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CONSULTING & ENGINEERING

STGEC 2023

Charlotte

Independent Comparison of Dynamic Pile Test Equipment

Michael Simpson, P.E.

ICE of CAROLINAS, PLLC

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(2) Filling Holes

Check the water inflow rate at the bottom of holes after all pumps have been removed. If the water inflow rate is greater than 6 inches per half hour or holes are stabilized with slurry, use an approved method for placing concrete, grout or flowable fill. Otherwise, remove any fluids and free fall concrete, grout or flowable fill into holes. Ensure that concrete, grout or flowable fill flows completely around piles. Place concrete, grout or flowable fill continuously and remove all temporary casings.

(F) Pile Driving Analyzer

When required, test piles in accordance with ASTM D4945 using a pile driving analyzer (PDA) manufactured by Pile Dynamics, Inc. Analyze PDA data with the CAse Pile Wave Analysis Program (CAPWAP) manufactured by Pile Dynamics, Inc. Use a prequalified PDA Consultant to perform PDA testing and CAPWAP analyses and provide PDA reports. Use a PDA Operator approved as a Field Engineer (key person) for the PDA Consultant. Provide PDA reports sealed by an engineer approved as a Project Engineer (key person) for the same PDA Consultant.

The Engineer will determine how many and which piles re[illegible]ing. Provide piles for PDA testing that are at least 5 feet longer than the estima[illegible]s shown in the plans. Do not drive piles until the proposed pile driving method[illegible]t have been preliminarily accepted. Notify the Engineer of the pile driving sc[illegible]7 days in advance.

The Engineer will complete the review of the proposed pile driving methods [illegible] within 7 days of receiving PDA reports and pile driving criteria. Do not place [illegible] caps or footings on piles until PDA reports and pile driving criteria have been ac[illegible]

(1) PDA Testing

If necessary, provide a shelter to protect the PDA Operator and equipment from conditions of sun, water, wind and temperature. The shelter should have a floor size of at least 6 feet x 6 feet and a roof height of at least 8 feet. If necessary, heat or cool the shelter to maintain a temperature between 50°F and 85°F. Place the shelter within reach of the PDA cables and clear view of piles being driven.

Drill holes for PDA instruments as directed. Place piles in leads and templates before attaching PDA instruments. Use only preliminarily accepted pile driving methods and equipment to drive piles. Drive piles as directed and in accordance with Subarticle 450-3(D). The PDA Operator or Engineer may require modified pile installation procedures during driving. Dynamic measurements will be recorded and used to evaluate the hammer performance, driving resistance and stresses, energy transfer, pile integrity and various soil parameters such as quake and damping.

If required, reattach PDA instruments and restrike or redrive piles in accordance with Subarticle 450-3(D)(4). Obtain the required stroke and at least 6 inches of pile movement as directed. Dynamic measurements will be recorded during restriking and redriving. The Engineer will determine when PDA testing has been satisfactorily completed.

(2) CAPWAP Analysis

CAPWAP analysis is required for at least a hammer blow near the end of initial drive and each restrike and redrive. Additional CAPWAP analyses may be required as determined by the PDA Consultant or Engineer.

(3) PDA Reports

Submit 2 copies of each PDA report within 7 days of completing PDA testing. Include the following in PDA reports:

NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
RALEIGH

STANDARD SPECIFICATIONS FOR ROADS AND STRUCTURES

2018

When required, test piles in accordance with ASTM D4945 using a pile driving analyzer (PDA) manufactured by Pile Dynamics, Inc. Analyze PDA data with the CAse Pile Wave Analysis Program (CAPWAP) manufactured by Pile Dynamics, Inc. Use a prequalified PDA Consultant to perform PDA testing and CAPWAP analyses and provide PDA reports. Use a PDA Operator approved as a Field Engineer (key person) for the PDA Consultant. Provide PDA reports sealed by an engineer approved as a Project Engineer (key person) for the same PDA Consultant.

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GEOTECHNICAL CONTRACTOR PREQUALIFICATION REQUIREMENTS
(CONTINUED)

Work Code	Work Description	Type of Work	Key Personnel Required	Registration/ Certification Required	Years of Continuous Experience Required	Additional Requirements
003060	Pile Driving Analyzer (PDA)		Project Engineer	P.E.[1] & Advanced[2] or Higher	5	Experience with PDA-S, CAse Pile Wave Analysis Program (CAPWAP), version 2014, and GRL Wave Equation Analysis Program (GRLWEAP), version 2010, manufactured by Pile Dynamics, Inc. One steel pile example and one prestressed concrete pile example; both PDA testing examples with CAPWAP analysis and driving criteria
			Field Engineer	Intermediate[2] or Higher	1	

[2]Certificate of Proficiency Rank from Pile Dynamics (www.pdaproficiencytest.com)

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- Goble Pile Check (GPC)
  - Refined Signal Matching with N-GAPA
  - 2 – combined accelerometer /strain gauges
  - Wireless
  - Option for instant (blow by blow) signal matching with iN-GAPA
- Pile Driving Analyzer (PDA) from Pile Dynamics, Inc.
  - **Refined Signal Matching with CAPWAP**
  - 2 strain gauges
  - 2 accelerometers
  - Wireless / Wired
  - Option for instant (blow by blow) signal matching with iCAP

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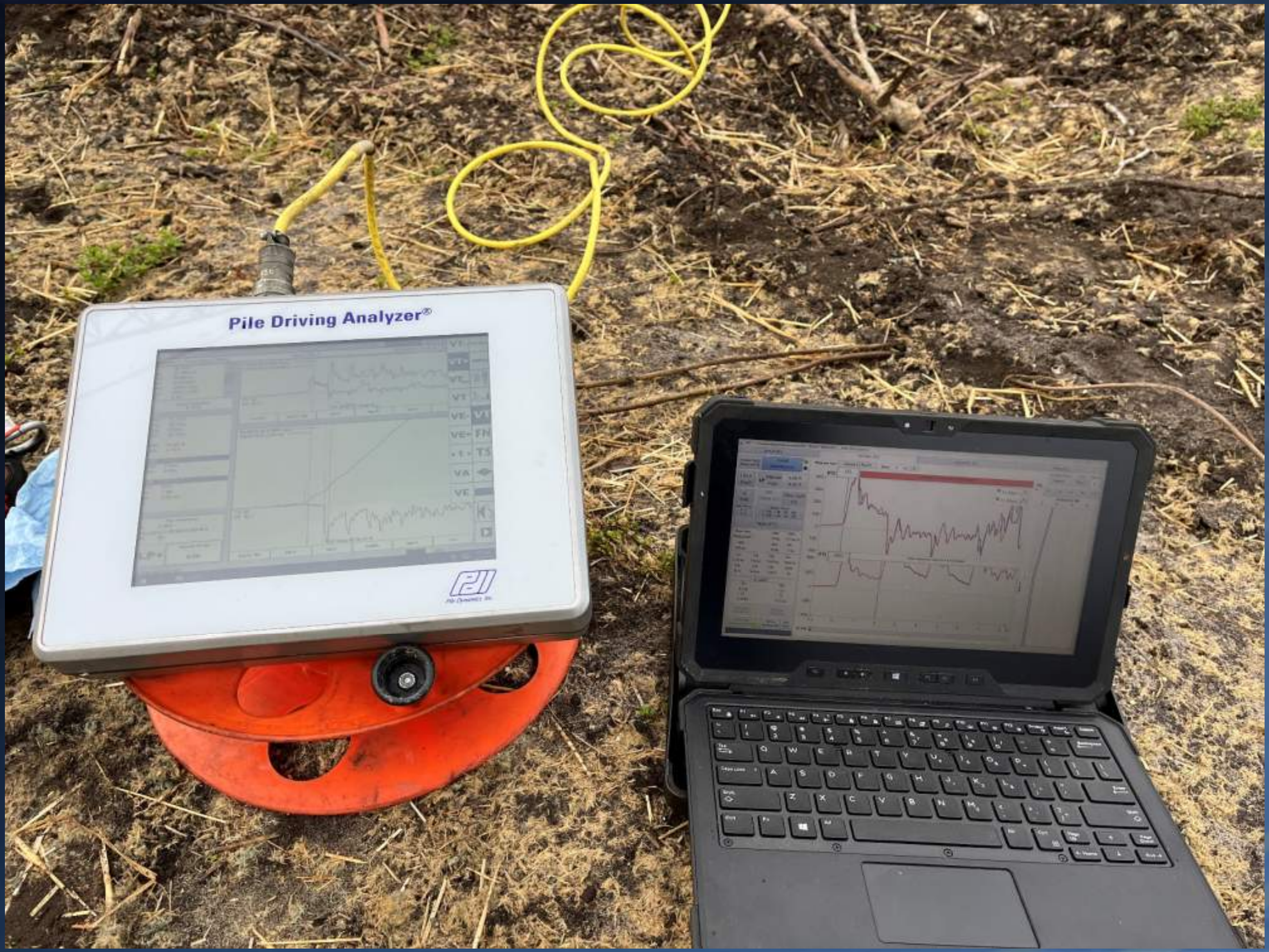
SYSTEMS



