Drilled Shaft Repair in Michigan's Upper Peninsula

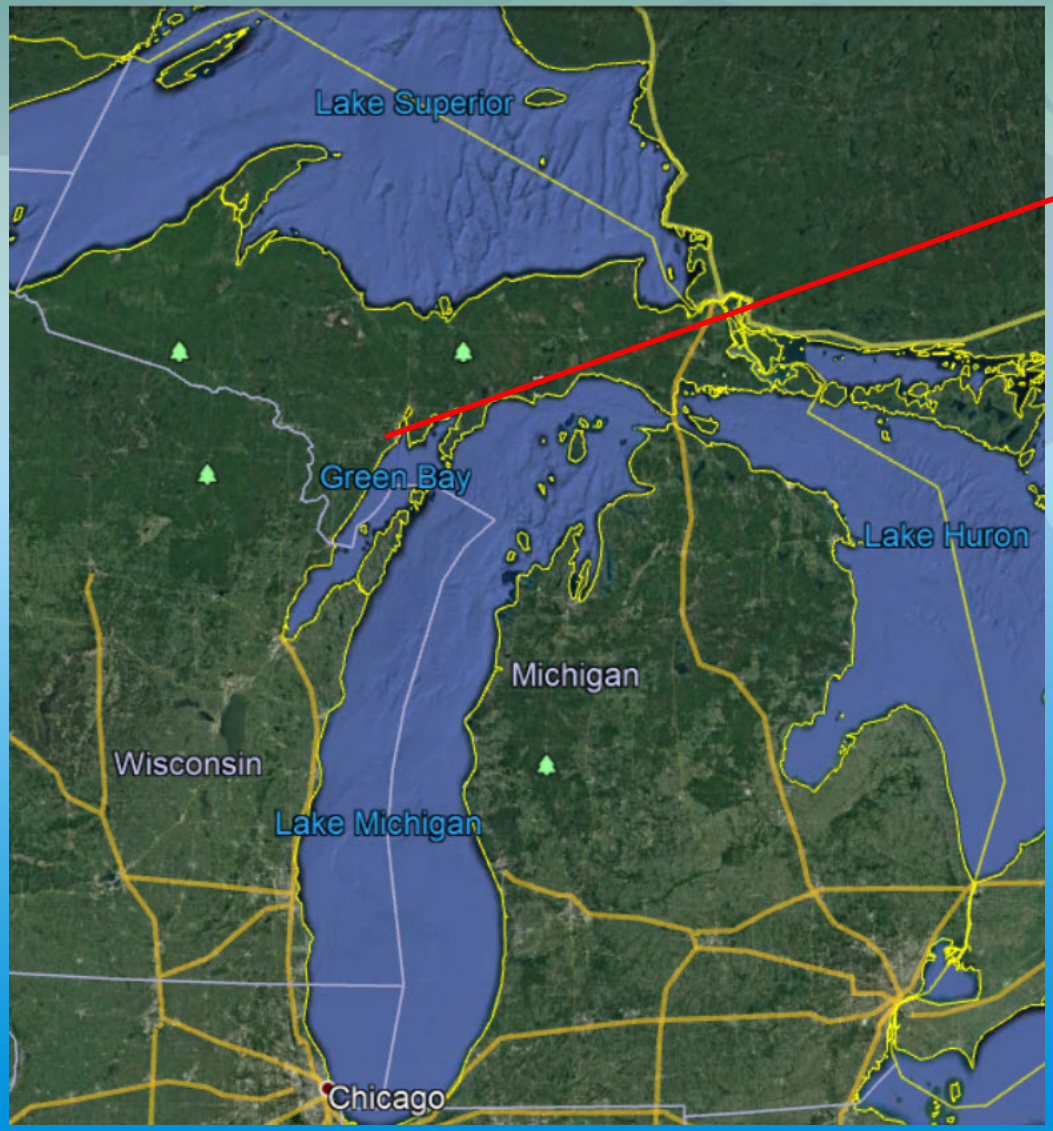
September 27, 2018

By Ryan Snook, P.E.
Foundation Analysis Engineer

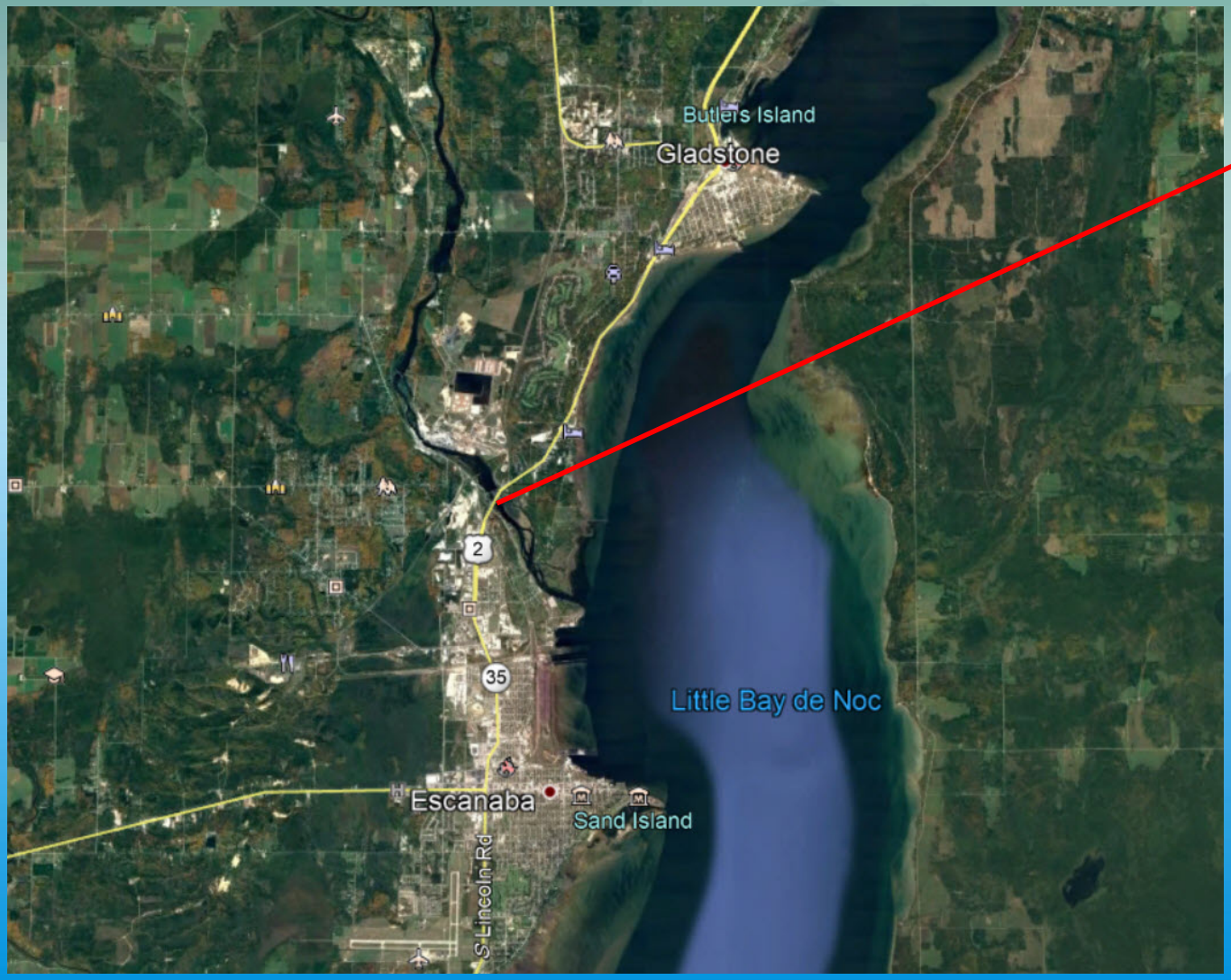
MDOT
Michigan Department of Transportation

