



THURBER ENGINEERING LTD.

MEMORANDUM

To: Mark Torrie, P.Eng.
Associated Engineering (Ont.) Ltd.

Date: January 7, 2019

From: Mohammad Eghtesadi, P.Eng.
Keli Shi, P.Eng.
(Reviewed by P.K. Chatterji, P.Eng.)

File: 24974

**INDEPENDENT REVIEW OF FOUNDATION DESIGN
HIGHWAY 11 STURGEON RIVER BRIDGE REPLACEMENT PROJECT (SITE #45-105)
TOWNSHIP OF SHENSTON, RAINY RIVER DISTRICT, ONTARIO
ASSIGNMENT 6016-E-0028 GWP 6855-14-00**

1. INTRODUCTION

This memorandum presents the results of an independent review of the foundation design component of the Highway 11 Sturgeon River Bridge Replacement project in the Township of Shenston, Rainy River District, Ontario.

The following documents were provided to Thurber and have been used in the review:

- The original Sturgeon River Bridge drawings (6 sheets), prepared by Toronto Bridge Office of Department of Highways Ontario, dated October, November and December 1955
- DRAFT Foundation Investigation and Design Report, Sturgeon River Bridge, Township of Shenston, District Rainy River, Highway 11, Latitude: 48.654788° Longitude: -94.027112°, Assignment 6016-E-0028, WP 6855-14-00, Geocres No. 52D-34, Site No. 45-105, prepared by TBT Engineering Limited, dated November 12, 2018
- Contract Drawings (40 Sheets), Contract No. 2018-6020, GWP No. 6855-14-00, prepared by Associated Engineering Ltd., dated November 12, 2018

It is a condition of this memo that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. REVIEW OF FOUNDATION DESIGN

At the request of Associated Engineering, we have carried out an independent review of the foundation design component for the above project in response to the following items:

- 1) Review the Sturgeon FIDR Report, proposed pile layout plan, existing and future abutment slope geometry, construction methodology;

○ *Review comments on the FIDR Report:*

- a) 9.3.1 Lateral geotechnical resistances: Page 21 last paragraph recommends no reduction in lateral pile resistance is required for 2.5D pile spacing normal to the direction of loading. Please check against CHBDC (2014) Clause C6.11.3.4 whether a reduction factor should be applied.
- b) 9.5 Wing Walls (RSS): At the proposed RSS wall base elevations 324 to 333 m, the subgrade typically consists of stiff to very stiff medium plastic clay based on the field shear vane strengths. The geotechnical resistances recommended for wing wall footings in Table 9.5 appear low, particularly the factored SLS resistances. The RSS wall designer will likely require higher SLS resistances for up to 4.3 m high RSS wall. A separate technical memo has been prepared by Thurber to address the bearing capacities of the proposed abutment RSS wing walls.

The base of RSS walls at both abutments will become submerged during high-water level (HWL) season, i.e. 0.2 to 0.4 m below the HWL. Design of the RSS walls should consider the submerged conditions and prevent loss of fines due to scour/erosion associated with river level fluctuation. Alternatively, the RSS wall bases may be raised above the HWL. The base of the RSS walls must be protected against scour and erosion.

- c) 11.2 Embankment – Global Stability: Section 2 of the FIDR indicates that the fore slopes of the existing approach embankments vary from 2H:1V to 2.5H:1V and range in height from 2 to 3 m. The fore slopes of the embankments along the riverbank are approximately 7 m high with slopes varying from 2H:1V to 5H:1V. The existing embankments show no signs of instability; however, some erosion is evident on the northwestern slope. The report has also noted that small landslides have occurred along the Rainy River, and minor slumping and erosion are evident along most streams due to low bearing capacity and shearing resistance of the glaciolacustrine deposits in this area.

Total stress strength parameters were provided in Table 11.1 of the FIDR. However, short-term global stability analysis cases were not included in the FIDR. Global stability of the valley slopes and embankment side slopes at the abutments are largely governed by the upper medium plastic clay. Effective stress strength parameters of the clay layer were established from direct shear testing. The results of the long-term global stability analysis indicate that the existing river valley slopes have a minimum factor of safety of 1.3. The long-term factors of safety of the valley slopes at both abutments after bridge replacement will range between 1.5 and 1.7. The design side slopes of 4H:1V have achieved a minimum factor of safety of 1.5. All above factors of safety are deemed acceptable.

- d) 11.2.2 West Abutment River Bank Fore Slope Global Stability: Excavation at the West Abutment will extend 1.7 m below the lowest RSS wall base or the underside of abutment stem. The extent of excavation also significantly exceeds the extent of RSS wall. Please check if such a large excavation is necessary, particularly close to the river bank. Additional assessment should be conducted to see if the extent of excavation can be

reduced.

○ Review Comments on the Contract Drawings:

- e) Sheet 13 General Arrangement: Scour and erosion protection measures are not shown for the river valley slopes and benches in front of the abutments.
- f) Sheet 18 Piles Layout and Abutment Details: HP310x132 steel piles driven to bedrock are proposed at abutments. The design ULS load of 2,300 kN per pile has exceeded the factored ULS geotechnical resistance of 2,200 kN per pile for an HP310x132 as recommended in the FIDR. Please check.

The H-piles will be driven through 6.3 m and 18.9 m of dense to very dense till at the West and East Abutments, respectively. Geotechnical boreholes at abutment locations were advanced using casing/coring method to penetrate through cobbles/boulders at approximate elevations 308 m and 304 m at the West and East Abutments, respectively, while the design pile tip elevations are 305 m and 293 m, respectively. Driving piles to reach bedrock may encounter refusal within the “100-blow” till at a higher elevation. Also, hard driving through “100-blow” till with high hammer energy will likely cause significant vibration in the foundation soils. Based on the historical drawings, the existing timber piles are located a minimum 2 m from the new piles and founded within the upper medium plastic clay and underlain by high plastic clay and loose to compact silt overlying the till. The ground vibration induced by high energy pile driving will trigger excess pore pressures in the clays and silts and cause subsequent settlement of the existing bridge when excess pore pressures dissipate. Pre-drilling or pre-augering to facilitate pile driving is discussed in the FIDR. However, effectiveness of pre-drilling or pre-augering is uncertain due to the presence of cobbles and boulders in the till.

To minimize ground disturbance associated with pile driving, piles driven to capacity or set into the very dense till rather than driving to bedrock may be considered. High-strain dynamic testing or PDA testing should be conducted to verify pile capacity. The number of piles required in a foundation element to meet the structural load demand will increase given the lower pile capacity for piles driven to till and therefore redesign of the abutments. The pile tip elevations and pile capacities for piles driven to till should be reassessed.

- 2) Conduct an independent detailed analysis, determine expected and permissible porewater pressures, permissible slope and foundation movements for the proposed construction, and determine measures to mitigate these effects if required;

An independent analysis has been conducted to assess excess porewater pressure (EPP) responses during pile driving. EPP generation in the foundation clay is typically triggered by two mechanisms, i.e. soil displacement around pile shaft during pile penetration and ground vibration associated with hard driving. The maximum EPP (typically governed by soil shear stiffness G and undrained shear strength C_u) due to soil displacement generally occurs immediately at pile shaft where soil is sheared and remoulded and decreases radially away from the pile shaft up to an approximate radius of ten times the pile diameter or width. In contrast, significant ground vibration during pile driving will induce widespread EPP within a



soil mass and the magnitude of EPP associated with ground vibration will depend on the intensity and duration of the ground vibration.

