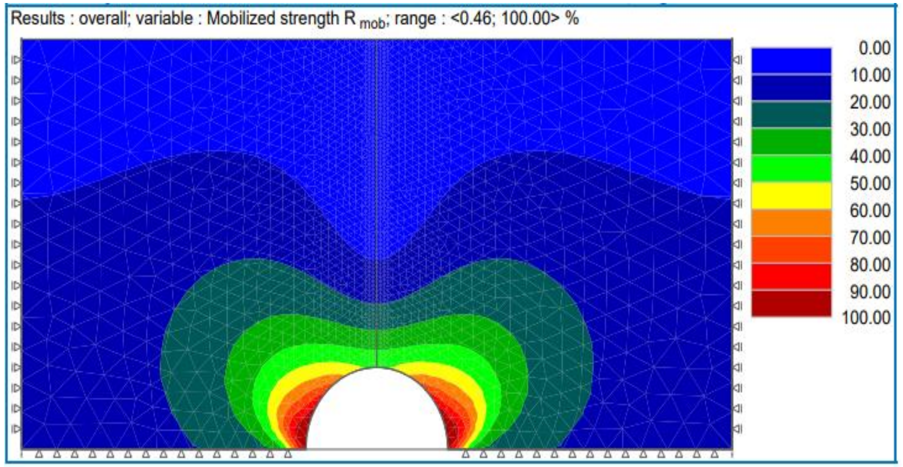
Location	Support type	
	Direction X	Direction Z
Vertical walls	Fixed	Free
Bedrock surface	Fixed	Fixed

Sensitivity Analysis – Overburden Thickness and Friction Angle

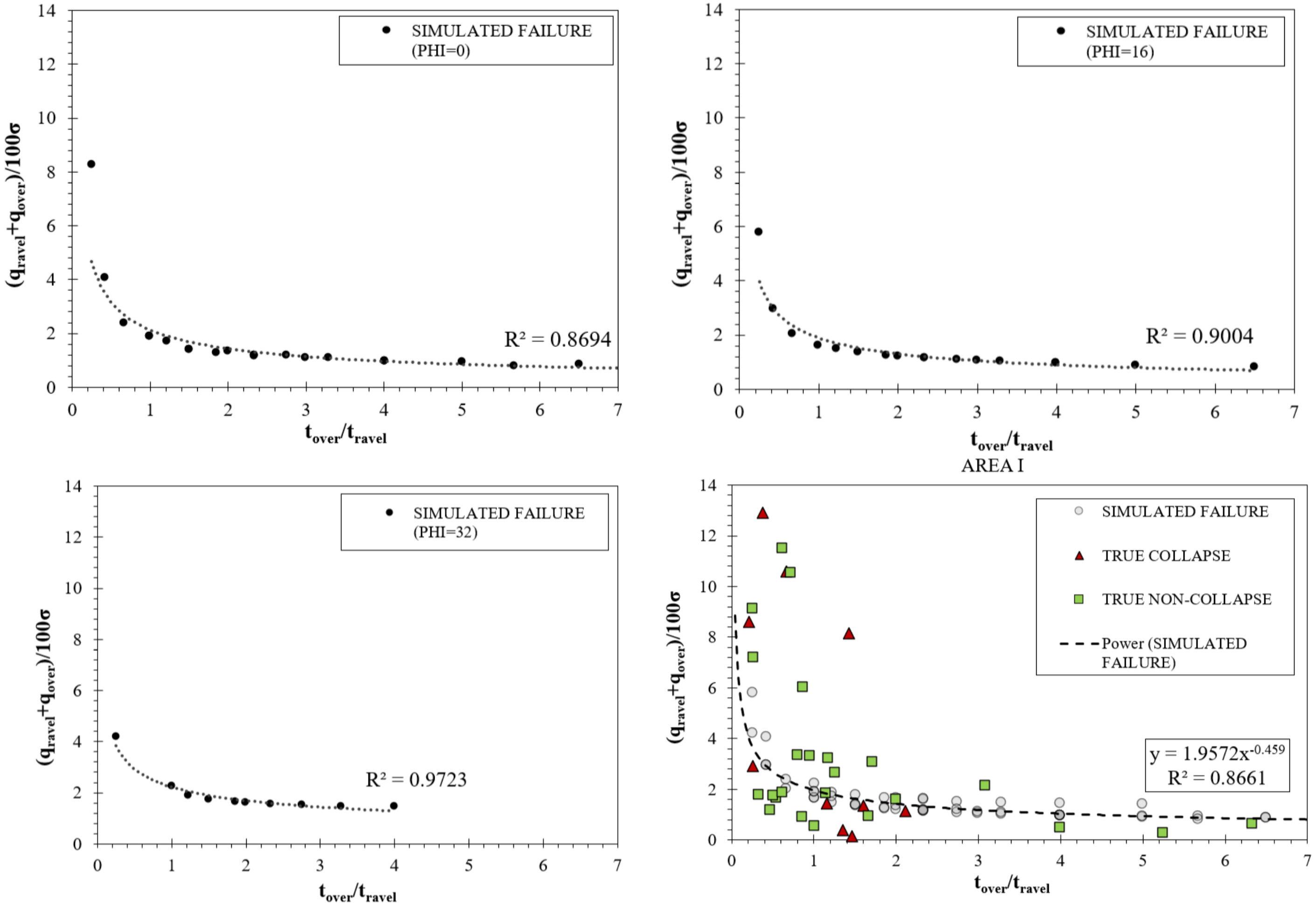
Effective Stress with the Presence of Void



Mobilized Strength with the Presence of Void



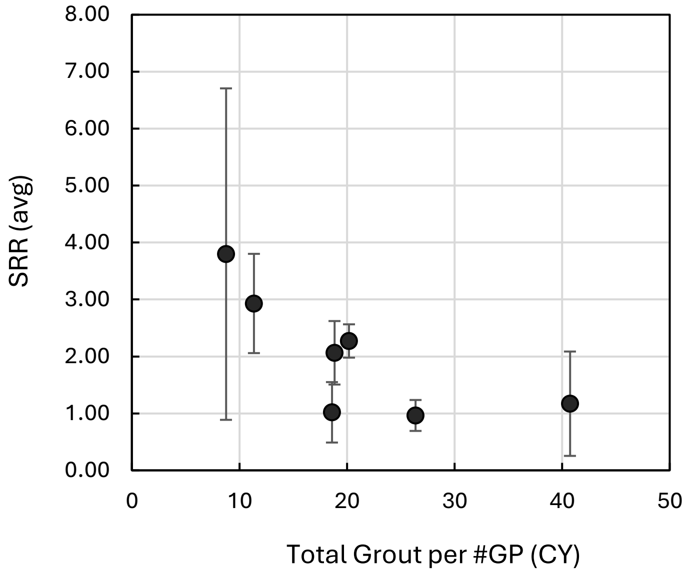
Stress redistribution in the overburden soil



Stability of **Area I Sinkhole** with various thicknesses and friction angles (from 0 to 32°) of overburden soil

