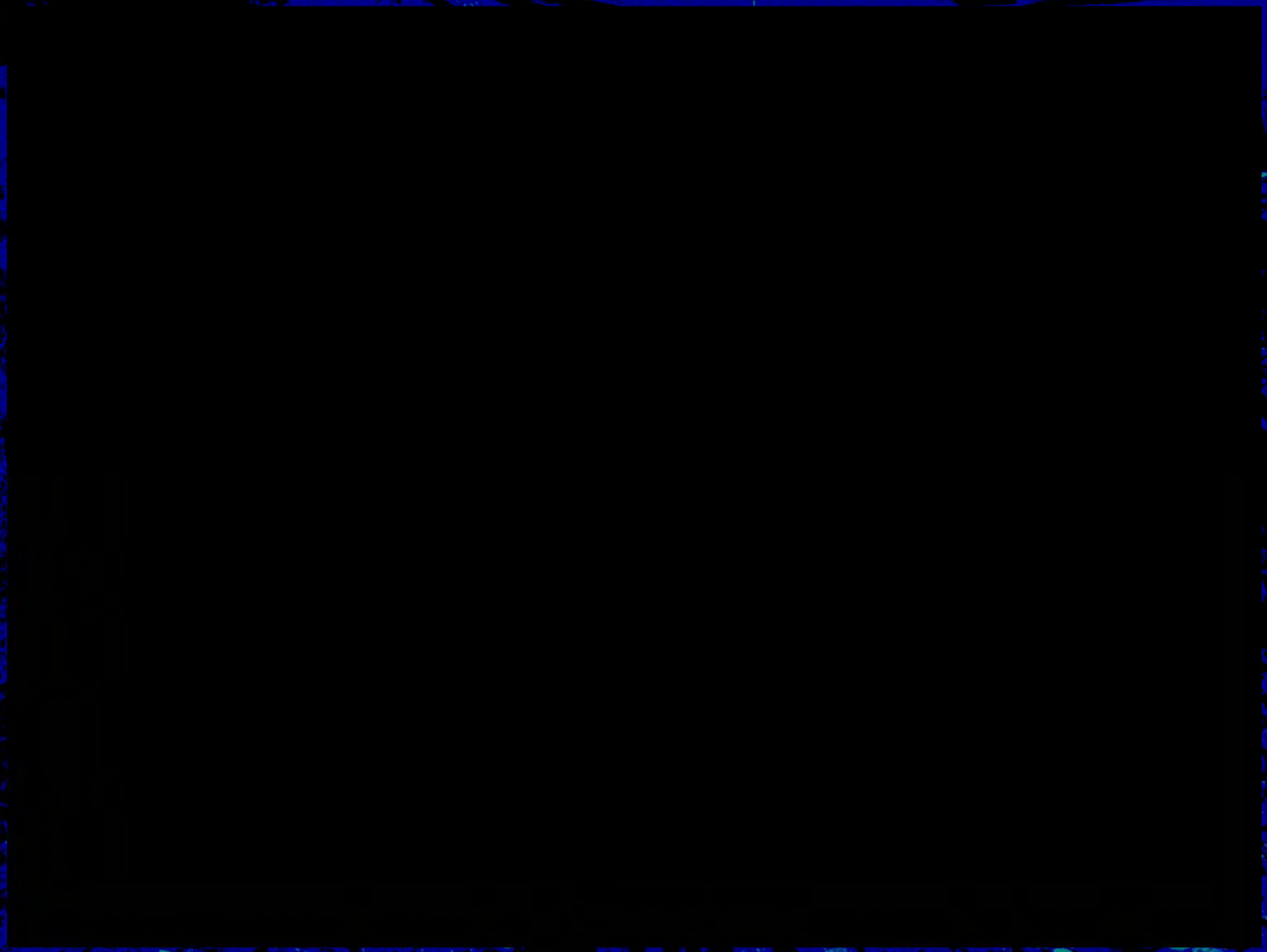
Follow-up on the "Land-Bridge" at milepost 96.1-A near Morristown, TN

John R. Tomlin, PE

Engineer – Geotechnical Services

NORFOLK SOUTHERN®

Bridge over troubled... water?

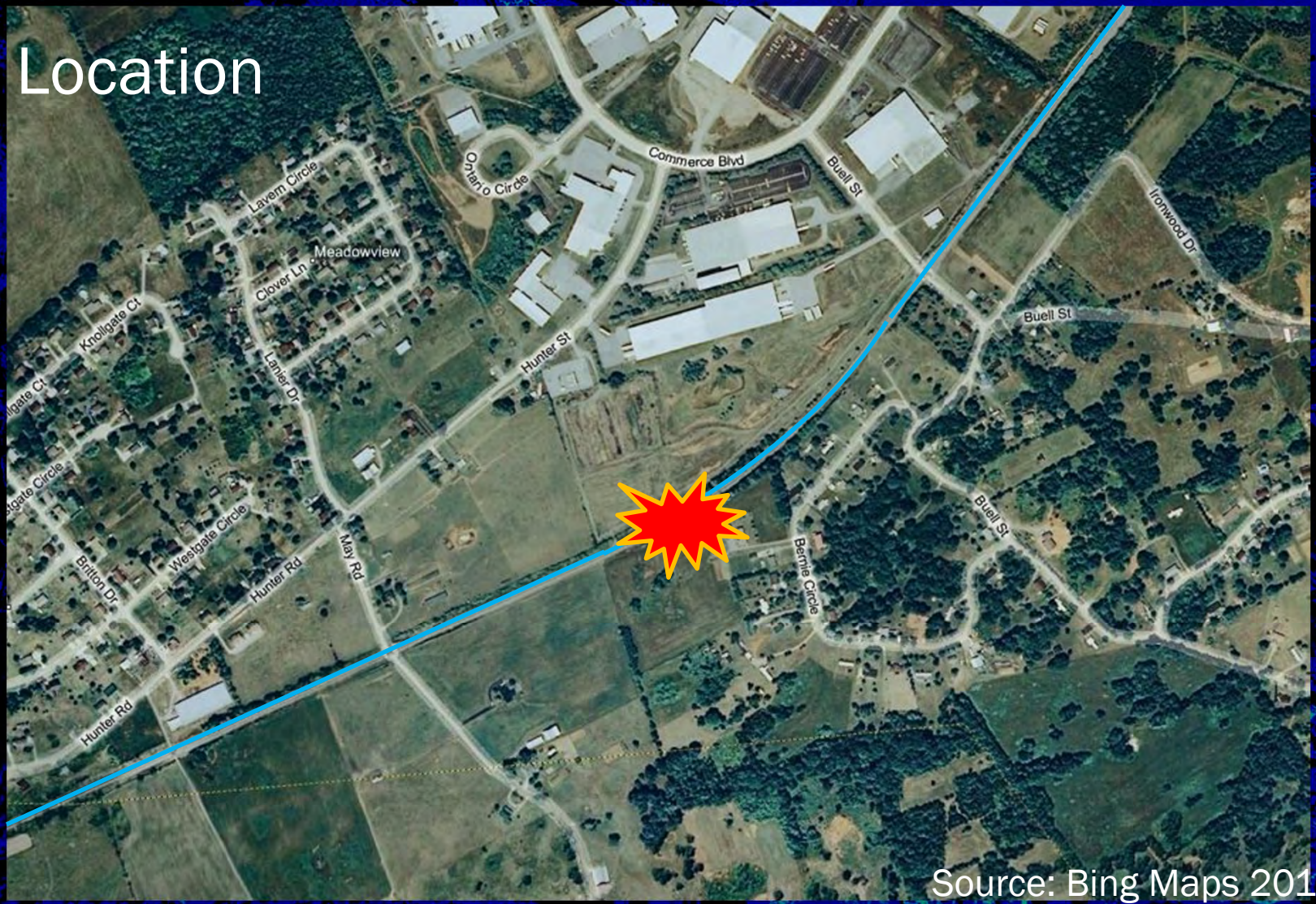


Problem Description

- Location:
  - 3.5 track miles south of Morristown, TN
  - Adjacent to Industrial Park on west
  - Rural/Agricultural on east
  - Typical Karst terrain