BUREAU of BRIDGES
SPANNING SAFETY
CONNECTING EFFICIENTLY
and STRUCTURES

Project Overview



Project Overview



Site

Project Overview

Site

Existing Bridge

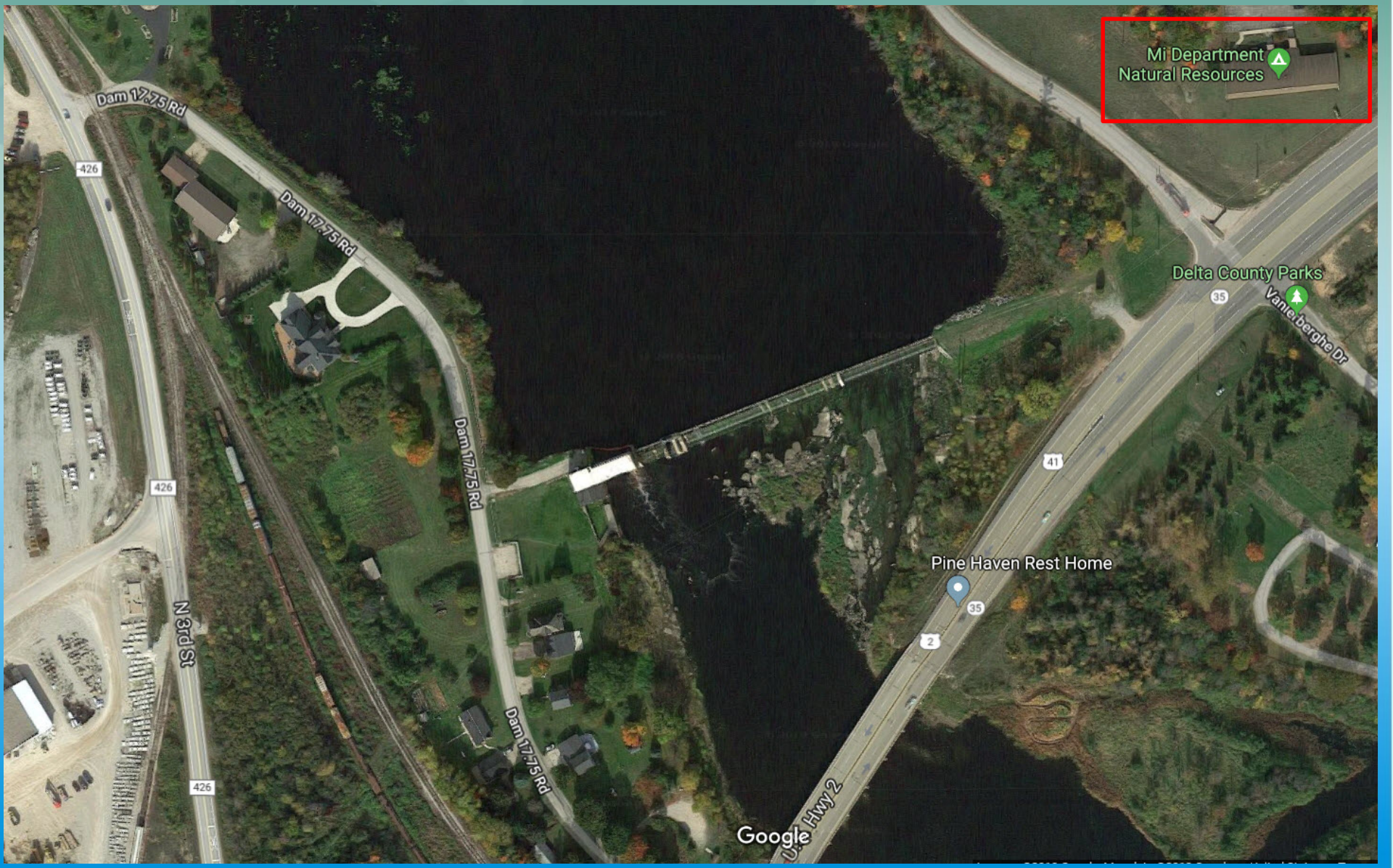
Existing Bridge

Existing Dam

Existing Bridge

Existing Bridge

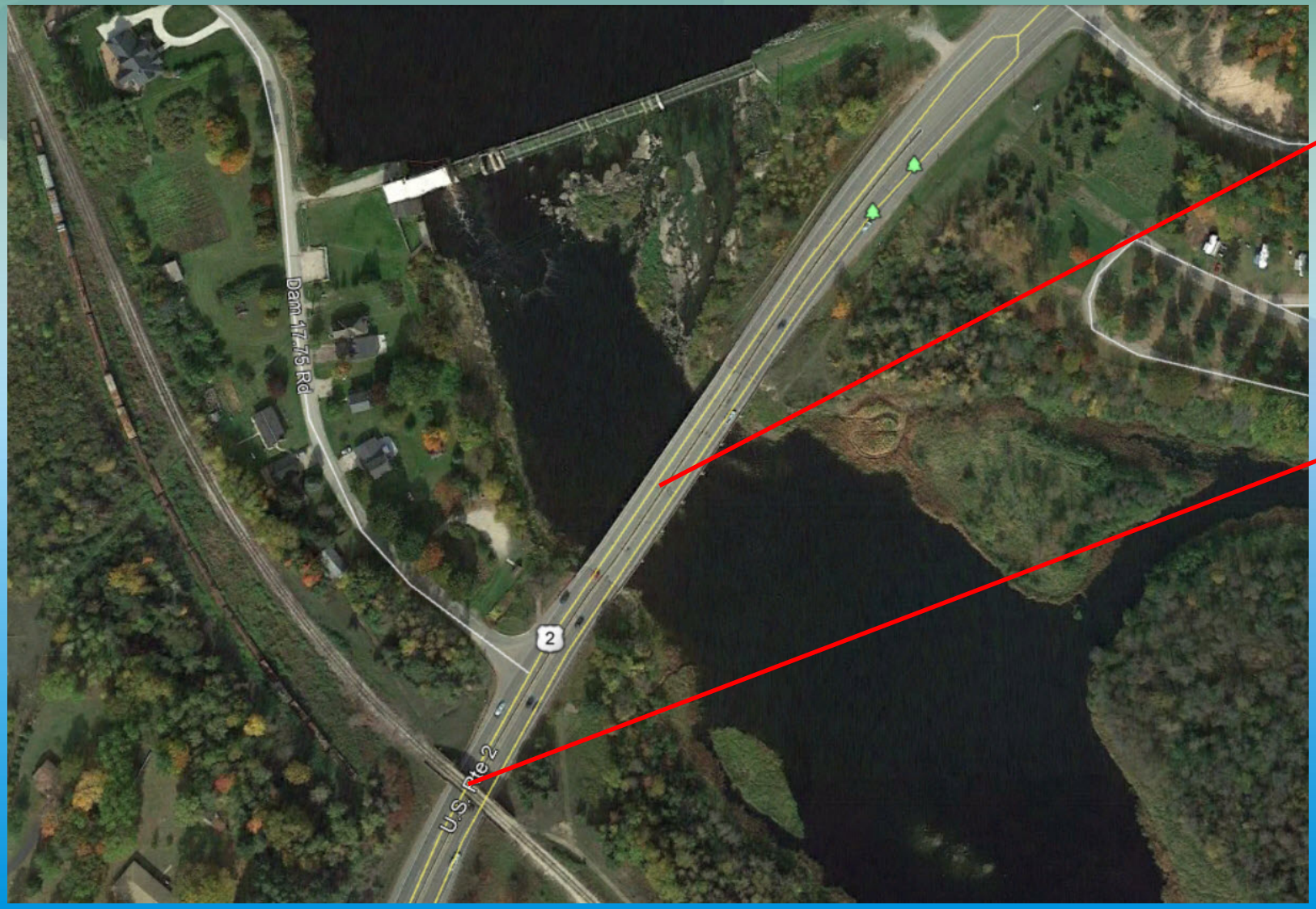
Site Overview



Adjacent Property

Adjacent Property

Project Overview



Site

RR Bridge

Existing Railroad Bridge

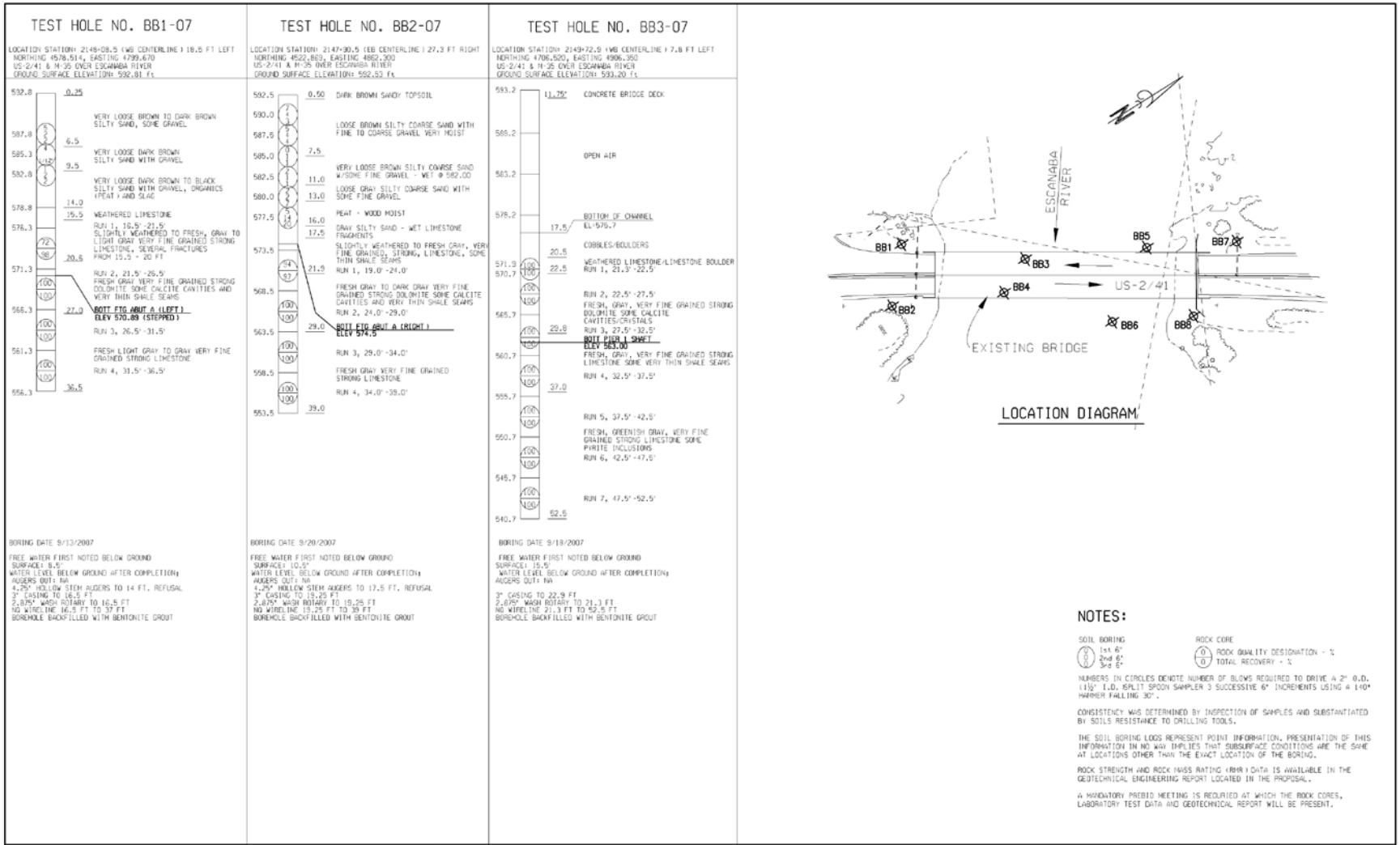
Existing Railroad Bridge

Design Phase

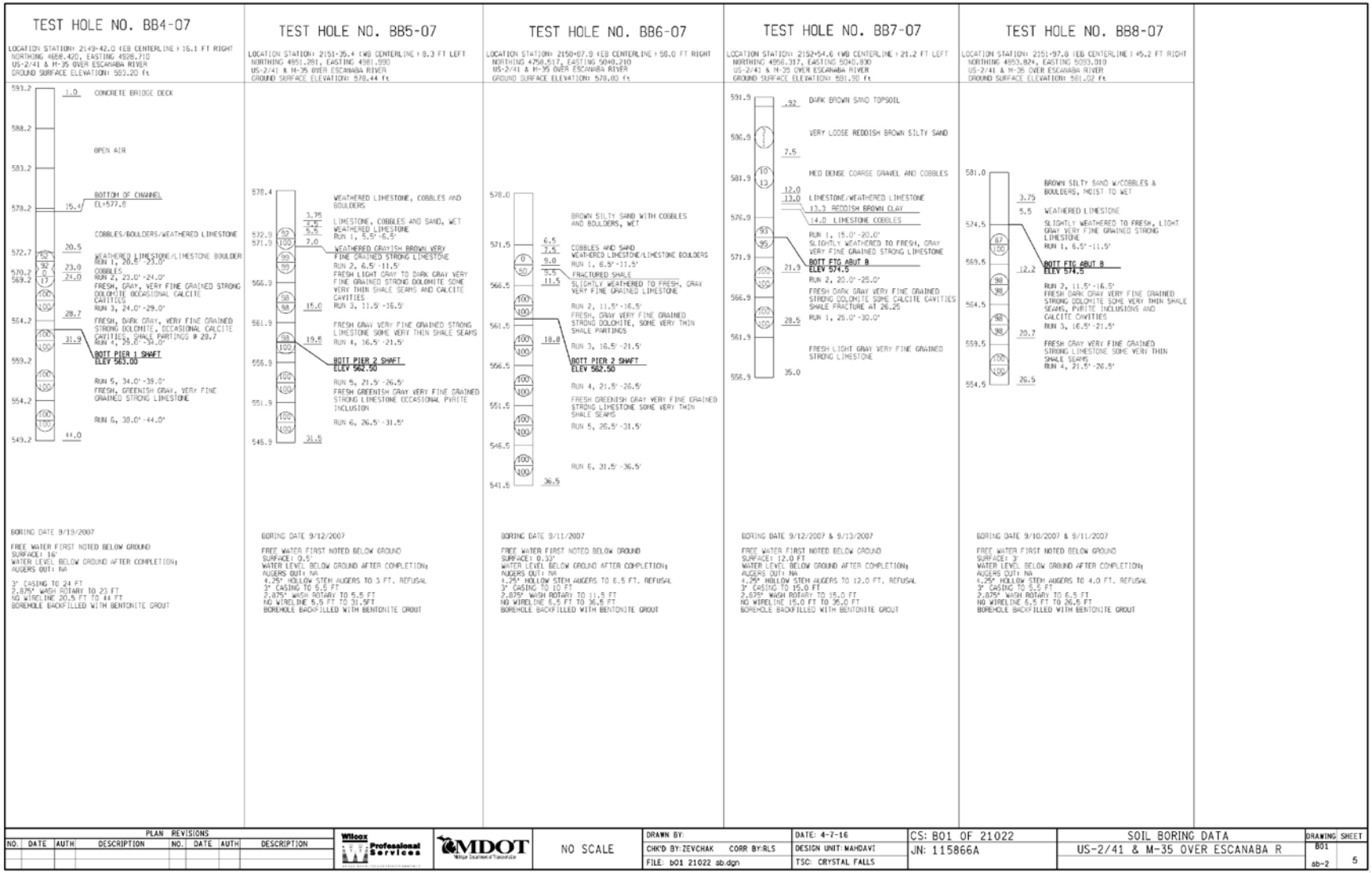
- Plan development began in 2007 (pre-LRFD design)
- Plan development cease in February 2008 due to railroad issue
- Consultant company preparing plans filed for bankruptcy in 2013
- Plan development restarted in 2016 (updated to current LRFD)
- Letting date of November 4, 2016

Soil Borings

Soil Borings

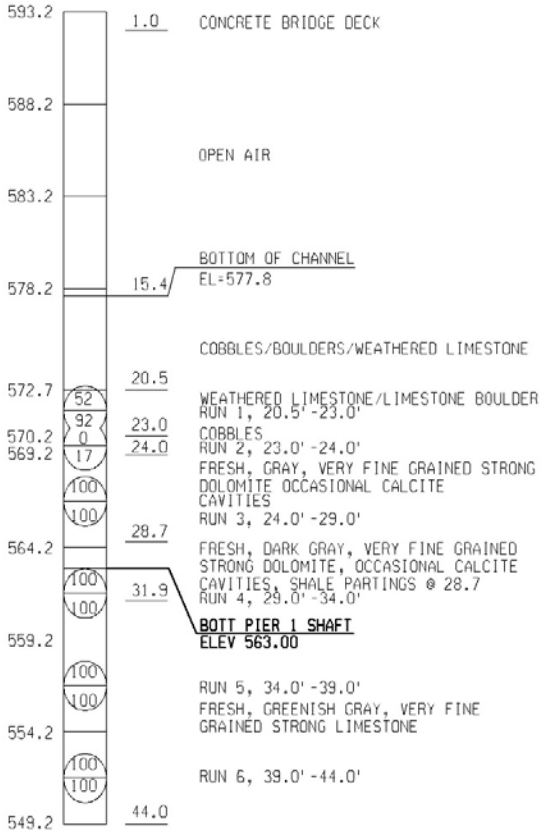


Soil Borings



TEST HOLE NO. BB4-07

LOCATION STATION: 2149+42.0 (EB CENTERLINE) 16.1 FT RIGHT
NORTHING 4658.420, EASTING 4928.710
US-2/41 & M-35 OVER ESCANABA RIVER
GROUND SURFACE ELEVATION: 593.20 ft



