



# Englobe

Soils Materials Environment

**Submitted To Triton Engineering Services Limited  
18 Robb Blvd Unit 8,  
Orangeville, Ontario L9W 3L2  
On Behalf of the Ontario Ministry of Transportation**

**Culvert Replacement at Station 10+000  
Highway 7044 - Township of Hart  
Site No. 46-390  
GWP 5119-12-00**

## **FINAL SHEET PILE DRIVING TEST REPORT**

Date: January 10, 2017  
Ref. N<sup>o</sup>: 11/11/11209

**GeocresNo. 41I-336A**



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## Final Sheet Pile Driving Test Report

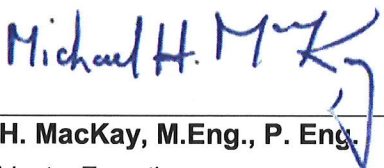
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MTO Designated Contact



2017-01-10

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## Property and Confidentiality

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Test results mentioned herein are only valid for the sample(s) stated in this report.

Englobe's subcontractors who may have accomplished work either on site or in laboratory are duly qualified as stated in our Quality Manual's procurement procedure. Should you require any further information, please contact your Project Manager."

Client:

Triton Engineering Services Limited

18 Robb Blvd., Unit 8

Orangeville, Ontario

L9W 3L2

Attention: **Mr. Howard Wray, P.Eng.**

REVISION AND PUBLICATION REGISTER		
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1 hard copy	File

## 1 INTRODUCTION

Englobe Corp. (Englobe), has been retained by Triton Engineering Services Limited on behalf of the Ministry of Transportation of Ontario (MTO), to carry out a sheet pile driving test at an existing centreline culvert site (Site No. 46-390) for the detail design of the required culvert replacement. The site is located at a local site chainage of Station 10+000 in the Township of Hart on GWP 5119-12-00 on Highway 7044, some 6.7 km south of Highway 144, as shown on Drawing No.1 in Appendix 1.

The foundation investigation for the preliminary design of the culvert replacement was carried out in December 2014. The Final Foundation Investigation and Design Report (FIDR) was submitted on December 22, 2015 (Geocres No. 411-336). After the FIDR was submitted, the option of Steel Sheet Pile Wall Culvert was chosen by MTO to avoid excavation and associated dewatering for the installation of new culverts/foundations.

It is understood that the preliminary structural design requires support of a factored 385 kN/m load at ULS along the sheet pile wall. Based on the geotechnical data at this site, it was estimated that the sheet pile wall would require 3 m penetration into the lower dense gravelly sand deposit or refusal to meet the structural loading requirement in order to achieve these factored loads. However, there is limited published testing data for the vertical capacity of sheet piles. From the available project data where sheet piles have been used to offer vertical resistance, the sheet piles were driven to refusal on bedrock. For the detail design purposes for the culvert replacement, MTO approved a Change Order No. 7 on July 26, 2016 to carry out an in-situ sheet pile driving test to verify the constructability of the sheet piling and associated set criteria (i.e. required energy rate of hammer and its advance rate). Pile Dynamic Analysis (PDA) was also carried out to establish the capacity of the sheet piles driven to the anticipated founding and/or refusal level during the trial testing.

## 2 SITE AND SUBSURFACE CONDITIONS

Triple Corrugated Steel Pipe (CSP) culverts are located at the site of this pile driving test, located on Highway 7044 some 6.7 km south of Highway 144 in the Township of Hart. The existing highway embankment currently supports two undivided lanes of highway, locally running in a north-south direction. The existing highway at the culvert location is constructed on a granular embankment approximately 2.1 m in height (at centreline), with centerline elevation of 98.2 m at the culvert location and has a granular surface. The culverts at this location consist of three 1,220 mm diameter Corrugated Steel Pipe (CSP) culverts approximately 12 m in length. Flow through the culvert is from the west to the east (right to left). Cobbles/boulders were observed in the stream bed, and in a berm along the south bank of the stream to the west of the culvert.

## 2.1 SUBSURFACE CONDITIONS

The existing embankment fill consists of compact to dense brown gravelly sand to sand and gravel to gravelly sand, trace silt, and was encountered to depths of 2.1 and 2.2 m below grade. Cobble-sized rock pieces were encountered in the embankment fill layer. The native soils underlying the embankment fill at the existing culvert generally consist of compact to dense sands and gravels to gravelly sands overlying the loose to compact sands to silts and sands overlying very dense gravelly sands encountered at Elevations 88.2, 87.8, and 85 m at Borehole Nos. 1 to 3, respectively. The embankment fills and subsurface soils contain boulder/cobble sized rock pieces. Three boreholes were terminated in the very dense gravelly sand deposit between Elevations 84.3 and 87.4 m as shown on Drawing No. 2 (Enclosure No. 1, Appendix 1).

## 2.2 GROUNDWATER DATA

At the time of the foundation investigation (December 4, 2014), the water level at the culvert inlets was measured at Elevation 96.6 m. The groundwater levels were measured at Elevations 96.9 m (December 3, 2014), 96.7 m (December 11, 2014), and 96.3 m (December 16, 2014) in Borehole Nos. 1, 2 and 3, respectively.

The groundwater and river water levels will fluctuate seasonally/yearly.

## 3 PLAN OF PILE DRIVING AND TESTING

To confirm the geotechnical capacity of the sheet piles, it was proposed to drive four sheet piles and carry out PDA testing. The procedures for the piles testing are described as follows:

- Drive the test sheets with a conventional crane equipped with leads and boom for both Vibratory Hammer and Delmag diesel hammer. Sheet piles are to be driven to the designated founding level or practical refusal whichever is encountered first;
- Allow the piles to set over-night. The pore water pressure were assumed to dissipate after 12 hours or more in the sands and gravels with the cobble and boulder-sized rock fragments present at this site;
- Set up Pile Dynamic Analysis (PDA) testing equipment on the sheet piles then drive the sheet piles using the Delmag diesel hammer Model No. D12-42 to establish the vertical geotechnical resistance and the final set of pile driving.

The piling work was completed by Bélanger Construction Limited located in Chelmsford, Ontario and the PDA testing was carried by AATech Scientific Inc. (AATech) from Ottawa, Ontario.

## 4 FIELD WORK

### 4.1 INITIAL DRIVE

Four test sheet piles (Test Pile Nos. 1 to 4) were advanced to the south of the culverts as show on Figure No.1 in Appendix 2. The EZ88 section sheet piles were supplied by Samuel Roll Form Group located in Mississauga, Ontario. Each of the sheet pile sections was 15.24 m (50') in length. The physical properties for the EZ88 sheet pile are provided in Enclosure No. 2 in Appendix 2.

The sheet piles were constructed as per the plan between August 23<sup>rd</sup> and 24<sup>th</sup>, 2016 using an excavator-mounted HMC Movax Model SP-100 Sonic SideGrip vibratory pile driver, and a Delmag diesel pile hammer, Model D12-42. The specifications for the two types of pile driving hammer are presented in Enclosure Nos. 3 and 4 in Appendix 2.

The sheet pile installation began in the afternoon on August 23<sup>rd</sup>, 2016. Test Piles Nos. 1, 2, and 3 were advanced interlocking one another, while Test Pile No. 4 was separately advanced as a single sheet pile. Test Pile Nos. 1 to 4 were initially advanced using a HMC vibratory pile driver to the approximate refusal depths of 10.7, 10.7, 10.4 and 9.6 m below grade, respectively. Test Pile Nos. 1 to 3 were advanced approximately 0.9 m into the very dense gravelly sand deposits using the vibratory hammer to Elevations between 87.6 and 87.3 m. Test Pile No. 4 was advanced approximately 0.4 m into the very dense gravelly sand deposit to Elevation 88.5 m. The sheet piles were left in place overnight.

The sheet pile installation continued in the early morning on August 24<sup>th</sup>, 2016. The Delmag diesel pile hammer of Model D12-42 was used to advance the sheet piles further into the very dense deposits. The diesel hammer was set up on the top of Test Pile No. 1; however the top of Test Pile 1 buckled after starting the pile driving. Following which, the diesel hammer was set up on the joint between Test Pile Nos. 1 and 2. The driving on Test Piles No. 1/2 resulted in blow counts of 19/75 mm, 17/25 mm, 14/25 mm, and 14/25 mm at both interlocked sheet piles together, terminating at an approximate depth of 10.9 m below grade (i.e. approximate Elevation 87.1 m). As such, it confirmed that Test Pile Nos. 1 and 2 had been advanced to the near practical refusal using the vibratory hammer on August 23<sup>rd</sup>, 2016. The four field records for pile driving of Test Pile Nos. 1 to 4 are presented in Enclosure No. 5 in Appendix 2.

### 4.2 PILE DRIVING ANALYZER TESTING

Pile Dynamic Analysis (PDA) testing was carried out by the technical staff of AATech near noon on August 24<sup>th</sup>, 2016 on four constructed sheet piles. PDA testing was first carried out on the independent Test Pile No. 4 without further driving with the diesel hammer after the initial vibratory installation on August 23<sup>rd</sup>, 2016. The blow counts on Test Pile No. 4 during PDA testing were initially 10 blows/300 mm and followed by 9 blows/195 mm to an approximately final depth of 10.4 m below grade (Elevation 87.6 m). PDA testing was also carried out on Test Pile No. 3 without further driving after the vibratory installation on August 23<sup>rd</sup>, 2016. The blow

counts on Test Pile No. 3 during PDA testing were initially in the order of 15 blows/50 mm and followed by 9 blows/113 mm to an approximately final depth of 10.6 m below grade (Elevation 87.4 m). The top of Test Pile No. 3 also buckled slightly during driving with the diesel hammer after the start of the pile driving.

Due to the buckling that had occurred at Test Piles No. 1 and 3, the tops of Test Pile Nos. 1, 2, and 3 were cut to allow PDA testing. Test Pile Nos. 1 and 2 were cut by about 1.47 m and Test Pile No. 3 was cut by about 1.75 m. During PDA testing of Pile No. 2, the diesel hammer was set up straddling on the joint between Test Pile Nos. 2 and 3. The blow counts for Test Pile Nos. 2/3 together during PDA testing were in the order of 9 blows/16 mm to a final depth of approximately 11 m below grade (Elevation 87.0 m). During testing of Pile No. 1, the diesel hammer was set up straddling on the joint between Test Pile Nos. 1 and 2. The blow counts on the interlocked Test Pile Nos. 1/2 together during PDA testing were in the order of 6 blows/15 mm to a final depth of approximately 11 m below grade (Elevation 87.0 m).

The four test piles were removed using the vibratory pile driver on August 25<sup>th</sup>, 2016. Upon removal, the toes of the piles were observed to be slightly buckled; however, the toe of Test Pile No. 4 appeared heavily damaged as shown on Photo No. 4 (Appendix 3). As such, the production sheet piles should be driven with the toe protector into the very dense gravelly sand deposit to prevent serious damage to the piles. The ground surface of the highway embankment at the test area was reinstated nearly to the original surface condition before the testing.



## 5 RECOMMENDATION AND CONCLUSION

### 5.1 GEOTECHNICAL RESISTANCE OF SHEET PILES

Based on the factual data of PDA tests carried out on August 24<sup>th</sup>, 2016, AATech analyzed and presented the geotechnical resistances of the tested sheet piles using the wave-equation theory and Case Pile Wave Analysis Program (CAPWAP) in their test report of Dynamic Testing of Piles dated August 26<sup>th</sup>, 2016 (Enclosure No. 6, Appendix 4). The ultimate vertical geotechnical resistances were 2,123 kN, 3,060 kN, 1,425 kN, and 1,313 kN for the interlocked Test Pile Nos. 1/2 together, the interlocked Test Pile Nos. 2/3 together, the interlocked Test Pile No. 3, and the independent Test Pile No. 4, respectively, as summarized and shown on Table 1 in Appendix 4. The higher geotechnical resistances for the interlocked sheet piles between Test Pile Nos. 1 to 3 might be induced by the frictions between the interlocks of sheet piles.

It is understood that, based on the structural loading requirements, a factored vertical capacity of 385 kN/m at ULS is required along the proposed sheet pile wall. Based on the results of the PDA testing on sheet piles, a factored geotechnical capacity of 650 kN per independent 635 mm wide pile (i.e. 1023 kN/m), at a geotechnical resistance factor of 0.5 per Canadian Foundation Engineering Manual (4<sup>th</sup> Edition), was confirmed for the independent Test Pile No. 4, and could meet the structural requirement for the ultimate geotechnical resistance of 490 kN per pile (i.e. 385 kN/m x 2 x 0.635 m). Accordingly the sheet piles at this site should be advanced a minimum of 0.5 m into the very dense gravelly sand deposit and/or the practical refusal of pile driving at a final set of 10 blows per 25 mm penetration, if a Delmag diesel pile hammer of Model D12-42 or equivalent pile driving equipment is used. As such, the Steel Sheet Pile Wall approach is acceptable to support the anticipated structural design loads for the proposed new culvert replacement.

### 5.2 SHEET PILE DESIGN CONSIDERATION

As discussed in Section 5.1, the sheet piles meeting specification for Rollform EZ88 sheet pile are an acceptable method for supporting the proposed culvert replacement. A factored geotechnical resistance at ULS is 650 kN/pile (i.e. 1,023 kN/m x 0.635 m) for the production sheet piles driven to the recommended founding levels below.

Sheet piles provided with adequate toe protectors shall be advanced to a minimum depth of 0.5 m and/or refusal into the very dense gravelly sand deposit (below Elevation 87.7 m), based on the verified set criteria provided by the Contractor for their equipment as required in Section 5.3.