In the absence of consolidation test data, empirical correlations were used to estimate the clay compressibility parameters. The permissible foundation movement of 25 mm was provided by the structural designer as an input for assessment of permissible EPP at the existing pile locations. The permissible EPP due to pile driving is estimated to be 30 kPa at the existing timber piles. To minimize the potential for triggering frequent stoppages of pile driving due to relatively low EPP alarm levels, the Monitoring Program NSSP has specified 40 and 50 kPa for EPP Review and Alert Levels, respectively. The settlement Review and Alert Levels are specified to be 15 and 20 mm, respectively.

Due to the variability in soil conditions across the site and the actual ground disturbance induced by pile driving, the EPP values obtained at the monitoring locations should be assessed in conjunction with settlement monitoring data.

Mitigative measures to minimize the effects of pile driving are recommended below:

- *Monitor bridge settlements and pore pressures in the foundation clay, and raise the bridge by lifting and shimming as required based on settlement monitoring data;*
- *Drive piles in sequence from the furthest to the closest to the existing timber piles;*
- *Pre-drill or pre-auger to allow piles to reach bedrock without hard driving. This option may not be practical due to the presence of cobbles/boulders in the till and the design pile lengths;*
- *Use piles driven to capacity or corresponding set in the very dense till and therefore redesign of the abutments.*

- 3) Prepare a monitoring and instrumentation plan and drawings;
- 4) Thurber shall provide a special provision for supply and installation of instruments and supervision required for installation of instruments;
- 5) Thurber shall provide a work plan for the Contract Administrator who will hire a high complexity foundations consultant listed in RAQS to ensure full compliance with the monitoring and instrumentation plan and other documents prepared by Thurber;
- 6) All deliverables produced by Thurber shall be signed and sealed by the assigned engineer and MTO designated contact;
- 7) Two contract documents shall be prepared by Thurber: one for the Contract Administrator and one for the Contractor.

Two monitoring NSSPs, i.e. Supply and Installation of Bridge Monitoring Equipment and Monitoring Program, have been prepared in response to Items 3, 4, 5 and 7, and are attached in Appendix A.



3. CLOSURE

The memorandum was prepared by Mohammad Eghtesadi, P.Eng. and Mr. Keli Shi, P.Eng., and reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



Keli Shi, P.Eng.
Associate, Senior Geotechnical Engineer



Dr. P.K. Chatterji, P.Eng.
Designated MTO Principal Contact

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.



APPENDIX A

NSSP – Supply and Installation of Bridge Monitoring Equipment

NSSP – Monitoring Program

SUPPLY AND INSTALLATION OF BRIDGE MONITORING EQUIPMENT

- Item No.

Special Provision

1.0 SCOPE

This special provision contains the requirements for the supply and installation of the following geotechnical instruments:

- Survey Benchmarks (BM)
- Settlement Pins (SP)
- Vibrating Wire Piezometers (VWP)

The purpose of these instruments is to monitor settlements of the existing bridge and pore water pressures in the foundation soils during pile installation for the proposed Sturgeon River Replacement Bridge on Highway 11.

The rate of pile driving, and hammer energy applied during pile driving shall be controlled by the instrumentation readings.

1.01 General Procedure

The benchmarks shall be installed prior to the bridge construction. The benchmarks consist of a steel rod anchored to the bottom of a borehole. Existing verified non-yielding benchmarks monuments can be considered as a replacement for new benchmarks following approval by the Contract Administrator.

The settlement pins shall be installed on the pavement of the travelled portion of the existing bridge and edge of the existing bridge deck. The settlement pins shall be masonry nail heads recessed below pavement surface and installed along the edge of the existing concrete deck.

The VW piezometers shall be installed in boreholes prior to any pile driving. The VW signal cables shall be extended underneath the existing bridge deck through a metal or plastic conduit buried in trenches to a data logger located out of the bridge footprint.

2.0 REFERENCES – Not Used

3.0 DEFINITIONS

3.01 Personnel

The Contractor shall retain a Geotechnical Consultant who is approved for MTO RAQS category of “**Geotechnical** (Structures and Embankments) – **Medium Complexity**”, to undertake the supply and installation of geotechnical instruments. Monitoring of the instruments shall be carried out by others.

The *Contractor* shall be understood to refer to the Contractor and his Geotechnical Consultant.

3.02 Or Equal

The term, “*or equal*”, shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration. Only one supplier should be selected for the supply of all vibrating wire instruments.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

The Contractor shall submit details of proposed installation methods, including location and types of data-acquisition system, survey benchmarks, and installation schedule to the Contract Administrator, a minimum of 15 days before the start of instrument installation.

5.0 MATERIALS

5.01 Survey Benchmarks (BM)

5.01.01 General

The Contractor shall supply all materials and equipment required for the installation of the benchmarks.

5.01.02 Rod

The Contractor shall supply a steel pipe Schedule 40 with an outside diameter not less than 25.4 mm (1"), supplied in lengths as required to complete the installation.

The top end of each length of rod shall be threaded to receive a cap. A rounded cap shall be installed at the top of the rod in such a way that a single survey point can be clearly identified and returned to.

5.01.03 Sand

The Contractor shall supply clean washed sand with the following gradation:

MTO Sieve Designation	Percentage Passing
4.5 mm - #4	100%
2 mm - #10	80% - 100%
850 µm - #20	20% - 100%
425 µm - #40	5% - 40%
150 µm - #100	0% - 5%

5.01.04 Grout

The Contractor shall supply cement-bentonite grout. A suitable grout mix design consists of 17.7 kg of bentonite (OPSS 1205), 284 litres of water and 42.6 kg of cement (Type 10 - OPSS 1301).

5.01.05 Rod Anchor Grout

The Contractor shall supply cement-bentonite grout. A suitable grout mix design consists of 14 kg of

bentonite (OPSS 1205), 49 litres of water and 40 kg of cement (Type 10 - OPSS 1301).

5.02 Settlement Pins (SP)

5.02.01 General

The Contractor shall supply all materials and equipment required for the installation of the settlement pins.

5.02.02 Nail

The Contractor shall supply a masonry nail with a minimum length of 25 mm. The head of the nail shall be rounded in such a way that a single survey point can be clearly identified and repeated.

5.02.03 Metal Identification Tag

The Contractor shall supply a metal identification tag to be installed with surveying nail. The diameter of tag shall be 35 mm.

5.03 Vibrating Wire Piezometers (VWP)

5.03.01 VW Piezometers

The Contractor shall supply VW borehole piezometers (e.g. Geokon model 4500S rated at -5 to 50 psi, or equal); compatible with a data logger (e.g. Geokon model 8002-1, 8002-4, 8002-16 data logger, or equal). All VW piezometers and data loggers shall be of the same make.

