

# Assessment of Drilled Shaft Capacity and QA/QC from Measuring While Drilling BED31-977-09

## GRIP Meeting

FDOT Project Manager:  
Dino Jameson, P.E.

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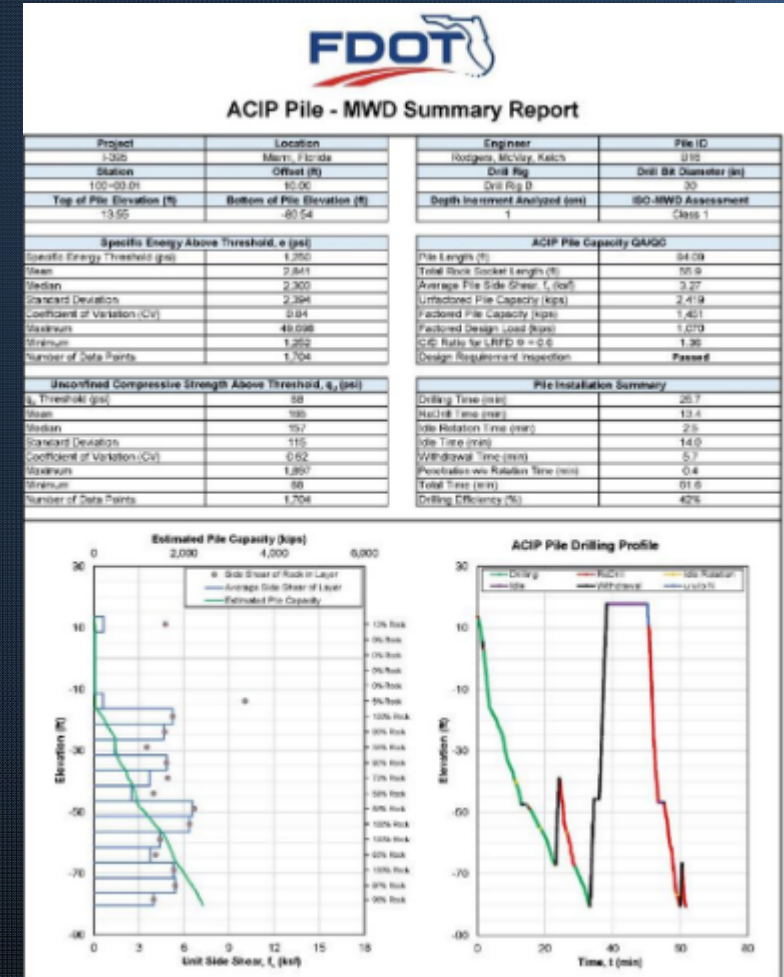
August 14, 2025





# Project Background

- FDOT investigated the use of MWD for Auger Cast Piles (ACP) to provide QA/QC during pile installations in Miami-Dade
  - BDV31-977-125
- A new analysis tool was developed
  - Transformed time-referenced data collected from AME to depth-referenced data that is compatible for MWD strength assessment
- For ACPs, a time-referenced data format collected from AME is most commonly used in Florida, and the ACP analysis tool was developed specifically to accommodate the data format



# Project Background

- For drilled shaft MWD...
  - Time-referenced data
  - Depth-referenced data
  - Both data formats
- A new analysis tool needed to be developed to accommodate the possible variations in raw data recording and reporting
- Provide the FDOT with a reliable method of drilled shaft QA/QC analysis, regardless of the monitoring system used
  - Contractors can utilize a variety of MWD systems
- On-site and remote monitoring should be explored to improve the quality control portion of the of the QA/QC tool
  - Providing real time strength assessments that can be viewed by all stakeholders



# Project Objectives

1. Using FDOT MWD criteria (FM 5-625), develop a versatile data analysis tool that will be used to provide drilled shaft MWD QA/QC
2. Conduct a feasibility study to identify the requirements of providing on-site and remote monitoring capabilities to enhance the QA/QC method
3. Monitor at least one load tested shaft and three production shafts at three independent sites to develop correlations for QA/QC purposes
4. Provide a QA/QC report for all shafts monitored during the research
5. Compare test results with previously derived correlations



# Tasks and Deliverables

- Deliverable 1 – Establish drilled shaft MWD data reduction criteria and procedures (Task 1)
- Deliverable 2 – On-site and remote monitoring implementation feasibility study (Task 2)
- Deliverable 3 – MWD specific energy vs. drilled shaft side shear correlation (Task 3)
- Deliverable 4 – MWD correlation validation for drilled shaft QA/QC (Task 4)
- Deliverable 5a - Draft Final (Task 5)
- Deliverable 5b - Closeout Meeting (Task 5)
- Deliverable 6 - Final Report (Task 6)





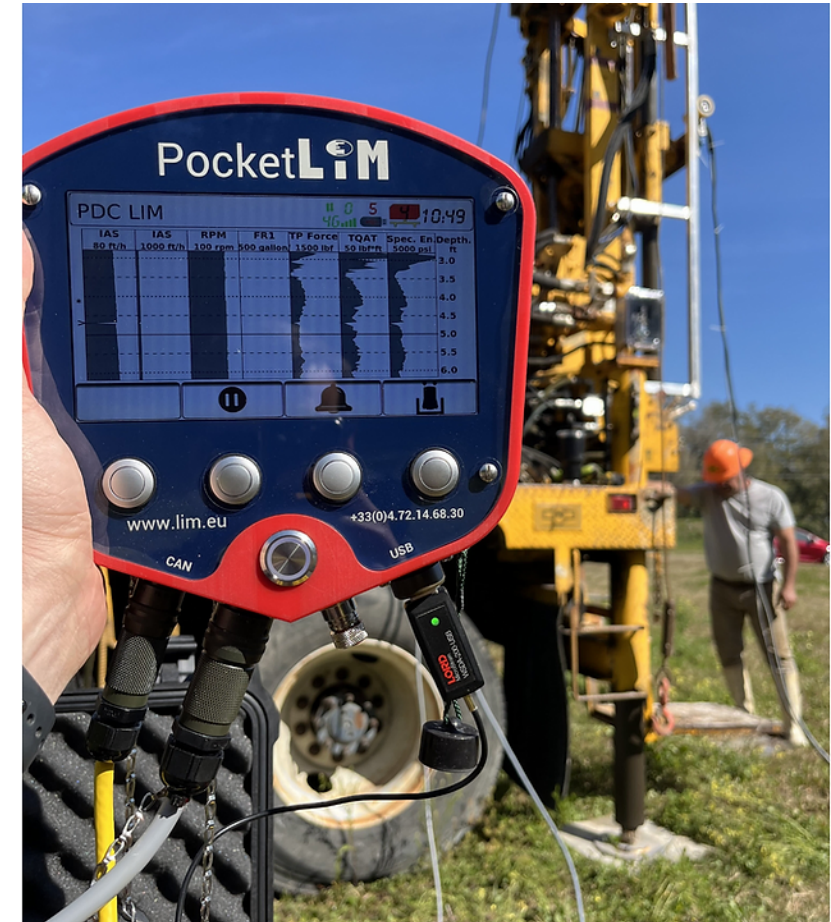


## Task 1a – Development of Specification Language

- UF Researchers submitted draft spec language for Drilled Shaft MWD:
- FDOT Standard Specifications for Road and Bridge Construction – Section 455
  - Section 455-15.1.2 – Drilled Shaft Installation Plan (DSIP)
  - Section 455-15.1.3.1 – Measuring While Drilling (MWD)
  - Section 455-15.10.5 – MWD Equipment
  - Section 455-15.10.6 – MWD Measurements
- Florida Method of Test (FM 5-625)
  - Section 3.6.1 – Minimum Accuracy of Measured Values



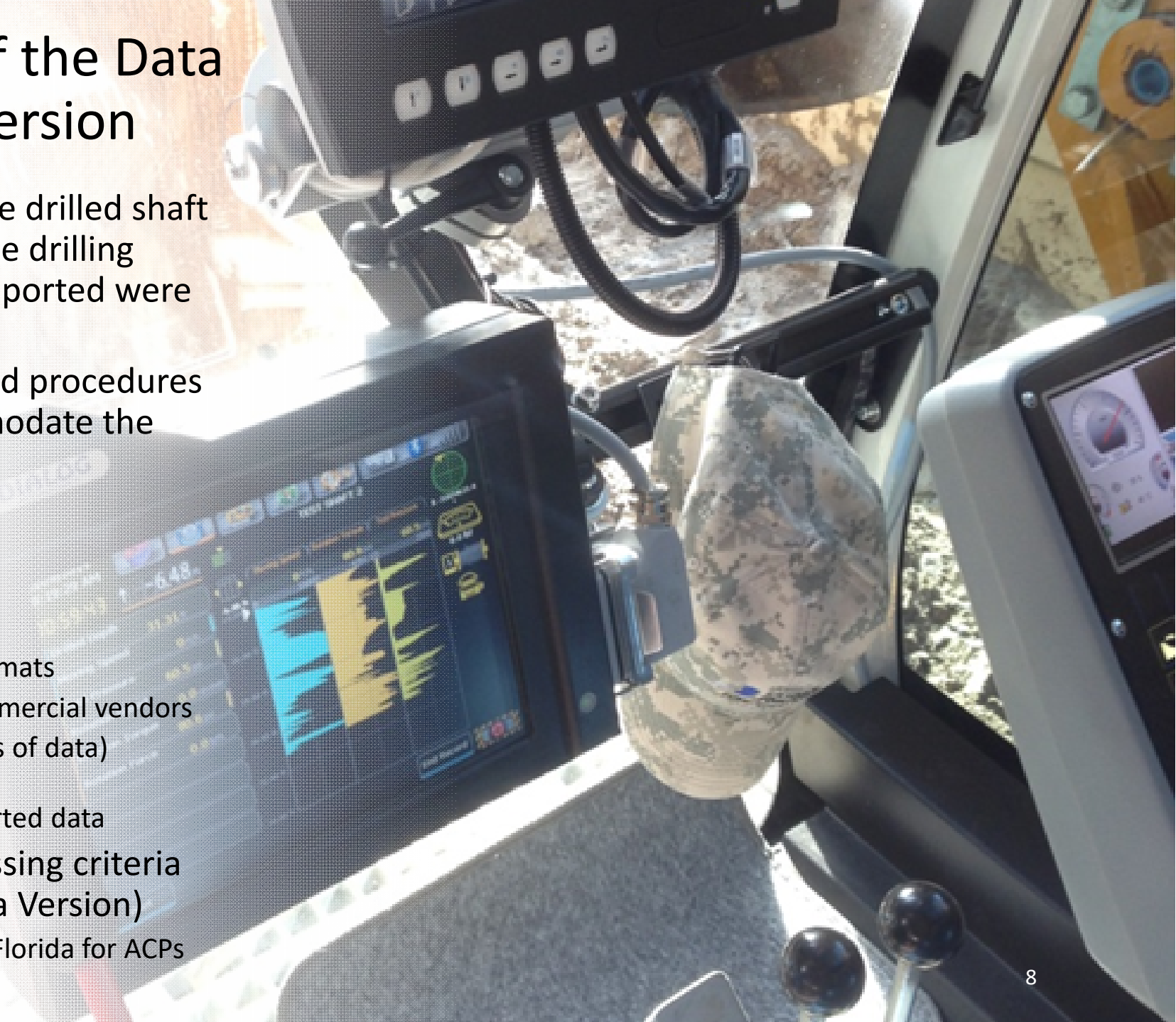
# Task 1b - New MWD System - LiM's PocketLiM





