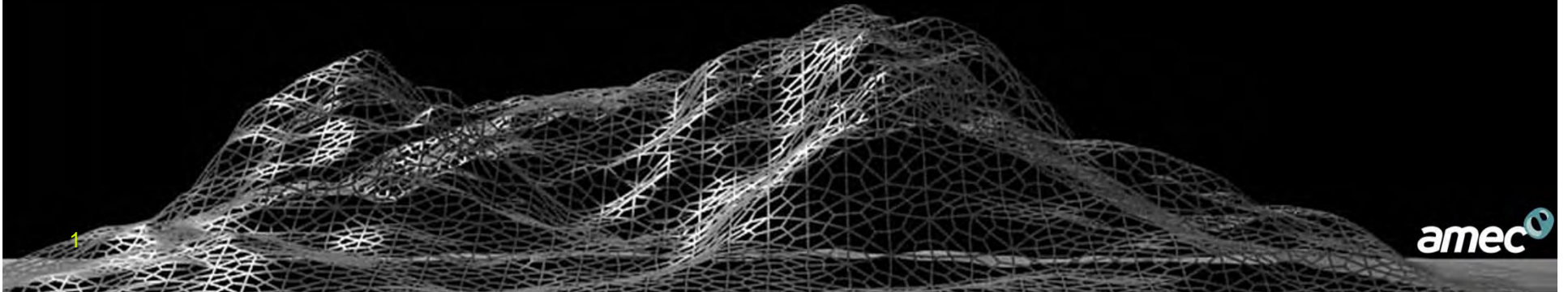


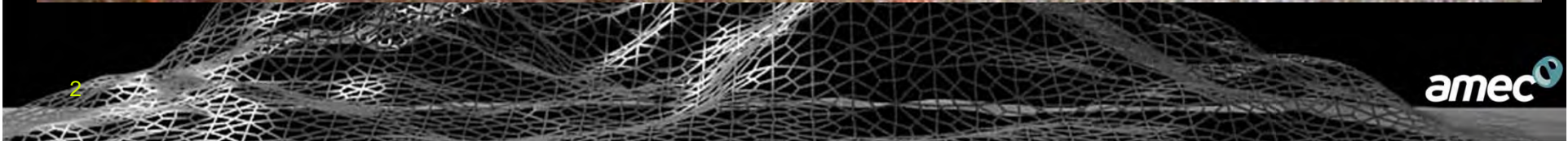
**11th Annual Technical Forum
GEOHAZARDS IMPACTING
TRANSPORTATION IN THE APPALACHIAN
REGION**

**GEO-DESIGN APPLICATIONS IN KARST
ENVIRONMENTS**

William D. Spencer, P.G.,
Jaye Richardson, and Chris Ramsey, P.E.
AMEC, Nashville TN
August 3, 2011



