2012 Southeastern Transportation Geotechnical Engineering Conference

Design and Installation of **Micropile Foundations for a Bridge in Karst Topography**

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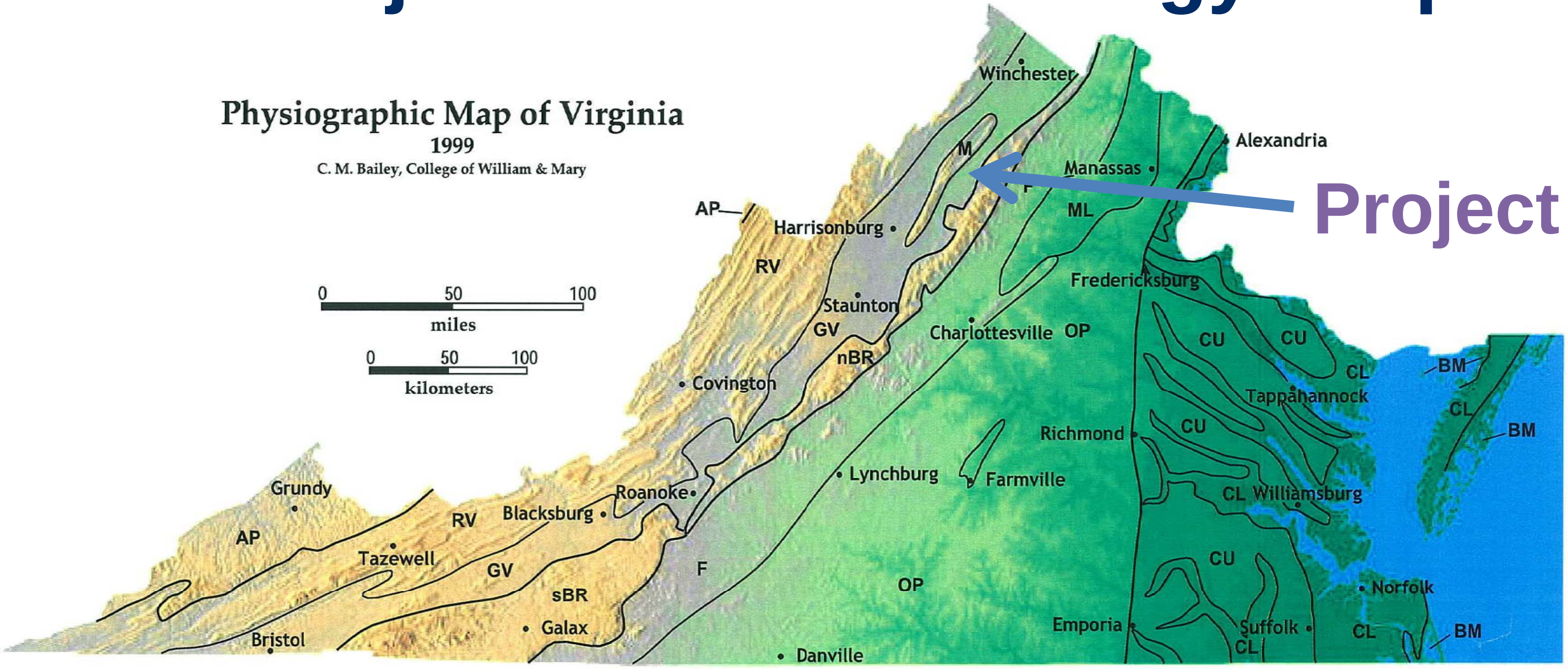
Presentation Overview

- Project Location
- Karst
- Geotechnical Explorations
- Foundations Type Selection Considerations
- Design and Construction Considerations
  - Lateral Loading
  - LRFD
  - Installation and Testing
- Construction and Observations
- Load Testing
- Concluding Comments

Route 340 Project Location/Geology Map



Appalachian Plateau province

AP- Rugged, well-dissected landscape with dendritic drainage pattern. Elevation- 1000'-3000' with High Knob rising to over 4000'.

Valley & Ridge province

RV- Ridge & Valley subprovince: long linear ridges separated by linear valleys with trellis drainage pattern. Elevation- 1000'-4500'.

GV- Great Valley subprovince: broad valley with low to moderate slopes underlain by carbonate rocks. Elevation- 500'-1500' north of Roanoke, 1200'-2300' south of Roanoke

M- Massanutten Mountain: Series of long linear ridges that rise to 3000' above the Great Valley

Blue Ridge province

nBR- northern Blue Ridge subprovince: rugged region with steep slopes narrow ridges, broad mountains, and high relief. Elevation 1500'-4200'.

sBR- southern Blue Ridge subprovince: broad upland plateau with moderate slopes. Elevation 2400'- 3000' with higher peaks rising above upland, including 5729' Mt. Rogers.

Piedmont province

F- Foothills subprovince: region with broad rolling hills and moderate slopes. Elevation 400'-1000' with peaks rising to 1500'-2500'.

ML- Mesozoic lowlands subprovince: region with modest relief and low slopes underlain by Mesozoic sedimentary and igneous rocks. Elevation 200'-400'.

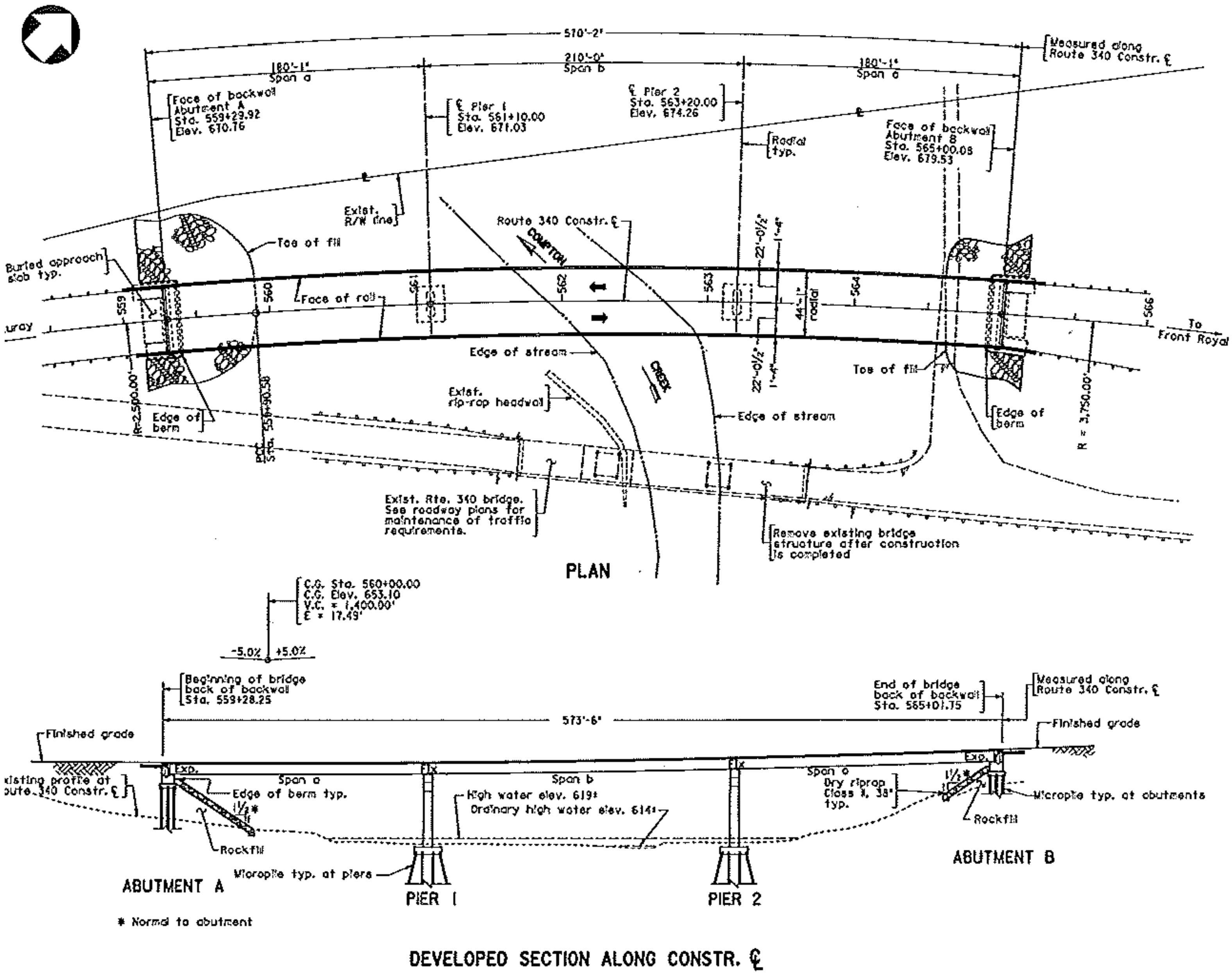
OP- Outer Piedmont subprovince: broad upland with low to moderate slopes. Elevation 600'-1000' in west gradually diminishing to 250'- 300' in east.

Coastal Plain province

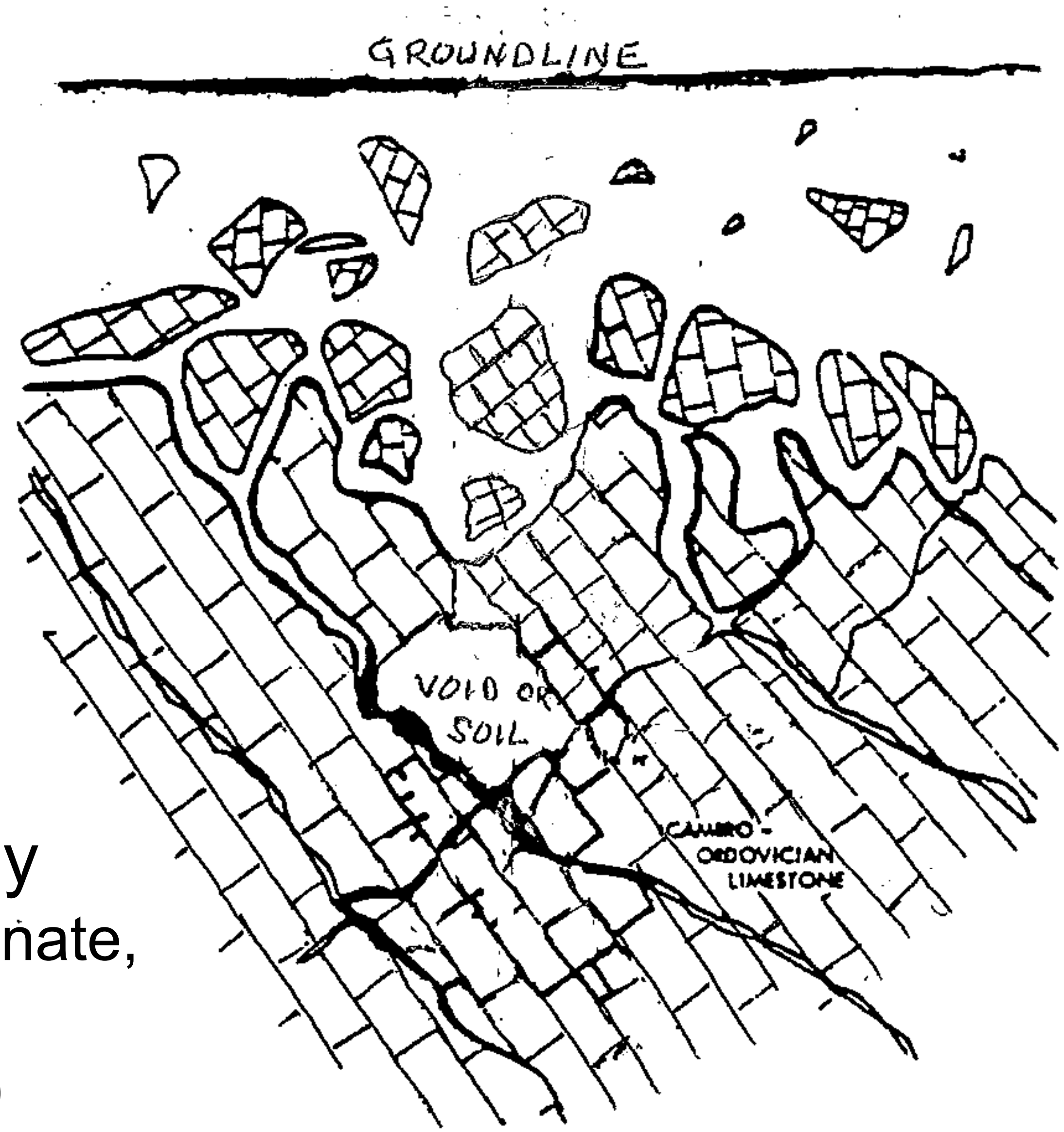
CU- Upland subprovince: broad upland with low slopes and gentle drainage divides. Steep slopes develop where dissected by stream erosion. Elevation- 60'-250'.