Sheet piles can be advanced to the designated depths described above using either a vibratory pile driver or a diesel pile hammer. A vibratory pile driver should have a minimum centrifugal force of 100 tons. Based on the results of PDA tests, a set criteria of 10 blows per 25 mm penetration has been estimated using the Delmag diesel pile hammer of Model D12-42 with the rated energy of 58 kJ. The set criteria is very difficult to be developed for the sheet piles

advanced using the vibratory methods; however a HMC vibratory pile driver of Model SP-100 with centrifugal force of 100 tons or equivalent vibratory pile driving equipment can be considered for driving the production sheet piles. Restrike the production sheet piles need be undertaken a minimum 24 hours post installation to allow the excess pore water pressures to dissipate after the sheet piles are driven to the designated founding level.

Additional pile load testing will be required if the “refusal” of the production sheet piles is encountered prior to reaching the required founding level described above. The PDA testing shall be carried out a minimum 24 hours post installation to allow the excess pore water pressures to dissipate after the tested sheet pile is driven to the tested levels.

### 5.3 CONSTRUCTION CONCERNS

Considering the nature of the embankment fills and subsurface soils containing boulder/cobble sized rock pieces, it is recommended that adequate pile driving equipment and toe protector properly fitting the size of sheet pile section (e.g. as supplied by Roll Form Group, Skylinesteel, or equivalent) should be used for driving the sheet piles in the Contract documents. The Contractor must be prepared to advance the sheet piles through these boulder/cobble materials to the designated founding level as required.

The results of pile driving tests carried out for the Detailed Design at the site indicated that practical refusal of the driven test piles was achieved below Elevation 87.7 m, with maximum penetration of 25 mm for an average of 10 hammer blows using the pile driving hammer having a minimum energy of 58 kJ. The Contractor shall determine a set criteria of refusal equivalent to the above using their equipment. The Contractor shall then perform Pile Driving Analyzer (PDA) tests to demonstrate that the ultimate geotechnical axial resistance of the piles exceeds 490 kN/pile. The Contractor shall then drive all piles to refusal based on the verified set criteria established by the PDA tests.

A Notice to Contractor is included in Appendix 4.

## 6 STATEMENT OF LIMITATIONS

The geotechnical design recommendations given in this sheet pile driving test report are applicable only to the project described in the text and only if constructed substantially in accordance with details of alignment and elevations stated in the report. Since all details of the design may not be known, in our analysis certain assumptions had to be made. The actual conditions may however, vary from those assumed, in which case changes and modifications may be required to our geotechnical recommendations. We recommend, therefore, that we be retained and provided the opportunity during the design stage to review the design drawings, site survey information, proposed elevations, etc. to verify that they are consistent with our recommendations or the assumptions made in our analysis. It is further recommended that we be retained to review the final design drawings and specifications relative to the geotechnical recommendations.

If, during construction, conditions in the field vary from those assumed at the design stage, an engineer from this office must be notified immediately.

Proper subgrade preparation, groundwater control, compaction, etc. are all critical aspects of the bearing capacity of native soils. It must be noted that different aspects of the geotechnical design are based on the assumption that Englobe will be retained during site preparation and construction of the proposed works to ensure that both the geotechnical site characteristics and the construction operations/techniques are consistent with our recommendations. Should Englobe not be involved during the full construction phase, our liability is strictly limited to the factual information contained herein only.

The comments in this report are intended solely for the guidance of the design engineer and address the geotechnical conditions only. Therefore, contractors bidding on this project or undertaking this work should make their own interpretations of the available subsurface information and carry out further work as they deem necessary to assess the scope of the project.

Section 5 of this reported is intended for the use of the client and the design team only and is not intended to be included in the tender documents. Inclusion of the factual information (Sections 1 to 5 inclusive) in the tender documents is furnished merely for the general information of bidders and is not in any way warranted or guaranteed by or on behalf of the owner or the owner's consultants and its subconsultants or the consultants' or subconsultants' employees, and neither the owner nor its consultants or its employees shall be liable for any representations negligent or otherwise contained in the documents.

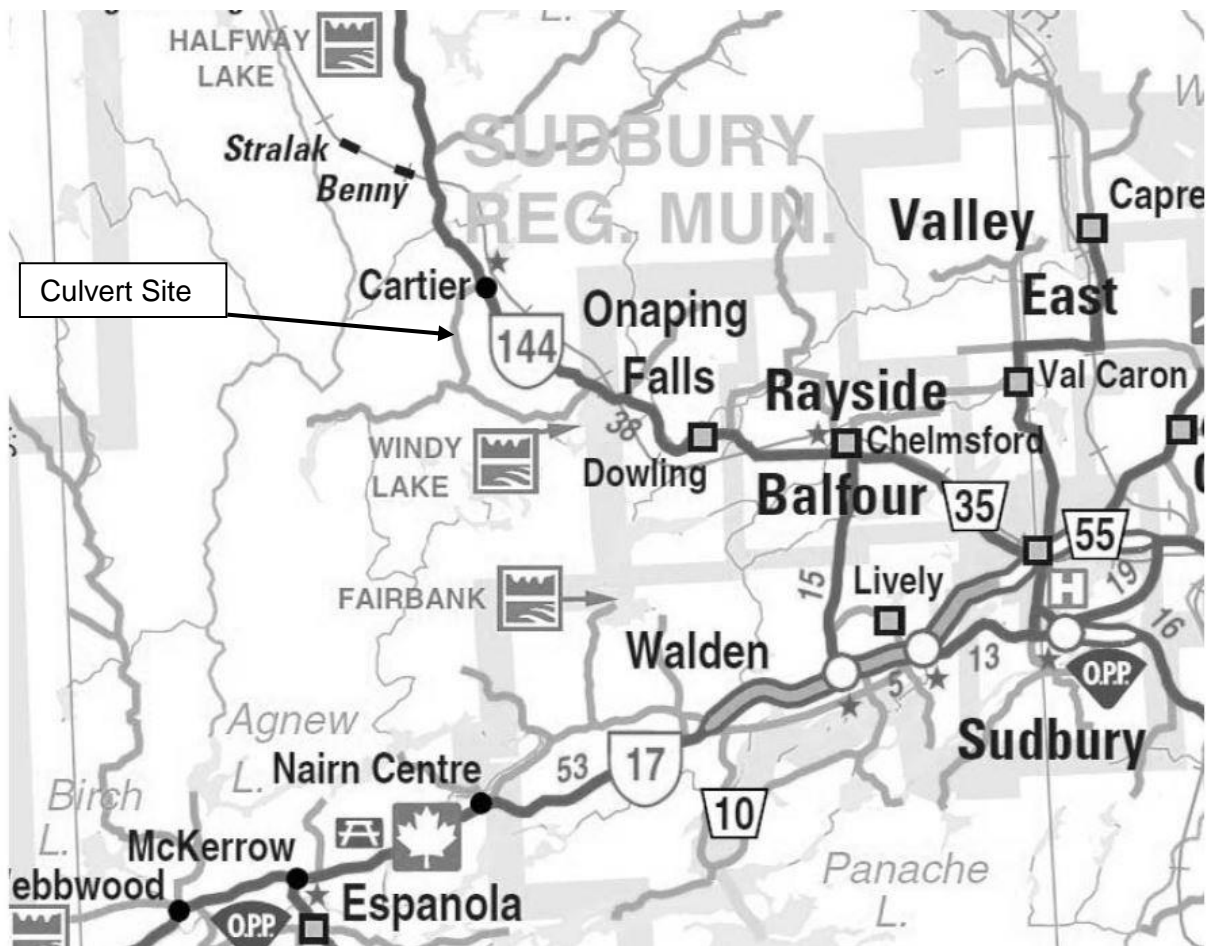
## Appendix 1 Site Information

Drawing No. 1 Key Plan  
Enclosure No.1: Borehole Locations and Soil Strata

# KEY PLAN

Drawing No. 1

NOT TO SCALE



**FINAL**  
**SHEET PILE DRIVING TEST REPORT**  
**GWP 5119-12-00**  
Highway 7044  
Site No. 46-390



Reference No: 11/11/11209

January 2017

DISTRICT  
CONT. No.  
GWP No. 5119-12-00



HIGHWAY 7044  
SITE NO. 46-390  
HART TOWNSHIP

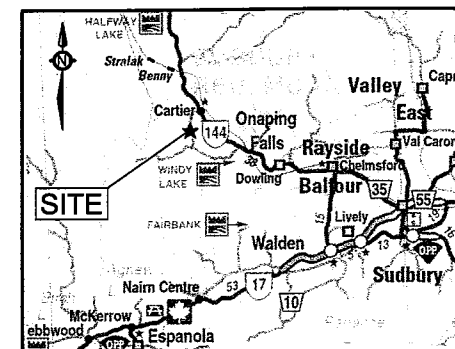
DRAWING

BOREHOLE LOCATIONS  
AND SOIL STRATA

2

LVM Merlex

METRIC



KEY PLAN  
N.T.S.

## LEGEND

- Borehole
- ⊕ Testpit
- N Blows/0.3 m (Std Pen Test, 475 J/blow)
- DCPT Blows/0.3 m (60' Cone, 475 J/blow)
- ▽ Water Level at Time of Investigation
- A/R Auger Refusal at Elevation
- E/S End of Sampling
- ⬆ Piezometer

