

**FOUNDATION INVESTIGATION AND DESIGN REPORT
STONE CREEK CULVERT FOOTING REHABILITATION
NEW LISKEARD DISTRICT, ONTARIO
GWP 5407-15-00 – HWY 112**

Geocres Number: 41P-66

Report to

MMM Group Limited

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Final FIDR\Stoney Creek Culvert Footing Rehabilitation FIDR FINAL.doc

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PART A: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the rehabilitation of an existing concrete culvert footing on Highway 112 over Stoney Creek in the Township of Marquis, New Liskeard District, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the proposed culvert footing rehabilitation location and, based on the data obtained, to provide borehole logs, borehole location plan, and written descriptions of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to MMM Group Limited, under the Ministry of Transportation Ontario (MTO) Agreement No. 5014-E-0019.

2 SITE DESCRIPTION

The existing rigid frame open footing culvert on Highway 112 is located approximately 0.4 km north of the Highway 11 and Highway 112 intersection. Significant erosion was noted beneath the footings at the culvert outlet (east end) which caused the footings to be partially unsupported and now requires footing rehabilitation. A sinkhole has developed behind the southeast wingwall as shown on Site Photos 5 and 6 in Appendix C.

The project site is located approximately 2.5 km south of Round Lake. The culvert is generally surrounded by wooded lands with sporadic residential properties located approximately 300 m to the north and south. The existing culvert carries the easterly meandering Stoney Creek through the highway embankment in a west-to-east direction. Photographs of the culvert and surrounding area presented in Appendix C show the partially unsupported footing bases and wingwalls, at least one of which has cracked.

The project site is located within the physiographic region known as the Abitibi Subprovince. Quaternary geologic mapping in the area suggests that the subsurface conditions at the site are characterized by quiet water glacio-lacustrine deposits of silts and clays with minor sands. The bedrock consisting of massive granodiorite to granite, an Archean unit, is either shallow or visible at

surface at this culvert location.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation at the culvert location was carried out between December 2 and 8, 2015. Three boreholes were advanced near the toe of wingwalls and beneath the headwall at the outlet or east end of the culvert. The drilled locations and termination depths of the boreholes are summarized as follows:

Table 3.1 – Borehole Locations and Termination Depths

Borehole No.	Borehole Location	Termination Depth (m)
15-01	Toe of South Wingwall	6.3
15-03	Beneath Headwall	7.0
15-04	Toe of North Wingwall	9.3

The approximate borehole locations are shown on the Borehole Locations Plan Drawing in Appendix E. The borehole locations and elevations were referenced from the wingwall footings.

Prior to commencing the site investigation, utility clearance was obtained at all borehole locations.

All boreholes were advanced using a portable tripod drill rig. Temporary wooden platforms were built to facilitate the borehole drilling in the creek.

NW/BW casings and wash boring techniques were used to advance the boreholes through the overburden soils. NQ coring was used to penetrate through the cobbles and boulders. Samples were obtained at selected intervals using a split spoon sampler in conjunction with the Standard Penetration Testing (SPT) where applicable. Upon casing refusal, NQ coring was carried out in Borehole 15-04 to confirm the presence and determine the quality of the underlying bedrock.

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.

The depth of water in the creek was measured during the drilling operations. All boreholes were backfilled in general accordance with MOE Regulation 903.

4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A.

Selected soil samples were subjected to a gradation analysis. The results of this testing program are shown on the Record of Borehole sheets and on the laboratory test result figures attached in Appendix B.

Recovered rock core samples were photographed and subjected to point load tests. The rock core photo and the results of the point load tests are attached in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference should be made to the Record of Borehole sheets in Appendix A. Details of the soil and rock stratigraphy encountered in the boreholes are presented on the Record of Borehole sheets. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

The stratigraphy encountered below the streambed consists of an upper layer of cobbles and boulders underlain by a layer of sandy silt over silty clay which in turn is underlain by a lower deposit of cobbles and boulders underlain by granitic bedrock.

5.1 Upper Cobbles and Boulders

Cobbles and boulders were encountered from the creek bed in all boreholes. The thickness of the cobble and boulder layer ranged from 1.4 m to 3.5 m, with the lower boundary at elevation 245.9 to 243.5 m. Penetration through the cobbles and boulders required coring, and SPT blow counts were not obtained within the layer. It is possible that all finer soil particles have been removed from this layer by scour and erosion.

5.2 Sandy Silt

A grey sandy silt deposit was found underlying the cobbles and boulders in all boreholes. This sandy silt contains trace to some gravel and trace clay. Borehole 15-01 was terminated within the sandy silt at 6.3 m depth (elevation 242.2 m) upon refusal on probable bedrock. Where the deposit was fully penetrated in Boreholes 15-03 and 15-04, the thicknesses of the sandy silt were 0.8 m and 2.6 m, respectively, with the lower boundary at 5.8 m and 5.2 m depths (elevations 242.7 and 243.3 m), respectively.