CL- Lowland subprovince: flat, low-relief region along major rivers and near the Chesapeake Bay. Elevation- 0-60'.

BM- Barrier Islands & Salt Marshes: low, open areas covered with sediment and vegetation in direct proximity to the Chesapeake Bay and Atlantic Ocean. Elevation 0'-15'.


510'-2"
Measured along Route 340 Constr. ℄
180'-1" Span a
210'-0" Span b
180'-1" Span a
Face of backwall Abutment A Sta. 559+29.92 Elev. 670.76
℄ Pier 1 Sta. 561+10.00 Elev. 671.03
℄ Pier 2 Sta. 563+20.00 Elev. 674.26
Radial typ.
Face of backwall Abutment B Sta. 565+00.08 Elev. 679.53
Exist. R/W line
Route 340 Constr. ℄
Toe of fill
Buried approach slab typ.
Face of rail
Edge of stream
Exist. rip-rap headwall
Edge of berm
Edge of stream
Toe of fill
Edge of berm
R=2,500.00'
R = 3,750.00'
To Front Royal
Exist. Rte. 340 bridge. See roadway plans for maintenance of traffic requirements.
Remove existing bridge structure after construction is completed
PLAN
C.G. Sta. 560+00.00
C.G. Elev. 653.10
V.C. = 1,400.00'
E = 17.49'
-5.0%
+5.0%
Beginning of bridge back of backwall Sta. 559+28.25
End of bridge back of backwall Sta. 565+01.75
Measured along Route 340 Constr. ℄
573'-6"
Finished grade
Finished grade
Existing profile at Route 340 Constr. ℄
Exp.
Span a
Edge of berm typ.
Fix
Span b
High water elev. 619±
Ordinary high water elev. 614±
Fix
Span a
Dry riprap Class I, 38" typ.
Micropile typ. at abutments
Rockfill
Rockfill
Micropile typ. at piers
ABUTMENT A
PIER 1
PIER 2
ABUTMENT B
* Normal to abutment
DEVELOPED SECTION ALONG CONSTR. ℄

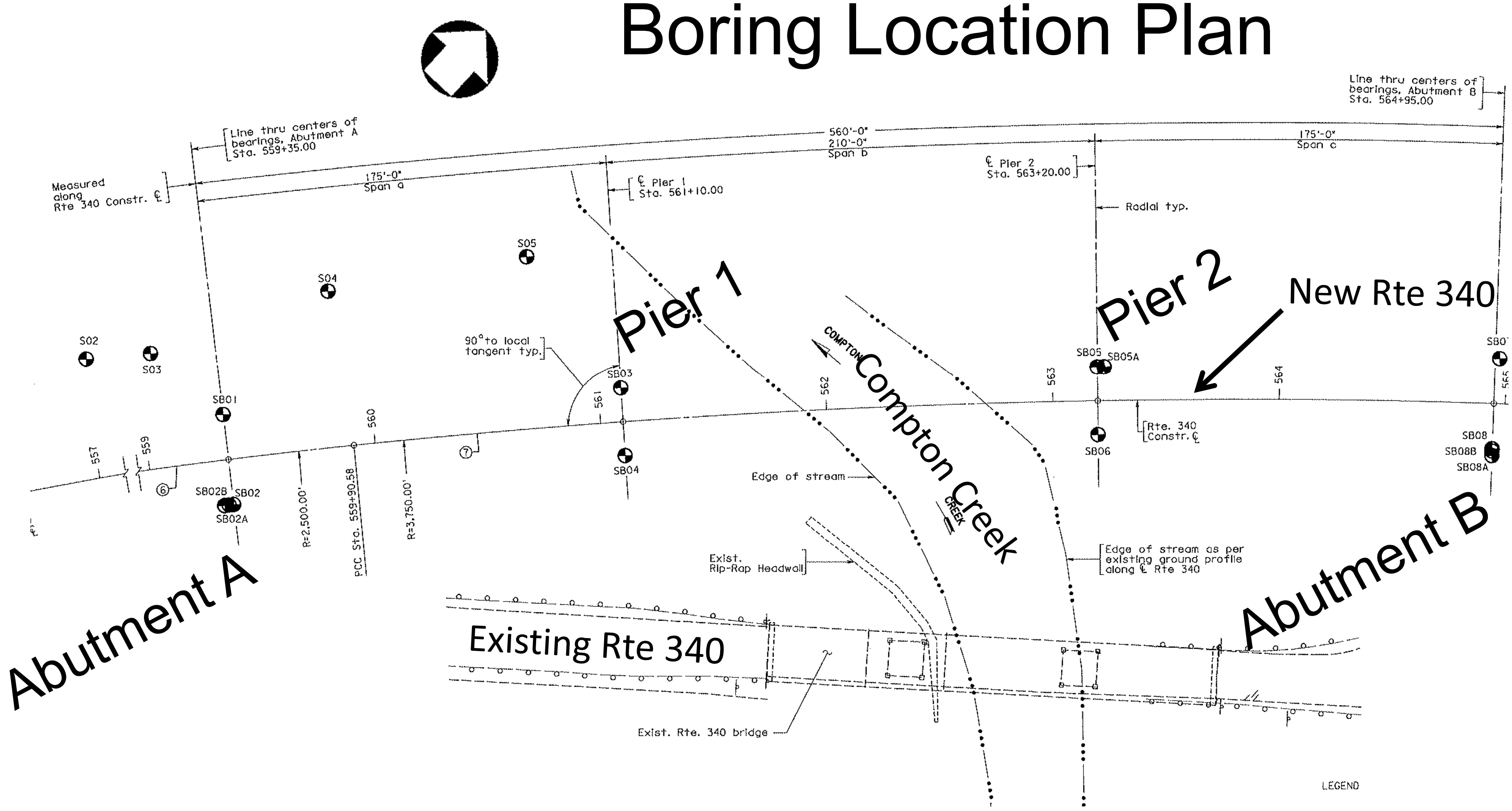
This is Karst !



Project Site Geology

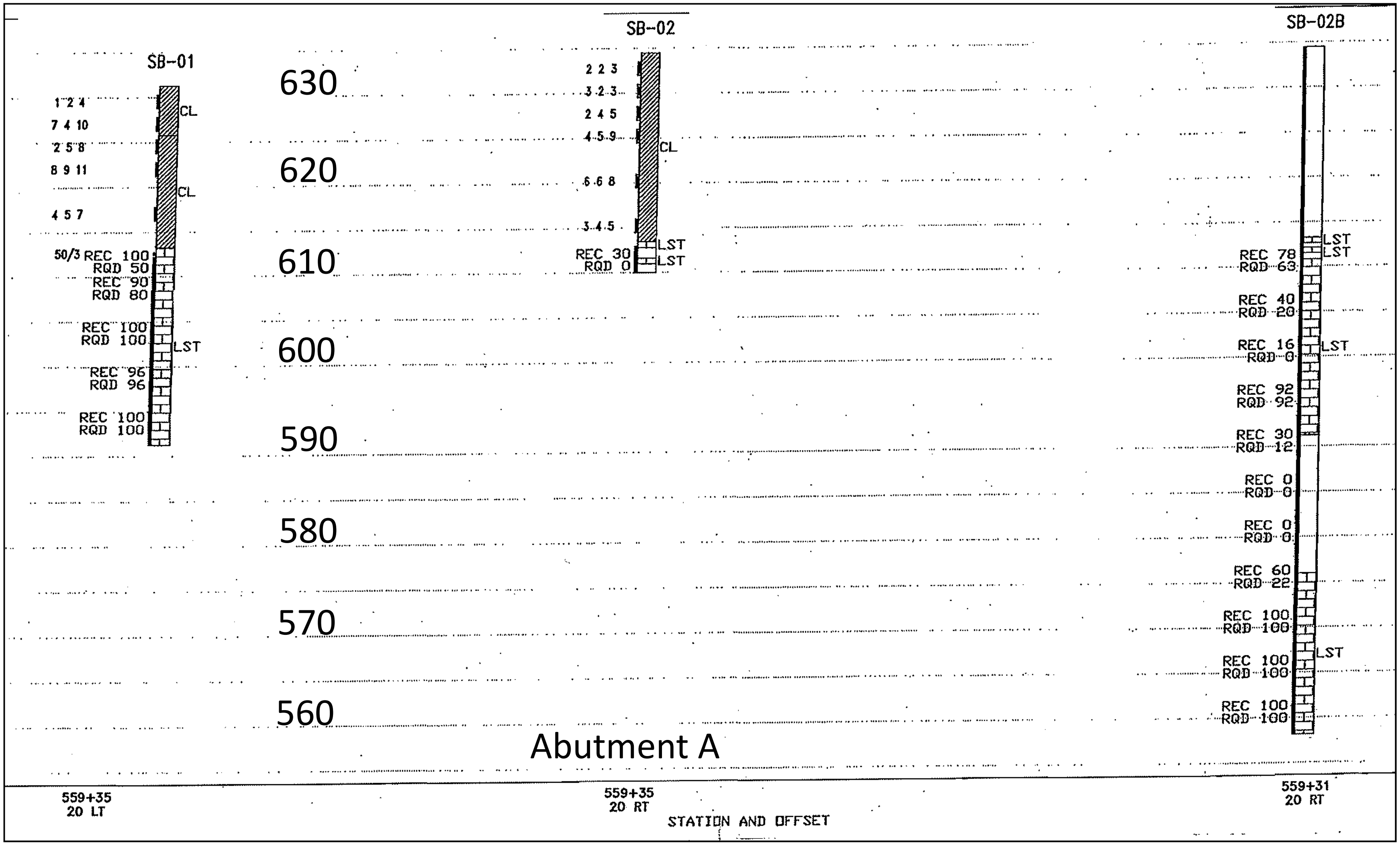
- Highly Soluble, Carbonate, Sedimentary Rocks (Beekmantown Group)

