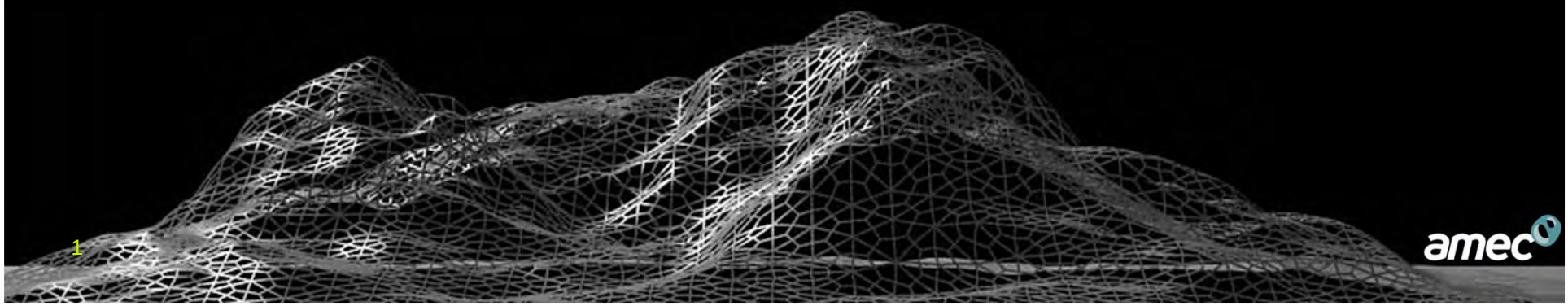
11th Annual Technical Forum
GEOHAZARDS IMPACTING TRANSPORTATION IN THE APPALACHIAN REGION

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

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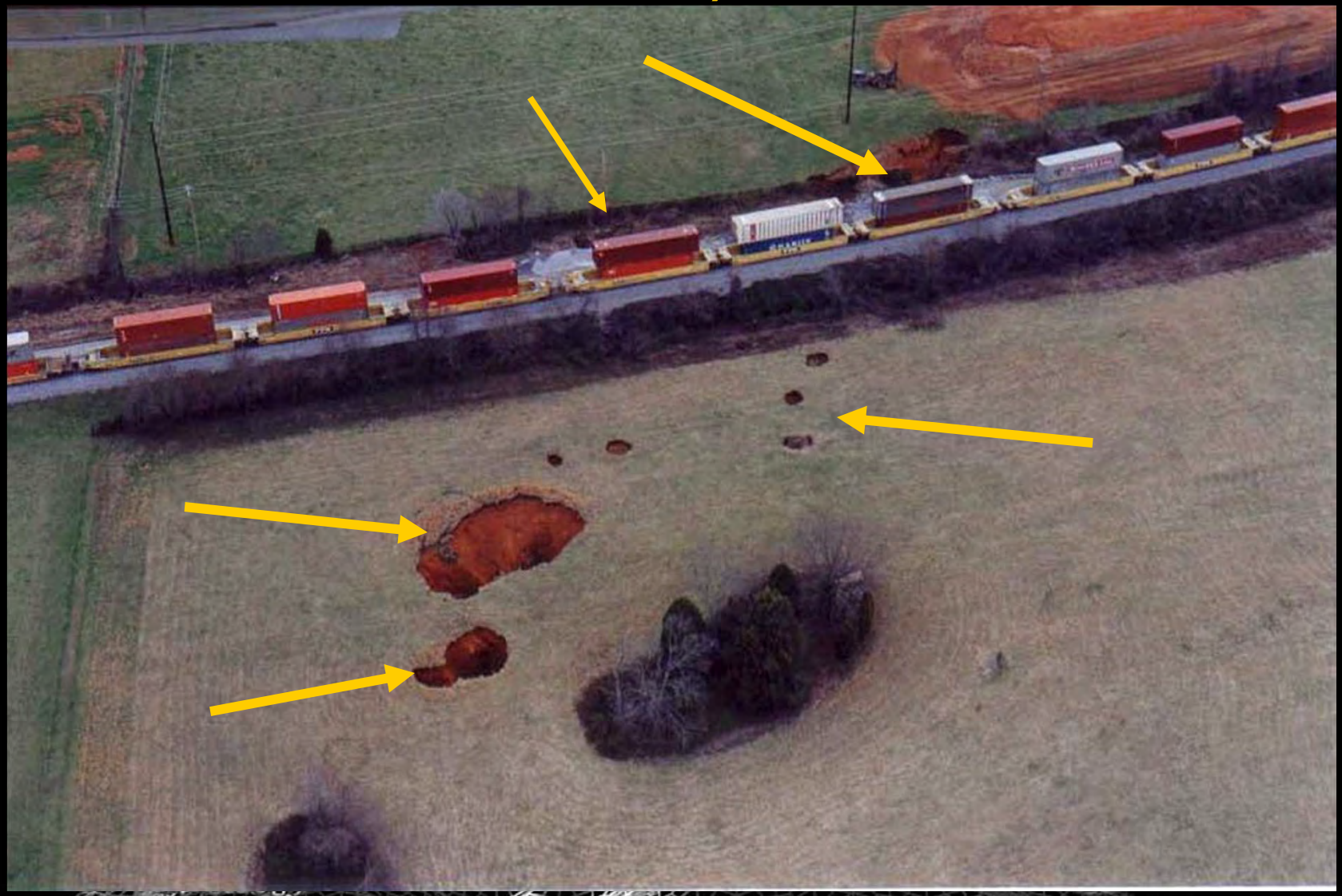
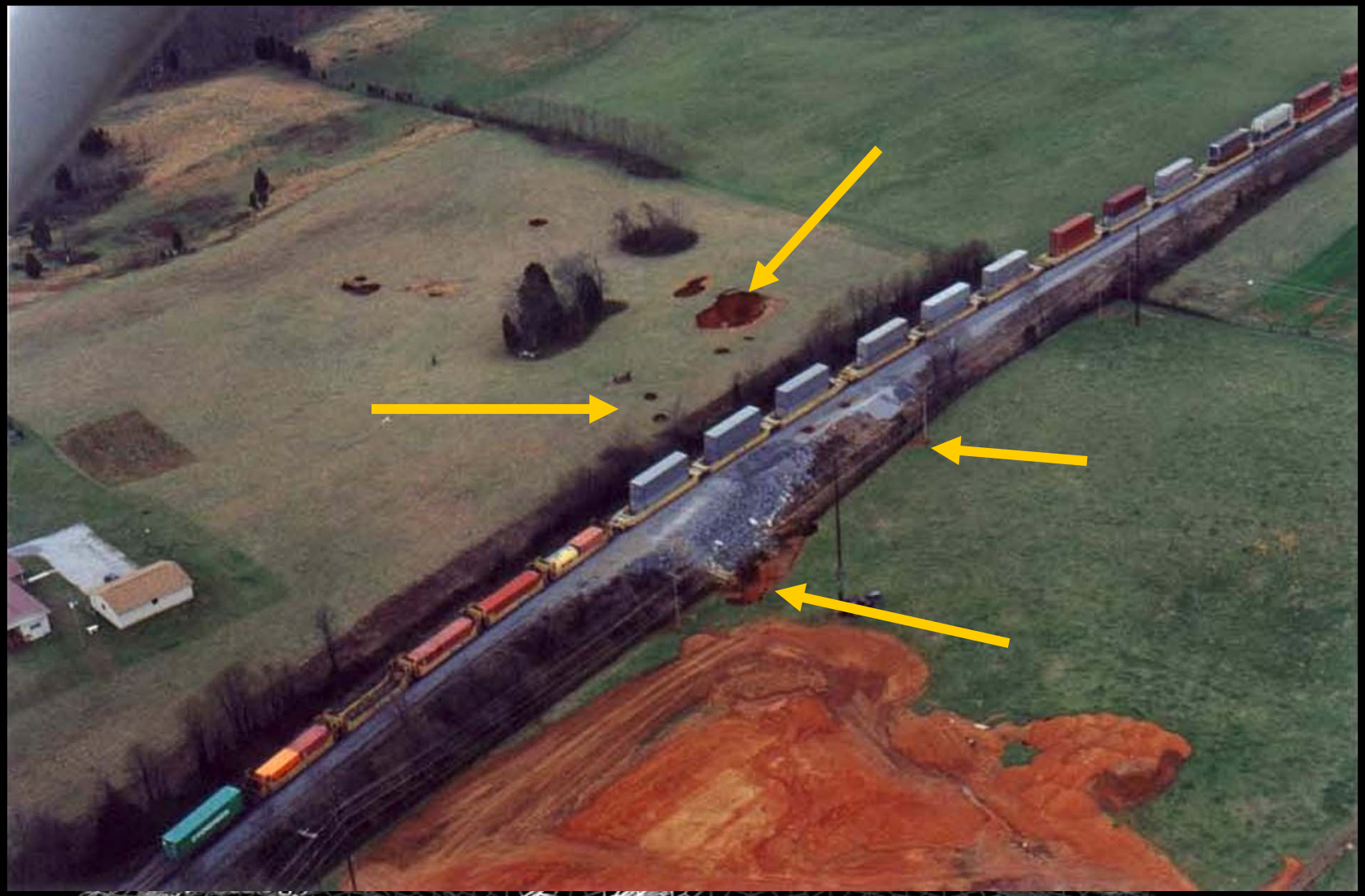
NSC Mainline Track at MP 96.1A
Morristown, Tennessee