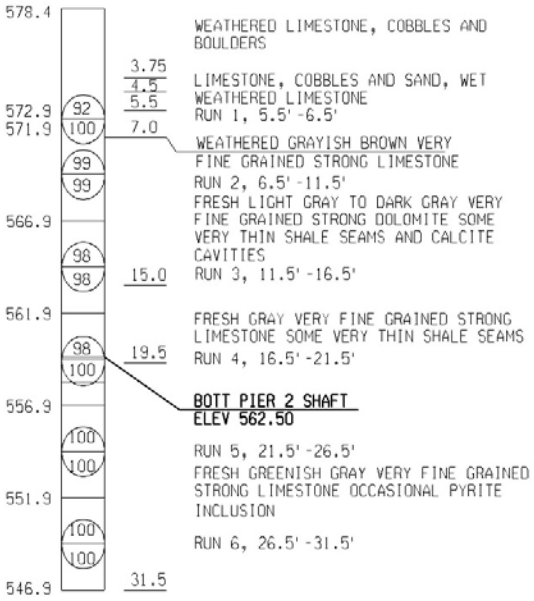
BORING DATE 9/19/2007

FREE WATER FIRST NOTED BELOW GROUND SURFACE: 16'
WATER LEVEL BELOW GROUND AFTER COMPLETION;
AUGERS OUT: NA

3" CASING TO 24 FT
2.875" WASH ROTARY TO 23 FT
NO WIRELINE 20.5 FT TO 44 FT
BOREHOLE BACKFILLED WITH BENTONITE GROUT

TEST HOLE NO. BB5-07

LOCATION STATION: 2151+35.4 (WB CENTERLINE) 8.3 FT LEFT
NORTHING 4851.281, EASTING 4981.990
US-2/41 & M-35 OVER ESCANABA RIVER
GROUND SURFACE ELEVATION: 578.44 ft

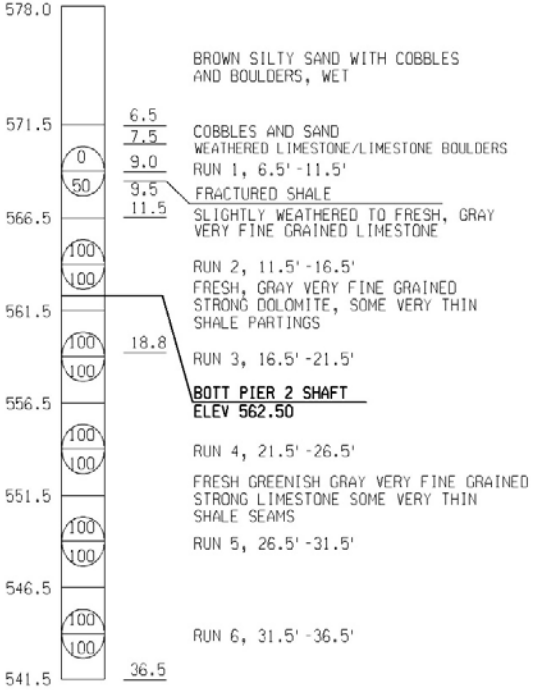


BORING DATE 9/12/2007

FREE WATER FIRST NOTED BELOW GROUND SURFACE: 0.5'
WATER LEVEL BELOW GROUND AFTER COMPLETION;
AUGERS OUT: NA
4.25" HOLLOW STEM AUGERS TO 3 FT. REFUSAL
3" CASING TO 5.5 FT
2.875" WASH ROTARY TO 5.5 FT
NO WIRELINE 5.5 FT TO 31.5FT
BOREHOLE BACKFILLED WITH BENTONITE GROUT

TEST HOLE NO. BB6-07

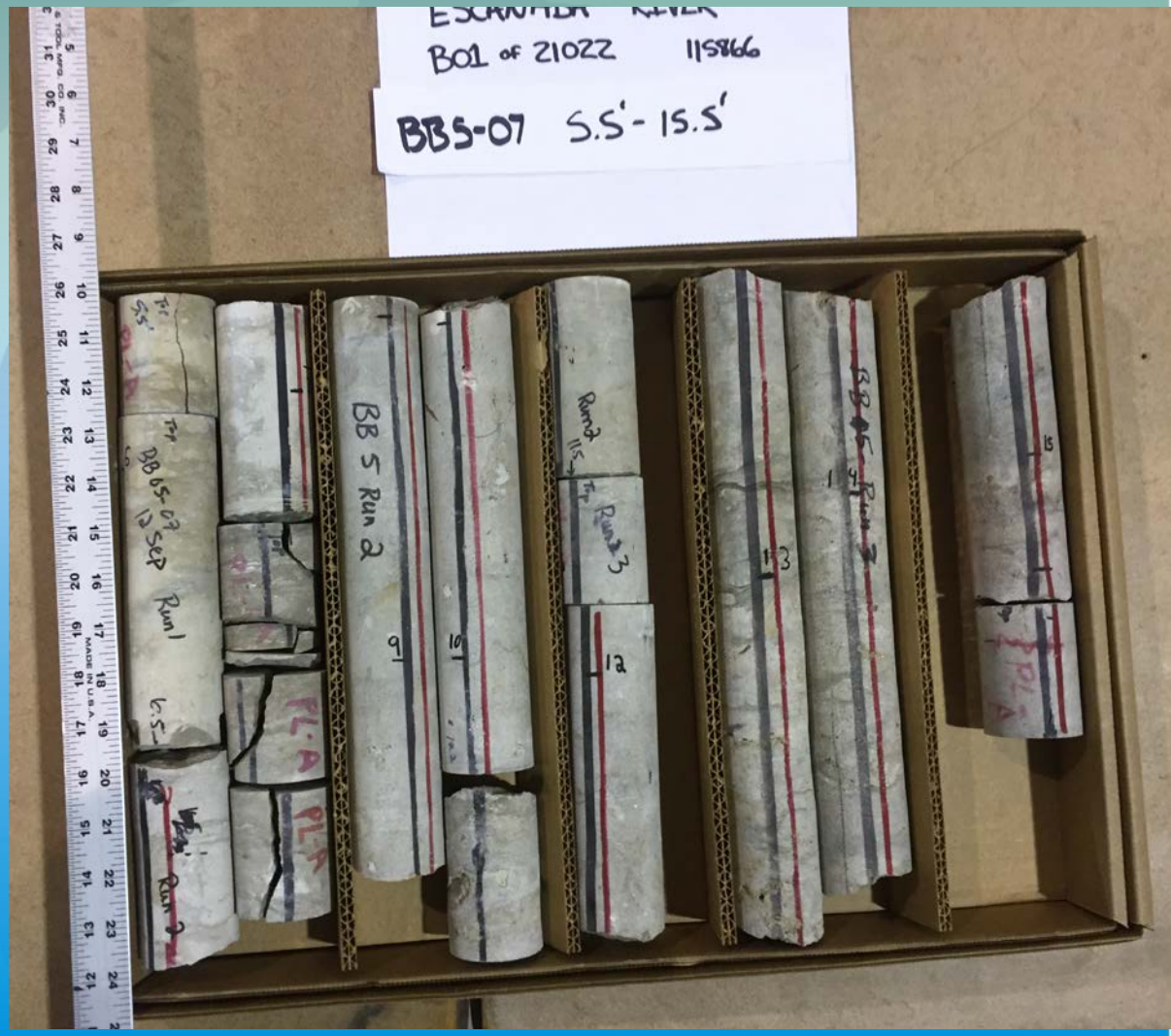
LOCATION STATION: 2150+87.9 (EB CENTERLINE) 56.0 FT RIGHT
NORTHING 4758.517, EASTING 5040.210
US-2/41 & M-35 OVER ESCANABA RIVER
GROUND SURFACE ELEVATION: 578.03 ft



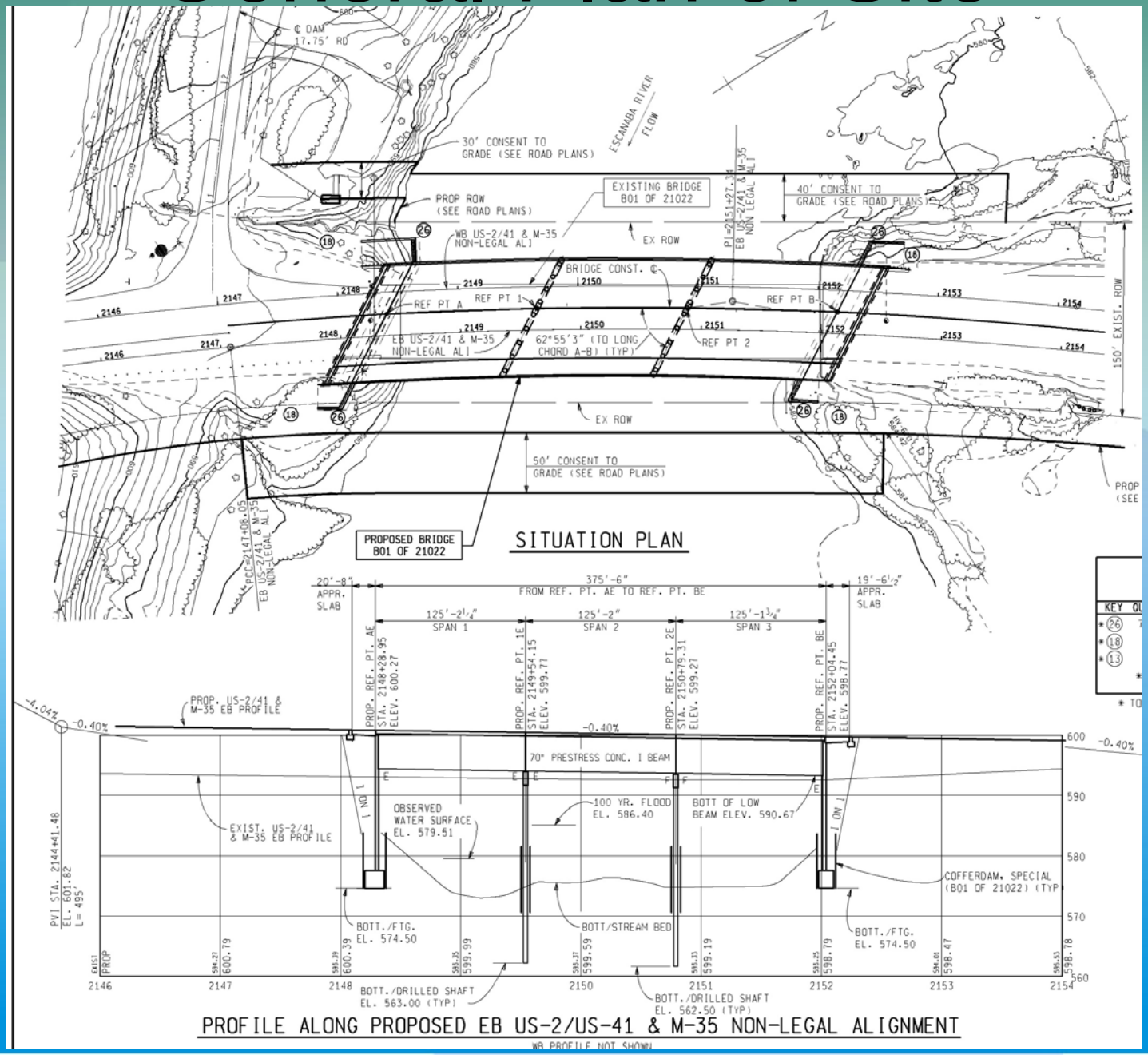
BORING DATE 9/11/2007

FREE WATER FIRST NOTED BELOW GROUND SURFACE: 0.33'
WATER LEVEL BELOW GROUND AFTER COMPLETION;
AUGERS OUT: NA
4.25" HOLLOW STEM AUGERS TO 6.5 FT. REFUSAL
3" CASING TO 10 FT
2.875" WASH ROTARY TO 11.5 FT
NO WIRELINE 6.5 FT TO 36.5 FT
BOREHOLE BACKFILLED WITH BENTONITE GROUT