Boring Location Plan

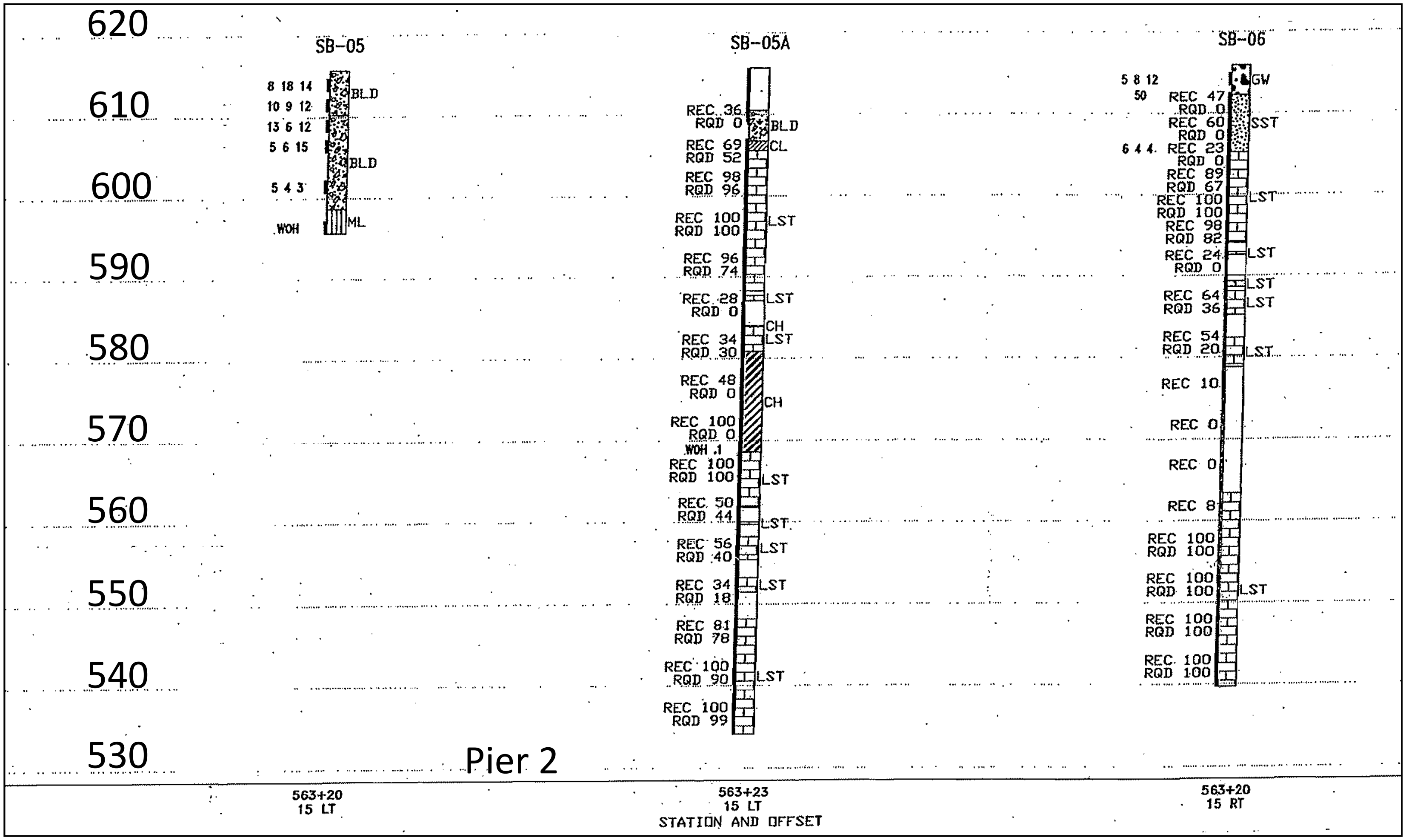


Boring Location

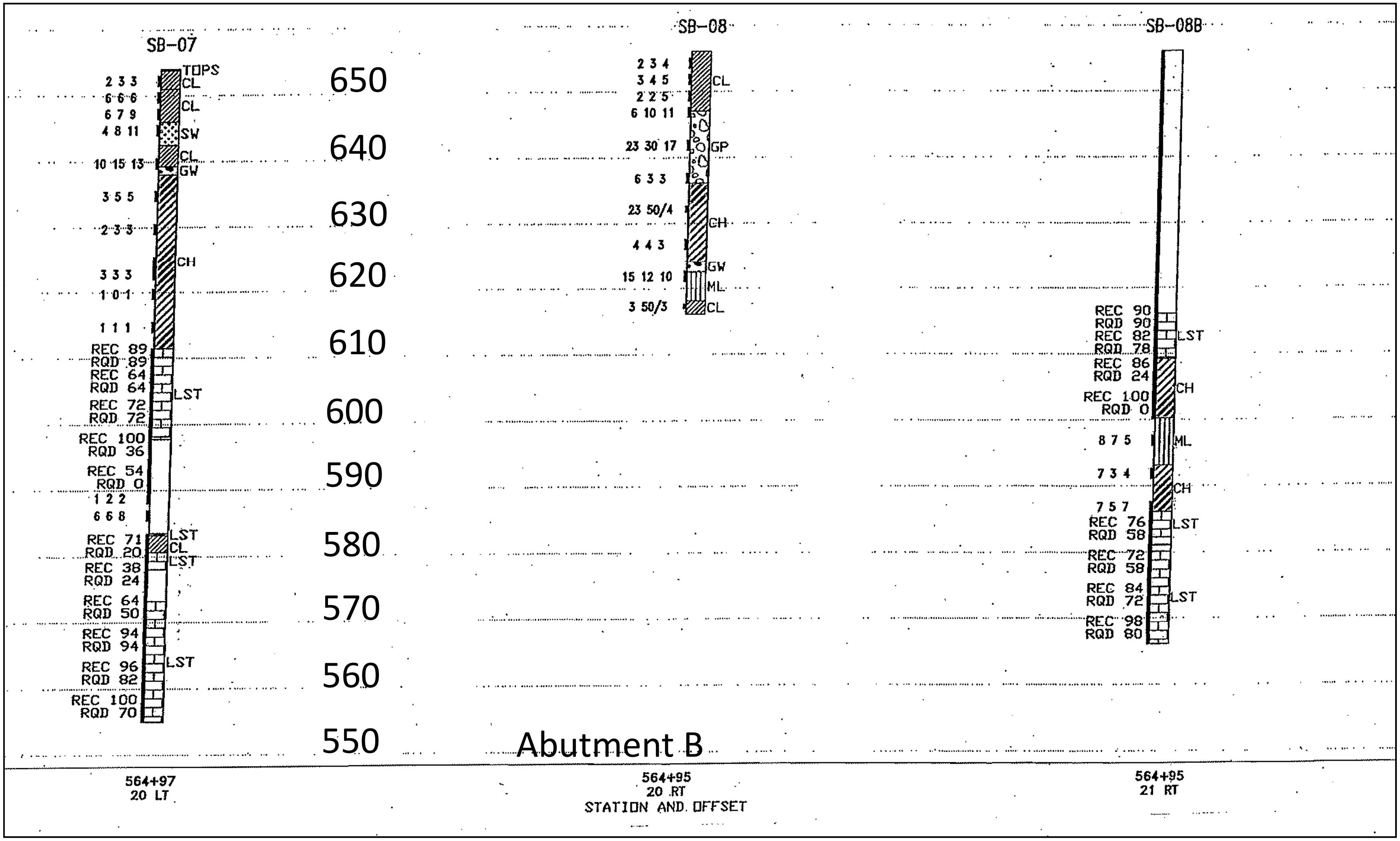
Boring Logs – Abutment A



Boring Logs – Pier 2



Boring Logs – Abutment B



Foundation Type Selection Considerations

- Variable Conditions (i.e.; erratic and intermittent quality of rock; soil layers and infilling; possible voids)
- Verification of Support Conditions;
- Design for Axial Loads;
- Design for Lateral Loads;
- Settlement and Possible NSF at Abutment Fills

Driven Piles, Drilled Shafts and Micropiles Considered

- Micropiles Selected

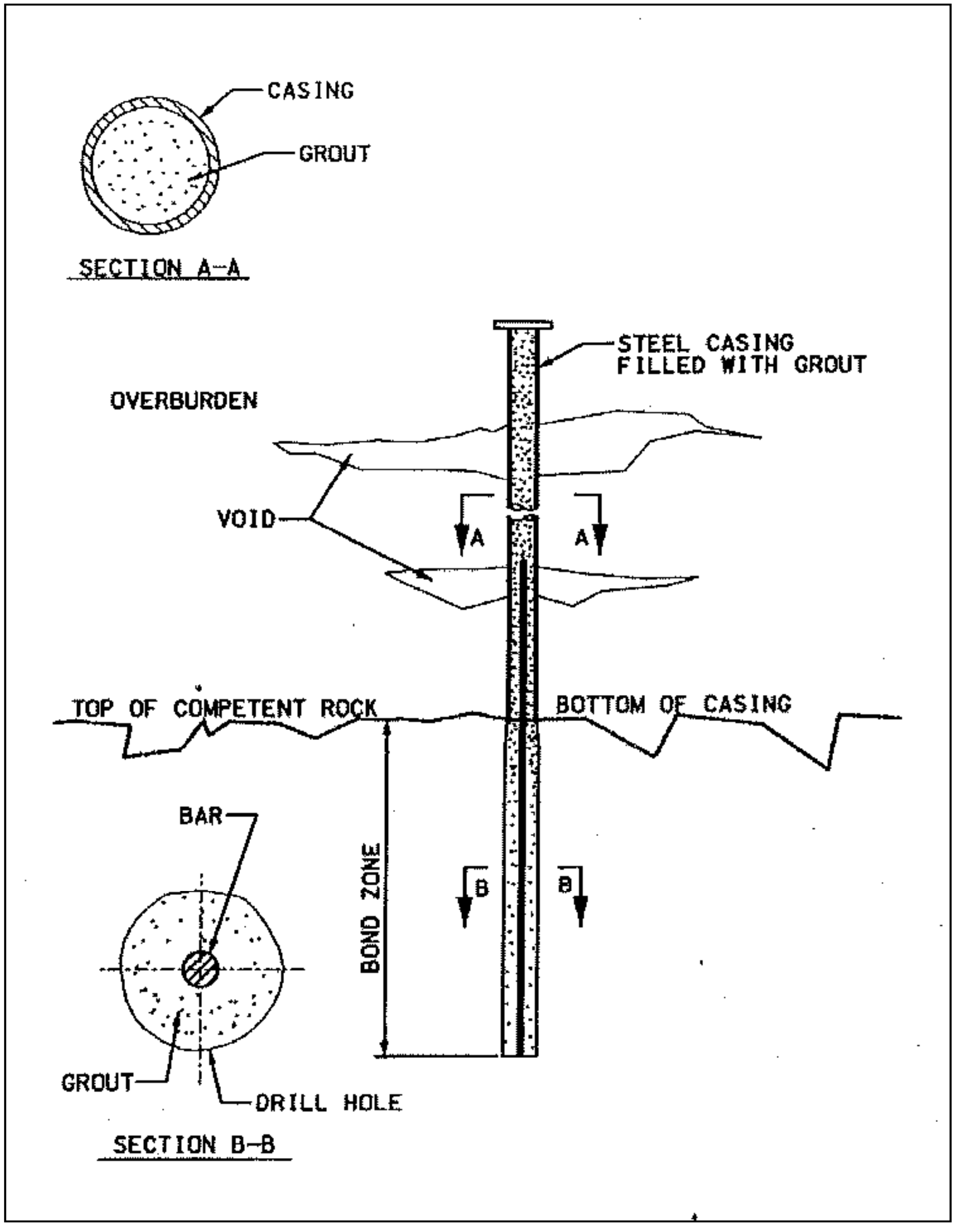
Possible Applications of Micropiles

- Restricted Access/Headroom or A Remote Area;
- Support System Close to Existing Structure;
- Supplemental Support For An Existing Structure (e.g. Settlement Control);
- **Difficult Ground Conditions (e.g., karst, mines, boulders, uncontrolled fill);**
- Risk of Liquefaction From Pile Driving;
- Need To Minimize Vibration And/Or Noise;
- Need To Reduce Or Eliminate Spoil At Hazardous Or Contaminated Sites
- As Alternate Deep Foundation Type, Especially Where Piles Penetrate Rock;
- Where Spread Footings Are Feasible but There Is Potential For Erosion or Scour