All VWPs shall be calibrated prior to installation and the calibration data for each VWP shall be provided to the Contract Administrator.

5.03.02 Signal Cable

The Contractor shall supply signal cable compatible with the VW equipment. The VWPs shall withstand all the temperature variations. The length of cable for each piezometer shall be carefully estimated from the construction drawings to ensure that there is enough signal cable for each piezometer to provide enough slack in the borehole and along the trenches.

5.03.03 VW Data Recorder

The Contractor shall supply a VW Data Recorder (e.g. Geokon model GK-404, or equal); compatible with the above VW piezometers. All VW equipment shall be of the same make.

5.03.04 VW Data Loggers

The VWP signal cables shall be connected to the nearest data logger. Data loggers such as Geokon LC-2 Series Model 8002-1 (single channel), 8002-4 (four channel) and/or 8002-16 (16 channel) or equal shall be used. The data logger shall include, but not be limited to, interface modules, interface cables, data logger retrieval computer software, and continuous power supply that will allow for regular monitoring over the duration of the bridge construction. All data loggers shall be of the same make and shall be compatible with the VWP instruments.

The VW data shall be retrieved on site by direct wire (e.g. RS232 or USB Cable) with a portable laptop

computer specified in Section 6.02.

5.03.05 Bentonite

The Contractor shall supply bentonite (OPSS 1205) in pellet form in sufficient quantity to form borehole plugs as required.

5.03.06 Grout

The annular space between the VWP cables and the borehole shall be filled with cement-bentonite grout prepared as follows: 17.7 kg of bentonite (OPSS 1205), 284 liters of water and 42.6 kg of cement (Type 10 - OPSS 1301).

5.03.07 Filter Sand

The Contractor shall supply clean sand for filter around VW sensors. The sand shall be Sakrete washed general purpose sand or equal.

5.03.08 Trench Burial and Conduit

The signal cable for each piezometer shall be buried in a shallow trench as shown in the contract drawings and taken out of the bridge footprint area. The Contractor shall supply suitable conduits (e.g. Schedule 40 - 75mm - 3" rigid PVC pipe) to protect the signal cables in the trenches and above ground surface. If appropriate, several signal cables may be housed in a single conduit and laid in a common trench. Before trenches are backfilled, the VW piezometers shall be tested.

5.03.09 Monitoring Enclosure

The Contractor shall supply all materials required to build weatherproof and lockable monitoring enclosures to house VW data loggers.

6.0 EQUIPMENT

6.01 Equipment Operation and Weather Conditions

All installation and monitoring equipment and associated materials shall be capable of withstanding the range of temperatures possible for their locations within the ground or on the surface. The instruments shall be capable of operating within the manufacturer's stated accuracy throughout the temperature range. The Contractor shall replace/repair non-functioning monitoring instruments as required at no cost to the Ministry.

6.02 Portable Laptop Computer

The Contractor shall supply a laptop computer, Lenovo X140e or equal, equipped with at least a 128 gigabyte (gb) solid state drive, 4gb of RAM, two batteries, Microsoft Windows 7 Professional (OS), Microsoft Office Home and Business 2017, Adobe Acrobat XI Standard and data logger software compatible with the selected data logger system.

The portable laptop computer shall be handed to the Contract Administrator after the installation of instruments and before the commencement of the Monitoring Program.

The calibration factors for all vibrating wire instruments shall be entered in the portable laptop computer by the Contractor for initialization of the instruments.

7.0 CONSTRUCTION

7.01 Installation

7.01.01 Drawings

Reference shall be made to the following drawings in the Contract Drawings:

- Monitoring Section Location Plan and Profile
- Monitoring Instrument Details

7.01.02 Subsurface Conditions

The subsurface conditions at the sites are described in the following report:

FOUNDATION INVESTIGATION AND DESIGN REPORT, STURGEON RIVER BRIDGE, TOWNSHIP OF SHENSTON, DISTRICT RAINY RIVER, HIGHWAY 11, ASSIGNMENT 6016-E-0028, WP 6855-14-00, SITE No. 45-105 (GEOCRETS NO. 52D-34), prepared by TBT Engineering Limited.

7.01.03 Instrument Locations and Quantities

Prior to the installation of instruments, the Contractor shall accurately survey and stake the location of each instrument and obtain a ground elevation and northing/easting coordinates at each instrument location.

The quantities and locations of instruments are shown in Table 1.

Table 1 – Instrument Quantities

Location		NO. OF INSTRUMENTS	
		SP	VWP
Pier No 1	18+452	2	
East of Pier No 1	18+454		2
Pier No 2	18+460	2	
Pier No 3	18+466	2	
Pier No 4	18+482	2	
Pier No 5	18+488	2	
Pier No 6	18+494	2	
Pier No 7	18+500	2	
West of Pier No 8	18+505		2
Pier No 8	18+506	2	
Total		16	4

7.01.04 Survey Benchmarks (BM)

The Contractor shall provide a minimum of two non-yielding temporary survey benchmarks (BM), one on

each side of the Sturgeon River.

The number and locations of benchmarks shall be such that direct sighting is possible from all settlement pins (SP) to at least one benchmark.

The locations of the temporary benchmarks are to be approved by the Contract Administrator prior to installation of the monitoring instruments.

7.01.04.01 Number and Location

A minimum of two (2) benchmarks shall be provided for the purposes of monitoring bridge settlements. The number and locations of benchmarks shall be adjusted in the field such that the benchmarks are located at sufficient distances from the bridge to remain non-yielding, not affected by the bridge construction or pile driving and direct sighting is possible from all settlement pins (SP) to at least one benchmark.

7.01.04.02 Borehole Installation

The borehole shall be advanced to a minimum depth of 25 m below the existing ground surface using suitable drilling techniques. The diameter of the borehole shall be sufficient to fit the rod and rod anchor. The borehole shall be stable and free of drilling mud and debris.

7.01.04.03 Rod Couplings

The coupling of the rods shall be such that all sections have the same axis and no separation or contraction will occur at the couplings.

7.01.04.04 Rod Anchor

The rod shall be installed vertically in the borehole with its bottom end resting at the bottom of the borehole. The rod shall be grouted in place.

7.01.04.05 Installation Details

The elevation, easting and northing of the top of the benchmark rod shall be surveyed.

7.01.05 Settlement Pins (SP)

The settlement pin shall be installed on paved surface and on the edge of concrete deck. The settlement pin installations in areas of vehicular traffic that could dislodge monitoring points (e.g. by snowplow) must be recessed below surrounding surface by a minimum of 5 mm.

7.01.05.01 Quantities

The locations of the settlement pins are shown on the contract drawings and are given in Table 1A.

Table 1A – SP Locations and Quantities

LOCATION	APPROX. OFFSET FROM CL (*)	NO. of SP
Pavement Surface	2 m South	8
Edge of Concrete Deck	5.5 m South	8

Note: (*) Centreline (CL) refers to the centreline of the bridge

7.01.05.02 Pre-drilled Hole

Prior to installing the masonry nail, a small size hole shall be drilled into the pavement or concrete. The inside of the hole must be clear of any drill powder or loose overbreak materials prior to installation.