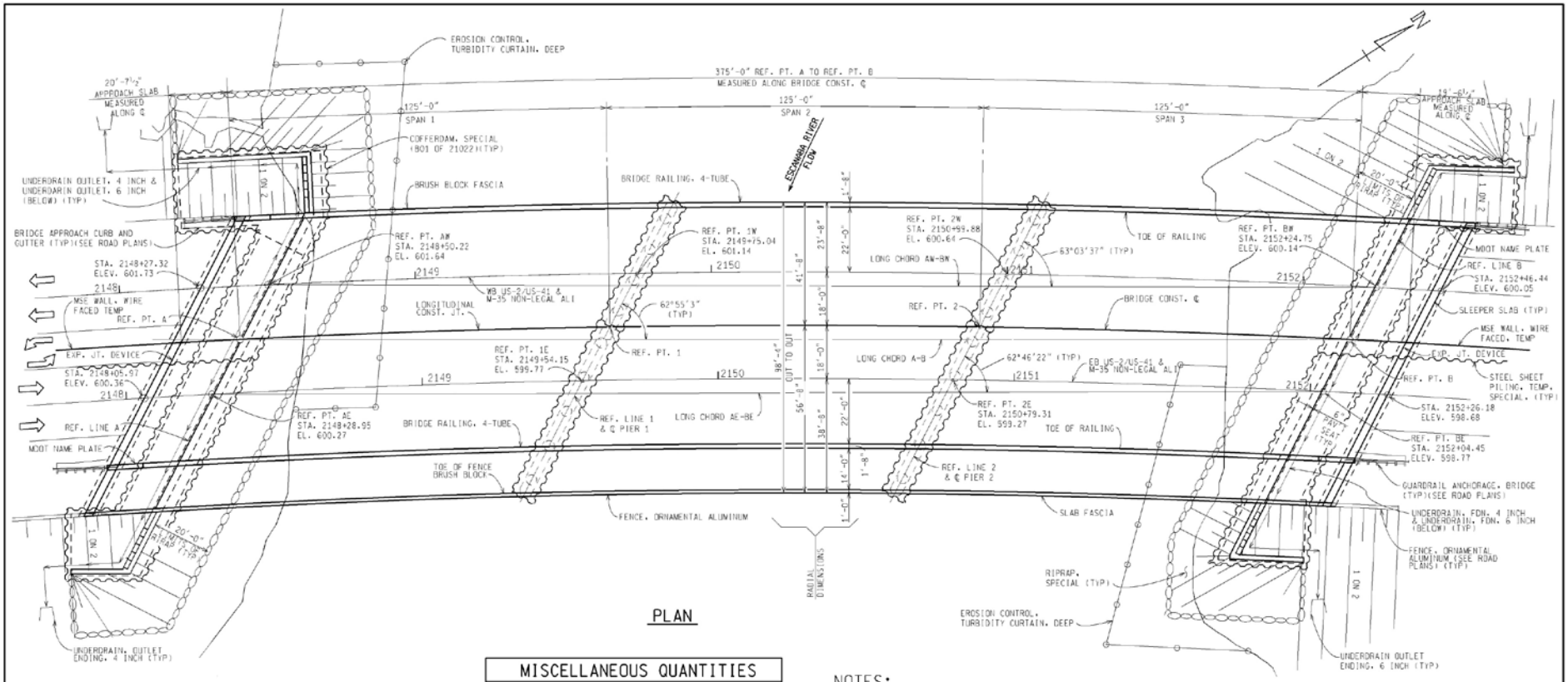
Rock Core Photos



General Plan of Site



General Plan of Structure



SUMMARY OF HYDRAULIC ANALYSIS							
EXISTING				PROPOSED			
FLOOD DATA	DIS-CHARGE (CFS)	WATER SURFACE ELEV. AT U/S FACE OF STRUCTURE	VELOCITY IN D/S CHANNEL (FPS)	WATER SURFACE ELEV. AT U/S FACE OF STRUCTURE	VELOCITY IN D/S CHANNEL (FPS)	WATERWAY AREA (SFT) AT D/S FACE	CHANGE IN WS EL U/S OF PROPOSED STRUCTURE
50 YEAR	13,000	588.65	12.92	585.96	4.69	2774.31	-2.69
100 YEAR	14,000	589.15	13.10	586.40	4.79	2919.89	-2.75
MAXIMUM BRIDGE AREA BELOW LOW CHORD IS 4477.06 SQUARE FEET							

BROKEN CONCRETE SHALL NOT BE USED FOR RIPRAP.

THE EXISTING MAXIMUM BRIDGE AREA BELOW THE LOW CHORD IS 1810.11 SQUARE FEET.

THE DRAINAGE AREA CONTRIBUTORY TO THIS CROSSING IS 902 SQUARE MILES.

THE WATER SURFACE AND/OR ENERGY GRADE ELEVATIONS SHOWN ON THE ABOVE HYDRAULIC TABLE ARE TO BE USED FOR COMPARISON PURPOSES ONLY AND ARE NOT TO BE USED FOR ESTABLISHING A REGULATORY FLOODPLAIN. THE ELEVATIONS MAY BE USED PROVIDED THEY ARE VERIFIED WITH THE LAND AND WATER MANAGEMENT DIVISION, MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY.

MISCELLANEOUS QUANTITIES

36,850 Sft	False Decking
3200 Cyd	Excavation, Fdn
1 LSUM	Structures, Rem (B01 OF 21022)
2670 Ton	Riprap, Special
1200 Cyd	Excavation, Rock Fdn
310 Ft	Underdrain, Fdn, 4 inch
210 Ft	Underdrain Outlet, 4 inch
4 Ea	Underdrain, Outlet Ending, 4 inch
310 Ft	Underdrain, Fdn, 6 inch
210 Ft	Underdrain Outlet, 6 inch
4 Ea	Underdrain, Outlet Ending, 6 inch
945 Cyd	Open-Graded Dr Cse, CIP
680 Syd	Geotextile, Separator
1 LSUM	Cofferdam, Special (B01 of 21022)
1000 Sft	Mechanically Stabilized Earth Wall, Wire Faced,Temp, Furn
1000 Sft	Mechanically Stabilized Earth Wall, Wire Faced,Temp, Install
2000 Cyd	Backfill, Select
2500 Sft	Steel Sheet Piling, Temp, Special
1 LSUM	Conc Surface Coating,Warranty (B01 OF 21022)
50 Cyd	Aggregate, 6A
2300 Cyd	Backfill,Structure, CIP
1 LSUM	Vibration Monitoring
400 Ft	Erosion Control, Turbidity Curtain, Deep

NOTES:

THE DESIGN OF THIS STRUCTURE IS BASED ON 1.2 TIMES THE CURRENT AASHTO LRFD BRIDGE DESIGN SPECIFICATION HL-93 LOADING WITH THE EXCEPTION THAT THE DESIGN TANDEM PORTION OF THE HL-93 LOAD DEFINITION SHALL BE REPLACED BY A SINGLE 60 KIP AXLE LOAD BEFORE APPLICATION OF THIS 1.2 FACTOR. THE RESULTING LOAD IS DESIGNATED HL-93 MOD. LIVE LOAD PLUS DYNAMIC LOAD ALLOWANCE DEFLECTION DOES NOT EXCEED 1/1000 OF SPAN LENGTH

THE DESIGN OF THE DECK SLAB IS BASED UPON THE STRIP METHOD AS DEFINED IN THE CURRENT AASHTO LRFD BRIDGE DESIGN SPECIFICATION.

GEOTEXTILE LINER SHALL BE PLACED ON ALL SLOPES PRIOR TO PLACING RIPRAP. PAYMENT FOR GEOTEXTILE LINER SHALL BE INCLUDED IN THE PAYMENT FOR RIPRAP.

THE ABUTMENT MAXIMUM AVERAGE FOUNDATION PRESSURE IS CALCULATED TO BE 4200 PSF FOR SERVICE LIMIT STATE, AND 5620 PSF FOR STRENGTH LIMIT STATE AND ARE BASED ON A GROSS FOOTING WIDTH OF 16 FT.

THE ABUTMENT AT THE NORTHWEST QUADRANT HAS A MAXIMUM AVERAGE FOUNDATION PRESSURE CALCULATED TO BE 4480 PSF FOR SERVICE LIMIT STATE, AND 5990 PSF FOR STRENGTH LIMIT STATE AND ARE BASED ON A GROSS FOOTING WIDTH OF 18.5 FT.

CONTACT THE REGION SOILS ENGINEER TO PERFORM A FOOTING CHECK A MINIMUM OF 72 HOURS PRIOR TO POURING THE SUBFOOTING

THE BID ITEM "STRUCTURES, REM (B01 OF 21022)" INCLUDES COMPLETE REMOVAL OF THE TEMPORARY ACCESS ROADS, EXISTING BRIDGE SUPERSTRUCTURE, ABUTMENTS AND PIERS.

FALSE DECKING SHALL INCLUDE THE AREA BOUNDED BY REFERENCE LINES A & B AND OUTSIDE FLANGE FASCIAS OF BEAMS A & P. THE ESTIMATED AREA IS 20,600 SQUARE FEET DURING REMOVAL AND 36,850 SQUARE FEET DURING PROPOSED CONSTRUCTION.

ITEMS CAST INTO STRUCTURAL PRECAST CONCRETE TO FACILITATE BRIDGE CONSTRUCTION (FORMING, FINISHING, ETC.) SHALL BE GALVINIZED OR EPOXY COATED.

DO NOT USE WHEELED, ROLLER BASED OR MACHINE MOUNTED COMPACTION EQUIPMENT TO COMPACT THE SUBGRADE, SUBBASE, AND BASE WITHIN 10' OF THE SLEEPER SLAB AFTER IT IS BUILT. USE ONLY HAND/PLATE COMPACTORS. CONTACT PRESSURE OF COMPACTION EQUIPMENT SHALL NOT EXCEED 10 PSI.

CONCRETE SURFACE COATING SHALL BE APPLIED TO THE RAILING AND FENCING BRUSHBLOCK, END WALLS, SLAB FASCIAS, DECK SOFFITS FROM SLAB FASCIA TO FASCIA BEAM, FASCIA BEAMS AND ALL EXPOSED SUBSTRUCTURE CONCRETE SURFACES. THE ESTIMATED AREA OF CONCRETE SURFACE COATING IS 2870 SQUARE YARDS. BOTTOM AND OUTSIDE OF FASCIA BEAMS SHALL BE COATED WITH FEDERAL STANDARD 595C, COLOR NUMBER 36350, DARK BEIGE. THE REMAINING COATED AREAS SHALL BE COATED WITH FEDERAL STANDARD 595C COLOR NUMBER 36405, PARCHMENT.

PLAN REVISIONS							
NO.	DATE	AUTH	DESCRIPTION	NO.	DATE	AUTH	DESCRIPTION

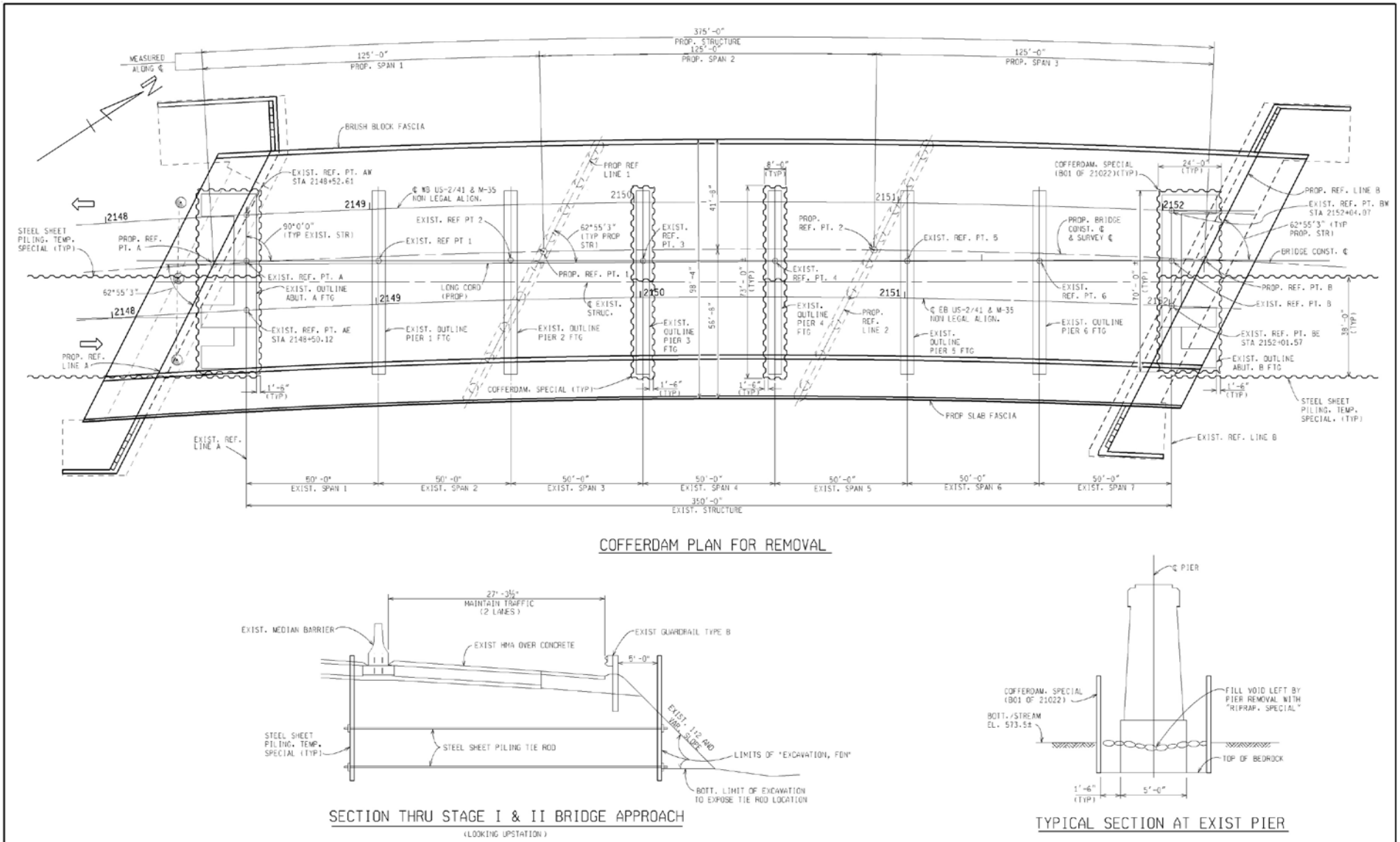
MDOT Michigan Department of Transportation

NO SCALE

DRAWN BY: SHAFFER	DATE: 08/29/2016	CS: B01 OF 21022	GENERAL PLAN OF STRUCTURE
CHK'D BY: ZEVCHAK CORR BY: RLS	DESIGN UNIT: MAHDAVI	JN: 115866A	US-2/US-41 & M-35 OVER ESCANABA R
FILE: b01 21022 st.dgn	TSC: CRYSTAL FALLS		