Ref: *FHWA-NHI-05-039*

Micropiles in Karst

- *FHWA-NHI-05-039 (Dec,2005) "Micropile Design and Construction"*
- *AASHTO LRFD Bridge Design Specifications 4th Edition, 2007, 2008 Interim Section 10.9;*
- *Other Experiences and Published Resources*



Micropile Construction in Karst Terrain

- Drill cased hole through soil, boulders and voids;
- Drill through full bond zone to verify conditions;
- No open hole drilling – Drill casing through bond zone;

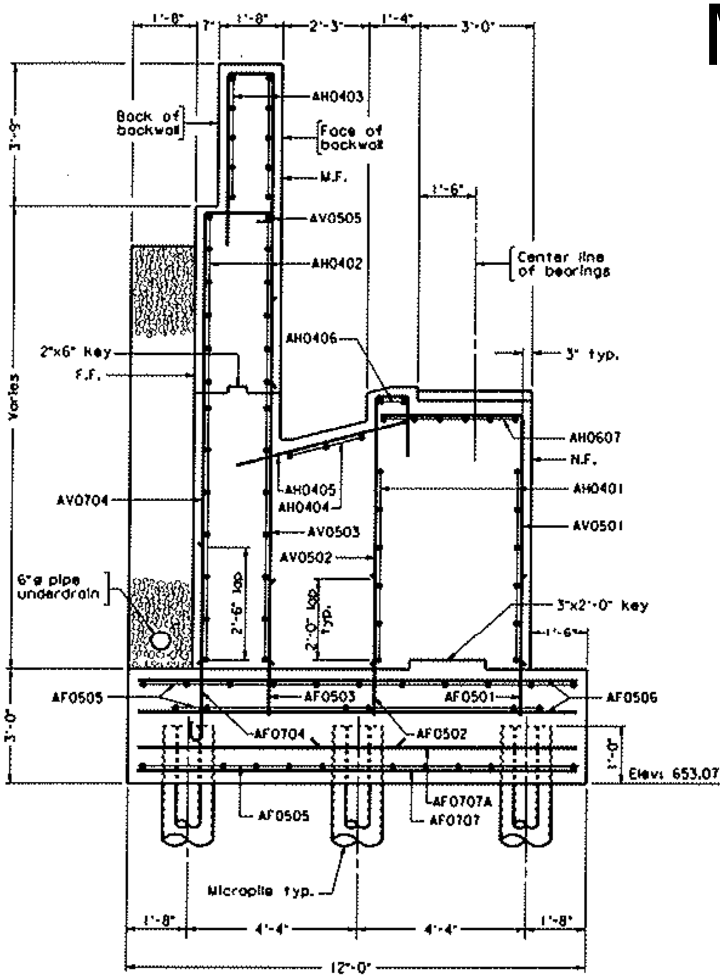
  (Use rotary percussive, eccentric duplex method)
- Monitor drilling rates and use to verify bond zone;
- Water testing and seal grouting.

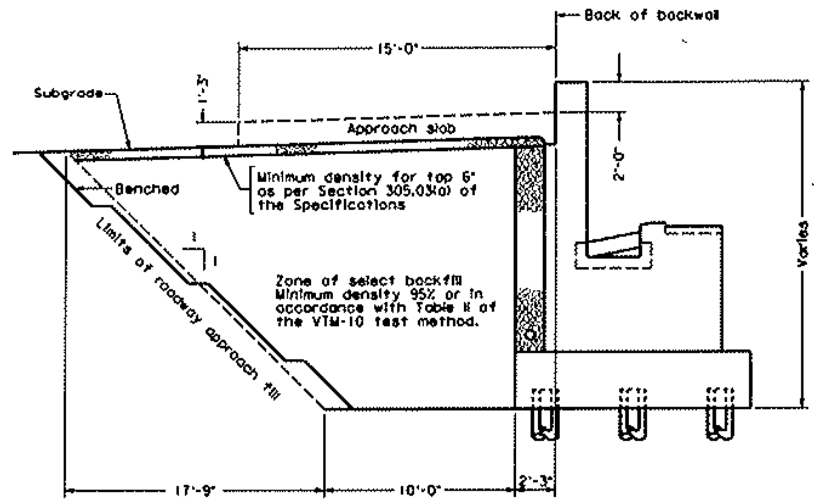
  (in highly broken/fractured rock or voided karstic rock)

Design and Construction Considerations

- Bond Zone Design (Nominal & Factored Resistance)
- Provide Preliminary Micropile Design
- Structural Design of Micropiles
- Design for NSF Loads at Abutments
- Design for Possible Void (20' Unsupported Length)
- Specifications for Construction
  - Experience of Specialty Contractor and Personnel
  - Drilling Methods
  - Allow Alternate Designs
  - Installation Plan including MP Documentation
  - Load Testing (Verification and Proof Load Tests)

Micropiles at Abutments

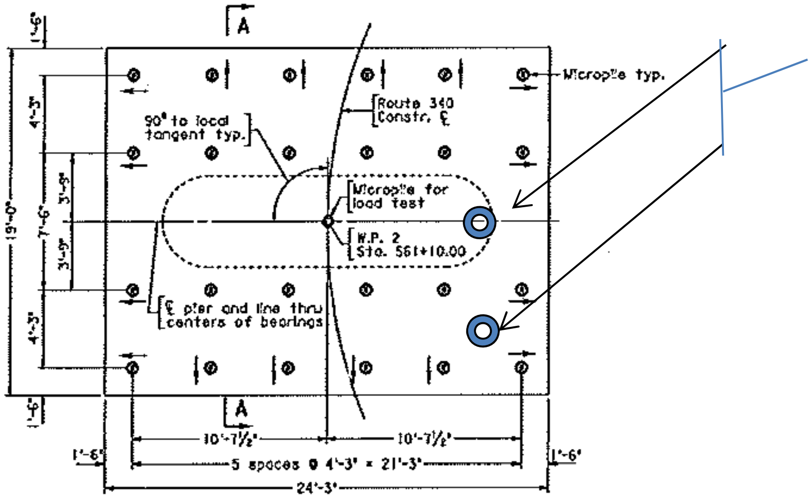




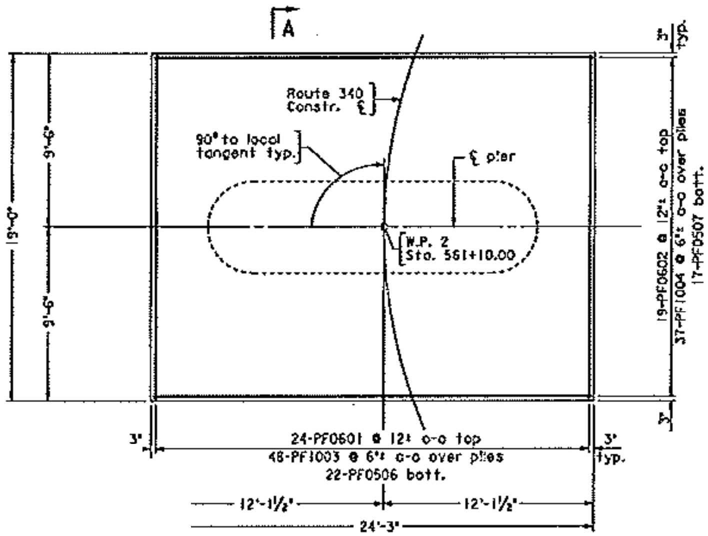
STRUCTURAL BACKFILL DETAIL
(Dimension measured at Rte. 340 Constr. ℄)
Abutment drainage not shown
Not to scale

Micropile Grouted Inside Vertical 16-inch OD Casings for Lateral Load Design

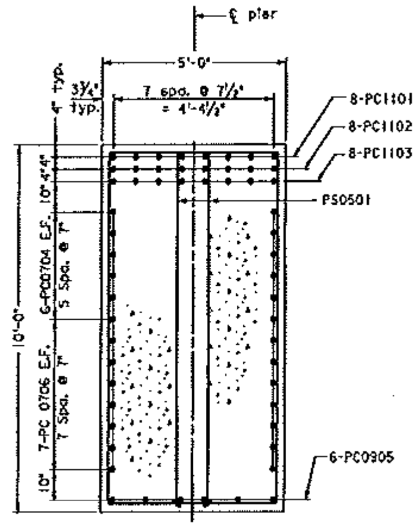
Alternate Micropile Positions, If Needed



FOOTING PLAN
Scale: ¼"=1'-0"