NSC Mainline Track at MP 96.1A
Morristown, Tennessee



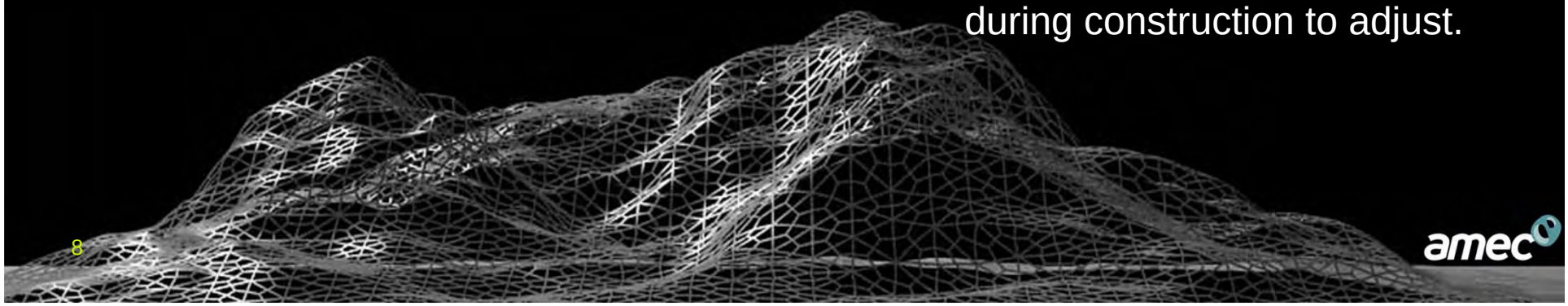
NSC Mainline Track at MP 96.1A
Morristown, Tennessee

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
• Driven Piles (H-Piles)	Low cost	Impossible to assess bearing strata
• 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.
• 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.



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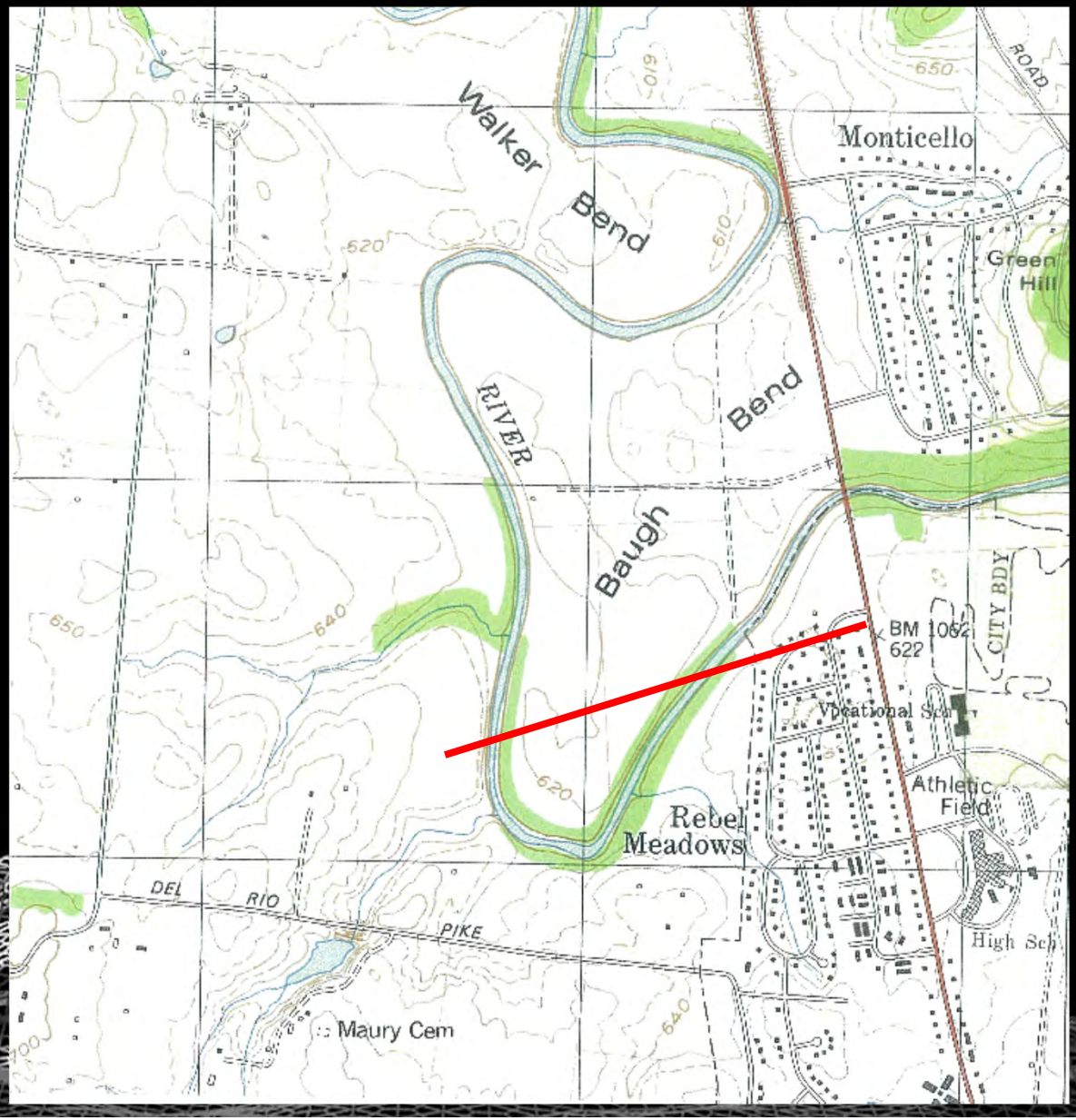
NSC Mainline Track at MP 96.1A
Morristown, Tennessee

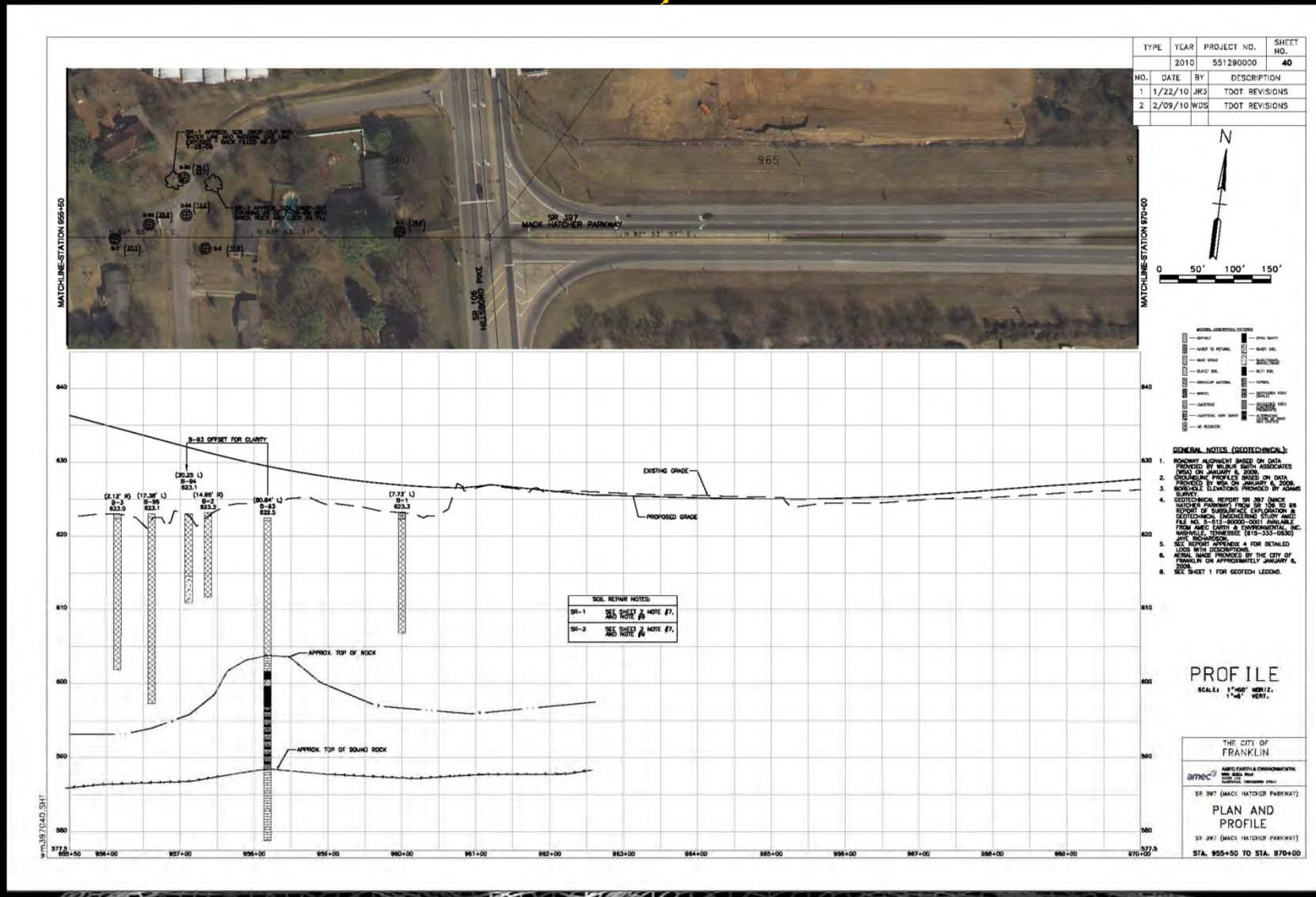
BEFORE
Karst engulfing the soil and ballast