Mitigation: The Sinkhole Index and the Grout-take Volume

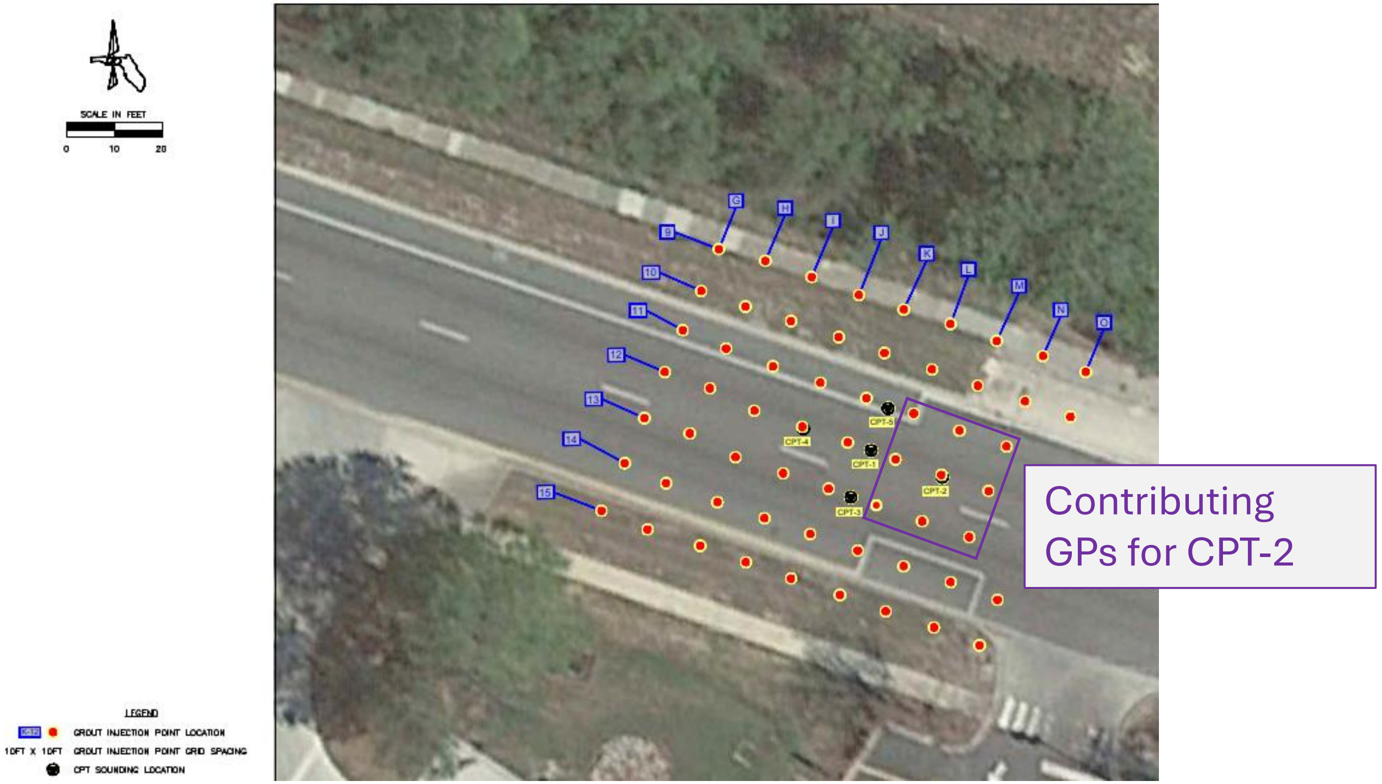
Site ID	Sinkhole Type	County (District)	lat	long	# Grout Points	Total Grout Volume (CY)
Wekiva Parkway Sec.6 STA 775 2019	Collapse	Lake (5)	28.812882°	-81.464594°	274	3109
SR50 Groveland 2020	Depression	Lake (5)	28.561992°	-81.858400°	60	1130
I4 Rest Area 2011	Collapse	Polk (1)	28.174157°	-81.767350°	27	1100
US27 Polk S 2010	Collapse	Polk (1)	27.847627°	-81.585336°	19	384
US27 Polk N 2010	Collapse	Polk (1)	27.861023°	-81.588964°	14	260
Wekiva Parkway Sec.6 STA 1130	Collapse	Lake (5)	28.813058°	-81.463690°	203	5354
US19 Sealawn 2011	Depression	Hernando (7)	28.478269°	-82.611443°	65	569

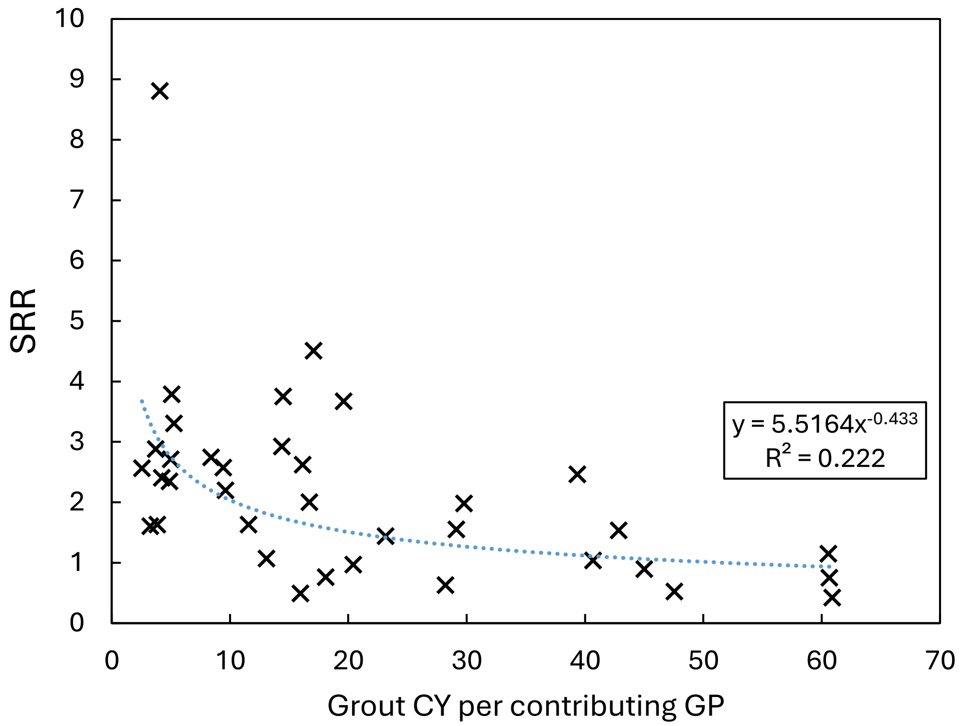


End of Project (2025): Forty-Four (44) sites

Using an Individual CPT-based Assessment

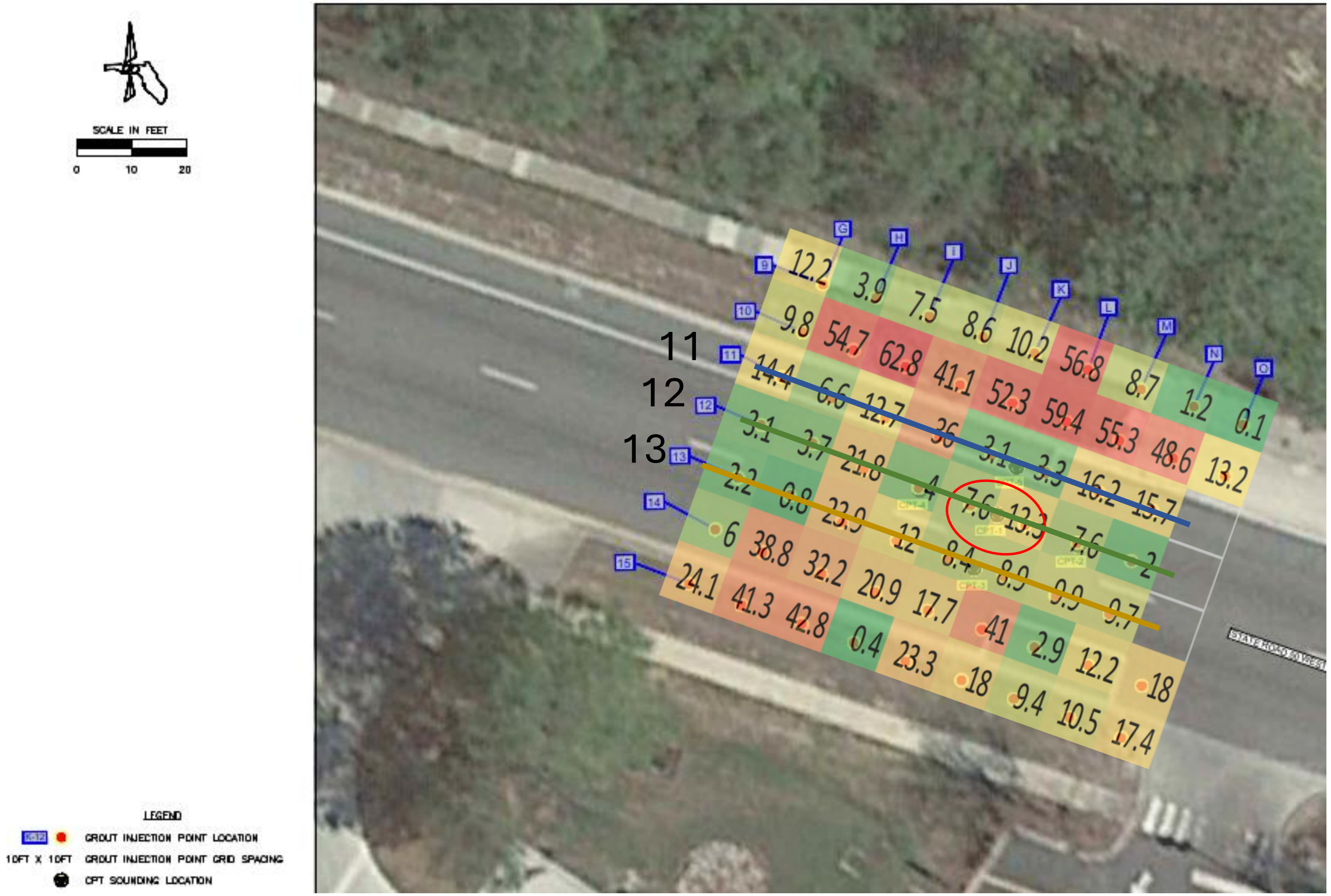
- SRR calculated from individual CPT
- Summation of Grout Volumes from within the *vicinity* of CPT.
  - Nearest Neighbor
  - Even Split
  - Tributary Distance