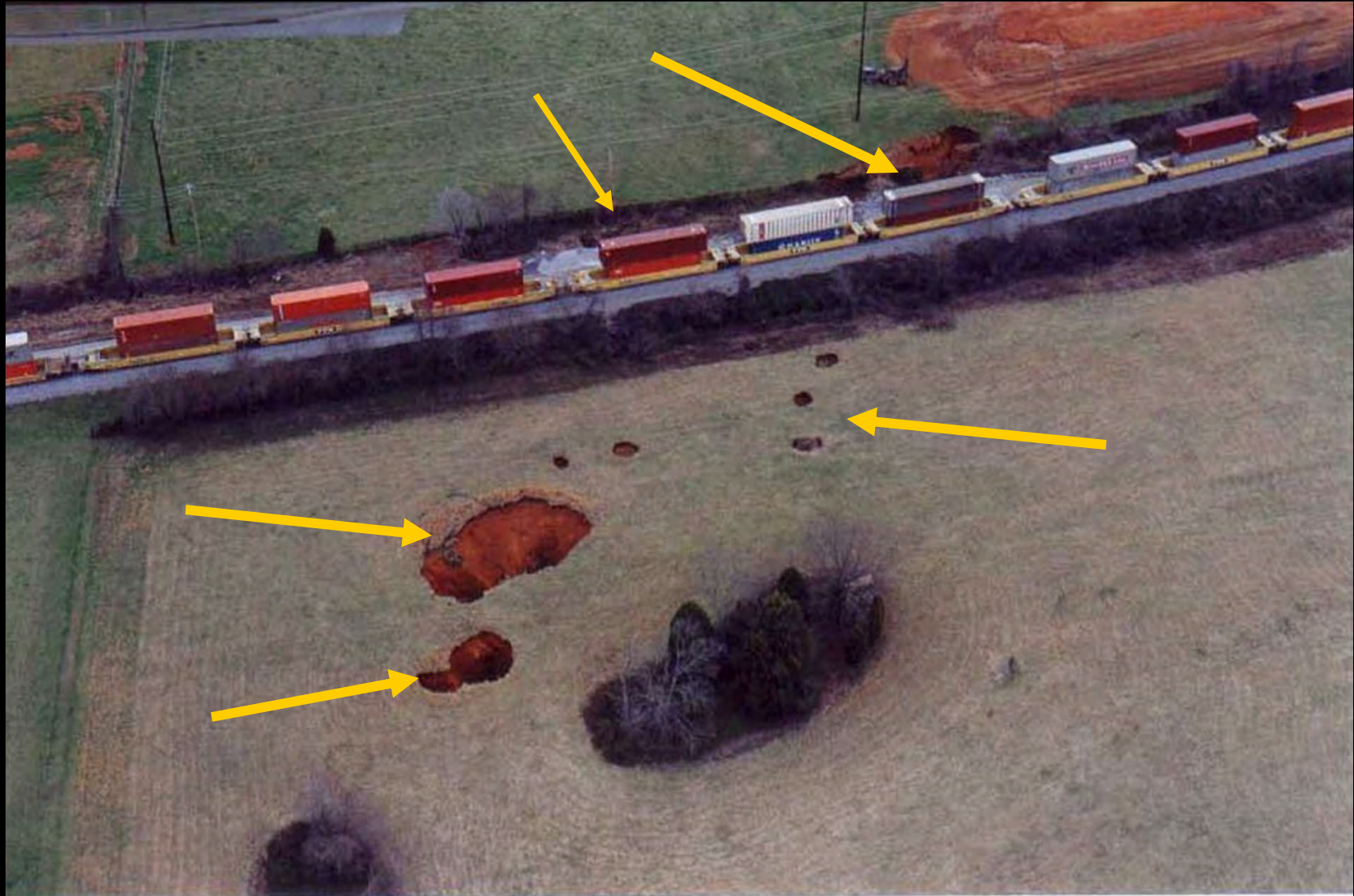
KARST CAN OCCUR ANYTIME AND ANYWHERE



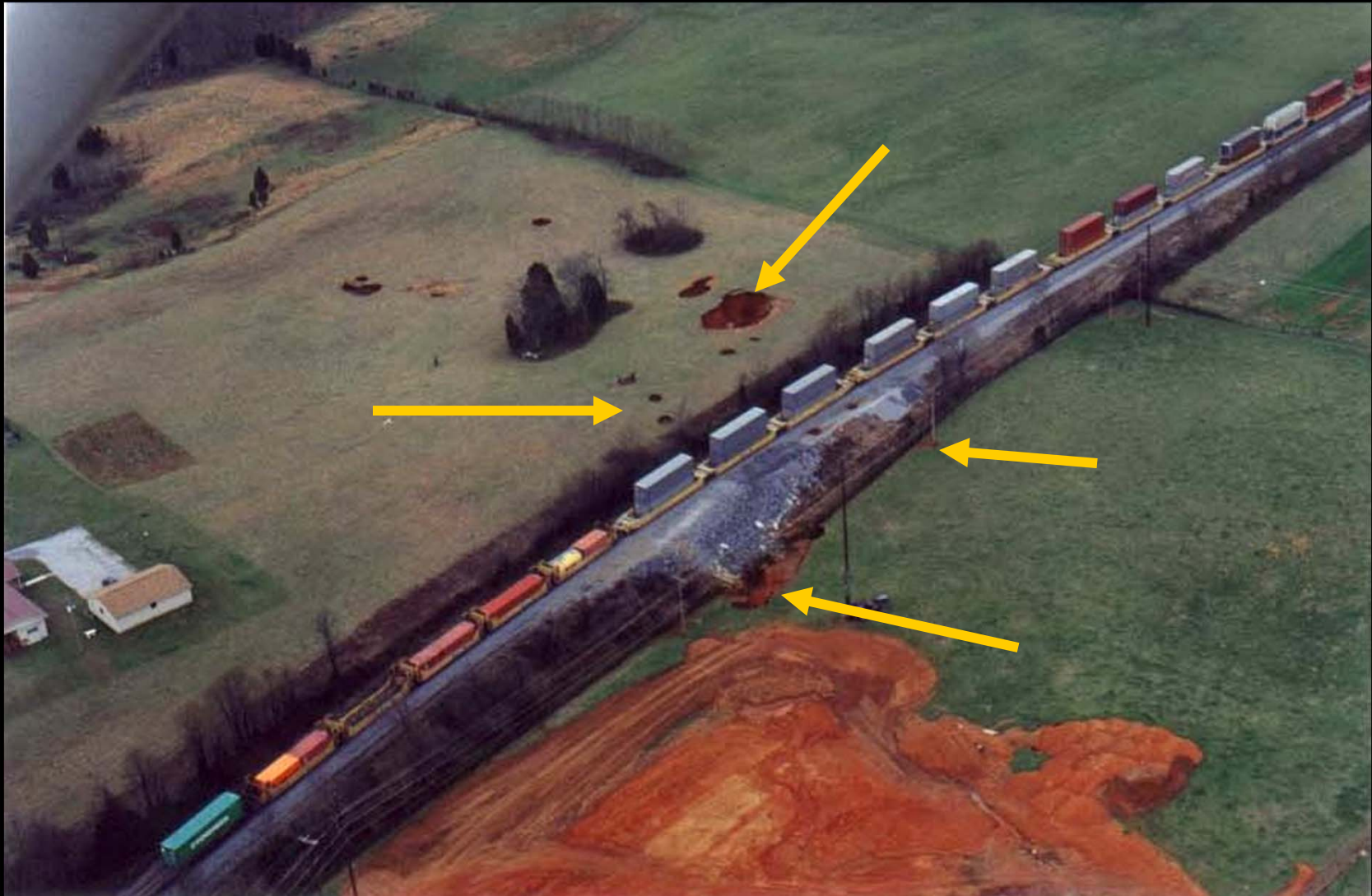
KARST CAN OCCUR ANYTIME AND ANYWHERE



NSC Mainline Track at MP 96.1A Morristown, Tennessee



NSC Mainline Track at MP 96.1A Morristown, Tennessee



NSC Mainline Track at MP 96.1A Morristown, Tennessee



NSC Mainline Track at MP 96.1A Morristown, Tennessee



NSC Mainline Track at MP 96.1A Morristown, Tennessee

SUMMARY OF DEEP FOUNDATION OPTIONS

OPTIONS	PERCEIVED ADVANTAGES	PERCEIVED DISADVANTAGES
<ul style="list-style-type: none">• Driven Piles (H-Piles)	Low cost	Impossible to assess bearing strata
<ul style="list-style-type: none">• Drilled Piers (Caissons)	High load capacity; low long term risk	High cost; potentially large voids in bedrock might take large quantities of concrete to fill.
<ul style="list-style-type: none">• Small Diameter Drilled Pipe Piles (Micro Piles)	Low long-term risk; easy to make adjustments	Moderate to high cost; smaller than “normal” pile size for bridge bents; requires real-time field engineering during construction to adjust.