BOREHOLE No.	ELEVATION	STATION	O/S	
1	98.1	10+003	3.2m Rt	
2	98.0	9+996	2.0m Lt	
3	96.7	9+990	7.7m Lt	

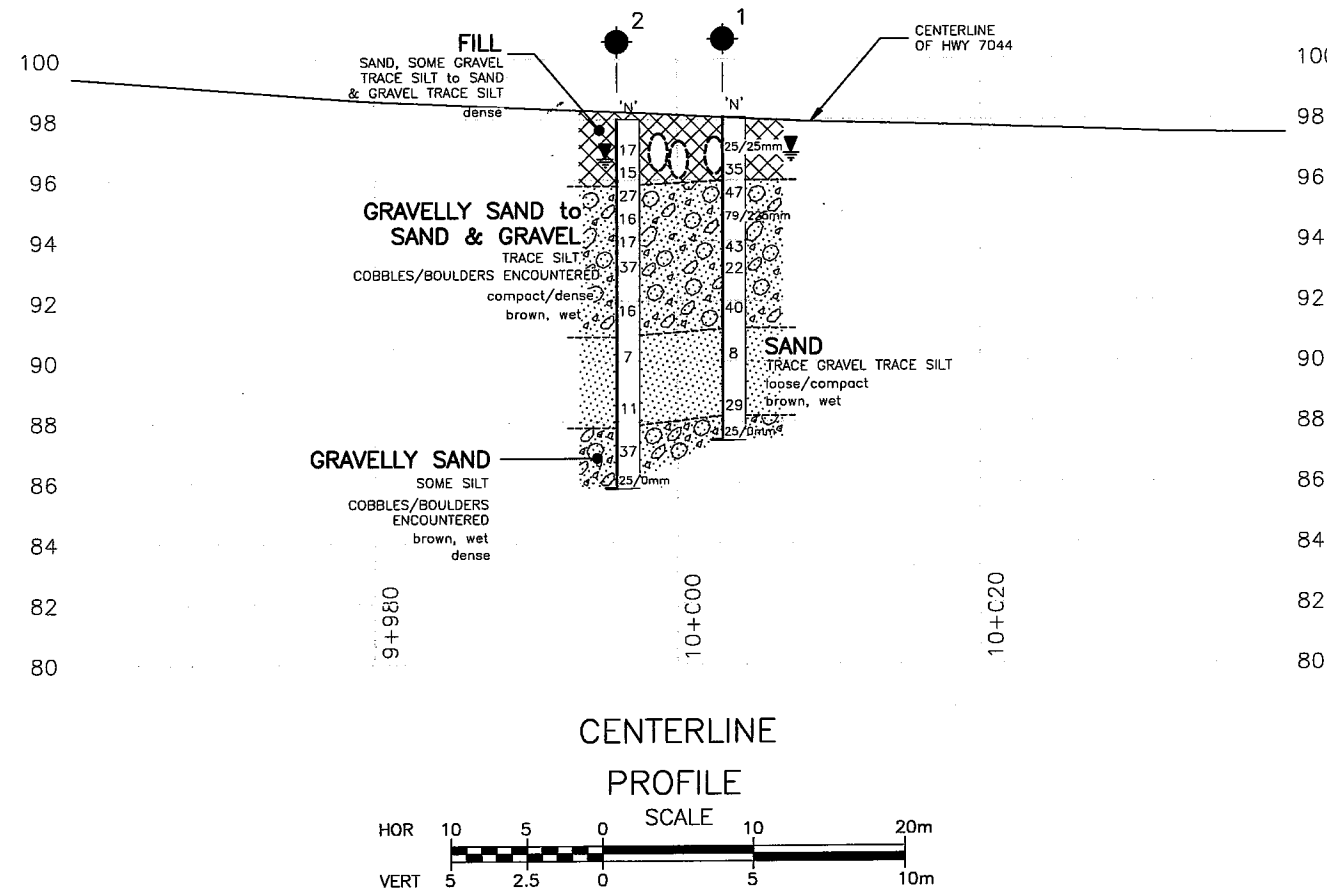
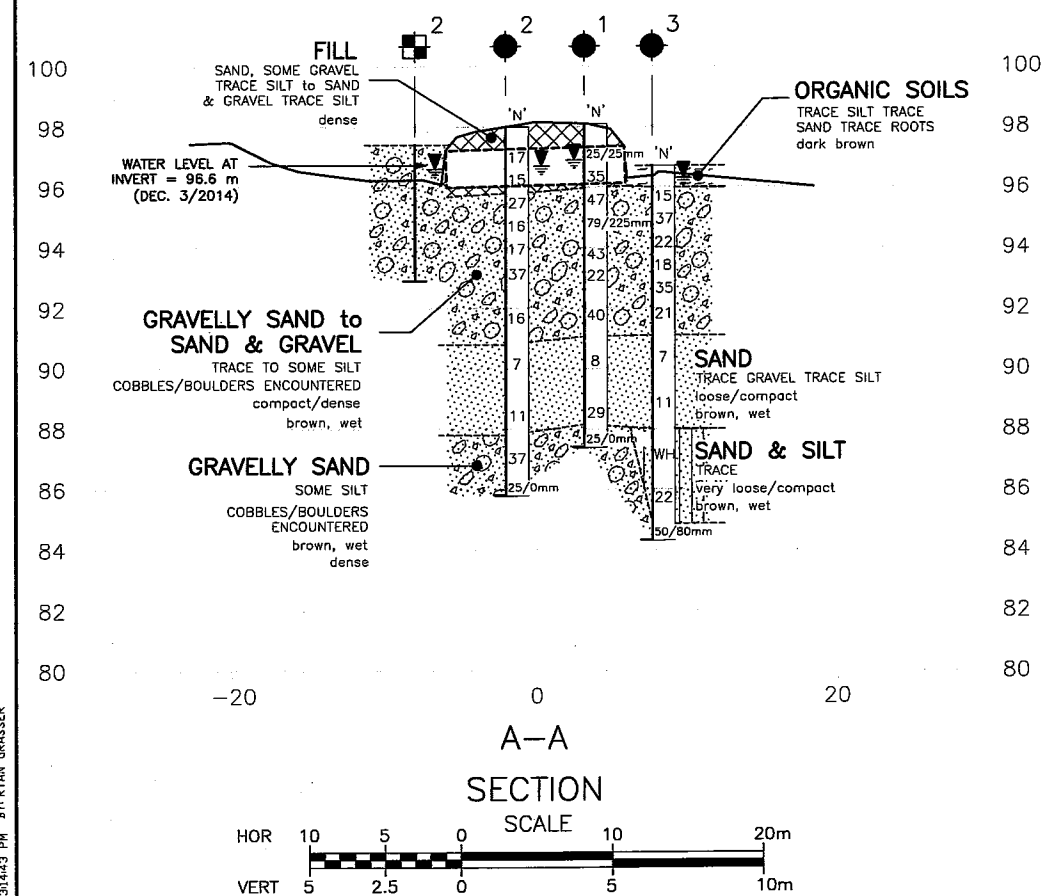
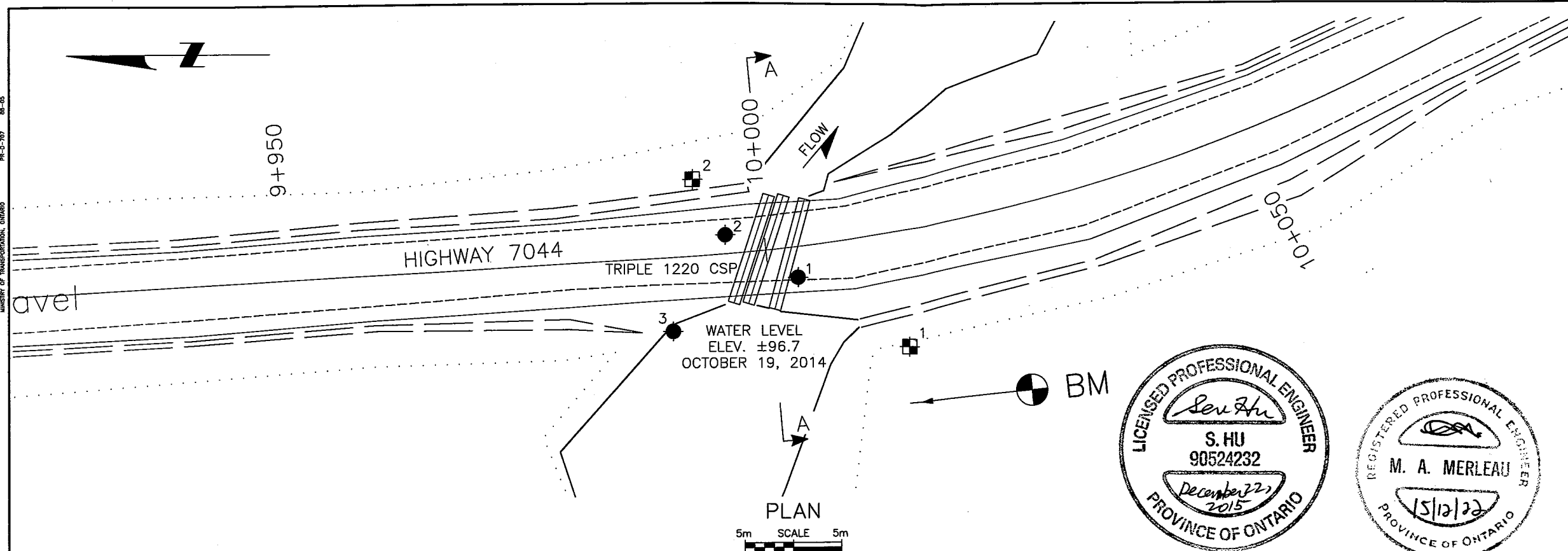
TESTPIT No.	ELEVATION	STATION	O/S	
1	97.3	10+013	12.0m Rt	
2	97.4	9+993	8.0m Lt	

## NOTES:

The boundaries between soil strata have been established at the borehole locations only. The boundaries illustrated and stratigraphy between boreholes on this drawing are assumed based on borehole data and may vary. They are intended for design only.

Base plan and alignment provided in digital format by exp. on December 10, 2014.

GEORES No. 411-336



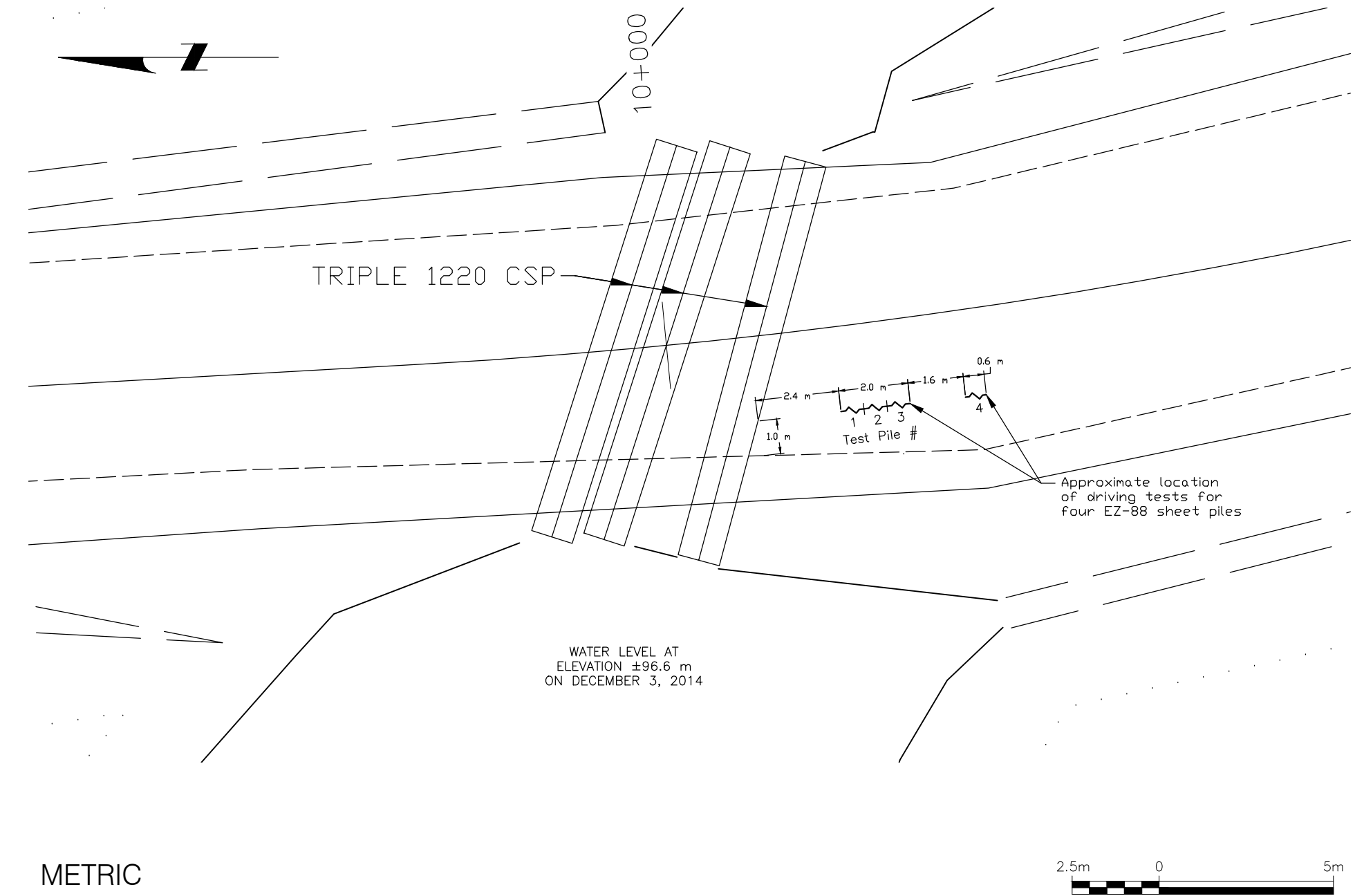
This drawing is for subsurface information only. Surface details and features are for conceptual illustration. The proposed structure location is shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

DRAWING NOT TO BE SCALED  
50mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION
APR/15	RG	DRAFT	
DEC/15	RG	FINAL	
DESIGN	CHK	CODE	LOAD
DRAWN	RG	CHK	AT
SITE	46-390	STRUCT	SCHEME
DATE	DEC/15	DWG	2

## Appendix 2 Data of Sheet Pile and Piling Drivers

Figure 1:	Location of Tested Sheet Piles at Culvert
Enclosure No. 2:	EZ series Sheet Piling
Enclosure No. 3:	Data sheet of HMC vibratory pile driver
Enclosure No. 4:	Data sheet of Delmag diesel hammer

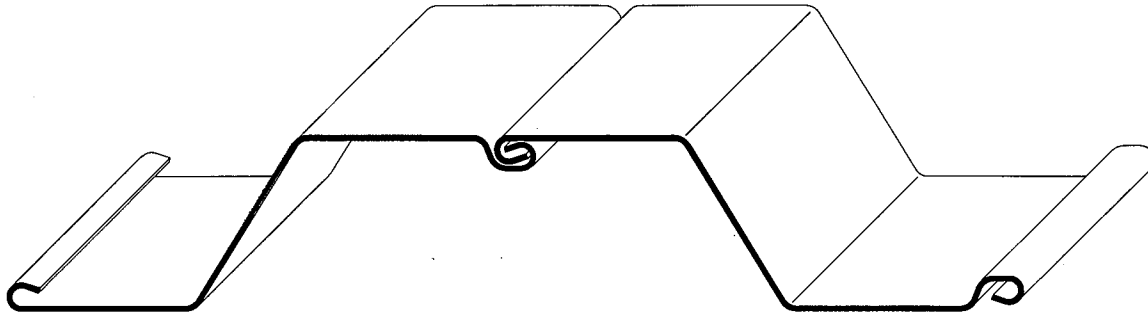


Highway 7044, Township of Hart - GWP No. 5119-12-00  
Location of Tested Sheet Piles at Culvert at Station 10+000

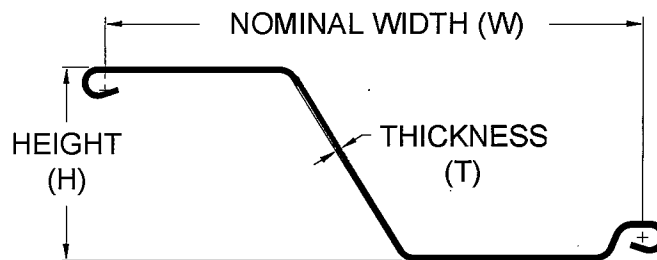
FIGURE NO. 1



## 'EZ' SERIES SHEET PILING



PAIRED SHEETS



## PHYSICAL PROPERTIES

NOTE: METRIC VALUES IN BRACKETS

SECTION	THICKNESS T in (mm)	HEIGHT H in (mm)	NOMINAL WIDTH W in (mm)	SECTION AREA $\text{in}^2$ ( $\text{cm}^2$ )	WEIGHT $\text{lbs/lin ft}$ ( $\text{Kg/lin m}$ )	WEIGHT $\text{lbs/ft}^2$ ( $\text{Kg/m}^2$ )	MOMENT OF INERTIA $\text{in}^4/\text{wall ft}$ ( $\text{cm}^4/\text{wall m}$ )	RADIUS OF GYRATION in (mm)	SECTION MODULUS $\text{in}^3/\text{wall ft}$ ( $\text{cm}^3/\text{wall m}$ )
EZ80	.315 (8.00)	10.75 (273)	25.0 (635)	12.1 (77.9)	41.1 (61.2)	19.8 (96.4)	110 (15000)	4.35 (110)	20.5 (1100)
EZ88	.344 (8.75)	10.78 (274)	25.0 (635)	13.2 (85.1)	44.9 (66.8)	21.6 (105)	121 (16500)	4.36 (111)	22.4 (1200)
EZ95	.375 (9.50)	10.81 (275)	25.0 (635)	14.4 (92.7)	48.9 (72.8)	23.5 (115)	131 (17900)	4.36 (111)	24.4 (1310)

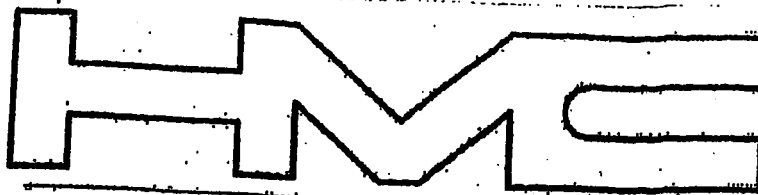
### MATERIAL SPECIFICATION

ASTM A572 GR. 50  
CSA G40.21 GR. 350W



TITLE: 'EZ' SERIES SHEET PILING

DATE: APRIL, 2005	DWG NO. EZPDF01
REVISED:	SCALE: N.T.S.
REV. NO.	APPR. BY:
DRAWN BY: R. McMartin	



**Foundation  
Equipment**

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CORPORATE OFFICE: 6025 NEW HAVEN AVE, FT. WAYNE, IN 46803 USA; TELEPHONE 800-343-1690; FAX 260-422-2040; WEBSITE  
<http://www.hme-us.com>

**Subject: Sonic SideGrip® SP100 Model Specifications**

The Sonic SideGrip® SP-100 Vibratory Driver/Extractor is a longer bodied machine than the other smaller models. It offers 4 eccentric gears rather than 2. This vibratory driver has been proven to have the same driving force in most soil conditions as a 4400 in-lbs/300 hp conventional vibratory hammer. It has driven H-pile to a tested capacity of 144 tons.