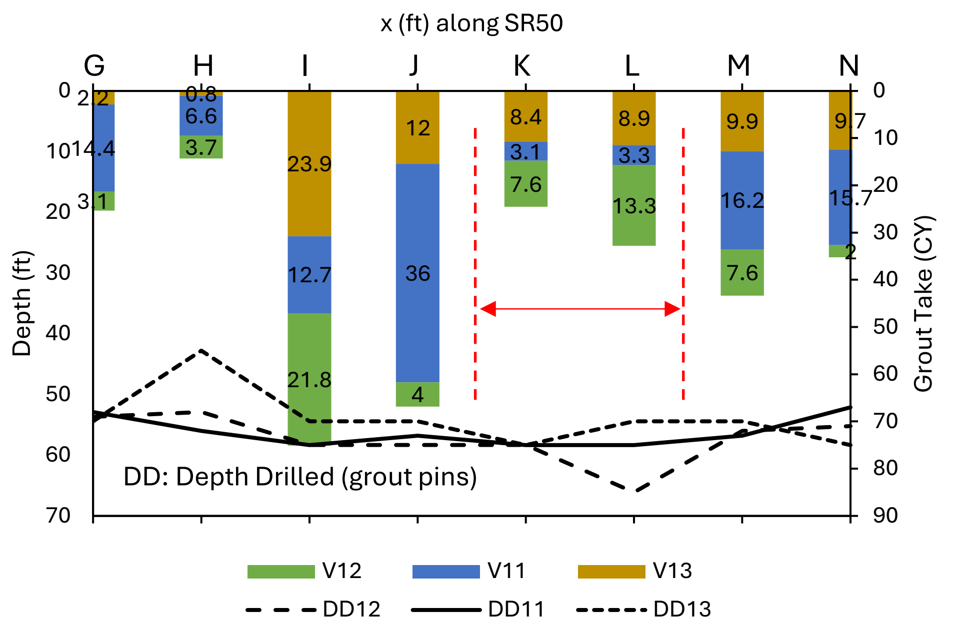


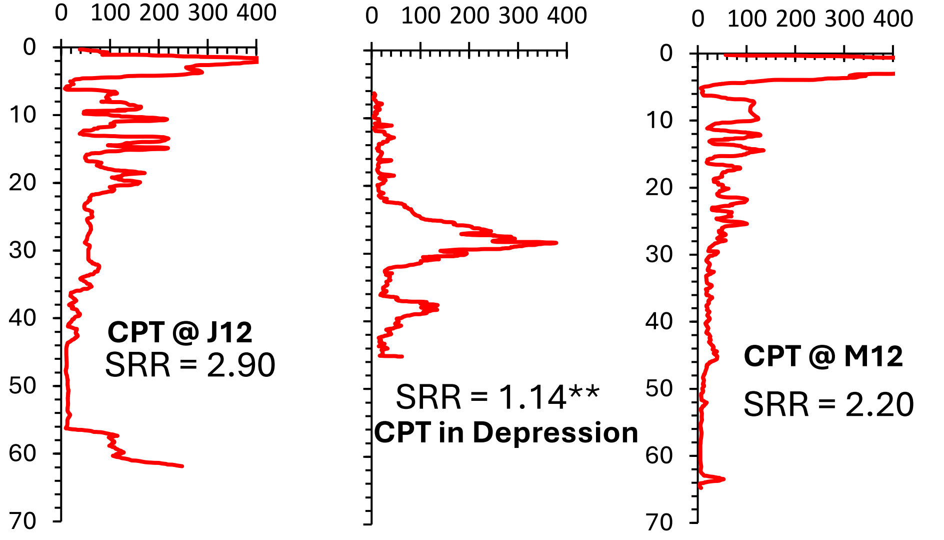
- Tributary Distance and Area?
- Grout take as a function of depth / stratigraphy?

Using an Individual CPT-based assessment



Grout Takes along Line 12, Line 11, Line 13

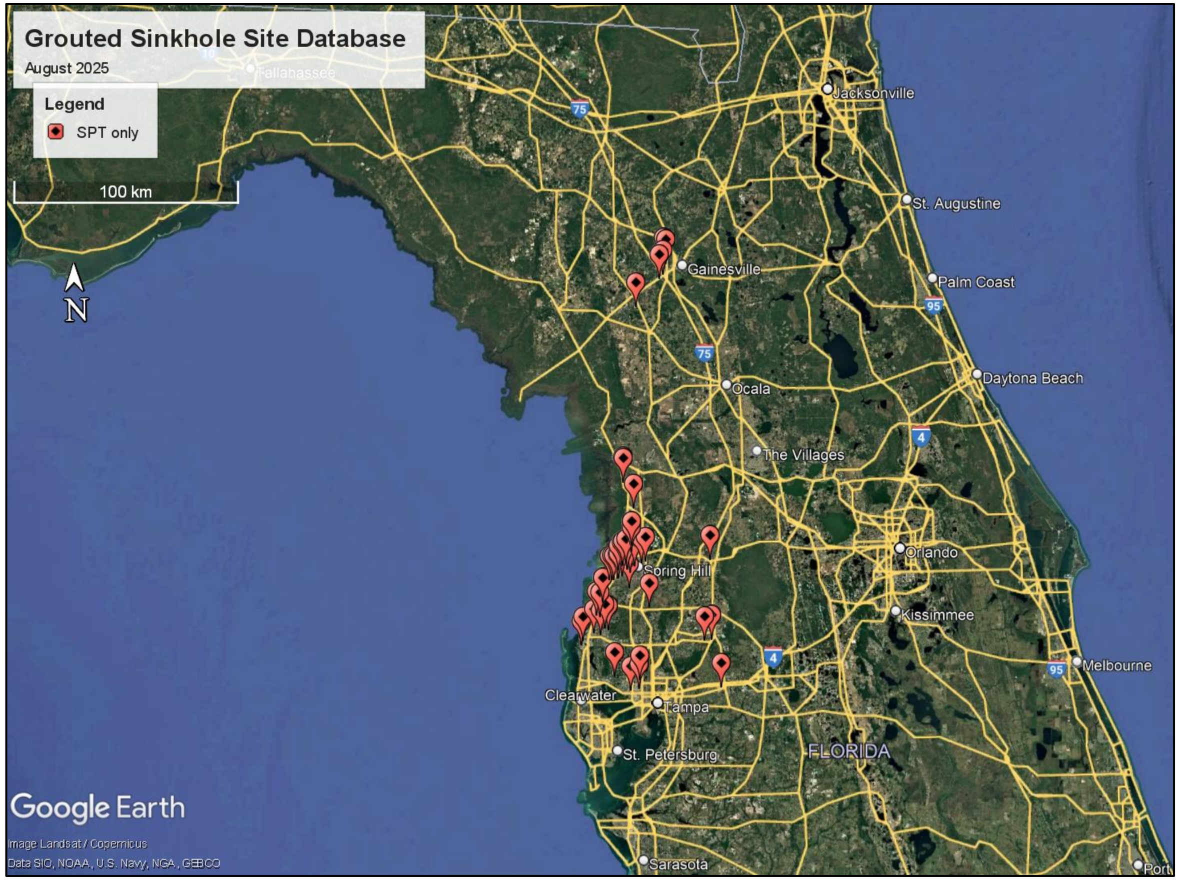




Variable Karst = Grout Takes (volume) do not correspond with severe CPTs or surface features