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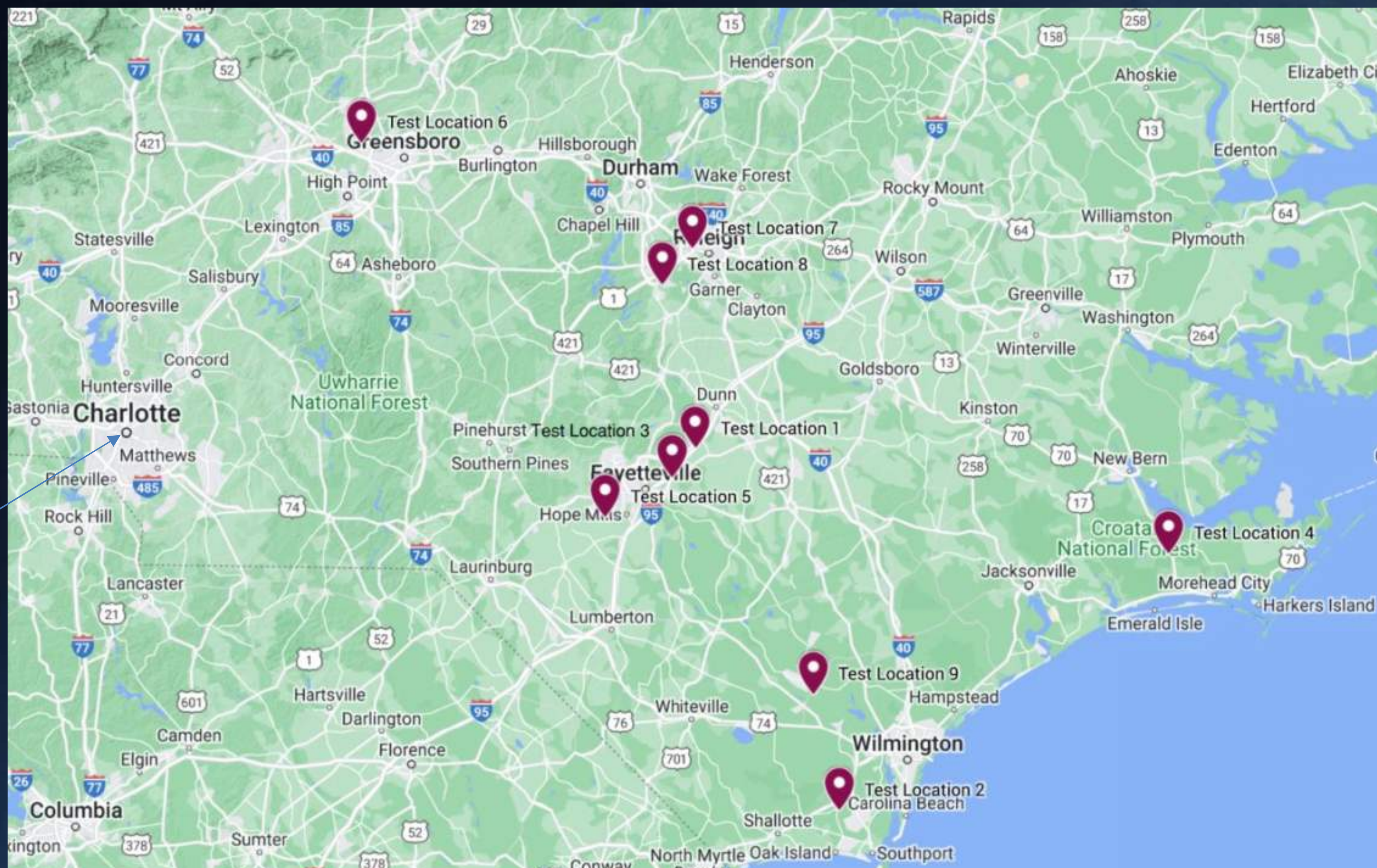
NCDOT TEST LOCATIONS



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NCDOT TEST LOCATIONS

Table 1. GPC and PDI Dynamic Pile Testing Comparison Locations

Location #	TIP	Contract	Pile Driving Contractor	County	Bridge #	Bridge Description	Bent #	Pile #	Pile Type	Pile Length (feet) {LT}	PDI Gage Location (feet) {LE}	GPC Gage Location (feet) {LE}	Required Driving Resistance (kips)	Hammer	Date	Initial Drive / Restrike	Signal Matching Comparison	Notes
1	I-5877	C204283	ST Wooten	Cumberland	155	SR 1813 (Percy Strickland Road) over I-95	End Bent 2	7	HP12x53	50 / 100 (NOTE 1)	48 / 98 (NOTE 1)	47 / 97 (NOTE 1)	430	Delmag D19-42	2/6/2023	Initial Drive	No	Data collected during driving of both bottom and top sections of Hpile, missed data near the end of drive due to loose strain gages
2	17BP.3.R.80	DC00314	TA Loving	Brunswick	104	NC 906 over Middle Swamp	End Bent 1	5	PP 14x0.5 Close Ended Pipe	50	47.7	47.7 (NOTE 2)	270	APE D19-52	2/7/2023	Short Term Restrike	No	Data only collected during short term restrike with very low capacity
3	I-5877	C204283	ST Wooten	Cumberland	148	I-95 over Reese Creek	2	7	PP 20x0.5 Open Ended Pipe	65	61.7	60.0	470	Pileco D30-32	2/24/2023	Initial Drive	Yes	Data collected during driving but missed some data towards the end of drive due to broken hangar bolt
4	R-1015	C204177	Balfour Beatty Infrastructure	Craven	274	US 70 (Havelock Bypass) Left Lane over NCRR	3	3	HP12x53	114	112.0	111.0	280	ICE I-19v2	3/3/2023	Initial Drive	Yes	
5	U-2519BA	C204110	Sanford	Cumberland	448	Fayetteville Outer Loop Right Lane over UT to Stewart's Crekk	1	6	HP14x73	70	68.0	67.6	360	ICE I-30v2	3/10/2023	Initial Drive	Yes	
6	HE-0005	C204781	APAC-Atlantic, Inc.	Guilford	1392	SR 1695 (Regional Road) over UT to Brush Creek	End Bent 2	4	HP12x53 w/ pile point	41	38.5	38.0	340	Berminghammer B-3305	3/14/2023	Initial Drive	Yes	
7	U-2719 / U-4437	C204157	Lane	Wake	-	Hillsborought Street over Blue Ridge Road	End Bent 2	3	HP12x53 w/ pile point	46	66.5	65.5	340	Pileco D19-42	3/20/2023	Initial Drive	Yes	
8	R-2721A	C204198	Flatiron	Wake	1557	NC 540 Right Lane over Middle Creek	End Bent 2	1	HP12x53	50	48.0	47.0	390	APE D19-42	3/20/2023	Initial Drive	Yes	
9	B-5694	C204362	ST Wooten	Bladen	-	Temporary Detour on NC 11 over White Oak Canal	End Bent 7	2	HP14x73	60	58.0	57.0	90	GPE D19-42	3/23/2023	Initial Drive	Yes	

NOTE 1 : Bottom section of pile / total top and bottom section of pile

NOTE 2 : GPC gages were located at the same distance from the pile head but rotated around pile 90 degrees from the PDI gage

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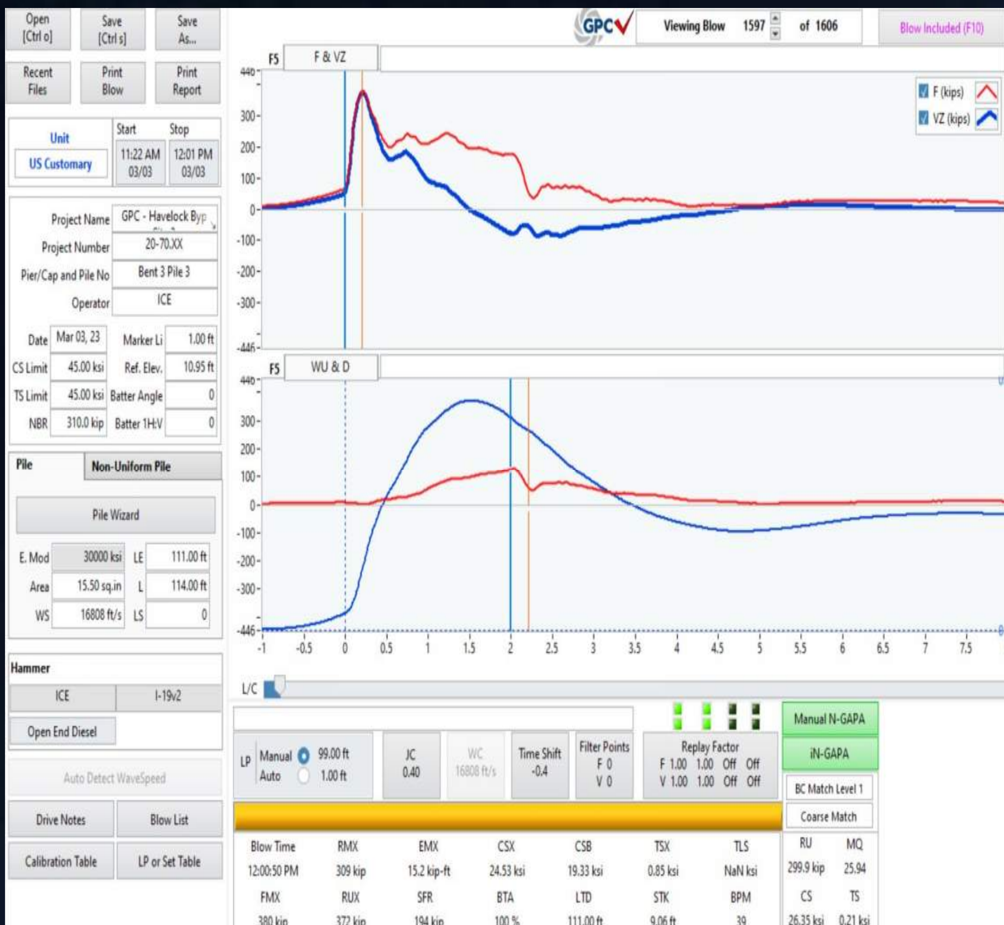
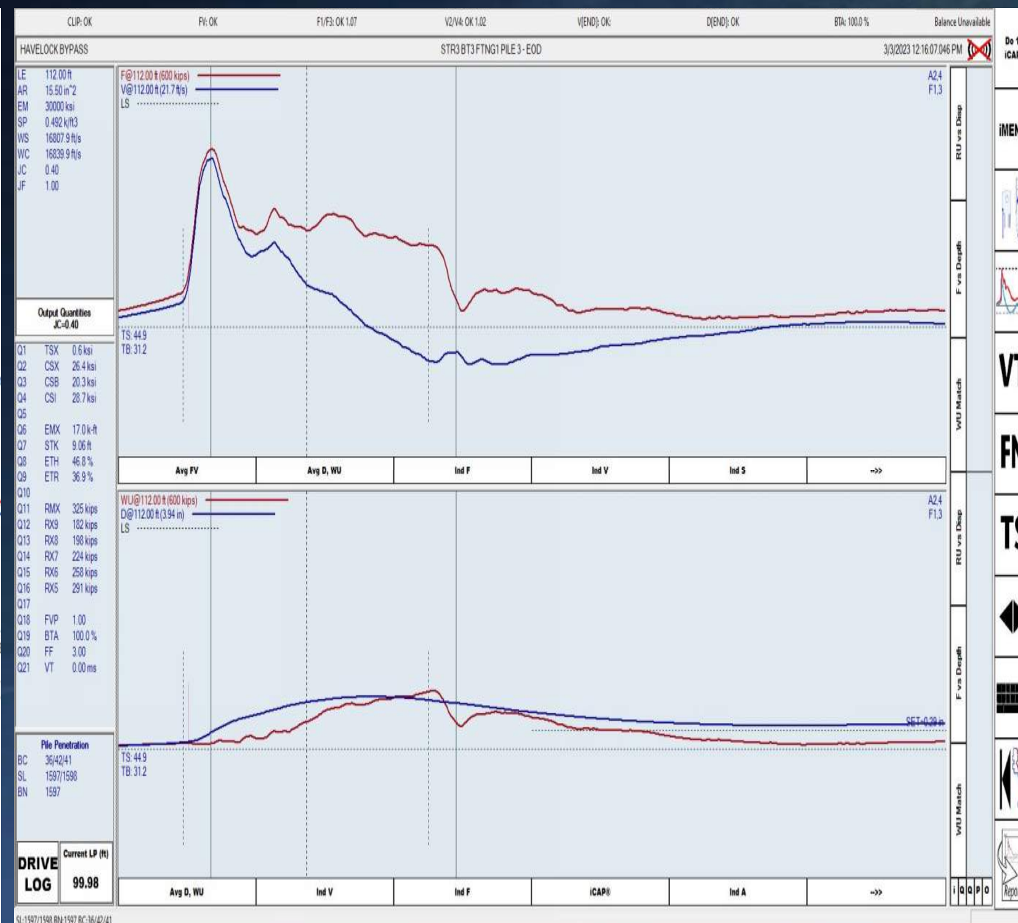
TYPICAL DATA ANALYSIS