The SPT 'N' values measured in this deposit ranged from 3 to 13 blows for 0.3 m penetration indicating a very loose to compact relative density. Measured moisture contents ranged from 20% to 29%.

The results of grain size distribution tests carried out on the sandy silt samples are shown on Figure B1 included in Appendix B and also summarized below:

Gravel (%)	0 to 23
Sand (%)	30 to 44
Silt (%)	45 to 65
Clay (%)	2 to 3

5.3 Silty Clay

A grey silty clay layer was encountered underlying the sandy silt in Borehole 15-04. This silty clay deposit contains some sand. Thickness of the silty clay encountered in 15-04 was 1.7 m with the lower boundary at 6.9 m depth (elevation 241.6 m).

An SPT 'N' value of 16 blows per 0.3 m penetration was recorded in the silty clay indicating a very stiff consistency. The measured moisture content was 35%.

The result of a grain size distribution test carried out on a silty clay sample is shown on Figure B2 included in Appendix B, and indicates that the silty clay contains 0% gravel, 15% sand, 56% silt and 29% clay.

5.4 Lower Cobbles and Boulders

Cobbles and boulders were encountered underlying the sandy silt in Borehole 15-03 and beneath the silty clay in Borehole 15-04. Borehole 15-03 was terminated within the cobbles and boulders layer at 7.0 m depth (elevation 241.5 m). Where the deposit was fully penetrated in Borehole 15-04, the thickness of the cobbles and boulders was 0.5 m with a lower boundary at 7.4 m depth (elevation 241.1 m). Penetration through the cobbles and boulders required coring, and split spoon samples and SPT blow counts could not be obtained within the layer. However, it is reasonable to assume that the cobbles and boulders are embedded in a sand and gravel matrix.

5.5 Bedrock

Granite bedrock was encountered below the lower cobbles and boulders layer in Borehole 15-04 at a depth of 7.4 m (elevation 241.1 m). Borehole 15-01 was terminated on probable bedrock at 6.3 m depth (elevation 242.2 m).

The greyish pink granite bedrock was described as slightly weathered to fresh jointed. Point load tests completed on the intact rock core samples indicated unconfined compressive strengths (UCS) ranging from 170 to 333 MPa or very strong to extremely strong.

Total Core Recovery (TCR) in the bedrock was typically 100% in all core runs. The Rock Quality Designation (RQD) determined from the recovered cores ranged from 0 to 78% indicating very poor to good rock quality. The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, ranged from 2 to greater than 10.

A photograph of the bedrock core can be found on Figure B3 included in Appendix B

5.6 Water Levels

The water levels in the creek were measured prior to drilling at each borehole. Fluctuation of the water level in the creek was observed during the drilling operations. The water depths and elevations were measured relative to the top of the wingwall footings and are summarized in the following table.

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
15-01	Dec. 8, 2015	0.6	247.9	Creek Level
15-03	Dec. 2, 2015	0.9	247.6	Creek Level
15-04	Dec. 6, 2015	0.7	247.8	Creek Level

As indicated on the borehole logs, the depth of water ranged from 0.5 to 0.6 m during the

current investigation.

The above water level measurements in the creek are short-term observations at the time of drilling. Seasonal fluctuations of the water level in the creek is to be expected.

6 MISCELLANEOUS

Ohlmann Geotechnical Services (OGS) of Almonte, Ontario supplied and operated the drilling and sampling equipment for the field program.

Full time supervision of the field activities, including obtaining utility clearances, was carried out by a Thurber field technician. Overall supervision of the field program was performed by Stephane Loranger of Thurber.

Interpretation of the field data and preparation of the report was undertaken by Ms. Deanna Pizycki, E.I.T. and Mr. Keli Shi, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng., and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART B: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides geotechnical recommendations for the proposed rehabilitation of the existing concrete culvert footing on Highway 112 over Stoney Creek in the Township of Marquis, New Liskeard District, Ontario.

According to the archive General Arrangement (GA) drawing dated November 1997, the existing culvert carries Highway 112 over Stoney Creek on a rigid frame open footing structure. The bilinear culvert is 50 m long along its centreline with a channel width of 4.0 m and a vertical clearance of approximately 3.0 m above the streambed. The archive drawing indicates that the culvert sidewalls were designed to be keyed and dowelled into the sound bedrock along the entire alignment. The inlet (west end) and outlet (east end) wingwalls were shown to be supported on footings.