A driving force table has been provided comparing conventional vibratory drivers to the Sonic SideGrip® product.

The inserted specification chart provides most of the specifications needed. The amplitude is 0.250 inches at the 3000 VPM frequency. The centrifugal force or inertial force is approximately 100 tons.

Please contact me at any timer with any other questions, thank you.

Sincerely yours,

Bryan Daniel  
Sonic SideGrip® Product Sales  
Hercules Machinery Corporation  
Manufacturer and Supplier of Foundation Equipment  
Direct: (260) 424-0405  
Mobile: (260) 615-5203  
Fax: (260) 422-2040  
Email: [bdaniel@hmc-us.com](mailto:bdaniel@hmc-us.com)



# HMC Movax Sonic SideGrip® Vibratory Pile Drivers

## SP Series Model Technical Specifications

	SP-40	SP-50	SP-60	SP-80	*SP-100*
<b>Excavator Class (Ton)</b>	18-20	25	25-30	25-40	30-55
<b>Oil Flow (GPM)</b>	32	40	47	57	62
<b>Net Weight (lbs.)</b>	4,026	4,070	4,114	5,280	5,280
<b>Maximum Tank Pressure (PSI)</b>	72.5	72.5	72.5	72.5	72.5
<b>Maximum Pressure Setting (PSI)</b>	4,000	4,000	4,000	4,450	4,680
<b>Frequency (1/min.)</b>	3,000	3,000	3,000	3,000	3,000
<b>Centrifugal Force (Tons)</b>	40	50	60	80	100
<b>Number of Elastomers</b>	10	10	10	16	16
<b>Machine Height (Inches)</b>	61	61	61	71	71
<b>Rotation/Tilt Angle (Degrees)</b>	360/30	360/30	360/30	360/30	360/30
<b>Number of Eccentrics</b>	2	2	2	4	4

### Common Features:

- 1.5" Bottom Plate
- Modular Fixed Jaw
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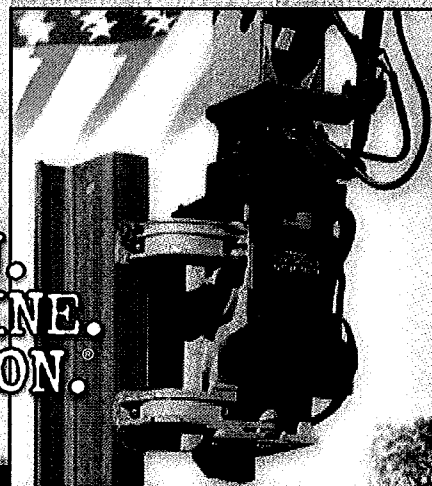
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# Dieselbären Diesel Pile Hammers





# Dieselbären



## Technische Daten / Technical Data

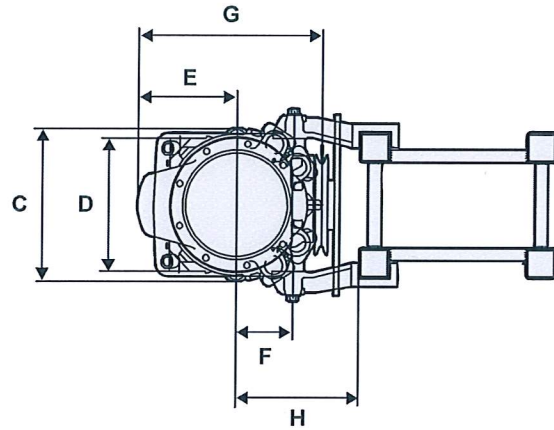
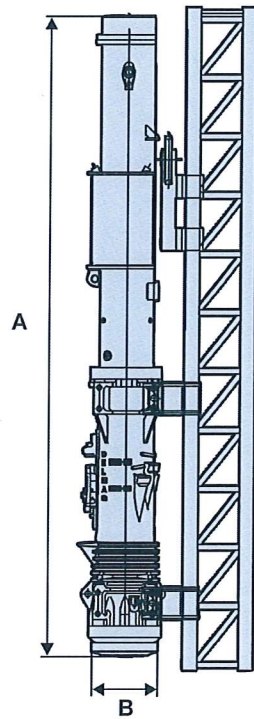
			D6-32	D8-22	D12-42	D16-32
Schlaggewicht (Kolben)	Impact weight (piston)	kg	600	800	1280	1600
Energie pro Schlag	Energy per blow	kNm	19-9	27-13	46-20	54-25
Schlagzahl	Number of blows	min-1	38-52	36-52	35-52	36-52
Geeignet zum Einrammen von Rammgut (abhängig von Boden und Rammgut)	Suitable for driving piles (depending on soil and pile)	kg	300-2000	500-3000	800-5000	1000-6000
<b>Verbrauch</b>		<b>Consumption</b>				
Dieselöl	Diesel oil	l/h	3,7	4	4,5	5
Schmierstoff	Lubricant	l/h	0,25	0,5	0,5	0,5
<b>Tankinhalt</b>		<b>Tank capacity</b>				
Dieseltank	Diesel oil tank	l	19	20	25	32
Schmierstofftank	Lube tank	l	5	6	6,5	9
Max. Seildurchmesser für optionale Umlenkrolle der Ausklinkvorrichtung	Max. rope diameter for deflector sheave of tripping device	mm	20	20	20	20
Max. Schrägrammung ohne / mit Verlängerung	Max. inclined pile driving without / with extension		1:3 / -	1:2 / -	1:5 / 1:1	1:5 / 1:1
<b>Gewicht</b>		<b>Weight</b>				
Dieselbär	Diesel pile hammer	kg	1620	1935	2735	3620
Ausklinkvorrichtung	Tripping device	kg	114	114	114	114

## Technische Daten / Technical Data

			D19-42	D25-32	D30-32
Schlaggewicht (Kolben)	Impact weight (piston)	kg	1820	2500	3000
Energie pro Schlag	Energy per blow	kNm	66-29	90-40	103-48
Schlagzahl	Number of blows	min-1	35-52	35-52	36-52
Geeignet zum Einrammen von Rammgut (abhängig von Boden und Rammgut)	Suitable for driving piles (depending on soil and pile)	kg	1100-6000	1600-7500	2000-9000
<b>Verbrauch</b>		<b>Consumption</b>			
Dieselöl	Diesel oil	l/h	7,5	7,5	10
Schmierstoff	Lubricant	l/h	0,5	0,6	1
<b>Tankinhalt</b>		<b>Tank capacity</b>			
Dieseltank	Diesel oil tank	l	32	67	67
Schmierstofftank	Lube tank	l	9	19	19
Max. Seildurchmesser für optionale Umlenkrolle der Ausklinkvorrichtung	Max. rope diameter for deflector sheave of tripping device	mm	20	22	22
Max. Schrägrammung ohne / mit Verlängerung	Max. inclined pile driving without / with extension		1:5 / 1:1	1:5 / 1:1	1:5 / 1:1
<b>Gewicht</b>		<b>Weight</b>			
Dieselbär	Diesel pile hammer	kg	3840	5670	6170
Ausklinkvorrichtung	Tripping device	kg	114	186	186

## Maße / Dimensions

		D6-32	D8-22	D12-42	D16-32	D19-42	D25-32	D30-32
A	mm	4300	4700	4770	5160	5160	5500	5500
B	mm	350	350	400	440	440	560	560
C	mm	465	410	440	480	480	670	670
D	mm	320	320	320	320	320	540	540
E	mm	310	315	335	345	345	405	405
F	mm	245	245	245	280	280	235	235
G	mm	590	590	610	700	700	780	780
H	mm	320	320	340	355	360	435	435



## Appendix 3

## Photo Essay

Enclosure No. 5:

Photo Nos. 1 to 6



Culvert Site Prior to Driving Test – Looking South

Photo: 1



Test Sheet Piles 1 to 4 - After Vibratory Installation

Photo: 2



Project: Inspection and Testing, Sheet Piles - Hwy 7044 Culvert

Photos Provided By: Englobe

Date: August 2016



Setup of Diesel Hammer on Test Pile 2

Photo: 3



Toe of Test Pile No. 4 after Removal from Ground

Photo: 4



Project: Inspection and Testing, Sheet Piles - Hwy 7044 Culvert

Photos Provided By: Englobe

Date: August 2016

Pile Toe – Test Pile No. 1

Photo: 5



Culvert Site Post Removal of Test Piles – Looking North

Photo: 6




Project: Inspection and Testing, Sheet Piles - Hwy 7044 Culvert

Photos Provided By:  
Englobe/Belanger

Date: August 2016

## **Appendix 4      Pile Test Records and Design Data**

Table 1:                      Summary of driven tested sheet piles  
Enclosure No. 6:           Field Records of Test Pile Nos. 1 to 4  
Enclosure No. 7:    AATech Report 1 of dynamic testing of piles  
   Notice to Contractor

Summary of Driven Tested Sheet Piles														
Test Pile No.	Pile Type	Date of Driving	Date of PDA Test	Ground Surface Elevation (m)	Original Pile Length (m)	Pile Length After Cut-off (m)	Depth at Top of Very Dense Gravelly Sand Deposit during Pile Driving <sup>1</sup> (m)	Approximate Top Elevation of Very Dense Gravelly Sand Deposit (m)	Pile Driven during PDA Testing(m) <sup>2</sup>				Ultimate Geotechnical Resistance by PDA Testing (kN)	Factored Geotechnical Resistance (kN)
									Final Driven Depth (m)	Final Driven Toe Elevation (m)	Maximum Energy Transmitted to Pile Head (kNm)	Final Set		
1	EZ88	8/23/16	8/24/16	98.0	15.2	13.8	9.8	88.3	11.0	87.0	28.8	10 blows/25 mm	2123 (TP1/2)	1061.5 (TP1/2)
2	EZ88	8/23/16	8/24/16	98.0	15.2	13.8	9.8	88.3	11.0	87.0	42.4	14 blows/25 mm	3060 (TP2/3)	1530 (TP2/3)
3	EZ88	8/23/16	8/24/16	98.0	15.2	13.5	9.4	88.6	10.6	87.4	12.7	7 blows/25 mm	1425	712.5
4	EZ88	8/23/16	8/24/16	98.0	15.2	13.5	9.1	88.9	10.4	87.6	30.3	12 blows/25 mm	1313	656.5

## Notes:

1. Sheet piles initially driven using HMC vibratory pile driver of Model SP-100 with the centrifugal force equal to 100 tons
2. Sheet piles driven using Delmag diesel pile hammer of Model D12-42 with the rated energy equal to 58 kJ for PDA tests

# Englobe Corp. Pile Driving Record

Start Time: 3:11

Job No.: 11209  
 Client: \_\_\_\_\_  
 Contractor: Belanger  
 Weather: \_\_\_\_\_

Pile No.: Test Pile 1  
 Pile Location \_\_\_\_\_  
 Date: Aug 23-24 2016

Hammer Type: D12-42  
 Rating: \_\_\_\_\_

Elevations: Ground 98.0m  
 Pile Tip \_\_\_\_\_  
 Cut Off \_\_\_\_\_

Depth/ Blows	Depth/ Blows	Depth/ Blows	Depth/ Blows
1	21	41	61
2	22	42	62
3	23	43	63
4	24	44	64
5	25	45	65
6	26	46	66
4	27	47	67
8	28	48	68
9	29	49	69
10	30	50	70
11	31	51	71
12	32	52	72
13	33	53	73
14	34	54	74
15	35	55	75
16	36	56	76
17	37	57	77
18	38	58	78
19	39	59	79
20	40	60	80

**Remarks:**

Alignment: ~~Vertical~~  
~~Horizontal~~

Splices: ~~Position~~  
~~Quality~~

Interruption: ~~Location~~  
~~Time~~  
~~Duration~~

Erratic Pile behaviour: ~~Time~~  
~~Tip Location~~

Heave: \_\_\_\_\_

Driving w/ diesel hammer (on pile 1+2)  
 Final Set (blows/inch): start 19/3", 17/1", 14/1", 14/1" stop, pile depth 35'9"  
cut off 53" - PDA Testing (hammer on pile 1+2) 6 blows/15mm test plus 1+2