7.01.05.03 Masonry Nail

The nail shall be hammered into the pre-drilled hole while maintaining contact with the inside wall. When fully inserted, the base of the head of the nail shall be flush with the pavement or concrete surface.

7.01.05.03 Installation Details

The elevation, easting and northing of the top of the nail shall be surveyed.

The Contractor shall install settlement pins as per the contract drawings provided.

7.01.06 VW Piezometers

7.01.06.01 Quantities

The Contractor shall install VW sensors at the locations and depths given in Table 1B.

Table 1B – VWP Locations and Quantities

LOCATION		APPROX. OFFSET FROM CL (*)	NO. of VWP	VWP TIP ELEVATION (m)
East of Pier No 1	18+454	0.5 m South	2	327.0
				320.0
West of Pier No 8	18+505	0.5 m South	2	327.0
				320.0

Note: (*) Centreline (CL) refers to the centreline of the bridge

7.01.06.02 Borehole Installation

The borehole shall be advanced to 500 mm below the lowest VWP tip elevation using suitable drilling techniques. The sides of the borehole shall be stable, and the borehole shall be free of drilling mud and debris.

The Contractor shall make a basic stratigraphic log of boreholes as they are being drilled. Occasional

Standard Penetration Test (SPT) sampling are required to confirm soil type. Other in-situ testing and laboratory testing are not required.

Boreholes shall be advanced using appropriate drilling methods and shall be as straight and vertical as practical from top of the bridge due to limited space below deck of bridge.

7.01.06.03 Data Logger Boxes and Monitoring Enclosure

The data-logger and all associated accessories shall be installed in a lockable enclosure to prevent vandalism and wear-out of the data-loggers against extreme weather.

The monitoring enclosure shall be lockable and weatherproof. The monitoring enclosure shall be attached on a wooden post (a minimum 100 mm x 100 mm) and secured in the ground. The monitoring enclosure shall be located approximately 1.5 m above the surrounding ground for easy access to data loggers. All data loggers and associated accessories shall be properly grounded and protected from lightning strike. The Contractor shall submit a detailed proposal of the monitoring enclosure (i.e. materials, location(s), etc.) to the Contract Administrator for review and approval, prior to construction.

The data loggers shall be securely attached inside the Monitoring Enclosure. The data logger accessories shall be properly grounded.

The Contractor shall ensure safe access to the Monitoring Enclosure at all times including, but not limited to, snow clearing in the winter.

7.01.06.04 Completion of Installation

It is known that the process of installing VW piezometers can temporarily alter the pore water pressure acting on the piezometer tip. The installation of a VW piezometer shall not be considered to be complete until the pore pressure acting on the piezometer has returned to and stabilized at the value prevailing in the surrounding, unaffected soil mass. The Contractor shall take daily reading of the pore pressures until the value has stabilized. Stabilization shall be deemed to have occurred:

- a) When no change in the measured value has occurred over a period of 5 days and the measured value is within 10% of the anticipated hydrostatic value;
- b) When the daily rate of change is less than (3) kPa per day for three consecutive days and the measured value is within 5% of the anticipated hydrostatic value;
- c) Failing either of the two above conditions, as determined by the Contract Administrator.

The Contractor should be prepared to wait for a period of 15 days after completion of installation of piezometers for the baseline readings to stabilize.

7.01.07 Accuracy of Surveying for Elevations

Elevations shall be surveyed to an accuracy of ± 2 mm or better.

7.01.08 Underground Utilities

The Contractor shall be responsible for locating and protecting all underground utilities prior to drilling boreholes for installing instruments. Any damage to underground utilities caused by the Contractor's work shall be repaired by the Contractor, at no cost to the Ministry.

7.01.09 Marking and Labelling

The location of any above ground monitoring fixture shall be made clearly visible to nearby traffic before, during and after bridge construction. Marking shall be of sufficient size to be visible from a reversing vehicle and after a heavy snow fall.

Instruments or their data cables shall be clearly labelled in the field, each instrument having a unique identifier. The labelling shall remain legible during the monitoring period.

7.01.10 Protection of Instruments

All instruments shall be adequately protected by the Contractor such that they are not damaged during construction. Any instrument damaged by the Contractor's work shall be immediately replaced at the Contractor's cost.

Instruments should also be adequately protected by the Contractor from construction activities and natural effects. This can be achieved by using appropriate grounding and transient protection systems; such as Geokon Lab 3 Surge Module, lightning diversion systems and/or equipotential grounding systems, or equal.

7.01.11 Installation Program

Instrument installation shall commence prior to existing bridge removal, pile driving and construction of any work. No material stockpiling shall be allowed within the bridge construction area during instrument installation. Table 2 gives a summary of the installation schedule requirements.

Table 2 – Installation Program

TYPE	START INSTALLATION	FINISH INSTALLATION
BM	-	Before installation of other monitoring instruments
SP	After completion of benchmark installation	Prior to any removal work on existing bridge
VWP	-	At least 15 days prior to any pile driving for new bridge

7.02 Coordination with Monitoring

7.02.01 Survey Benchmarks (BM)

7.02.01.01 Notification

The Contractor shall notify the Contract Administrator no later than 3 days after installing a benchmark. At this time the Contractor shall also supply the following information to the Contract Administrator:

- Elevations of the bottom of the rod anchor and the top of rod;
- Dates of installation;
- Stratigraphic log of subsurface conditions at the benchmark, including drilling method notes;
- Installation notes, sketches and photographs;
- Description of benchmarks.

7.02.01.02 Monitoring

Monitoring of settlement with reference to the benchmarks shall be done by others. Monitoring shall be conducted before, during and after pile driving for the new bridge. The Contractor shall provide installation information as specified above and provide access to the benchmarks for monitoring including, but not limited to, snow clearing in the winter. The contractor shall provide electric power and general area lighting as needed.

7.02.02 Settlement Pins (SP)

7.02.02.01 Notification

The Contractor shall notify the Contract Administrator no later than 3 days after installing a settlement pin. At this time the Contractor shall also supply the following information to the Contract Administrator:

- Settlement pin location, easting and northing;
- Elevation of top of pin;
- Dates of installation and datum readings;
- Installation notes, sketches and photographs;

7.02.02.02 Monitoring

Monitoring of the settlement pins shall be done by others. Monitoring shall be conducted before, during and after the pile driving. The Contractor shall provide installation information as specified above and provide access to the settlement pins for settlement monitoring.

7.02.03 VW Piezometers (VWP)

7.02.03.01 Notification

The Contractor shall notify the Contract Administrator no later than 3 days after installing a VW piezometer. At this time, the Contractor shall also supply the following information to the Contract Administrator.

- VW piezometer location, easting, northing;
- Elevations of VWP sensor tips;
- Stratigraphic log of subsurface conditions, including drilling method notes;
- Dates of installation;
- Installation notes, grounding method, sketches and photographs;
- Model, make and serial number of VW sensors, data logger and signal cable;
- Calibration details of VW sensors.

7.02.03.02 Monitoring

Monitoring of the VW piezometers, including establishment of baseline data, shall be done by others. Monitoring shall be conducted before, during and after the pile driving. The Contractor shall provide installation information as specified above and provide access to the monitoring shed for data retrieval.