# Task 1b – Development of the Data Analysis Tool – Beta Version

- The monitoring systems onboard the drilled shaft drill rigs, and the format in which the drilling parameters may be recorded and reported were unknown
- New raw data processing criteria and procedures needed to be developed to accommodate the data, regardless of the format
  - Data layout
  - File type
    - e.g., .xlsx, .csv, .txt, .guh, etc.
- The research team considered:
  - Prior MWD data collected in various formats
  - Obtained sample drilling data from commercial vendors
  - Simulated large data sets (1 million rows of data)
    - 20 hrs of drilling at 16 Hz (MWD system max)
  - Investigated multiple file types for reported data
- Allowed UF to develop initial processing criteria and a preliminary analysis tool (Beta Version)
  - 5<sup>th</sup> iteration of Beta version in use in S. Florida for ACPs





# Raw Data Variations Based on MWD System

Time (s)	Depth (feet)	Penetration Rate (ft/min)	RPM (rev/min)	Torque pressure (psi)	Crowd pressure (psi)	Crowd Force (Tf)	Bottom Grout (psi)	Top Grout pressure (psi)	Grout Flow (yd3/h)	Grout Volume yd3
0.00	0.000	0.00	0.00	116.03	406.10	0.183	45.122	3.881091138	0	0
0.00	0.000	0.00	0.00	111.20	402.48	0.176	45.097	4.39633378	0	0
2.37	0.082	0.54	0.00	111.33	408.06	1.826	45.133	4.606430907	0	0
2.56	0.157	20.85	0.00	116.03	406.10	4.572	45.017	4.608424711	0	0
2.75	0.236	23.92	0.00	116.03	410.94	4.978	45.058	4.654531436	0	0
3.01	0.312	16.72	0.00	116.03	413.36	4.807	45.049	4.624562065	0	0
3.14	0.397	28.84	0.00	116.03	406.10	4.725	45.001	4.583066013	0	0
3.39	0.479	14.80	0.00	112.40	416.98	4.816	45.045	4.704096164	0	0
3.59	0.551	20.33	0.00	101.53	406.10	6.433	45.040	4.377891091	0	0
3.78	0.627	22.90	0.00	140.20	406.10	5.865	44.924	3.953709229	0	0
3.97	0.696	22.90	0.00	328.75	454.45	6.040	44.934	3.958319901	0	0
4.23	0.771	15.19	0.00	681.67	732.44	6.009	44.966	3.94679322	0	0
4.42	0.840	18.97	0.00	1005.59	1256.99	6.020	45.035	3.87993847	0	0
4.61	0.909	21.53	0.00	841.21	1165.13	5.836	45.058	4.290288315	0	0
4.80	0.988	22.56	1.10	836.38	1131.29	5.892	44.994	4.66375278	0	0
5.06	1.056	16.34	3.30	997.13	1334.34	5.862	44.987	4.648768095	0	0
5.25	1.132	18.63	3.30	1213.48	1580.90	5.850	44.984	4.580760677	0	0
5.38	1.201	27.94	3.30	1319.84	1791.21	5.849	44.987	4.659142108	0	0
5.83	1.316	11.75	3.30	1429.65	1808.82	5.844	44.980	4.613694051	0	0

Time	Duration (min)	Gear Box RPM	Penetration Rate (ft/min)	Penetration Rate (ft/min)	Depth (ft)	Gear Box Pressure (ft-lbs)	Crowd Pressure (ft-lbs)	Thrust (lb)
6/10/2020 7:29:31 AM	0	-81.89	-46.9488204	3.048	0	639.0361062	0	221.0374548 3426.96
6/10/2020 7:29:32 AM	0.02	-82.5	-49.1469832	3.048	0	66.2822289	0	201.8924784 3130.14
6/10/2020 7:29:33 AM	0.03	-84.45	-51.2467208	3.048	0.0656168	0	44.8166493	694.837
6/10/2020 7:29:34 AM	0.05	-88.47	-53.0183744	3.048	0.0656168	664.9978545	0	213.0603813 3303.29
6/10/2020 7:29:35 AM	0.07	-80.52	-48.4908152	3.048	0.0656168	589.4332128	0	224.2282842 3476.44
6/10/2020 7:29:36 AM	0.08	11.97	1.0498688	0.9525	0.0984252	584.0668179	0	213.4954944 3310.03
6/10/2020 7:29:37 AM	0.1	12.45	1.6076116	0.622040816	0.164042	620.9063937	0	248.3045424 3849.71
6/10/2020 7:29:38 AM	0.12	14.51	1.8372704	0.544285714	0.1968504	691.1046405	0	253.2358242 3926.17
6/10/2020 7:29:39 AM	0.13	18.86	1.804462	0.554181818	0.2624672	653.5398762	0	256.4266536 3975.64
6/10/2020 7:29:40 AM	0.15	21.26	2.3950132	0.417534247	0.2952756	661.5169497	0	250.915221 3890.19
6/10/2020 7:29:41 AM	0.17	22.16	2.8543308	0.350344828	0.328084	652.66965	0	273.5411022 4240.98
6/10/2020 7:29:42 AM	0.18	22.64	2.8543308	0.350344828	0.3937008	653.1047631	0	280.3578741 4346.67
6/10/2020 7:29:43 AM	0.2	23.07	2.952756	0.338666667	0.4593176	691.9748667	0	259.1823699 4018.36
6/10/2020 7:29:44 AM	0.22	23.33	3.0183728	0.331304348	0.492126	686.8985472	0	258.6022191 4009.37
6/10/2020 7:29:45 AM	0.23	23.55	2.9855644	0.334945055	0.5577428	710.1045792	0	252.6556734 3917.17
6/10/2020 7:29:46 AM	0.25	23.7	2.952756	0.338666667	0.5905512	732.2953473	0	269.1899712 4173.52
6/10/2020 7:29:47 AM	0.27	24.06	2.9855644	0.334945055	0.6233596	678.776436	0	255.4113897 3959.9
6/10/2020 7:29:48 AM	0.28	24.24	2.8871392	0.346363636	0.6889764	694.5855453	0	254.8312389 3950.9
6/10/2020 7:29:49 AM	0.3	24.38	2.8543308	0.350344828	0.7217848	679.3565868	0	252.8007111 3919.42

## [PARAMETER]

Date;Depth;P-Grout;P-Rotary Head;P-Crowd;Rotation;Torque;Speed;X-Axis;Y-Axis;Grout  
0;m;bar;bar;bar;RPM;kNm;cm/min;°;°;1/min;L;%;-;-;-;1/min

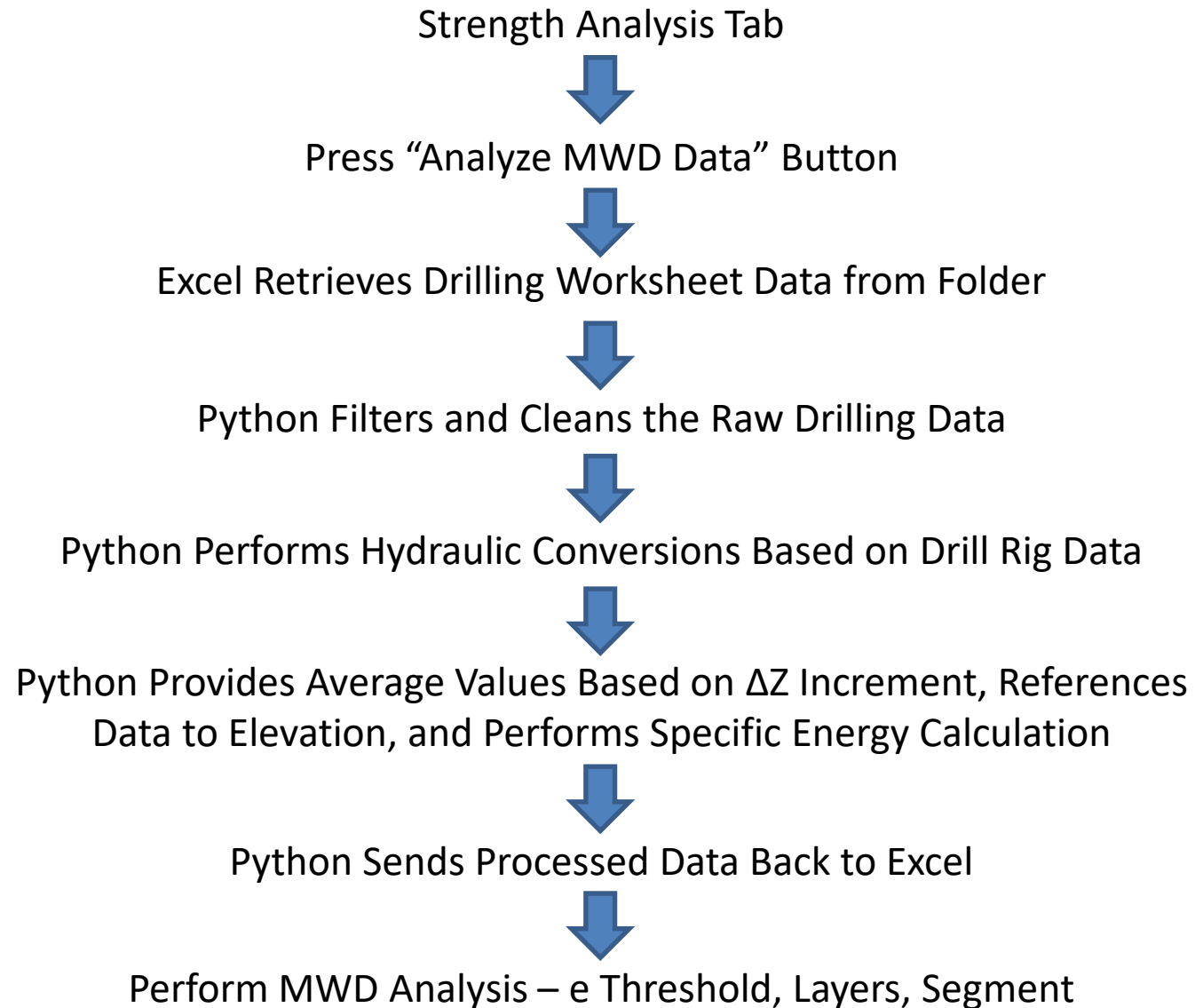
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# FLMWWD Analysis Tool Workflow

- New MWD analysis tool utilizes python to perform the background calculations
  - No longer have to copy and paste data or files into analysis tool
    - Imports all data and files from folders
    - Never have to open a single drilling file to analyze your MWD data
  - Much smaller file sizes
    - > 3MB compared to 40 to 50 MB
  - Easier to track changes during upgrades and modifications
- Provides a similar user interface (UI) to ACIP analysis tool
  - Specific energy threshold and layers can be adjusted without triggering the program to reanalyze the data





# Info Sheet

AutoSave Off FLMWD\_Beta1.3 Search Rodgers, Michael B

File Home Insert Page Layout Formulas Data Review View Automate Developer Help Acrobat Power Pivot