Significant erosion has occurred at the culvert outlet, which has resulted in undermining of the foundations. Depth of undermining was estimated to be in the order of 0.5 to 1.0 m below the underside of the footings. The undermining due to erosion has rendered a segment of east end of the culvert footings and both outlet wingwall footings partially or completely unsupported. A vertical crack was visible adjacent to the east headwall throughout the entire height of the southeast wingwall behind which a sizeable sinkhole is present in the retained highway embankment slope.

It is understood that rehabilitation of the culvert at the outlet will consist of underpinning the undermined footings, repairing or replacing the southeast wingwall and restoring the affected embankment slope.

The discussion and recommendations presented in this report are based on the information provided by MMM Group Limited and on the factual data obtained in the course of the investigation. The recommendations that are provided are intended to support the urgent reinstatement of the undermined footings in a manner that can be reasonably assumed to provide adequate support in the future. These recommendations may not be as rigorous as the recommendations that would be provided for new designs.

8 REHABILITATIONS

The subsurface stratigraphy encountered below the streambed generally consists of a layer of cobbles and boulders underlain by sandy silt and discontinuous silty clay which in turn are underlain by a lower deposit of cobbles and boulders over granitic bedrock. The very strong to extremely strong bedrock was encountered at a depth of 7.4 m (elevation 241.1) in one borehole (15-04).

Our interpretation of the existing conditions is that all finer material has been removed by scour and erosion and the streambed now consists of the remaining cobbles and boulders, which have probably been reworked by stream action and are now present in a loosely deposited state.

The Geocres report (No. 41P-25) for this site dated November 1997 indicated that all footings supporting the culvert were designed to be founded on sound bedrock. Mass concrete was to be placed where the top of sound bedrock was found to be lower than the design founding elevation. Mass concrete is noted below the footings (see Site Photo 4) and erosion and undermining is noted below the mass concrete. The report recommended a factored ULS bearing resistance of 2,000 kPa for the footings founded on bedrock or mass concrete. The current investigation indicates that the footings at the east end of the culvert were not founded on sound bedrock but over overburden soils.

The current culvert distresses and embankment sinkhole observed at the outlet indicate that undermining of the footings associated with loss of finer soils as a result of scour by the stream.

From a geotechnical standpoint, the issues that have to be addressed include:

1. Stabilization of the cobble and boulder streambed
2. Underpinning the footings to provide support to the culvert and the wingwalls
3. Prevention of future scour that might undermine the remedial works
4. Reinstatement of the sinkhole

To some extent, Items 1 and 3, above, should be considered together since, for any remediation to be successful, it is necessary to prevent future undermining by scour. The analysis and design of scour protection is not part of Thurber's assignment and must be conducted by a specialist in the field.

At the same time, it is not considered to be advisable to attempt to excavate below the undermined footings in order to remove the loosened cobbles and boulders and consideration should be given to in-place stabilization. One possible method of stabilization would be to pump cementitious grout into the voids between the cobbles and boulders in an attempt to prevent future movement within this layer. If acceptable by other disciplines, the grouting could be carried out across the width of the creek bed and to some distance downstream of the culvert as a method of reducing scour.

After the streambed has been stabilized, temporary formwork could be erected in front of the footings and flowable concrete could be pumped in to underpin the footings. It is very difficult to estimate geotechnical resistances for the layer of cobbles and boulders. However, from a practical point of view, the scouring action has probably removed most of the fine material and left the cobbles and boulders in hard contact with each other. If this array of cobbles and boulders is stabilized by grouting, it seems reasonable that it will provide adequate support for the foundations.

After the foundations have been stabilized, the sinkhole may be backfilled. Before this is done, a structural engineer must analyse the ability of the wingwalls to retain the backfill and implement such structural remediation as may be required.

Lateral earth pressure parameters for granular backfill are provided in Section 10. If it is necessary to reduce the forces acting on the wingwall, backfilling using lightweight fill could be considered. From a geotechnical standpoint, the following lightweight fill materials could be considered:

- Expanded polystyrene (EPS)
- Expanded blast furnace slag
- Tire-derived aggregate (TDA), or
- Foam concrete.

While any of these alternatives may be suitable geotechnically, there are environmental concerns to be addressed, which is beyond the scope of Thurber's assignment. The design of lightweight backfill must also take into consideration the potential flotation effects during high water level events.

Depending on the results of the structural analysis, granular backfill in conjunction with tie-backs to deadman anchors could be considered for remediation of the sinkhole.

9 CONSTRUCTABILITY

To facilitate grouting and placement of concrete, the stream flow must be diverted and the site dewatered to the maximum practical extent. Dewatering should be carried out in accordance with OPSS 517 and OPSS 518.

The preliminary GA drawing provided to us indicates the use of a flume pipe to divert the stream flow around the work area and that should be a suitable system.