DRAWING	SHEET
B01 st-2	8

General Plan of Structure



PLAN REVISIONS							
NO.	DATE	AUTH	DESCRIPTION	NO.	DATE	AUTH	DESCRIPTION

MDOT

NO SCALE

DRAWN BY: DUDA
CHK'D BY: ZEVCHAK CORR BY: RLSMR
FILE: b01 21022 st.dgn

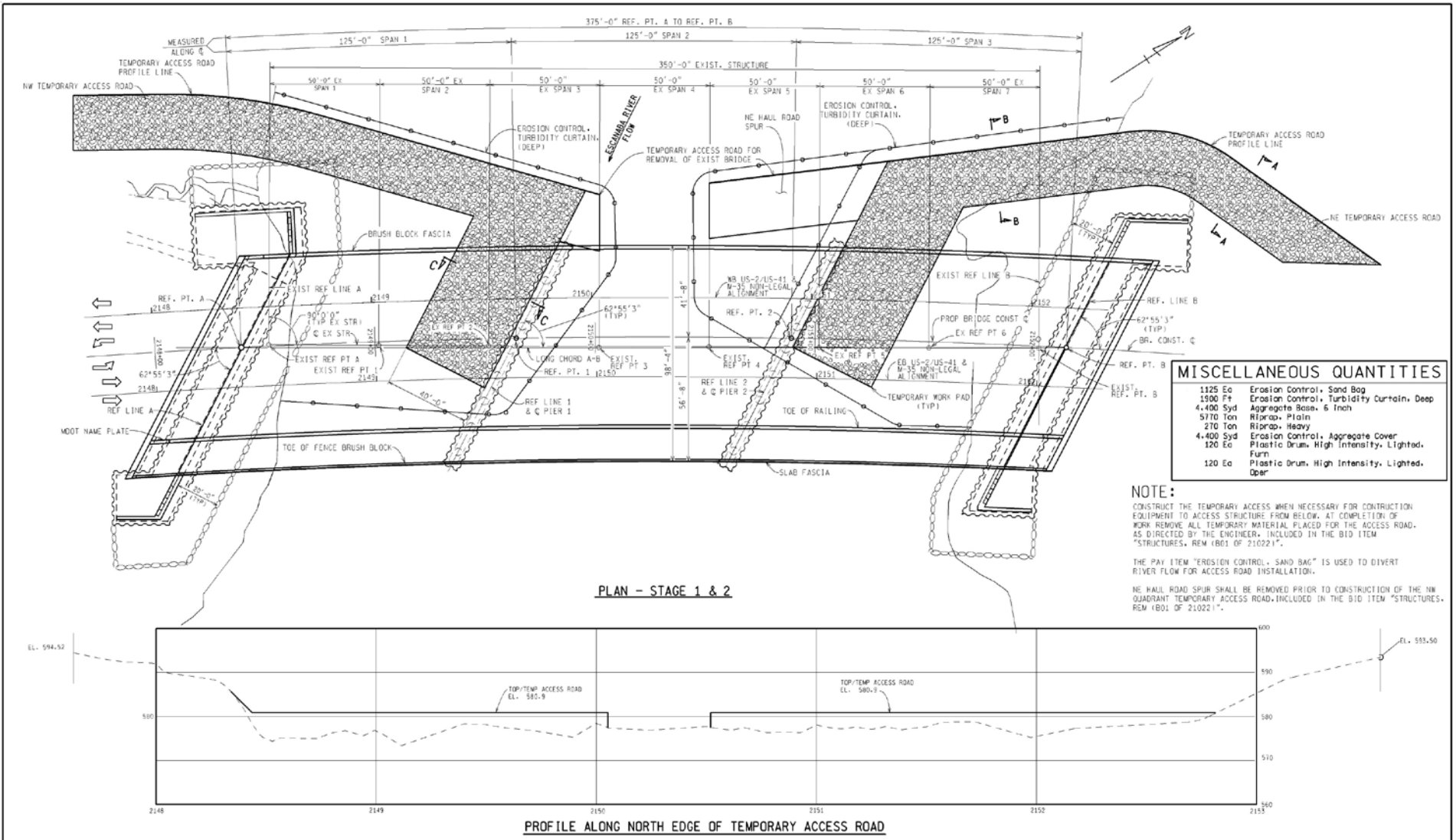
DATE: 8-17-16
DESIGN UNIT: MAHDAVI
TSC: CRYSTAL FALLS

CS: B01 OF 21022
JN: 115866A

GENERAL PLAN OF STRUCTURE
US-2/US-41 & M-35 OVER ESCANABA R

DRAWING | SHEET
8

General Plan of Structure



MISCELLANEOUS QUANTITIES

1125	Ea	Erosion Control, Sand Bag
1900	Ft	Erosion Control, Turbidity Curtain, Deep
4,400	Syd	Aggregate Base, 6 Inch
5770	Ton	Riprap, Plain
270	Ton	Riprap, Heavy
4,400	Syd	Erosion Control, Aggregate Cover
120	Ea	Plastic Drum, High Intensity, Lighted, Furn
120	Ea	Plastic Drum, High Intensity, Lighted, Oper

NOTE:

CONSTRUCT THE TEMPORARY ACCESS WHEN NECESSARY FOR CONTRUCTION EQUIPMENT TO ACCESS STRUCTURE FROM BELOW. AT COMPLETION OF WORK REMOVE ALL TEMPORARY MATERIAL PLACED FOR THE ACCESS ROAD. AS DIRECTED BY THE ENGINEER. INCLUDED IN THE BID ITEM "STRUCTURES, REM (B01 OF 21022)".

THE PAY ITEM "EROSION CONTROL, SAND BAG" IS USED TO DIVERT RIVER FLOW FOR ACCESS ROAD INSTALLATION.

NE HAUL ROAD SPUR SHALL BE REMOVED PRIOR TO CONSTRUCTION OF THE NW QUADRANT TEMPORARY ACCESS ROAD. INCLUDED IN THE BID ITEM "STRUCTURES, REM (B01 OF 21022)".

PLAN REVISIONS							
NO.	DATE	AUTH	DESCRIPTION	NO.	DATE	AUTH	DESCRIPTION

MDOT Michigan Department of Transportation

NO SCALE

DRAWN BY: J WILLIAMS
CHK'D BY: A. ZEVCHAK CORR BY: RLS
FILE: b01 21022 haul.dgn

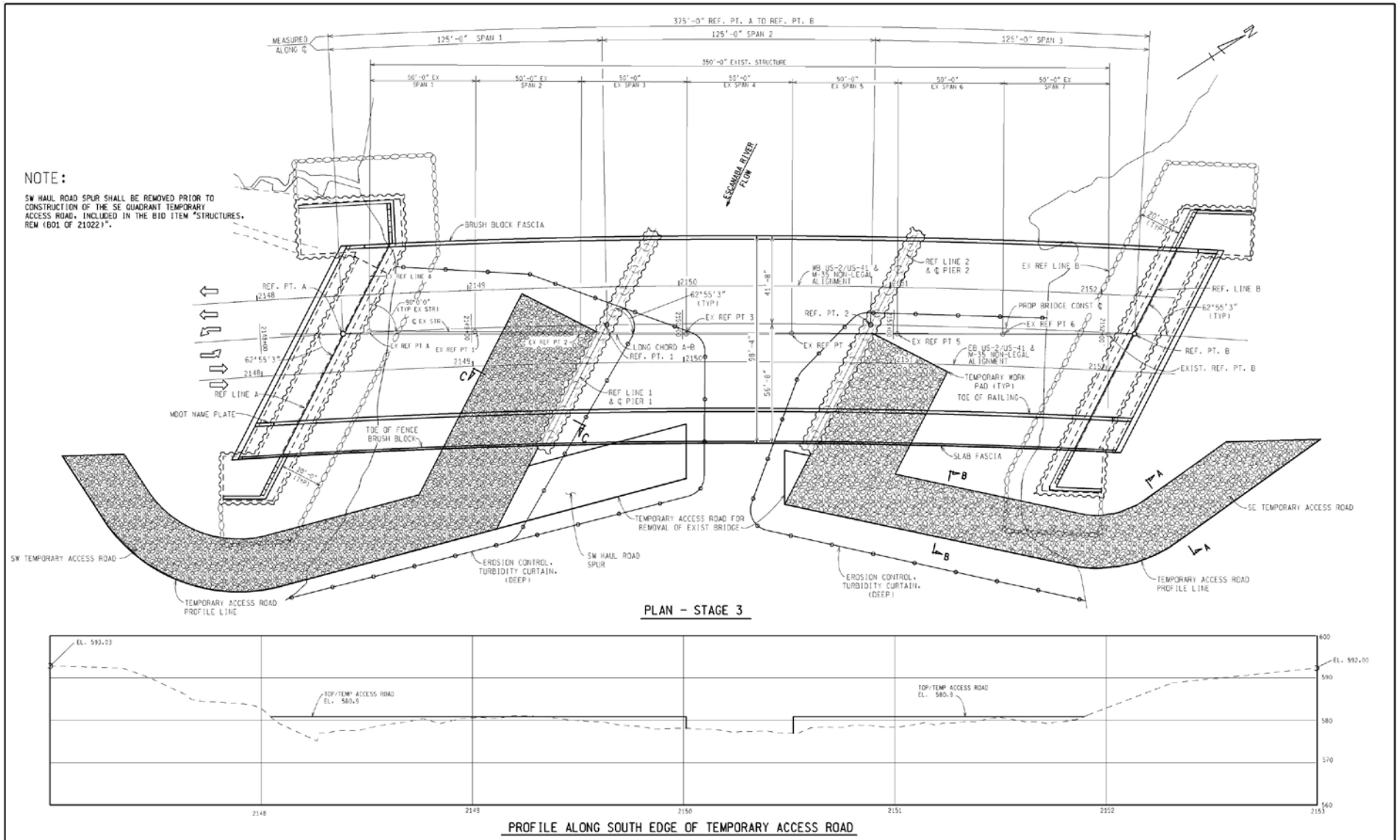
DATE: 9/6/2016
DESIGN UNIT: MAHDAVI
TSC: CRYSTAL FALLS