Final length below grade @ time of driving: \_\_\_\_\_

Inspector: AG

Final depth - 36'0"  
 Distance Grade to Cut-Off \_\_\_\_\_

End Time: \_\_\_\_\_  
 End Date: \_\_\_\_\_



# Englobe Corp. Pile Driving Record

Start Time: \_\_\_\_\_

Job No.: 11209  
Client: \_\_\_\_\_  
Contractor: Belanger  
Weather: \_\_\_\_\_

Pile No.: Test Pile 2  
Pile Location: \_\_\_\_\_  
Date: Aug 23-24/16

Hammer Type: D12-42  
Rating: \_\_\_\_\_

Elevations: Ground 98.0  
Pile Tip \_\_\_\_\_  
Cut Off \_\_\_\_\_

Depth/ Blows	Depth/ Blows	Depth/ Blows	Depth/ Blows
1 Start	21	41	61
2 vibratory driving	22	42	62
3	23	43	63
4 easy advanced	24	44	64
5	25	45	65
6	26	46	66
7	27	47	67
8	28	48	68
9	29	49	69
10	30	50	70
11	31	51	71
12	32 dense mat'l	52	72
13	33 @ 32' slow	53	73
14	34 advance	54	74
15	35 vibratory refused	55	75
16	36 @ 35'	56	76
17	37 switch to hammer	57	77
18	38 Aug 24/16	58	78
19	39	59	79
20	40	60	80

## Remarks:

Alignment: Vertical \_\_\_\_\_  
Horizontal \_\_\_\_\_

Splices: Position \_\_\_\_\_  
Quality \_\_\_\_\_

Interruption: Location \_\_\_\_\_  
Time \_\_\_\_\_  
Duration \_\_\_\_\_

Erratic Pile behaviour: \_\_\_\_\_  
Time \_\_\_\_\_  
Tip Location \_\_\_\_\_

Heave: \_\_\_\_\_

Driving w diesel hammer - (pile 1+2)

Final Set (blows/inch): see Pile 1

cut @ 58" PDA testing (hammer on pile 2+3) - 9 blows/16mm

Final length below grade @ time of driving: \_\_\_\_\_ Inspector: A

final depth 36"

Distance Grade to Cut-Off \_\_\_\_\_

End Time: \_\_\_\_\_

End Date: \_\_\_\_\_

# Englobe Corp. Pile Driving Record

Start Time: \_\_\_\_\_

Job No.: 11209  
Client: \_\_\_\_\_  
Contractor: Belanger  
Weather: \_\_\_\_\_

Pile No.: Test pile 3  
Pile Location: \_\_\_\_\_  
Date: Aug 23-24 2016

Hammer Type: D12-42  
Rating: \_\_\_\_\_

Elevations: Ground 98.0 m  
Pile Tip \_\_\_\_\_  
Cut Off \_\_\_\_\_

Depth/ Blows	Depth/ Blows	Depth/ Blows	Depth/ Blows
1 start vibratory	21	41	61
2 advance	22	42	62
3	23	43	63
4	24 easy	44	64
5 easy	25 advance	45	65
6 advance	26	46	66
4	27	47	67
8	28	48	68
9	29	49	69
10	30	50	70
11	31 ↓ dense material	51	71
12	32 slow advance	52	72
13	33	53	73
14	34 ↓ vibrational refused 34'	54	74
15	35 switch to diesel hammer	55	75
16	36 Aug 24/16	56	76
17	37	57	77
18	38	58	78
19	39	59	79
20 ↓	40	60	80

## Remarks:

Alignment: Vertical \_\_\_\_\_ Splices: Position \_\_\_\_\_  
Horizontal \_\_\_\_\_ Quality \_\_\_\_\_

Interruption: Location \_\_\_\_\_ Erratic Pile behaviour: \_\_\_\_\_  
Time \_\_\_\_\_  
Duration \_\_\_\_\_ Tip Location \_\_\_\_\_

Heave: \_\_\_\_\_

Final Set (blows/inch): Driving w/ diesel hammer start 15 blow/2"  
cut off 69" after PDA testing

Final length below grade @ time of driving: PDA testing - 3 blows/ 40mm, 3/42mm, 3/31mm  
Inspector: AS

Distance Grade to Cut-Off final depth 34' 9"  
\_\_\_\_\_

End Time: \_\_\_\_\_  
End Date: \_\_\_\_\_

# Englobe Corp. Pile Driving Record

Start Time: \_\_\_\_\_

Job No.: 11209  
Client: \_\_\_\_\_  
Contractor: Belanger  
Weather: \_\_\_\_\_

Pile No.: Test pile 4  
Pile Location: \_\_\_\_\_  
Date: Aug 23-24 2016

Hammer Type: D12-42  
Rating: \_\_\_\_\_

Elevations: Ground 98.0  
Pile Tip \_\_\_\_\_  
Cut Off \_\_\_\_\_

Depth/ Blows	Depth/ Blows	Depth/ Blows	Depth/ Blows
1 start vibratory	21	41	61
2 advance	22	42	62
3	23	43	63
4 easy	24	44	64
5 advance	25	45	65
6	26	46	66
4	27	47	67
8	28	48	68
9	29	49	69
10	30	50	70
11	31 vibratory refusal 31'4"	51	71
12	32 10 blows/12"	52	72
13	33	53	73
14	34	54	74
15	35	55	75
16	36	56	76
17	37	57	77
18	38	58	78
19	39	59	79
20	40	60	80

## Remarks:

Alignment: Vertical \_\_\_\_\_ Splices: Position \_\_\_\_\_  
Horizontal \_\_\_\_\_ Quality \_\_\_\_\_

Interruption: Location \_\_\_\_\_ Erratic Pile behaviour: \_\_\_\_\_  
Time \_\_\_\_\_  
Duration \_\_\_\_\_ Tip Location \_\_\_\_\_

Heave: \_\_\_\_\_

Final Set (blows/inch): PDA Testing 3blow/64mm, 3/62mm, 3/69mm

Final length below grade @ time of driving: 31'0" Inspector: AS

Distance Grade to Cut-Off \_\_\_\_\_

End Time: \_\_\_\_\_  
End Date: \_\_\_\_\_





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# Highway 7044 Culvert Cartier, Ontario

## Dynamic testing of piles

### Report 1

Project No. 83871608

Prepared for  
Englobe  
2 – 120 Progress Court  
North Bay, ON P1A 0C2

August 26, 2016



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08/26/2016

Prepared by:

Ion Bejancu, B.A.Sc.

Fred Agharazi, M.Eng., P.Eng.

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## Appendices

### **Appendix 1: CAPWAP Analysis Results**

## Highway 7044 Culvert Cartier, Ontario

### Report 1

## 1 . Introduction

AATech Scientific Inc. (ASI) was retained by Englobe Corporation to perform dynamic PDA testing on driven sheet test piles at Highway 7044 replacement culvert location in Cartier, Ontario. This report presents the factual results of the PDA testing performed during one-day site visit, on August 24, 2016.

Four sheetpiles were tested at restrike during this site visit. The tested piles are EZ88 steel sheetpiles, 274 mm height and 635 mm nominal width.

A Delmag D19-42, open end diesel hammer, rated energy of 58 kJ, was used to test the piles at this location. The piles were previously installed with a vibratory hammer. For the scope of the PDA tests, one sheetpile, TP4, was installed as single and the other three (TP1, TP2 and TP3) were installed interlocked to each other.

The objective of the testing is to evaluate the pile capacity and driving conditions. No required sheetpile capacity was reported to ASI. The PDA testing and the interpretation provided in this report are in accordance with ASTM Standard D4945-00.

## 2 . PDA Test Procedures

Traditional pile testing methods have considerable drawbacks; energy formula are dangerously unreliable, while static load tests are expensive, time consuming and in many cases physically impossible to conduct. Dynamic pile testing is a cost effective and highly reliable quality assurance method.

### 2.1 . PILE DRIVING ANALYZER (PDA)

The PDA uses signals from reusable strain and acceleration transducers which are bolted and anchored to the test pile.

PDA utilizes closed form solutions to wave propagation theory to solve the following:

- hammer performance to qualify pile driving equipment;
- preliminary estimates of activated bearing capacity (CASE Method Estimates) during pile driving, or later during re-strike to include time dependent soil strength changes;
- driving stresses to investigate potentially damaging situations, and assess effects of changes to the driving system;
- structural integrity of pile shaft.

Quasi instantaneous response from the PDA is displayed for each hammer impact offering the engineer multiple resources to monitor the test progress in real time.

It is important to note that values obtained on field are rough estimates, particularly capacity estimates. These preliminary estimates are highly dependent on pile type and geometry as well as other field conditions. Consequently, more elaborate analysis such as CAPWAP is required to obtain refined results.

## **2.2 . CAPWAP ANALYSIS**

Case Pile Wave Analysis Program (CAPWAP) combines measured force and velocity data with wave equation analysis to calculate the soil resistance forces acting on the pile. CAPWAP models the pile as a series of continuous segments. Each segment is of uniform cross-section but segments may be different from another to accommodate non-uniform piles. A soil model similar to Smith's wave equation model is assumed, which includes the total resistance and its distribution, damping constants and quake. The CAPWAP results are based on best possible match between a computed pile top variable (i.e. the pile top force) and its measured equivalent. The traces of force and velocity measured in the field will be matched with force and velocity computed by CAPWAP to provide the foundation engineer with the following wave equations parameters:

- Applicable Case Method Estimates of capacity;
- Shaft resistance: magnitude and distribution;
- Toe resistance;
- Shaft and toe damping;
- Shaft and toe quake;
- Simulated pile behavior under static analysis.

## **2.3 . WAVE EQUATION ANALYSIS OF PILE DRIVING (WEAP)**

WEAP is a computer software that simulates motion and force responses in a foundation pile when struck by an impact pile driving hammer. Based on available soil information, dynamic soil parameters are used

in a pile model for a given design embedment to simulate its response to impact by a specific hammer and driving system in a Bearing Graph Analysis. Where actual dynamic testing data is available, more representative dynamic soil parameters determined by CAPWAP analysis can be substituted to produce a Site-Specific WEAP Analysis.

In a Bearing Graph analysis, WEAP computes the following parameters:

- the blow count of a pile for an assumed ultimate resistance given a specific hammer and driving system;
- the axial stress in a pile corresponding to the computed blow count;
- the energy transferred to the pile.

Based on the results, the following can be indirectly derived:

- the pile's bearing capacity at the time of driving or re-striking, given its penetration resistance (blow count)
- the stresses during driving;
- the expected blow count if the actual static bearing capacity of the pile is known in advance (i.e. from static soil analysis).

Combined with Dynamic testing and CAPWAP analysis, a Site-Specific Bearing Graph offer the most reliable correlation between observed blow count and pile capacity.

Another application is the Driveability Analysis. The analysis is performed to simulate the actual driving of the pile and can be described as a series of Bearing Graph analyses performed at different depths of penetration.

## **2.4 . PDA PLOT**

The PDILOT program will directly read data from PDA W01 or X01 files and present them in graphical and/or tabular form. The program allows the presentation in a variety of different ways.

PDA present graphically the measured/computed values of the following PDA quantities vs. depth:

- Maximum transferred energy (EMX)
- Penetration resistance (Blow count, BLC)
- Maximum force (FMX)
- Applicable CASE method estimate (RX#)
- Maximum compressive stress (CSX)
- Maximum computed stress at the pile toe (CSB)

### **3 . Site Characteristics**

No soil information was provided to us for this specific area prior to the PDA testing.

### **4 . Characteristics of Test Piles and Hammer**

The tested piles at this project location are EZ88 steel sheetpiles, 274 mm height and 635 mm nominal width with 8.75 mm wall thickness. A Delmag D19-42, open end diesel hammer rated energy of 58 kJ, was used to test the piles at this location. All tested piles were previously installed using a vibratory hammer. The scope of the testing was to verify the capacity of the piles.

### **5 . Test Results**

Pile TP4, previously installed as single sheetpile to an embedment of about 9.45 m, was initially tested at restrike. Driving was continued after the restrike test and the sheetpile was retested at end of driving and it was terminated around 10.40 m embedment. A significant increase in penetration resistance (PRES) and total mobilized resistance was observed between the two tests.

Piles TP1, TP2 and TP3, were driven interlocked in sequence to embedments of 10.80 m, 10.80 m and 10.40 m, respectively. These three piles were all tested at restrike. Please note that, in order to avoid bending and mushrooming the sheetpiles during testing, setting the helmet on two adjacent sheetpiles even though the PDA sensors were attached just on one of the two sheetpiles, was considered. Sheetpiles TP1+TP2 were tested at restrike having the helmet set on both sheetpiles with the gauges attached on TP1. Same scenario was adopted when testing interlocked sheetpiles TP2 and TP3 while the gauges were attached to TP2. In both cases, the results were consistent with testing a composite sheetpile formed by the two interlocked sheetpiles and are reported accordingly. Sheetpile TP3 was also tested as single interlocked sheetpile than driven further and retested before terminating it at about 10.55 m embedment. A significant increase in PRES was measured from the beginning to the end of of restrike of this sheetpile.

A total of three CAPWAP analyses were performed on a representative hammer blow record from the PDA data at beginning or end of the restrike. CAPWAP analyses are performed mainly to verify the applicable CASE Method estimates, and to determine soil parameters and resistance distribution for

evaluating the test results. The mobilized static resistance computed by CAPWAP showed an agreement with RMX CASE Method Estimate (CMES) with a CASE damping factor of 0.8 (RX8). Results of the CAPWAP analyses and corresponding values of RX8, are summarized in Table 2, and the complete outputs are enclosed in Appendix 1 at the end of this report.

The total mobilized resistance for the composite TP1 and TP2 sheetpiles tested in this area is in excess of 2,100 kN.

Measured compressive driving stresses were up to 196 MPa throughout the testing which is well within the acceptable limits for Grade 3 or higher steel.

## **6 . Conclusion and Recommendations**

Driving stresses were maintained within acceptable limits throughout the testing. Additional increase in pile resistance may be expected with time. The total mobilized resistance for the tested sheetpiles is expected in excess of 1,350 kN. These test results are representative of site conditions at the time of testing (water level, existing ground level around the location of the test piles), and apply only to production piles in the same site location, and showing similar behavior to that of the tested piles. Any changes in site conditions and/or pile behavior during driving should be reported to the engineer for further evaluation.