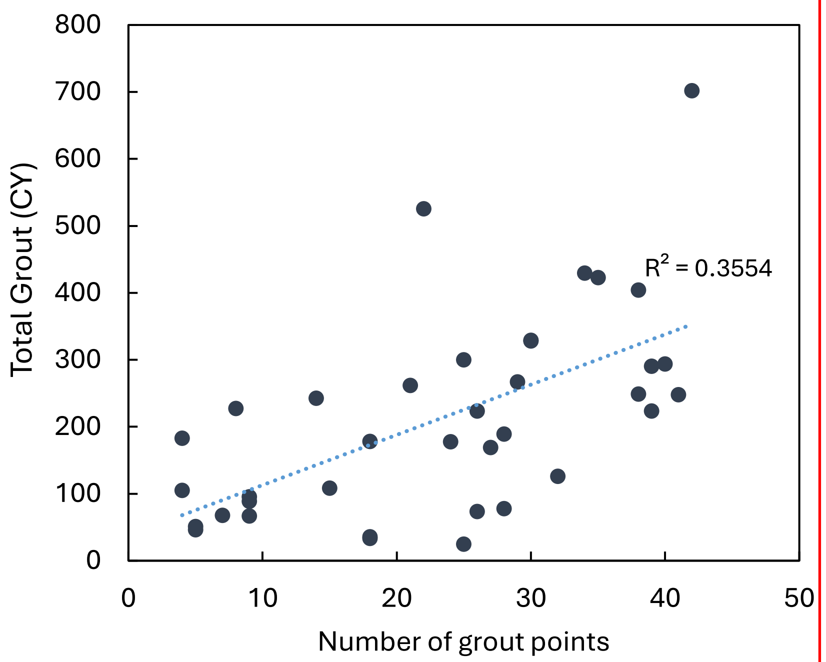
Using a Site-based Assessment

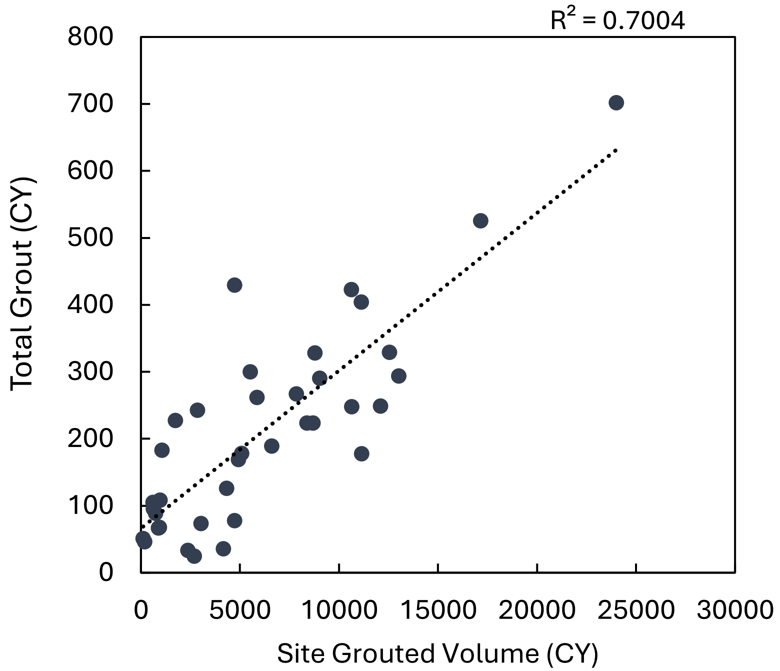
Site ID	Sinkhole Type	County (District)	lat	long	# Grout Points	Total Grout Volume (CY)	Total Grouted Length (ft	Grouted S.A (ft2)
I4 Rest Area 2011	Collapse	Polk (1)	28.174157°	-81.767350°	27	1100	3033	2827
US27 Polk N 2010	Collapse	Polk (1)	27.861023°	-81.588964°	14	260	1428	1590
US27 Polk S 2010	Collapse	Polk (1)	27.847627°	-81.585336°	19	384	1779	5655
SR574Euclid 2010	Collapse	Polk (1)	28.010611°	-82.156664°	4	183	288	400
Wekiva Parkway Sec.6 STA 1130	Collapse	Lake (5)	28.813058°	-81.463690°	203	5354	11929	15200
2019	Collapse	Lake (5)	28.812882°	-81.464594°	274	3109	9900	9325
SR50Hernando 2020	Collapse	Hernando (7)	28.508070°	-82.197500°	8	227	473	800
US19Goshawk 2020	Collapse	Citrus (7)	28.811662	-82.576695	15	109	560	700
US98Oakvillage 2020	Collapse	Citrus (7)	28.711130°	-82.532136°	25	300	4144	900
3534NW7th 2021	Collapse	Alachua (2)	29.658701	-82.375767	4	105	222	300
SW43RD 2018	Collapse	Alachua (2)	29.617465	-82.389362	5	46	185	144
SR52PascoTrails1 2018	Depression	Pasco (7)	28.324650°	-82.468567°	9	67	540	400
SR56Pasco 2018	Depression	Pasco (7)	28.508070	-82.197500	9	89	456	400
US301Pasco311 2019	Depression	Pasco (7)	28.198045°	-82.195455°	9	96	385	400
SR50 Groveland 2020	Depression	Lake (5)	28.561992°	-81.858400°	60	1130	4079	2000
i4Mango 2019	Depression	Hillsborough (7)	28.005706°	-82.303572°	14	243	722	1500
US19 Sealawn 2011	Depression	Hernando (7)	28.478269°	-82.611443°	65	569	1813	5400
Mazzuco-Alshin.11	depression	Hernando (7)	28.54207	-82.54417	42	702	3439	7920
US19HomosassaMarine 2019	Depression	Citrus (7)	28.816911	-82.577309	7	68	254	700
SW63RD BLVD 2017	Depression	Alachua (2)	29.600785	-82.406163	5	51	146	100
Corr.10	insurance	Pasco (7)	28.196287	-82.763232	18	34	500	2305
Curcio-berry.09	insurance	Pasco (7)	28.178882	-82.770352	26	74	695	3063
Grotto.11	insurance	Pasco (7)	28.426350	82.617890	29	267	2561	2400
Haskell.10	insurance	Pasco (7)	28.294560	-82.702340	32	126	1163	3220
Lopez.12	insurance	Pasco (7)	28.244560	-82.665680	39	224	1559	5670
McCarthy.10	insurance	Pasco (7)	28.225700	-82.714920	34	430	1134	3838
Sears.12	insurance	Pasco (7)	28.238860	-82.650330	35	423	1910	5260
Siberman.11	insurance	Pasco (7)	28.432780	-82.624190	21	262	1027	3240
Stacy.12	insurance	Pasco (7)	28.431998	-82.643906	24	178	1489	4850
Cardenas.07	insurance	Hillsborough (7)	28.043321	-82.514358	18	36	863	2346
Currie.08	insurance	Hillsborough (7)	28.056960	-82.625450	38	404	2085	5476
Denova.08	insurance	Hillsborough (7)	28.056960	-82.625450	25	25	555	3290
Dexter.08	insurance	Hillsborough (7)	28.290459	-82.686619	39	291	2263	4202
Morejon.12	insurance	Hillsborough (7)	28.002190	-82.555380	18	178	936	2640
Roque.12	insurance	Hillsborough (7)	28.009580	-82.518160	28	78	1307	2738
Bennett.12	insurance	Hernando (7)	28.565860	-82.542973	40	294	1671	8420
Carey.13	insurance	Hernando (7)	28.497370	-82.568970	28	189	1138	4396
Groesbeck.11	insurance	Hernando (7)	28.448620	-82.585820	30	329	2110	4820
McCluskey.08	insurance	Hernando (7)	28.486040	-82.530880	41	248	2315	5090
Oliveria.08	insurance	Hernando (7)	28.489494	-82.583720	22	525	3024	3370
Serafin.08	insurance	Hernando (7)	28.485570	-82.588610	26	224	1498	4076
Simpson.11	insurance	Hernando (7)	28.472864	-82.563504	30	328	1760	4045
Steele.10	insurance	Hernando (7)	28.439424	-82.603208	27	169	997	3600
Wilkinson.11	insurance	Hernando (7)	28.504216	-82.482914	38	249	2088	5950

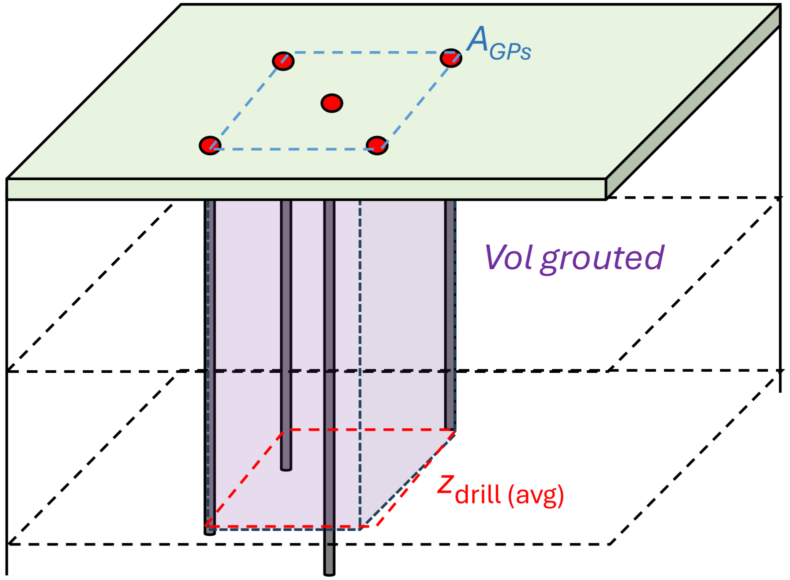


Using a Site-based Assessment

- *Averaged Subsurface indices near sinkhole will show some trend of overall anticipated grout volume at site (n =44).*
  - IF SPT/CPT performed near collapse showed residual soil (where sinkhole already collapsed); removed.
- Stratigraphy Considerations averaged per site (1-4 SPTs per site)





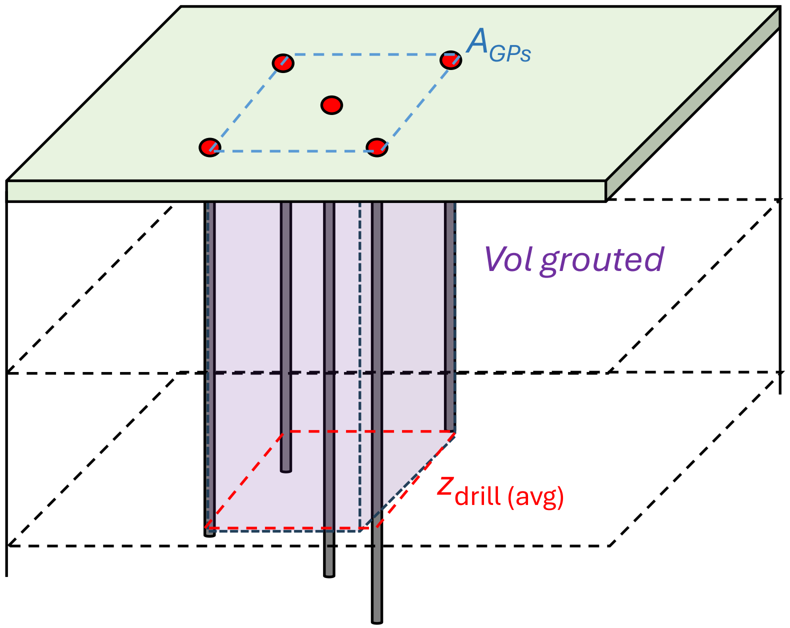


Site Grouted Volume =(Average depth of drilled GPs) x (Surface area of Grout Plan)