Problem Description

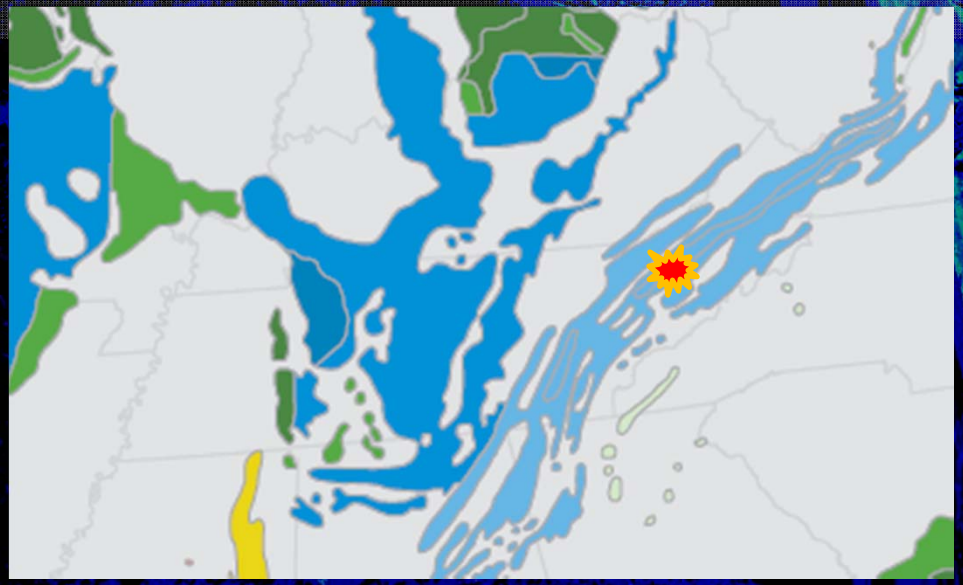
- Location



Source: Bing Maps 2010

Problem Description

- USGS Karst Map
  - Fissures, Tubes, and Caves over 1000 feet (300 m) long; 50 ft (15 m) to 250 ft (75 m) in Vertical Extent
  - In moderately to steeply dipping beds of Carbonate Rock



FISSURES, TUBES, AND CAVES OVER 1,000 FT (300 M) LONG; 50 FT (15 M) TO OVER 250 FT i75 M) VERTICAL EXTENT

- In metamorphosed limestone, dolostone, and marble
- In moderately to steeply dipping beds of carbonate rock
- In gently dipping to flat-lying beds of carbonate rock
- In gently dipping to flat-lying beds of carbonate rock beneath an overburden of noncarbonate material 10 ft (3 m) to 200 ft (60 m) thick

Abers Equal Area Projection

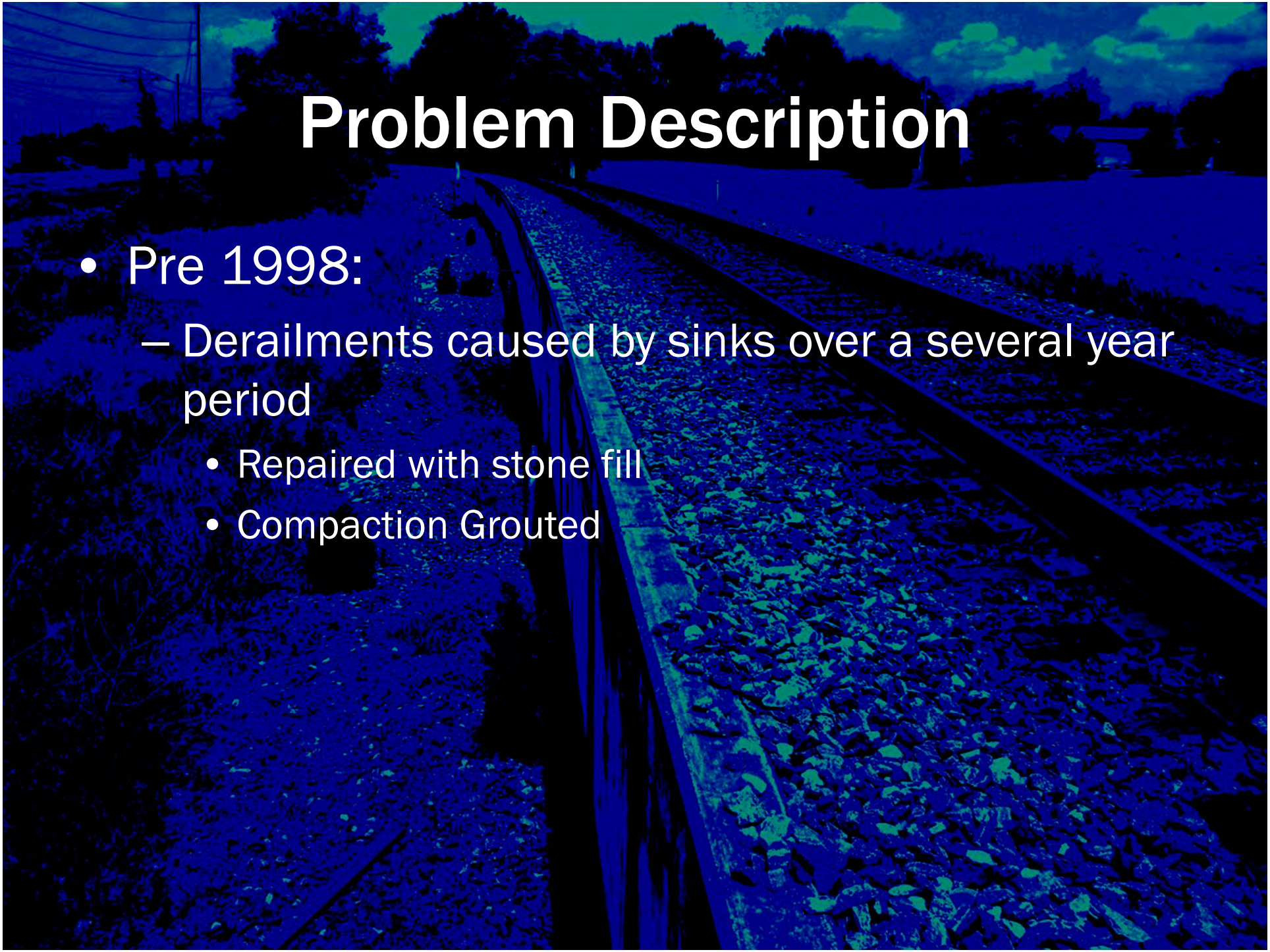
SCALE 1:7,500,000

Redrawn from the map by

Davies, W.E., Simpson, J.H., Ohlmacher, G.C., Kirk, W.S., and Newton, E.G., 1984, Engineering aspects of karst: U.S. Geological Survey, National Atlas, scale 1:7,5000

Problem Description

- History:
  - Historically Active Sinkhole Area for Railroad
    - 19 locations grouted from milepost 78.8-A to 164.0-A over 20 year period
  - Repair Methods Historically Employed:
    - Rock Fill
    - Pressure Injection Grouting



Problem Description

- Pre 1998:
  - Derailments caused by sinks over a several year period
    - Repaired with stone fill
    - Compaction Grouted

Problem Description

- 1998:
  - Large Sinkholes (drop-outs) begin forming in fields adjacent to tracks
- 1999:
  - Sinkholes develop under track, surface water washed overburden into drop-outs
  - Maintained with rock fill
  - 10 mph Slow Order placed for Train Traffic
    - (Typically 60 mph)

Problem Description

MP 96.1A Morristown, TN
Norfolk Southern Corporation
Ogden Project No. 8-4366-0003-0000

Photograph 1 – Aerial view of open sinks near track. Largest measures approximately 65 feet long, 40 feet wide and at least 35 feet deep. (3-31-99)

Problem Description

MP 96.1A Morristown, TN
Norfolk Southern Corporation
Ogden Project No. 8-4366-0003-0000

Photograph 3 – Oblique overhead view of site and widespread sinks in adjacent field. Note washout north of tracks in upper right corner of photo. (3/31-99)

Problem Description

Photograph 6 – Washout north of track at toe of rock fill. (3-31-99)

Problem Description

Photograph 8 – Three foot diameter opening at west end of washout north of track. Note adjacent rock pinnacle. Opening appears to bend horizontally beneath track (to left in photo). (3-31-99)