CS: B01 OF 21022
JN: 115866A

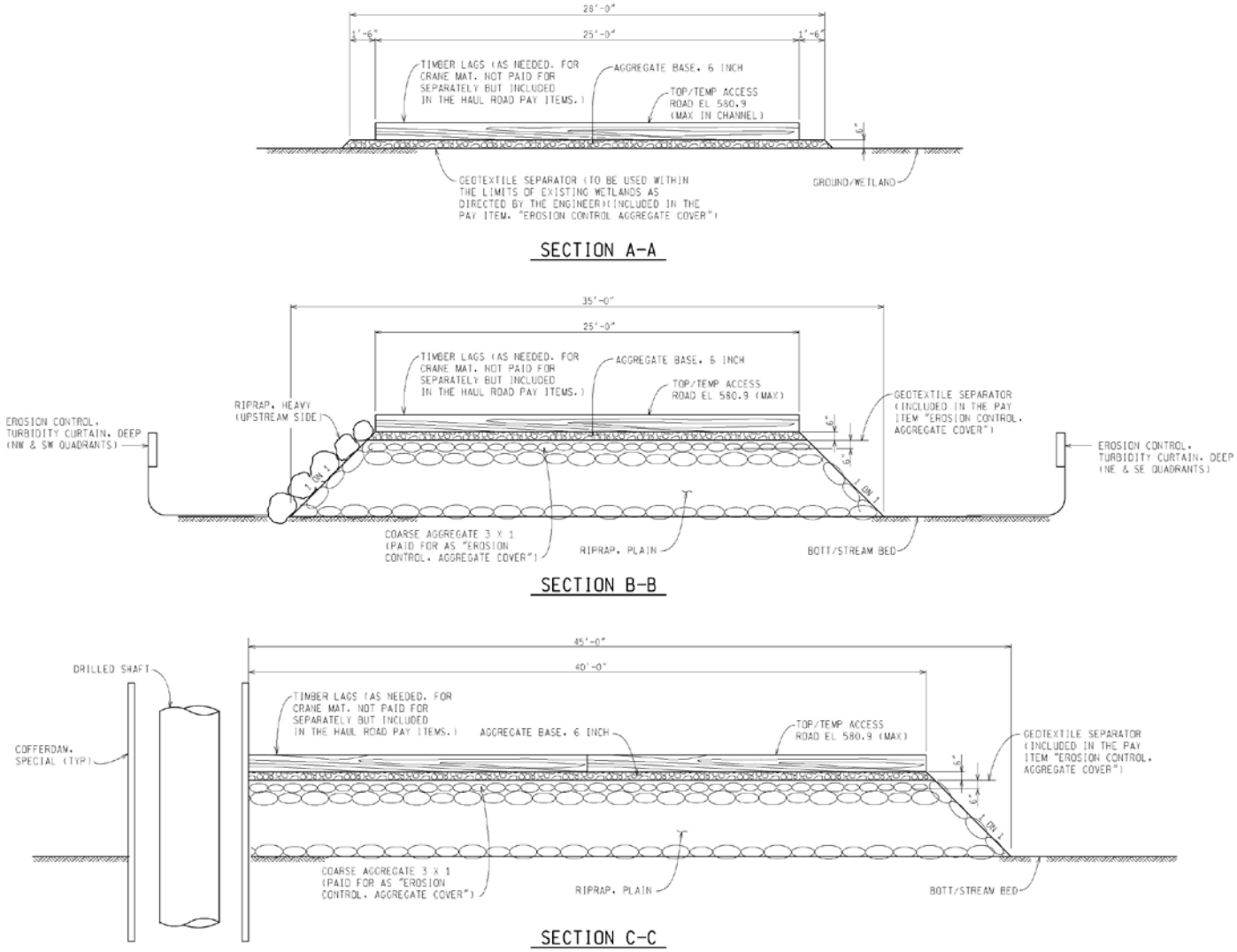
GENERAL PLAN OF STRUCTURE
US-2/US-41 & M-35 OVER ESCANABA RIVER

DRAWING: B01 st-1
SHEET: 11

General Plan of Structure



General Plan of Structure



PLAN REVISIONS							
NO.	DATE	AUTH	DESCRIPTION	NO.	DATE	AUTH	DESCRIPTION

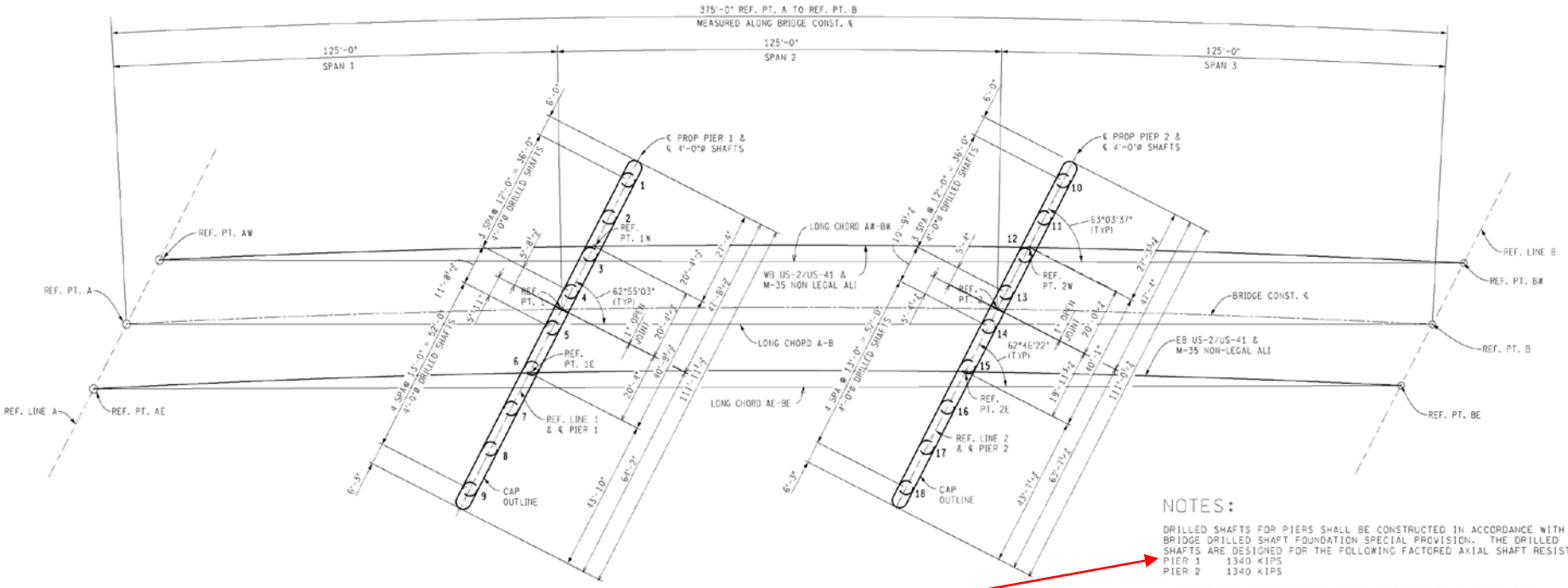
MDOT Michigan Department of Transportation

NO SCALE

DRAWN BY: J WILLIAMS	DATE: 4-7-16	CS: B01 OF 21022	GENERAL PLAN OF STRUCTURE
CHK'D BY: ZEVCHAK CORR BY: RLS	DESIGN UNIT: MAHDAVI	JN: 115866A	US-2/US-41 & M-35 OVER ESCANABA RIVE
FILE: b01 21022 haul.dgn	TSC: CRYSTAL FALLS		

DRAWING	SHEET
b01	13

Drilled Shafts



PLAN OF DRILLED SHAFT LAYOUT

NOTES:

DRILLED SHAFTS FOR PIERS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE BRIDGE DRILLED SHAFT FOUNDATION SPECIAL PROVISION. THE DRILLED SHAFTS ARE DESIGNED FOR THE FOLLOWING FACTORED AXIAL SHAFT RESISTANCE:
PIER 1 1340 KIPS
PIER 2 1340 KIPS

Nominal of 2680 kips, end bearing

MISCELLANEOUS QUANTITIES	
1 LSUM	Drilled Shaft Equipment, Furn, Special (801 OF 21022)
126 Ft	Drilled Shaft, Rock, 42 inch
360 Ft	Drilled Shaft, Standard, 48 inch
360 Ft	Permanent Casing
50000 Dlr	Obstruction Removal, Special
2200 Ft	Crosshole Sonic Logging Access Tube
18 Ea	Crosshole Sonic Log Testing

NOTES:

DRILLED SHAFTS FOR PIERS SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE BRIDGE DRILLED SHAFT FOUNDATION SPECIAL PROVISION. THE DRILLED SHAFTS ARE DESIGNED FOR THE FOLLOWING FACTORED AXIAL SHAFT RESISTANCE:
PIER 1 1340 KIPS
PIER 2 1340 KIPS

CONCRETE FOR DRILLED SHAFTS SHALL BE GRADE S2 OR GRADE T IN ACCORDANCE WITH THE SPECIAL PROVISION FOR BRIDGE DRILLED SHAFT FOUNDATION.

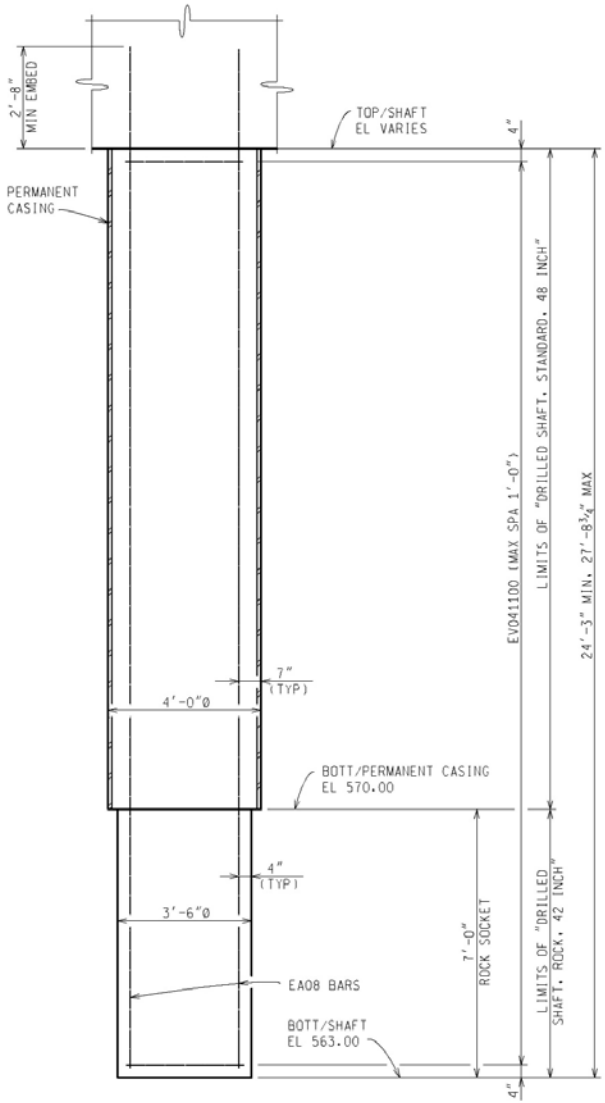
THE BOTTOM OF THE DRILLED SHAFTS ELEVATION IS BASED ON THE BORING LOGS. THE ACTUAL GROUND LINE MAY VARY.

CONCRETE AND STEEL REINFORCEMENT FOR DRILLED SHAFT IS NOT PAID FOR SEPARATELY, BUT INCLUDED IN ALL THE DRILLED SHAFT BID ITEMS. CONCRETE AND STEEL REINFORCING QUANTITIES SHOWN ARE FOR ONE DRILLED SHAFT ONLY AND ARE FOR INFORMATION ONLY. FOR DRILLED SHAFT AND OTHER RELATED ITEMS, SEE SPECIAL PROVISION FOR BRIDGE DRILLED SHAFT FOUNDATION.

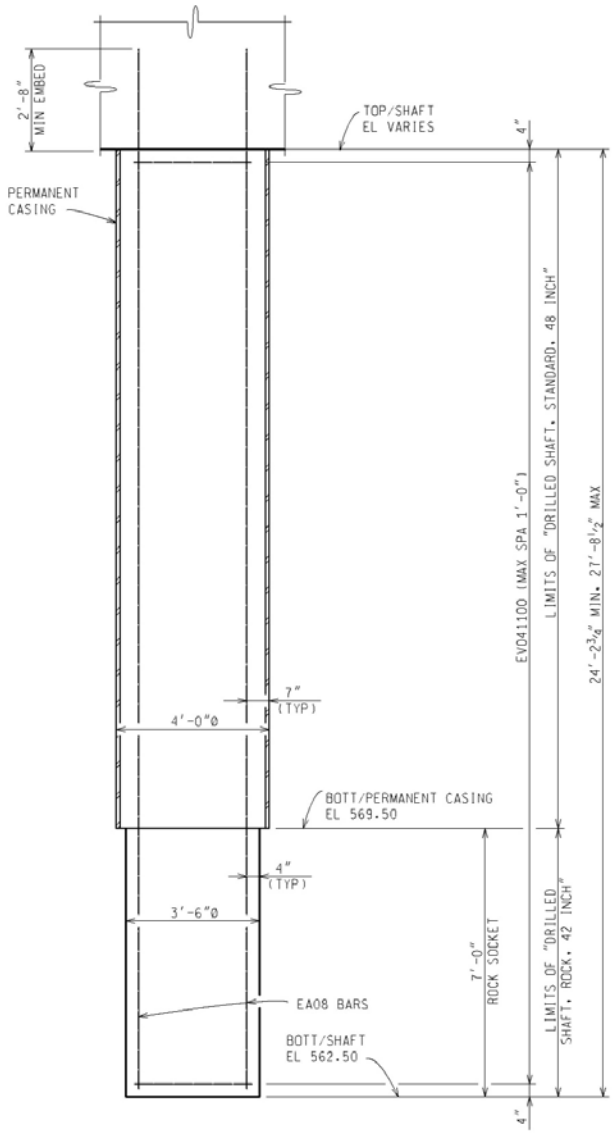
DRILLED SHAFT PERMANENT CASING SHALL HAVE A MINIMUM OF 4'-0" O.D. AND 0.5 INCH THICKNESS FOR PIERS 1 & 2.

LOW TEMPERATURE PROTECTION OF CONCRETE SHALL BE APPLIED ACCORDING TO SECTION 706.03 J OF THE STANDARD SPECIVICATIONS FOR CONSTRUCTION. LOW TEMPERATURE PROTECTION OF CONCRETE SHALL NOT BE PAID FOR SEPARATELY, BUT WILL BE INCLUDED IN THE BID ITEMS FOR DRILLED SHAFTS.

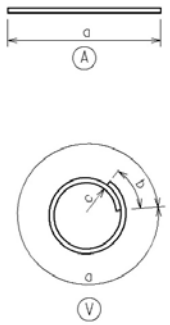
Drilled Shaft Details

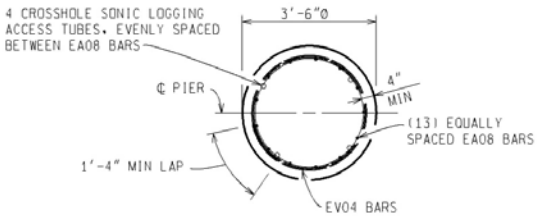


DRILLED SHAFT - PIER 1

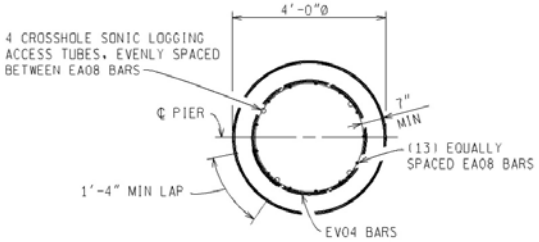


DRILLED SHAFT - PIER 2





SECTION THRU COLUMN - ROCK SOCKET



SECTION THRU COLUMN - DRILLED SHAFT

Letting Results

Letting of November 04, 2016

Letting Call: 1611 017

Low Bid: $18,315,597.17

Project: BRT 21022-113777 , ETC

Engineer Estimate: $18,050,285.72

Local Agreement:

Pct Over/Under Estimate: 1.47 %

Start Date: April 17, 2017

Completion Date: September 21, 2018

Description:

Replacement of two bridges, installation of ice detection and other weather sensors, construction of one box culvert, concrete surface coating, road reconstruction and realignment, and widening on US-2/M-41/M-35 over the Escanaba River, Delta County. This project includes a 5 year materials and workmanship pavement warranty and a 2 year warranty on concrete surface coating.