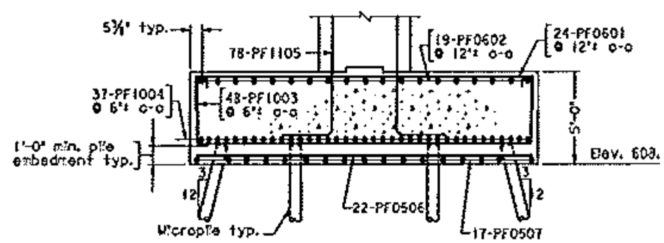


FOOTING REINFORCEMENT PLAN
Scale: ¼"=1'-0"
Micropiles not shown for clarity

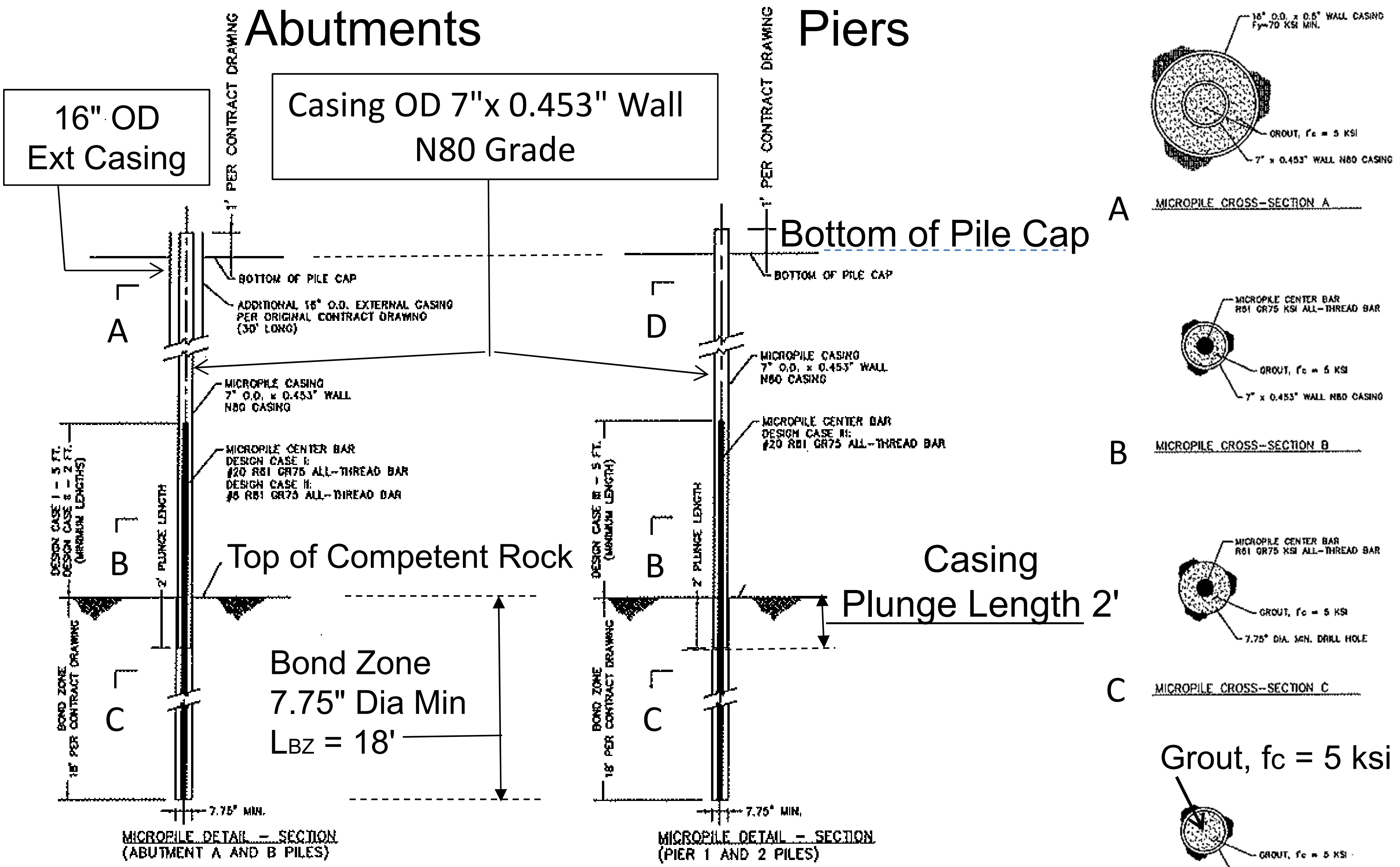


SECTION B
Scale: ½"=1'-0"

Micropiles at Piers



SECTION A-A
Scale: ¼"=1'-0"



Alternate Micropile Design

Micropile Axial Load Design (LRFD)

Foundation	Design Case	Factored Design Load	Nominal Resistance
		Compression	
Abutments	I	295k	536k
	II	170k	309k
Piers	III	392k	713k
Tension Load – 0 kips			
Grout-to-Ground α_{Bond}, Nominal Resistance = 19.2ksf [135psi] Resistance Factor (RF) = 0.55			
Design Case - Refers to Pile Locations in Foundation			

Micropile Installation and Testing

Numa T-150 Eccentric Percussive Drill Bit

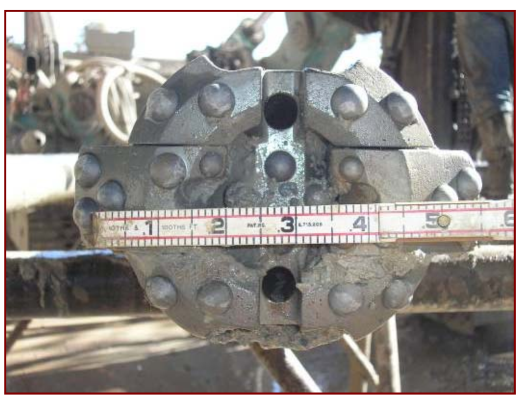
OD_{Casing} = 7.000"

ID_{Casing} = 6.094"

$D_{Retracted\ Bit}$ = 5.905"

$D_{Expanded\ Bit}$ = 7.750"

$D_{Hole\ min}$ = 7.750"



Pier 2 MP Installation

Communication During Drilling

Example Micropile Log

Abutment B - Pile 14

- Drilling
- Initial Grouting

DATE DRILLED:	10/13/2011		
PROJECT #:	11-0203	DRILLER:	G.B.
HOLE #:	Abut. B - #14	TIME START:	8:20
DRILL RIG:	M9-1	TIME STOP:	12:32
HOLE DIA.:	7.75"	PILE LENGTH (FROM CUTOFF):	91.00
DRILL EL.:	662.33	TIP EL.	553.33 53.33

SOIL / ROCK DESCRIPTION	COMMENTS / DIFFICULTIES	TIME	FROM	TO
Grout		8:20	0.0	30.0
Broken Rock		9:22	30.0	31.0
Clay		9:25	31.0	35.0
Rock Ledge		9:27	35.0	36.0
Clay		9:28	36.0	48.0
Rock Ledge		9:50	48.0	54.0
Clay/Rock		10:07	54.0	58.0
Rock Ledge		10:12	58.0	63.0
Broken Rock		10:42	62.0	65.0
Clay		10:45	65.0	68.0
Rock Ledge		10:58	68.0	77.0
Rock/Clay		11:05	77.0	80.0
Clay	Soft	11:22	80.0	90.0
Broken Rock		11:39	90.0	91.0
Rock		11:42	91.0	96.0
Rock		11:57	96.0	101.0
Rock		12:12	101.0	106.0
Rock		12:25	106.0	109.0
Rock Socket Time Start:		11:42		
Rock Socket Time Stop:		12:32		

GROUTING INFORMATION		*MATERIALS USED / COMMENTS*	
DATE GROUTED:	10/13/2011	CASING USED:	93'
GROUT TAKE:	461.3 gallons	CENTRAL REINFORCEMENT:	
GROUT COMMENTS		*GENERAL COMMENTS*	
This hole would not grout up. Needs redrilled.			

Example Micropile Log

DATE DRILLED: 10/14/2011

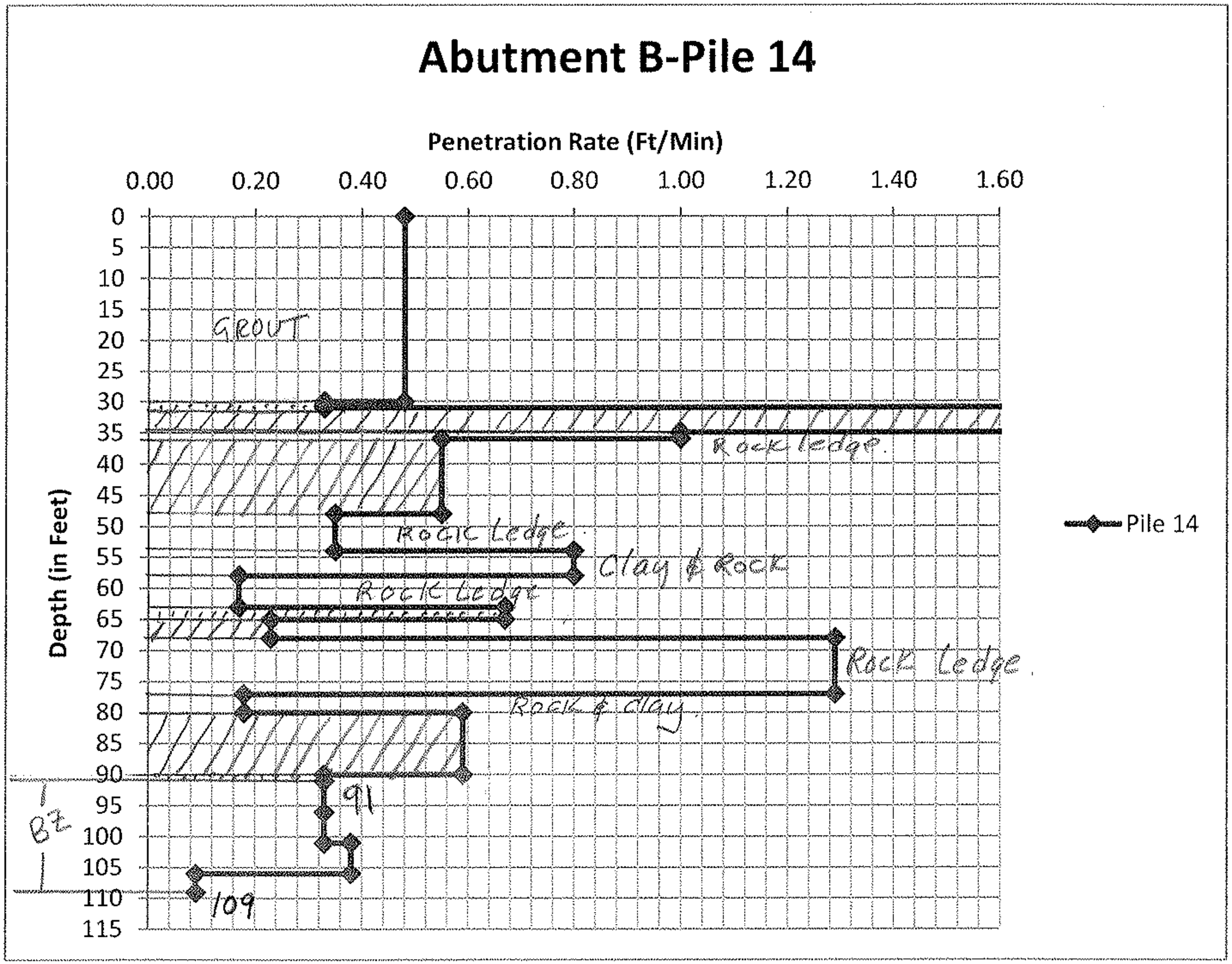
PROJECT #:	11-0203	DRILLER:	G.B.
HOLE #:	Abut. B - #14 REDRILL	TIME START:	1:45
DRILL RIG:	M9-1	TIME STOP:	2:26
HOLE DIA.:	7.75"	PILE LENGTH (FROM CUTOFF):	109.00
DRILL EL.:	662.33	TIP EL.:	553.33