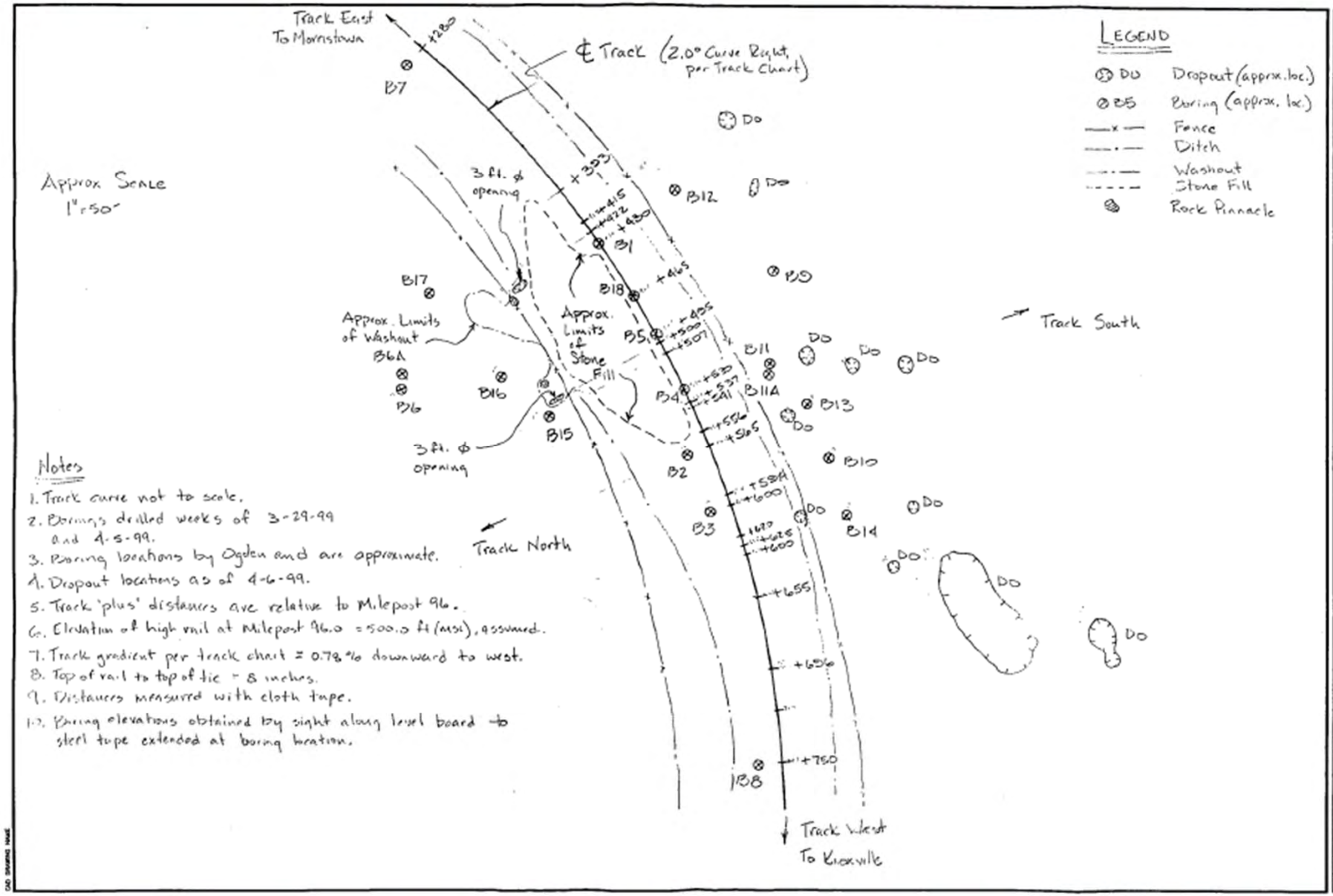
Analysis

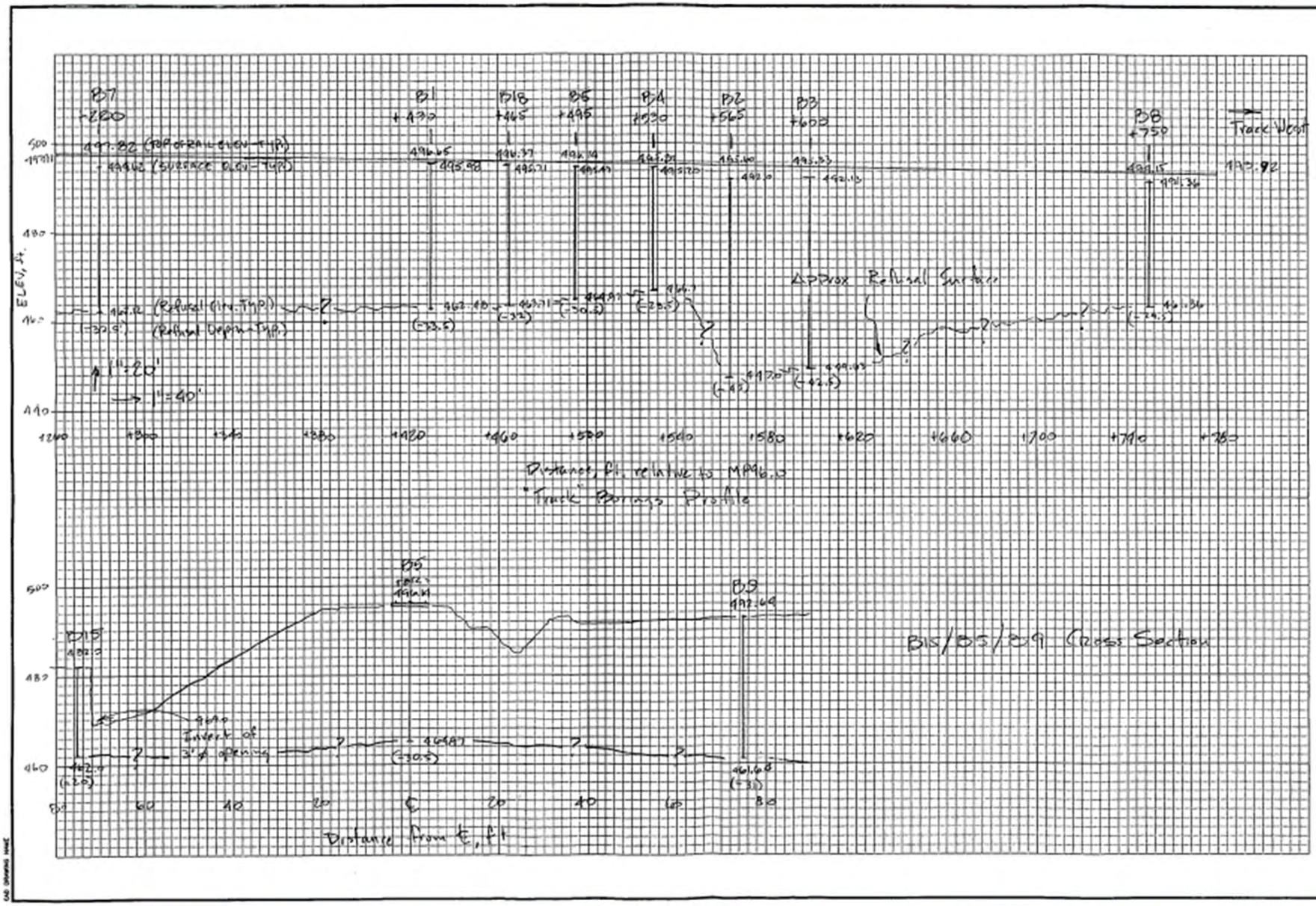
- March/April 1999: Exploration
  - Ogden Environmental (now AMEC) conducted a site investigation: 20 Boreholes
    - Power Auger for Overburden Thickness
    - Drive Sampling of overburden
    - 7 Borings into rock to assess degree and depth of weathering

Analysis

- Subsurface Conditions:
  - From Ogden report April 1999

Published geologic information (USGS 7.5 Minute Geologic Quadrangle for Talbot, Tennessee) indicates the bedrock unit at this site is siliceous, cherty Mascot Dolomite. That rock type is typically fine- to medium-grained with bedding thickness in the medium to thick range. The relatively pure limestone is highly susceptible to solution weathering along vertical joints, bedding planes and fractures, and therefore, the upper bedrock surface is quite irregular. Numerous cutters (deep soil-filled joints) and pinnacles are common. This condition was typically confirmed by the boring data where depth to refusal varies significantly over a relatively short horizontal distance.


Track East
To Morristown
℄ Track (2.0° Curve Right, per Track Chart)
Approx Scale
1"=50'
3 ft. ϕ opening
Approx. Limits of Washout
Approx. Limits of Stone Fill
3 ft. ϕ opening
Track South
Track North
Track West
To Knoxville
LEGEND
DO Dropout (approx. loc.)
B5 Boring (approx. loc.)
Fence
Ditch
Washout
Stone Fill
Rock Pinnacle
Notes
1. Track curve not to scale.
2. Borings drilled weeks of 3-29-99 and 4-5-99.
3. Boring locations by Ogden and are approximate.
4. Dropout locations as of 4-6-99.
5. Track 'plus' distances are relative to Milepost 96.
6. Elevation of high rail at Milepost 96.0 = 500.0 ft (msl), assumed.
7. Track gradient per track chart = 0.78% downward to west.
8. Top of rail to top of tie = 8 inches.
9. Distances measured with cloth tape.
10. Boring elevations obtained by sight along level board to steel tape extended at boring location.
MP 96.14 Morristown Sinkhole
PREPARED FOR: Norfolk Southern Corp.
PREPARED BY: OGDEN
SCALE: Shown
PLAN
84366003
JSV
4-12-99
1 of 2



MP96.14 Morristown Sinkhole

PREPARED FOR: Norfolk Southern Corp.