3.00 % DBE participation required

Bidder	As-Submittted
Zenith Tech, Inc.	$18,315,597.17
Anlaan Corporation	$19,597,320.07

Total Number of Bidders: 2

Construction

Construction

Construction

Construction

Construction

Construction

Construction

Construction

Be aware of traffic.
Safety first.

Construction

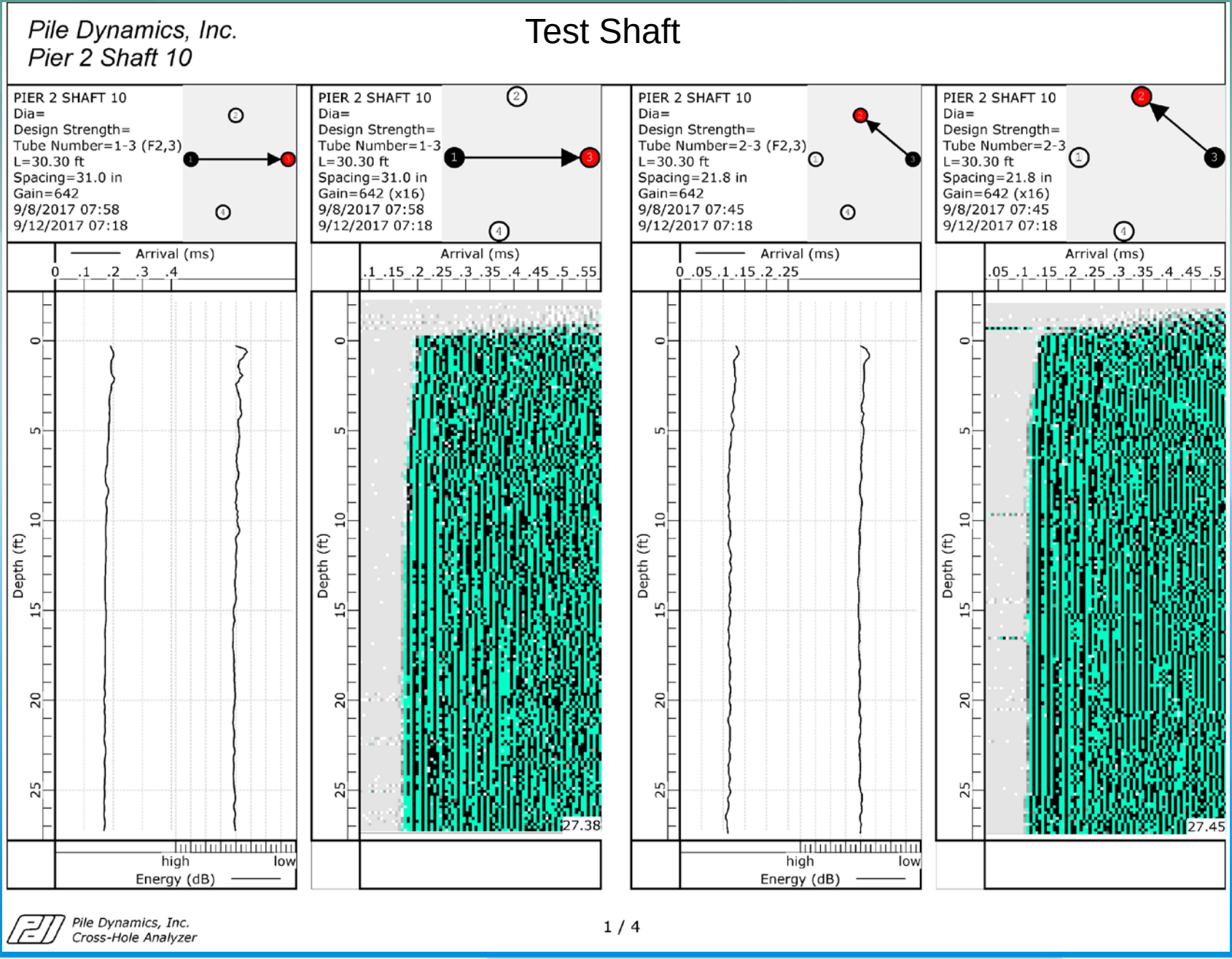
Construction

Construction

Construction

- Test shaft was installed first without an issues and CSL testing was acceptable.
- Overall, 2 of the first 4 shafts at Pier 2 were able to be sealed and were dry pours
- The other 2 shafts of the first 4 were wet pours by tremie tube.
- The remaining shafts were CSL tested successfully and were accepted.

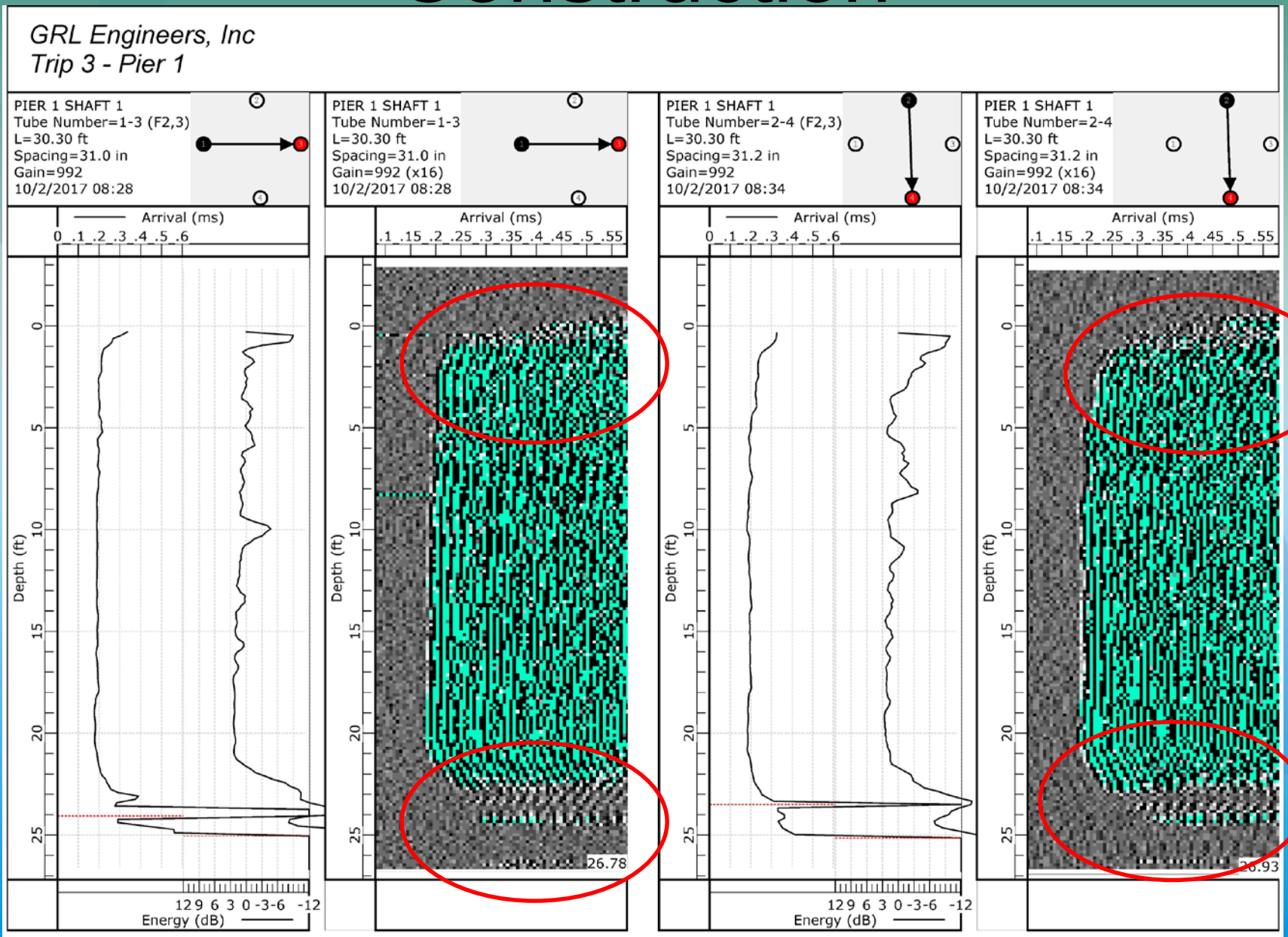
Construction



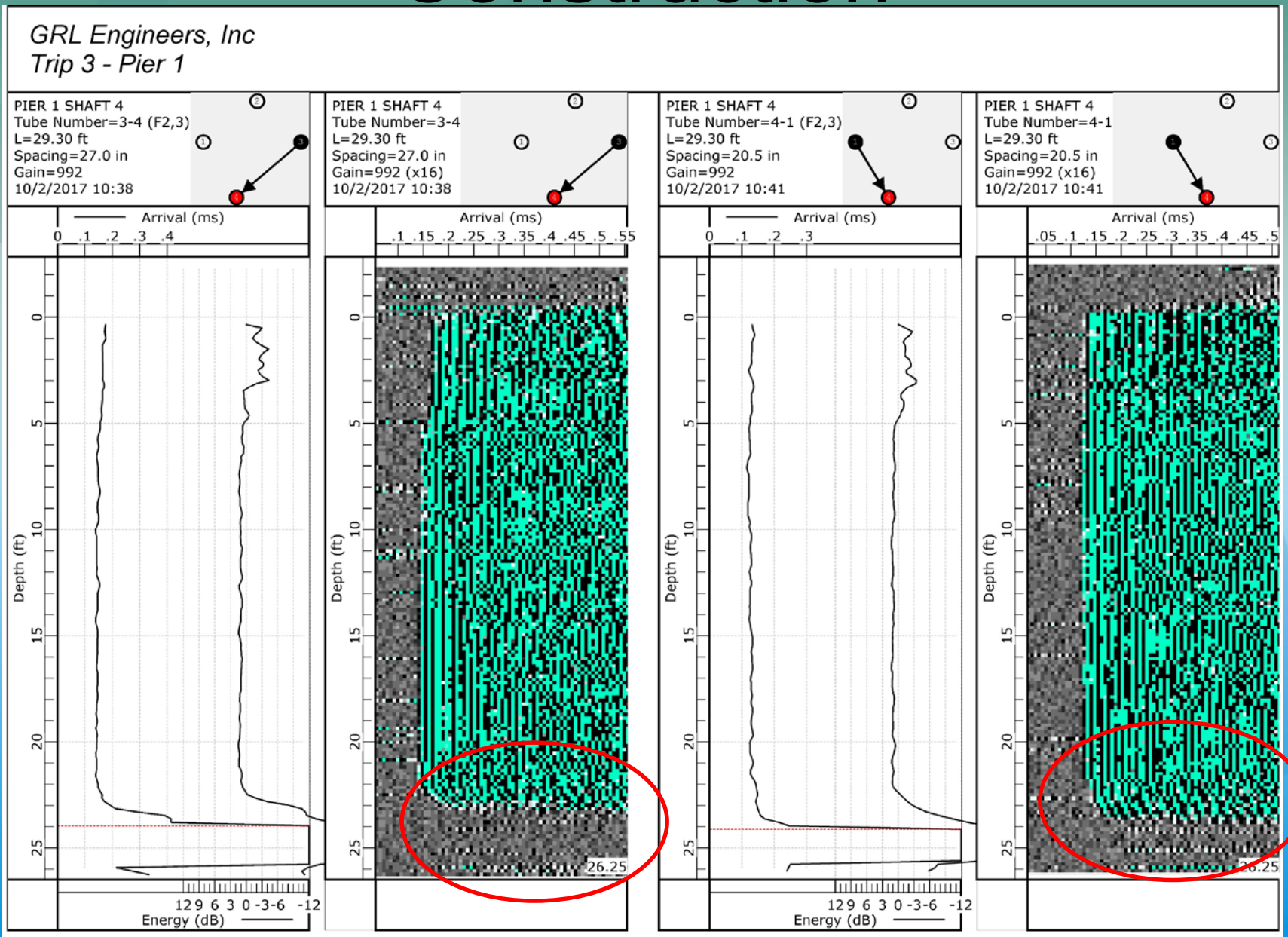
Construction

- The contractor then moved to Pier 1.
- Pier 1, shafts 2 and 3 were poured, CSL tested and accepted.
- Pier 1, shafts 1 and 4 were poured and CSL testing indicated major defect in the bottom of the shaft.
- Pier 1, shaft 1 also had an issue at the top of the shaft.
- Need to core shafts 1 and 4.

Construction



Construction



Construction

- What happened?
- Need to review the contractor's log and the inspector's log.

- Pier 1, shaft 1 was dry poured with 1-1.5 ft of water in the bottom. 5 inches of bleed water on top the next day.
- Pier 1, shaft 4, unclear from records.