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LOFTING PILES

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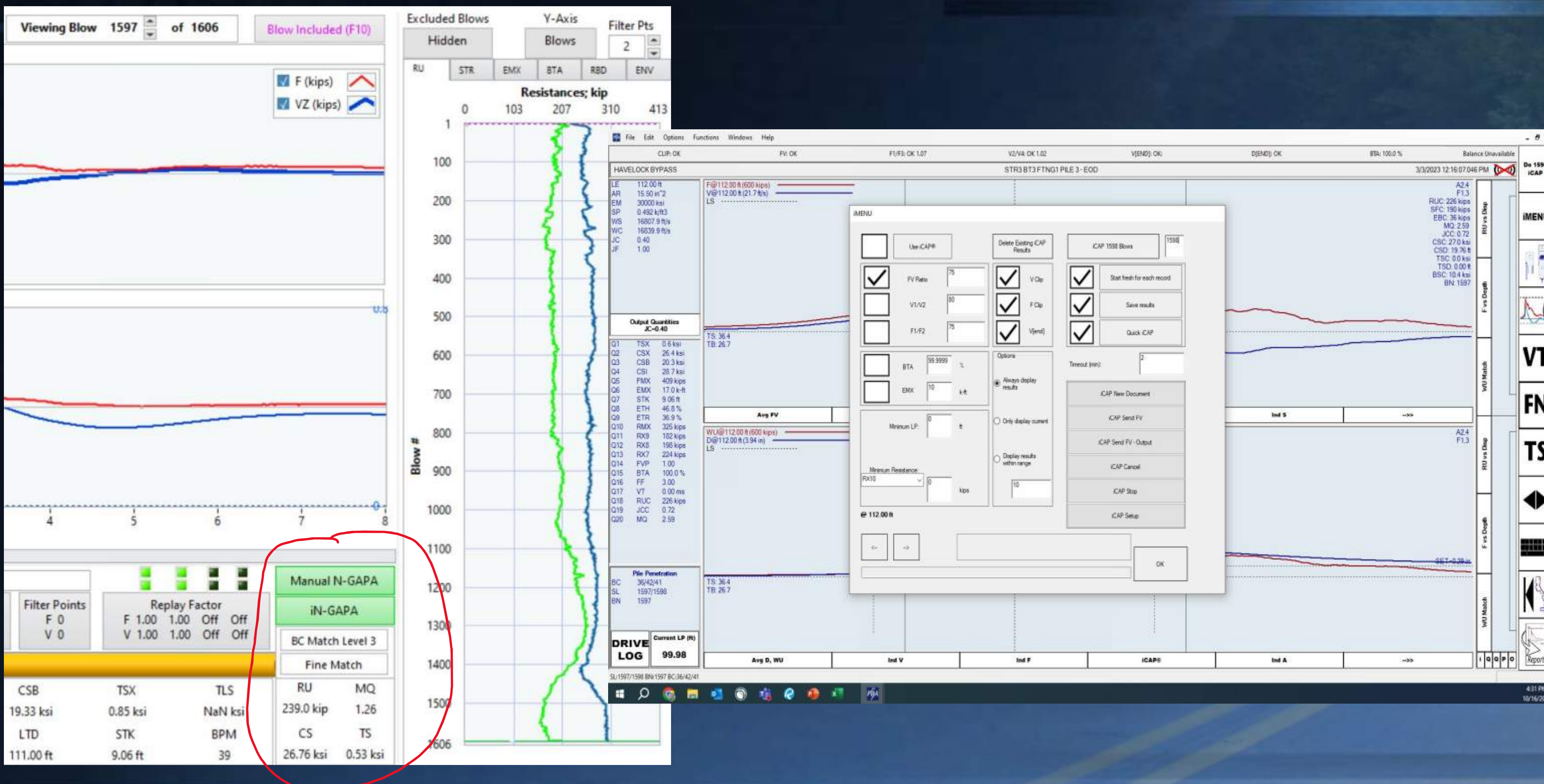
PREPPING PILES

TYPICAL INSTANT SIGNAL MATCH



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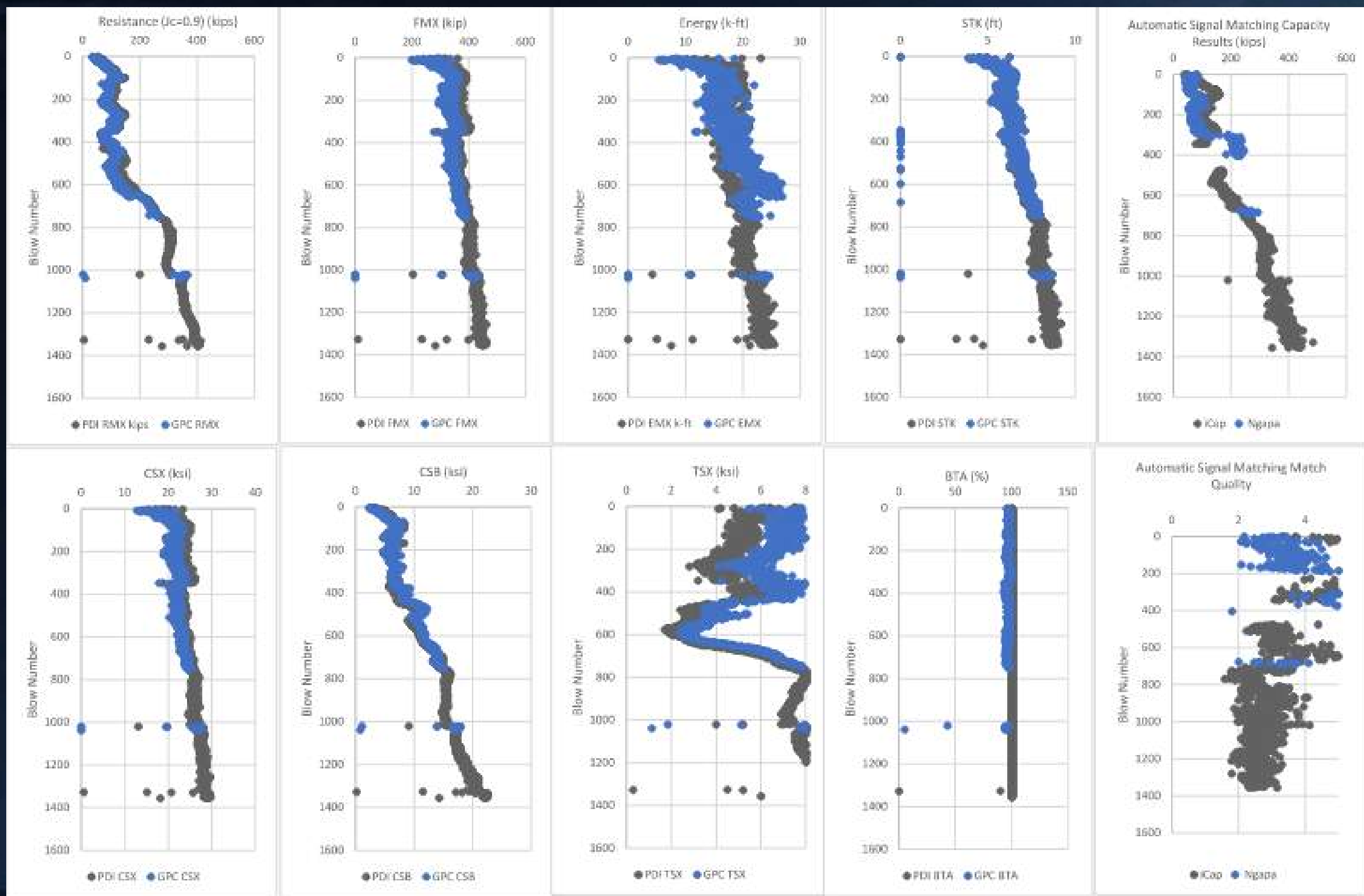
#1 HP12x53 50/100’ Delmag D19-42