PREPARED BY: OGDEN

SCALE: Shown

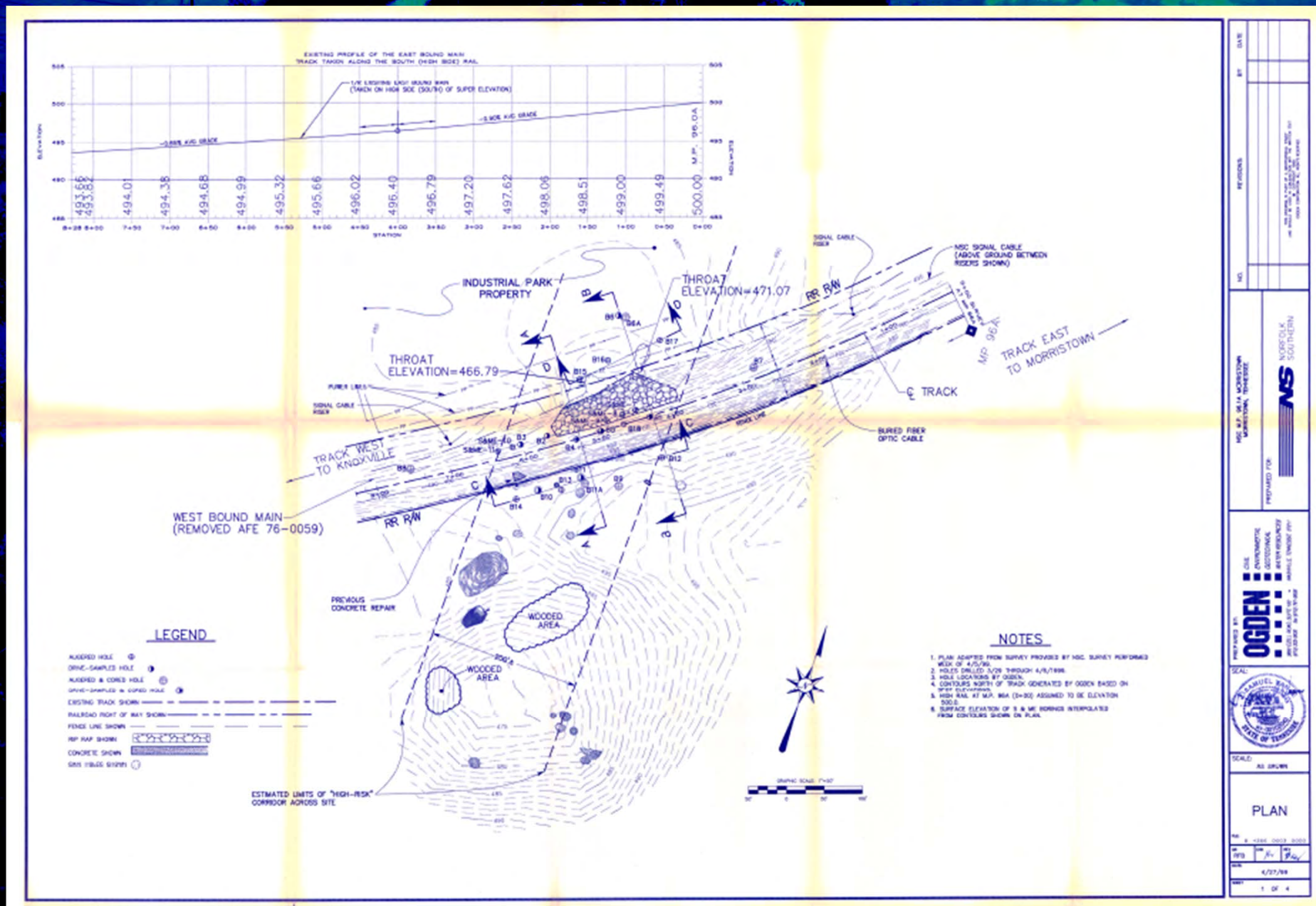
PROFILES AND SECTIONS

84366 0003

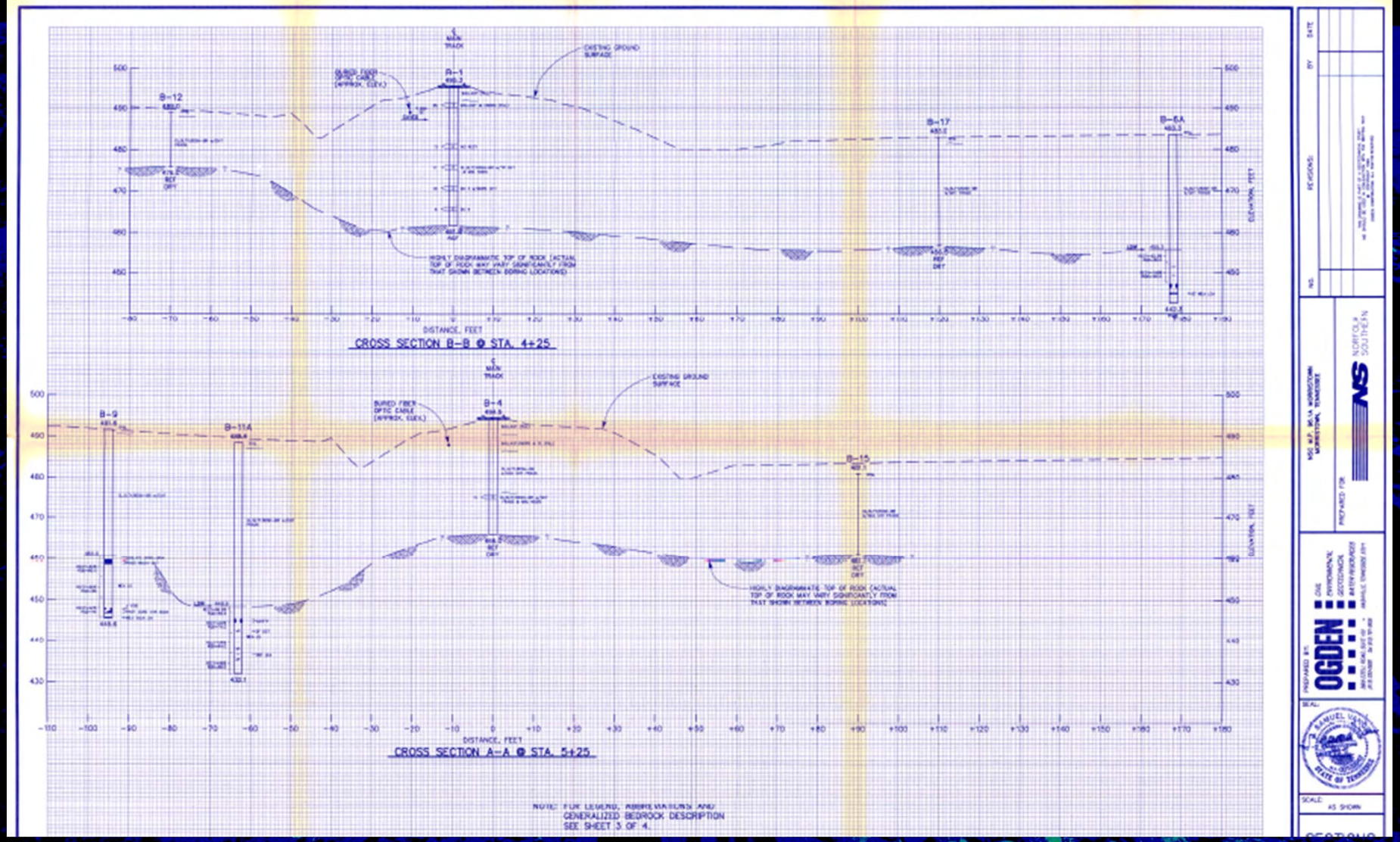
JSY

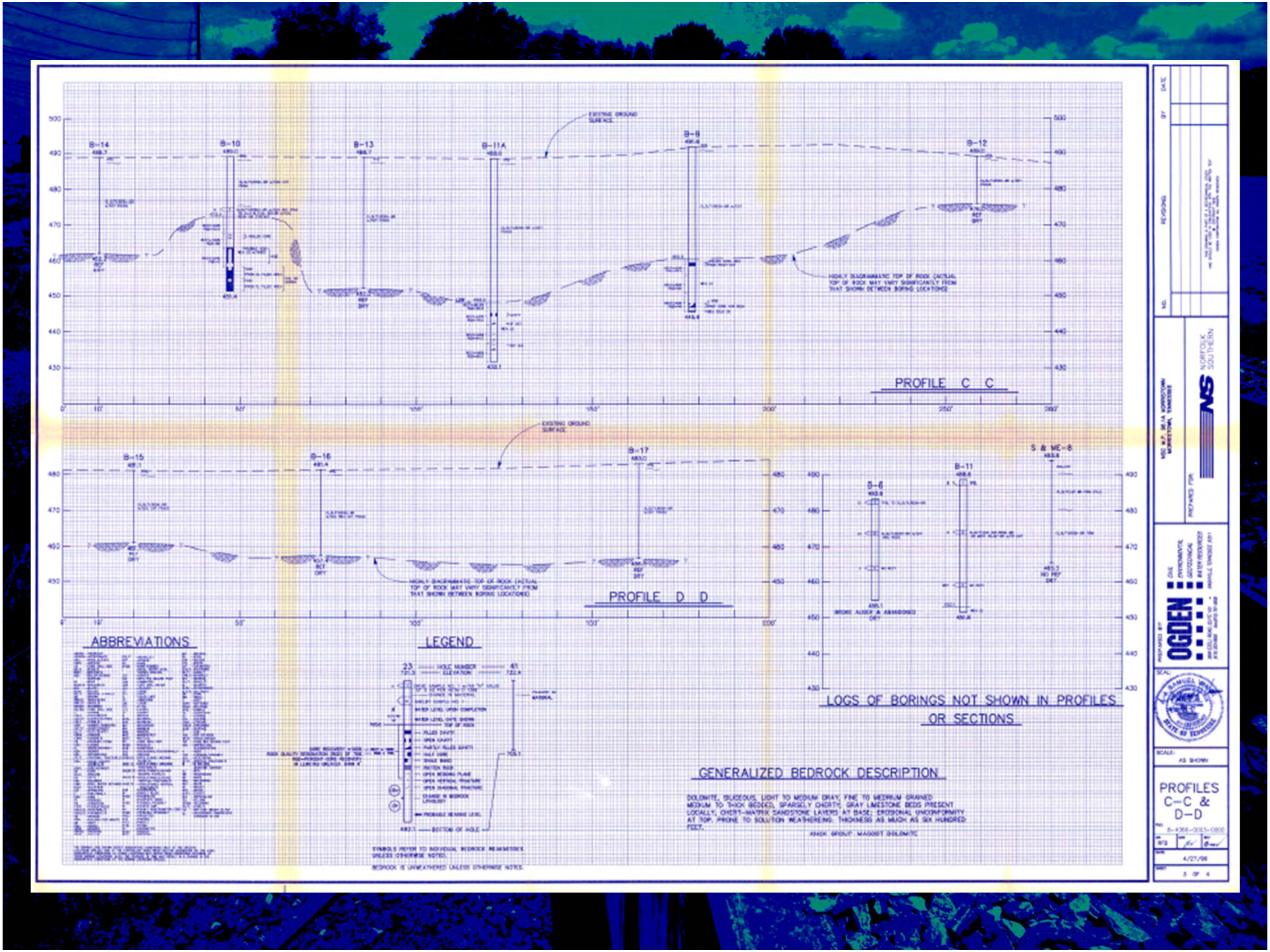
4-12-99

2 of 2


EXISTING PROFILE OF THE EAST BOUND MAIN TRACK TAKEN ALONG THE SOUTH (HIGH SIDE) RAIL
ELEVATION
STATION
M.P. 96.0A
INDUSTRIAL PARK PROPERTY
THROAT ELEVATION=471.07
THROAT ELEVATION=466.79
RR R/W
NSC SIGNAL CABLE (ABOVE GROUND BETWEEN RISERS SHOWN)
SIGNAL CABLE RISER
TRACK EAST TO MORRISTOWN
℄ TRACK
BURIED FIBER OPTIC CABLE
TRACK WEST TO KNOXVILLE
WEST BOUND MAIN (REMOVED AFE 76-0059)
PREVIOUS CONCRETE REPAIR
WOODED AREA
ESTIMATED LIMITS OF "HIGH-RISK" CORRIDOR ACROSS SITE
LEGEND
NOTES
OGDEN
NORFOLK SOUTHERN
PLAN

Analysis


CROSS SECTION B–B @ STA. 4+25
DISTANCE, FEET
CROSS SECTION A–A @ STA. 5+25
DISTANCE, FEET
NOTE: FOR LEGEND, ABBREVIATIONS AND GENERALIZED BEDROCK DESCRIPTION SEE SHEET 3 OF 4.
OGDEN
NORFOLK SOUTHERN



PROFILE C C
PROFILE D D
EXISTING GROUND SURFACE
B-14
B-10
B-13
B-11A
B-9
B-12
B-15
B-16
B-17
B-6
B-11
S & ME-8
HIGHLY DIAGRAMMATIC TOP OF ROCK (ACTUAL TOP OF ROCK MAY VARY SIGNIFICANTLY FROM THAT SHOWN BETWEEN BORING LOCATIONS)
LOGS OF BORINGS NOT SHOWN IN PROFILES OR SECTIONS
ABBREVIATIONS
LEGEND
HOLE NUMBER
ELEVATION
BOTTOM OF HOLE
GENERALIZED BEDROCK DESCRIPTION
DOLOMITE, SILICEOUS, LIGHT TO MEDIUM GRAY, FINE TO MEDIUM GRAINED MEDIUM TO THICK BEDDED, SPARSELY CHERTY, GRAY LIMESTONE BEDS PRESENT LOCALLY, CHERT-MATRIX SANDSTONE LAYERS AT BASE; EROSIONAL UNCONFORMITY AT TOP. PRONE TO SOLUTION WEATHERING. THICKNESS AS MUCH AS SIX HUNDRED FEET.