Clipboard Font Alignment Number Styles Cells Editing Sensitivity Add-ins Adobe Acrobat

V1

B		D	F	G	H	K	O
Raw Data Workbooks File Address		Active File Name	List of Files	Elevation (ft)	Bit Diameter (ft)	MWD System	Start Depth (ft)
D:\FLMWD_Beta1.3\raw_data_workbooks/		B7W-3-1.xlsx	2023-06-26 ACP 102-3L-1.xlsx	34.02	2.0	PIMS	0
FLMWD Program Folder File Address		Pile Elevation (ft)	2023-06-27 ACP 102-3L-2.xlsx	34.02	2	PIMS	0
D:\FLMWD_Beta1.3\dist\FLMWD_Beta1.3		13.4	2023-06-27 ACP 102-3L-5.xlsx	34.02	2	PIMS	0
Workbook Address	Program Address	Bit Diameter (ft)	B7W-3-1.xlsx	13.40	2.5	PIMS	0
		2.50	B7W-3-10.xlsx	13.40	2.5	PIMS	0
Project Information		MWD System	B7W-3-11.xlsx	13.46	2.5	PIMS	0
		PIMS	B7W-3-12.xlsx	13.42	2.5	PIMS	0
Engineer		Drill Rig	B7W-3-13.xlsx	13.51	2.5	PIMS	0
Michael Rodgers		Drill Rig B	B7W-3-14.xlsx	13.52	2.5	PIMS	0
Project		Start Depth (ft)	B7W-3-15.xlsx	13.54	2.5	PIMS	0
UF Demo		0.00	B7W-3-16.xlsx	13.58	2.5	PIMS	0
Location		Depth Increment (cm)	B7W-3-2.xlsx	13.52	2.5	PIMS	0
Gainesville, FL		1	B7W-3-3.xlsx	13.50	2.5	PIMS	0
Station		e Threshold (psi)	B7W-3-4.xlsx	13.58	2.5	PIMS	0
100+00.01		1,250	B7W-3-5.xlsx	13.51	2.5	PIMS	0
Offset		Cleanout Depth (ft)	B7W-3-6.xlsx	13.55	2.5	PIMS	0
10.0			B7W-3-7.xlsx	13.55	2.5	PIMS	0
Custom Pile ID			B7W-3-8.xlsx	13.53	2.5	PIMS	0
			B7W-3-9.xlsx	13.55	2.5	PIMS	0
<input type="checkbox"/> Use Custom Pile ID?			G&H Drilling Dataset Example.guh	0.00	2.5	G&H	0
			I395_B26_Demo.xlsx	34.02	2.0	PIMS	0
			I395_B26_Test_Pile_1-1.xlsx	35.70	2.0	PIMS	0
			I395_B26_Test_Pile_1.xlsx	33.32	2.5	PIMS	0
			Selmon_TS4_One_Million.xlsx	10.70	3.5	Jean Lutz	15.28
			wyatt_book.xlsm	10.70	3.5	Jean Lutz	15.28
			wyatt_book2.xlsm	10.70	3.5	Jean Lutz	15.28
			JL_Selmon_TS4_1s.xlsx	10.70	3.5	Jean Lutz	15.28
			ZP2_2024-02-27T15+35+39.xlsx	0	2.5	Jean Lutz	0
			04.17.2024.- 6-11-7 Pile Installation Summary Report.xlsx	0	2.5	PIMS	0

Refresh List of Files

Agreement Info Enter Drill Rig Data Strength Analysis Pile Summary Report GeoStat



# Enter Drill Rig Data

Bridge7W-3

drill\_rig\_workbooks

FLMWD\_Beta1.2

geostat\_workbooks

Pile Summary Reports

raw\_data\_workbooks

8/13/2023 12:14 AM

8/12/2023 1:37 PM

8/10/2023 7:03 PM

8/12/2023 2:07 PM

8/12/2023 2:19 PM

8/9/2023 10:13 AM

File folder

File folder

File folder

File folder

File folder

File folder

drill\_rig\_workbooks

OK

Cancel

FDOT Drill Rig List Workbook Address

E:/FLMWD\_Beta1.2\_GRIP\_2023/drill\_rig\_workbooks/

FDOT Drill Rig List Workbook Name

FDOT\_Drill\_Rig\_List\_Demo

Drill Rig Workbook Address

FDOT Drill Rig List

Custom

Drill Rig A

Drill Rig B

Drill Rig C

Drill Rig D

Drill Rig E

Drill Rig F

Rotational Speed, N (RPM)

FLMWD\_Beta1.2 - Last Modified: Just now

Search

Michael Rodg

File

Home

Insert

Page Layout

Formulas

Data

Review

View

Automate

Developer

Help

Acrobat

Power Pivot

T12

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

1

2

3

4

5

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Drill Rig B

Maximum Operating Pressure,  $OP_{max}$  (psi)

Hydraulic Motor Displacement,  $s$  (in<sup>3</sup>/rev)

Hydraulic Flow Rate,  $Q_h$  (in<sup>3</sup>/min)

Gear Case Reduction

Gear 1

Gear 2

# of Motors

4,640

9.76

4.27

39,055

167.7

76.7

2

Drill Rig B

Torque,  $T$  (in-lb)

Rotational Speed,  $N$  (RPM)

3,000,000

2,500,000

2,000,000

1,500,000

1,000,000

500,000

0

0

10

20

30

40

50

60

70

Drill Rig B

Torque Check

$N$  (RPM)

30

$T_s$  (psi)

4,640

$T_{ss}$  (psi)

0

$T$  (in-lbf)

961,381

$T$  (ft-lbf)

80,115

$T$  (kN-m)

109

Crowd Specifications

$F_{max}$  (lbf)

89,924

$OP_{max}$  (psi)

4,640

$K_s$  (lb/psi)

19.38

FDOT Drill Rig List Workbook Address

E:/FLMWD\_Beta1.2\_GRIP\_2023/drill\_rig\_workbooks/

FDOT Drill Rig List Workbook Name

FDOT\_Drill\_Rig\_List\_Demo

Drill Rig Workbook Address

FDOT Drill Rig List

Custom

Drill Rig A

Drill Rig B

Drill Rig C

Drill Rig D

Drill Rig E

Drill Rig F

FLMWD\_Beta1.2 - Saved

Search

Michael Rodg

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Formulas

Data

Review

View

Automate

Developer

Help

Acrobat

Power Pivot

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32

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34

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36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

Drill Rig E

Maximum Operating Pressure,  $OP_{max}$  (psi)

Hydraulic Motor Displacement,  $s$  (in<sup>3</sup>/rev)

Hydraulic Flow Rate,  $Q_h$  (in<sup>3</sup>/min)

Gear Case Reduction

Gear 1

Gear 2

# of Motors

4,200

3.42

3.42

19,650

64.0

64.0

2

Drill Rig E

Torque,  $T$  (in-lb)

Rotational Speed,  $N$  (RPM)

2,000,000

1,500,000

1,000,000

500,000

0

0

5

10

15

20

25

30

35

40

45

50

Drill Rig E

Torque Check

$N$  (RPM)

30

$T_s$  (psi)

3,000

$T_{ss}$  (psi)

0

$T$  (in-lbf)

208,852

$T$  (ft-lbf)

17,404

$T$  (kN-m)

24

Crowd Specifications

$F_{max}$  (lbf)

90,000

$OP_{max}$  (psi)

4,500

$K_s$  (lb/psi)

20.00

FDOT Drill Rig List Workbook Address

E:/FLMWD\_Beta1.2\_GRIP\_2023/drill\_rig\_workbooks/

FDOT Drill Rig List Workbook Name

FDOT\_Drill\_Rig\_List\_Demo

Drill Rig Workbook Address

FDOT Drill Rig List

Custom

Drill Rig A

Drill Rig B

Drill Rig C

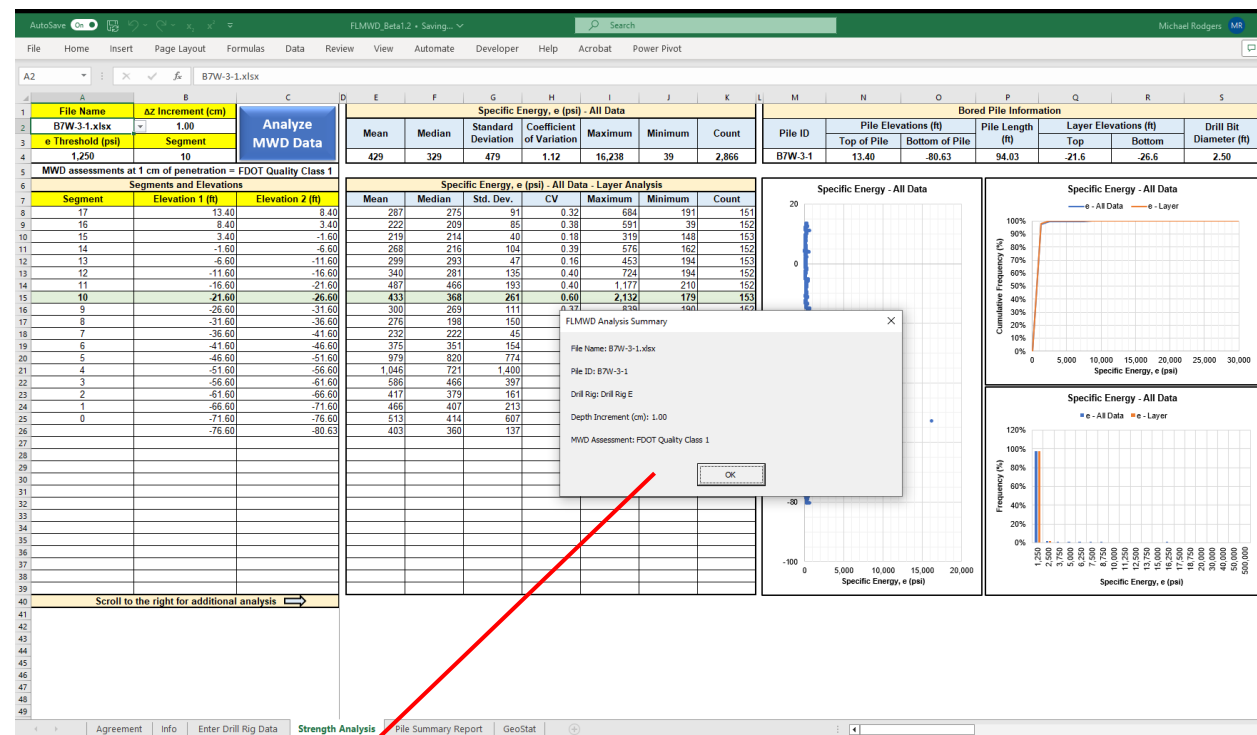
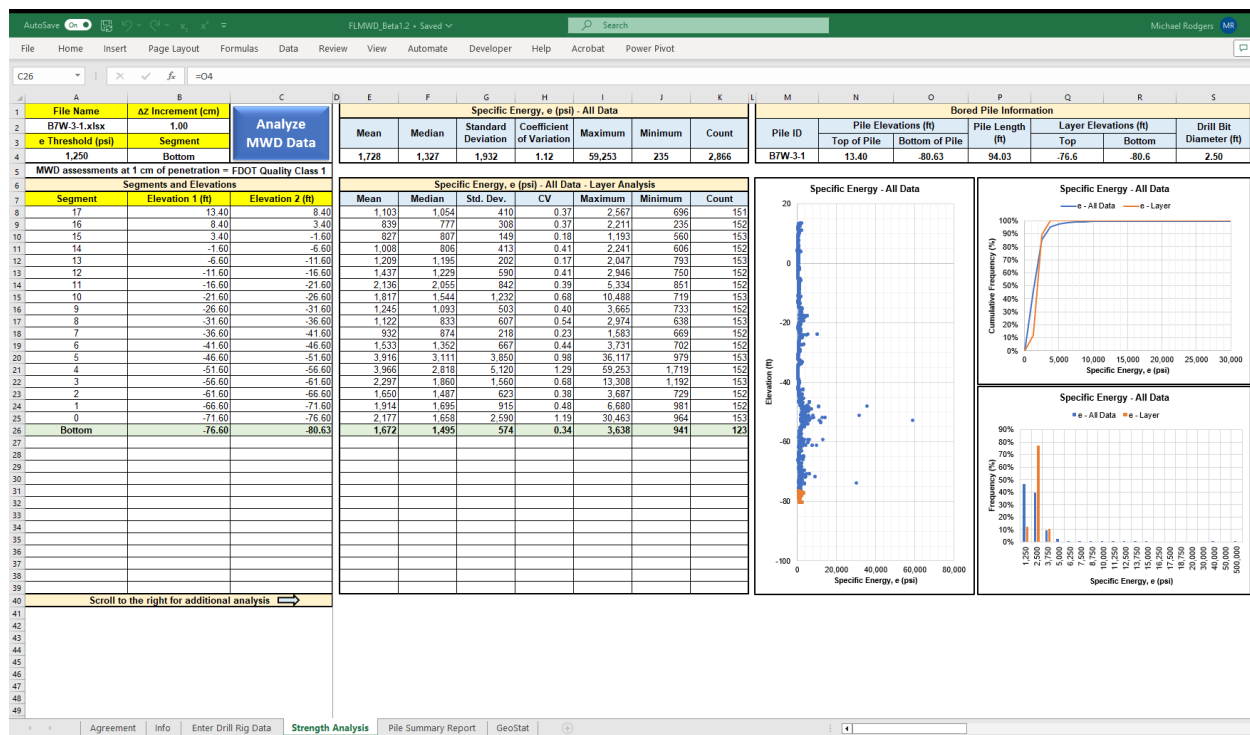
Drill Rig D