Table 1: PDA Data Summary Table

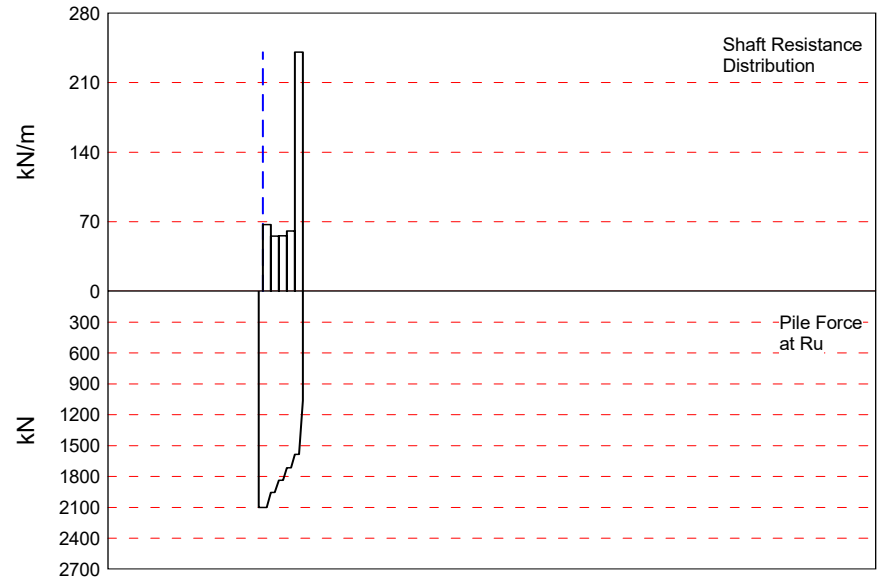
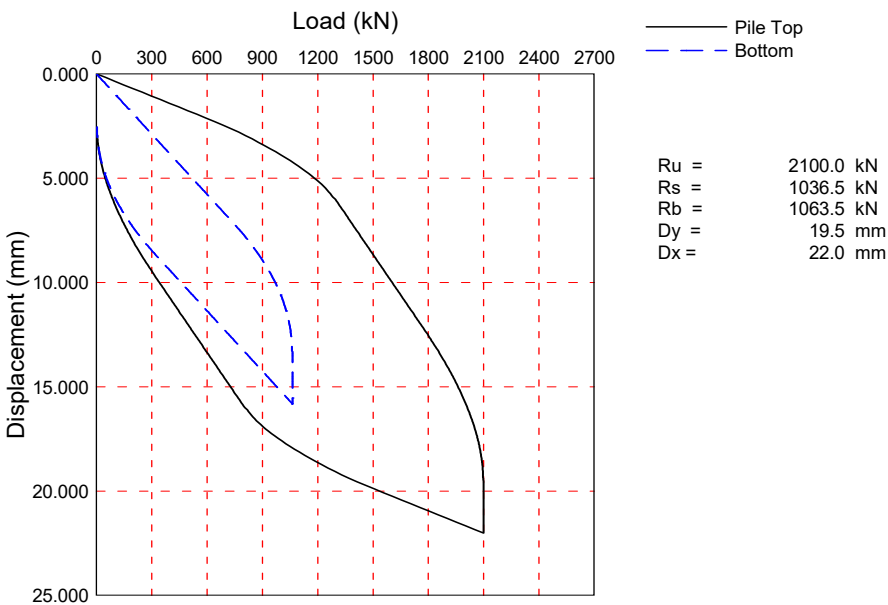
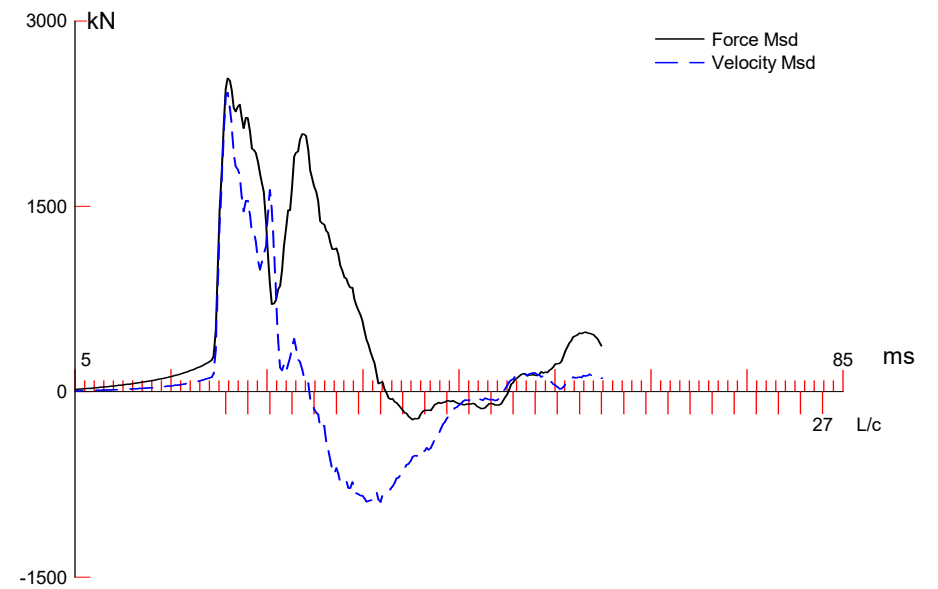
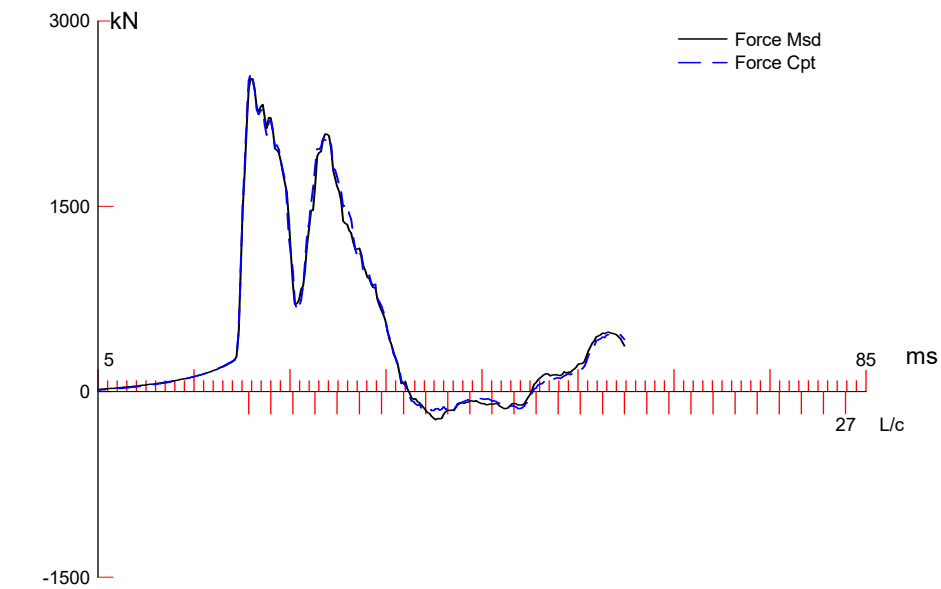
Pile	Pile type	Pile Inclination	Testing Hammer	Date	Date	Test	Blow	Embed.	EMX	EMX Ratio	FMX	CSX	CSB	Hammer	PRES at E	Case Method Est. (kN)
No.	& size (mm)	(Vertical/Battered)	Type	Driven	Tested	(E / R)	No.	(m)	(kN-m)	(%)	(kN)	(Mpa)	(Mpa)	Stroke (m)	(Bl./25mm)	RX8
TP1 + TP2	EZ 88	V	D19-42	Aug 23, 2016	Aug 24, 2016	R	4	10.80	28.8	49.7	2,550	150	123	1.9	10.0	2,123
TP2 + TP3	EZ 88	V	D19-42	Aug 23, 2016	Aug 24, 2016	R	11	10.80	42.4	73.1	3,041	179	195	3.1	14.0	3,060
TP3	EZ 88	V	D19-42	Aug 23, 2016	Aug 24, 2016	R	2	10.40	16.1	27.8	1,217	143	145	1.9	2.0	1,205
						ER	17	10.55	12.7	21.9	1,345	158	178	2.2	7.0	1,425
TP4	EZ 88	V	D19-42	Aug 23, 2016	Aug 24, 2016	R	4	9.45	18.3	31.6	1,125	132	117	1.7	1.2	893
						ER	45	10.40	30.3	52.2	1,810	213	179	2.1	12.0	1,313
Embed. EMX EMX Ratio FMX	Length below adjacent grade at the time of testing Maximum energy transferred to the pile head Ratio of transferred energy to rated energy of hammer Maximum force measured				E R PRES TP# + TP#	End of driving Restrike Penetration resistance Two interlocked sheetpiles				CSX CSB NM	Maximum compressive stress measured in the pile Computed compressive stress near the pile toe No pile movement					

Table 2: CAPWAP Summary Table

Pile  No.	Hammer	Date	Date	Test	Blow	Embed.	PRES at E / R	Case Method Est. (kN)	Computed Resistance (kN)			Smith damping (s/m)		Quake (mm)	
	Type	Driven	Tested	(E / R)	No.	(m)	(Bl./25mm)	RX8	Total	Shaft	Toe	Shaft	Toe	Shaft	Toe
TP1 + TP2	D19-42	Aug 23, 2016	Aug 24, 2016	R	4	10.80	10.0	2,123	2,100	1,037	1,063	0.2	0.4	1.9	10.2
TP2 + TP3	D19-42	Aug 23, 2016	Aug 24, 2016	R	11	10.80	14.0	3,060							
TP3	D19-42	Aug 23, 2016	Aug 24, 2016	R	2	10.40	2.0	1,205							
				ER	17	10.55	7.0	1,425	1,400	492	908	0.5	0.3	2.0	5.3
TP4	D19-42	Aug 23, 2016	Aug 24, 2016	R	4	9.45	1.2	893							
				ER	45	10.40	12.0	1,313	1,350	220	1,130	0.3	0.2	1.6	22.5
Embed. PRES NM	Length below adjacent grade at the time of testing Penetration resistance (Blows per 25 mm) No pile movement				E R PRES	End of driving Restrike Penetration resistance			RX8 TP# + TP#	RMX / RSP CASE Method with a J-Factor of # Two interlocked sheetpiles					

# **Appendix 1**

## **CAPWAP Analysis Results**



HWY7044 CULVERT (ENGLOBE); Pile: TP1 + TP3  
R; Blow: 4  
AATech Scientific Inc

Test: 24-Aug-2016 15:36:  
CAPWAP (R) 2006-2  
OP: TM

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 2100.0; along Shaft 1036.5; at Toe 1063.5 kN

Soil Sgmt No.	Dist. Below Gages m	Depth Below Grade m	Ru kN	Force in Pile kN	Sum of Ru kN	Unit Resist. (Depth) kN/m	Unit Resist. (Area) kPa	Smith Damping Factor s/m
				2100.0				
1	3.2	2.2	145.0	1955.0	145.0	67.29	19.23	0.245
2	5.4	4.3	120.0	1835.0	265.0	55.52	15.86	0.245
3	7.6	6.5	120.5	1714.5	385.5	55.75	15.93	0.245
4	9.7	8.6	131.0	1583.5	516.5	60.61	17.32	0.245
5	11.9	10.8	520.0	1063.5	1036.5	240.59	68.74	0.245
Avg. Shaft			207.3			95.97	27.42	0.245
Toe			1063.5				62485.31	0.447

Soil Model Parameters/Extensions

		Shaft	Toe
Quake	(mm)	1.885	10.239
Case Damping Factor		0.367	0.687
Damping Type			Smith
Unloading Quake	(% of loading quake)	75	110
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	20	
Resistance Gap (included in Toe Quake)	(mm)		2.655
Soil Plug Weight	(kN)		0.89

CAPWAP match quality	=	3.14	(Wave Up Match) ; RSA = 0
Observed: final set	=	2.500 mm;	blow count = 400 b/m
Computed: final set	=	3.579 mm;	blow count = 279 b/m
max. Top Comp. Stress	=	153.9 MPa	(T= 21.4 ms, max= 1.038 x Top)
max. Comp. Stress	=	159.7 MPa	(Z= 3.2 m, T= 21.8 ms)
max. Tens. Stress	=	-12.02 MPa	(Z= 3.2 m, T= 40.8 ms)
max. Energy (EMX)	=	28.00 kJ;	max. Measured Top Displ. (DMX)=15.95 mm

HWY7044 CULVERT (ENGLOBE); Pile: TP1 + TP3  
R; Blow: 4  
AATech Scientific Inc

Test: 24-Aug-2016 15:36:  
CAPWAP (R) 2006-2  
OP: TM

EXTREMA TABLE

Pile Sgmt No.	Dist. Below Gages m	max. Force kN	min. Force kN	max. Comp. Stress MPa	max. Tens. Stress MPa	max. Trnsfd. Energy kJ	max. Veloc. m/s	max. Displ. mm
1	1.1	2620.1	-176.2	153.9	-10.35	28.00	3.4	15.287
2	2.2	2674.0	-182.5	157.1	-10.72	27.43	3.3	14.697
3	3.2	2718.4	-204.5	159.7	-12.02	26.88	3.2	14.122
4	4.3	2506.2	-167.6	147.3	-9.85	23.44	3.2	13.603
5	5.4	2550.2	-182.8	149.8	-10.74	22.93	3.1	13.149
6	6.5	2383.2	-163.9	140.0	-9.63	20.31	3.2	12.703
7	7.6	2430.2	-179.8	142.8	-10.57	19.91	3.2	12.218
8	8.6	2248.2	-157.4	132.1	-9.25	17.43	3.5	11.747
9	9.7	2118.6	-176.0	124.5	-10.34	17.10	3.6	11.250
10	10.8	1884.5	-148.9	110.7	-8.75	14.64	3.9	10.789
11	11.9	2005.9	-165.8	117.9	-9.74	6.87	4.1	10.328
Absolute	3.2			159.7			(T =	21.8 ms)
	3.2				-12.02		(T =	40.8 ms)