The Contractor shall transfer the Portable Laptop Computer and VW Data Recorder to the Contract Administrator, including all data logging software and hardware, operating instructions and calibration

constants. The contractor shall also transfer the keys for the locks of the Enclosure(s). The contractor shall be available for one site meeting with the Contract Administrator to transfer the items and answer any questions the Contract Administrator may have regarding the data-logging system.

7.03 Decommissioning of Instruments

The Contractor shall decommission the VWP's at the end of the monitoring program following the end of construction unless advised otherwise by the Contract Administrator. The Benchmarks (BM) shall not be decommissioned unless advised otherwise by the Contract Administrator. Decommissioning of instrumentation shall be carried out as per the Ontario Water Resources Act, R.R.O. 1990, Regulation 903.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement for Payment for the Supply and Installation of Bridge Monitoring Equipment shall be Lump Sum.

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No 2018-6020
GWP No 6855-14-01



HIGHWAY 11
STURGEON RIVER BRIDGE
REPLACEMENT
MONITORING SECTION LOCATION PLAN

SHEET

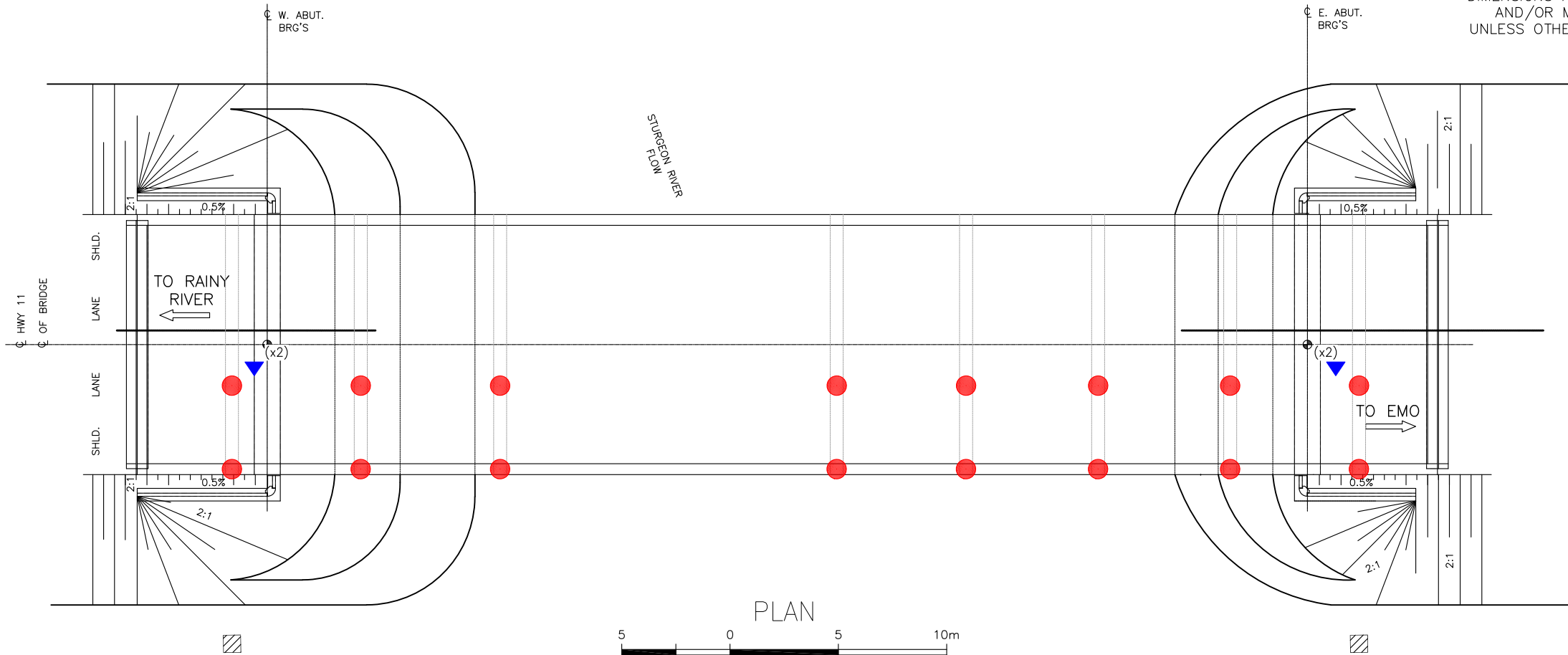


LEGEND

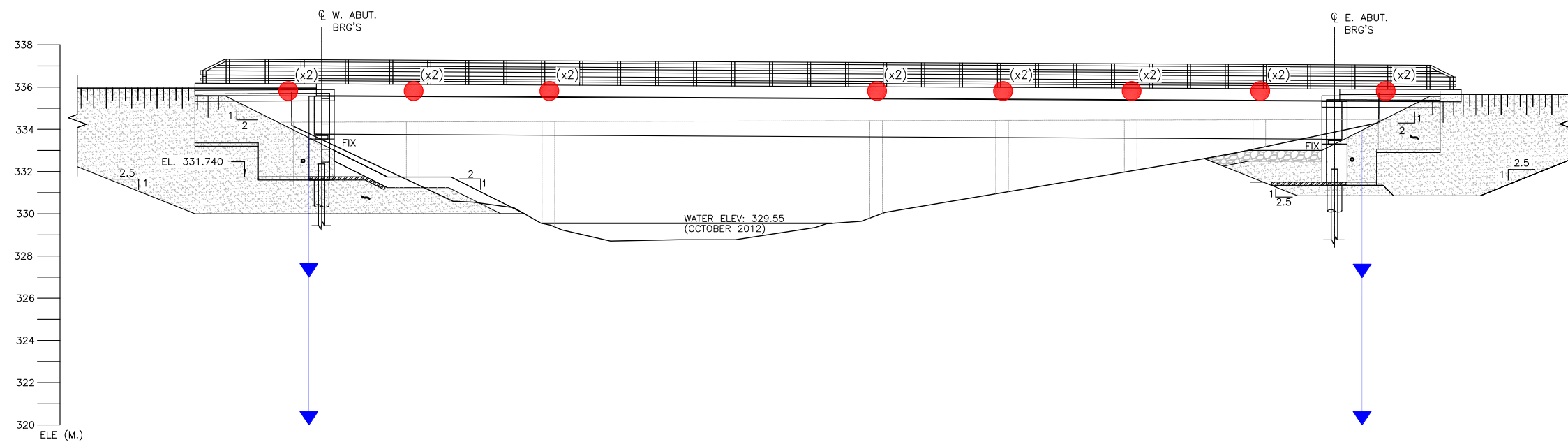
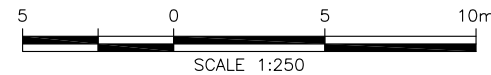
- Settlement Pin (SP)
- ▼ Vibrating Wire Piezometer (VWP)
- Benchmark (BM*)
- (x2) Two Piezometers At Different Elevations/
Two SPs At Different Locations
- ▨ Monitoring Enclosure

-NOTES-

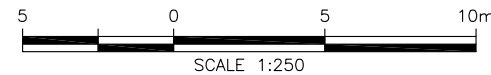
1. Base plan, highway and alignments are current as of November 2018.
2. Instrument locations are approximate. For actual locations refer to Typical Monitoring Sections. Some field adjustment to instrument locations may be required.
3. Locations of monitoring sheds shown are schematic only. Actual installation locations of the monitoring sheds should be selected by the contractor and approved by the contract administrator.