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

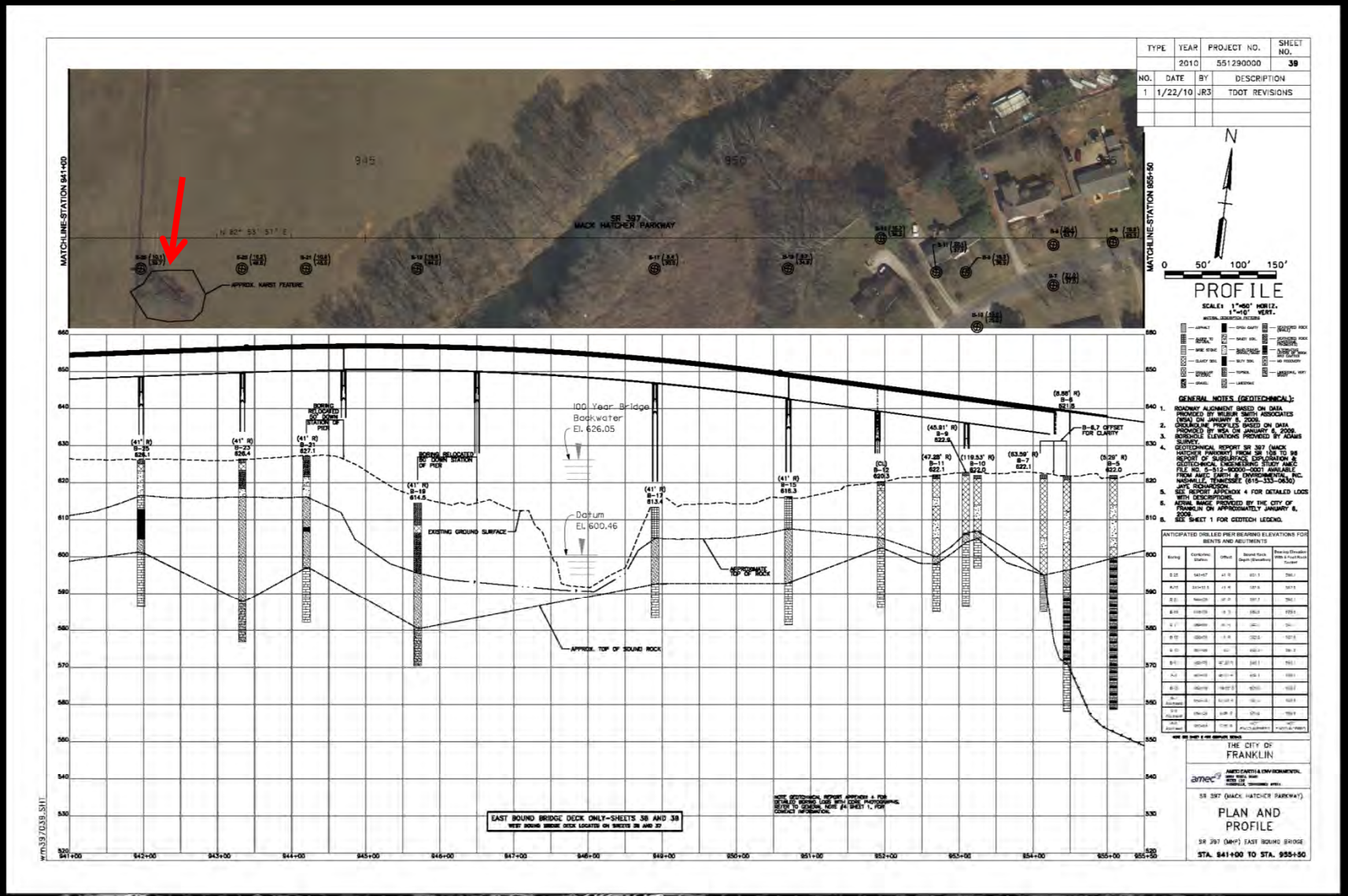
Mack Hatcher Parkway
Franklin, Tennessee



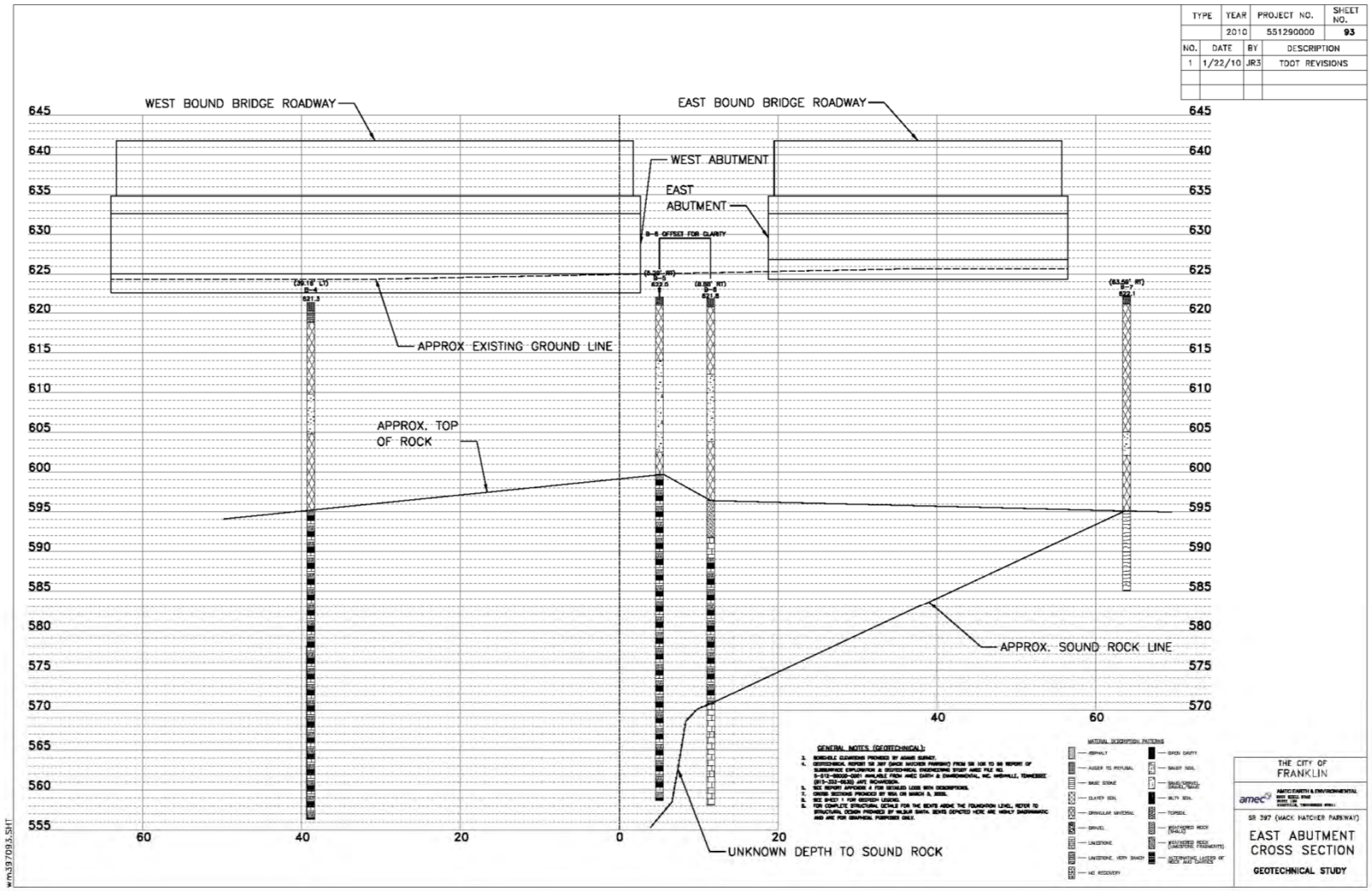
Mack Hatcher Parkway
Franklin, Tennessee