Drill Rig E

Drill Rig F



# Strength Analysis



## FLMWD Analysis Summary

File Name: B7W-3-1.xlsx

Pile ID: B7W-3-1

Drill Rig: Drill Rig E

Depth Increment (cm): 1.00

MWD Assessment: FDOT Quality Class 1

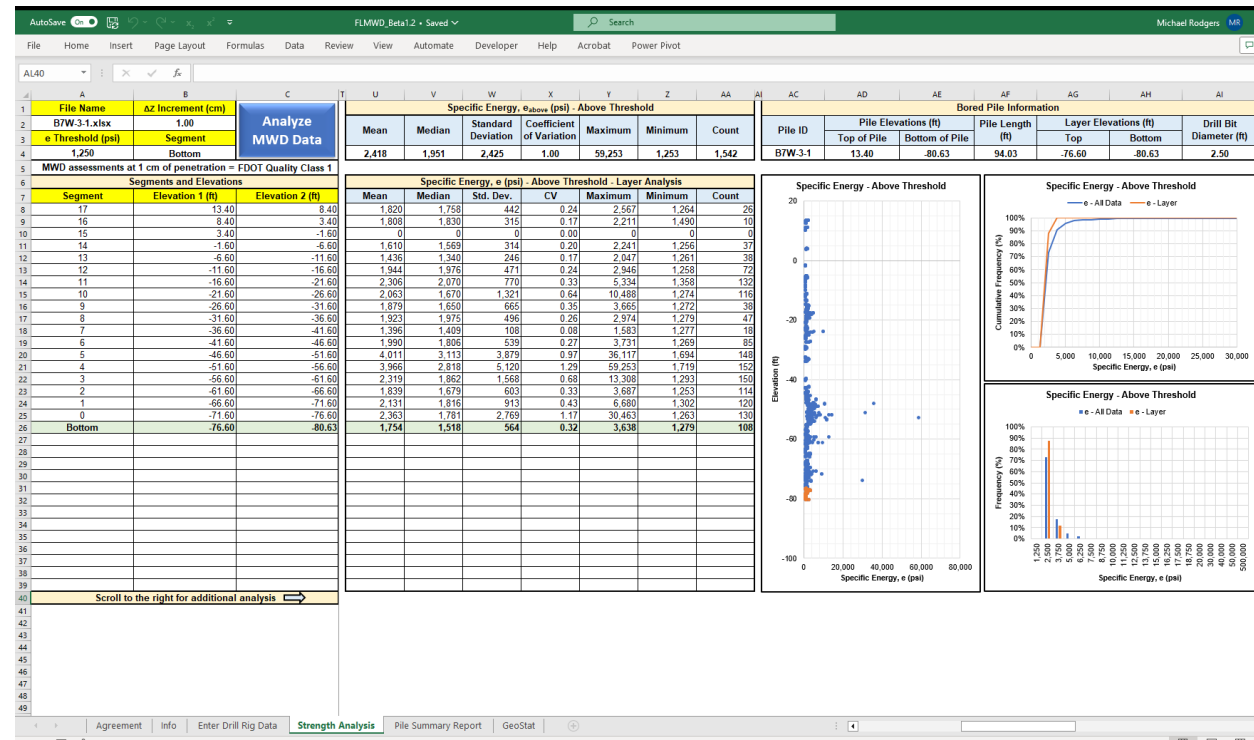
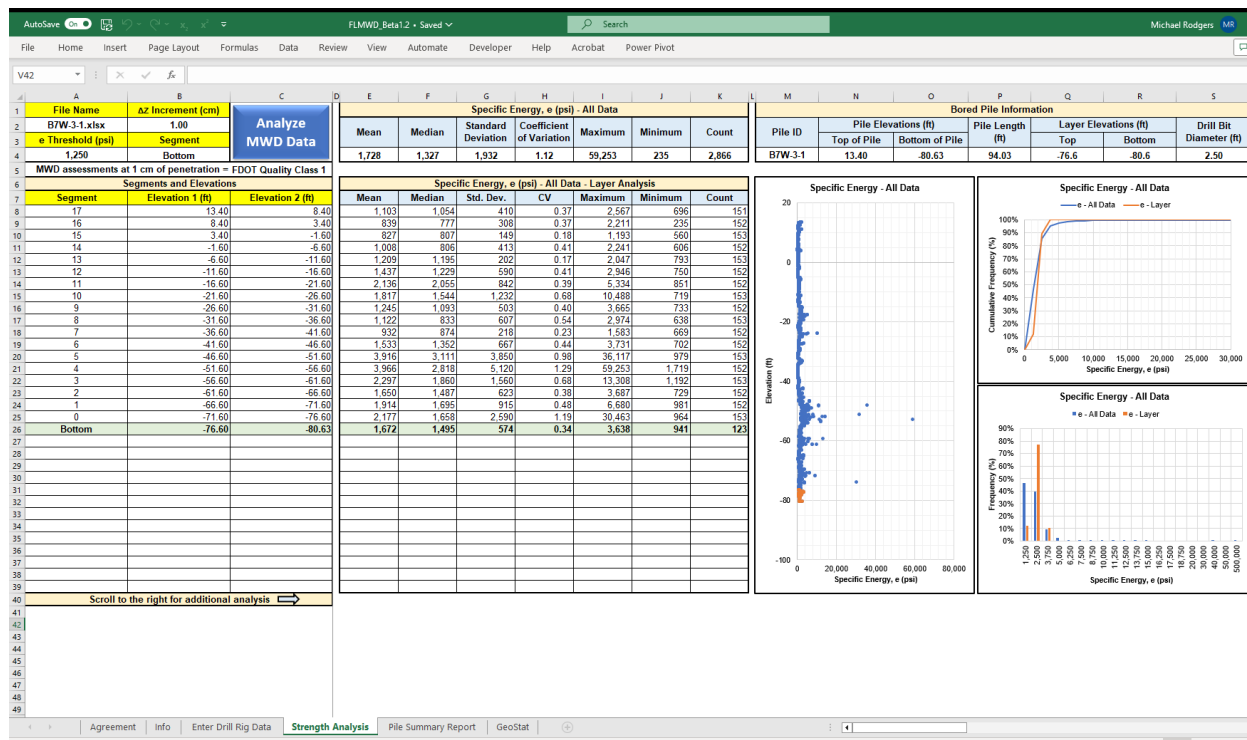
OK