NSC Mainline Track at MP 96.1A Morristown, Tennessee



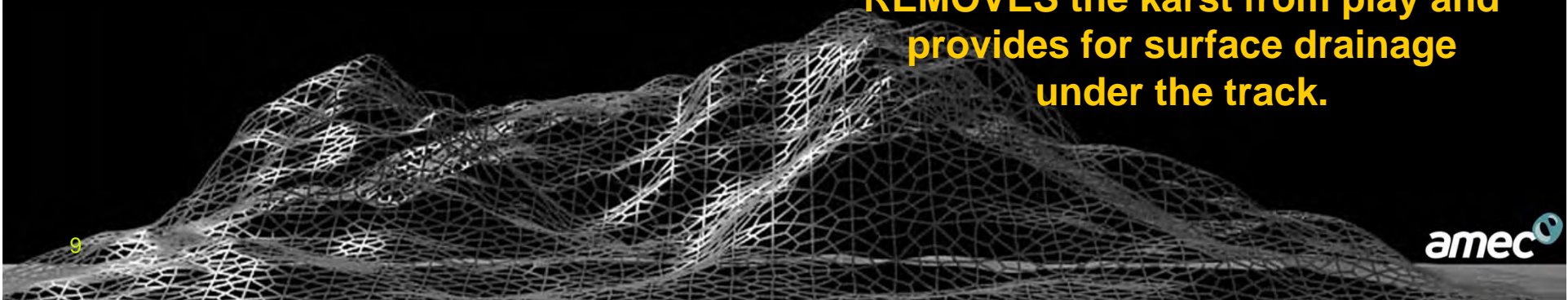
BEFORE

Karst engulfing the soil and ballast

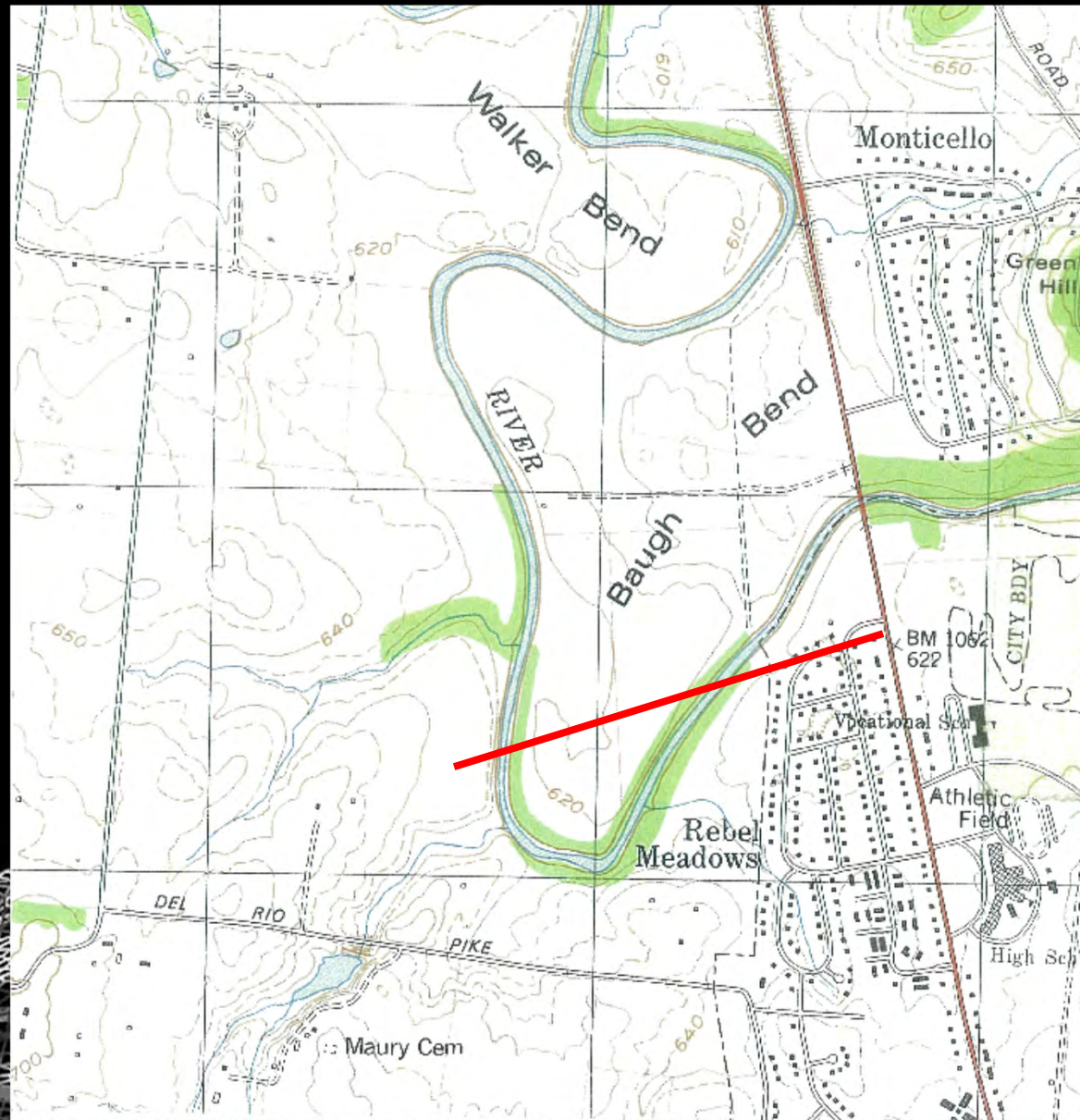


AFTER

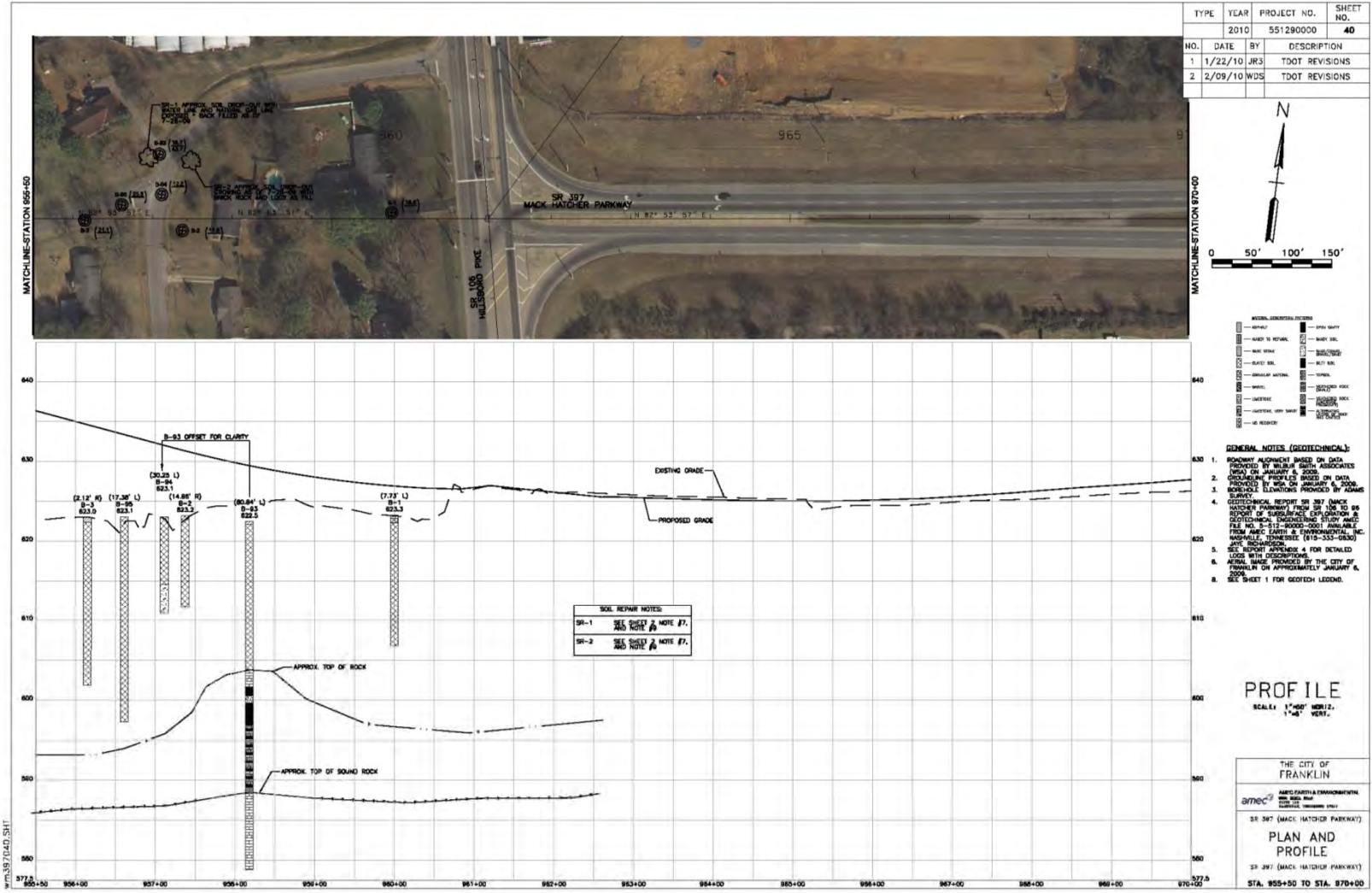
**Micro pile and structural land bridge
REMOVES the karst from play and
provides for surface drainage
under the track.**