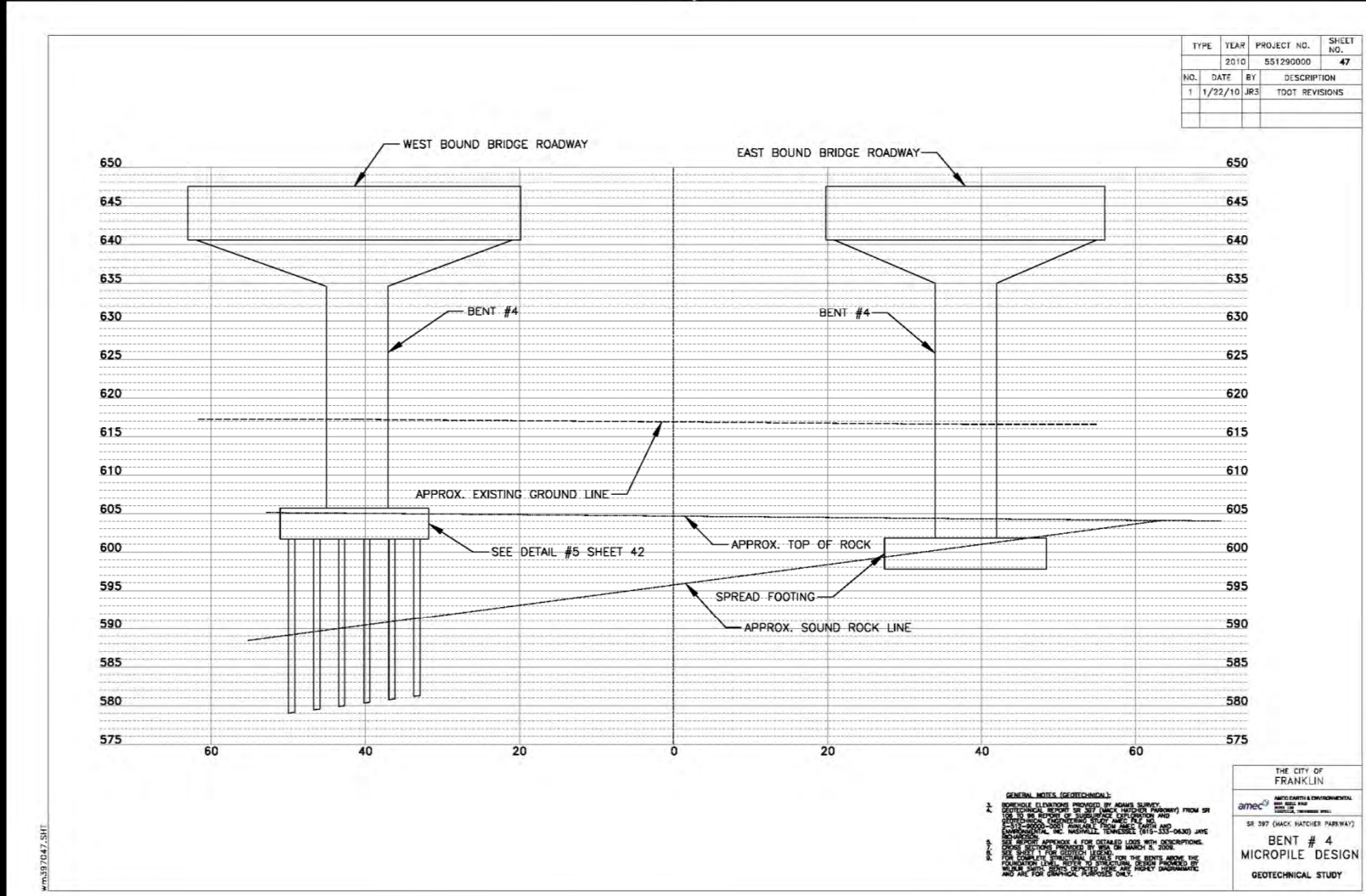
Mack Hatcher Parkway
Franklin, Tennessee



Mack Hatcher Parkway
Franklin, Tennessee



Mack Hatcher Parkway
Franklin, Tennessee



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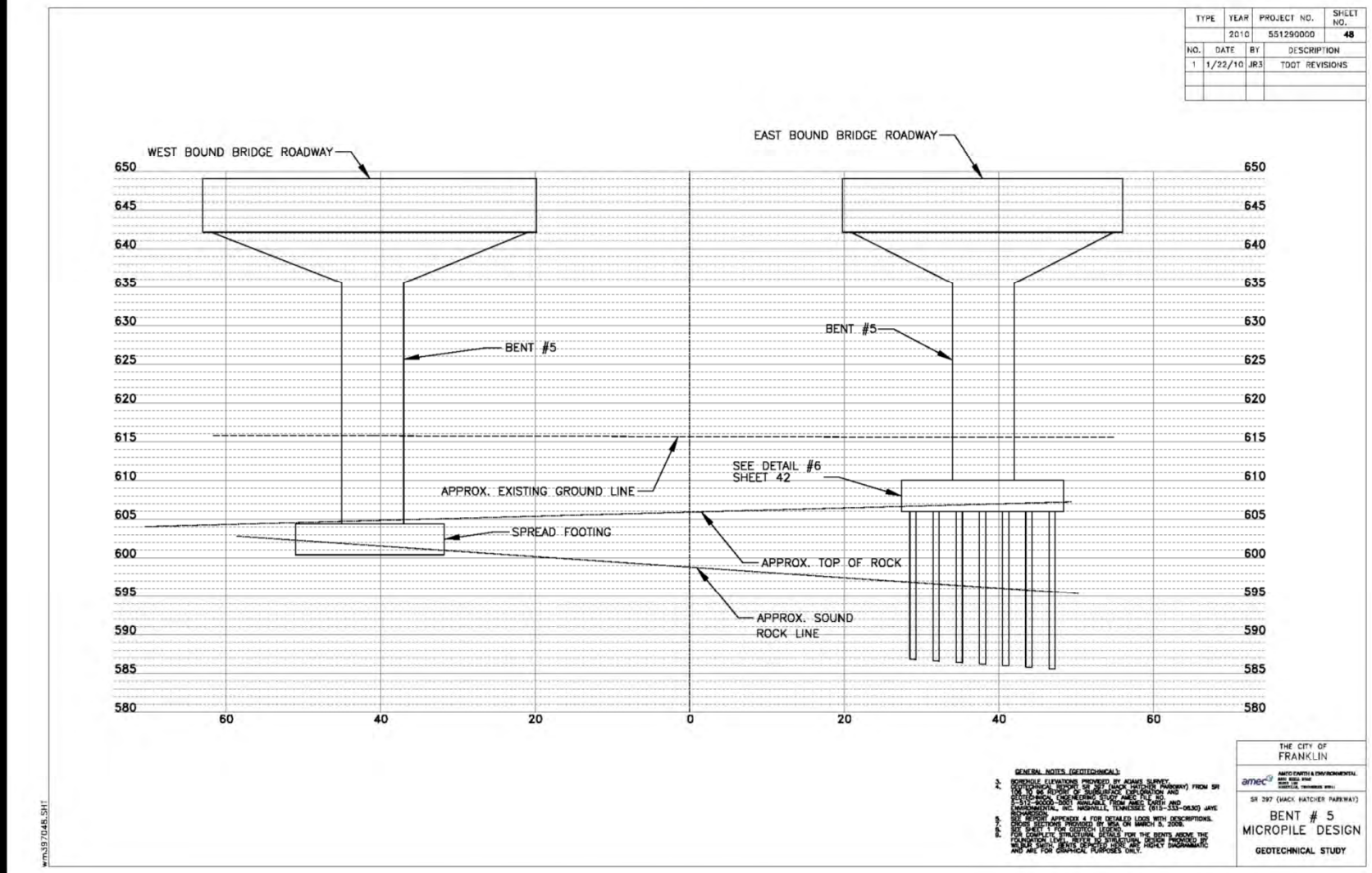
Franklin, Tennessee