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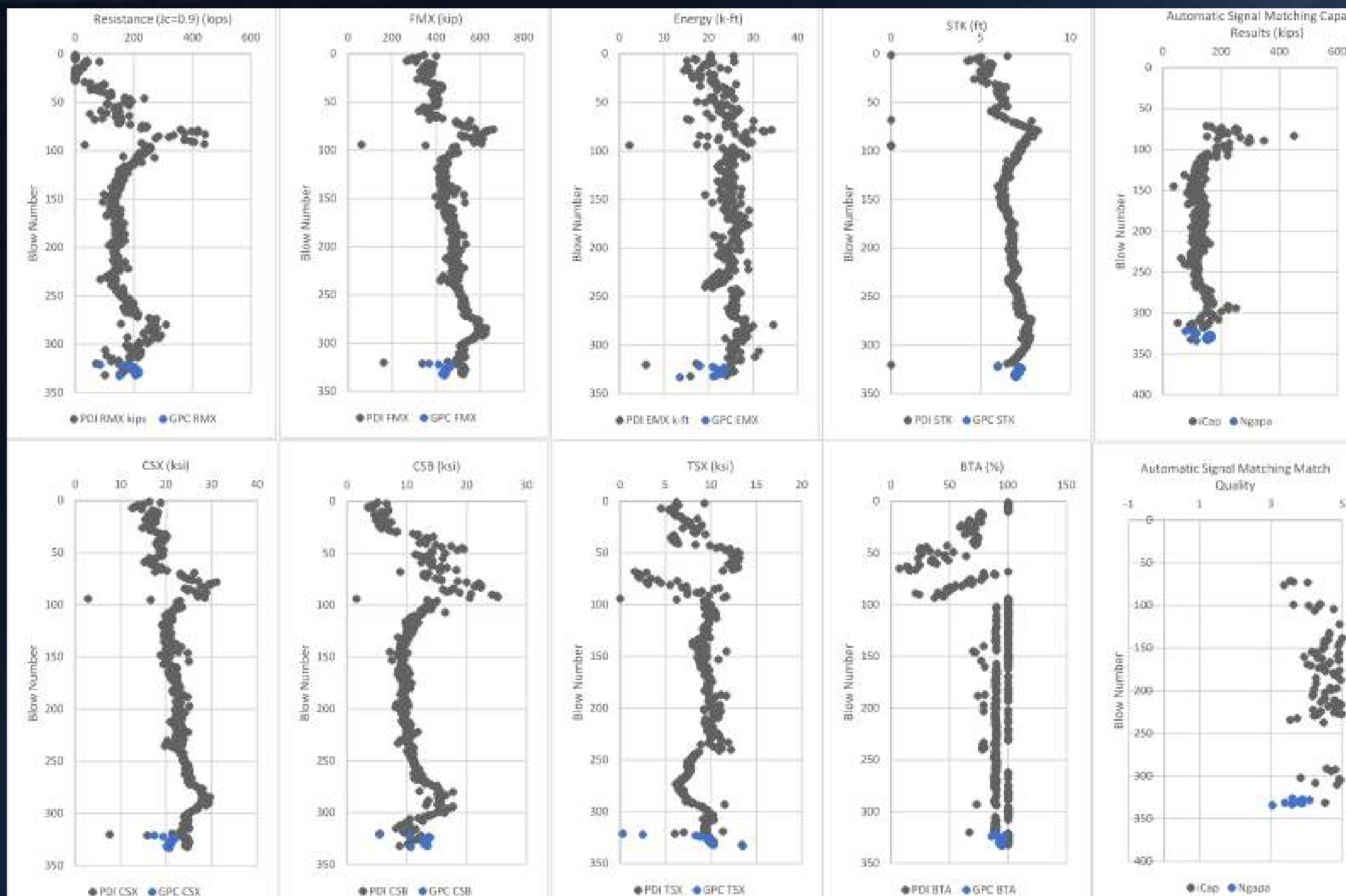
#2 PP14x0.5 CEPP 50’ APE D19-52



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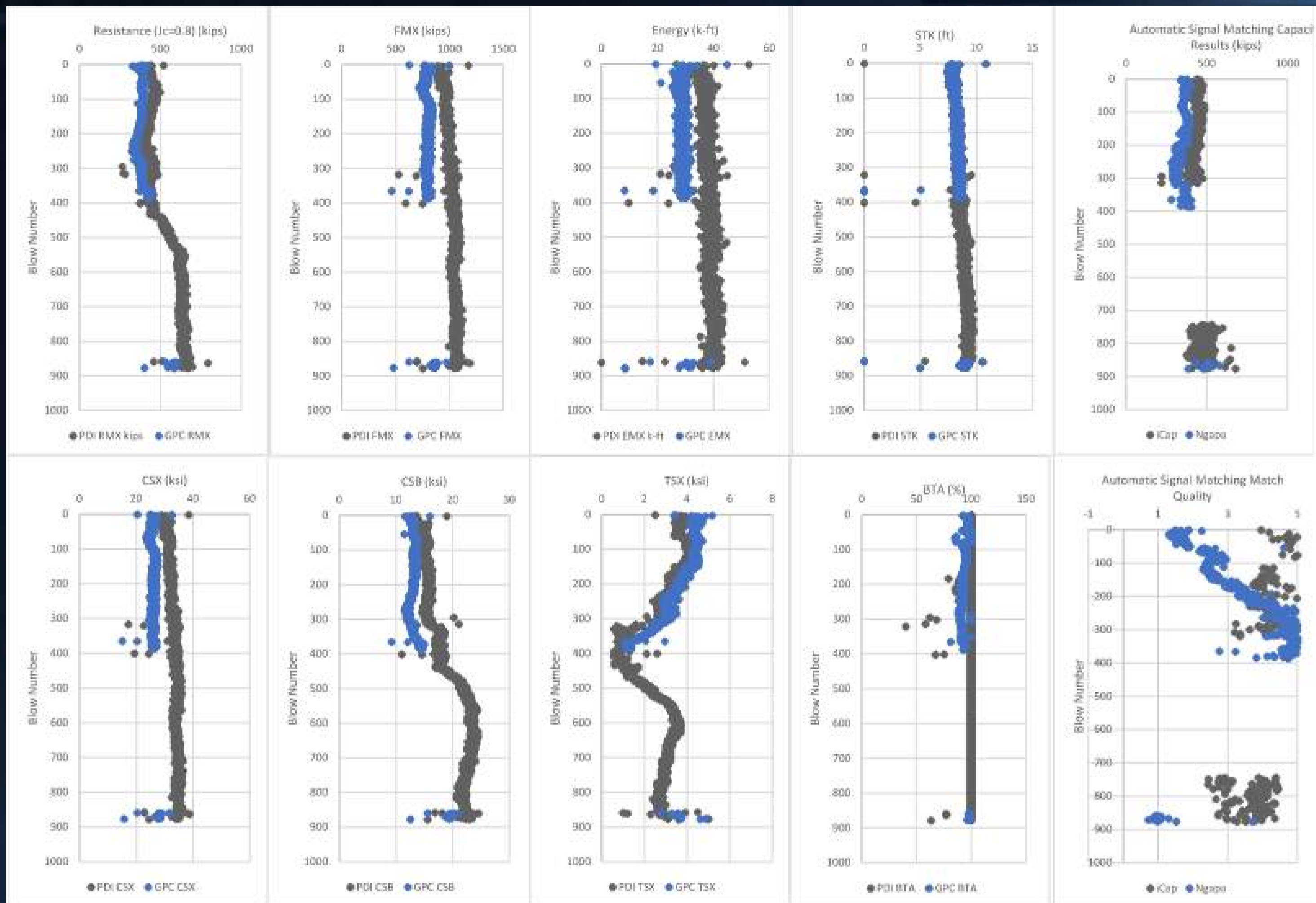
#3 PP20x0.5 OEPP 65' Pileco D30-32



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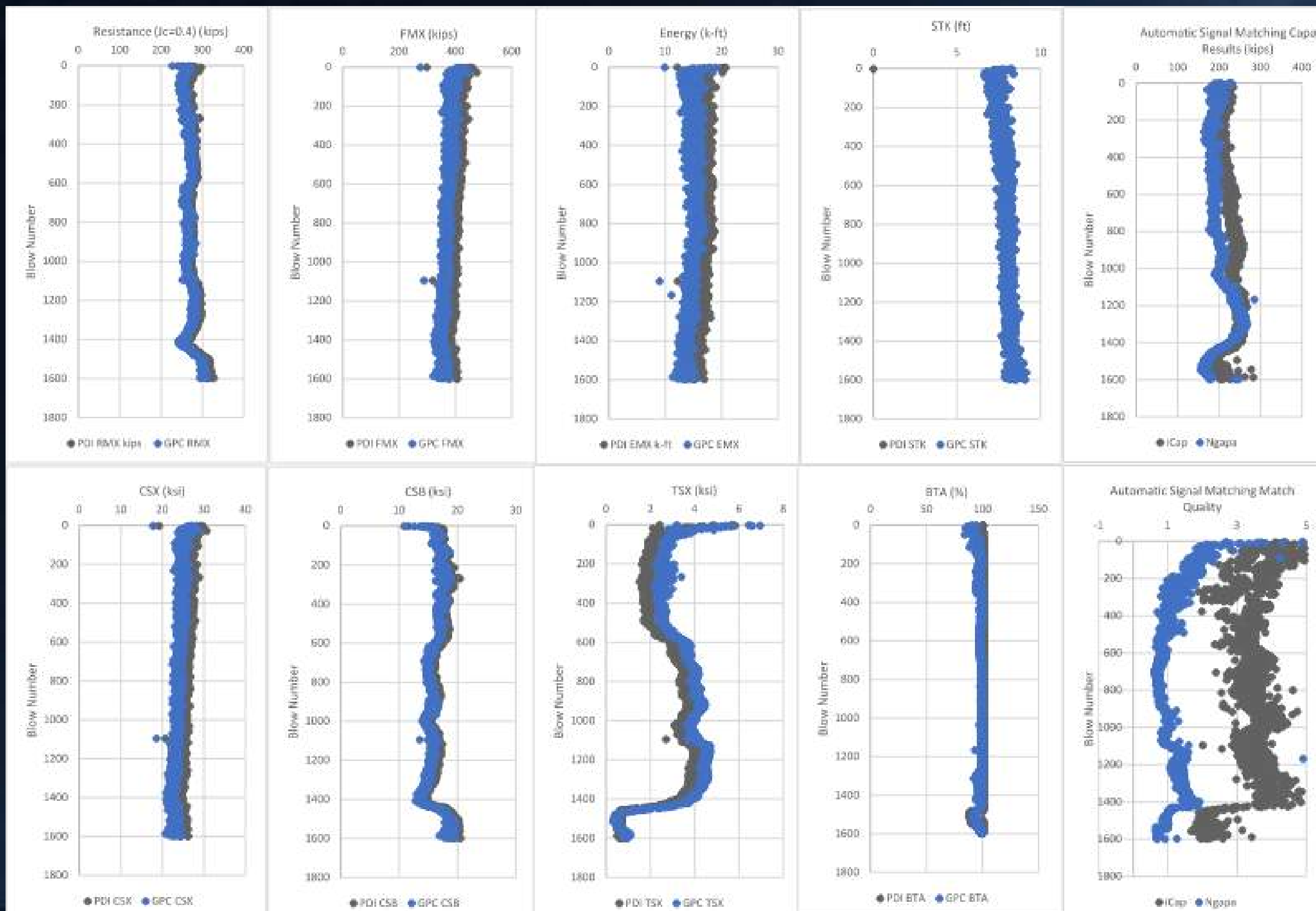
#4 HP12x53 114’ ICE I-19v2