PLAN



PROFILE



*2 BM'S (■) shall be installed in this area as per the contract documents.

REVISIONS						
DATE	BY	DESCRIPTION				
DESIGN	ME	CHK	KS	CODE	LOAD	DATE DEC 2018
DRAWN	AN	CHK	ME	SITE	STRUCT	DWG 1

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No 2018-6020
GWP No 6855-14-01

HIGHWAY 11
STURGEON RIVER BRIDGE
REPLACEMENT
MONITORING INSTRUMENT DETAILS

SHEET



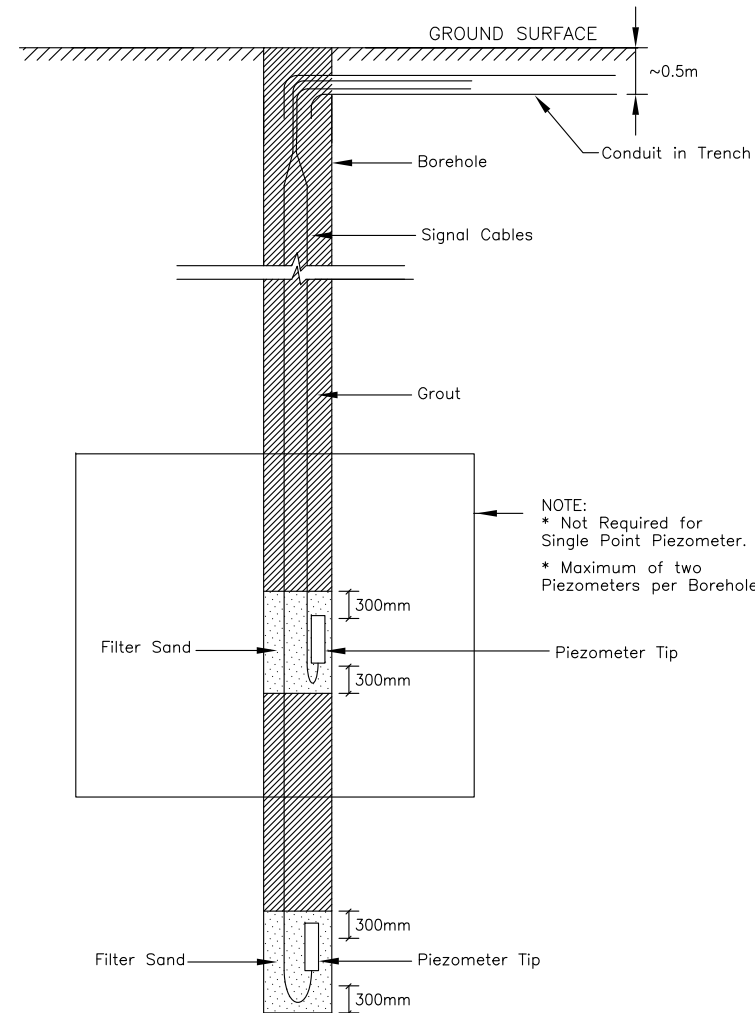
LEGEND

-NOTES-

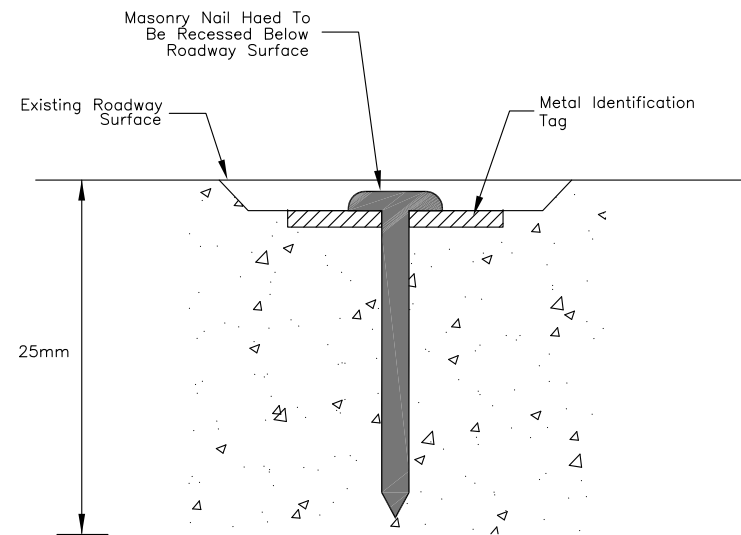
1. This drawing is schematic only. Please refer to Special Provision *Supply and Installation of Embankment Monitoring Equipment* for installation depth of instrument.

REVISIONS		DATE	BY	DESCRIPTION
DESIGN	ME	CHK	KS	CODE
DRAWN	AN	CHK	ME	SITE
		LOAD	DATE	DEC 2018
		STRUCT	DWG	2

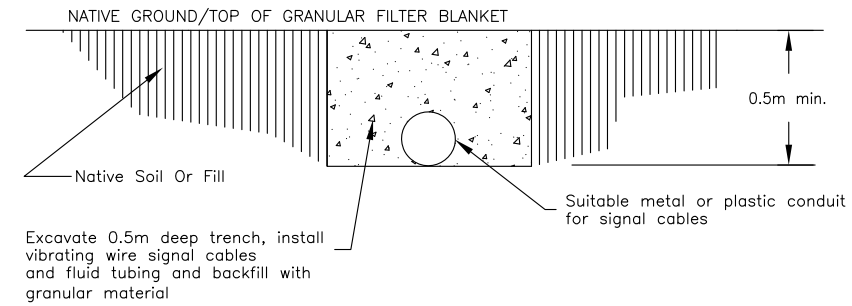
FILENAME: H:\Drafting\24000\24974\TED-24974-MonitoringPlan.dwg
PLOT DATE: 12/14/2018 1:57 PM



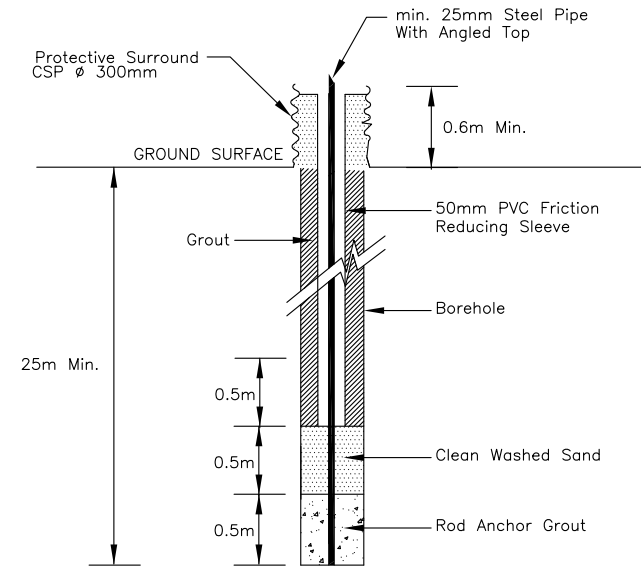
VIBRATING WIRE PIEZOMETER (VWP)