Using a Site-based assessment

Grout Variables

- Total Grout Volume
- Number of Grout Points (GPs)
- Grout per GP
- Length of Grout Points
- **Effective Volume of grouted site (CY/CY)**



Geotech Variables

- **H_SAND (AVG)**
  N_SPT_ SAND (AVG)
- **H_CLAY (AVG)**
- **N_SPT_CLAY (AVG)**
- **N_SPT_LIMESTONE (AVG)**
- **N_SPT_LIMESTONE (SD)**
- **T_RAVELING (ft)**
  - Raveling Index (RI)?
  - Sinkhole Resistance Ratio(SRR)

$$\text{Effective Volume Grouted (\%)} = \frac{Total\ Grout\ Volume}{(Area\ of\ GP)*(Average\ Drill\ Depth\ of\ GPs)}$$

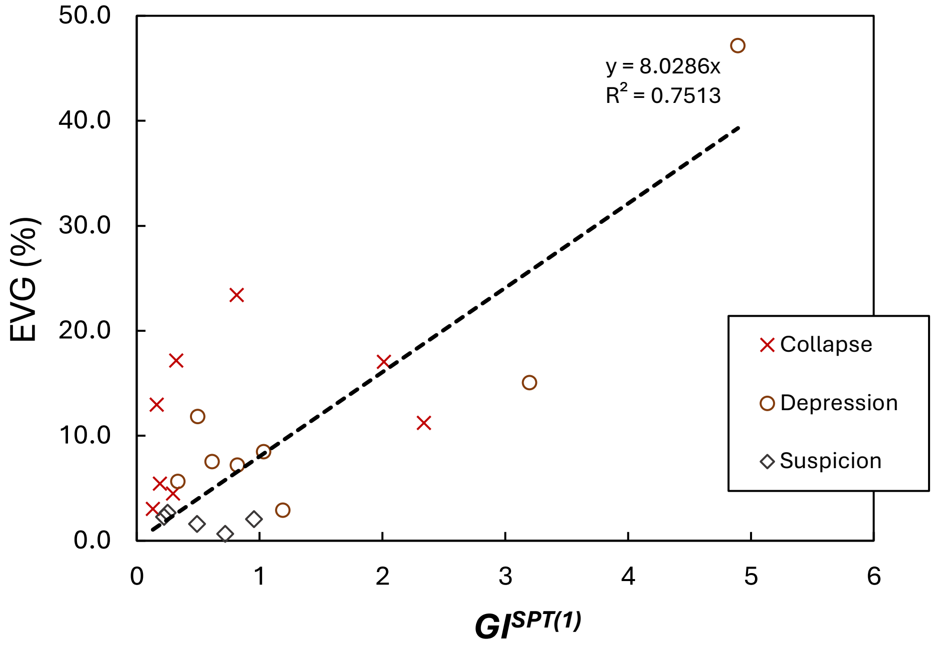
(n = 21)

PEARSON	Averaged layer thickness (ft)			Averaged SPT blow counts (N, bl/ft)						
	SAND	CLAY	RAVEL	SAND	CLAY	Limestone	Depth to Limestone (ft)	Collapse type	Ravel/Over	$GI^{SPT(1)}$
TGV (CY)	0.252	0.420	0.182	-0.151	0.230	0.337	0.327	0.030	-0.262	-0.296
TGV/nGP (CY)	0.253	0.410	0.186	-0.226	0.113	0.388	0.240	0.621	-0.116	-0.135
TGV/LF (CY/FT)	-0.164	0.022	-0.130	-0.155	0.174	0.021	-0.234	0.483	0.185	0.222
TGV/EVG(%)	-0.333	-0.189	-0.051	0.061	0.122	-0.306	-0.287	0.332	0.709	0.755

Key Takeaways for the Mitigation

- Limited dataset (n=22) suggests index can be used to estimate grout take for repair using subsurface exploration testing.
- "Effective Volume Grouted" (normalizing grout per grouted volume) shown to provide the least biased in the dataset.
- Correlated parameters suggest a "grout index" can be created to estimate EVG

$$GI^{SPT(1)} = \frac{100 \times \bar{t}_{ravel}}{\bar{t}_{over}(\bar{N}_{LIMESTONE} + \bar{t}_{SAND})}$$



Proposed Correlation to estimate Total Grout Volume (CY) based on SPT testing:

$$TGV\ (CY) \approx \left[\frac{8.027\bar{t}_{ravel}}{\bar{t}_{over}(\bar{N}_{LIMESTONE} + \bar{t}_{SAND})}\right] \times [\bar{t}_{GD} \times A_{Grout}]$$

$\bar{t}_{ravel}$: average thickness of raveled soil encountered
$\bar{t}_{over}$: average depth to raveled soil
$\bar{t}_{SAND}$: average thickness of surficial Sand
$\bar{t}_{GD}$: average planned drilled depth (yd)

$N_{Limestone}$: average measured SPT-value of limestone (maximum of 50, cap at 20ft of 50 bls/ft)
A_{grout}: surface area of grout plan (yd^2) if single point, use unit value of 1yd^2

Summary of Findings

Critical conditions (Numerical Model)

- Field data from cover collapse sinkholes suggests $SRR_{critical} = 2.0$ (from phase 1 of this project)
- 115 FEM stability to find SRR simulated in various soil and geometry conditions.
- Bottom-end $SRR_{FS=1.0}$ between 0.3 - 0.5
- Stability Style Chart shows promise when comparing $SRR_{FS=1.0}$ to field data

Critical conditions (Laboratory)

- to test SRR using large scale viable method determined soil box with simulated void and failure.
  - PANDA DCPT → q_d
- Stress monitoring shows signs of soil arching.
- **A-3 backfill** → Void formed, identified growth (dCPTs), no collapse (+80 days)
- **SRR values near void: 1.1 – 1.7. Matching SRR_{FEM} & $SRR_{historical}$**

Additional Analysis Potential (Grout Take Statistics)

- Field Data shows grout take highly variable in karst conditions in all sinkhole area types.
- **More drilling = more grout** *(duh)*
- Collapse "type" not correlated to total grout volume (cy)
- **Index Produced correlated to *Effective Grouted Volume ($R^2 = 0.75$)***
- Geologic formation may play a role; multivariable, "region-based" parameters.

Products and Implementations

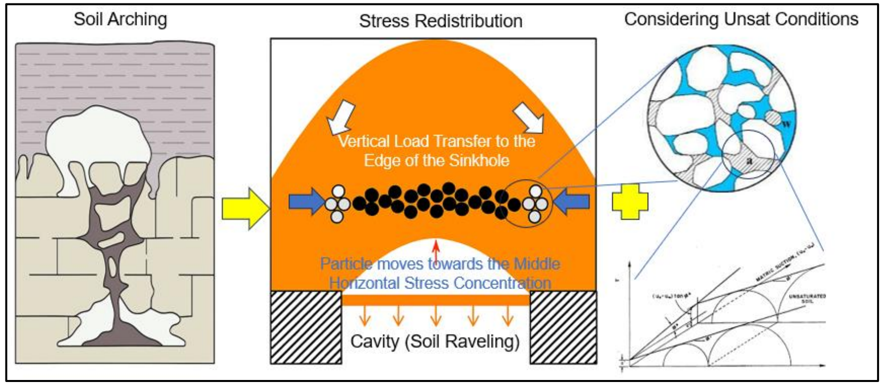
- Kim, B., Natarajan, Y., Preethaa, K. S., Danushkumar, V., Shamet, R., Chen, J., ... & An, J. (2025). Advancements in Sinkhole Remediation: Field data-driven Sinkhole grout volume prediction model via machine learning-based regression Analysis. Artificial Intelligence in Geosciences, 100159.
- Copeland, T., Shamet, R., An, J., Chen, J., & Nam, B. H. (2024). Developing a Correlation Method to Determine Grout Intake Volume of Raveled Soil. In Geo-Congress 2024 (pp. 67-76).
- Pesha, S., Shamet, R., Copeland, T., Chen, J., & An, J. (2024). Assessment of Sinkhole vulnerability indices using a probabilistic approach for cover collapse and solution-type sinkholes in Florida. In Geo-Congress 2024 (pp. 654-664).