KNOX GROUP: MAGGOT DOLOMITE
SYMBOLS REFER TO INDIVIDUAL BEDROCK REMINISSES UNLESS OTHERWISE NOTED.
BEDROCK IS UNWEATHERED UNLESS OTHERWISE NOTED.
NORFOLK SOUTHERN
OGDEN
AS SHOWN
PROFILES C-C & D-D
4/27/99
3 OF 4

Analysis

Subsurface Conditions:

From Ogden report April 1999

1. Deemed “High Risk” site
2. Surface Drainage needed to be modified
3. Subgrade Support needed to be improved

Solution

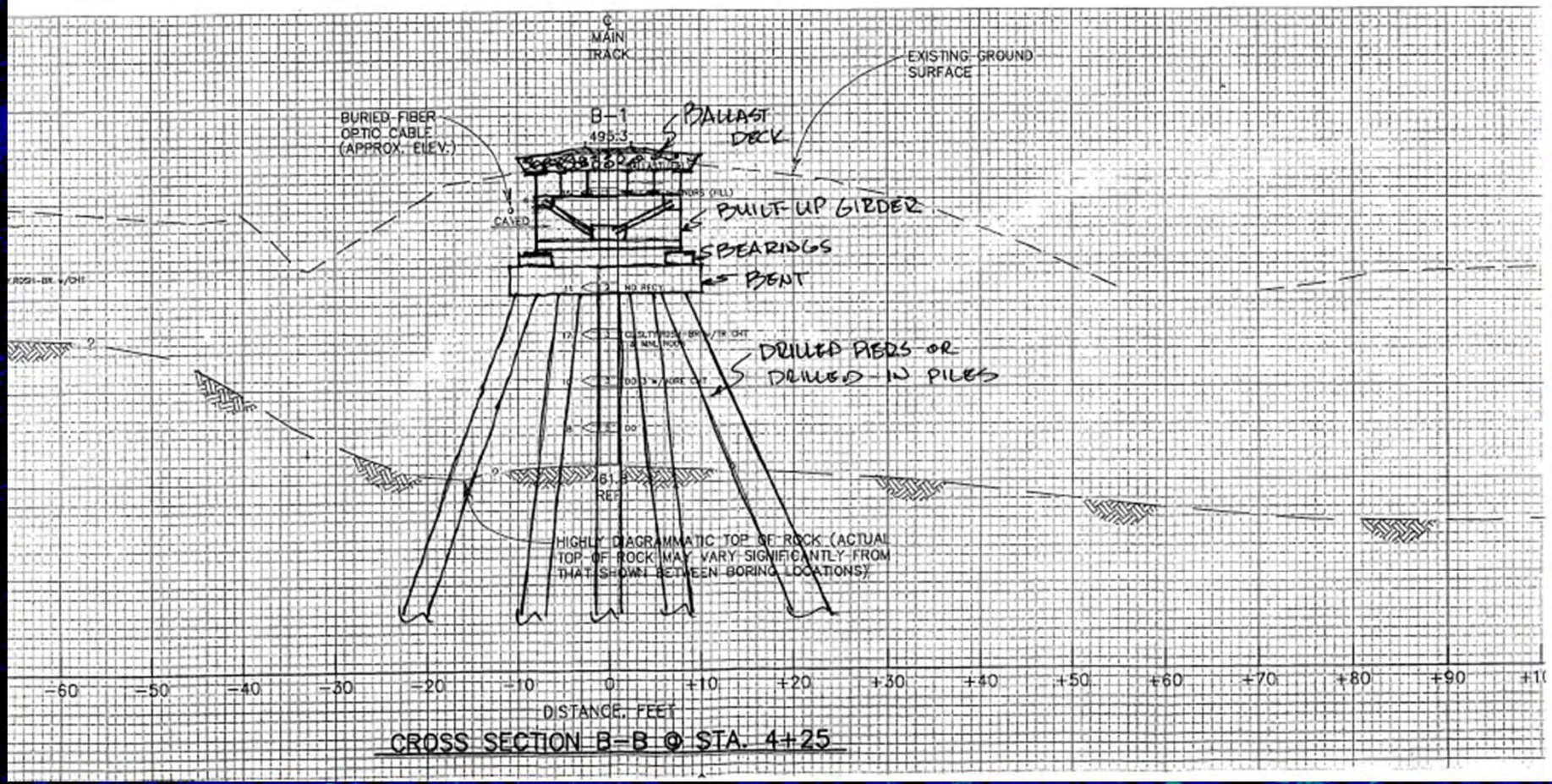
TABLE 1
SUMMARY OF KARST REMEDIATION OPTIONS

Option	Perceived Advantages	Perceived Disadvantages	Estimated Construction Costs
1. At-Grade Bridge	Stand alone structure; relatively low risk of future track failure	High cost; may need temporary run-around	$1.47 million
2. Subgrade Repair with Permanent Run-Around Track	Positive subgrade repair; allows exposure and treatment of specific defects	Weather sensitive; high costs; need to acquire more right-of-way; probable traffic delays	$950,000
3. Subgrade Repair with Temporary Run-Around Track	Positive subgrade repair; allows exposure and treatment of specific defects	Have to move track twice; weather sensitive; high costs; probable traffic delays	$700,000
4. Compaction Grout Treatment	Good control over grout placement and take; successful performance in similar geologic settings for other railroad projects; low costs; low impact to traffic	Indirect treatment of specific defects; may not get "complete" coverage; moderate risk of future sinkhole recurrence; requires careful field engineering and adjustment to program.	$350,000