Further dewatering must be designed by a specialist in that field. However, it will likely, as a minimum, involve forming a cofferdam immediately downstream and pumping, possibly from sumps. The material in the streambed is expected to be highly permeable and consequently high volumes of water may have to be pumped to effect even a small drawdown. Suggested text for an NSSP for dewatering is included in Appendix D.

The need for a PTTW should be assessed after an appropriate dewatering scheme is selected for final design.

It will be important to establish firm contact between the underside of the footing and the material used for underpinning. Two approaches that might be considered are:

- Place highly plastic concrete to some distance above the underside of the footing and rely on vibration to fill all voids
- Place concrete almost up to the underside of the footing, allow it to harden then pressure grout the remaining space

10 BACKFILL AND LATERAL EARTH PRESSURES

New backfill behind the culvert sidewalls and wingwalls will be required to fill the sinkhole. New fill should be placed in accordance with OPSS 902. All backfill material should consist of Granular A, Granular B Type II or III material meeting the specifications of OPSS.PROV 1010. Compaction equipment to be used adjacent to the walls should be restricted in accordance with OPSS 501.

Lateral earth pressures acting on the culvert structure may be assumed to be distributed triangularly and to be governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but generally are given by the expression:

$$p_h = K (\gamma h + q)$$

Where: p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 10.1)

γ = unit weight of retained soil (see Table 10.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert structure are dependent on the material used as backfill and the existing material adjacent to the wall. Typical values are given in Table 10.1.

Table 10.1 – Earth Pressure Coefficients (K)

Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or III, or Existing Granular Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.38*	0.31	0.46*
At-rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-

* For wingwalls.

The earth pressure coefficients in Table 10.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to use in design may be estimated from Figure C6.16 in the Commentary to the Canadian Highway Bridge Design Code.

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I or III, or at a depth of 2.0 m for Granular A or Granular B Type II.

11 SEISMIC CONSIDERATIONS

The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 1
- Zonal Velocity Ratio 0.05
- Acceleration Related Seismic Zone 2
- Zonal Acceleration Ratio 0.10
- Peak Horizontal Acceleration 0.035

The soil profile type at this site has been classified as Type I. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 should be used in seismic design.

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 11.1 may be used.

Based on review of the soil data, the foundation soils at this site are assessed as not being prone to liquefaction under the design earthquake motion.

Table 11.1 – Earth Pressure Coefficients for Earthquake Loading (KE)

Conditions	OPSS Granular A or Granular B Type II $\phi = 35^\circ; \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I or III, or Existing Granular Fill $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (K_{AE})*	0.28	0.42	0.32	0.51
Passive (K_{PE})	3.6	-	3.2	-
At Rest (K_{OE})**	0.47	-	0.52	-

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods

12 SCOUR AND EROSION CONTROL

Erosion protection must be provided along any soil surfaces that may be in contact with the creek flow. In particular, erosion protection measures should be provided along the toe of the embankment slopes where not protected by wingwalls.

An extended concrete apron is recommended at the culvert outlet to avoid recurrences of the current erosion issue. Length and thickness of the apron beyond the outlet should be determined based on a hydraulic analysis by qualified personnel.

A vegetation cover should be established on all other exposed earth surfaces to protect against

surficial erosion, in general accordance with OPSS 804.

13 GROUNDWATER CONTROL

Culvert rehabilitation may be carried out in stages to maintain creek flow at all times if creek diversion is not allowed. Design of the temporary dewatering systems is the responsibility of the Contractor. However, an effective dewatering system may consist of a cofferdam enclosure and multiple surface water pumps. The dewatering system must be capable of lowering the water level within the enclosure to streambed level and maintaining the water level throughout the course of the footing repair operation.

14 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Given the presence of coarse granular streambed deposits, lowering of the water level within an enclosure may be challenging.
- Tremie grouting of the cobbles and boulders may be difficult and slow in progress due to the creek flow if culvert channel is to remain partially open during construction.
- Placement of mass concrete beneath the footings poses practical difficulties to quality control during construction.
- Water levels in the creek may fluctuate during culvert rehabilitation.

15 CLOSURE

Engineering analysis and preparation of the report were carried out by Mr. Keli Shi, P.Eng. The report was reviewed by Mr. Alastair Gorman, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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Appendix A
Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS


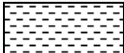



ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	Approximate Uniaxial Compressive Strength (psi)	Field Estimation of Hardness*
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS




Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

RECORD OF BOREHOLE No 15-01

1 OF 1

METRIC

W.P. 5407-15-00 LOCATION Stoney Creek Culvert ORIGINATED BY AHF
 HWY 112 BOREHOLE TYPE Tripod/ NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2015.12.08 - 2015.12.08 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
248.5	TOP OF WINGWALL FOOTING							20	40	60	80	100					
0.0																	
247.9							248										
0.6	WATER																
247.3																	
1.2	COBBLES and BOULDERS						247										
							246										
245.2							245										
3.3	Sandy SILT, trace to some gravel, trace clay Loose to Very Loose Grey Wet		1	SS	7									○			17 33 47 3
			2	SS	4		244							○			
			3	SS	5									○			
							243										
			4	SS	3									○			0 32 65 3
242.2																	
6.3	END OF BOREHOLE AT 6.3m ON PROBABLE BEDORCK. BOREHOLE BACKFILLED WITH BENTONITE CEMENT GROUT TO STREAM BED LEVEL.																