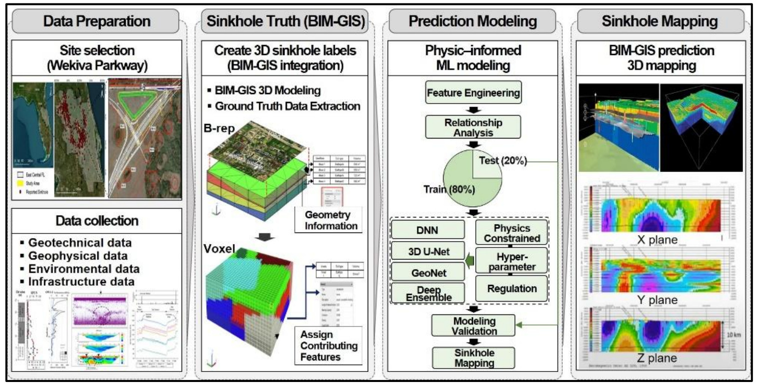
Research Proposal and Research Plan Led by This Project

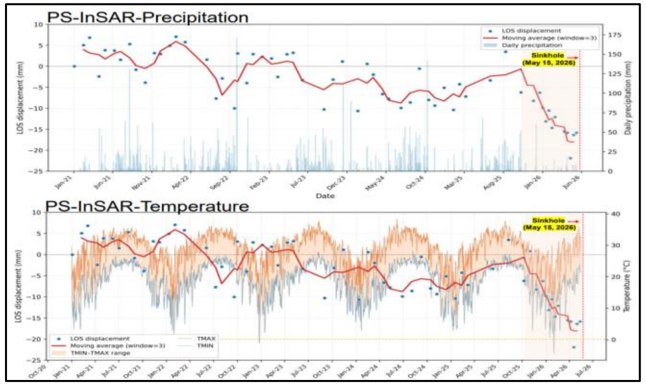
Physical and Numerical Sinkhole Simulation with Coupled Thermo-Hydro-Mechanical Behavior

Physics-Informed AI Models for Sinkhole Structure Reconstruction Using 3D BIM-GIS Integration

Remote Sensing–Enhanced Sinkhole Index for Florida Transportation Infrastructure



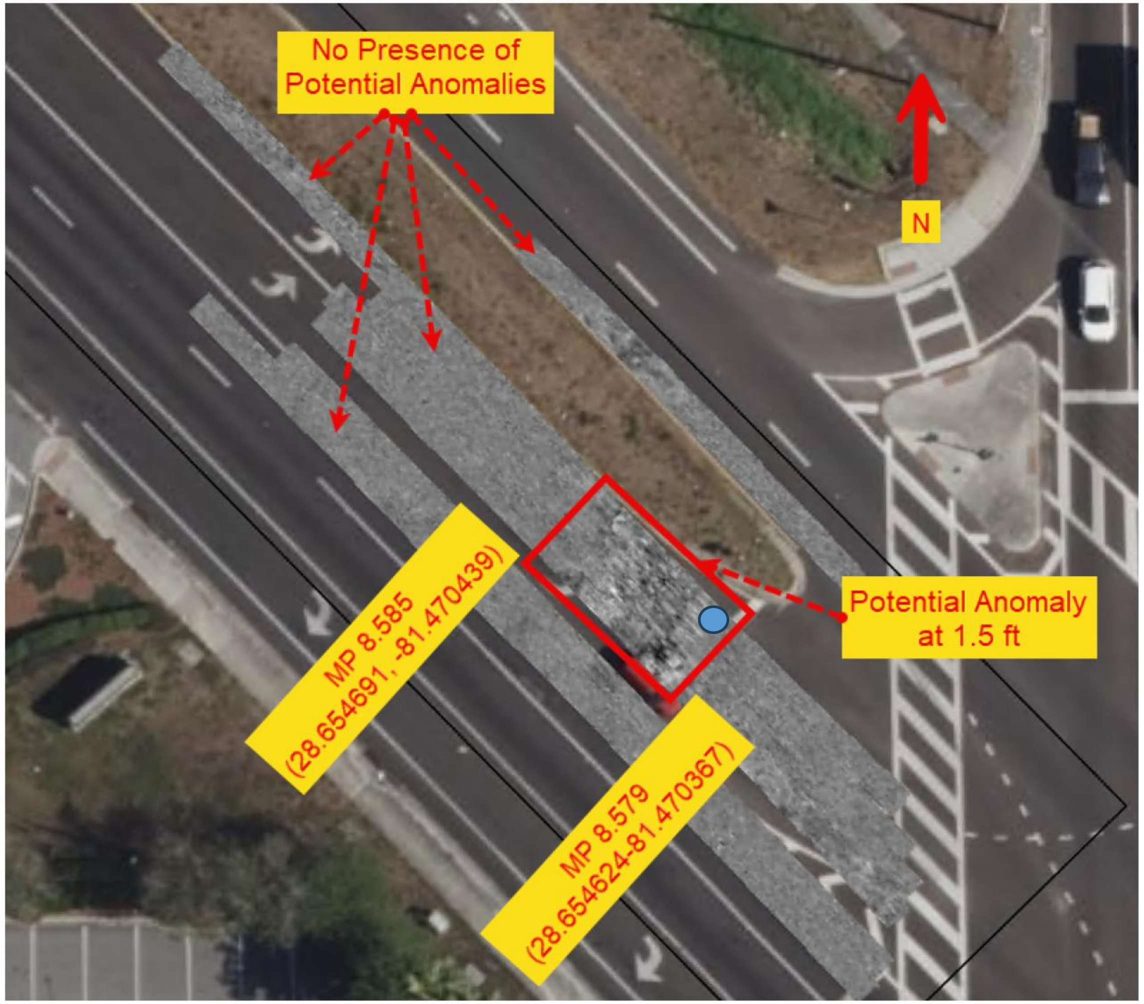




SRR Example – US 441 Hiawassee Rd. (June. 2026)

Depression observed and patched

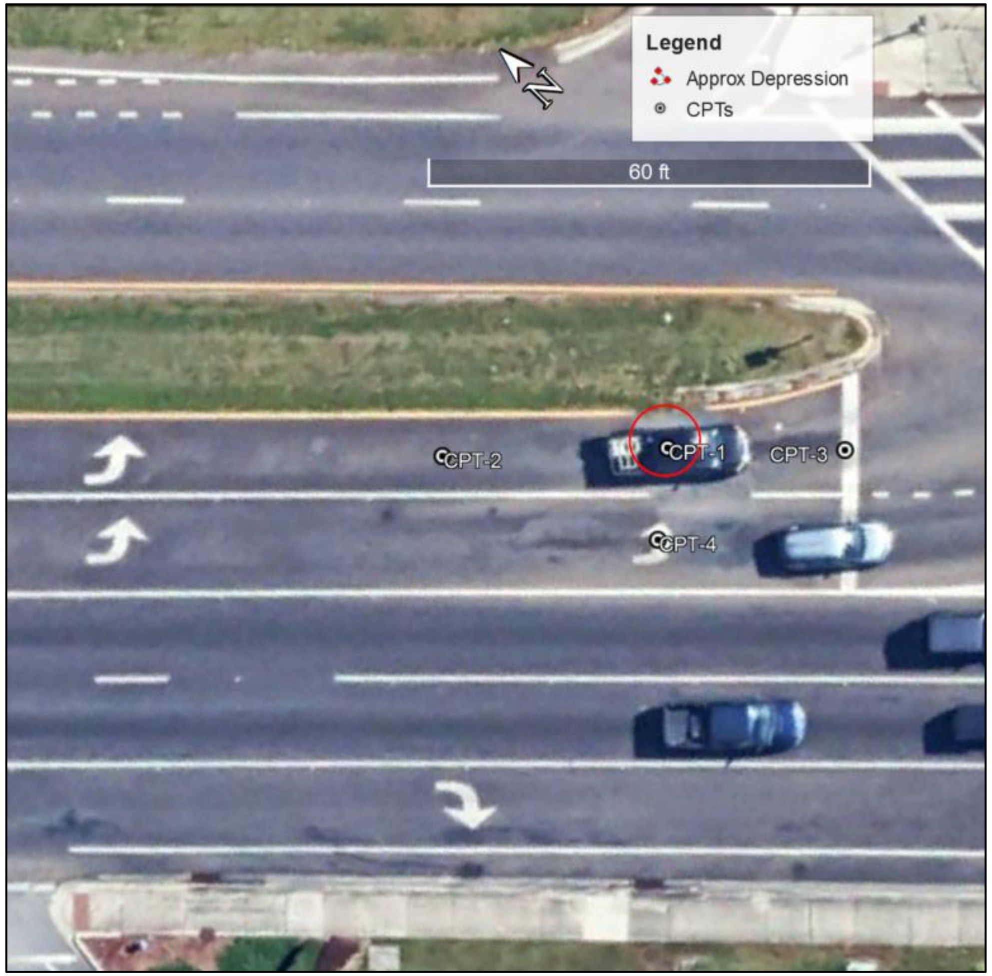
- FOUR (4) CPTs performed
- 3D GPR Scan (SMO)
- Grouting Grid Planned (TBD?)