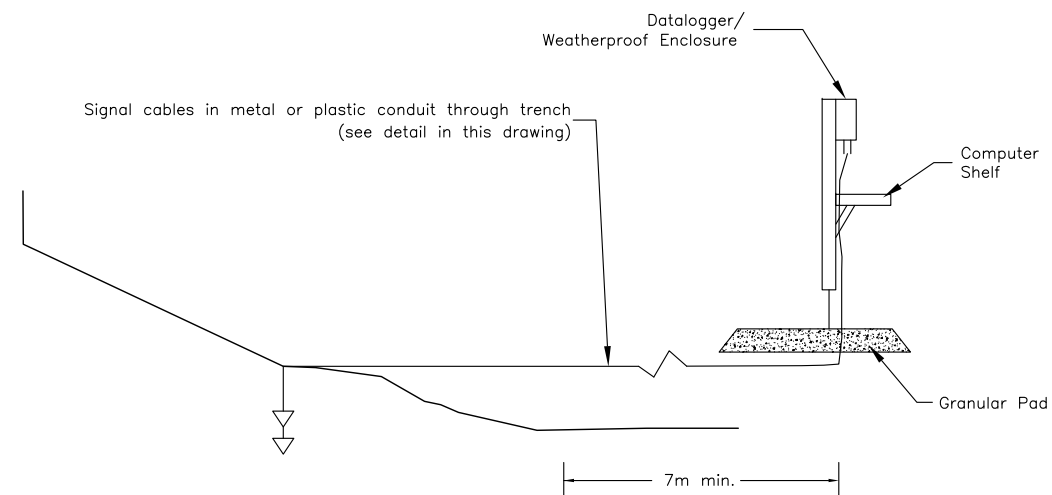
SETTLEMENT PIN (SP)



TRENCH FOR SIGNAL CABLES



BENCHMARK (BM)



DATA SELECTION SET-UP FOR VIBRATING WIRE PIEZOMETERS

MONITORING PROGRAM – Item No.

Special Provision

1.0 GENERAL

Requirements specified for Specialist Qualifications; Services, Deliverables and Records; and the Foundation Monitoring Plan apply to all the Instrumentation Monitoring. Instrumentation monitoring is required for the following items:

- Survey Benchmarks (BM)
- Settlement Pins (SP)
- Vibrating Wire Piezometers (VWP)

The instrumentation monitoring services include:

1. Data collection, data reduction and reporting;
2. Adherence to criteria used to assess the impact on the existing bridge foundation during pile installation of the new Sturgeon River Bridge.

1.0.1 Or equal

The term, “*or equal*”, shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration.

1.0.2 Specialist Qualifications

The Foundation Engineering Consultant services required for this assignment have been categorized *Geotechnical* specialty – **High Complexity**.

The Foundation Engineering Consultants that are registered in MTO's consultant acquisition system (RAQS) at complexity ratings in the required specialty that meet or exceed the identified complexity requirement for this assignment are eligible to provide Foundation Engineering services for this project. The Foundation Monitoring Consultant shall be retained by the Contract Administrator. The Foundation Monitoring Consultant shall not be the same Geotechnical Consultant retained by the Contractor for the supply and installation of monitoring equipment.

1.0.3 Services, Deliverables and Records

The Foundation Monitoring Consultant shall:

- Review the Monitoring Program and, if deemed necessary, submit in writing to the Contract Administrator recommendations for modifications to the Monitoring Program;
- Review the proposal of installation of VWP and data logger setup by the Contractor;
- Conduct an on-site quality inspection during instrument installation;
- Meet with the Contractor in order to receive the VW Data Recorder, Portable Laptop Computer and associated software used for monitoring vibrating wire instruments and to receive reports

with details about installation of instruments installed by the Contractor, as specified in Special Provision entitled “Supply and Installation of Bridge Monitoring Equipment”, included in the contract documents. Contractor’s reports shall include all calibration certificates;

- Calibrate and maintain monitoring equipment;
- Take instrument readings, reduce data, prepare reports;
- Provide transmittal of instrument readings and reports to the Contract Administrator;
- Interpret instrument readings as needed for the purposes of ongoing construction;
- Notify the Contract Administrator of required modifications to the construction procedures accordingly, if necessary. Interpretation shall include making correlations between instrumentation data and specific construction activities;
- Notify the Contract Administrator within 24 hours if review level, as specified herein, for any instrument is reached;
- Discuss within 48 hours with the Contract Administrator response action(s) proposed by the contractor, to prevent the critical instrument readings (i.e. review/alert levels) from being exceeded.

A brief weekly progress report shall be provided to the Contract Administrator during the monitoring period. The progress report shall provide a summary of the monitoring that was completed for the week.

The Contract Administrator shall maintain a Foundations Monitoring diary and shall provide this diary to the Foundation Monitoring Consultant. The diary shall document original conditions, work in progress, including pile driving progress and associated bridge settlement, any unusual or problem situations that arise, record of actions taken by the Contractor to rectify the situation, and restored conditions. The diary shall be supported by photographs of these conditions.

1.0.4 Submission of Foundation Monitoring Plan

The Foundation Monitoring Consultant shall, in a brief narrative, discuss the applicable experience and qualifications of specialist staff, the role that each will play in administration of the contract, the authority to be assumed, and the reporting relationships with the construction administration staff.

The Foundation Monitoring Consultant shall also complete the Foundation Monitoring Plan table in the format provided below.

Foundation Monitoring Plan		
Major Monitoring Tasks	Level of Monitoring	Deliverable Record(s)
List major monitoring tasks associated with foundation monitoring.	State frequency/level of monitoring.	List associated Deliverable Records for each task.

1.1 **PURPOSE**

The purpose of these instruments is to monitor settlements of the existing bridge and pore water pressures in the foundation soils during pile driving for the proposed Sturgeon River Replacement Bridge on Highway 11.

The rate of pile driving, and hammer energy applied during pile driving shall be controlled by the

instrumentation readings.

The instrumentation shall not be decommissioned unless instructed by the Contract Administrator after discussion with and concurrence from MTO.

1.2 DRAWINGS

Reference shall be made to the drawings titled Bridge Monitoring Equipment – Plan, Sections and Details included in the Contract Package and as listed below:

- Monitoring Section Location Plan and Profile
- Monitoring Instrument Details

1.3 SUBSURFACE CONDITIONS

The subsurface conditions at the sites are described in the following reports:

- FOUNDATION INVESTIGATION AND DESIGN REPORT, STURGEON RIVER BRIDGE, TOWNSHIP OF SHENSTON, DISTRICT RAINY RIVER, HIGHWAY 11, WP 6855-14-00, SITE NO. 45-108 (GEOCRETS NO. 52D-34).