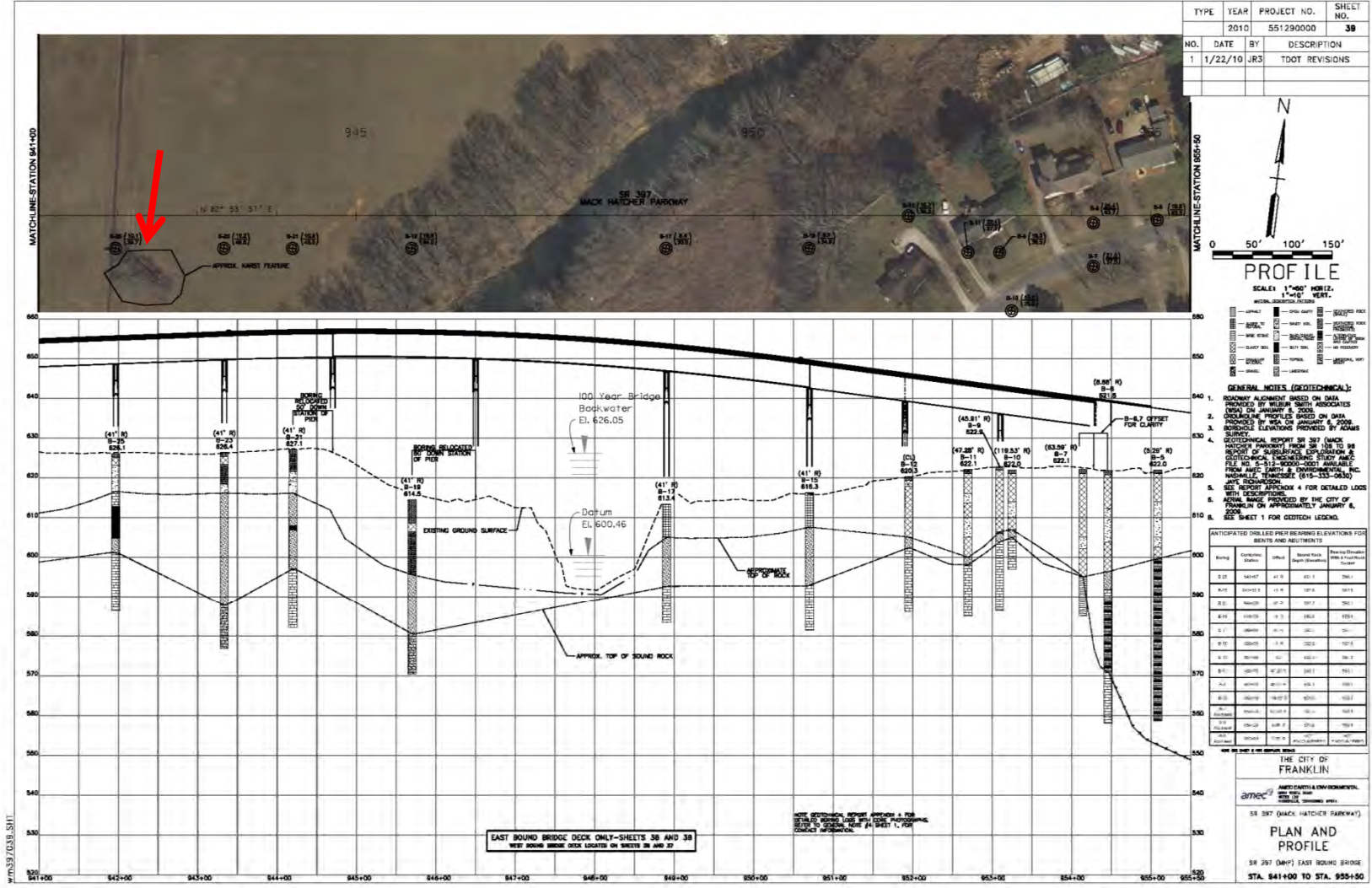
Mack Hatcher Parkway Franklin, Tennessee



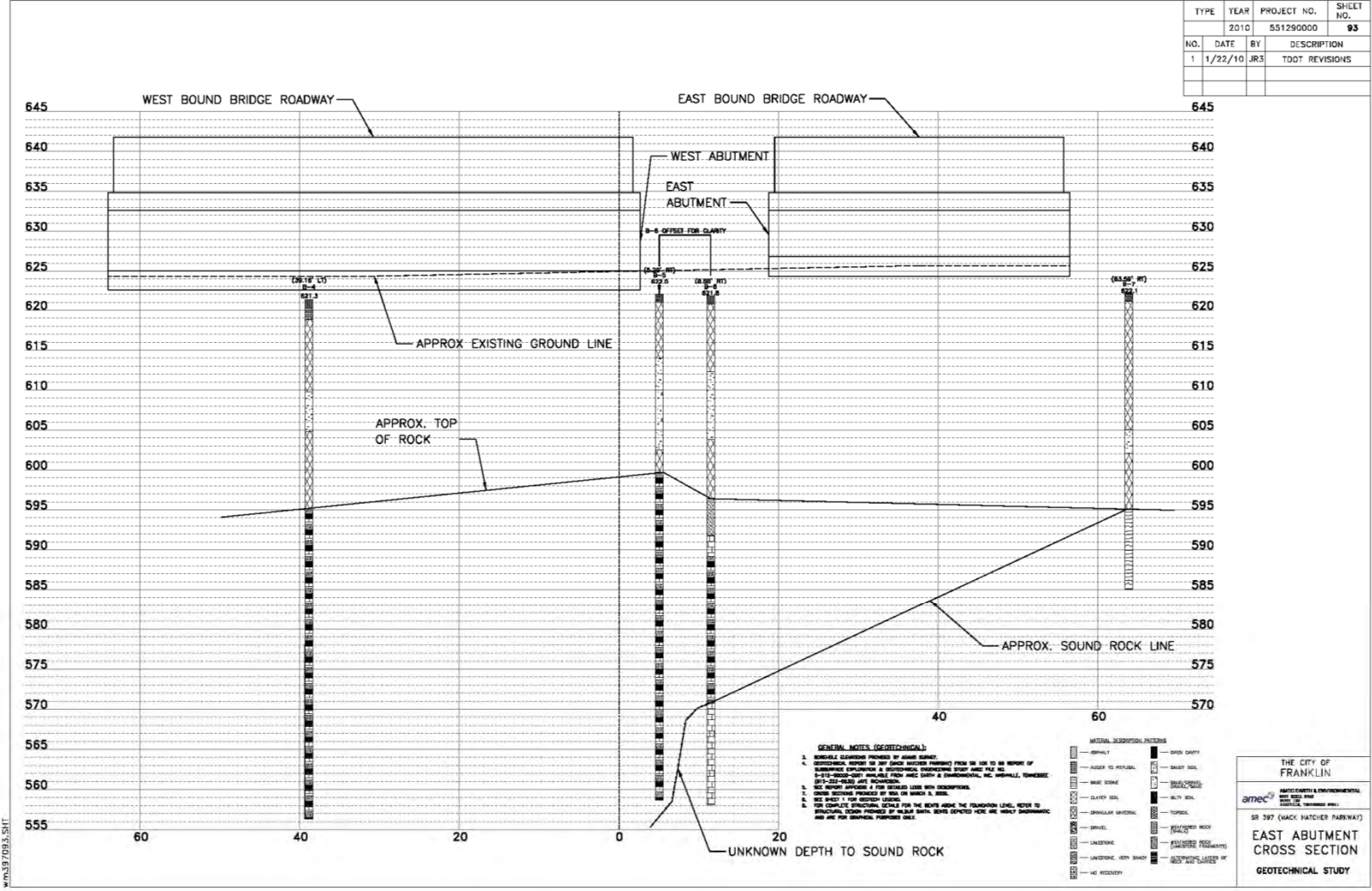
Mack Hatcher Parkway Franklin, Tennessee