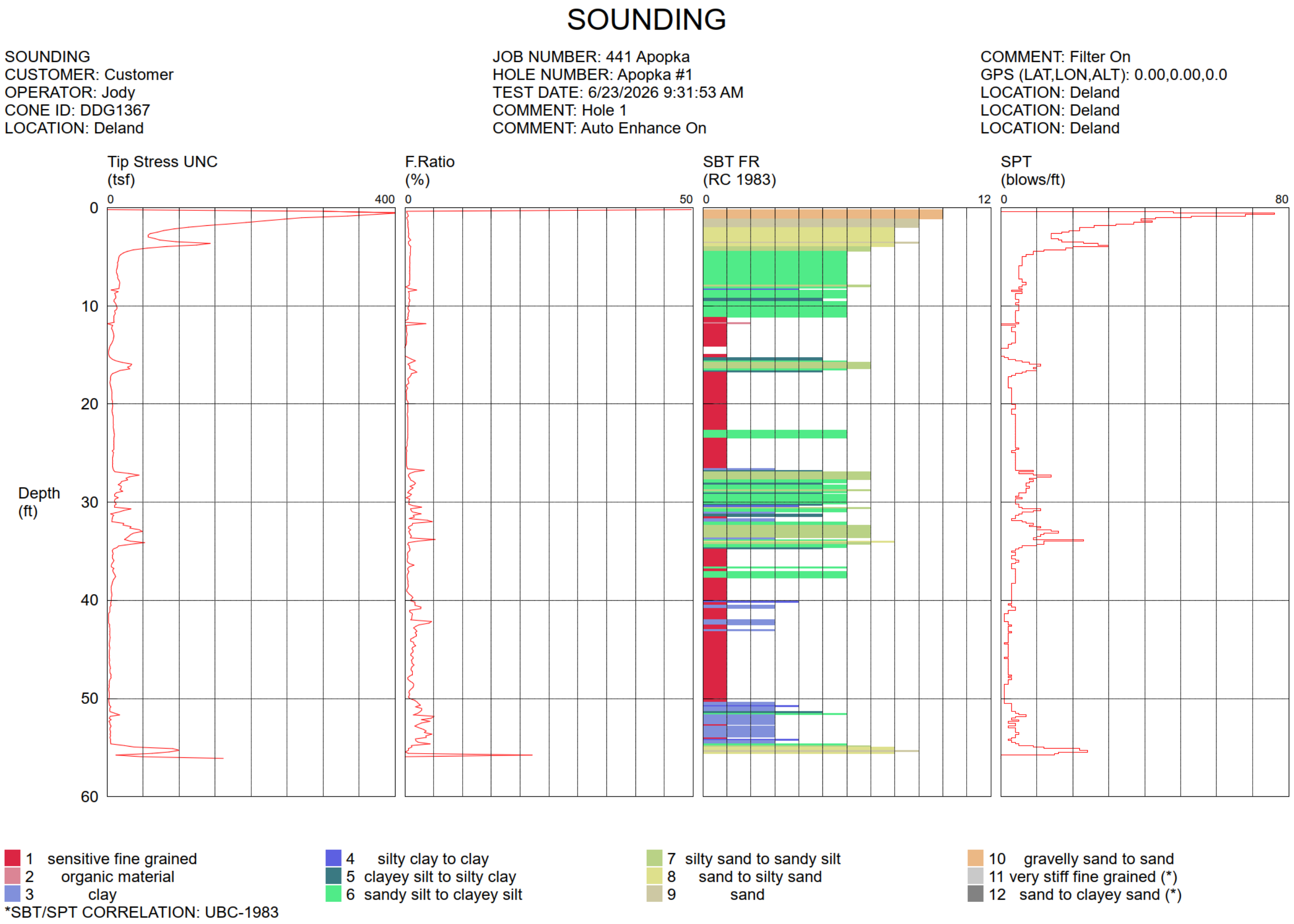


Depth Profile of US 441

Thank you to District 5 for providing pictures and data!

SRR Example – US 441 Hiawassee Rd. (June. 2026)