ONTMT4S 10098.GPJ 2015TEMPLATE(MTO).GDT 1/19/16

RECORD OF BOREHOLE No 15-03

1 OF 1

METRIC

W.P. 5407-15-00 LOCATION Stoney Creek Culvert ORIGINATED BY AHF
 HWY 112 BOREHOLE TYPE Tripod/ NW Casing COMPILED BY AN
 DATUM Geodetic DATE 2015.12.02 - 2015.12.05 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			
								20	40	60	80						100	20	40	60
							○ UNCONFINED + FIELD VANE													
							● QUICK TRIAXIAL × LAB VANE													
248.5	TOP OF WINGWALL FOOTING															GR SA SI CL				
0.0																				
247.6							248													
0.9	WATER																			
247.0							247													
1.5	COBBLESand BOULDERS																			
							246													
							245													
							244													
243.5																				
5.0	Sandy SILT, some gravel, trace clay Compact Grey Wet		1	SS	13		243									23 30 45 2				
242.7																				
5.8	COBBLESand BOULDERS						242													
241.5																				
7.0	END OF BOREHOLE AT 7.0m. BOREHOLE BACKFILLED WITH BENTONITE CEMENT GROUT TO STREAM BED LEVEL.																			

ONTMT4S 10098.GPJ 2015TEMPLATE(MTO).GDT 1/19/16

RECORD OF BOREHOLE No 15-04

1 OF 1

METRIC

W.P. 5407-15-00 LOCATION Stoney Creek Culvert ORIGINATED BY AHF
 HWY 112 BOREHOLE TYPE Tripod/ NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2015.12.06 - 2015.12.06 CHECKED BY KS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
248.5	TOP OF WINGWALL FOOTING						20	40	60	80	100	W _P	W	W _L	kN/m ³	GR SA SI CL
0.0																
247.8																
0.7	WATER															
247.3																
1.2	COBBLESand BOULDERS															
245.9																
2.6	Sandy SILT, trace clay Loose to Very Loose Grey Wet		1	SS	6								○			0 44 53 3
			2	SS	8								○			
			3	SS	3											
243.3																
5.2	Silty CLAY, some sand Very Stiff Grey Moist to Wet		4	SS	16								○			0 15 56 29
241.6																
6.9	COBBLESand BOULDERS															
241.1																
7.4	GRANITE slightly weathered to fresh jointed, very strong to extremely strong, greyish pink Horizontal joints at 6.2m, 6.4m and 6.6m Horizontal joints at 6.7m and 6.8m Sub-horizontal joints 50mm at 6.3m, 6.8m, 7.2m and 7.3m Sub-vertical joint 50mm at 7.2m Vertical joint 125mm at 7.3m Highly broken zone 150mm at 7.5m and 100mm at 7.8m Sub-vertical joints 150mm at 7.6m, 7.8m and 100mm at 7.7m		1	RUN												RUN #1 TCR=100% SCR=72% RQD=78% UCS=333MPa
			2	RUN												RUN #2 TCR=100% SCR=65% RQD=60% UCS=209MPa
			3	RUN												RUN #3 TCR=100% SCR=11% RQD=0%
			4	RUN												RUN #4 TCR=100% SCR=12% RQD=15% UCS=224MPa
239.2																
9.3	END OF BOREHOLE AT 9.3m. BOREHOLE BACKFILLED WITH BENTONITE CEMENT GROUT TO STREAM BED LEVEL															