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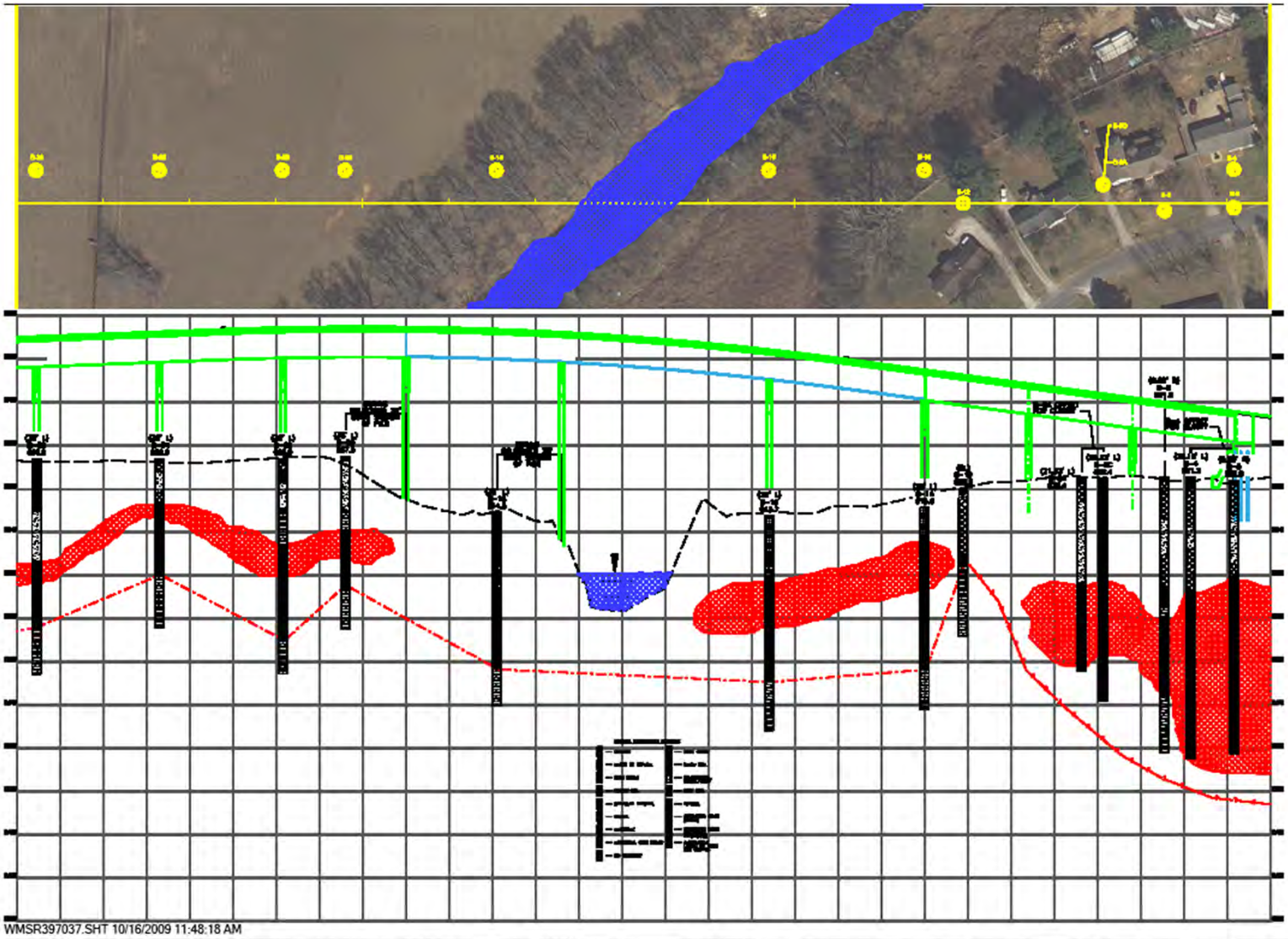
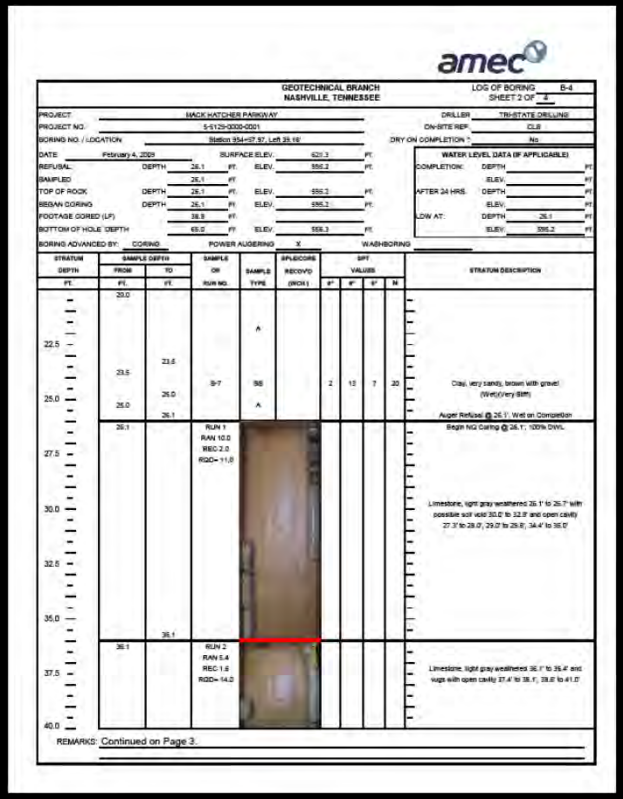
Franklin, Tennessee



Mack Hatcher Parkway
Franklin, Tennessee



GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

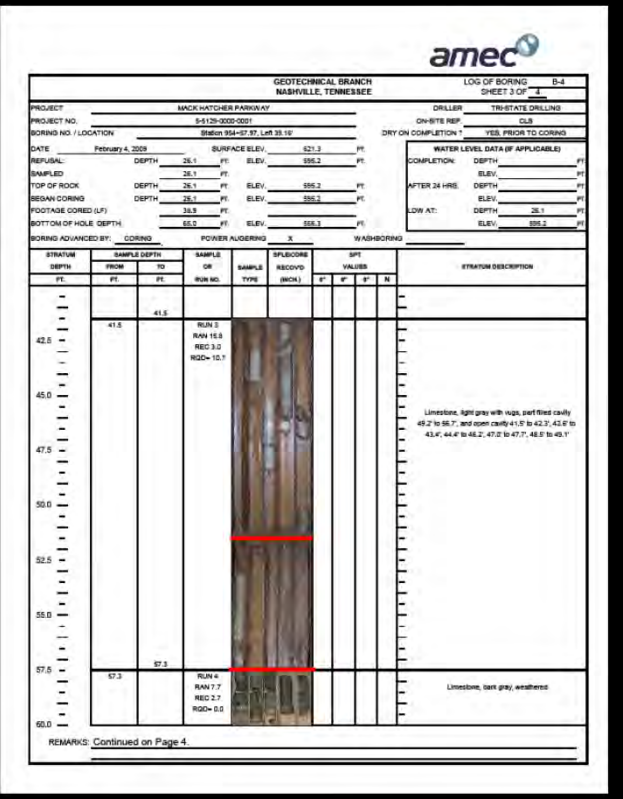
LOG OF BORING B-4
SHEET 2 OF 4

PROJECT: MACK HATCHER PARKWAY
PROJECT NO.: 5-5129-0000-0001
BORING NO. / LOCATION: Station 954+57.97, Left 39.19'
DRILLER: TRI-STATE DRILLING
ON-SITE REP.: CLS
DRY ON COMPLETION ?: No
DATE: February 4, 2009
SURFACE ELEV.: 621.3 FT.
REFUSAL: DEPTH 26.1 FT. ELEV. 595.2 FT.
SAMPLED: DEPTH 26.1 FT.
TOP OF ROCK: DEPTH 26.1 FT. ELEV. 595.2 FT.
BEGAN CORING: DEPTH 26.1 FT. ELEV. 595.2 FT.
FOOTAGE CORED (LF): 38.9 FT.
BOTTOM OF HOLE DEPTH: 65.0 FT. ELEV. 556.3 FT.
BORING ADVANCED BY: CORING POWER AUGERING X WASHBORING

WATER LEVEL DATA (IF APPLICABLE)
COMPLETION: DEPTH FT. ELEV. FT.
AFTER 24 HRS: DEPTH FT. ELEV. FT.
LOW AT: DEPTH 26.1 FT. ELEV. 595.2 FT.