Mack Hatcher Parkway Franklin, Tennessee



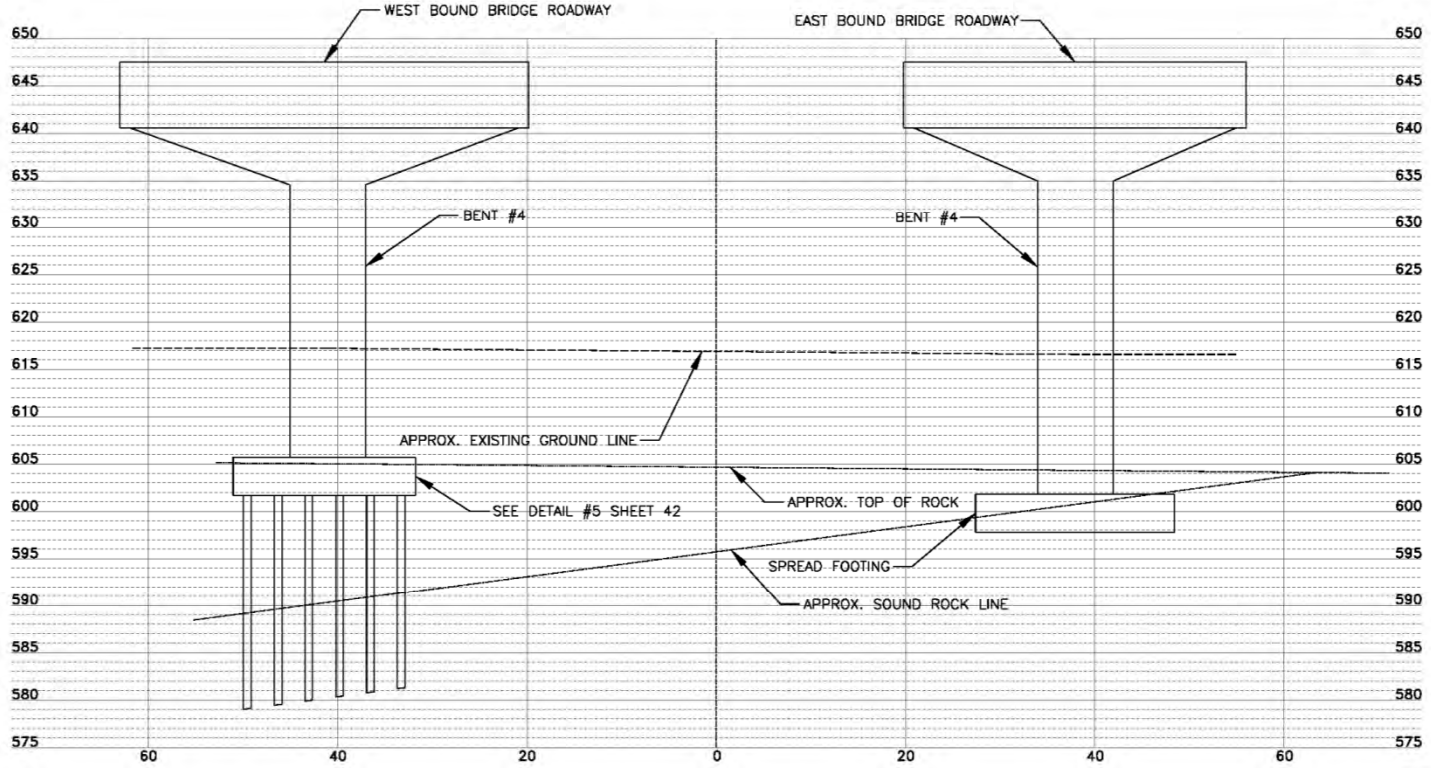
Mack Hatcher Parkway Franklin, Tennessee



TYPE	YEAR	PROJECT NO.	SHEET NO.
	2010	551290000	93
NO.	DATE	BY	DESCRIPTION
1	1/22/10	JRS	TDOT REVISIONS

Mack Hatcher Parkway Franklin, Tennessee

TYPE	YEAR	PROJECT NO.	SHEET NO.
	2010	551290000	47
NO.	DATE	BY	DESCRIPTION
1	1/22/10	JRS	TDOT REVISIONS



GENERAL NOTES (GEOTECHNICAL):
 1. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 2. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 3. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 4. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 5. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 6. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 7. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 8. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 9. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.
 10. BORING LOGS PROVIDED BY ADAMS SURVEY AND CONSULTING ENGINEERS (ASAC) FROM SR 397 TO BE REPORT OF SURFACE ELEVATION AND GEOTECHNICAL DATA FOR THE PROJECT AND TO BE USED FOR DESIGN PURPOSES ONLY.

THE CITY OF
FRANKLIN

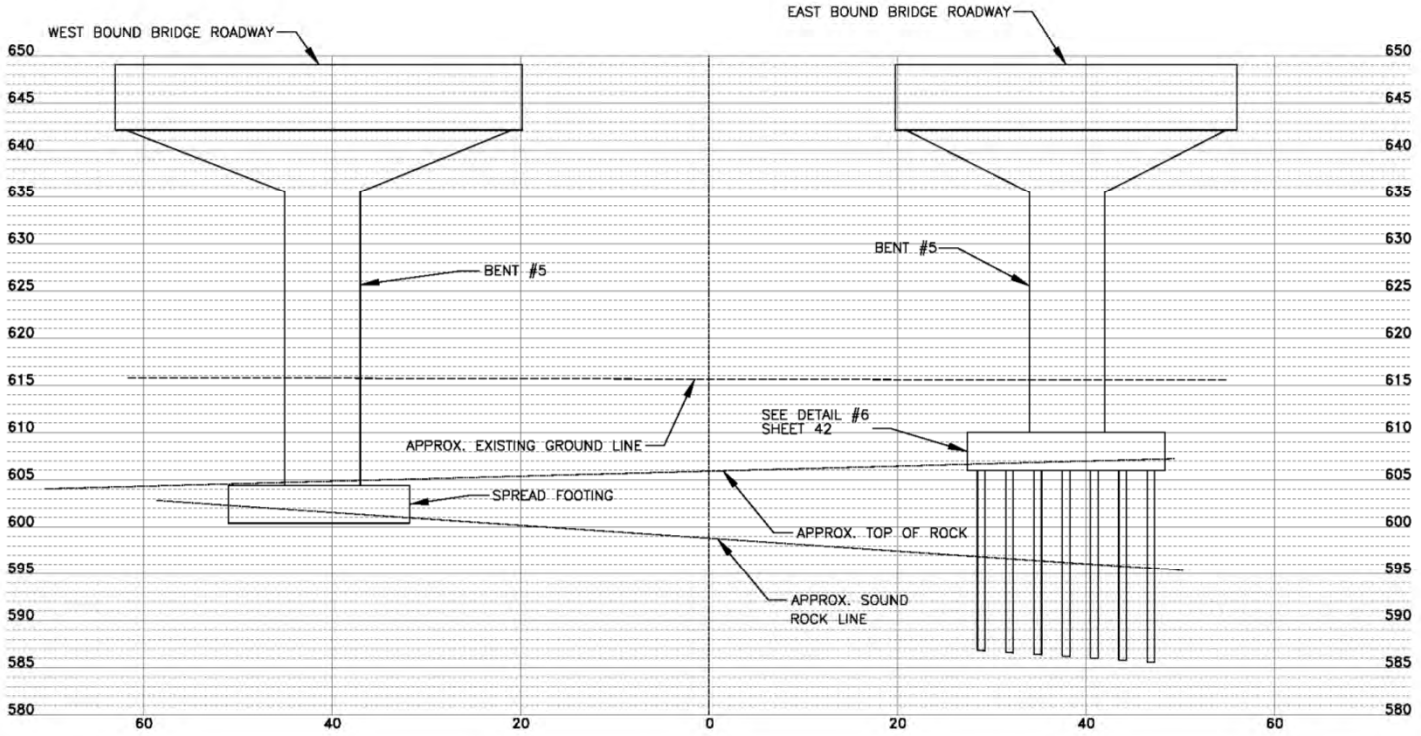
amec ENVIRONMENTAL AND INFRASTRUCTURE

SR 397 (MACK HATCHER PARKWAY)
BENT # 4
MICROPILE DESIGN
GEOTECHNICAL STUDY

wms397047.SMT

Mack Hatcher Parkway Franklin, Tennessee

TYPE	YEAR	PROJECT NO.	SHEET NO.
	2010	551290000	48
NO.	DATE	BY	DESCRIPTION
1	1/22/10	JR3	TDOT REVISIONS



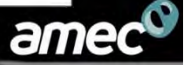
GENERAL NOTES (GEO TECHNICAL):
 1. BENTHOLE ELEVATIONS PROVIDED BY AGATE SURVEY. (GEOLOGICAL RECORD OF THE MACK HATCHER PARKWAY) FROM SH 297 TO BE USED FOR DESIGN, CONSTRUCTION AND MAINTENANCE OF THE BRIDGE. (SEE SHEET 42) FOR BENTHOLE LOCATION AND ELEVATION DATA. (SEE SHEET 42) FOR BENTHOLE LOCATION AND ELEVATION DATA.
 2. SEE SHEET 42 FOR BENTHOLE LOCATION AND ELEVATION DATA.
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THE CITY OF
FRANKLIN