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 10 (%) STRAIN AT FAILURE

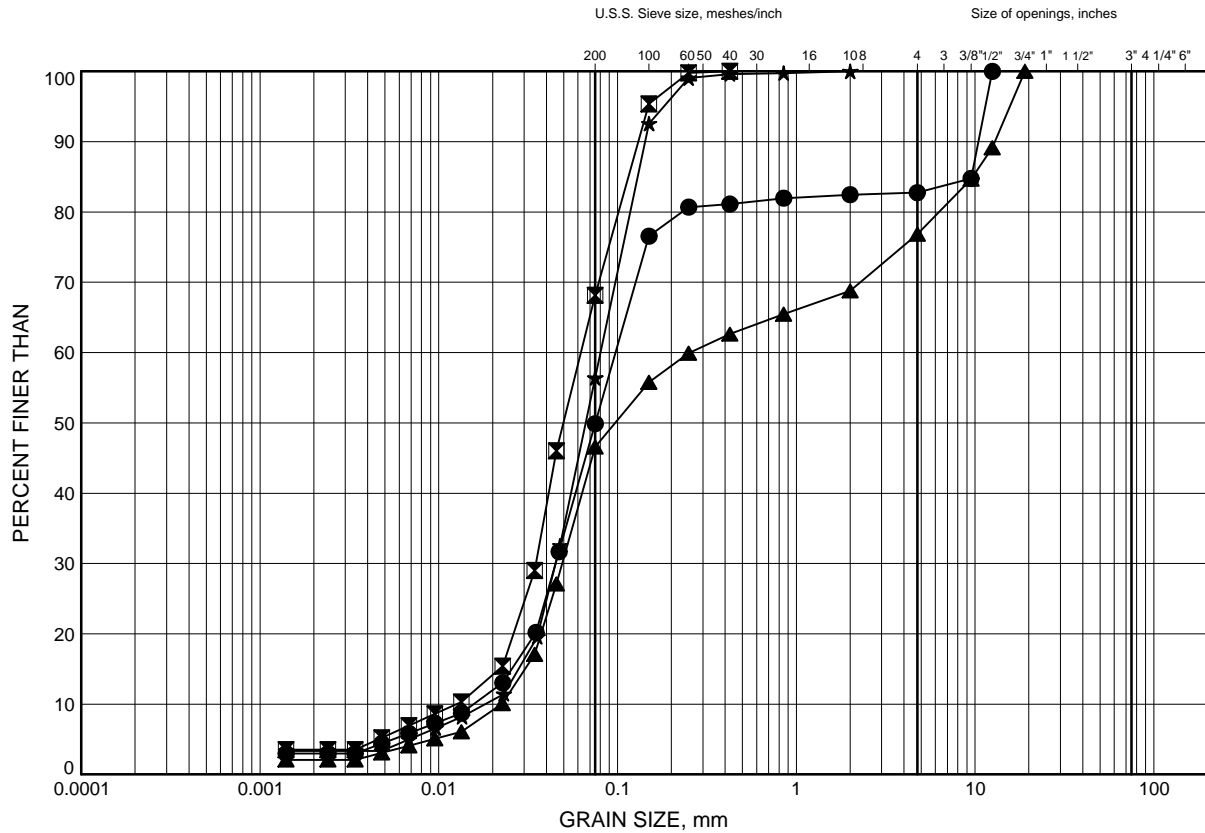
ONTMT4S 10098.GPJ 2015TEMPLATE(MTO).GDT 1/19/16

Appendix B
Laboratory Test Results

Hwy 112 Stoney Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B1

Sandy SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-01	3.70	244.80
⊠	15-01	5.99	242.51
▲	15-03	5.30	243.20
★	15-04	2.88	245.62