STRATUM DEPTH FT.	SAMPLE DEPTH FROM FT.	SAMPLE DEPTH TO FT.	SAMPLE OR RUN NO.	SAMPLE TYPE	SPLICECORE RECOVD (INCH.)	SPT VALUES 6"	6"	6"	N	STRATUM DESCRIPTION
20.0										
23.5		23.5		A						
25.0		25.0	B-7	SS		2	13	7	20	Clay, very sandy, brown with gravel (Wet)(Very Stiff)
26.1		26.1		A						Auger Refusal @ 26.1'. Wet on Completion
26.1			RUN 1 RAN 10.0 REC 2.0 RQD= 11.0							Begin NQ Coring @ 26.1'; 100% DWL. Limestone, light gray weathered 26.1' to 26.7' with possible soil void 30.0' to 32.8' and open cavity 27.3' to 28.0', 29.0' to 29.8', 34.4' to 35.0'
36.1		36.1	RUN 2 RAN 5.4 REC 1.6 RQD= 14.0							Limestone, light gray weathered 36.1' to 36.4' and vugs with open cavity 37.4' to 38.1', 39.6' to 41.0'

REMARKS: Continued on Page 3.



GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

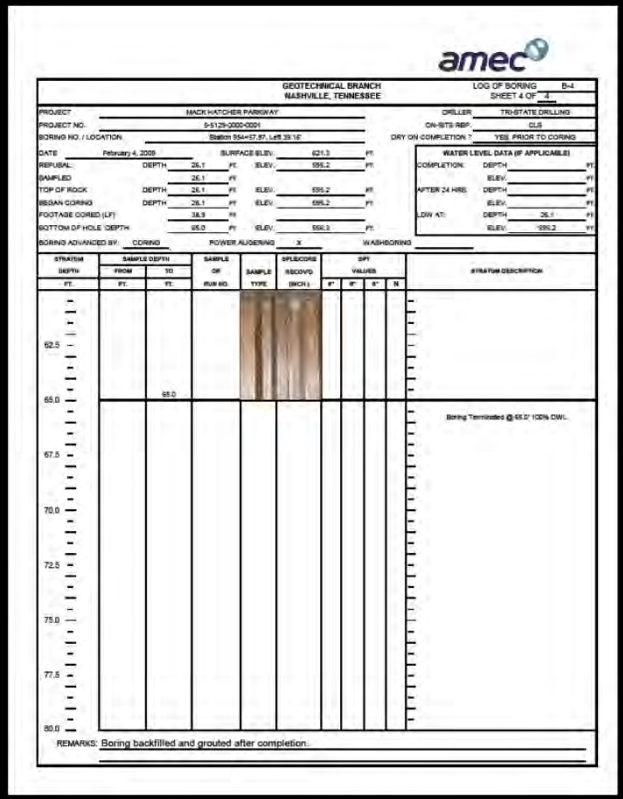
LOG OF BORING B-4
SHEET 3 OF 4

PROJECT: MACK HATCHER PARKWAY
PROJECT NO.: 5-5129-0000-0001
BORING NO. / LOCATION: Station 954+57.97, Left 39.19'
DRILLER: TRI-STATE DRILLING
ON-SITE REP.: CLS
DRY ON COMPLETION ?: YES, PRIOR TO CORING
DATE: February 4, 2009
SURFACE ELEV.: 621.3 FT.
REFUSAL: DEPTH 26.1 FT. ELEV. 595.2 FT.
SAMPLED: DEPTH 26.1 FT.
TOP OF ROCK: DEPTH 26.1 FT. ELEV. 595.2 FT.
BEGAN CORING: DEPTH 26.1 FT. ELEV. 595.2 FT.
FOOTAGE CORED (LF): 38.9 FT.
BOTTOM OF HOLE DEPTH: 65.0 FT. ELEV. 556.3 FT.
BORING ADVANCED BY: CORING POWER AUGERING X WASHBORING

WATER LEVEL DATA (IF APPLICABLE)
COMPLETION: DEPTH FT. ELEV. FT.
AFTER 24 HRS: DEPTH FT. ELEV. FT.
LOW AT: DEPTH 26.1 FT. ELEV. 595.2 FT.

STRATUM DEPTH FT.	SAMPLE DEPTH FROM FT.	SAMPLE DEPTH TO FT.	SAMPLE OR RUN NO.	SAMPLE TYPE	SPLICECORE RECOVD (INCH.)	SPT VALUES 6"	6"	6"	N	STRATUM DESCRIPTION
41.5		41.5								
42.5	41.5		RUN 3 RAN 10.0 REC 3.0 RQD= 10.1							Limestone, light gray with vugs, part filled cavity 49.2' to 56.7', and open cavity 41.5' to 42.3', 43.6' to 43.4', 44.4' to 46.2', 47.0' to 47.7', 48.6' to 49.1'
57.3		57.3								
57.5	57.3		RUN 4 RAN 7.7 REC 2.7 RQD= 0.0							Limestone, dark gray, weathered

REMARKS: Continued on Page 4.



GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

LOG OF BORING B-4
SHEET 4 OF 4

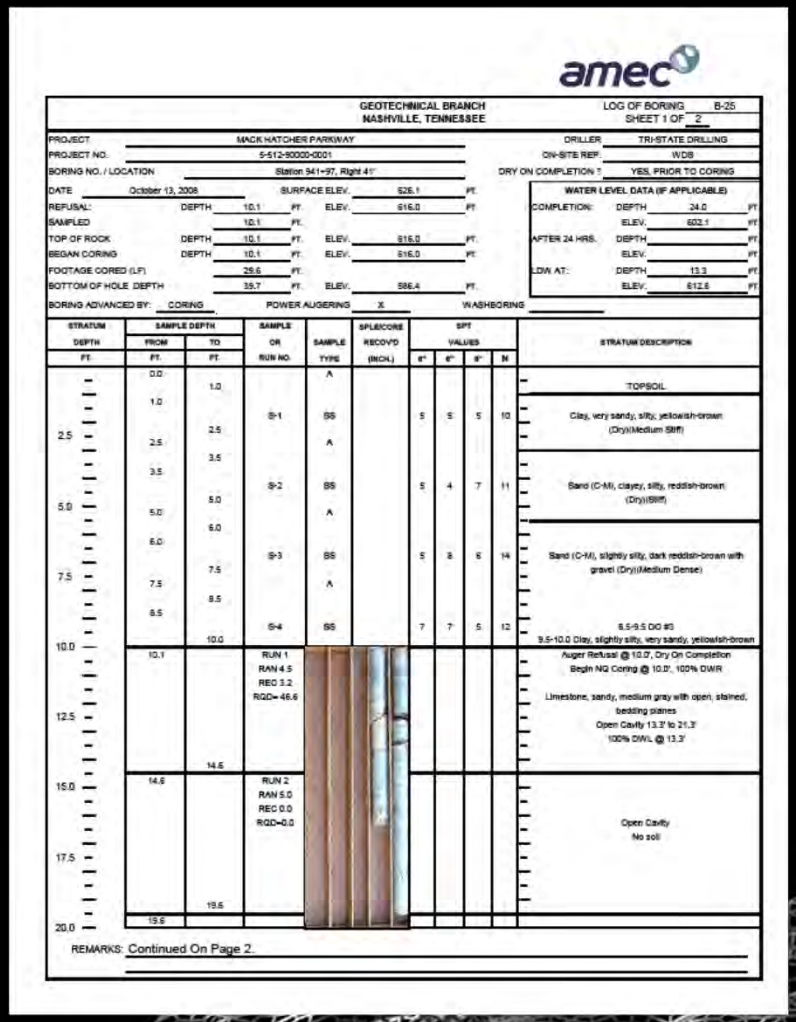
PROJECT: MACK HATCHER PARKWAY
PROJECT NO.: 5-5129-0000-0001
BORING NO. / LOCATION: Station 954+57.97, Left 39.19'
DRILLER: TRI-STATE DRILLING
ON-SITE REP.: CLS
DRY ON COMPLETION ?: YES, PRIOR TO CORING
DATE: February 4, 2009
SURFACE ELEV.: 621.3 FT.
REFUSAL: DEPTH 26.1 FT. ELEV. 595.2 FT.
SAMPLED: DEPTH 26.1 FT.
TOP OF ROCK: DEPTH 26.1 FT. ELEV. 595.2 FT.
BEGAN CORING: DEPTH 26.1 FT. ELEV. 595.2 FT.
FOOTAGE CORED (LF): 38.9 FT.
BOTTOM OF HOLE DEPTH: 65.0 FT. ELEV. 556.3 FT.
BORING ADVANCED BY: CORING POWER AUGERING X WASHBORING

WATER LEVEL DATA (IF APPLICABLE)
COMPLETION: DEPTH FT. ELEV. FT.
AFTER 24 HRS: DEPTH FT. ELEV. FT.
LOW AT: DEPTH 26.1 FT. ELEV. 595.2 FT.