Solution

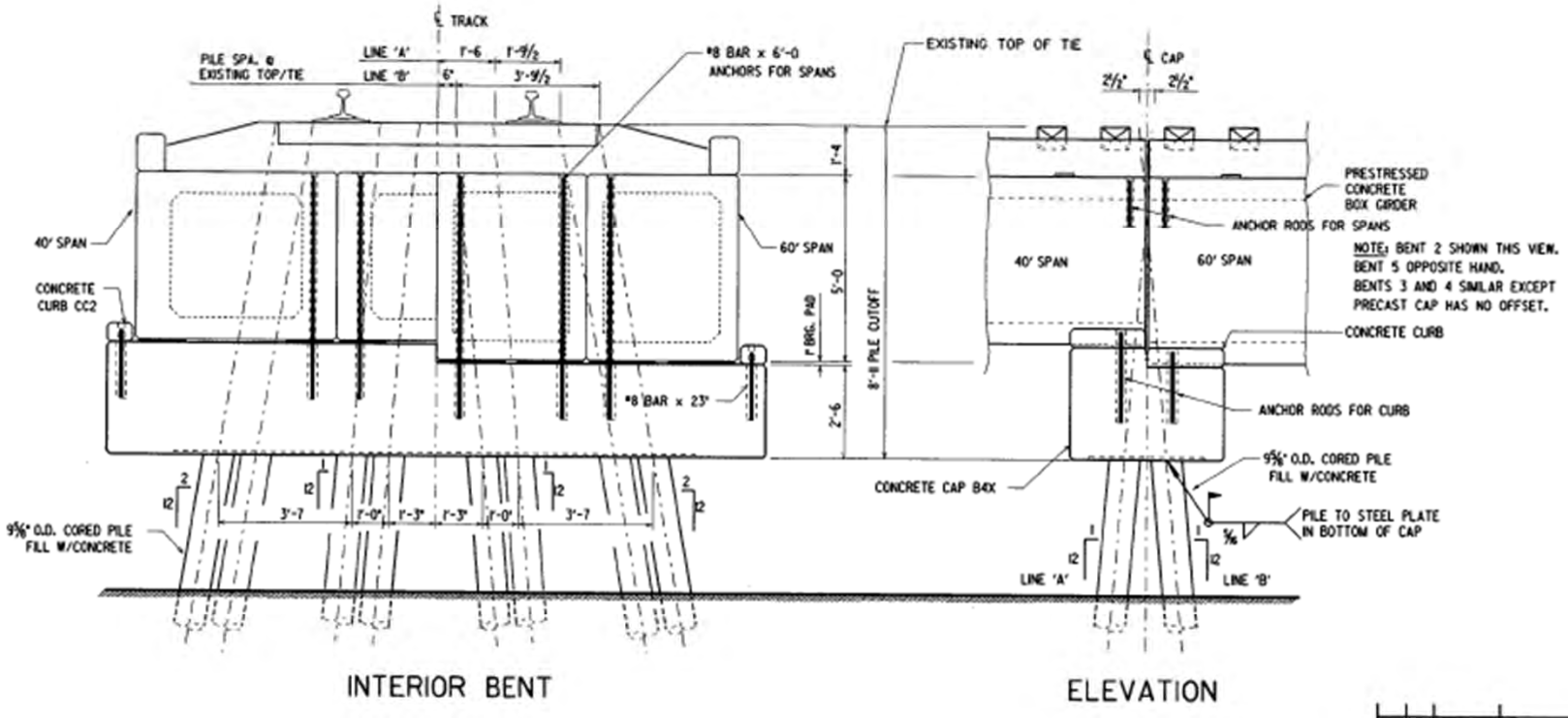
- NS chose the bridge solution
  - Best for long term
  - Feared cavern system more extensive than could be detected
  - Due to topography, surface water would continue to be an issue

OPTION 1
CONCEPTUAL SKETCH
AT-GRADE BRIDGE
MP96.1A MORRISTOWN, TN
OGDEN PROJ No. 813660003



CROSS SECTION B-B @ STA. 4+25

Solution



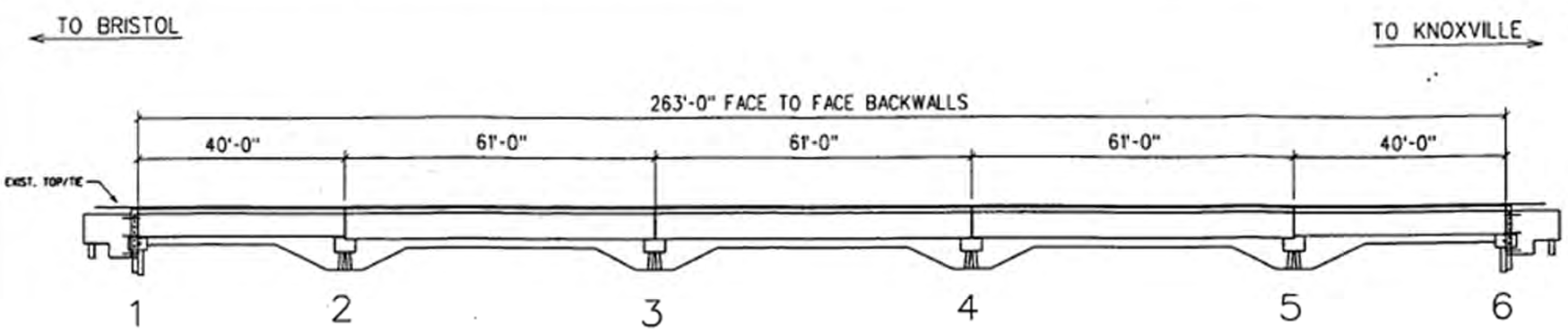
NORFOLK SOUTHERN

NORFOLK SOUTHERN RAILWAY
TENNESSEE DIVISION

MILEPOST 96J-A MORRISTOWN, TN
DOUBLE FOUR PILE BENT DETAILS
INTERIOR BENTS

DWN GCM | MILEPOST 96J-A
CHK | DATE 6/29/99
SHEET NUMBER | DRAWING NUMBER 96J-A 99 01

Solution



PROFILE

ESTIMATED COST: $ 814,000

776,000 CAPITAL

38,000 EXPENSE

PROPOSED STRUCTURE: 263' CONCRETE BALLAST DECK
BEAMS (40' SPANS) - THREE PIECE PRESTRESSED CONCRETE BOX GIRDERS - 54" DEEP
BEAMS (60' SPANS) - FOUR PIECE PRESTRESSED CONCRETE BOX GIRDERS - 60" DEEP
BENTS 1 & 6 - 6 CORED PIPE PILE
BENTS 2 THRU 5 - 8 CORED PIPE PILE
ALIGNMENT: TANGENT

REQUIRED MATERIAL LIST

QTY	DESCRIPTION	WEIGHT
44	9⅝" O.D. CORED PIPE PILING	
3	HP12X53X60'-0 STEEL PILING	1.6 TONS
27	WT4 x 12 x 30'-0	360 LBS
2	1¼" DIA. THREADED ROD x 24'-6 FOR BACKWALLS	
2	PRECAST CONCRETE BACKWALL FOR 54" DEEP SPANS - BW54	11.7 TONS
2	PRECAST CONCRETE END CAP - B1	11.7 TONS
3	PRECAST CONCRETE INT. CAP - B4X	14.4 TONS
3	PRECAST CONCRETE INT. CAP - B4M	13.5 TONS
30	#8 X 20'-0 REBAR: A615 GR 60 - ANCHORS FOR BACKWALL & SPANS	
72	ELASTOMERIC BEARING PADS FOR CONCRETE BOX GIRDERS	
4	PRESTRESSED CONCRETE EXT. BOX SECTION 54" DEEP x 40'	43.0 TONS
2	PRESTRESSED CONCRETE INT. BOX SECTION 54" DEEP x 40'	40.9 TONS
6	PRESTRESSED CONCRETE EXT. BOX SECTION 60" DEEP x 60'	44.0 TONS
6	PRESTRESSED CONCRETE INT. BOX SECTION 60" DEEP x 60'	40.6 TONS
90	MAINLINE GRADE TIES	

GENERAL NOTES: DESIGN: COOPER'S E-80 WITH DIESEL IMPACT. PILE BEARING CAPACITY 90 TONS. (60 TON DESIGN)
WORKMANSHIP: TO BE IN ACCORDANCE WITH CURRENT A.R.E.A. SPECIFICATIONS FOR CONCRETE RAILWAY BRIDGES.
PILE DRIVING: BENT LOCATIONS ARE TO BE VERIFIED IN THE FIELD BEFORE DRIVING PILES.
AN ACCURATE LOG SHALL BE KEPT OF ALL DRIVEN PILE AND SENT TO THE CHIEF ENG. BRIDGES & STRUCTURES.