Date January 2016
Project 5407-15-00

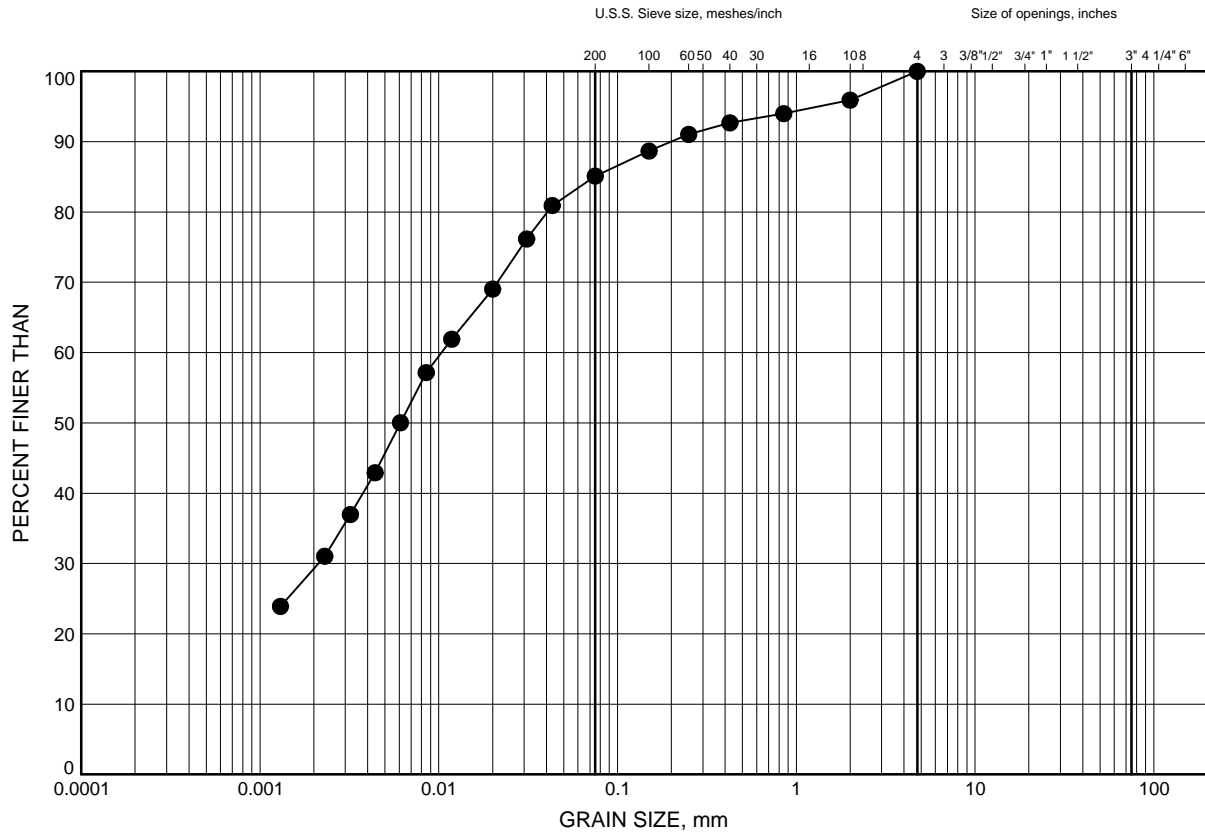


Prep'd AN
Chkd. KS

Hwy 112 Stoney Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-04	6.08	242.42

Date January 2016
Project 5407-15-00



Prep'd AN
Chkd. KS

FIGURE B3

BOREHOLE: **BH 15-04**
CORE RUN #1: 20' 4" – 21' 10"
CORE RUN #2: 21' 10" – 23' 6"
CORE RUN #3: 23' 6" – 24' 3"
CORE RUN #4: 24' 3" – 26' 5"





THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

Job No : 10098 Client : MMM Group Limited
 Date Drilled : 08-Dec-15
 Project Name : Highway 112 Stoney Creek Culvert Date Tested : 15-Dec-15
 Core Size : NQ BH No : BH 15-04 Tester : ISP

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	UCS (MPa)	Rock Type	Notes
1	1	6.3	D	41.9	48.6	151.2	333	Granite	Extremely Strong
2	2	6.8	D	21.5	48.7	151.2	170	Granite	Very Strong
3	2	7.0	D	31.2	48.7	131.5	247	Granite	Very Strong
4	4	8.0	D	28.3	48.7	112.3	224	Granite	Very Strong
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
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28									
29									
30									
31									
32									
33									

* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

Appendix C
Site Photographs



Photo 1 – Looking West at Culvert Outlet



Photo 2 – Unsupported Wingwall Footings at Culvert Outlet



Photo 3 – Unsupported South Footing and Cracked Wingwall



Photo 4 – Partially Supported South Footing



Photo 5 – Sinkhole behind Southeast Wingwall (Looking Downstream)



Photo 6 – Sinkhole behind Southeast Wingwall (Looking Upslope)

Appendix D

List of Standard Specifications and Special Provisions

1) The following Standard Specifications and Special Provisions are referenced in this report:

OPSS 501
OPSS 804
OPSS 902
OPSS 517
OPSS 518
OPSS.PROV 1010

2) Suggested text for “NSSP – Dewatering”

To facilitate grouting and placement of concrete, the stream flow must be diverted and the site dewatered to the maximum practical extent. The use of a flume pipe to divert the stream flow around the work area should be a suitable system. Further dewatering must be designed by a specialist in that field. A dewatering system will likely involve, as a minimum, forming a cofferdam immediately downstream and pumping from sumps. The Contractor must be alerted that the material in the streambed is expected to be highly permeable and consequently high volume of water may have to be pumped to effect even a small drawdown. Design of the temporary flow diversion and dewatering systems remains the Contractor’s responsibility.