# Strength Analysis – Specific Energy Threshold

## All Specific Energy Data

### Only Specific Energy Data Above Threshold

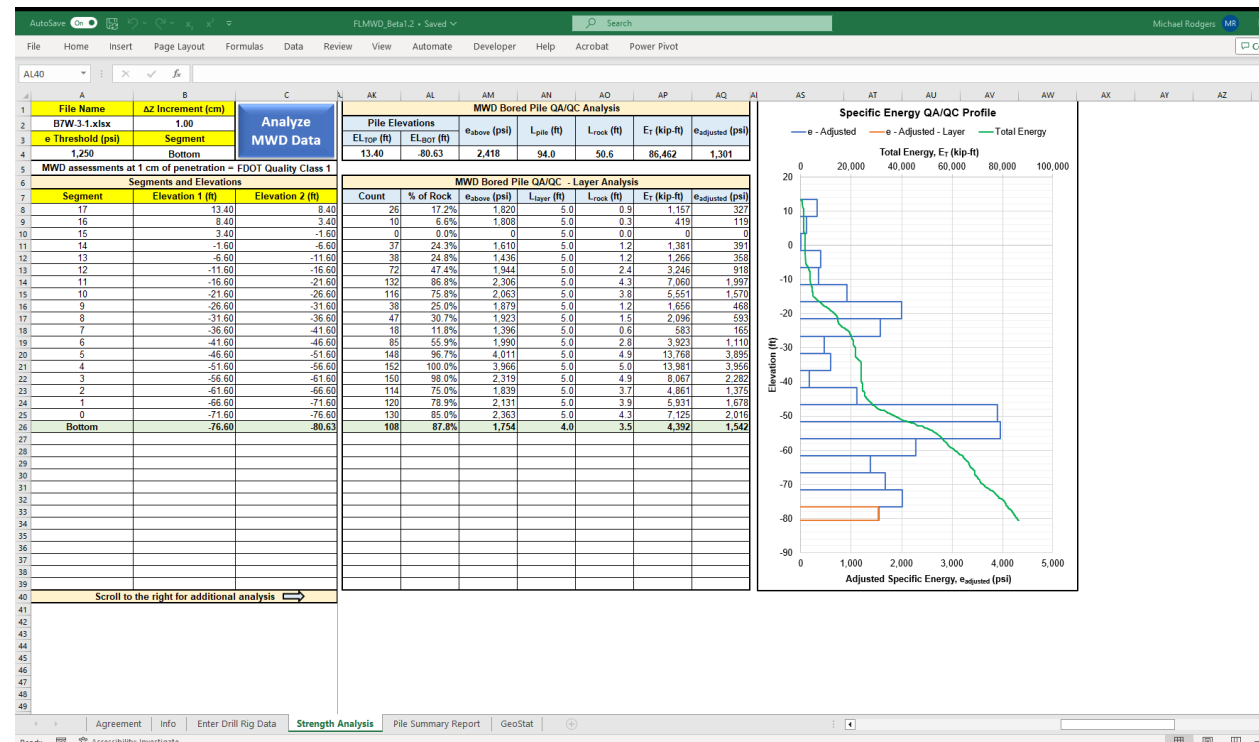
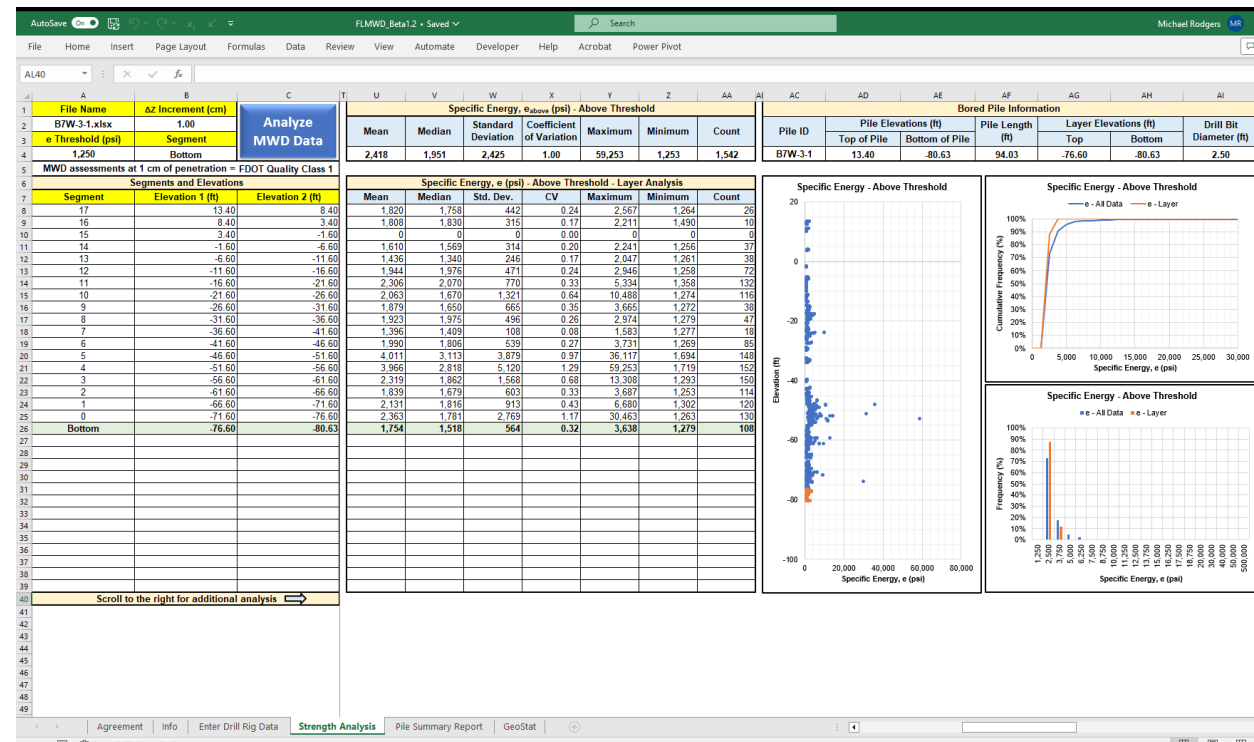




# Strength Analysis – Specific Energy Threshold

Only Specific Energy Data Above Threshold

Bored Pile QA/QC Analysis

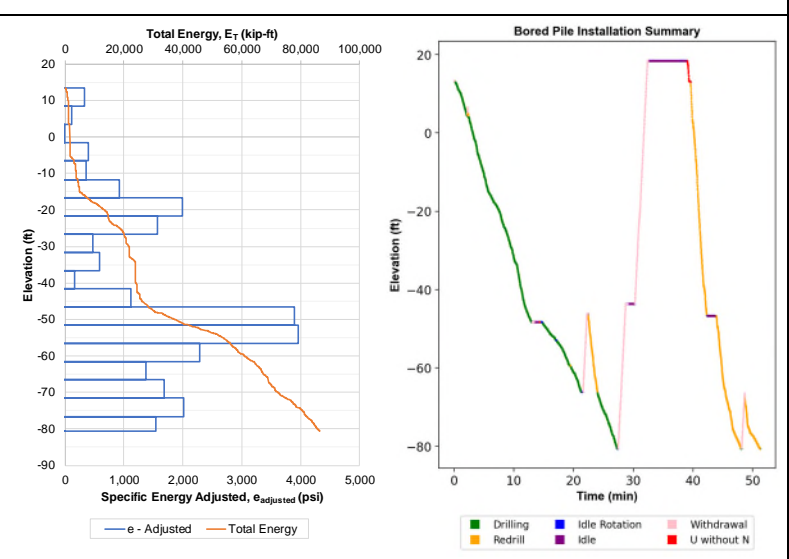






MWD Summary Report

Engineer Michael Rodgers	Pile ID 7W-3-1	Drill Rig Drill Rig B	Drill Bit Diameter (in) 30
Project	Location	Top of Pile Elevation (ft)	Bottom of Pile Elevation (ft)
UF Demo	Gainesville, FL	13.40	-80.63
Station	Offset (ft)	Depth Increment Analyzed (cm)	MWD Assessment
100+00.01	10.00	1.00	FDOT Quality Class 1
Specific Energy, $e$ (psi) - All Data		ACIP Pile QA/QC - Rock Socket Assessment	
Mean	1,728	Pile Length (ft)	94.03
Median	1,327	Total Rock Socket Length (ft)	50.59
Standard Deviation	1,932	Pile Percentage of Rock (%)	54%
Coefficient of Variation (CV)	1.12	Specific Energy Threshold (psi)	1,250
Maximum	59,253	Specific Energy, $e_{above}$ (psi)	2,418
Minimum	235	Specific Energy, $e_{adjusted}$ (psi)	1,301
Number of Data Points	2,866	Total Energy, $E_T$ (kip-ft)	86,469
Specific Energy, $e_{above}$ (psi) - Above Threshold		Bored Pile Installation Summary - Time (min)	
Mean	2,418	Drilling	23.33
Median	1,951	Redrill	11.43
Standard Deviation	2,425	Idle Rotation	1.55
Coefficient of Variation (CV)	1.00	Idle	9.10
Maximum	59,253	Withdraw	5.33
Minimum	1,253	Penetration without Rotation	0.52
Number of Data Points	1,542	Total	51.27



**Notes:**

Enter notes here.

Date of Analysis: 8/12/2024

Create PDF

MWD Summary Report PDF Address  
D:\FLMWD\_Beta1.3\Pile Summary Reports

PDF Folder Address

# Pile Summary Report

Notes:

Enter notes here.

Date of Analysis: 8/12/2024

Create PDF

MWD Summary Report PDF Address

PDF Folder Address

Notes:

Enter notes here.

Date of Analysis: 8/12/2024

Create PDF

MWD Summary Report PDF Address  
D:\FLMWD\_Beta1.3\Pile Summary Reports

PDF Folder Address



# Pile Summary Report

PDF Saved

PDF saved to: D:\FLMWD\_Beta1.3\Pile Summary Reports\7W-3-1.pdf

OK

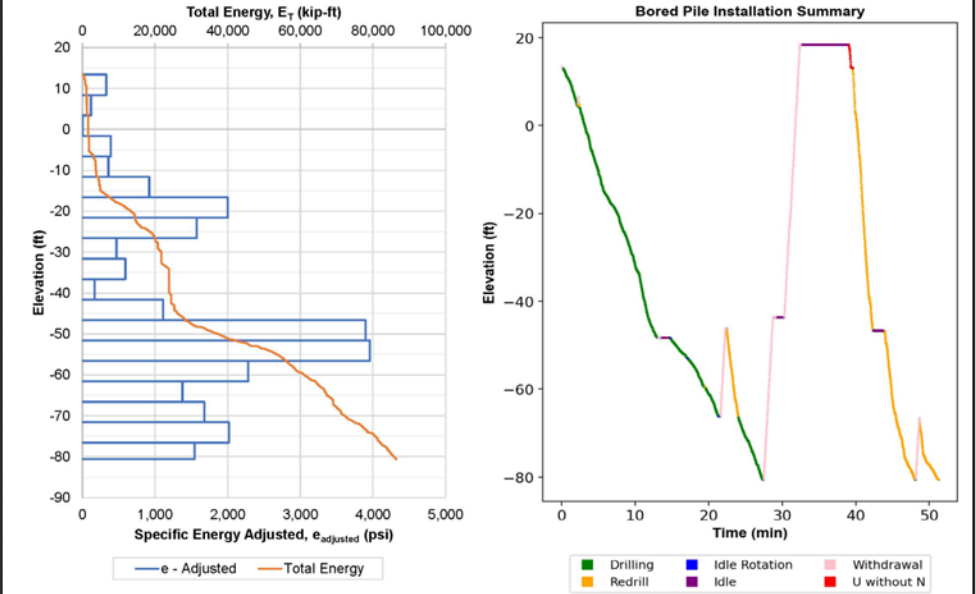
USB Drive (D:) > FLMWD\_Beta1.3 > Pile Summary Reports

Name	Date modified
 7W-3-1	8/12/2024 2:43 PM
 7W-3-6	4/25/2024 12:47 PM
 7W-3-8	4/30/2024 11:59 AM



## MWD Summary Report

Engineer	Pile ID	Drill Rig	Drill Bit Diameter (in)
Michael Rodgers	7W-3-1	Drill Rig B	30
Project	Location	Top of Pile Elevation (ft)	Bottom of Pile Elevation (ft)
UF Demo	Gainesville, FL	13.40	-80.63
Station	Offset (ft)	Depth Increment Analyzed (cm)	MWD Assessment
100+00.01	10.00	1.00	FDOT Quality Class 1
Specific Energy, $e$ (psi) - All Data		ACIP Pile QA/QC - Rock Socket Assessment	
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Minimum	1,253	Penetration without Rotation	0.52
Number of Data Points	1,542	Total	51.27