DRAWING INDEX

DRWG No.	DESCRIPTION
1	PROFILE & REQUIRED LIST
2	GENERAL DETAILS
3	BACKWALL & DBL 3 PILE END BENT INSTALLATION
4	DOUBLE FOUR PILE INT. BENT DETAIL
5	PRECAST CONCRETE BACKWALL FOR 54" DEEP SPANS
6	PRECAST CONCRETE END CAP - B1
7	PRECAST CONCRETE INT. CAP - B4X
8	PRECAST CONCRETE INT. CAP - B4M
9	PRESTRESSED CONCRETE BOX GIRDER 54" DEEP x 40 FT
10	PRESTRESSED CONCRETE BOX GIRDER 54" DEEP x 40 FT
11	PRESTRESSED CONCRETE BOX GIRDER 60" DEEP x 60 FT

NORFOLK SOUTHERN
NORFOLK SOUTHERN RAILWAY
TENNESSEE DIVISION

MILEPOST: 96.1-A MORRISTOWN, TN
CONCRETE BALLAST DECK TRESTLE
PROFILE & REQUIRED LIST

96.1-A
6/1/99
96.1-A 99 01

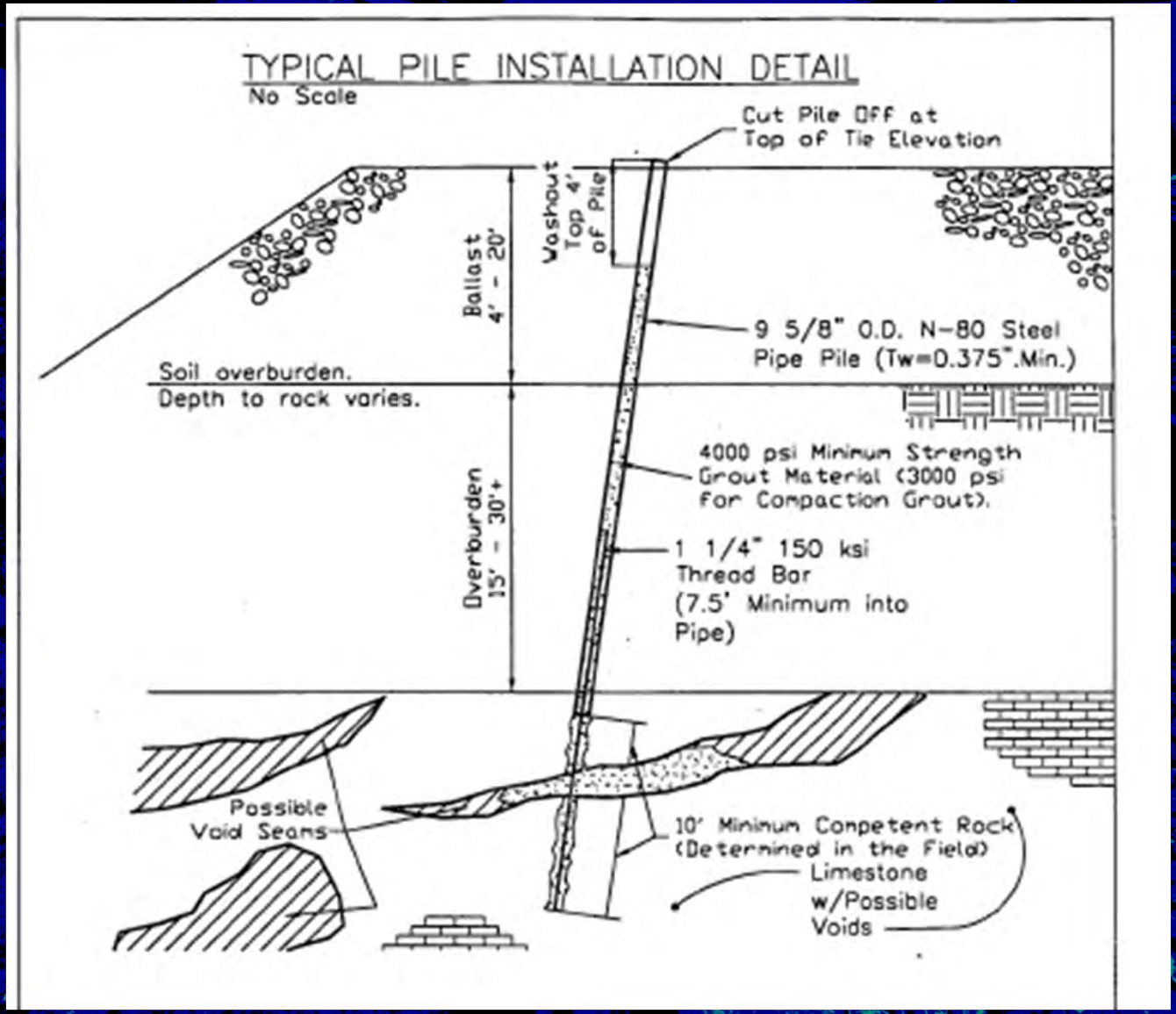
Solution

- Ballast Deck Bridge
  - Decking (top) and caps designed by NS
  - Micro-piles designed by AMEC
    - to be cored into competent rock
  - Estimated cost $820,000 to $1.47 million

Execution

- Hayward Baker contracted to install micro-piles
- Work done at night (10pm – 4am)
- Piling Procedures Developed
  - Procedures varied according to void seam width
    - < 6”
    - 6” – 60”
    - > 60”
  - Governed grout quantity and re-drilling

Execution


TYPICAL PILE INSTALLATION DETAIL
No Scale
Cut Pile Off at Top of Tie Elevation
Washout Top 4' of Pile
Ballast 4' - 20'
9 5/8" O.D. N-80 Steel Pipe Pile (Tw=0.375".Min.)
Soil overburden.
Depth to rock varies.
Overburden 15' - 30'+
4000 psi Minimum Strength Grout Material (3000 psi For Compaction Grout).
1 1/4" 150 ksi Thread Bar (7.5' Minimum into Pipe)
Possible Void Seams
10' Minimum Competent Rock (Determined in the Field)
Limestone w/Possible Voids

Execution

- Daily Work Logs

HAYWARD BAKER
A Keller Company

DAILY SITE REPORT

SHEET NO 1 OF 1
SHIFT ■ 1st ☐ 2nd ☐ 3rd

DATE Friday 12-3-99

JOB NO 20051	PROJECT NAME: Norfork Southern	TYPE OF WORK MINIPILES
LOCATION: Morristown, Tennessee		WEATHER: Sunny, warm
CLIENT Norfork Southern	ENGINEER Mike Terry	

SITE ACTIVITY

B2/H1 Took 1 bag to topoff. Drilled B3/H2, Casing to 26'. Hammered rock to 26' to 31', Broken rock and Seams 31' to 38', Rock 41' 44.5'. Seam 44.5' to 45', rock 45' to 53. Set 40'bar and grouted, 70 bags.

Topoff B3/H5 w/5 bags.

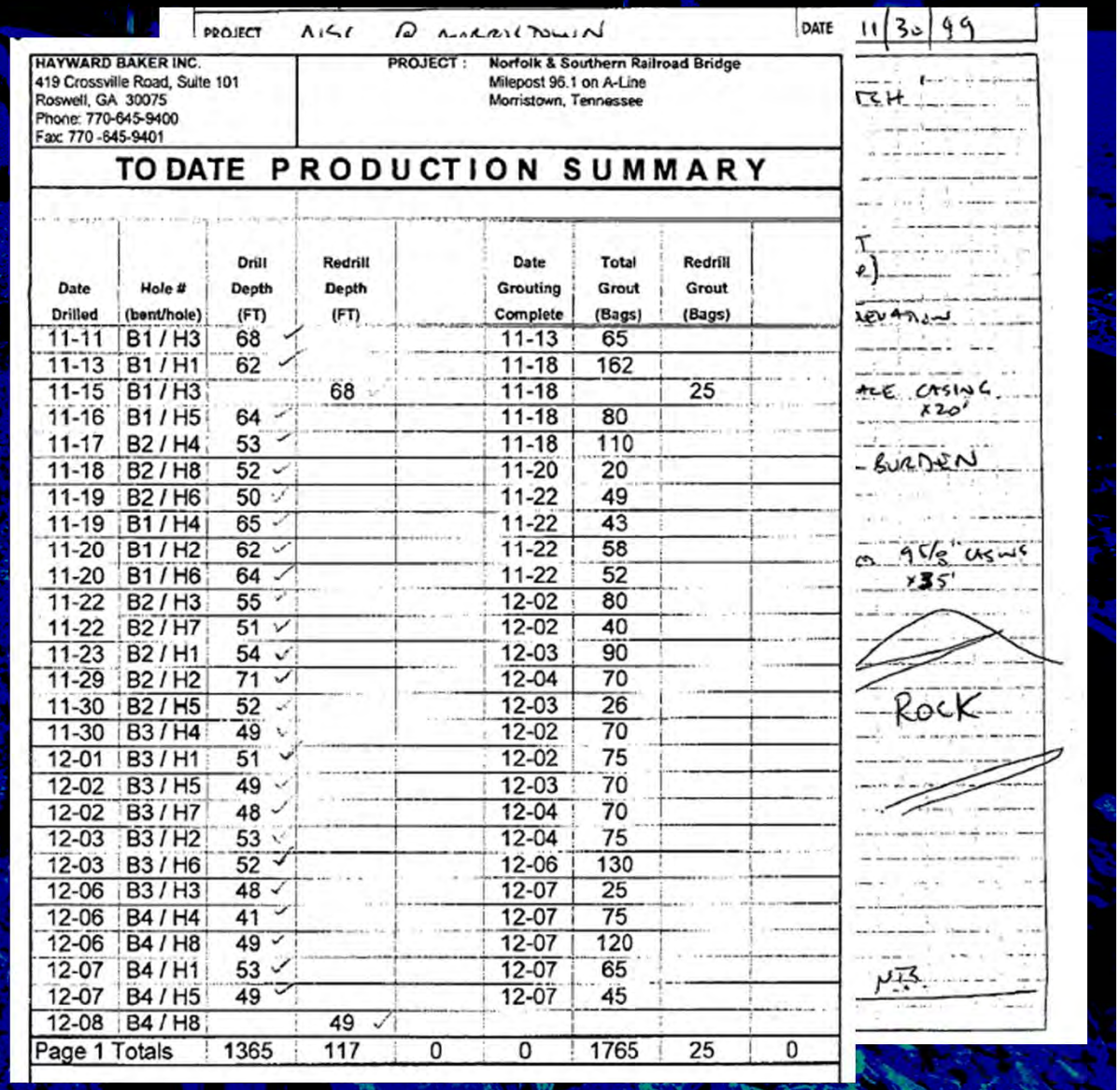
Drilled B3/H6, casing to 38' rock socket 38' to 52' broken seam 46' to 47'.