Appendix E
Borehole Locations Plan Drawing

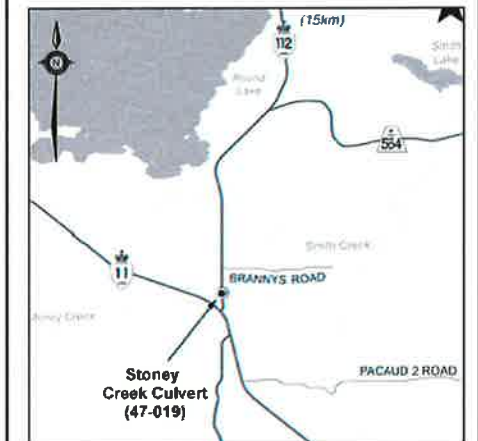
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No 2016-5141
WP No 5407-15-00



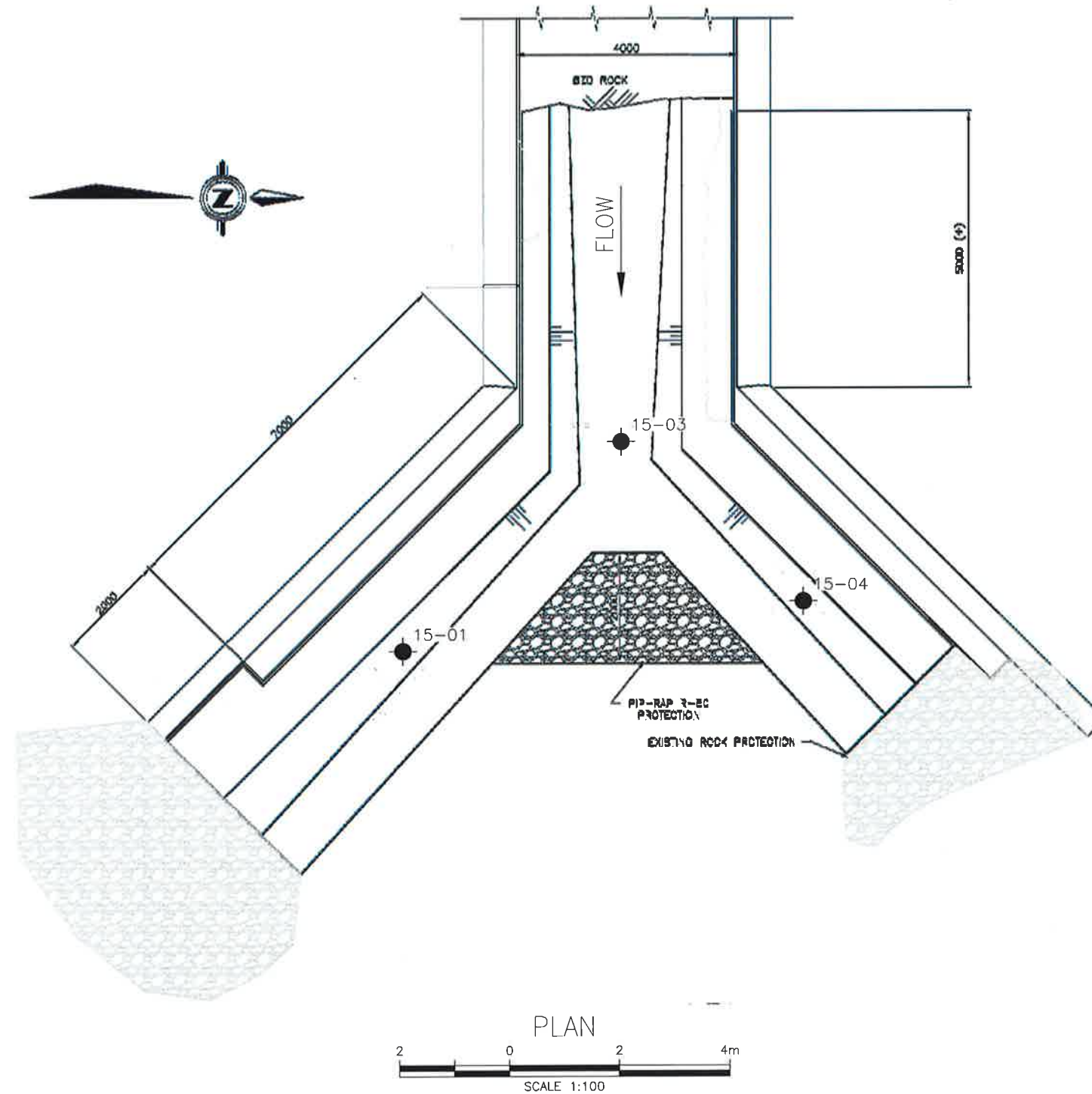
STONEY CREEK CULVERT
HIGHWAY 112
FOOTING REHABILITATION
BOREHOLE LOCATIONS PLAN

SHEET
4



KEYPLAN
LEGEND

◆ Borehole



NOTE:

The borehole locations are approximate based on measurements relative to the existing culvert during investigation.

REVISIONS		DATE	BY	DESCRIPTION
DESIGN	KS	CHK	KS	CODE
DRAWN	AN	CHK		SITE
				LOAD
				STRUCT
				DWG 4
				DATE MAR 2016