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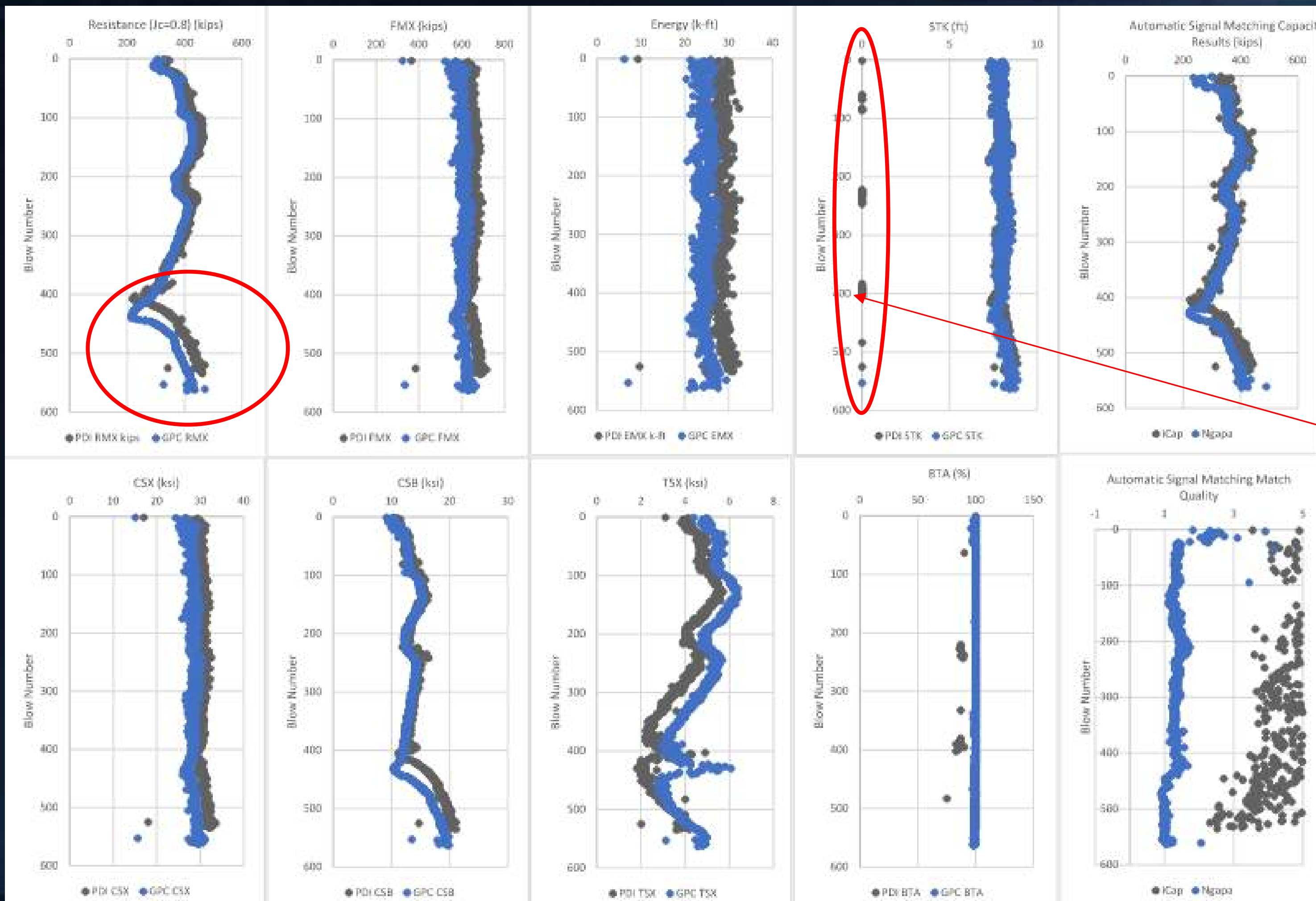
#5 HP14x73 70’ ICE I-30v2



PDI Wireless Radios Triggering Issue (Blows missed)

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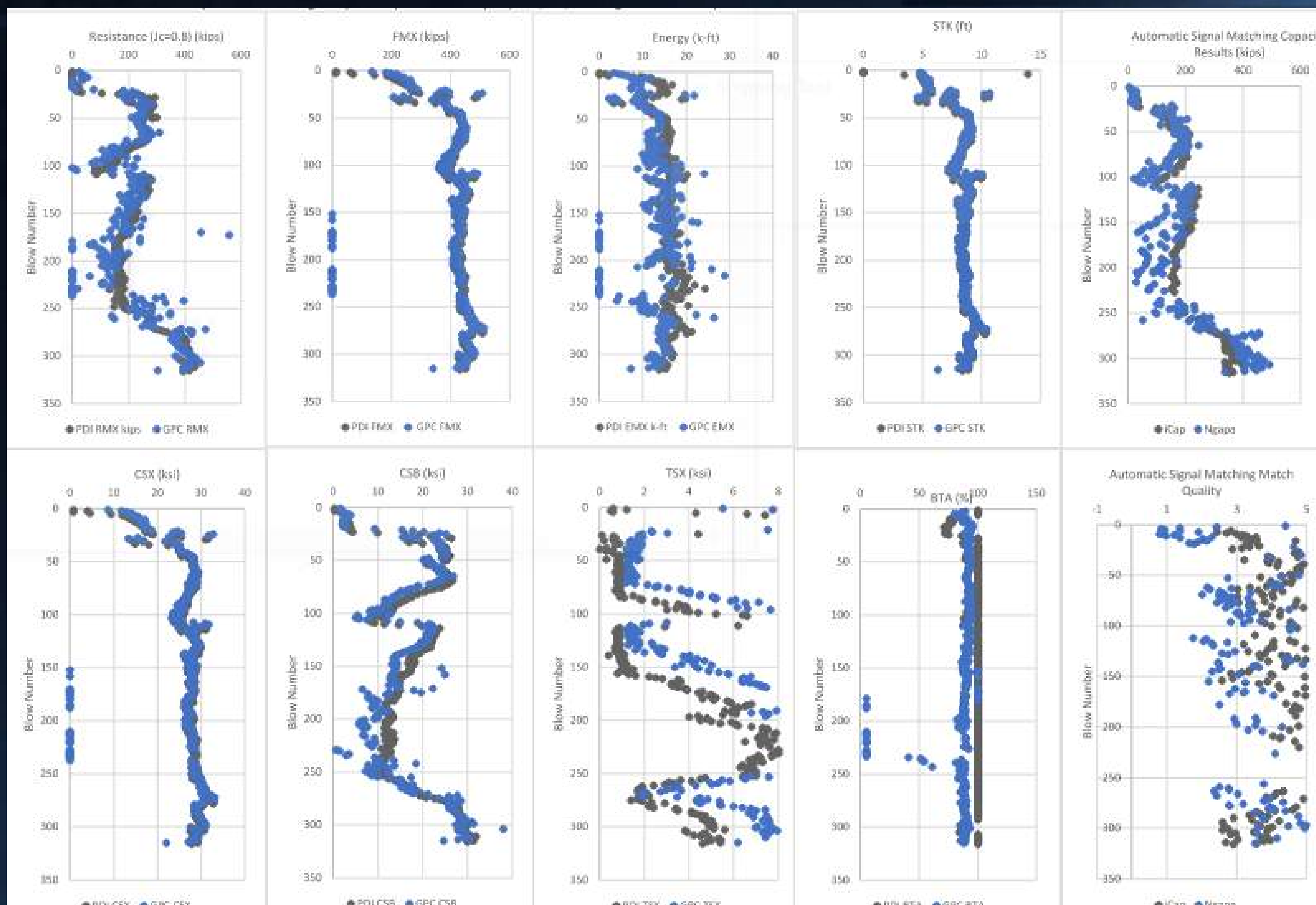
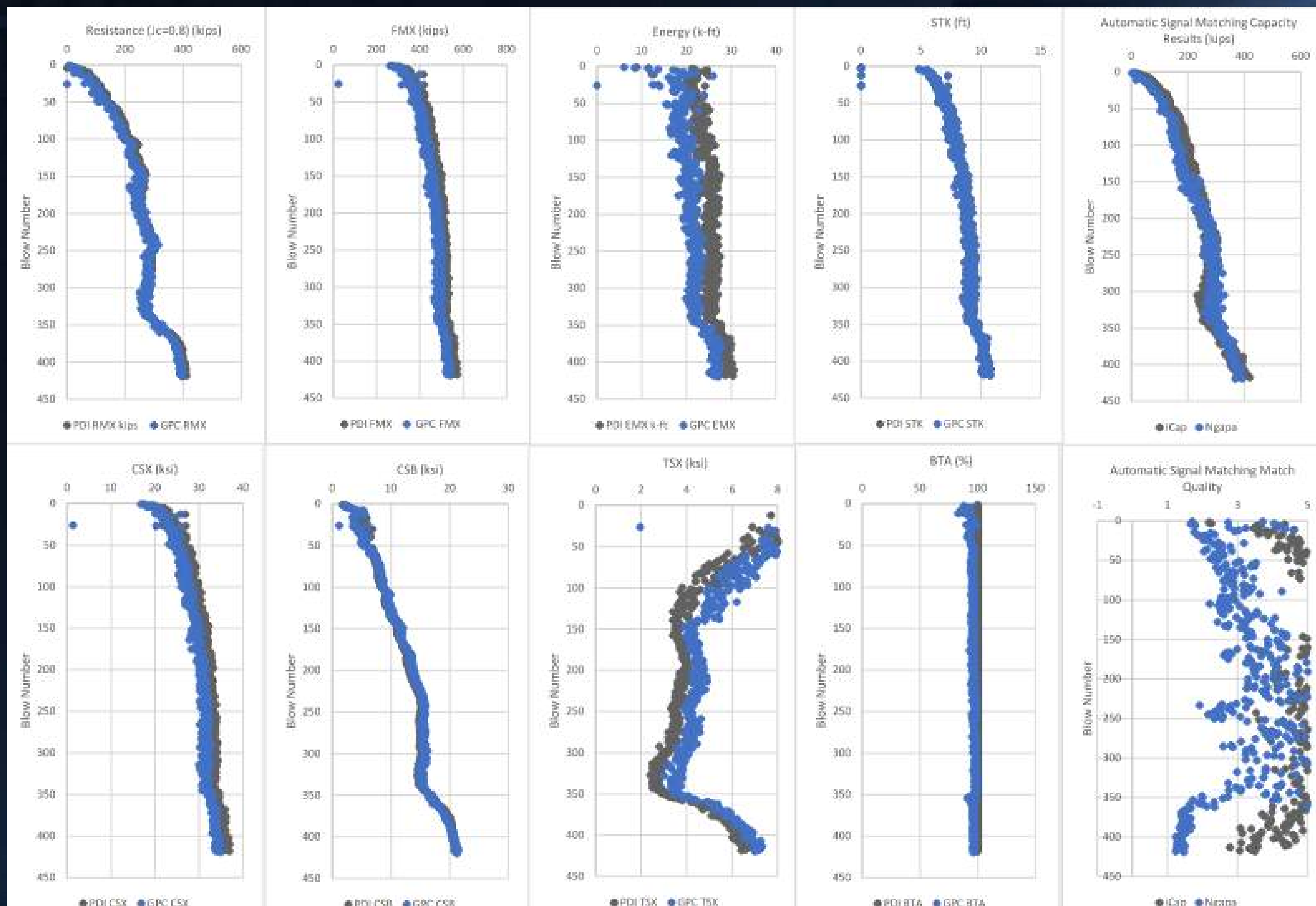
#6 HP12x53 w/ pile point 41' B'ham B3305