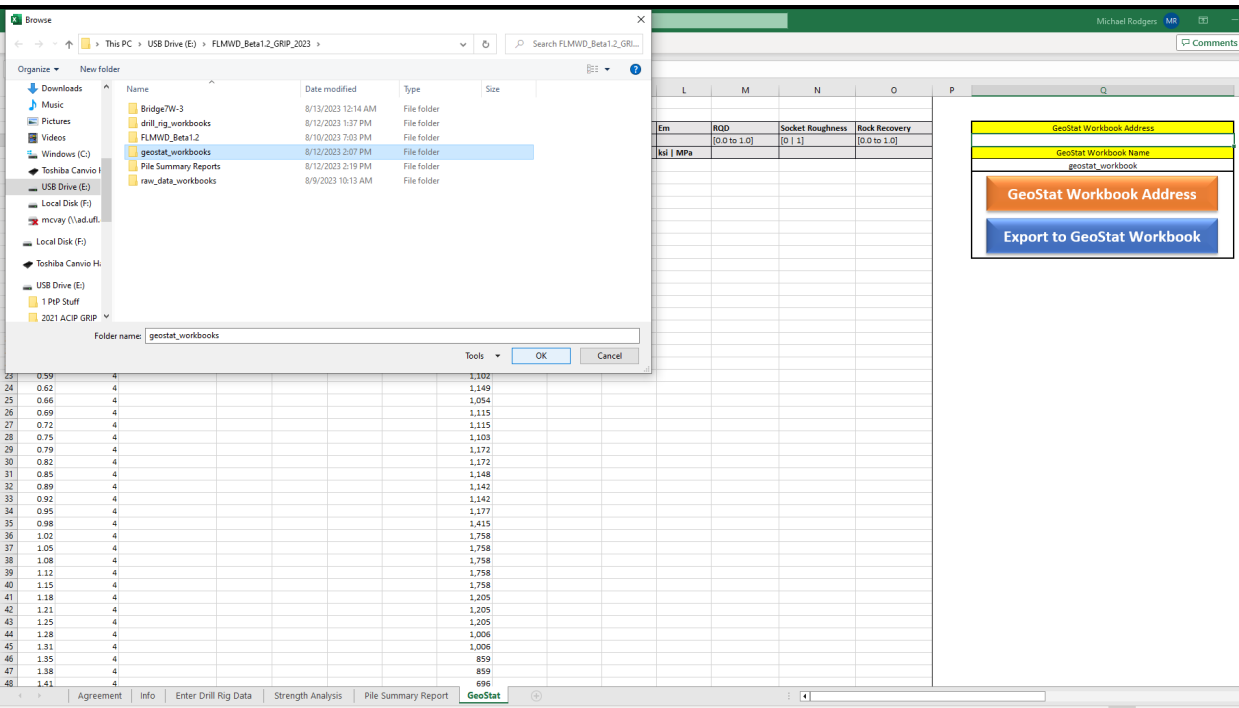


### Notes:

Enter notes here.



# GeoStat



AutoSave Off Save Undo Redo Print Formulas Data Review View Automate Developer Help Acrobat Power Pivot

geostat\_workbook - Excel Search

File Home Insert Page Layout Formulas Data Review View Automate Developer Help Acrobat Power Pivot

AA29 fx

**1 This tab must be populated with data prior to loading GS-Deep.**

**2**

**3 Depth Soil Type N. Blows qt (CPT) fs (CPT) Unit Weig Cu e qu qt qb Em RQD Socket Ro Rock Recovery**

**4 [1 2 3] [0.0 to 1.0] [0 1] [0.0 to 1.0]**

**5 ft m blows/ft tsf | MPa tsf | kPa pcf | kN/r tsf | kPa psi | kPa tsf | kPa tsf | kPa tsf | kPa ksi | MPa**

**6 0.03 4 2,567**

**7 0.07 4 2,567**

**8 0.10 4 2,567**

**9 0.13 4 2,567**

**10 0.16 4 1,785**

**11 0.20 4 1,785**

**12 0.23 4 1,739**

**13 0.26 4 1,675**

**14 0.30 4 1,675**

**15 0.33 4 1,279**

**16 0.36 4 1,060**

**17 0.39 4 1,061**

**18 0.43 4 1,061**

**19 0.46 4 1,086**

**20 0.49 4 1,086**

**21 0.52 4 1,055**

**22 0.56 4 1,102**

**23 0.59 4 1,102**

**24 0.62 4 1,149**

**25 0.66 4 1,054**

**26 0.69 4 1,115**

**27 0.72 4 1,115**

**28 0.75 4 1,103**

**29 0.79 4 1,172**

**30 0.82 4 1,172**

**31 0.85 4 1,148**

**32 0.89 4 1,142**

**33 0.92 4 1,142**

**34 0.95 4 1,177**

**35 0.98 4 1,415**

**36 1.02 4 1,758**

**37 1.05 4 1,758**

**38 1.08 4 1,758**

**39 1.12 4 1,758**

**40 1.15 4 1,758**

**41 1.18 4 1,205**

**42 1.21 4 1,205**

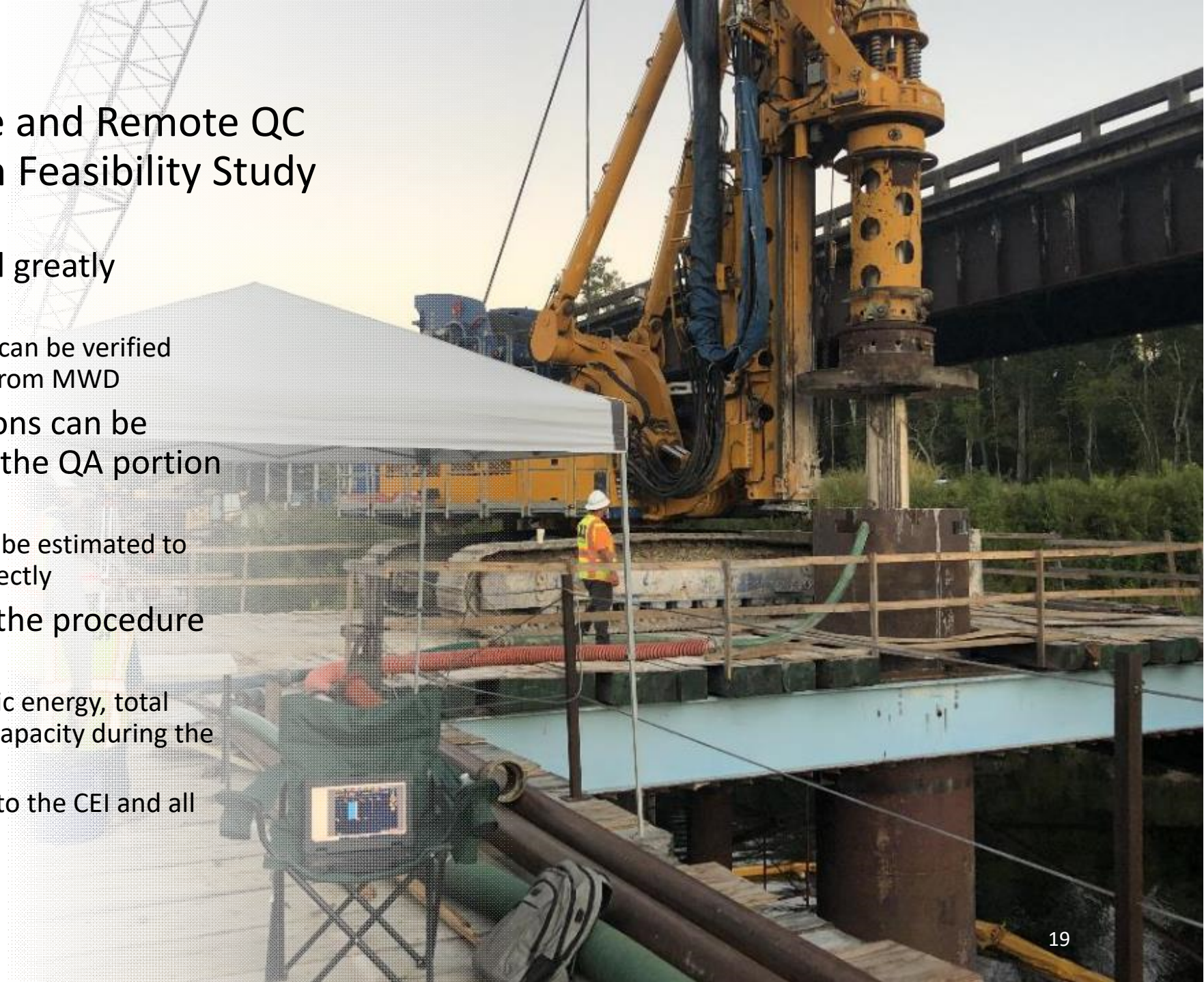
**43 1.25 4 1,205**

**5. Spatial Variability 6. Method Error 7. LRFD-phi B7W-3-2 B7W-3-3 B7W-3-1**



## Task 2 – Real Time, On-site and Remote QC Monitoring Implementation Feasibility Study

- The new MWD analysis tool will greatly improve drilled shaft QA/QC
  - Quality and length of rock sockets can be verified through specific energy obtained from MWD
- When MWD-load test correlations can be established for a site or region, the QA portion of the procedure is improved
  - Allows the shaft's axial capacity to be estimated to ensure it meets design criteria, directly
- Quality control (QC) portion of the procedure could be further improved
  - Real-time measurements of specific energy, total energy, and side shear axial shaft capacity during the drilling process
  - Requires actual data transmission to the CEI and all project stakeholders





# Task 2 – Real Time, On-site and Remote QC Monitoring Implementation Feasibility Study

- Can currently view drilling parameters live
- Need to develop a robust method that can transmit MWD data that is applicable to all monitoring systems
  - Likely through CAN bus integration
  - SBC module can transmit actual data on-site and to remote locations via CAN and Modem hats added in
- Method demonstrated using technology already being placed on rigs



# On-site and Remote Monitoring Demonstration

- **Demonstration Overview**

- Used an SBC with web broadcast and an instrumented drill rod (BED31-977-03)
- Custom sensor provides real-time torque, crowd, and 3-axis vibration data integrated into Jean Lutz DIALOG DAQ system

- **Custom Programming**

- Developed SBC programming to only stream 3-axis accelerometer data
  - 4 parameters per axis, 12 total
- 1 Hz average sampling, replicating FDOT MWD bored pile QA/QC requirements

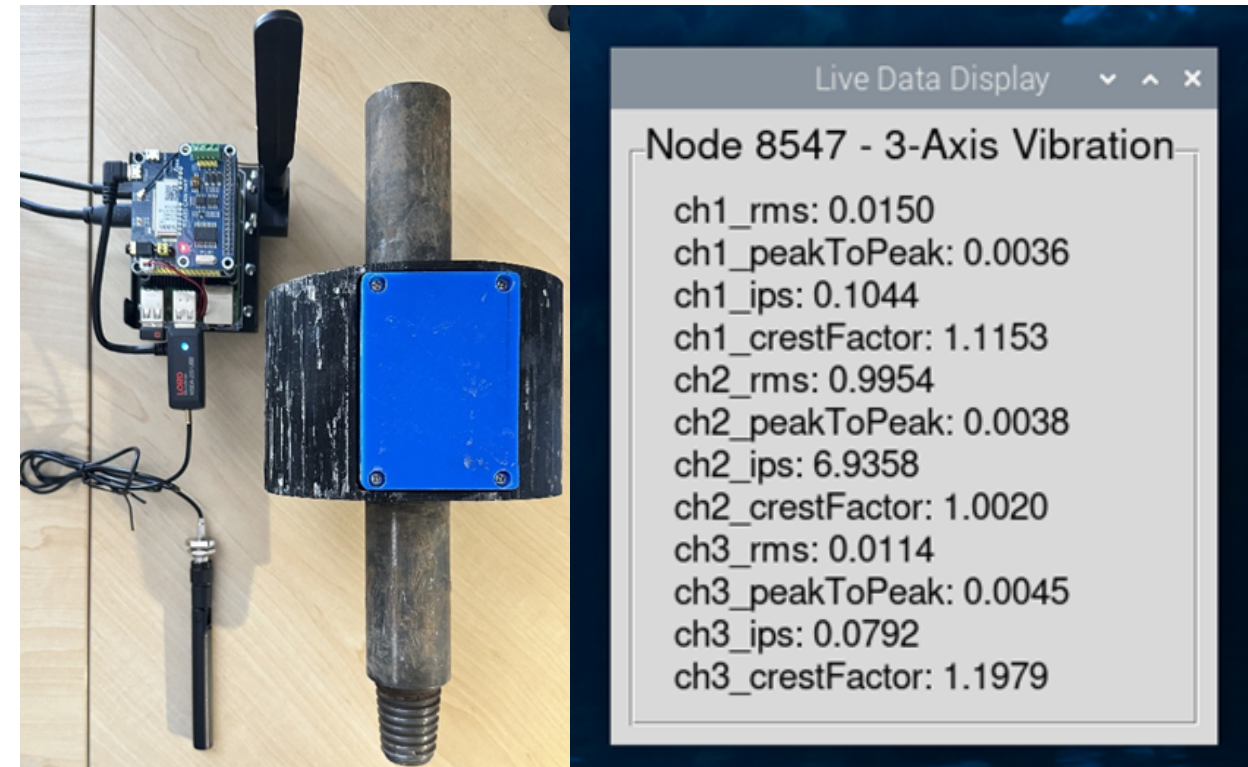
- **Data Simulation & Storage Insight**

- Streamed 12 parameters from 3-axis accelerometer to simulate typical FDOT MWD data stream
- Data used to assess storage requirements for current FDOT MWD applications