1.4 EQUIPMENT OPERATION

Monitoring equipment supplied by the Contractor shall be maintained and rendered operational throughout the monitoring period by the contractor.

1.5 READING SCHEDULE AND FREQUENCY

The Foundation Monitoring Consultant shall save and archive raw data in electronic and hard copy format.

Monitoring shall commence immediately after the installation of an instrument. Monitoring is to continue during a period from the completion of instrument installation to after completion of pile driving and Stage 3 construction and traffic switching before start of Stage 4 removals as per the Contract Drawings.

The minimum monitoring frequencies along with the anticipated number of readings are given in the following sections. Instruments shall be read more or less frequently if determined to be required by the Contract Administrator.

It should be noted that the number of readings given in the following sections are approximate and may vary due to uncertainties associated with the pore water dissipation.

1.5.1 Minimum Monitoring Frequency

The minimum monitoring frequency for the instruments is summarized in the following section.

Table 1 Minimum Monitoring Frequency of Sturgeon River Bridge

STAGE	FREQUENCY	ANTICIPATED NUMBER OF READINGS ^(*)
Baseline Readings (**)	3 readings on 3 consecutive days, no sooner than 15 days following installation	3
Immediately prior to pile driving (Stage 3 construction)	Once	1
During pile driving (Stage 3 construction)	Twice daily for SP	14 (***)
	Twice daily for VWP (Automatic Data Acquisition on Datalogger Hourly)	14 (***)
After completion of pile driving (Stage 3 construction) before commencement of Stage 4 removals	For first week; -Daily For the remainder of period; -Twice weekly	11 (***)

- Note: (*) Due to the uncertainty of the construction schedule, or the possibility that the pore pressure dissipates slowly in foundation clay, the number of readings may be greater than shown above.
- (**) Baseline Readings: Value of instrumentation readings taken prior to construction to provide a baseline against which all subsequent readings are compared.
- (***) Estimated assuming 7 days for pile driving during Stage 3 construction and another 3 weeks for completing the first half of the new bridge.

2.0 INSTRUMENTATION SPECIFIC REQUIREMENTS

2.0 SETTLEMENT PINS (SP)

2.0.1 Surveying

The northing, easting and elevation of the survey target of the settlement pins (SP) shall be surveyed to an accuracy of plus/minus two (+/- 2) mm or better and shall be reported to the nearest millimeter.

Surveying for settlement monitoring shall be conducted by a licensed surveyor with appropriate equipment and experience. The surveyor shall be retained by the Contract Administrator.

2.0.2 Reporting

The Contract Administrator shall be notified within 24 hours if review level measurement readings are reached and a brief interpretation of the updated monitoring data shall be reported to the Contract Administrator within 24 hours after each set of readings is obtained during pile driving and 2 working days following pile driving. A full set of up-to-date and processed monitoring data shall be presented in tabular and graphical form in the weekly progress report.

As a minimum the following shall be submitted to the Contract Administrator in the monthly progress report based on the readings collected from SP instruments:

- A plot of settlement versus time;
- Plan view showing location of the SPs being monitored.

2.0.3 Review and Alert Levels

The following settlement levels measured at Settlement Pins relative to the baseline or zero readings are to be observed:

Table 2 – Review and Alert Levels for Settlement Monitoring

Instrument Type	Settlement Response Levels (mm)	
	Review	Alert
SP	15	20

Review Level – If the Review Level is exceeded, the Foundation Monitoring Consultant shall immediately notify the Contract Administrator and MTO. Pile driving activities may be continued with the permission of MTO provided the Alert Level is not reached.

Alert Level – If the Alert Level is reached, the Foundation Monitoring Consultant shall immediately notify the Contract Administrator and MTO. The CA shall instruct the Contractor to suspend all pile driving activities. The Foundation Monitoring Consultant shall discuss immediately with the Contract Administrator and MTO a plan of action provided by Contractor.

2.1 VIBRATING WIRE PIEZOMETERS (VWP)

2.1.1 Data Logger and Readout Unit

The VWPs shall be read using the VW Data Loggers and Data Recorder supplied by the Contractor.

The data logger units shall be tested prior to taking any baseline readings to ensure functionality.

2.1.2 Coordination of Readings

The VWP data reduction (calculation of excess pore pressure - EPP: pore pressure in excess of hydrostatic) requires the hydrostatic groundwater level elevation at the time the VWPs were read. Excess pore pressure should be calculated based on the hydrostatic ground water level measured by VWP before commencing pile installation.

2.1.3 Reporting

The Contract Administrator shall be notified within 24 hours if review level measurement readings

are reached and a brief interpretation of the updated monitoring data shall be reported to the Contract Administrator within 24 hours after each set of readings is obtained during pile driving and 2 working days following pile driving. A full set of up-to-date and processed monitoring data shall be presented in tabular and graphical form in the monthly progress report.

As a minimum the following shall be submitted to the Contract Administrator in the monthly progress report based on the readings collected from VWP instruments:

- Plots of piezometric elevation versus time for VWPs;
- Plots of excess pore pressure (EPP);
- Plan view, cross section and profile sketches showing the status of pile driving while the VWP readings were being taken.

2.1.4 Review and Alert Levels

If the maximum excess pore pressure measured exceeds the review levels in Table 3, the Foundation Monitoring Consultant shall immediately inform the Contract Administrator and Contract Administrator will ask Contractor for response action(s). The Contractor shall submit a plan of action(s) to prevent alert level being reached. This will be reviewed by the Foundation Monitoring Consultant who will provide assessment of the course of action to the Contract Administrator. All construction work shall be continued such that instrument alert levels are not reached.

If the maximum excess pore pressure measured exceeds the Alert Levels in Table 3, the Foundation Monitoring Consultant shall immediately inform the Contract Administrator and the Contract Administrator shall instruct the Contractor to suspend all piling activities. No construction shall take place on or nearby the affected pile until all the following conditions are satisfied:

- The cause of the excess pore pressure has been identified and analyzed by the Foundation Monitoring Consultant;
- Contract Administrator to ask Contractor to submit a plan of corrective action(s)
- Foundation Monitoring Consultant to review Contractors plan of corrective action and provide recommendations for corrective actions to the Contract Administrator
- Any corrective action deemed necessary by Contract Administrator and the Foundation Monitoring Consultant has been implemented.

Table 3– Review and Alert Levels for Excess Pore Pressures

LOCATION		Elevation of VWP Sensor Tip (m)	Excess Pore Pressure (EPP) Response Levels (kPa)	
STATION	APPROX. OFFSET FROM CL (*)		Review	Alert
18+454	0.5 m South	327.0	40	50
		320.0		
18+505	0.5 m South	327.0	40	50
		320.0		

Note: (*) Centreline (CL) refers to the centreline of the bridge

2.2 CONTROL MONITORING LEVELS

2.2.1 General

The monitoring program will provide input for the control of the rate of pile driving and appropriate time to shim the existing timber bridge.

3.0 FINAL REPORT

At the completion of the monitoring program, a final monitoring report shall be issued to the Contract Administrator. The monitoring results shall be presented in tabular and graphical form as described above for each instrument type. Interpretation of the monitoring readings shall be included in the report.