STRATUM DEPTH FT.	SAMPLE DEPTH FROM FT.	SAMPLE DEPTH TO FT.	SAMPLE OR RUN NO.	SAMPLE TYPE	SPLICECORE RECOVD (INCH.)	SPT VALUES 6"	6"	6"	N	STRATUM DESCRIPTION
65.0		65.0								Boring Terminated @ 65.0' 100% DWL.

REMARKS: Boring backfilled and grouted after completion.

Mack Hatcher Parkway
Franklin, Tennessee



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GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

LOG OF BORING B-25
SHEET 1 OF 2

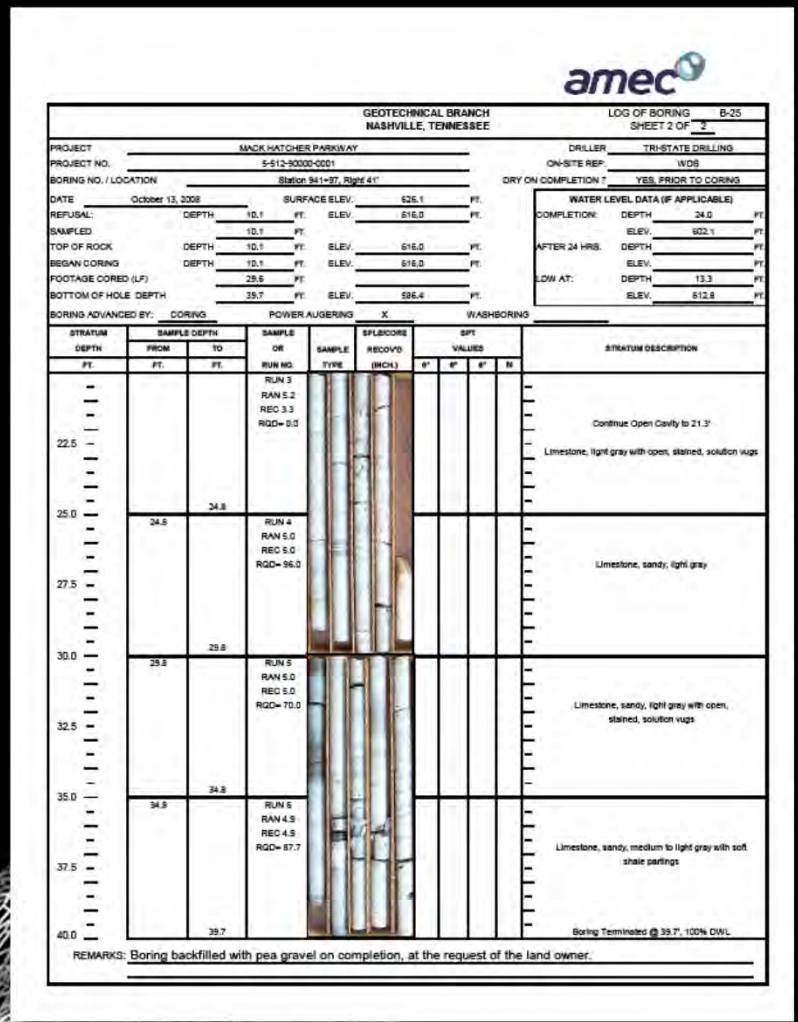
PROJECT: MACK HATCHER PARKWAY
PROJECT NO.: 5-512-90000-0001
BORING NO. / LOCATION: Station 941+97, Right 41'
DATE: October 13, 2008
SURFACE ELEV.: 626.1 FT.
REFUSAL: DEPTH 10.1 FT. ELEV. 616.0 FT.
SAMPLED: 10.1 FT.
TOP OF ROCK: DEPTH 10.1 FT. ELEV. 616.0 FT.
BEGAN CORING: DEPTH 10.1 FT. ELEV. 616.0 FT.
FOOTAGE CORED (LF): 29.6 FT.
BOTTOM OF HOLE DEPTH: 39.7 FT. ELEV. 586.4 FT.
BORING ADVANCED BY: CORING
POWER AUGERING: X
WASHBORING:
DRILLER: TRI-STATE DRILLING
ON-SITE REP.: WDB
DRY ON COMPLETION ?: YES, PRIOR TO CORING

WATER LEVEL DATA (IF APPLICABLE)

COMPLETION:	DEPTH	24.0	FT.
	ELEV.	602.1	FT.
AFTER 24 HRS.	DEPTH		FT.
	ELEV.		FT.
LOW AT:	DEPTH	13.3	FT.
	ELEV.	612.8	FT.

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

REMARKS: Continued On Page 2.



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GEOTECHNICAL BRANCH
NASHVILLE, TENNESSEE

LOG OF BORING B-25
SHEET 2 OF 2

PROJECT: MACK HATCHER PARKWAY
PROJECT NO.: 5-512-90000-0001
BORING NO. / LOCATION: Station 941+97, Right 41'
DATE: October 13, 2008
SURFACE ELEV.: 626.1 FT.
REFUSAL: DEPTH 10.1 FT. ELEV. 616.0 FT.
SAMPLED: 10.1 FT.
TOP OF ROCK: DEPTH 10.1 FT. ELEV. 616.0 FT.
BEGAN CORING: DEPTH 10.1 FT. ELEV. 616.0 FT.
FOOTAGE CORED (LF): 29.6 FT.
BOTTOM OF HOLE DEPTH: 39.7 FT. ELEV. 586.4 FT.
BORING ADVANCED BY: CORING
POWER AUGERING: X
WASHBORING:
DRILLER: TRI-STATE DRILLING
ON-SITE REP.: WDB
DRY ON COMPLETION ?: YES, PRIOR TO CORING

WATER LEVEL DATA (IF APPLICABLE)

COMPLETION:	DEPTH	24.0	FT.
	ELEV.	602.1	FT.
AFTER 24 HRS.	DEPTH		FT.
	ELEV.		FT.
LOW AT:	DEPTH	13.3	FT.
	ELEV.	612.8	FT.

STRATUM DEPTH FT.	SAMPLE DEPTH FROM FT.	SAMPLE DEPTH TO FT.	SAMPLE OR RUN NO.	SAMPLE TYPE	SPLSCORE RECOV'D (INCH.)	SPT VALUES 6"	6"	6"	N	STRATUM DESCRIPTION
		24.8	RUN 3 RAN 5.2 REC 3.3 RQD= 0.0							Continue Open Cavity to 21.3' Limestone, light gray with open, stained, solution vugs
25.0	24.8	29.8	RUN 4 RAN 5.0 REC 5.0 RQD= 96.0							Limestone, sandy, light gray
30.0	29.8	34.8	RUN 5 RAN 5.0 REC 5.0 RQD= 70.0							Limestone, sandy, light gray with open, stained, solution vugs
35.0	34.8	39.7	RUN 6 RAN 4.9 REC 4.9 RQD= 87.7							Limestone, sandy, medium to light gray with soft shale partings Boring Terminated @ 39.7', 100% DWL
40.0										

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

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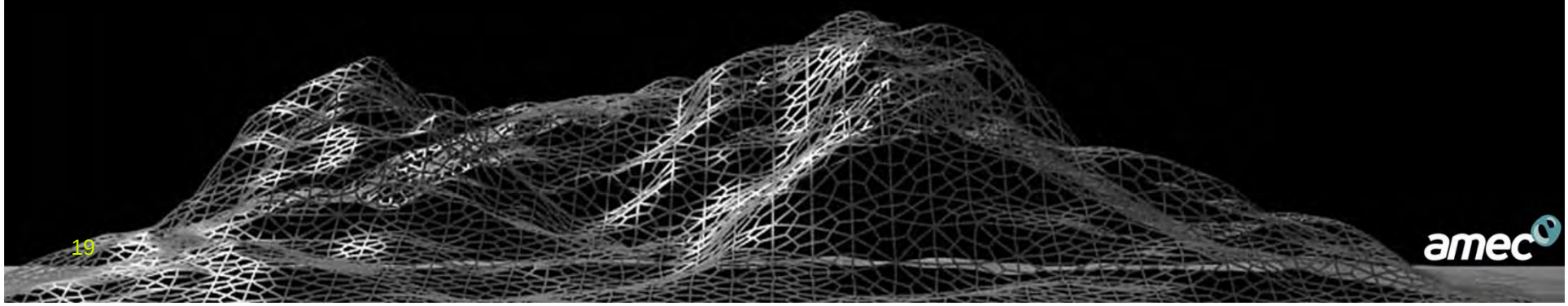
Mack Hatcher Parkway
Franklin, Tennessee

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

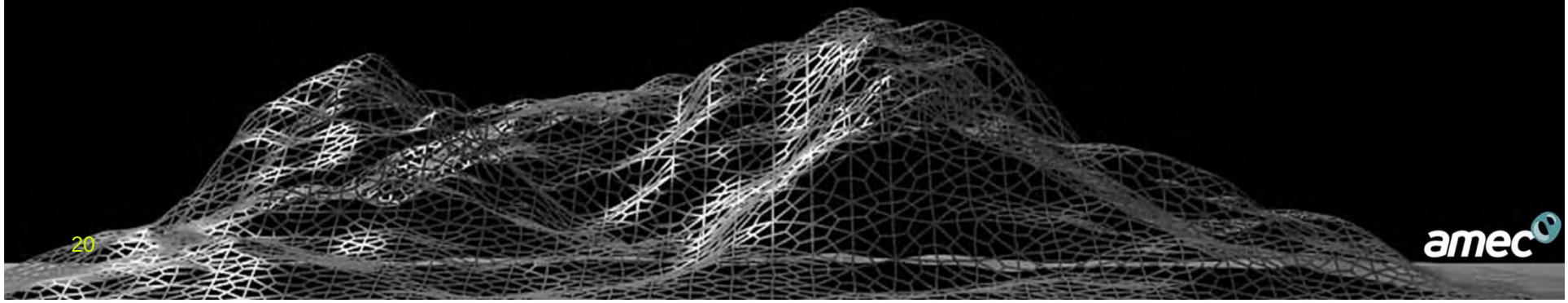
WHY ?