Typical FDOT Bored Pile Data Stream

	A	B	C	D	E	F	G	H	I	J	K
1	Time	Duration (min)	Gear Box RPM	Penetration Rate (ft/min)	Penetration Rate (min/ft)	Depth (ft)	Gear Box Pres	Torque (ft-lbs)	Crowd Pressun	Thrust (lbs)	
2	6/4/2020 10:16:38 AM	0	-79.39	-49.8359596	3.048	0	551.8684485	0	210.1596273	3258.31	
3	6/4/2020 10:16:39 AM	0.02	-79.66	-50.4921276	3.048	0	519.5250414	0	218.2817385	3384.24	
4	6/4/2020 10:16:40 AM	0.03	-79.75	-50.524936	3.048	0	448.166493	0	221.0374548	3426.96	
5	6/4/2020 10:16:41 AM	0.05	-79.8	-50.524936	3.048	0	537.6547539	0	217.8466254	3377.49	
6	6/4/2020 10:16:42 AM	0.07	-31.19	-25.262468	3.048	0	559.9905597	0	288.625023	4474.84	
7	6/4/2020 10:16:43 AM	0.08	19.49	0.0984252	10.16	0.0328084	504.8762337	0	209.7245142	3251.57	
8	6/4/2020 10:16:44 AM	0.1	19.62	0.4265092	2.344615385	0.0328084	520.685343	0	219.2970024	3399.98	
9	6/4/2020 10:16:45 AM	0.12	19.58	0.4593176	2.177142857	0.0328084	545.4867897	0	240.762582	3732.78	
10	6/4/2020 10:16:46 AM	0.13	19.54	0.984252	1.016	0.1312336	603.2117943	0	231.4801692	3588.87	

MWD Components and Simulated Data Stream Display





# The SBC Code

- With the live MWD data now in place, the researchers then developed programming on the SBC to send the live data
  - External computer that mimicked onsite monitoring by the CEI
  - To the cloud to mimic remote monitoring by stakeholders involved in the project
    - Google Cloud Service, GCS
- Key Functions
  - Collect vibration data from a sensor node via a wireless base station
  - Provide visual display from SBC to simulate DAQ module display
  - Log the data into a local temporary CSV file
  - Periodically upload the data to the cloud (GCS)
  - Stream the data to a connected client (external computer) using a web socket server

# SBC Main Components and Functions

- **CSV File Management**
  - Initialize a CSV file (tempdata.csv) with proper headers
  - Dynamically append new rows of sensor data to the file while ensuring headers remain consistent
- **Data Parsing and Aggregation**
  - Parse data (data packet): Extract channel data from a sensor data packet
  - Append to CSV (timestamp, channel values): Write timestamped, aggregated channel data to the CSV file
- **WebSocket Server**
  - Implement a WebSocket server that an external computer can connect to
  - Historical Data: In case of a disconnection, the system reads unsent data from the temporary CSV file and sends it to the client once connection is reestablished
  - Real-Time Data: Send live sensor data to the client after sending any historical data
- **Google Cloud Service (GCS) Configuration**
  - Authentication: Uses a service account JSON key to authenticate to GCS
  - Interaction: Upload the CSV file to a specified GCS bucket every 10 seconds
- **Periodic Updates**
  - Process incoming sensor data sweeps from the base station
  - Update GUI labels on SBC interface with the latest data
  - Scan temporary CSV file for prior entries so duplicate data is avoided
  - Log only new data to the CSV file and trigger sending data via cloud and web socket



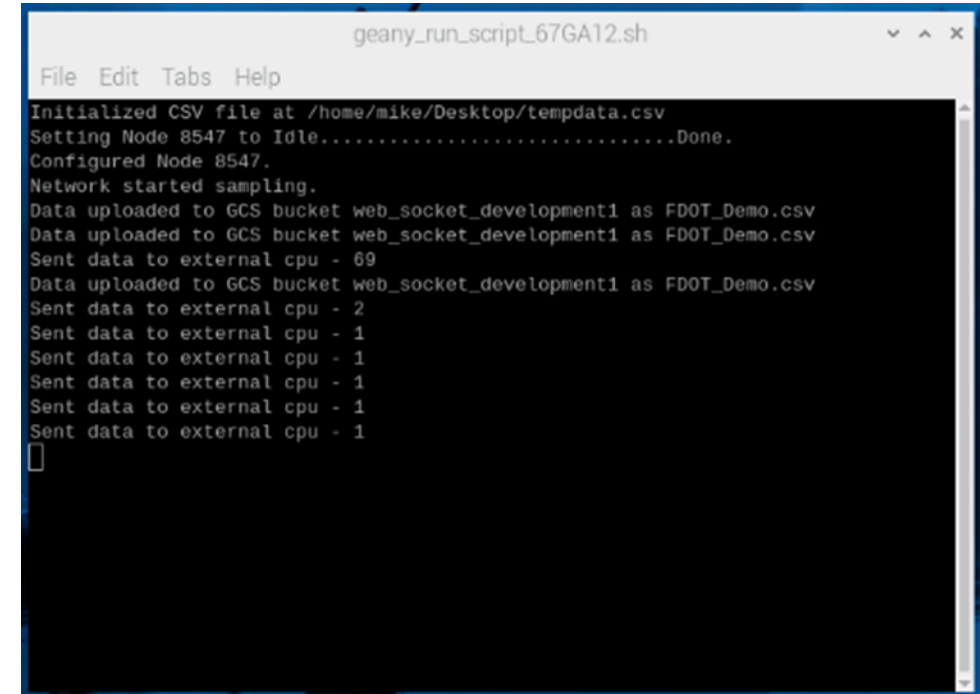
# External Computer Code

- In addition to the SBC, programming was also required on the external computer side to connect with the SBC web socket server to receive and log the data
- Two data storage formats were investigated:
  - USB hard drive
  - Cloud-based drive (OneDrive)
  - This was done to determine the best mechanism to interact with the newly developed MWD bored pile analysis tool
- Key Functions
  - WebSocket Communication: Connect to the SBC web socket server to receive data
  - Data Logging: Log historical and real-time data into two text files: hard drive (USB) and a cloud-based drive (OneDrive)
  - Duplicate Prevention: Ensure no duplicate data are written using a persistence mechanism
  - Real-Time Monitoring: Open a PowerShell session to monitor data in a real-time feed

# Workflow Interaction Between SBC and External Computer

- **SBC**
  - Collect sensor data and log it to a local CSV file
  - Periodically upload the data to the cloud
    - Every 10 seconds during trials
  - Stream historical and real-time data through a web socket server
  - Provide informational messages based on connection status and data sent
- **External Computer**
  - Connect to the SBC web socket server
  - Collect historical data (unsent data) first, followed by real-time data
  - Log the received data into two text file locations:
    - Hard drive (USB)
    - Cloud-based drive (OneDrive)
  - Monitor data using PowerShell for real-time feed
  - Provide informational messages based on connection status and data received

## SBC Terminal Messages Sent



```
geany_run_script_67GA12.sh
File Edit Tabs Help
Initialized CSV file at /home/mike/Desktop/tempdata.csv
Setting Node 8547 to Idle.....Done.
Configured Node 8547.
Network started sampling.
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Sent data to external cpu - 69
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Sent data to external cpu - 2
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
```

## External Computer Messages Received

```
File C:\Users\micha\OneDrive\Documents\FDOT_Demo.txt is ready with headers.
Persisted timestamps reset for new file creation.
File D:\Sensor Data From Pi\FDOT_Demo.txt is ready with headers.
Persisted timestamps reset for new file creation.
PowerShell tailing started in a new window.
Connected to WebSocket server.
Received data from SBC - 69
Received data from SBC - 2
Received data from SBC - 1
Received data from SBC - 1
Received data from SBC - 1
Received data from SBC - 1
Received data from SBC - 1
Received data from SBC - 1
```



# Simulate Client Disconnect

- SBC Connection Loss Handling
  - SBC detects when external computer (client) disconnects
  - Historic data is stored while the connection is lost
- Reconnection Process
  - Once client is reconnected, SBC sends stored historic data first
  - Real-time data transmission resumes
- Data Integrity
  - Logs confirm no data loss during disconnection and reconnection
  - 48 data packets sent, 48 data packets received after reconnection
  - Data always sent to the cloud

```

geany_run_script_67GA12.sh
File Edit Tabs Help
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Client disconnected.
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Sent data to external cpu - 38
Sent data to external cpu - 1
Sent data to external cpu - 2
Sent data to external cpu - 1
Sent data to external cpu - 1
Sent data to external cpu - 1
Data uploaded to GCS bucket web_socket_development1 as FDOT_Demo.csv
Sent data to external cpu - 2
Sent data to external cpu - 1
Sent data to external cpu - 1