#7 HP12x53 w/ pile point 46’ Pileco D19-42



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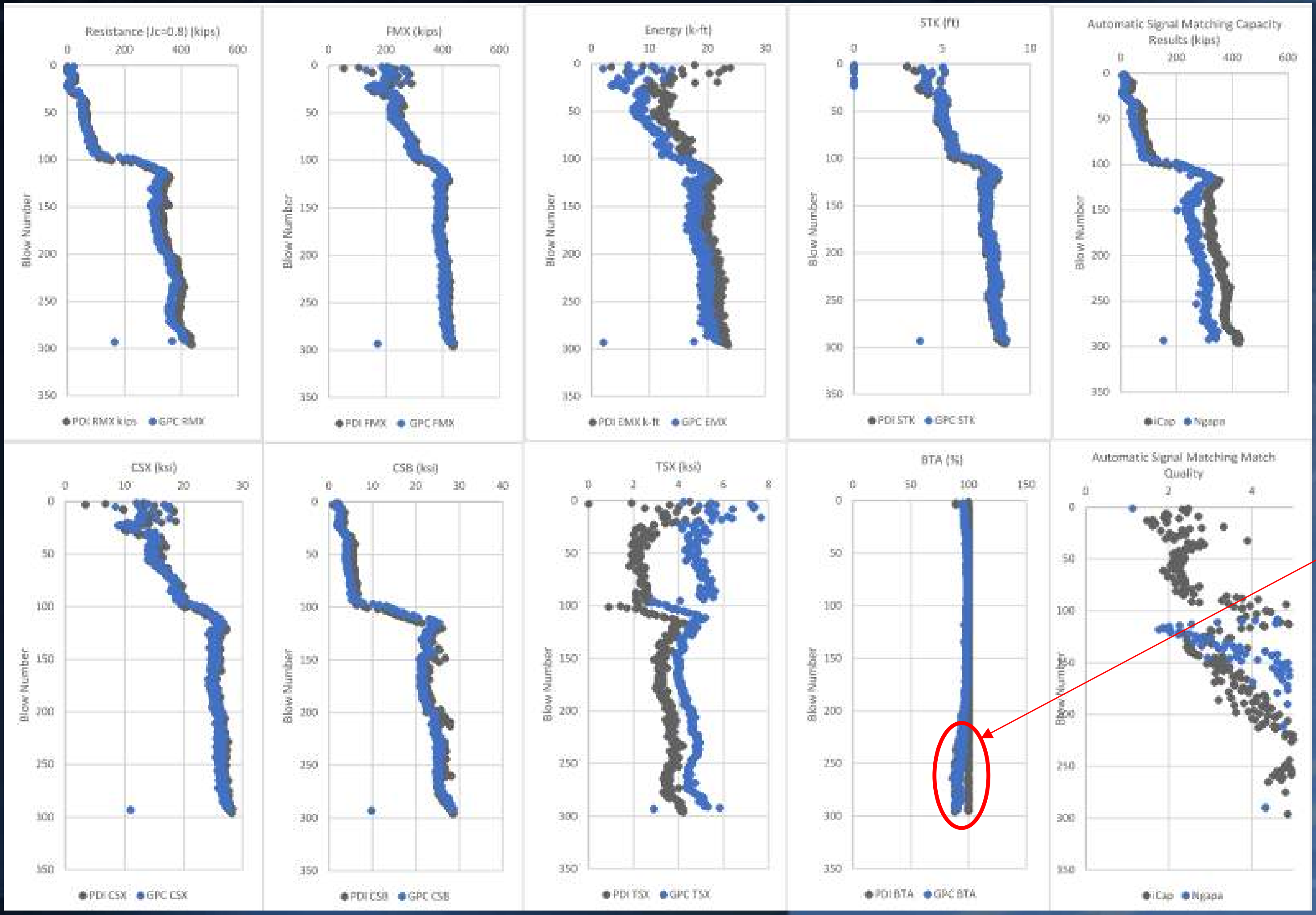
#8 HP12x53 50' APE D19-42



Initiation of pile tip damage per GPC?

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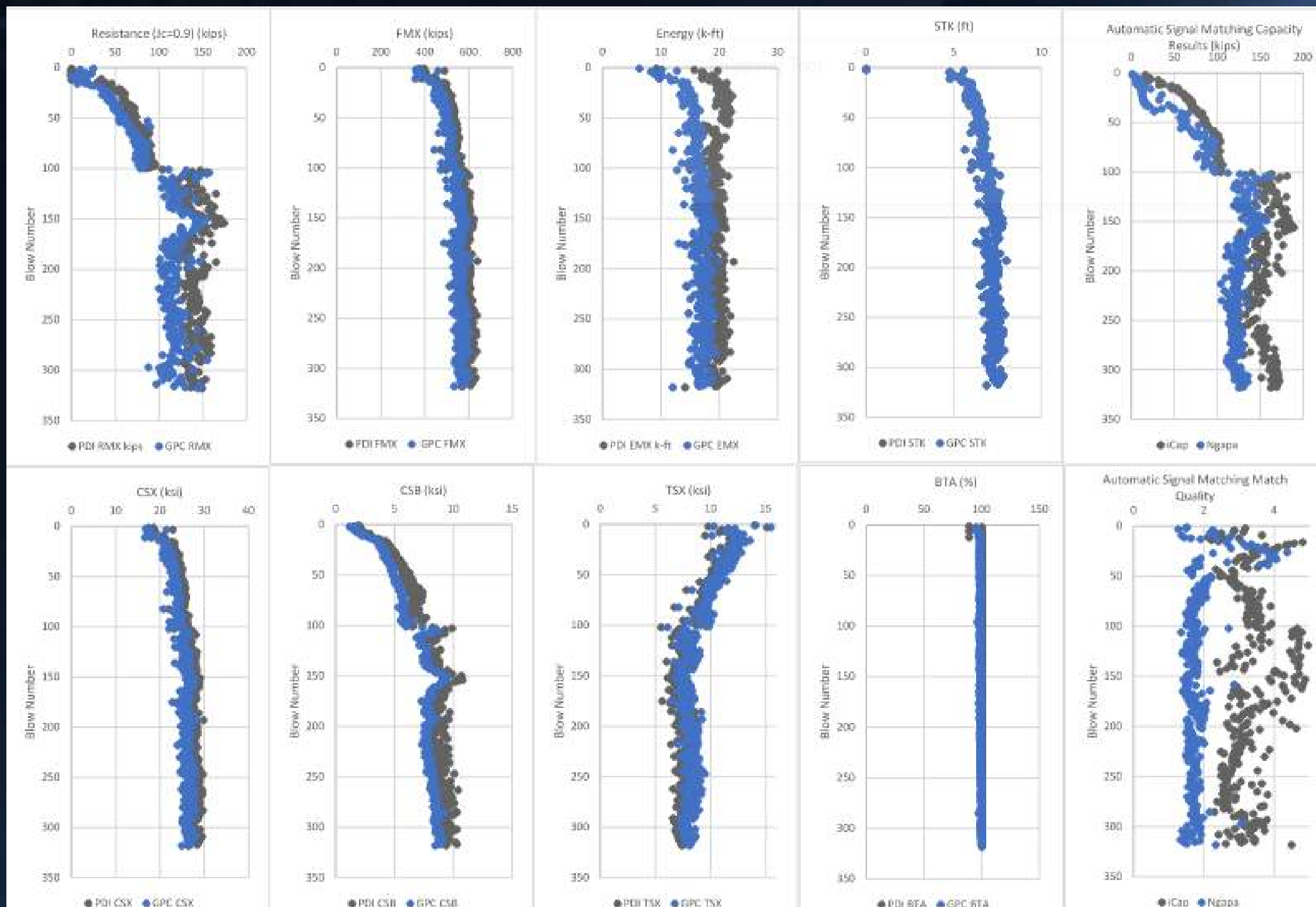
#9 HP14x73 60' GPE D19-42