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	2043.2	1763.1	1483.0	1202.9	922.8	642.6	362.5	82.4	0.0	0.0
RX	2522.1	2403.5	2335.5	2268.0	2211.2	2172.4	2133.7	2095.0	2056.3	2017.6
RU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RAU = 1598.6 (kN); RA2 = 2470.6 (kN)

Current CAPWAP Ru = 2100.0 (kN); Corresponding J(RP)= 0.00; J(RX) = 0.69

VMX	TVP	VT1*Z	FT1	FMX	DMX	DFN	SET	EMX	QUS
m/s	ms	kN	kN	kN	mm	mm	mm	kJ	kN
3.49	20.93	2393.2	2451.2	2534.8	15.948	4.568	2.500	28.7	3116.3

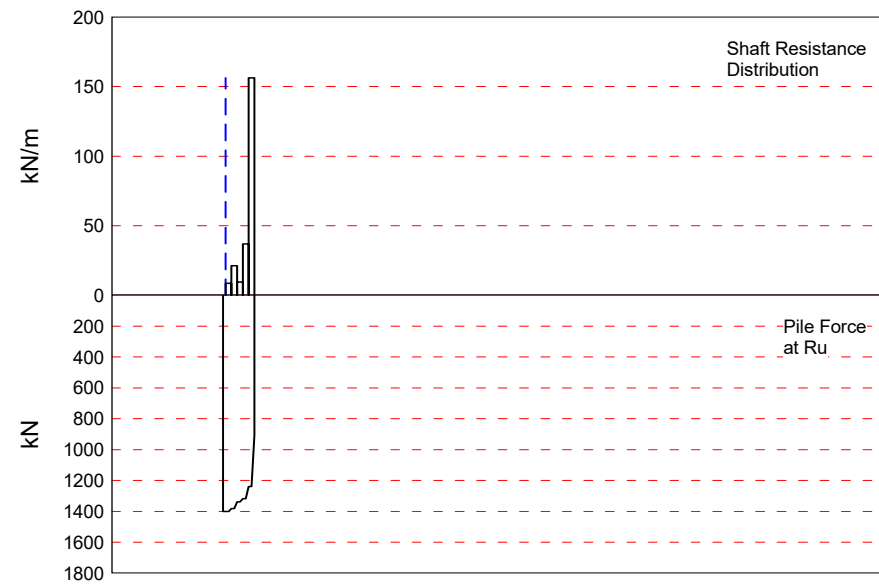
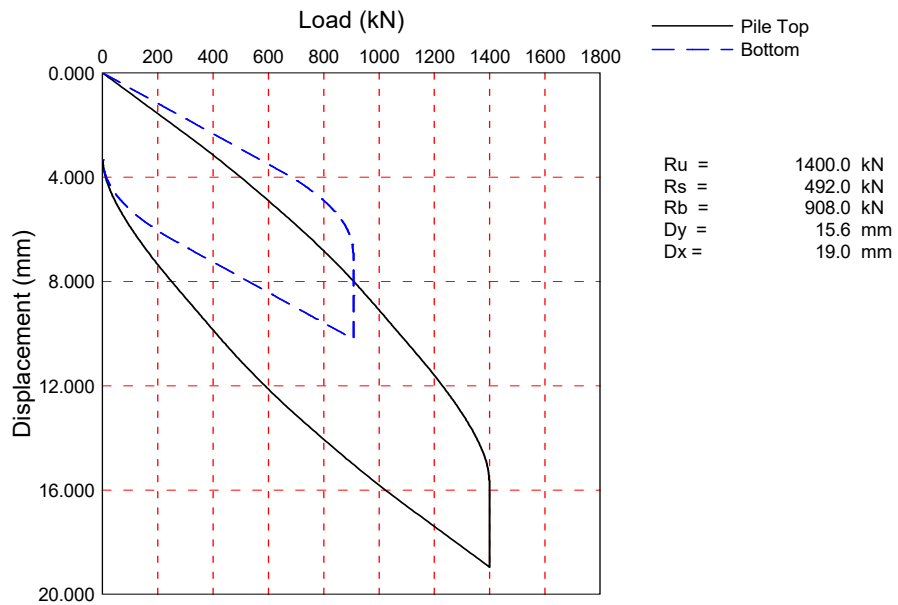
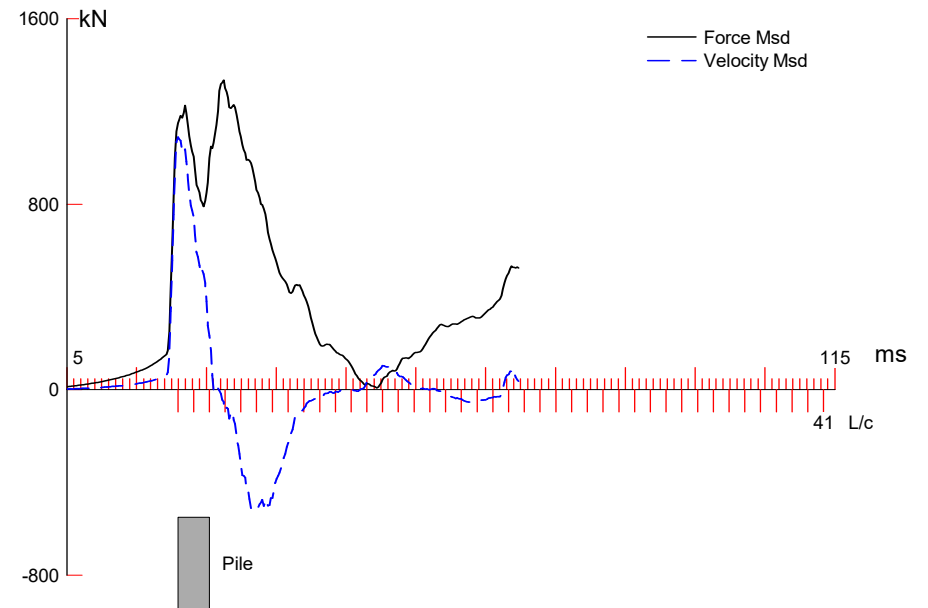
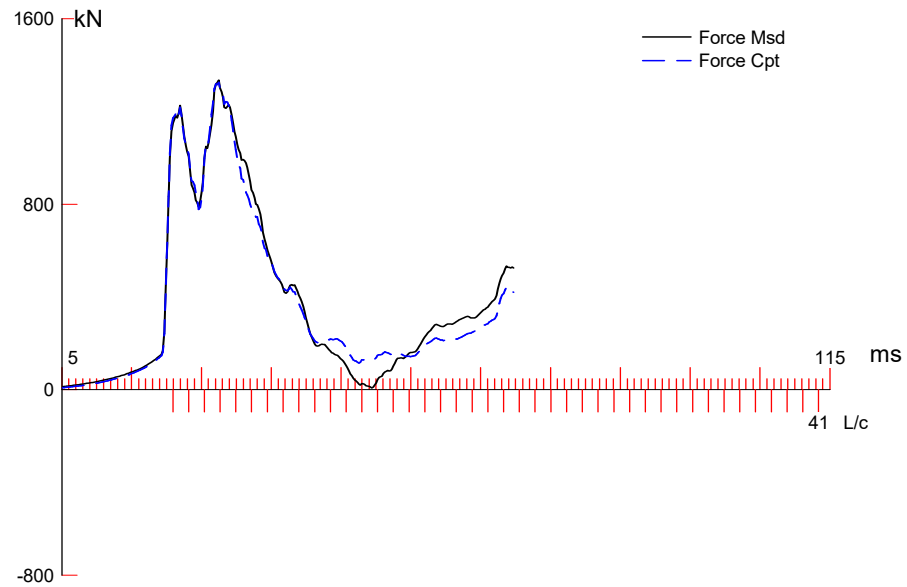
PILE PROFILE AND PILE MODEL

Depth m	Area cm <sup>2</sup>	E-Modulus MPa	Spec. Weight kN/m <sup>3</sup>	Perim. m
0.00	170.20	210000.0	77.287	3.500
11.89	170.20	210000.0	77.287	3.500

Toe Area 0.017 m<sup>2</sup>

Top Segment Length 1.08 m, Top Impedance 692.41 kN/m/s

File Damping 1.0 %, Time Incr 0.209 ms, Wave Speed 5162.0 m/s, 2L/c 4.6 ms



HWY7044 CULVERT (ENGLOBE); Pile: TP3 EOD  
E; Blow: 17  
AATech Scientific Inc

Test: 24-Aug-2016 14:10:  
CAPWAP (R) 2006-2  
OP: TM

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1400.0; along Shaft 492.0; at Toe 908.0 kN

Soil Sgmt No.	Dist. Below Gages m	Depth Below Grade m	Ru kN	Force in Pile kN	Sum of Ru kN	Unit Resist. (Depth) kN/m	Unit Resist. (Area) kPa	Smith Damping Factor s/m
				1400.0				
1	3.2	2.1	18.0	1382.0	18.0	8.65	4.94	0.545
2	5.3	4.2	45.0	1337.0	63.0	21.26	12.15	0.545
3	7.4	6.3	20.0	1317.0	83.0	9.45	5.40	0.545
4	9.5	8.4	78.0	1239.0	161.0	36.85	21.05	0.545
5	11.6	10.5	331.0	908.0	492.0	156.36	89.35	0.545
Avg. Shaft			98.4			46.64	26.65	0.545
Toe			908.0				106698.00	0.313

Soil Model Parameters/Extensions

		Shaft	Toe
Quake	(mm)	2.099	5.300
Case Damping Factor		0.775	0.821
Damping Type			Smith
Unloading Quake	(% of loading quake)	300	79
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	41	
Resistance Gap (included in Toe Quake)	(mm)		0.800
Soil Plug Weight	(kN)		0.02

CAPWAP match quality = 6.75 (Wave Up Match) ; RSA = 0  
Observed: final set = 3.333 mm; blow count = 300 b/m  
Computed: final set = 3.179 mm; blow count = 315 b/m  
max. Top Comp. Stress = 157.0 MPa (T= 27.5 ms, max= 1.100 x Top)  
max. Comp. Stress = 172.6 MPa (Z= 11.6 m, T= 24.6 ms)  
max. Tens. Stress = 0.00 MPa (Z= 1.1 m, T= 0.0 ms)  
max. Energy (EMX) = 12.19 kJ; max. Measured Top Displ. (DMX)=13.18 mm

HWY7044 CULVERT (ENGLOBE); Pile: TP3 EOD

Test: 24-Aug-2016 14:10:

E; Blow: 17

CAPWAP (R) 2006-2

AATech Scientific Inc

OP: TM

EXTREMA TABLE

Pile Sgmt No.	Dist. Below Gages m	max. Force kN	min. Force kN	max. Comp. Stress MPa	max. Tens. Stress MPa	max. Trnsfd. Energy kJ	max. Veloc. m/s	max. Displ. mm
1	1.1	1335.6	0.0	157.0	0.00	12.19	3.1	12.715
2	2.1	1338.8	0.0	157.3	0.00	11.77	3.0	12.013
3	3.2	1337.2	0.0	157.1	0.00	11.33	3.0	11.287
4	4.2	1314.0	0.0	154.4	0.00	10.48	2.9	10.566
5	5.3	1309.5	0.0	153.9	0.00	10.01	2.8	9.819
6	6.4	1260.6	0.0	148.1	0.00	8.68	2.8	9.080
7	7.4	1321.7	0.0	155.3	0.00	8.21	2.8	8.325
8	8.5	1367.1	0.0	160.6	0.00	7.40	2.9	7.568
9	9.5	1441.2	0.0	169.4	0.00	6.90	2.8	6.790
10	10.6	1398.3	0.0	164.3	0.00	5.52	2.7	6.048
11	11.6	1469.0	0.0	172.6	0.00	2.74	2.2	5.306
Absolute	11.6			172.6			(T =	24.6 ms)
	1.1				0.00		(T =	0.0 ms)

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	1490.4	1414.6	1338.8	1263.0	1187.2	1111.4	1035.6	959.8	884.0	808.3
RX	1708.3	1653.6	1616.0	1578.7	1541.5	1504.2	1474.6	1454.2	1435.3	1416.4
RU	1490.4	1414.6	1338.8	1263.0	1187.2	1111.4	1035.6	959.8	884.0	808.3
RAU =	1320.1	(kN);		RA2 =	1615.4	(kN)				

Current CAPWAP Ru = 1400.0 (kN); Corresponding J(RP)= 0.12; matches RX9 within 5%

VMX	TVP	VT1*Z	FT1	FMX	DMX	DFN	SET	EMX	QUS
m/s	ms	kN	kN	kN	mm	mm	mm	kJ	kN
3.18	21.12	1099.5	1148.8	1344.5	13.183	3.298	3.333	12.6	1524.7

PILE PROFILE AND PILE MODEL

Depth m	Area cm <sup>2</sup>	E-Modulus MPa	Spec. Weight kN/m <sup>3</sup>	Perim. m
0.00	85.10	210000.0	77.287	1.750
11.64	85.10	210000.0	77.287	1.750
Toe Area	0.009	m <sup>2</sup>		



HWY7044 CULVERT (ENGLOBE); Pile: TP3 EOD

Test: 24-Aug-2016 14:10:

E; Blow: 17

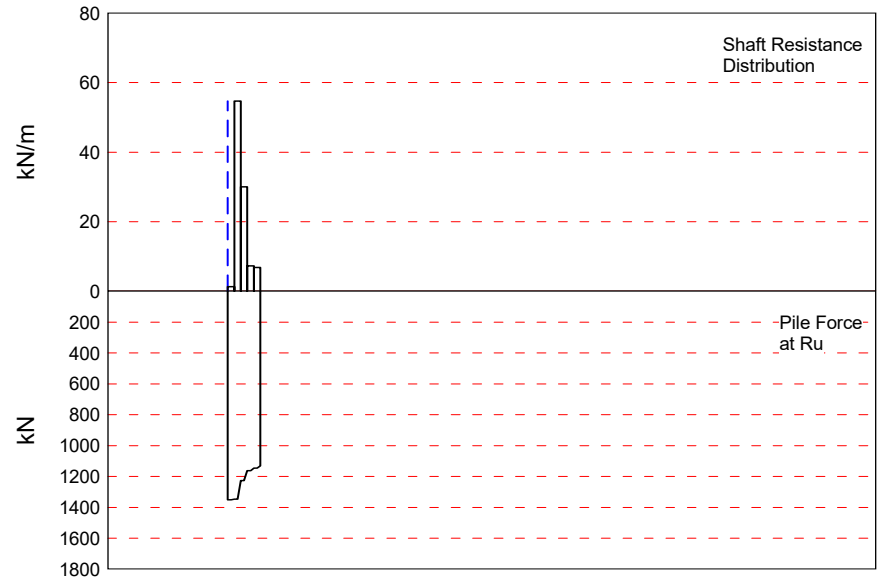
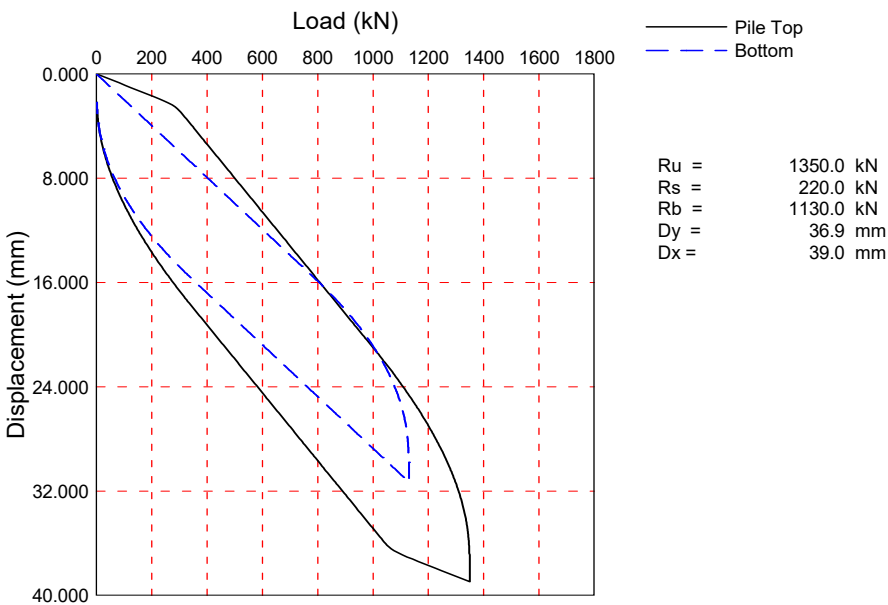
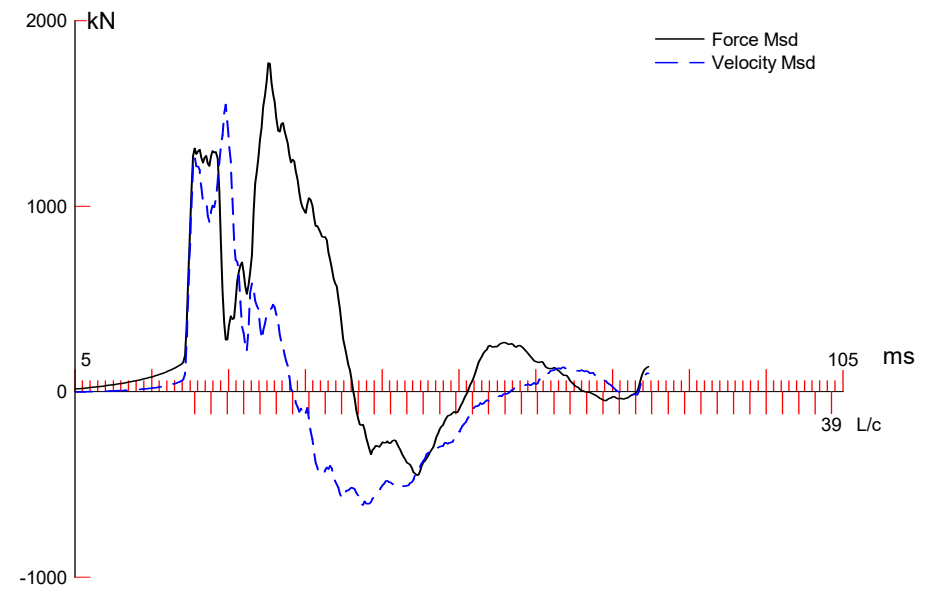
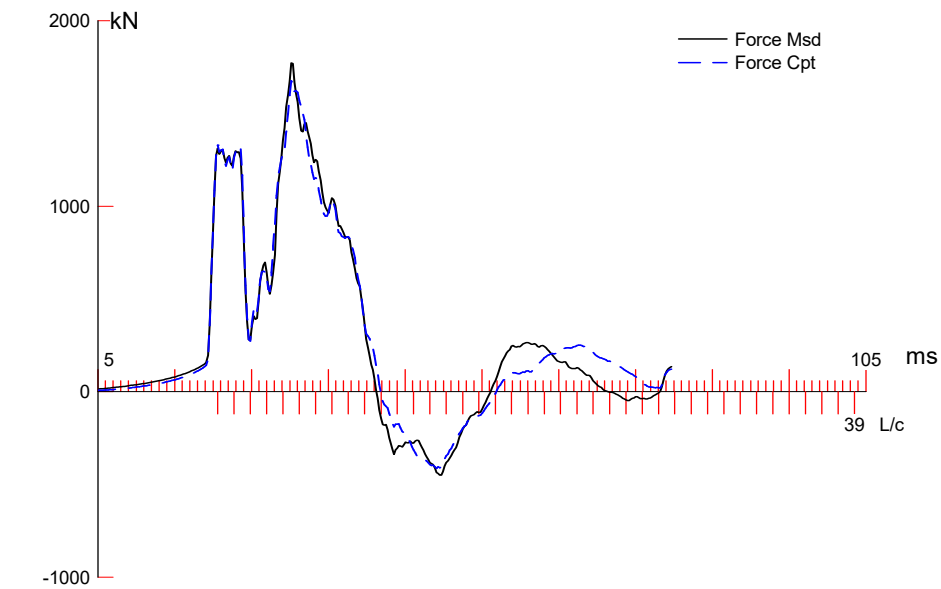
CAPWAP (R) 2006-2

AA Tech Scientific Inc

OP: TM

Segmnt Number	Dist. B.G. m	Impedance kN/m/s	Imped. Change %	Slack mm	Tension Eff.	Compression Slack mm	Compression Eff.	Perim. m
1	1.06	346.20	0.00	0.000	0.000	-0.000	0.000	1.750
10	10.58	346.20	0.00	0.000	0.000	-0.000	1.000	1.750
11	11.64	346.20	0.00	0.000	0.000	-0.000	0.000	1.750

Pile Damping 1.0 %, Time Incr 0.205 ms, Wave Speed 5162.0 m/s, 2L/c 4.5 ms



HWY7044 CULVERT (ENGLOBE); Pile: TP4 EOD  
E; Blow: 45  
AATech Scientific Inc

Test: 24-Aug-2016 13:28:  
CAPWAP (R) 2006-2  
OP: TM

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 1350.0; along Shaft 220.0; at Toe 1130.0 kN

Soil Sgmt No.	Dist. Below Gages m	Depth Below Grade m	Ru kN	Force in Pile kN	Sum of Ru kN	Unit Resist. (Depth) kN/m	Unit Resist. (Area) kPa	Smith Damping Factor s/m
				1350.0				
1	2.2	1.6	3.0	1347.0	3.0	1.85	1.06	0.251
2	4.4	3.8	120.0	1227.0	123.0	54.68	31.25	0.251
3	6.6	6.0	66.0	1161.0	189.0	30.07	17.19	0.251
4	8.8	8.2	16.0	1145.0	205.0	7.29	4.17	0.251
5	11.0	10.4	15.0	1130.0	220.0	6.84	3.91	0.251
Avg. Shaft			44.0			21.15	12.09	0.251
Toe			1130.0				132784.96	0.150

Soil Model Parameters/Extensions

		Shaft	Toe
Quake	(mm)	1.600	22.450
Case Damping Factor		0.160	0.489
Damping Type			Smith
Unloading Quake	(% of loading quake)	110	30
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	34	
Resistance Gap (included in Toe Quake)	(mm)		1.950

CAPWAP match quality = 7.79 (Wave Up Match) ; RSA = 0  
Observed: final set = 2.083 mm; blow count = 480 b/m  
Computed: final set = 2.491 mm; blow count = 401 b/m  
max. Top Comp. Stress = 198.5 MPa (T= 30.8 ms, max= 1.037 x Top)  
max. Comp. Stress = 205.8 MPa (Z= 3.3 m, T= 31.2 ms)  
max. Tens. Stress = -49.80 MPa (Z= 2.2 m, T= 49.7 ms)  
max. Energy (EMX) = 28.56 kJ; max. Measured Top Displ. (DMX)=28.95 mm

HWY7044 CULVERT (ENGLOBE); Pile: TP4 EOD  
 E; Blow: 45  
 AATech Scientific Inc

Test: 24-Aug-2016 13:28:  
 CAPWAP (R) 2006-2  
 OP: TM

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages m	max. Force kN	min. Force kN	max. Comp. Stress MPa	max. Tens. Stress MPa	max. Trnsfd. Energy kJ	max. Veloc. m/s	max. Displ. mm
1	1.1	1689.1	-419.6	198.5	-49.30	28.56	4.6	29.212
2	2.2	1730.7	-423.8	203.4	-49.80	28.54	5.2	28.580
3	3.3	1751.6	-420.1	205.8	-49.36	28.33	5.2	27.911
4	4.4	1707.7	-420.8	200.7	-49.45	28.31	5.2	27.210
5	5.5	1451.8	-336.0	170.6	-39.48	21.53	5.0	26.547
6	6.6	1449.9	-331.8	170.4	-38.99	21.21	5.2	25.859
7	7.7	1386.0	-298.5	162.9	-35.07	17.94	5.2	25.205
8	8.8	1392.2	-296.3	163.6	-34.81	17.59	5.6	24.543
9	9.9	1343.7	-271.1	157.9	-31.85	16.57	5.6	23.867
10	11.0	1348.8	-262.1	158.5	-30.79	16.80	5.6	23.177
Absolute	3.3			205.8			(T =	31.2 ms)
	2.2				-49.80		(T =	49.7 ms)

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	695.5	503.8	312.0	120.2	0.0	0.0	0.0	0.0	0.0	0.0
RX	1671.4	1614.8	1558.2	1501.5	1456.0	1416.2	1381.6	1360.4	1346.9	1333.6
RU	695.5	503.8	312.0	120.2	0.0	0.0	0.0	0.0	0.0	0.0

RAU = 1251.7 (kN); RA2 = 1183.4 (kN)

Current CAPWAP Ru = 1350.0 (kN); Corresponding J(RP)= 0.00; J(RX) = 0.78

VMX	TVP	VT1*Z	FT1	FMX	DMX	DFN	SET	EMX	QUS
m/s	ms	kN	kN	kN	mm	mm	mm	kJ	kN
4.54	20.83	1285.7	1327.7	1810.1	28.949	2.074	2.083	28.4	1828.6

PILE PROFILE AND PILE MODEL

Depth m	Area cm <sup>2</sup>	E-Modulus MPa	Spec. Weight kN/m <sup>3</sup>	Perim. m
0.00	85.10	210000.0	77.287	1.750
10.97	85.10	210000.0	77.287	1.750

Toe Area 0.009 m<sup>2</sup>

Top Segment Length 1.10 m, Top Impedance 346.20 kN/m/s

File Damping 1.0 %, Time Incr 0.213 ms, Wave Speed 5162.0 m/s, 2L/c 4.3 ms

**NOTICE TO CONTRACTOR – Obstructions in Fills and Native Soils as well as Fluctuations of Ground/Surface Water**

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Special Provision

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The Contractor is notified that, during foundation field investigations and the pile driving tests for the Culverts at Site No. 46-390, located at Station 10+000 on Highway 7044, cobble/boulder sized rock pieces were encountered in the embankment fills, and native sands and gravels deposits. Adequate pile driving equipment and toe protector properly fitting the size of sheet pile section should be used for driving the sheet piles.

The results of pile driving tests carried out for the Detailed Design at the site indicated that practical refusal of the driven test piles was achieved below Elevation 87.7 m, with maximum penetration of 25 mm for an average of 10 hammer blows using the pile driving hammer having a minimum energy of 58 kJ. The Contractor shall determine a set criteria of refusal equivalent to the above using their equipment. The Contractor shall then perform Pile Driving Analyzer (PDA) tests to demonstrate that the ultimate geotechnical axial resistance of the piles exceeds 490 kN/pile. The Contractor shall then drive all piles to refusal based on the verified set criteria established by the PDA tests.

The seasonal and yearly fluctuations of the groundwater and the surface water shall be considered for excavation and construction.