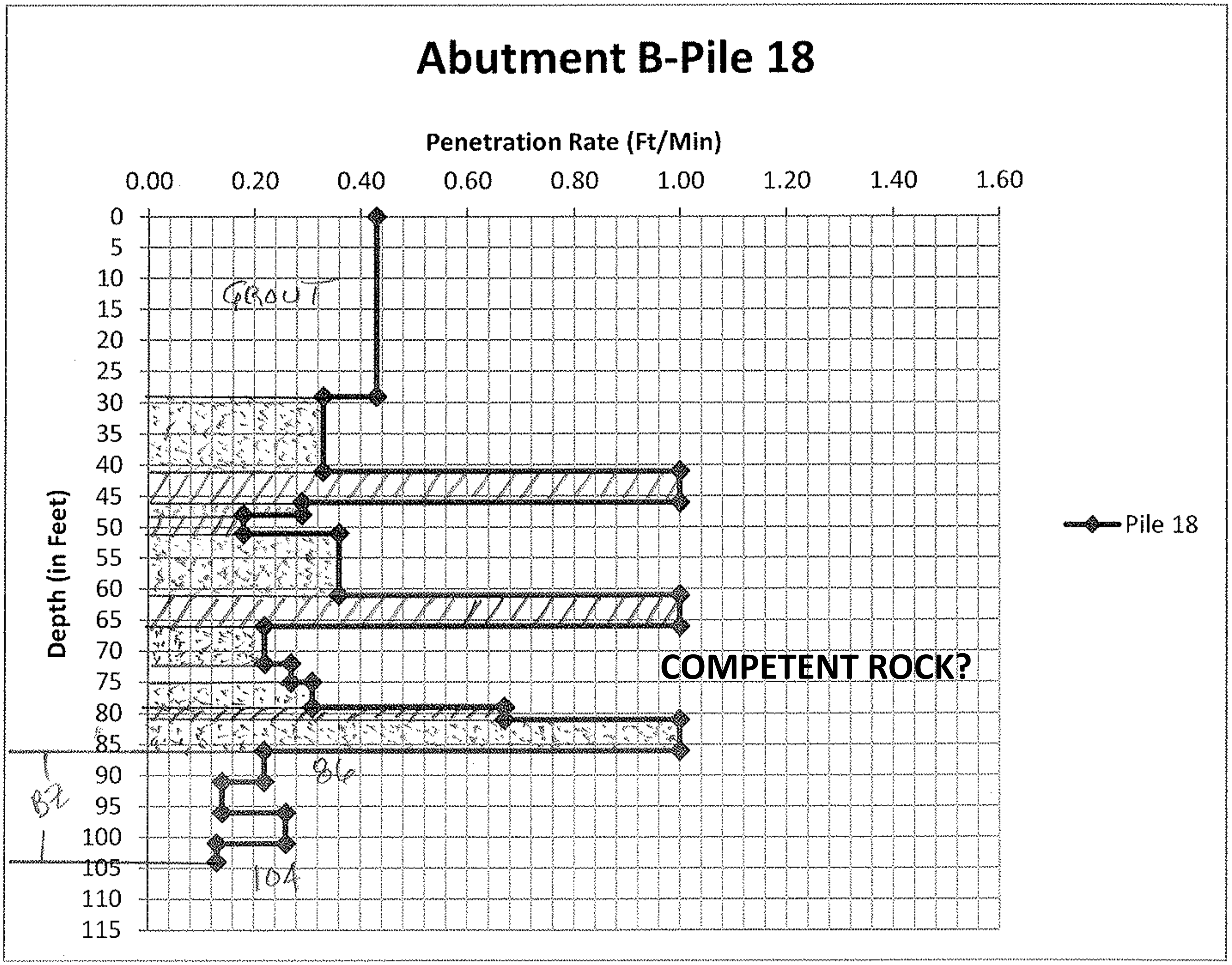
SOIL / ROCK DESCRIPTION	COMMENTS / DIFFICULTIES	TIME	FROM	TO
Grout	Redrill	*1:45*	68.0	109.0
		2:26		
Rock Socket Time Start:				
Rock Socket Time Stop:				

GROUTING INFORMATION		***MATERIALS USED / COMMENTS***	
DATE GROUTED:	*10/14/2011*	CASING USED:	
GROUT TAKE:	*228.7 gallons*	CENTRAL REINFORCEMENT:	*25' #8 bar*
GROUT COMMENTS		***GENERAL COMMENTS***	

Abutment B - Pile 14

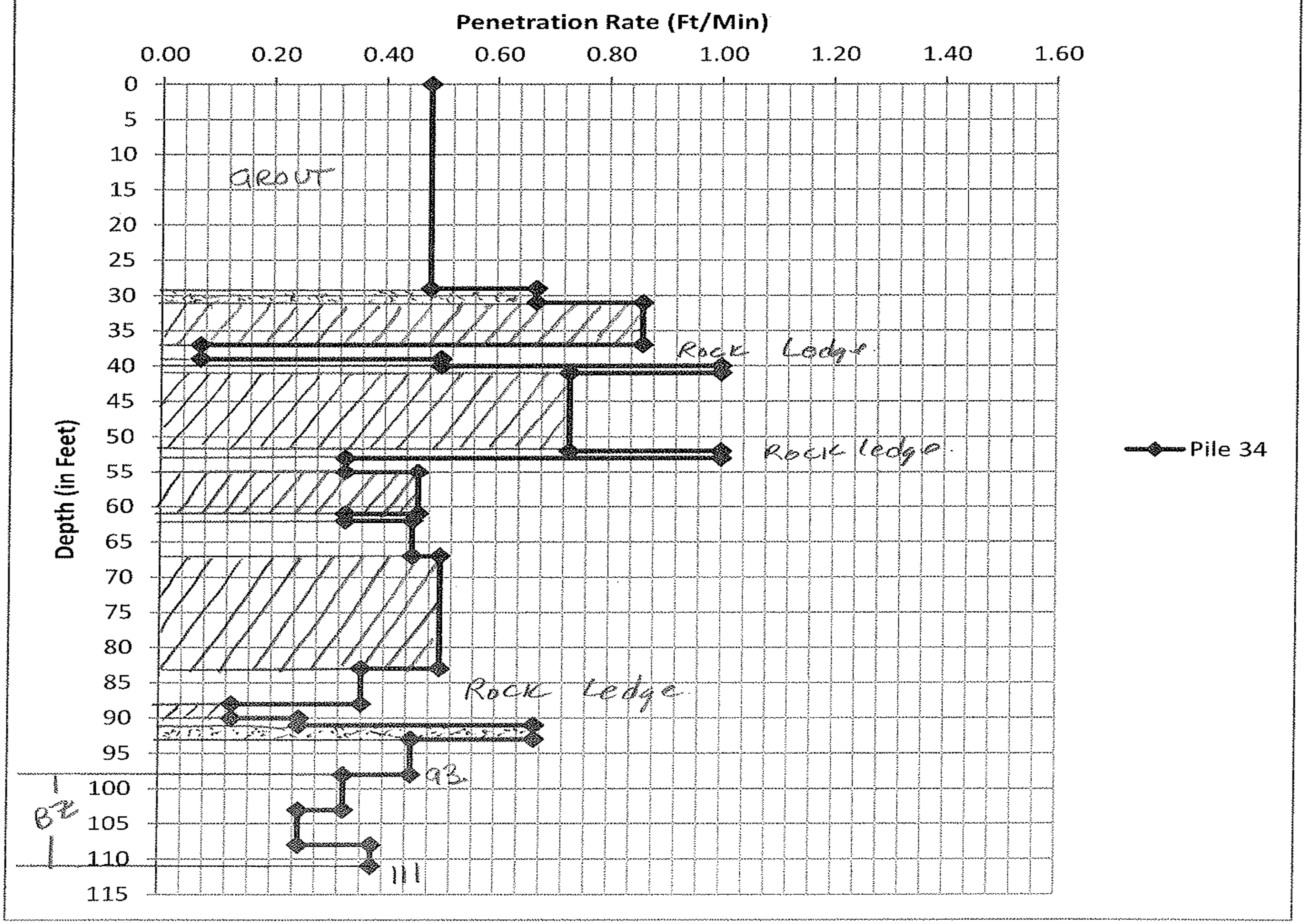
- Re-Drilling
- Re-Grouting


Abutment B-Pile 14
Penetration Rate (Ft/Min)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
Depth (in Feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
GROUT
Rock ledge.
Rock Ledge.
Clay & Rock
Rock Ledge
Rock Ledge.
Rock & clay.
91
BZ
109
Pile 14



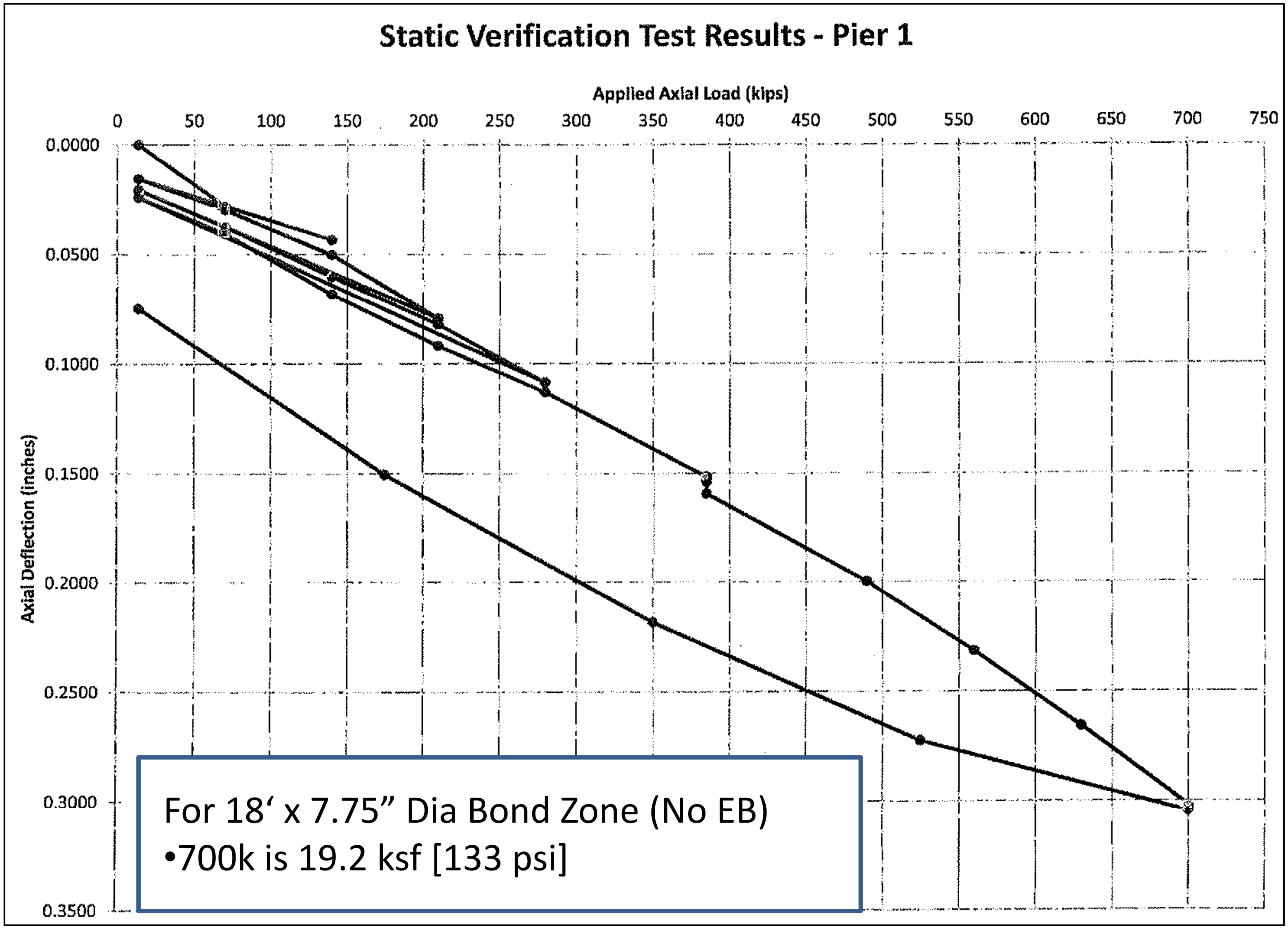
Abutment B-Pile 18
Penetration Rate (Ft/Min)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
Depth (in Feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
GROUT
COMPETENT ROCK?
86
104
Pile 18