```

## External Computer Messages Received

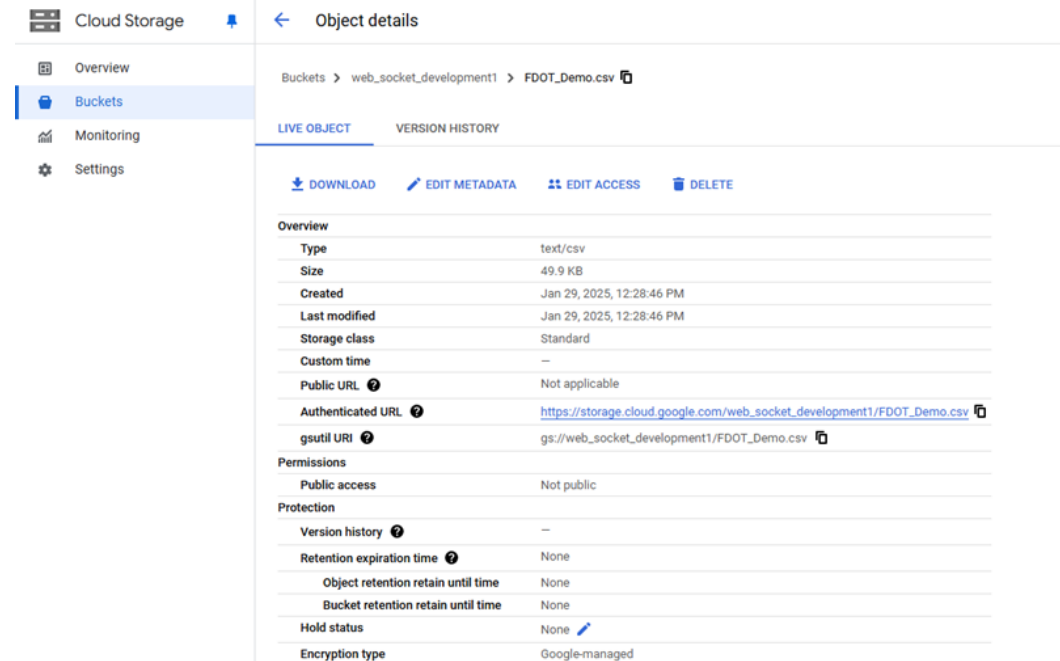
```

PowerShell tailing started in a new window.
Connected to WebSocket server.
Received data from SBC - 38
Received data from SBC - 1
Received data from SBC - 2
Received data from SBC - 1
Received data from SBC - 1
Received data from SBC - 1
Received data from SBC - 2
Received data from SBC - 1
Received data from SBC - 1

```

# Remote Monitoring

- Cloud Data Broadcasting
  - SBC uploads data to cloud every 10 seconds
  - Stored in GCS bucket
- Streamlined FDOT Analysis
  - Future separate buckets for each MWD project
  - Direct upload eliminates manual downloads/emails
- Real-Time Monitoring
  - CEI can flag issues during installation for FDOT review
  - FDOT makes informed decisions from remote locations
- Data Access and Security
  - Data downloadable in CSV format compatible with MWD analysis tool
  - Secure access via JSON key, encryption by GCS or similar
- Data Health Monitoring
  - Server/client error rate tracking
  - Confirm successful data transmission
- Future Integration
  - Insights for FDOT's MWD system specifications
  - Ensures compatibility with new MWD QC tool



The screenshot shows a Microsoft Excel spreadsheet with a large data table. The table has 15 columns labeled A through M, and 37 rows of data. The data appears to be a time-series or sensor data, with columns containing timestamps, numerical values, and possibly categorical data. The first row of data is on row 2, starting with a timestamp '1/29/2025 12:26' and followed by numerical values. The table continues down to row 37, with the last row of data starting with a timestamp '1/29/2025 12:26' and followed by numerical values.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	timestamp	ch1_rms	ch1_peakToPeak	ch1_rms	ch1_crestFactor	ch2_rms	ch2_peakToPeak	ch2_rms	ch2_crestFactor	ch3_rms	ch3_peakToPeak	ch3_rms	ch3_crestFactor	
2	1/29/2025 12:26	0.01488991	0.003612238	0.10369952	1.119898915	0.995375633	0.005236745	6.93598938	1.00249362	0.008960897	0.0044179	0.062286206	1.29647366	
3	1/29/2025 12:26	0.014878351	0.003989167	0.103613347	1.132380366	0.995376527	0.005142748	6.936090469	1.002539992	0.008987277	0.005127341	0.062506667	1.288666606	
4	1/29/2025 12:26	0.014909999	0.004444623	0.103798836	1.144723654	0.995366037	0.005816936	6.935966492	1.002296815	0.008973416	0.00594965	0.062315706	1.331984282	
5	1/29/2025 12:26	0.014903844	0.003690765	0.103690596	1.128359553	0.995368302	0.004954576	6.935911179	1.002485275	0.008956819	0.00490161	0.062542071	1.298972929	
6	1/29/2025 12:26	0.014889778	0.003690704	0.103690596	1.128359553	0.99537037	0.005111396	6.935960912	1.002591133	0.008973032	0.004853227	0.062328015	1.251180291	
7	1/29/2025 12:26	0.014863324	0.00387923	0.103319176	1.134581923	0.995372057	0.005221128	6.935965061	1.002579994	0.008998837	0.004627507	0.062551804	1.231466889	
8	1/29/2025 12:26	0.014885786	0.004318961	0.103636522	1.158191442	0.995357275	0.005158424	6.935804844	1.002543688	0.008955388	0.005078971	0.062119156	1.232040048	
9	1/29/2025 12:26	0.014874455	0.003926347	0.103550304	1.154850245	0.995367408	0.005017281	6.93593359	1.002596378	0.008960144	0.004579134	0.062312089	1.261977553	
10	1/29/2025 12:26	0.014876427	0.00343948	0.103578404	1.118802547	0.995377719	0.004923224	6.935993195	1.002428532	0.008982831	0.004837118	0.062380403	1.262380481	
11	1/29/2025 12:26	0.014865587	0.003596533	0.103521504	1.113279462	0.995370269	0.004829109	6.935924053	1.002483249	0.008953421	0.005772293	0.062327988	1.297141314	
12	1/29/2025 12:26	0.014870094	0.003919641	0.103439912	1.126672268	0.995362163	0.004719377	6.935892582	1.002381206	0.008967258	0.004611384	0.062416181	1.275361061	
13	1/29/2025 12:26	0.014889847	0.003296132	0.103589322	1.109556046	0.995370746	0.004938841	6.935925298	1.002482772	0.00898772	0.004486269	0.062396914	1.34547771	
14	1/29/2025 12:26	0.014868411	0.003588827	0.103464	1.106730103	0.995369196	0.004989829	6.935960372	1.002437115	0.008989601	0.00464963	0.062382419	1.275778294	
15	1/29/2025 12:26	0.014886122	0.00347089	0.103757553	1.11807394	0.995363772	0.005158424	6.935902596	1.002526967	0.008982866	0.004434023	0.06242257	1.237246156	
16	1/29/2025 12:26	0.014874333	0.003423775	0.10359776	1.11368072	0.995375872	0.004844844	6.936035633	1.002509117	0.008945114	0.005112127	0.062246725	1.273110628	
17	1/29/2025 12:26	0.014883693	0.00367506	0.103724234	1.121421933	0.995366275	0.004970253	6.935963631	1.002439976	0.00897554	0.00464363	0.062359467	1.24723804	
18	1/29/2025 12:26	0.014880343	0.003172489	0.103663616	1.101621032	0.995389462	0.004923224	6.936090946	1.002653003	0.00897856	0.00467588	0.062366176	1.262980938	
19	1/29/2025 12:26	0.014871621	0.003580829	0.103594027	1.102267146	0.995394349	0.004688025	6.936116219	1.002333045	0.008983115	0.00464363	0.06250196	1.278494358	
20	1/29/2025 12:26	0.014884967	0.003188193	0.103650517	1.111829877	0.995374441	0.004989529	6.936025841	1.00247976	0.008966547	0.00490161	0.062289603	1.298383854	
21	1/29/2025 12:26	0.014882569	0.003659355	0.103669328	1.124589553	0.995359719	0.005064309	6.935964825	1.002483858	0.00911355	0.004853241	0.062615196	1.287012935	
22	1/29/2025 12:26	0.01487348	0.002219604	0.103571735	1.11744497	0.995358169	0.005158365	6.93607705	1.002719549	0.008976966	0.004408515	0.062421985	1.218515482	
23	1/29/2025 12:26	0.014880985	0.00326672	0.10371466	1.104739666	0.9953807	0.004672348	6.936009884	1.002299547	0.008974631	0.005057808	0.062425453	1.304855347	
24	1/29/2025 12:26	0.014871879	0.003392363	0.103526548	1.113864541	0.995373905	0.005048692	6.935929298	1.002574086	0.008973217	0.00403396	0.062330451	1.283498645	
25	1/29/2025 12:26	0.014890177	0.003643649	0.103732951	1.12304306	0.995371819	0.004989529	6.935966478	1.00244761	0.008926776	0.004028929	0.061953094	1.239601731	
26	1/29/2025 12:26	0.014870198	0.003423775	0.10355293	1.113990426	0.995389342	0.005020542	6.9360075	1.002527118	0.008947221	0.004675876	0.06222792	1.254789829	
27	1/29/2025 12:26	0.014888331	0.003679509	0.103665985	1.123182297	0.995365918	0.005033016	6.936014175	1.002566457	0.008944965	0.005068174	0.062180772	1.343431115	
28	1/29/2025 12:26	0.014870643	0.003722175	0.103650692	1.132967333	0.995387912	0.004876136	6.936113358	1.002497777	0.008937638	0.0050514475	0.062121466	1.292215824	
29	1/29/2025 12:26	0.014880808	0.003706472	0.103563175	1.127420396	0.995345831	0.005017281	6.935922487	1.002523861	0.008946848	0.005011055	0.062167704	1.278384805	
30	1/29/2025 12:26	0.014745807	0.003663525	0.102357477	1.122372776	0.995431112	0.004107893	6.936059722	1.002053976	0.009228173	0.004143797	0.064800769	1.207851887	
31	1/29/2025 12:26	0.014900702	0.003784997	0.10351878	1.11735921	0.995397389	0.004688025	6.93614006	1.002361417	0.00893432	0.004756495	0.062064275	1.265596867	
32	1/29/2025 12:26	0.014871565	0.003784997	0.103611723	1.117715875	0.995377541	0.005221128	6.935959816	1.002343237	0.008952421	0.004740376	0.062321138	1.216239214	
33	1/29/2025 12:26	0.014865276	0.003679509	0.103537902	1.109635315	0.995390058	0.004891872	6.93607378	1.002258539	0.008943141	0.004708126	0.062127594	1.260771036	
34	1/29/2025 12:26	0.014849608	0.003313837	0.103530191	1.107074022	0.995387137	0.004750729	6.936071196	1.002365052	0.008940786	0.004949979	0.062229272	1.253889561	
35	1/29/2025 12:26	0.014873584	0.003423774	0.10360726	1.126407862	0.995392859	0.005377889	6.936070919	1.002413273	0.008946687	0.005030598	0.062207259	1.303524137	
36	1/29/2025 12:26	0.014870705	0.003529542	0.103550315	1.109727859	0.995366871	0.005025241	6.935928345	1.002596874	0.008974805	0.004727805	0.062525741	1.229374528	
37	1/29/2025 12:26	0.014886184	0.00326672	0.103689209	1.104353905	0.995383352	0.005268157	6.936021805	1.002533878	0.008956216	0.00472456	0.06212629	1.307538271	



# Remaining Tasks

- Deliverable 1 – Establish drilled shaft MWD data reduction criteria and procedures (Task 1)
- Deliverable 2 – On-site and remote monitoring implementation feasibility study (Task 2)
- Deliverable 3 – MWD specific energy vs. drilled shaft side shear correlation (Task 3)
- Deliverable 4 – MWD correlation validation for drilled shaft QA/QC (Task 4)
- Deliverable 5a - Draft Final (Task 5)
- Deliverable 5b - Closeout Meeting (Task 5)
- Deliverable 6 - Final Report (Task 6)



# Questions?