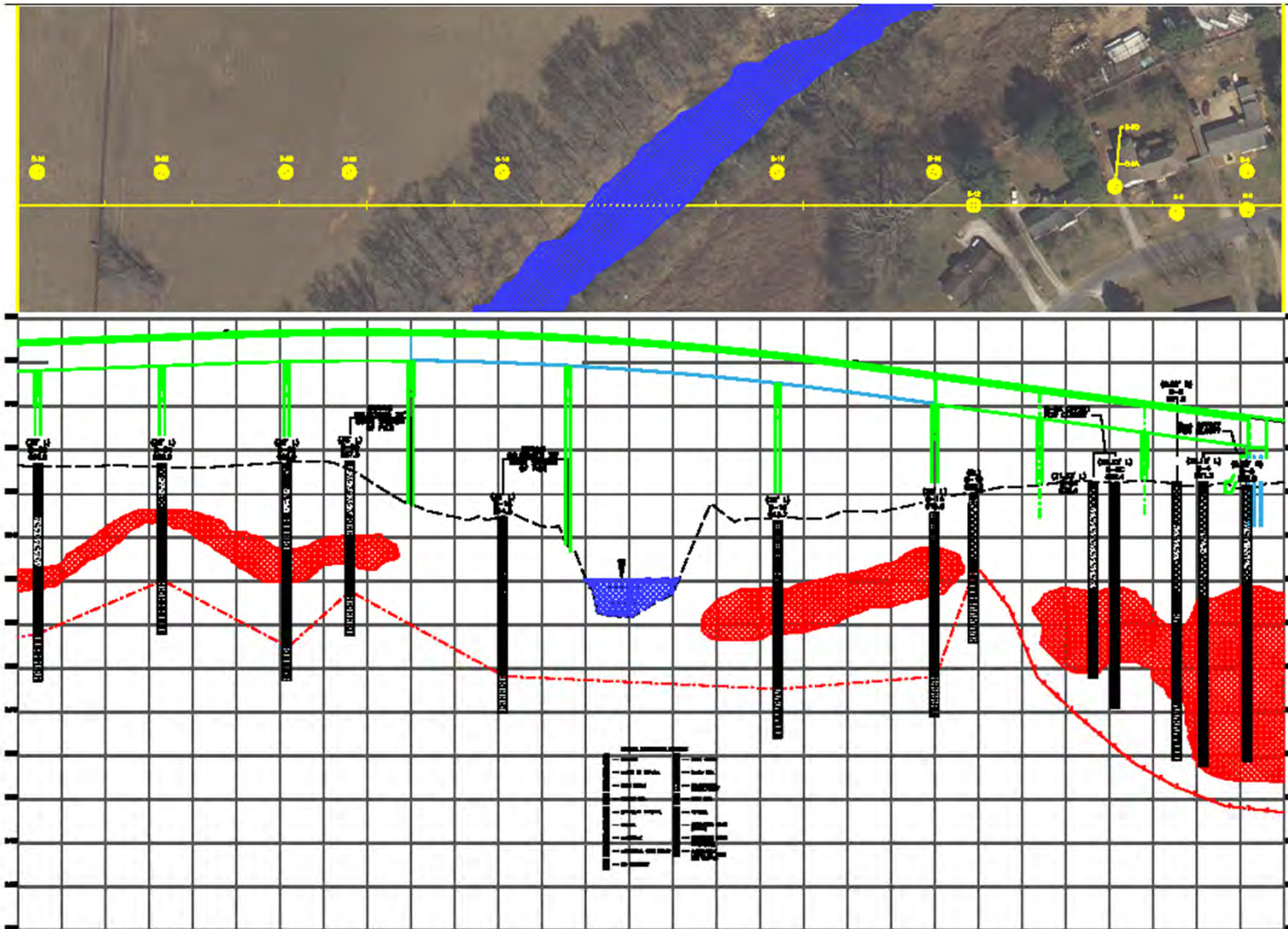
amec
AMERICAN ENVIRONMENTAL
AND ENGINEERING
CORPORATION

SH 297 (MACK HATCHER PARKWAY)
BENT # 5
MICROPILE DESIGN
GEO TECHNICAL STUDY

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Mack Hatcher Parkway Franklin, Tennessee



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Mack Hatcher Parkway Franklin, Tennessee

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GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

LOG OF BORING
SHEET 3 OF 4

PROJECT: MACK HATCHER PARKWAY
PROJECT NO: 6-128-2005-001
BORING NO. / LOCATION: B8800 354+47.57, Lot 25 10'

DRILLER: TRI-STATE DRILLING
ON-SITE REP: CLS
DRY ON COMPLETION?: NO

DATE: February 4, 2009
SURFACE ELEV.: 621.3 FT
WATER LEVEL DATA (IF APPLICABLE):
REFUSAL: DEPTH 25.1 FT ELEV. 595.2 FT
COMPLETION: DEPTH _____ FT
SAMPLED: DEPTH 25.1 FT ELEV. 595.2 FT
AFTER 24 HRS: DEPTH _____ FT
TOP OF ROCK: DEPTH 25.1 FT ELEV. 595.3 FT
RESMAN CORING: DEPTH 25.1 FT ELEV. 595.3 FT
FOOTAGE CORDED (LFT): 25.1 FT
BOTTOM OF HOLE DEPTH: 65.0 FT ELEV. 555.3 FT
LOW AT: DEPTH 25.1 FT ELEV. 595.2 FT

BORING ADVANCED BY: CORING POWER AUGERING X WASH-BORING

STRATUM DEPTH	SAMPLE DEPTH			SAMPLE OR RUN NO.	SAMPLE TYPE	SPKCORNO (BCH)	SPT VALUES			STRATUM DESCRIPTION
	FROM	TO	DEPTH				F	S	N	
20.0										
22.5				A						
23.5	23.5	23.5		B-7	96	2	13	7	20	Clay, very sandy, brown with gravel (2%)(very firm)
25.0	25.0	25.1		A						Auger Refusal @ 25.1' Well on Completion Begin HQ Coring @ 28.1' 100% CIVL
27.5	28.1	35.1		RUN 1 RUN 10.2 REC 2.0 REC- 11.0						Limestone, light gray weathers 35.1' to 25.1' with possible voids 30.0' to 32.0' and open cavity 27.3' to 28.0', 29.0' to 28.0', 34.4' to 35.0'
30.0										
32.5										
35.0	35.1	35.1		RUN 2 RUN 5.4 REC 1.8 REC- 14.0						Limestone, light gray weathers 35.1' to 35.0' and voids with open cavity 27.3' to 28.1', 28.0' to 41.0'
37.5										
40.0										

REMARKS: Continued on Page 3.