CAISSONS ARE DIFFICULT TO INSTALL IN IRREGULAR BEDROCK CONDITIONS

THEY ARE COSTLY $$

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

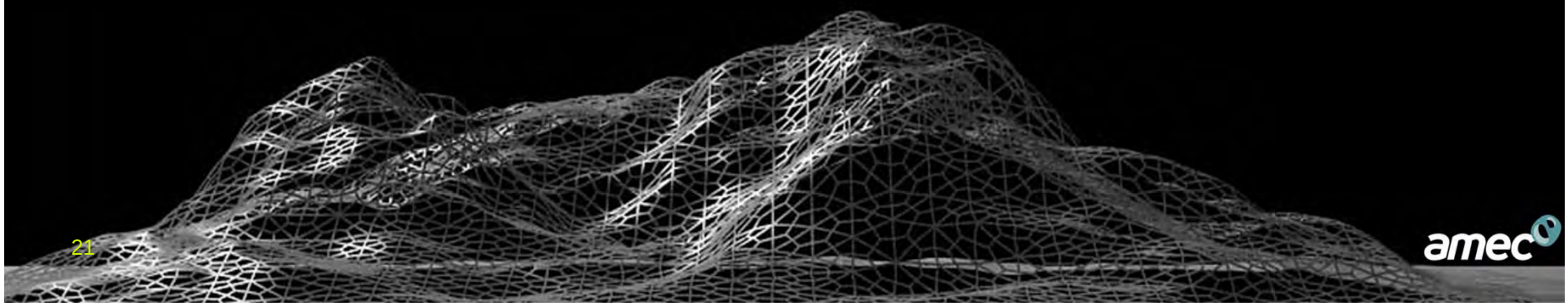
HOW MUCH DOES IT COST TO USE PERMANENT CASING IN THE GROUND TO CONTROL CONCRETE PLACEMENT?



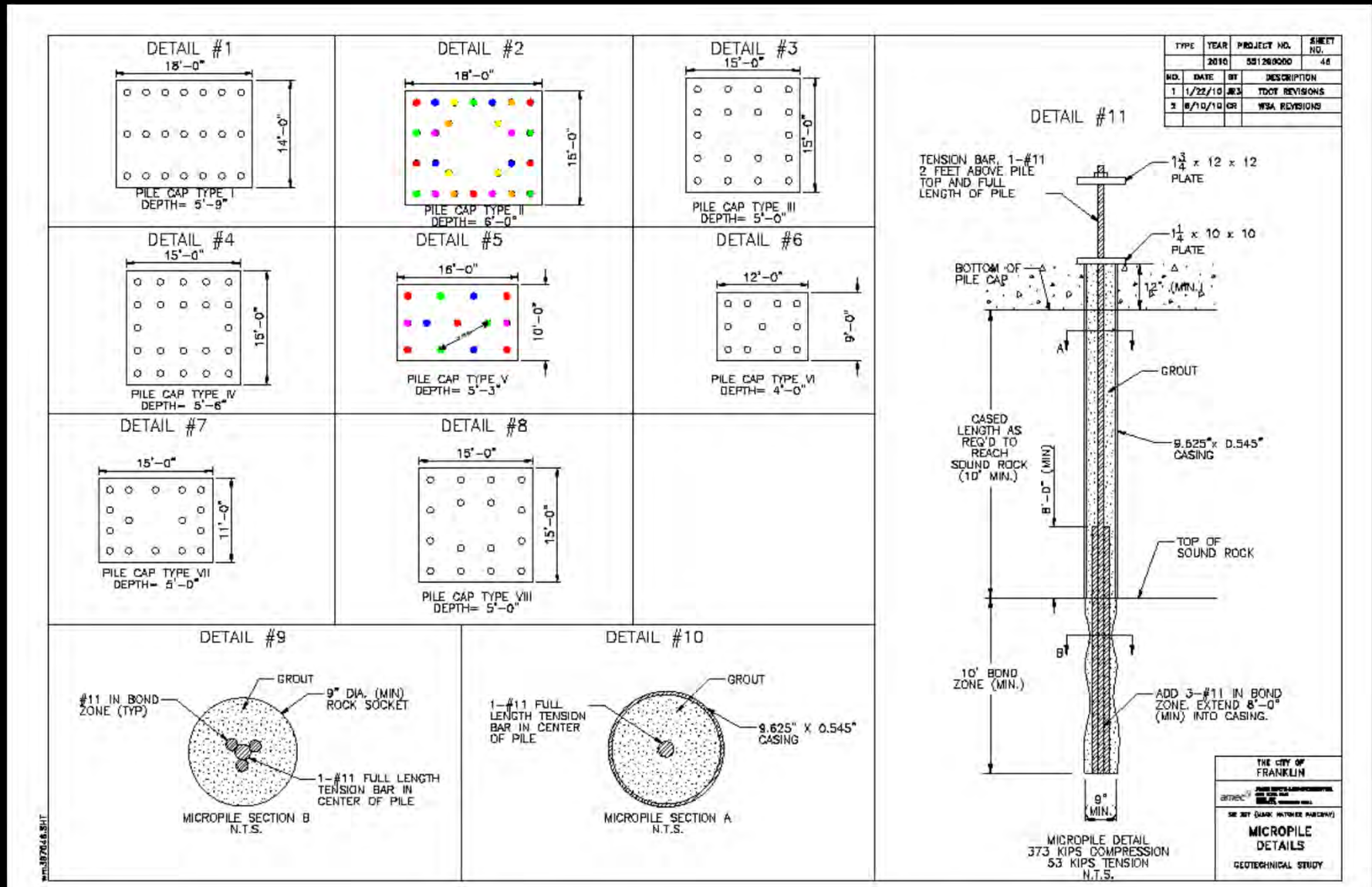
Mack Hatcher Parkway
Franklin, Tennessee

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

WE DON’T KNOW



Micro-piles as a SOLUTION



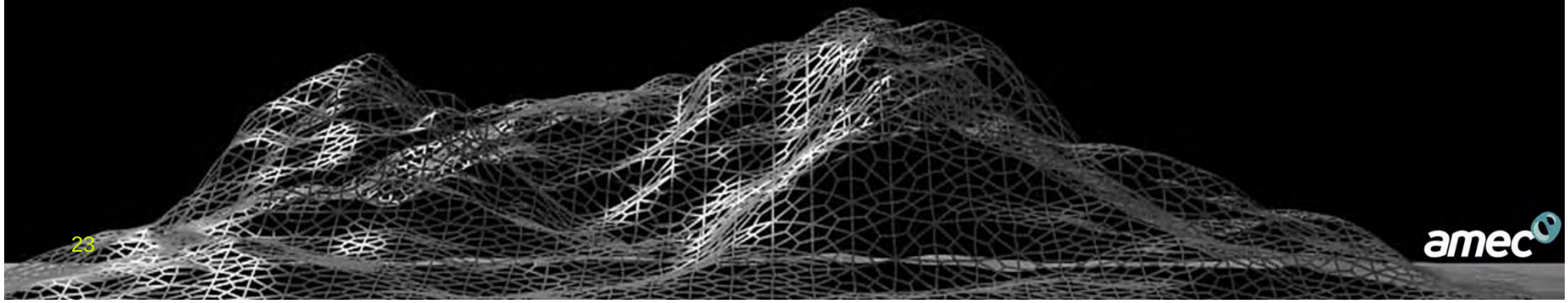
RECENT LOAD TESTING ON INSTALLED MICRO-PILES

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