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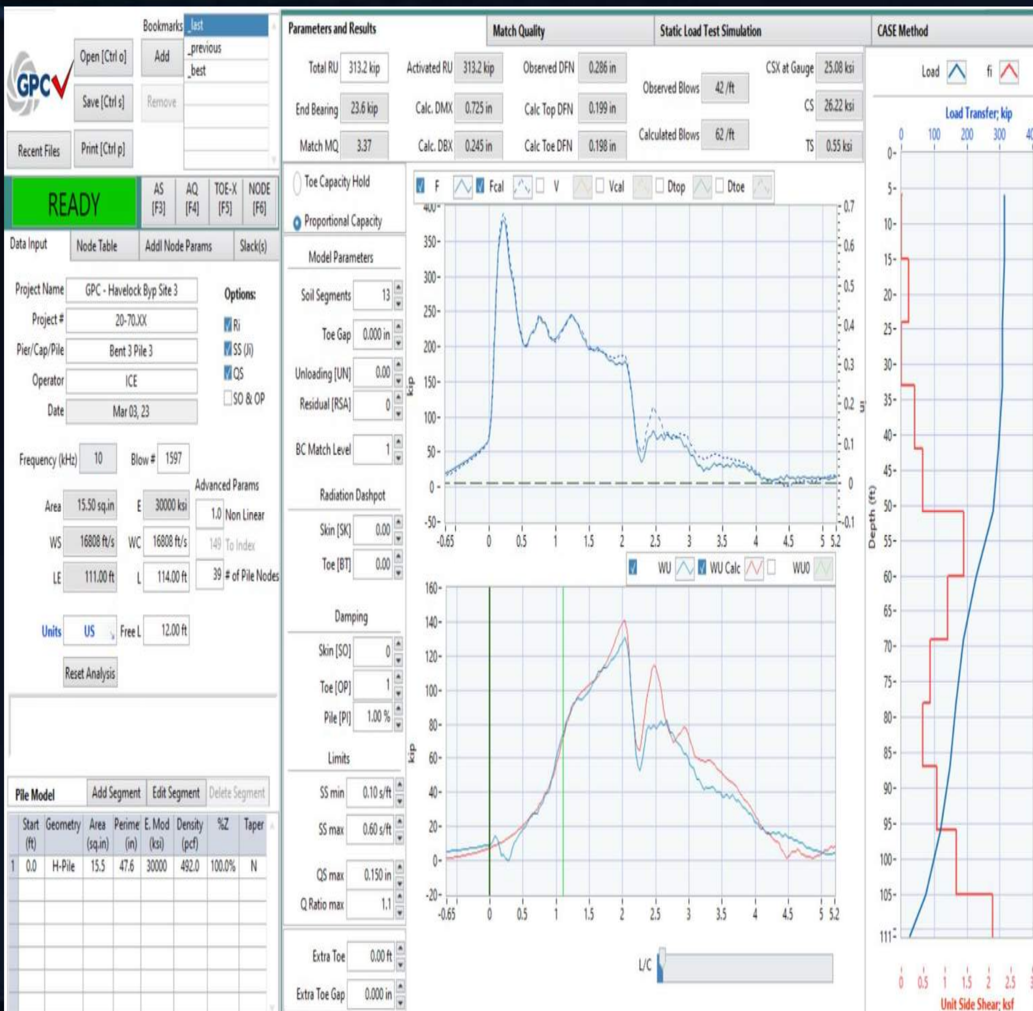
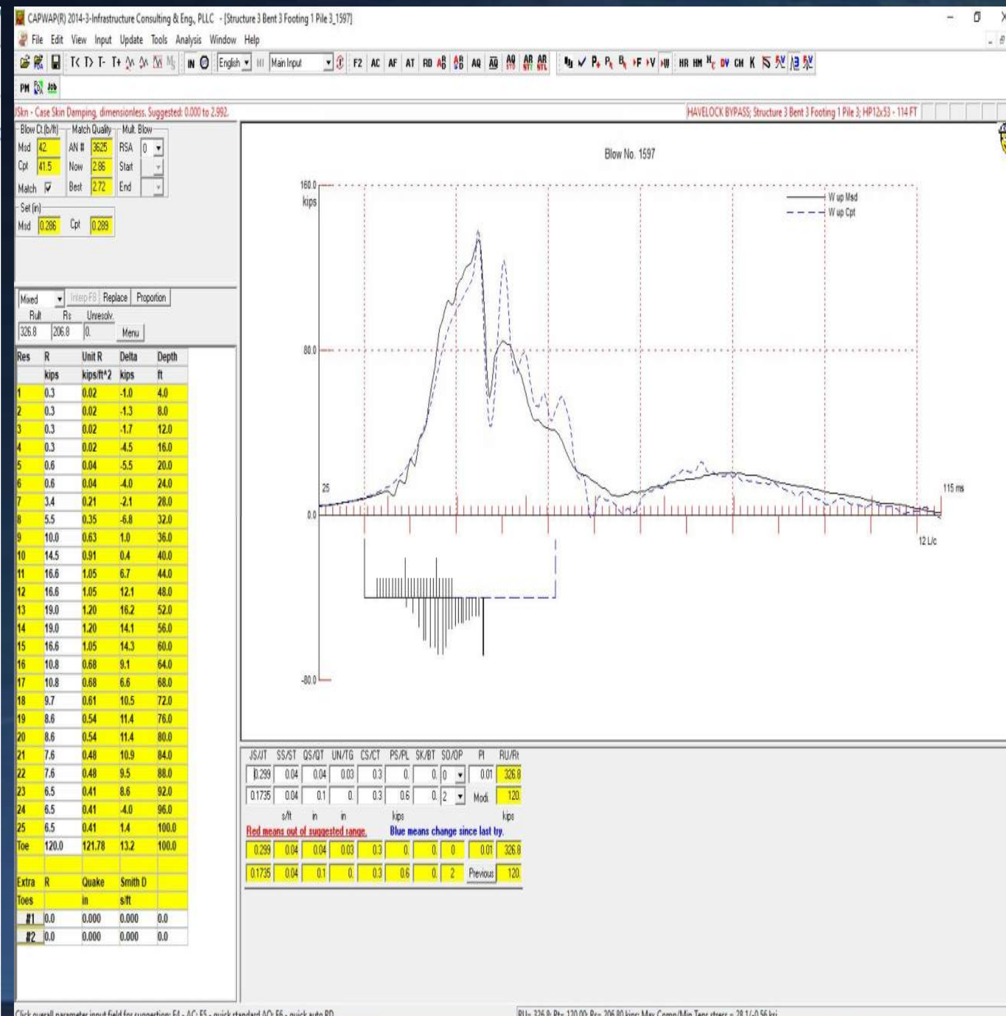
TYPICAL SIGNAL MATCH ANALYSIS





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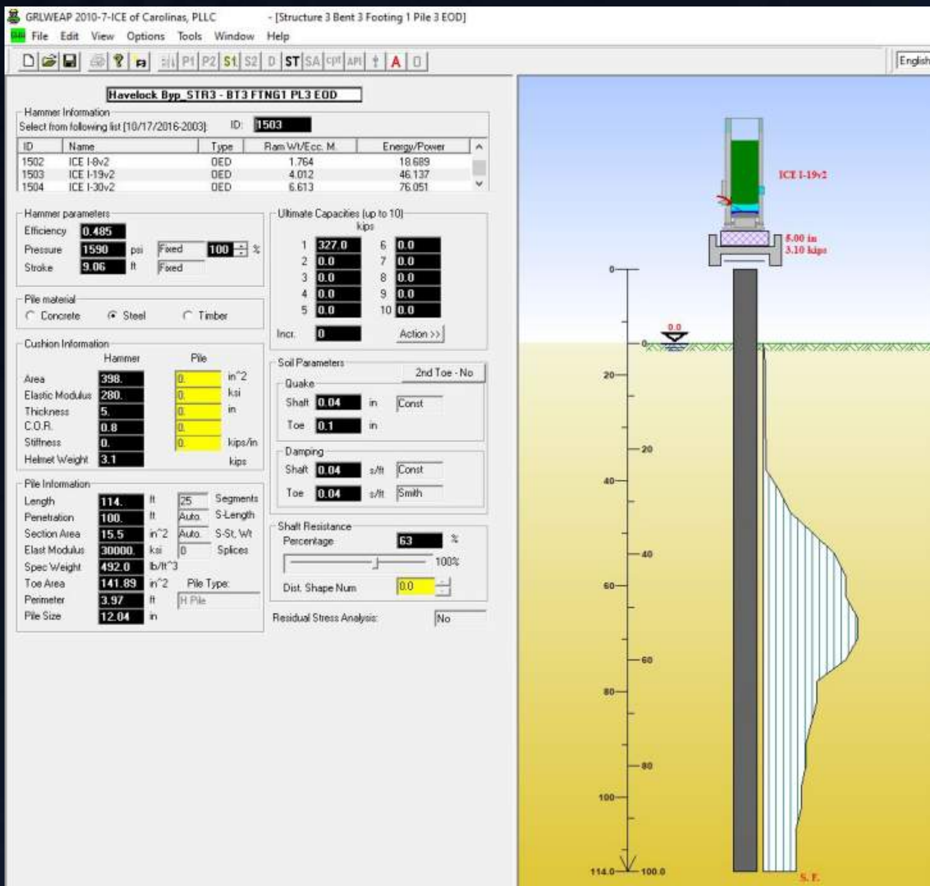
PDI WAVE EQUATION CALIBRATION