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GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

LOG OF BORING
SHEET 3 OF 4

PROJECT: MACK HATCHER PARKWAY
PROJECT NO: 6-128-2005-001
BORING NO. / LOCATION: B8800 354+47.57, Lot 25 10'

DRILLER: TRI-STATE DRILLING
ON-SITE REP: CLS
DRY ON COMPLETION?: YES, PRIOR TO CORING

DATE: February 4, 2009
SURFACE ELEV.: 621.3 FT
WATER LEVEL DATA (IF APPLICABLE):
REFUSAL: DEPTH 25.1 FT ELEV. 595.2 FT
COMPLETION: DEPTH _____ FT
SAMPLED: DEPTH 25.1 FT ELEV. 595.2 FT
AFTER 24 HRS: DEPTH _____ FT
TOP OF ROCK: DEPTH 25.1 FT ELEV. 595.3 FT
RESMAN CORING: DEPTH 25.1 FT ELEV. 595.3 FT
FOOTAGE CORDED (LFT): 25.1 FT
BOTTOM OF HOLE DEPTH: 65.0 FT ELEV. 555.3 FT
LOW AT: DEPTH 25.1 FT ELEV. 595.2 FT

BORING ADVANCED BY: CORING POWER AUGERING X WASH-BORING

STRATUM DEPTH	SAMPLE DEPTH			SAMPLE OR RUN NO.	SAMPLE TYPE	SPKCORNO (BCH)	SPT VALUES			STRATUM DESCRIPTION
	FROM	TO	DEPTH				F	S	N	
41.0	41.0	41.0		RUN 3 RUN 15.8 REC 3.0 REC- 10.1						Limestone, light gray with vugs, partially cavity 42.2' to 56.7', and open cavity 41.0' to 42.2', 42.0' to 43.4', 44.4' to 46.2', 47.0' to 47.7', 48.0' to 49.7'
42.0										
45.0										
47.5										
50.0										
52.5										
55.0										
57.5	57.3	57.3		RUN 4 RUN 7.7 REC 2.7 REC- 8.0						Limestone, tan gray, weathered
60.0										

REMARKS: Continued on Page 4.

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GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

LOG OF BORING
SHEET 4 OF 4

PROJECT: MACK HATCHER PARKWAY
PROJECT NO: 6-128-2005-001
BORING NO. / LOCATION: B8800 354+47.57, Lot 25 10'

DRILLER: TRI-STATE DRILLING
ON-SITE REP: CLS
DRY ON COMPLETION?: YES, PRIOR TO CORING


DATE: February 4, 2009
SURFACE ELEV.: 621.3 FT
WATER LEVEL DATA (IF APPLICABLE):
REFUSAL: DEPTH 25.1 FT ELEV. 595.2 FT
COMPLETION: DEPTH _____ FT
SAMPLED: DEPTH 25.1 FT ELEV. 595.2 FT
AFTER 24 HRS: DEPTH _____ FT
TOP OF ROCK: DEPTH 25.1 FT ELEV. 595.3 FT
RESMAN CORING: DEPTH 25.1 FT ELEV. 595.3 FT
FOOTAGE CORDED (LFT): 25.1 FT
BOTTOM OF HOLE DEPTH: 65.0 FT ELEV. 555.3 FT
LOW AT: DEPTH 25.1 FT ELEV. 595.2 FT

BORING ADVANCED BY: CORING POWER AUGERING X WASH-BORING

STRATUM DEPTH	SAMPLE DEPTH			SAMPLE OR RUN NO.	SAMPLE TYPE	SPKCORNO (BCH)	SPT VALUES			STRATUM DESCRIPTION
	FROM	TO	DEPTH				F	S	N	
52.5										
65.0										Boring Terminated @ 65.0' 100% CIVL
67.5										
70.0										
72.5										
75.0										
77.5										
80.0										

REMARKS: Boring backfilled and grouted after completion.


Mack Hatcher Parkway Franklin, Tennessee



GEOTECHNICAL BRANCH NASHVILLE, TENNESSEE		LOG OF BORING SHEET 1 OF 2	
PROJECT: MACK HATCHER PARKWAY		DRILLER: TRI-STATE DRILLING	
PROJECT NO.: 5-512-9000-0001		ON-SITE REP: WDB	
BORING NO. / LOCATION: Station 341+97, Right 41'		DRY ON COMPLETION ? YES, PRIOR TO CORING	
DATE: October 13, 2008		SURFACE ELEV.: 526.1 FT.	
REFUSAL: DEPTH 10.1 FT. ELEV. 516.0 FT.	WATER LEVEL DATA (IF APPLICABLE)		
SAMPLED: DEPTH 10.1 FT.	COMPLETION: DEPTH 24.0 FT. ELEV. 502.1 FT.		
TOP OF ROCK: DEPTH 10.1 FT. ELEV. 515.9 FT.	AFTER 24 HRS. DEPTH 10.1 FT. ELEV. 516.0 FT.		
BEGAN CORING: DEPTH 10.1 FT. ELEV. 516.0 FT.	LOW AT: DEPTH 13.3 FT. ELEV. 512.6 FT.		
FOOTAGE CORED (LF): 25.6 FT.			
BOTTOM OF HOLE DEPTH: 39.7 FT. ELEV. 506.4 FT.			
BORING ADVANCED BY: CORING		POWER AUGERING: X	
		WASHBORING:	

STRATUM DEPTH	SAMPLE DEPTH		SAMPLE OR RUN NO.	SAMPLE TYPE	SPLICED CORE (INCH)	SPT VALUES				STRATUM DESCRIPTION
	FROM	TO				6"	6"	6"	N	
0.0	0.0	1.0		A						TOPSOIL
1.0	1.0	2.5	8-1	SS		5	5	5	10	Clay, very sandy, silty, yellowish-brown (Dry)(Medium Stiff)
2.5	2.5	3.5		A						
3.5	3.5	5.0	8-2	SS		5	4	7	11	Sand (C-M), clayey, silty, reddish-brown (Dry)(Stiff)
5.0	5.0	6.0		A						
6.0	6.0	7.5	8-3	SS		5	3	6	14	Sand (C-M), slightly silty, dark reddish-brown with gravel (Dry)(Medium Dense)
7.5	7.5	8.5		A						
8.5	8.5	10.0	8-4	SS		7	7	5	12	6.5-9.5 OQ #5
10.0	10.1	14.6	RUN 1 RAN 4.5 REC 3.2 RQD=46.6							3.5-10.0 Clay, slightly silty, very sandy, yellowish-brown Auger Refusal @ 10.7, Dry On Completion Begin NQ Coring @ 10.7, 100% DWR Limestone, sandy, medium gray with open, stained, bedding planes Open Cavity 13.3' to 21.3' 100% DWR @ 13.3'
12.5	14.6	14.6								
15.0	14.6	19.6	RUN 2 RAN 5.0 REC 0.0 RQD=0.0							Open Cavity No soil
17.5	19.6	19.6								
20.0	19.6	19.6								

REMARKS: Continued On Page 2.