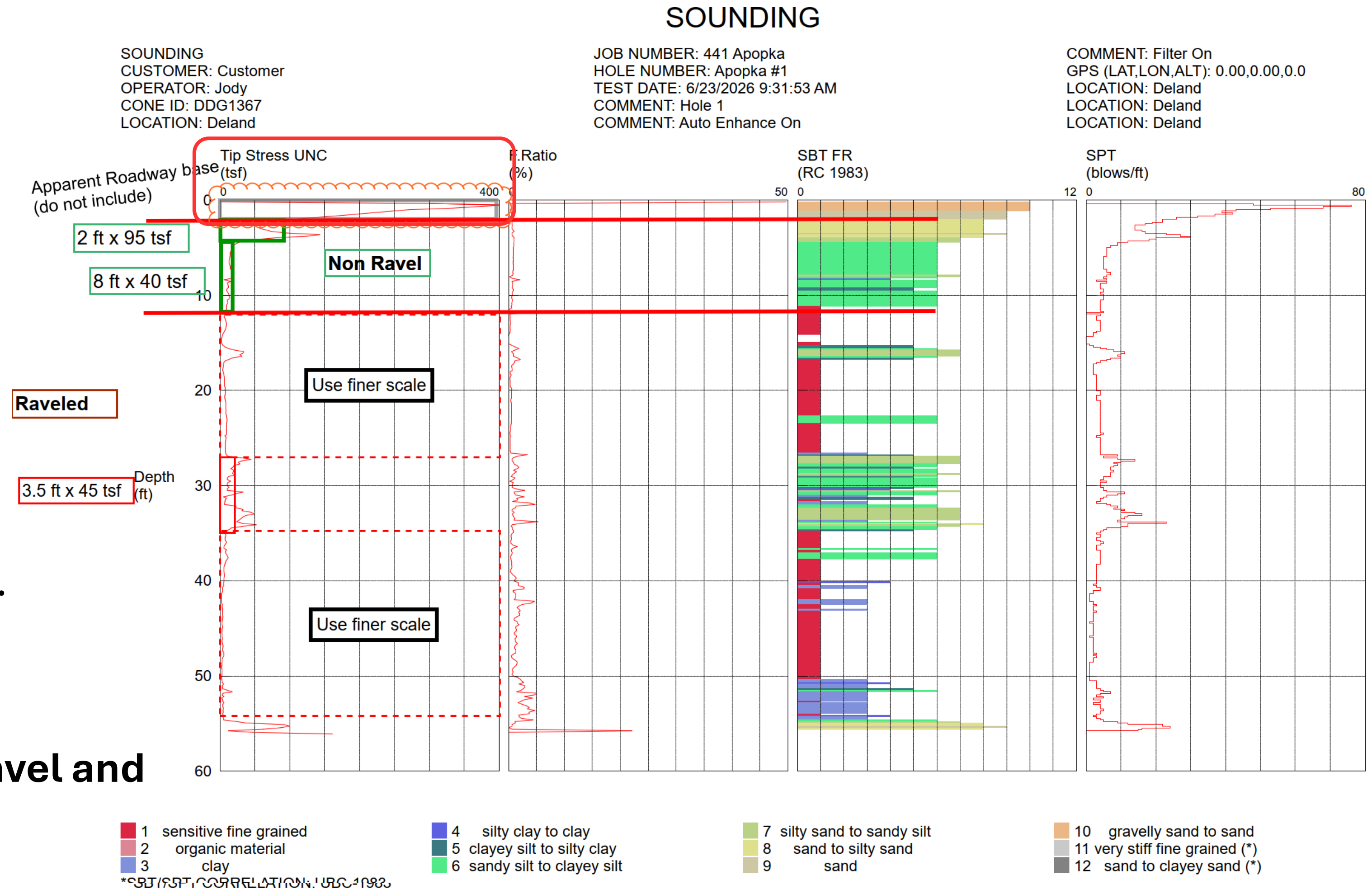




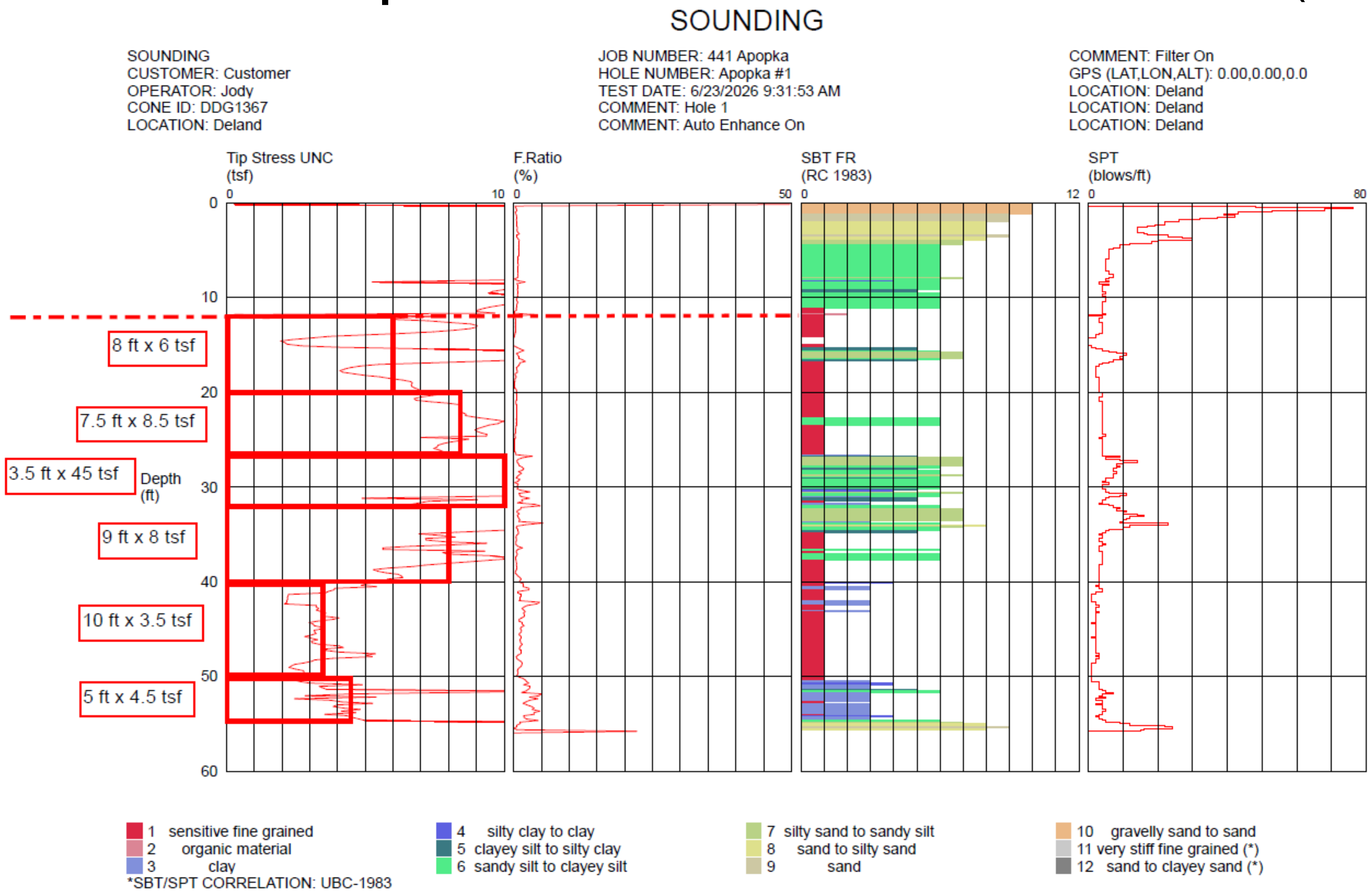
SRR Example – US 441 Hiawassee Rd. (June. 2026)

STEPS:

1. **Identify extents of raveled and non-raveled soil.**
   - ➢ “raveled” zone starts at first encountered raveled (disturbed) material.
   - ➢ Use CPT-based raveling chart
   - ➢ And engineering judgement knowing local extent of hawthorn group of soils / validate nearby SPTs.
2. **Identify encountered base or compacted soils** (roadway application).
   - ➢ Include in depth calculations.
   - ➢ <u>Remove</u> for cone tip resistance.
3. **Weighted average of respective non-ravel and raveled soil tip resistance values)**
4. **Establish SRR parameters**



SRR Example – US 441 Hiawassee Rd. (June. 2026)



$$\boxed{SRR = \left(\frac{q_{over} + q_{ravel}}{100 * \sigma'_{vo}}\right)\left(\frac{t_{over}}{t_{ravel}}\right)}$$

$$t_{over} = 11 \text{ ft}$$

$$t_{ravel} = 54 - 11 = 42 \text{ ft}$$

$$q_{over} = \frac{(3ft * 95\, tsf) + (8\, ft * 40\, tsf)}{11\, ft}$$

$$q_{over} = 60.5\, tsf$$

$$q_{ravel} = 9.3\, tsf$$

(same weighted average technique as qover)

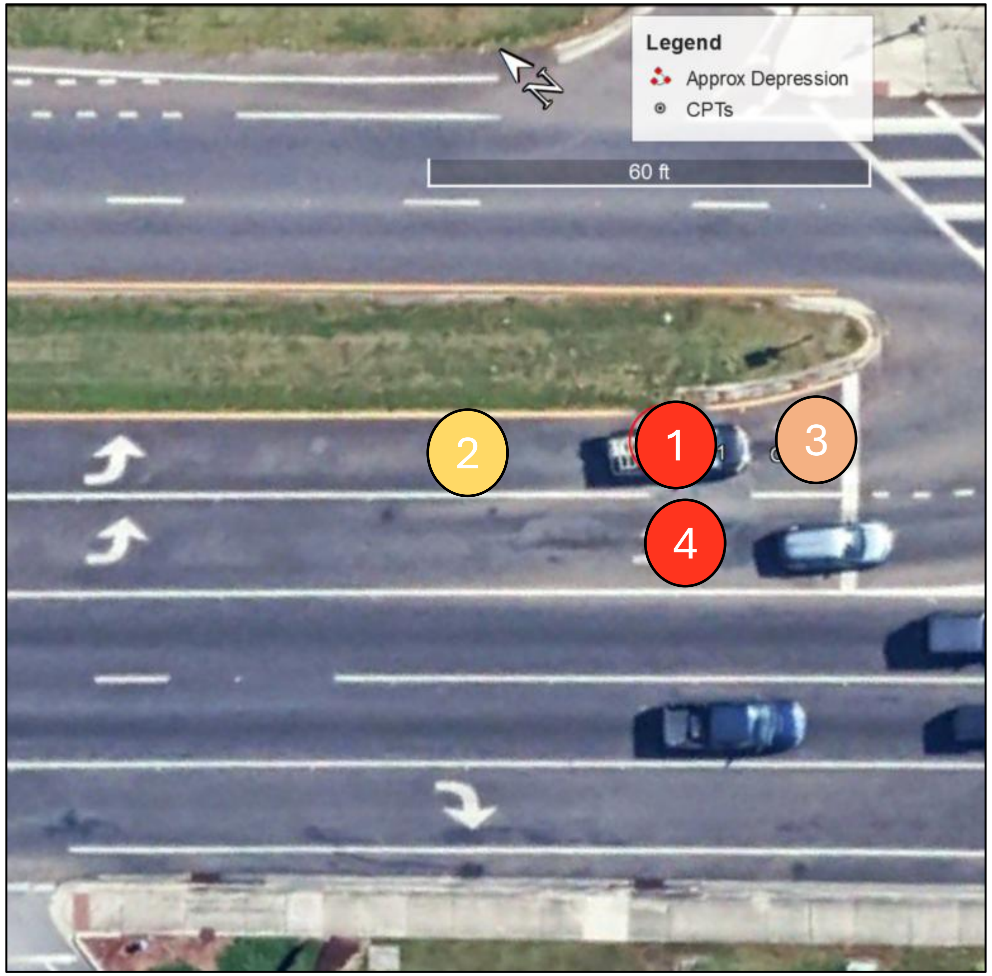
$$\sigma'_{vo} = t_{over} \times \gamma_{soil} \cong 0.6\, tsf$$

Soil unit weight correlated or assumed based on non-raveled density

$$SRR = \left(\frac{60.5 + 9.3}{100 * 0.6}\right)\left(\frac{11\, ft}{42\, ft}\right) = \mathbf{0.35}$$

$$RI = \left(\frac{42\, ft}{11\, ft}\right) = \mathbf{3.50}$$

SRR Example – US 441 Hiawassee Rd. (June. 2026)



CPT	Location	RI	SRR	(p(x)) from RI	(p(x)) from SRR
CPT1	CENTER	3.50	0.35	**0.91**	**0.89**
CPT2	24	0.36	1.78	**0.64**	**0.62**
CPT3	30	0.59	1.08	**0.74**	**0.72**
CPT4	15	1.04	0.25	**0.82**	**0.92**

$Probability\ of\ Sinkhole\ Occurence$:

$$RI: p(x) = \frac{0.96 \times RI}{RI + 0.18} \qquad SRR: p(x) = 1 - \frac{0.87 \times SRR}{SRR + 2.31}$$

- Enables comparison of “highest risk” locations within site
  - ✓ Focus grout point grid
  - ✓ Focus grout point order
  - ✓ Justification for lane closure / mitigation

Thank you!

Jiannan Nick Chen, Ph.D. (UCF) Jiannan.Chen@unf.edu

Ryan Shamet, Ph.D., P.E. (UNF) Ryan.shamet@unf.edu

Questions/Suggestions/Feedback?

Photo: 2004 Sinkhole Howland Blvd / Barbara Perez, Orlando Sentinel

Workforce Development

Sylvia Pesha, M.S., E.I. (UNF, graduated in 2024 Spring) – Numerical Modeling

Chloe Molina, B.S., (UCF, graduated in 2024 Fall) – Data Analysis

Miguel Da Silva, B.S., (UCF, graduated in 2025 Fall) – Help with the report and analysis

SRR Calculation (from simulated data)

$$s_u = \frac{q_t - \sigma_v}{N_{kt}}$$

N_{kt}= 18

(Robertson,2009)

Rearrange

$$q_t = s_u N_{kt} + \sigma_v$$

$$s_u = c_f + \sigma_v{}' \tan \phi$$

$$SRR = \left(\frac{t_{over}}{t_{ravel}}\right)\left(\frac{q_{over} + q_{ravel}}{C \times \sigma'_{vo}}\right)$$

- s_u: *Undrained shear strength*
- Cone factor, N_{kt}= 10 - 18

- Assume q_{ravel}= 0
- q_t= Tip resistance at top of void assumed equal to average tip resistance of overburden (q_{over})