Helped Myron (N/S) tamp rail ties.

6 hr. track time : 1st. 4:20 pm to 11:10pm,

Execution

- Field Reports
- Production Summaries



PROJECT AISC @ MORRISTOWN DATE 11/30/99

HAYWARD BAKER INC.
419 Crossville Road, Suite 101
Roswell, GA 30075
Phone: 770-645-9400
Fax: 770-645-9401

PROJECT : Norfolk & Southern Railroad Bridge
Milepost 96.1 on A-Line
Morristown, Tennessee

TO DATE PRODUCTION SUMMARY

Date Drilled	Hole # (bent/hole)	Drill Depth (FT)	Redrill Depth (FT)		Date Grouting Complete	Total Grout (Bags)	Redrill Grout (Bags)	
11-11	B1 / H3	68			11-13	65		
11-13	B1 / H1	62			11-18	162		
11-15	B1 / H3		68		11-18		25	
11-16	B1 / H5	64			11-18	80		
11-17	B2 / H4	53			11-18	110		
11-18	B2 / H8	52			11-20	20		
11-19	B2 / H6	50			11-22	49		
11-19	B1 / H4	65			11-22	43		
11-20	B1 / H2	62			11-22	58		
11-20	B1 / H6	64			11-22	52		
11-22	B2 / H3	55			12-02	80		
11-22	B2 / H7	51			12-02	40		
11-23	B2 / H1	54			12-03	90		
11-29	B2 / H2	71			12-04	70		
11-30	B2 / H5	52			12-03	26		
11-30	B3 / H4	49			12-02	70		
12-01	B3 / H1	51			12-02	75		
12-02	B3 / H5	49			12-03	70		
12-02	B3 / H7	48			12-04	70		
12-03	B3 / H2	53			12-04	75		
12-03	B3 / H6	52			12-06	130		
12-06	B3 / H3	48			12-07	25		
12-06	B4 / H4	41			12-07	75		
12-06	B4 / H8	49			12-07	120		
12-07	B4 / H1	53			12-07	65		
12-07	B4 / H5	49			12-07	45		
12-08	B4 / H8		49					
Page 1 Totals		1365	117	0	0	1765	25	0

Execution

- Construction Issues

MEMORANDUM

DATE: December 23, 1999

TO: File

FROM: GCM

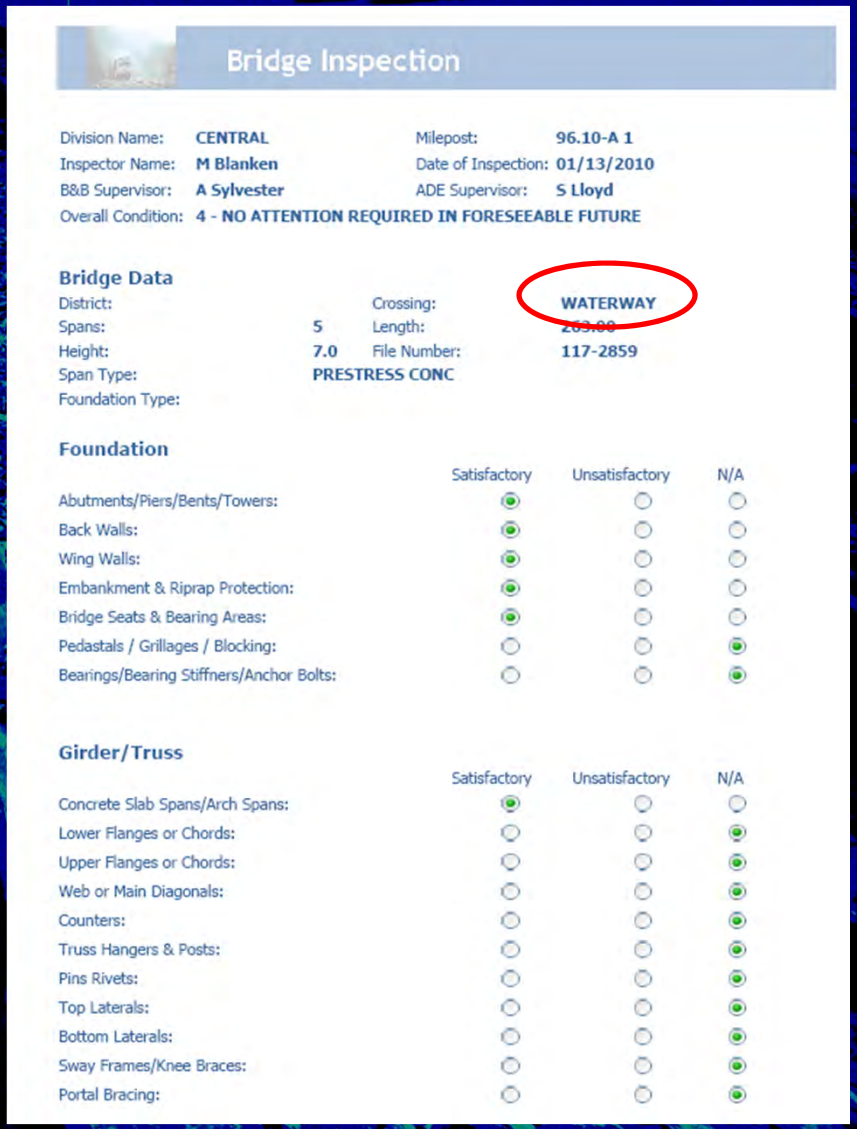
RE: 96.1-A Sink Hole

CC: [*Names*]

Kaz called to report this A.M. that small sinkhole opend up under rear wheel of pickup yesterday afternoon. The hole was approx. 30" Dia. x 48" Deep. It was located 105' West of Bent #6 and 35' North of C-L Track. Filled with Rip-Rap. Hayward-Baker is demobilizing from the site.

Follow-Up

- Annual Bridge Inspections
- Drive-by inspections
- 10-Year Photos



Bridge Inspection

Division Name:	CENTRAL	Milepost:	96.10-A 1
Inspector Name:	M Blanken	Date of Inspection:	01/13/2010
B&B Supervisor:	A Sylvester	ADE Supervisor:	S Lloyd
Overall Condition:	4 - NO ATTENTION REQUIRED IN FORESEEABLE FUTURE		

Bridge Data

District:		Crossing:	WATERWAY
Spans:	5	Length:	[illegible]
Height:	7.0	File Number:	117-2859
Span Type:	PRESTRESS CONC		
Foundation Type:			

Foundation

	Satisfactory	Unsatisfactory	N/A
Abutments/Piers/Bents/Towers:	●	○	○
Back Walls:	●	○	○
Wing Walls:	●	○	○
Embankment & Riprap Protection:	●	○	○
Bridge Seats & Bearing Areas:	●	○	○
Pedastals / Grillages / Blocking:	○	○	●
Bearings/Bearing Stiffners/Anchor Bolts:	○	○	●

Girder/Truss

	Satisfactory	Unsatisfactory	N/A
Concrete Slab Spans/Arch Spans:	●	○	○
Lower Flanges or Chords:	○	○	●
Upper Flanges or Chords:	○	○	●
Web or Main Diagonals:	○	○	●
Counters:	○	○	●
Truss Hangers & Posts:	○	○	●
Pins Rivets:	○	○	●
Top Laterals:	○	○	●
Bottom Laterals:	○	○	●
Sway Frames/Knee Braces:	○	○	●
Portal Bracing:	○	○	●

10-Year Thoughts…

- Final Cost = $1,088,000 (1999 dollars)
- Few issues at location since construction
  - Cost savings un-calculable
- Depending on rock properties, a land bridge is a viable option if conditions warrant

Questions?