Abutment B-Pile 34

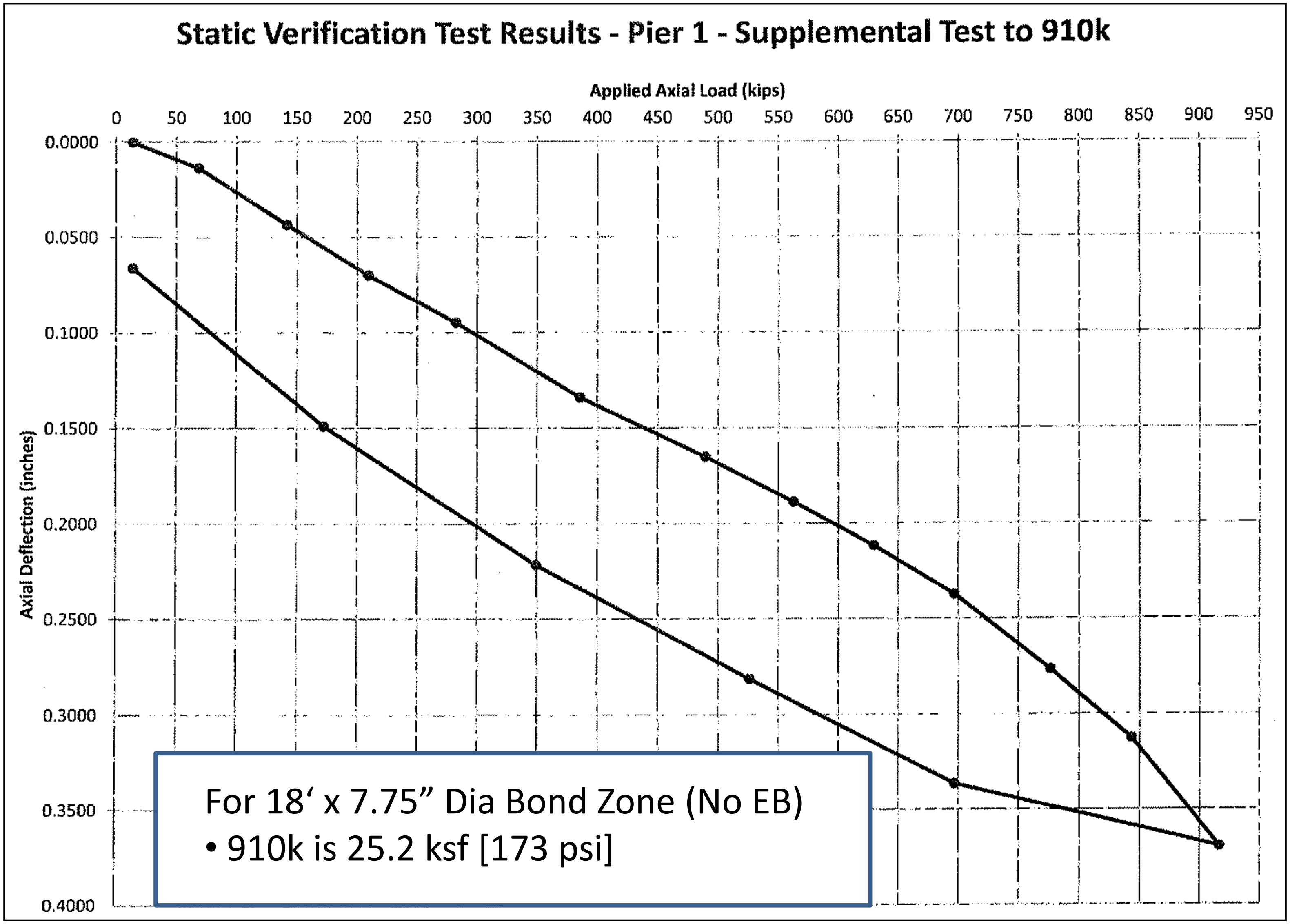


Load Testing Arrangement

Verification Load Test – Pier 1

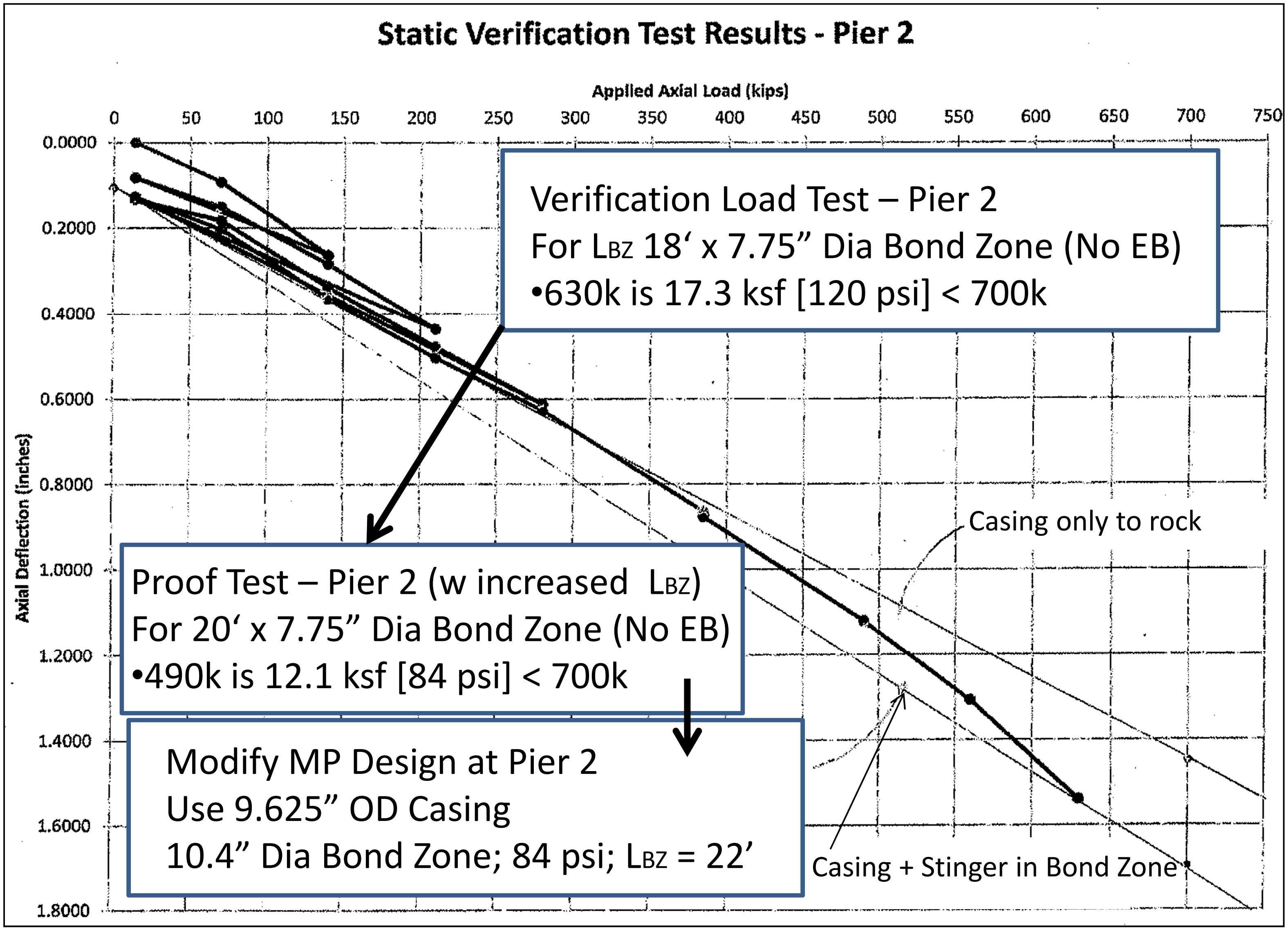


Verification Load Test (Supplemental) – Pier 1



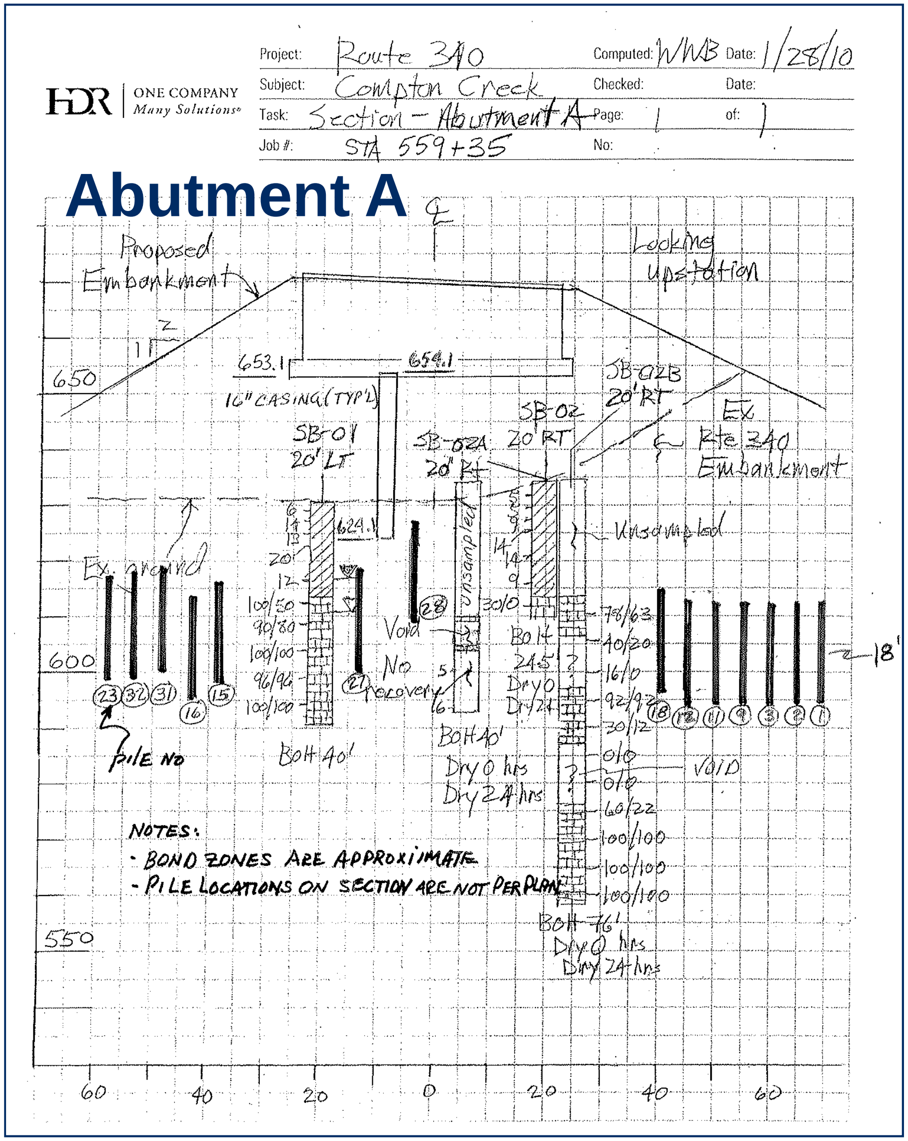
For 18' x 7.75" Dia Bond Zone (No EB)
- 910k is 25.2 ksf [173 psi]