Gwa - [R:\Projects\19-79 - Balfour Beatty Foundation Testing\19-79.01 Balfour Beatty Ha]

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Havelock Byp_STR3 - BT3 FTNG1 PL3 EOD 10/16/2023

ICE of Carolinas, PLLC GRLWEAP VERSION 2010

Rult kips	Set inch	BlCt Bl/ft	TopFx kips	MxCS ksi	MxTS ksi	ENTHRU kip-ft	ActRes kips	Stroke ft
327	0.28	42.2	314.4	21.952	2.576	17.0	327	9.1

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OVERVIEW RESULTS

Table 2. GPC and PDI Signal Matching Results Location #3

Type	Blow Number	Penetration Below Ground (ft)	Total Capacity (kips)	Shaft Capacity (kips)	Percent Shaft Capacity (%)	Toe Capacity (kips)	Measured Blow Count (bpf)	Computed Blow Count (bpf)	Stroke (ft)	Energy (kip-ft)	Shaft Quake (in)	Toe Quake (in)	Shaft Damping	Toe Damping	Match Quality	J(c)
PDI	869	48.2	665	566	85	100	69	69	8.9	37.1	0.04	0.22	0.15	0.03	2.24	0.8
GPC	10	48.2	579	392	68	187	69	63	8.9	30.4	0.04	0.22	0.16	0.03	4.40	0.8

Table 3. GPC and PDI Signal Matching Results Location #4

Type	Blow Number	Penetration Below Ground (ft)	Total Capacity (kips)	Shaft Capacity (kips)	Percent Shaft Capacity (%)	Toe Capacity (kips)	Measured Blow Count (bpf)	Computed Blow Count (bpf)	Stroke (ft)	Energy (kip-ft)	Shaft Quake (in)	Toe Quake (in)	Shaft Damping	Toe Damping	Match Quality	J(c)
PDI	1597	100	327	207	63	120	42	42	9.1	16.9	0.04	0.10	0.04	0.04	2.86	0.4
GPC	1597	100	313	289	92	24	42	62	9.1	15.0	0.05	0.10	0.06	0.07	3.37	0.4

Table 4. GPC and PDI Signal Matching Results Location #5

Type	Blow Number	Penetration Below Ground (ft)	Total Capacity (kips)	Shaft Capacity (kips)	Percent Shaft Capacity (%)	Toe Capacity (kips)	Measured Blow Count (bpf)	Computed Blow Count (bpf)	Stroke (ft)	Energy (kip-ft)	Shaft Quake (in)	Toe Quake (in)	Shaft Damping	Toe Damping	Match Quality	J(c)
PDI	530	48.4	457	227	50	230	40	40	8.5	30.2	0.04	0.20	0.08	0.09	2.82	0.8
GPC	558	48.4	419	188	45	231	40	39	8.5	27.6	0.04	0.20	0.08	0.04	2.18	0.8

Table 5. GPC and PDI Signal Matching Results Location #6

Type	Blow Number	Penetration Below Ground (ft)	Total Capacity (kips)	Shaft Capacity (kips)	Percent Shaft Capacity (%)	Toe Capacity (kips)	Measured Blow Count (bpf)	Computed Blow Count (bpf)	Stroke (ft)	Energy (kip-ft)	Shaft Quake (in)	Toe Quake (in)	Shaft Damping	Toe Damping	Match Quality	J(c)
PDI	311	23.5	437	116	27	320	120	120	8.9	15.1	0.06	0.18	0.06	0.04	3.52	0.8
GPC	311	23.5	460	49	11	411	120	931	8.9	12.8	0.08	0.20	0.18	0.04	4.01	0.5

Table 6. GPC and PDI Signal Matching Results Location #7

Type	Blow Number	Penetration Below Ground (ft)	Total Capacity (kips)	Shaft Capacity (kips)	Percent Shaft Capacity (%)	Toe Capacity (kips)	Measured Blow Count (bpf)	Computed Blow Count (bpf)	Stroke (ft)	Energy (kip-ft)	Shaft Quake (in)	Toe Quake (in)	Shaft Damping	Toe Damping	Match Quality	J(c)
PDI	418	31.5	411	186	45	225	48	48	10.8	30.6	0.04	0.25	0.17	0.03	1.96	0.8
GPC	419	31.5	396	169	43	227	48	66	10.8	27.2	0.04	0.25	0.17	0.02	2.24	0.8

Table 7. GPC and PDI Signal Matching Results Location #8

Type	Blow Number	Penetration Below Ground (ft)	Total Capacity (kips)	Shaft Capacity (kips)	Percent Shaft Capacity (%)	Toe Capacity (kips)	Measured Blow Count (bpf)	Computed Blow Count (bpf)	Stroke (ft)	Energy (kip-ft)	Shaft Quake (in)	Toe Quake (in)	Shaft Damping	Toe Damping	Match Quality	J(c)
PDI	295	27.7	431	117	27	314	80	80	8.4	22.6	0.13	0.40	0.03	0.03	3.62	0.5
GPC	290	27.7	344	65	19	279	80	124	8.4	21.4	0.13	0.28	0.11	0.11	4.59	2

Table 8. GPC and PDI Signal Matching Results Location #9

Type	Blow Number	Penetration Below Ground	Total Capacity	Shaft Capacity	Percent Shaft Capacity (%)	Toe Capacity (kips)	Measured Blow Count (bpf)	Computed Blow Count (bpf)	Stroke (ft)	Energy (kip-ft)	Shaft Quake (in)	Toe Quake (in)	Shaft Damping	Toe Damping	Match Quality	J(c)
PDI	115	28.6	138	45	33	93	11	11	7.2	20.7	0.10	0.04	0.19	0.03	3.91	0.9
GPC	115	28.6	115	43	37	72	11	12	7.2	17.3	0.10	0.04	0.19	0.02	3.12	0.9

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GRLWEAP CALIBRATION RESULTS

Table 9. Signal Matching/GRLWEAP Calibration Results Location #3 (NOTE 1)

Type	Resistance Distribution	Blow Count	Blow Count / GRLWEAP Blow Count	Energy	Signal Match Eng. / GRLWEAP Eng.
PDI	Triangular	67	1.03	36.4	1.02
GPC	Triangular	64	1.08	30.1	1.01

Table 10. Signal Matching/GRLWEAP Calibration Results Location #4 (NOTE 1)

Type	Resistance Distribution	Blow Count	Blow Count / GRLWEAP Blow Count	Energy	Signal Match Eng. / GRLWEAP Eng.
PDI	Actual	42	1.00	17.0	1.00
GPC	Triangular	50	0.84	15.6	0.96

Table 11. Signal Matching/GRLWEAP Calibration Results Location #5 (NOTE 1)

Type	Resistance Distribution	Blow Count	Blow Count / GRLWEAP Blow Count	Energy	Signal Match Eng. / GRLWEAP Eng.
PDI	Triangular	40	0.99	30.1	1.00
GPC	Triangular	32	1.23	27.5	1.00

Table 12. Signal Matching/GRLWEAP Calibration Results Location #6 (NOTE 1)

Type	Resistance Distribution	Blow Count	Blow Count / GRLWEAP Blow Count	Energy	Signal Match Eng. / GRLWEAP Eng.
PDI	Actual	120	1.00	15.1	1.00
GPC	Triangular	702	0.17	13.3	0.96

Table 13. Signal Matching/GRLWEAP Calibration Results Location #7 (NOTE 1)

Type	Resistance Distribution	Blow Count	Blow Count / GRLWEAP Blow Count	Energy	Signal Match Eng. / GRLWEAP Eng.
PDI	Actual	48	0.99	30.6	1.00
GPC	Triangular	50	0.96	27.6	0.99

Table 14. Signal Matching/GRLWEAP Calibration Results Location #8 (NOTE 1)

Type	Resistance Distribution	Blow Count	Blow Count / GRLWEAP Blow Count	Energy	Signal Match Eng. / GRLWEAP Eng.
PDI	Actual	80	1.00	22.6	1.00
GPC	Triangular	60	1.33	21.4	1.00

Table 15. Signal Matching/GRLWEAP Calibration Results Location #9 (NOTE 1)

Type	Resistance Distribution	Blow Count	Blow Count / GRLWEAP Blow	Energy	Signal Match Eng. / GRLWEAP Eng.
PDI	Triangular	11	1.01	20.6	1.00
GPC	Triangular	10	1.06	17.2	1.01

NOTE 1 -Signal matching analyses calibrated with GRLWEAP using actual hammer, helmet, and hammer cushions as well as actual values of total capacity, quakes, dampings, and percent shaft capacity from signal matching. Iterated as needed to get closest blow count and energy match

GPC over- or underpredicting overall capacity versus GRLWEAP?

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OVERALL COMMENTS / RECOMMENDATIONS

- Good comparison between GPC and PDI results
- No issues with GPC Wireless connection or data transfer
- No issues with GPC combination accelerometer/strain gauges
- By design GPC Signal Matching is more automated compared to CAPWAP…
- Both require experienced engineer for analysis
- Recommend NCDOT revise Prequalified Geotech Contractor Requirements to be more generic or add “or equivalent” (2024 Specs already updated)

2024

(F) High-Strain Dynamic Pile Testing (Dynamic Pile Testing)

When required, test piles in accordance with ASTM D4945 using dynamic pile testing equipment with external transducers manufactured by Pile Dynamics, Inc. or another approved vendor. Approved vendors can be found on the Geotechnical Engineering Unit’s website. Analyze collected data using signal matching software (CAse Pile Wave Analysis Program (CAPWAP) manufactured by Pile Dynamics, Inc. or equivalent by another approved vendor). Use a prequalified consultant to perform dynamic pile testing and signal matching analyses and provide dynamic pile testing reports. Use a dynamic pile testing operator approved as a Field Engineer (key person) for the dynamic pile testing consultant. Provide dynamic pile testing reports signed and sealed by an engineer approved as a Project Engineer (key person) for the same dynamic pile testing consultant.

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QUESTIONS ?