GEOTECHNICAL BRANCH NASHVILLE, TENNESSEE		LOG OF BORING SHEET 2 OF 2	
PROJECT: MACK HATCHER PARKWAY		DRILLER: TRI-STATE DRILLING	
PROJECT NO.: 5-512-9000-0001		ON-SITE REP: WDB	
BORING NO. / LOCATION: Station 341+97, Right 41'		DRY ON COMPLETION ? YES, PRIOR TO CORING	
DATE: October 13, 2008		SURFACE ELEV.: 526.1 FT.	
REFUSAL: DEPTH 10.1 FT. ELEV. 516.0 FT.	WATER LEVEL DATA (IF APPLICABLE)		
SAMPLED: DEPTH 10.1 FT.	COMPLETION: DEPTH 24.0 FT. ELEV. 502.1 FT.		
TOP OF ROCK: DEPTH 10.1 FT. ELEV. 515.9 FT.	AFTER 24 HRS. DEPTH 10.1 FT. ELEV. 516.0 FT.		
BEGAN CORING: DEPTH 10.1 FT. ELEV. 516.0 FT.	LOW AT: DEPTH 13.3 FT. ELEV. 512.6 FT.		
FOOTAGE CORED (LF): 25.6 FT.			
BOTTOM OF HOLE DEPTH: 39.7 FT. ELEV. 506.4 FT.			
BORING ADVANCED BY: CORING		POWER AUGERING: X	
		WASHBORING:	

STRATUM DEPTH	SAMPLE DEPTH		SAMPLE OR RUN NO.	SAMPLE TYPE	SPLICED CORE (INCH)	SPT VALUES				STRATUM DESCRIPTION
	FROM	TO				6"	6"	6"	N	
0.0	0.0	1.0		A						TOPSOIL
1.0	1.0	2.5								
2.5	2.5	3.5								
3.5	3.5	5.0								
5.0	5.0	6.0								
6.0	6.0	7.5								
7.5	7.5	8.5								
8.5	8.5	10.0								
10.0	10.1	24.8	RUN 3 RAN 5.2 REC 3.3 RQD=0.0							Continue Open Cavity to 21.3'
12.5	24.8	24.8								Limestone, light gray with open, stained, solution vugs
15.0	24.8	29.8	RUN 4 RAN 5.0 REC 5.0 RQD=96.0							Limestone, sandy, light gray
17.5	29.8	29.8								
20.0	29.8	34.8	RUN 5 RAN 5.0 REC 5.0 RQD=70.0							Limestone, sandy, light gray with open, stained, solution vugs
22.5	34.8	34.8								
25.0	34.8	39.7	RUN 6 RAN 4.5 REC 4.8 RQD=87.7							Limestone, sandy, medium to light gray with soft shale partings
27.5	39.7	39.7								Boring Terminated @ 39.7', 100% DWR
30.0	39.7	39.7								
32.5	39.7	39.7								
35.0	39.7	39.7								
37.5	39.7	39.7								
40.0	39.7	39.7								

REMARKS: Boring backfilled with pea gravel on completion, at the request of the land owner.

Mack Hatcher Parkway Franklin, Tennessee

SO HOW DO WE BUILD A BRIDGE FOUNDATION ON
EXTREMELY KARSTIC AND VARIABLY BEDROCK??

BY A COMBINATION OF INTEGRAL ABUTMENTS,
SPREAD FOOTINGS, WHERE POSSIBLE,
AND MICROPILES

Mack Hatcher Parkway Franklin, Tennessee

WHY ?

CAISSONS ARE DIFFICULT TO INSTALL IN IRREGULAR
BEDROCK CONDITIONS

THEY ARE COSTLY \$\$

HOW MUCH ADDITIONAL CONCRETE WILL BE USED
TO FILL THE OPEN CAVITIES?

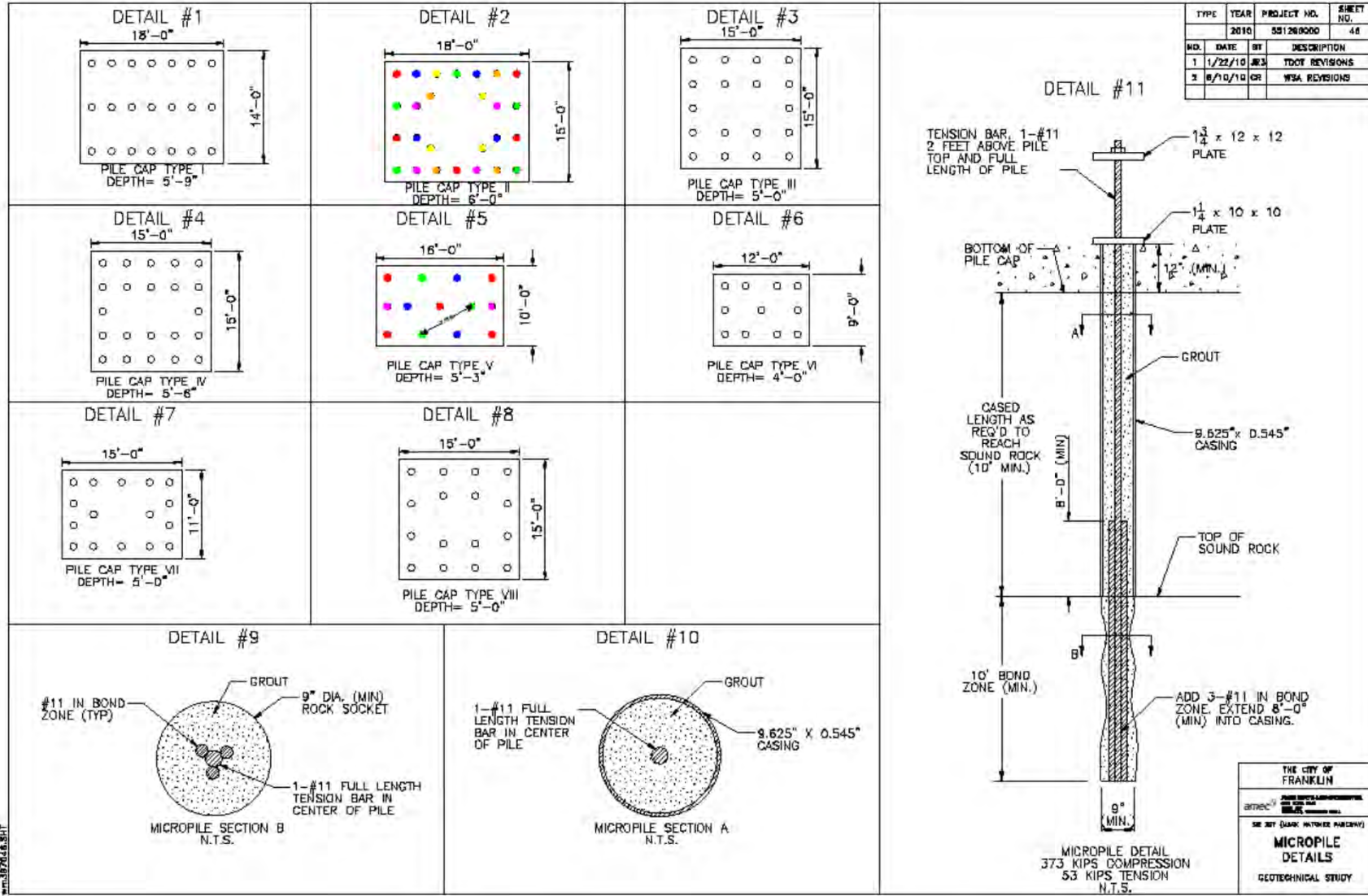
HOW MUCH DOES IT COST TO USE PERMANENT CASING
IN THE GROUND TO CONTROL CONCRETE PLACEMENT?

Mack Hatcher Parkway Franklin, Tennessee

HOW CLOSE IS THAT END BEARING H-PILE TO THE
WEATHERED ROCK OR OPEN CAVITY?

WE DON'T KNOW

Micro-piles as a SOLUTION



RECENT LOAD TESTING ON INSTALLED MICRO-PILES

DESIGN LOADS WERE 300 KIPS COMPRESSION
AND 180 KIPS TENSION

COMPRESSION LOADING EXCEEDED 200% OR
600 KIPS

TENSION LOADING FAILED AT 200% OR
360 KIPS DUE TO FOLIATION OF WEATHERED ROCK

FOLLOW-UP LOAD TESTING EXCEEDED 200% OF DESIGN
FOR TENSION AND COMPRESSION

QUESTIONS??



THANK-YOU