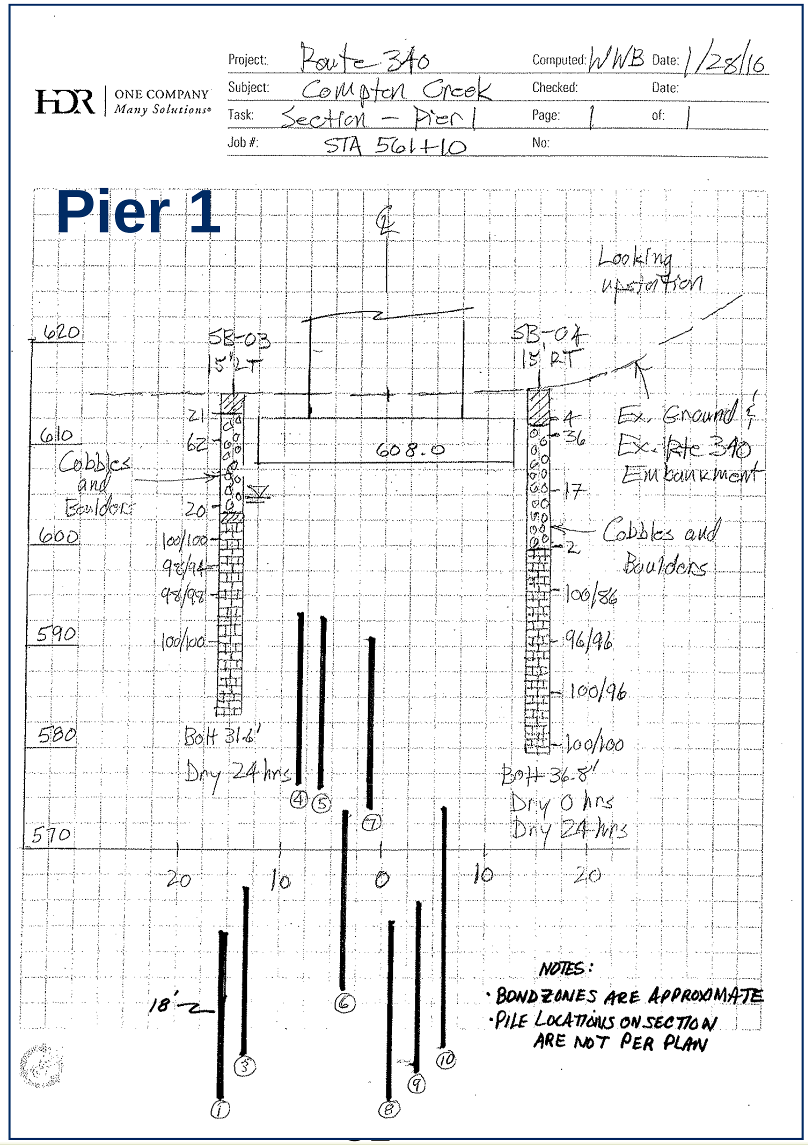
Verification Load Test – Pier 2



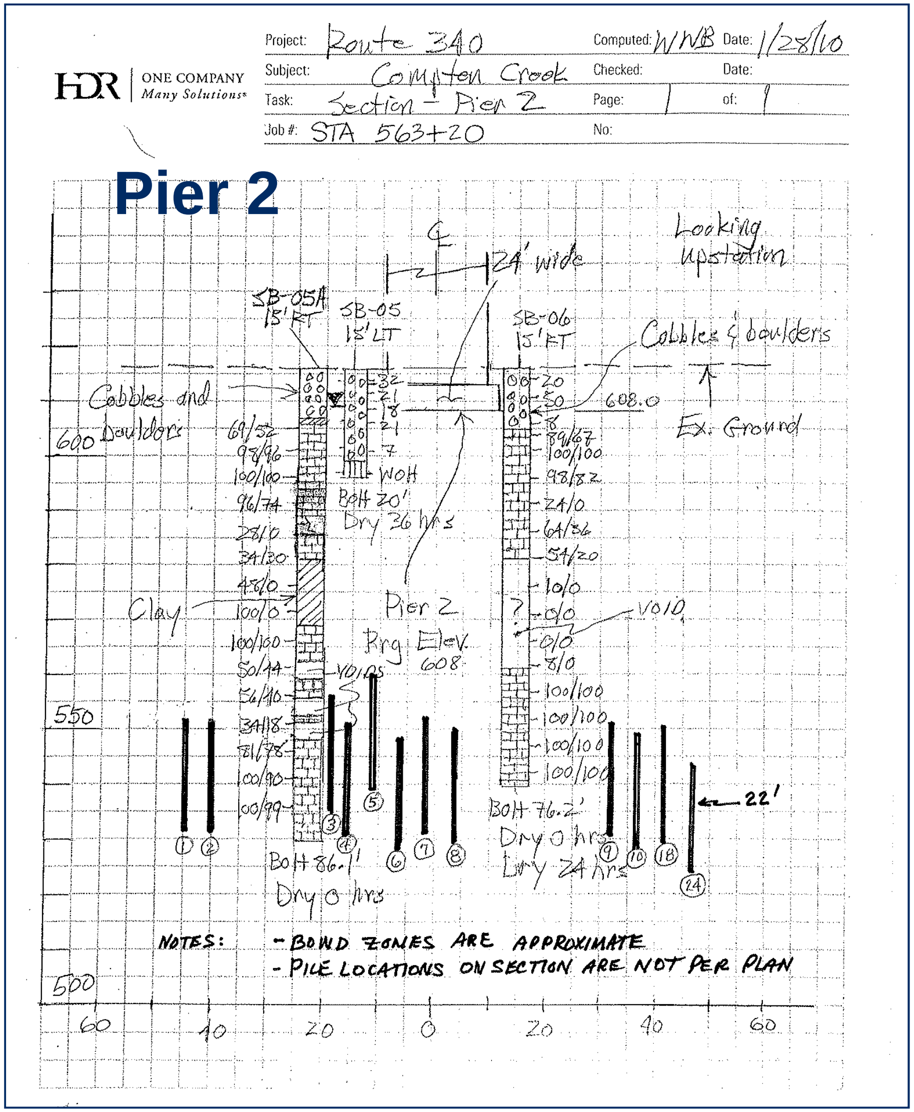
Increase bond zone length 10%...get a 20% reduction in capacity!

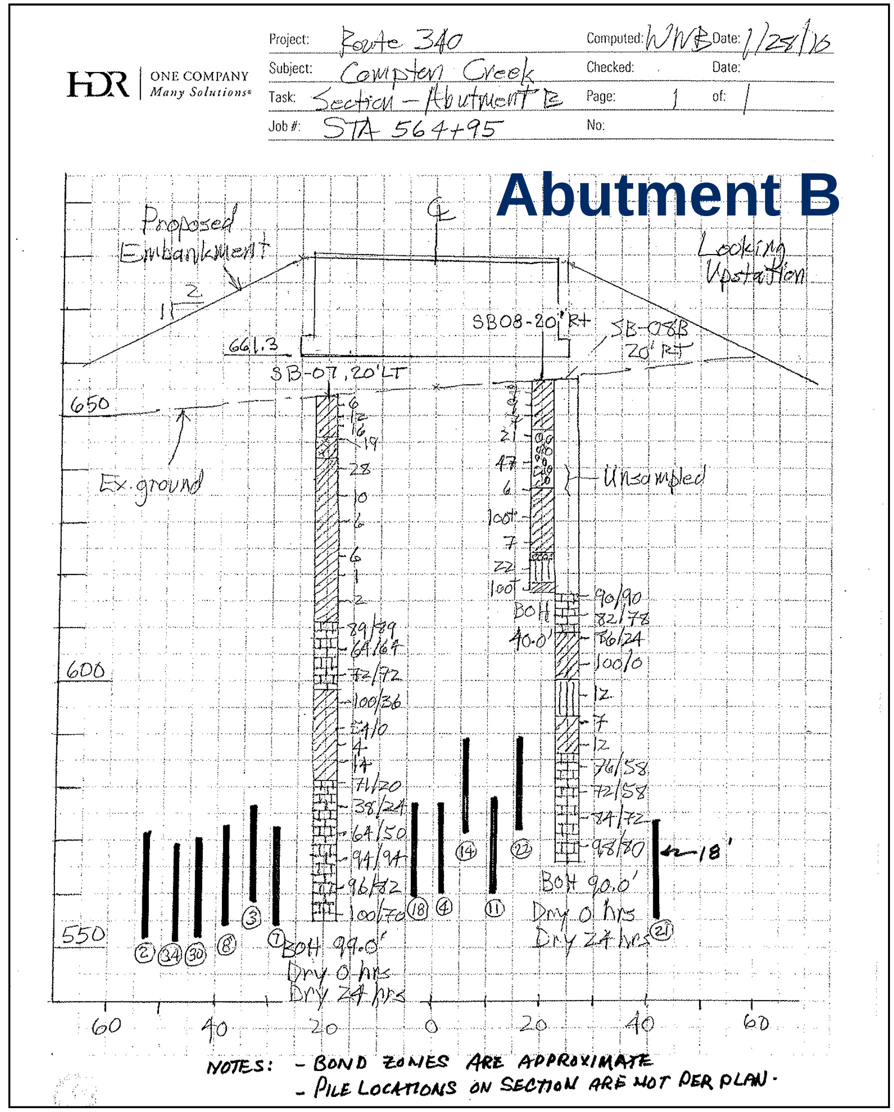
Schematic Sections with Micropile Bond Zones





Schematic Sections with Micropile Bond Zones





Alternate Load Testing Methods
[Review for Limitations]

GRL's Apple

Birminghammer – AFT Statnamic

View from Abutment A – looking north.

View south, Pier 2, with Pier 1 in background.

Concluding Comments

- Design and construction in karst geology is uniquely challenging.
- Micropiles are a feasible deep foundation support elements in karst.
- Care must be taken to sufficiently characterize subsurface conditions during design and confirm during construction.
- Contract documents need to be developed to capture the design intent without being overly restrictive; karst demands the ability to adapt to erratic and varying conditions.
- Experience is essential.

Thank You

Questions?