Construction

Construction

Coring

Defect

Coring

Defect

Construction

- For Pier 1, shaft 4 the bottom 5 ft needed to be removed by high pressure water jetting and then grouted in.
- For Pier 1, shaft 1 the bottom 5.8 ft needed to be removed by high pressure water jetting and then grouted in. The top 80 inches of shaft 1 also needs to be removed by chipping and then re-poured with concrete.
- Required the contractor to video inspect the bottom of the shafts and verify all of the bad concrete was removed before grouting.

Construction

- Contractor then submitted their corrective action plan.
  - Install two packers, one in each hole
  - Flush the sand/gravel out of the core holes by pumping at up to 800 psi
  - If not successful then hire a subcontractor to perform high pressure jetting with a vacuum truck.
  - Once cleaned, tremie grout the void in with neat cement grout. Then pressure the grout to 50 psi.
  - At pier 1, after grouting, chip and repour the top 80 inches.

Construction

Construction

Construction

2017/10/19 16:20:39

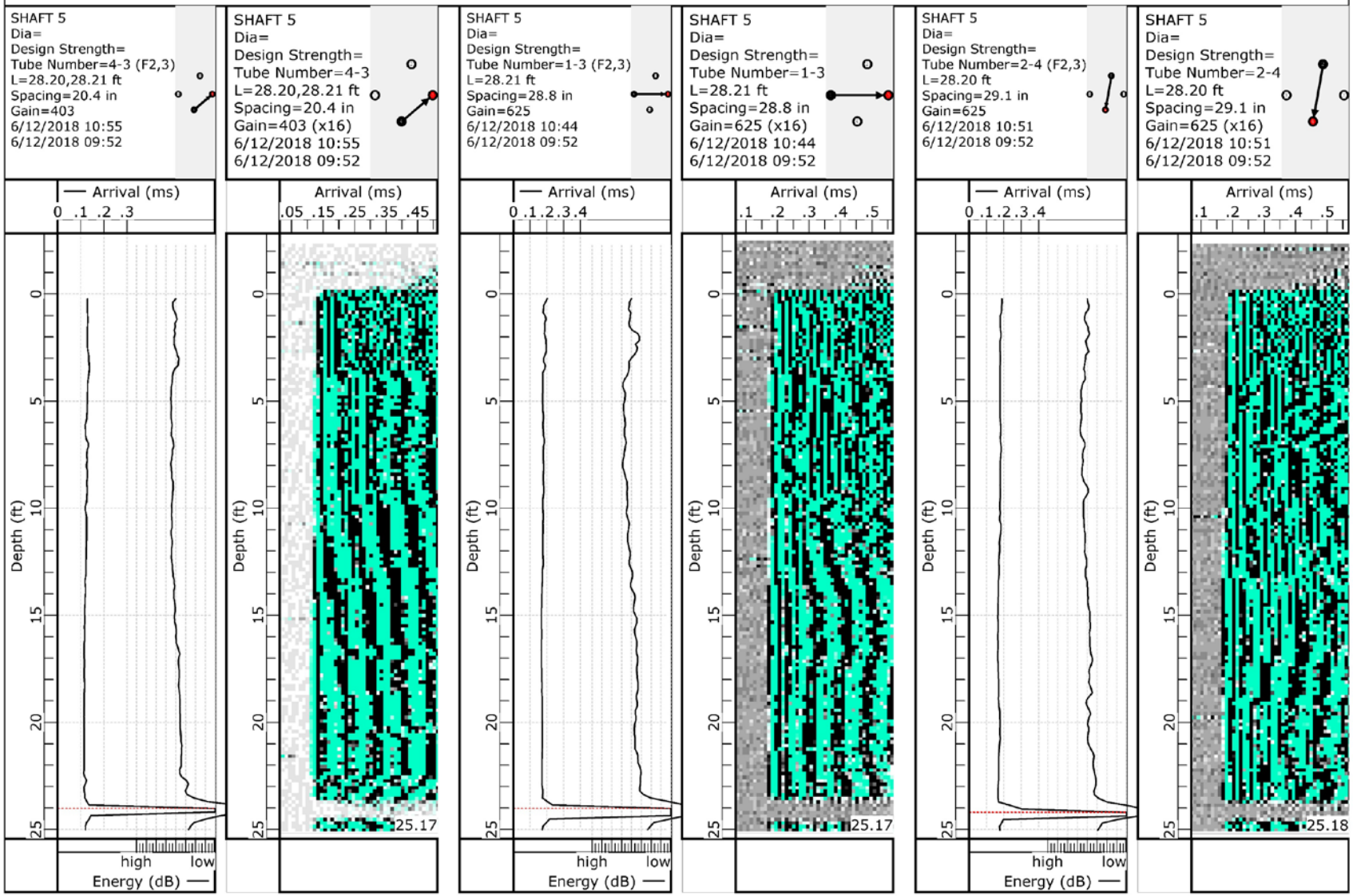
2017/10/19 16:24:50

Construction

- Stage 1 shut down for the winter
- Stage 2 started up in the spring
  - New drilled shaft crew
  - New mistakes
  - Had defects on shafts 5 and 15.
    - These problems were traced back to a different issue – concrete slump issues which lead to raising the tremie tube too high to start the pour.

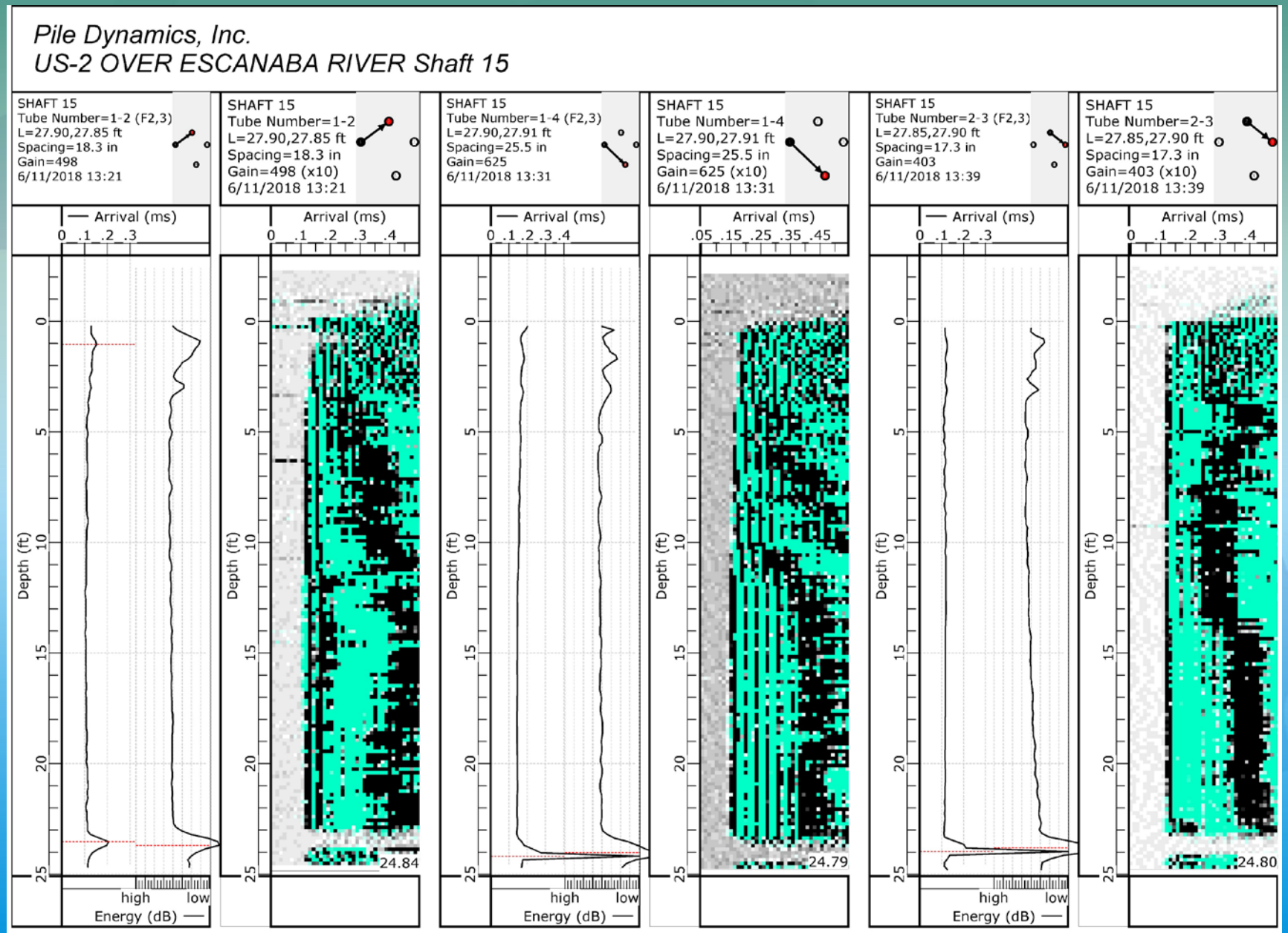
Construction

GRL Engineers, Inc.
US-2 OVER ESCANABA RIVER Shaft 5



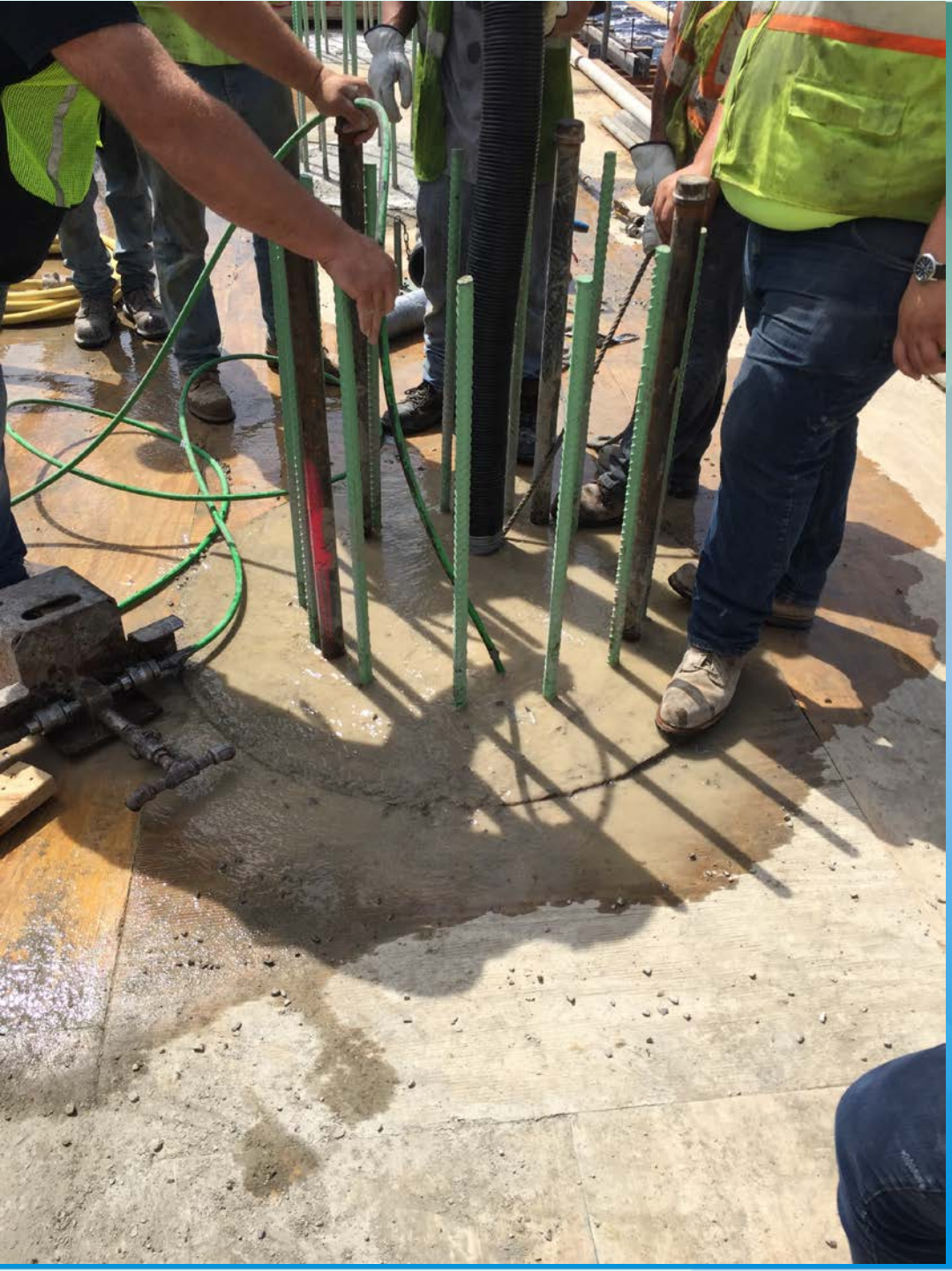
Pile Dynamics, Inc.
Cross-Hole Analyzer

Construction



Construction

Any idea what was hit here?



Construction

06/21/18 01:53 49' 11"

Conclusions

- The defective drilled shafts were successfully repaired.
- The repair on each stage took three weeks to complete.
- Contractor incurred costs are unknown at this time.
- Provided an extension of time equal to the time that it took MDOT to provide direction after coring was completed since the shafts were on the critical path.

Questions?