



**THURBER** ENGINEERING LTD.

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**MEMORANDUM  
PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN  
PIKE RIVER BRIDGE REPLACEMENT  
HIGHWAY 572, SITE 39E-152  
G.W.P. 5196-13-00, W.P. 417-91-01  
GEOCRE NO.: 42A-106**

## **1 INTRODUCTION**

This memorandum presents a summary of the subsurface conditions obtained from a preliminary foundation investigation carried out for the replacement of the existing Pike River Bridge located on Highway 572, New Liskeard District, Ontario.

Three alternatives for the Pike River Bridge replacement are being considered. Based on the preliminary drawings provided by MMM group showing the horizontal and vertical alignments for the proposed replacement bridge, the considered design alternatives could be summarized as follows:

Alternative 1 – replacement of the bridge along the existing alignment with a 3 m longer structure span.

Alternative 2 – minor shift of the horizontal alignment to the east; the shift would be approximately 9 m to 14 m at the abutment locations, resulting in the span of the replacement bridge of approximately 60 m with some sections of the approach embankments up to 5.5 m in height.

Alternative 3 – major shift of the horizontal alignment to the east; the new bridge abutments will be located as much as 70 m to 80 m east of the existing bridge abutments or the existing highway alignment. The span of the replacement bridge will be approximately 40 m with approaches to the bridge up to 6.5 m in height. The Alternative 3 alignment will require significant length of relatively high new embankments, as well as some cuts.

The foundation investigation was carried out for the Alternatives 2 and 3 alignments. No subsurface information is available at the existing bridge location.

This memorandum provides preliminary geotechnical recommendations for foundation design to assist the designers in planning, structure evaluation and preliminary design of the structure



replacement. Once a replacement plan is finalized, additional subsurface investigation will be carried out and Foundation Investigation and Design Report will be prepared for the final location of the replacement structure.

## **2 SITE DESCRIPTION**

The existing Pike River Bridge is located on Highway 572, approximately 4.5 km south of Highway 101, in the Township of Hislop and Guibord in the New Liskeard area. The existing bridge is a single-span bailey bridge with a grated steel deck, and supported on timber crib abutments, as evident on the photographs enclosed in Appendix C. The bridge has a span of approximately 37 m and is 3.4 m in width. The structure was constructed in 1975 and upgraded in 2008.

The inspection report from the site visit on July 10, 2013, generated on November 8, 2013, indicated deficiencies of the bridge abutments/timber cribs, including “continuous” settlement/movement of the abutment walls, barrier post and bridge elements. Deterioration of the gabion baskets, especially at the north abutment, and timber forming the cribs were reported. Erosion of the river banks at the bridge location, including oversteepening of the fore slopes at the abutments and undermining/loss of ground below the underside of the cribs can be observed on the photographs enclosed in Appendix C.

Pike River flows from east to northwest at the bridge site. In the vicinity of the existing bridge, the south side of the river valley is relatively steep, and the land on the north side is low and relatively flat within approximately 140 m distance from the bridge. The river valley is densely vegetated with trees, shrubs and grass.

Photographs in Appendix C show the general nature of the site and the existing bridge.

Based on the published geological information, the general area of the project is covered by glaciolacustrine sediments of clays and silts deposited during the Pleistocene period. These deposits are mostly varved clays, but massive clays are also present in some areas. Below the clays are glacial outwash deposits of silts, sands and gravel underlain by Precambrian mafic to intermediate metavolcanic bedrock.

## **3 SUBSURFACE CONDITIONS**

The field investigation and testing was carried out between March 5 and 8, 2016. A total of four boreholes, denoted as Boreholes PR-01 to PR-04 were drilled in conjunction with Standard Penetration Test (SPT) and Dynamic Cone Penetration Tests (DCPT) to depths of 10.8 m to 14.0 m below the ground surface. A track-mounted CME 45 drill rig was used to advance the boreholes using NW casing/wash boring techniques. An NQ core barrel was used to penetrate through cobbles and boulders. Boreholes PR-01 and PR-02 were drilled near the locations of the proposed abutments for Alternative 2 structure, which was a short distance to the east from the existing alignment. Boreholes PR-03 and PR-04 were drilled near the south and north abutments of the proposed Alternative 3 bridge alignment. The approximate borehole locations are shown on the Borehole Locations and Soil Strata drawing included in Appendix D.



The existing subsurface information is also available in the MTO Foundation Investigation and Design Report dated September 30, 1983 (Geocres No. 42A-36), which was prepared for the then proposed replacement of the Pike River Bridge on Line "B". The locations of the boreholes or/and Line "B" from the 1983 report cannot be determined with sufficient accuracy to reference in the subsurface stratigraphy described in this memorandum; however, based on the configuration of the river and topography of the site as shown in that report, the Line "B" could be located in the vicinity of Alternative 3 alignment. Furthermore, that investigation was carried out for a 3-span bridge. It is noted that the existing structure is a single span bridge. The factual data is, in general, consistent with the stratigraphy observed on site during the current investigation.

An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets in Appendix A governs any interpretation of the soil conditions. It must be recognized that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered in the boreholes consisted of a layer of silty clay to clayey silt, underlain by a silty sand till with trace to some clay, trace to some gravel and occasional cobbles and boulders. A layer of peat was encountered underlying the silty clay in Borehole PR-04.

Topsoil was encountered only in Borehole PR-04, drilled near the location of the north abutment of Alternative 3. The thickness of the topsoil was 150 mm. It should be noted that topsoil thickness may vary in other areas of the site.

Underlying the topsoil or extending from the ground surface was a layer of silty clay to clayey silt. The silty clay graded to clayey silt in Boreholes PR-02 and PR-03. The deposit typically contained trace to some sand, trace gravel and occasional rootlets and wood fibres at shallow depths. It was noted that the amount of organic material in the silty clay in Borehole PR-04 was increasing with depth. The thickness of the silty clay to clayey silt varied from 1.4 to 4.1 m with the base varying from Elev. 280.1 to Elev. 277.4. SPT-N values in the deposit ranged from 3 to 21 blows per 0.3 m of penetration, with most values recorded between 6 and 21 blows per 0.3 m of penetration, indicating in general, a firm to very stiff consistency. Moisture contents of the silty clay to clayey silt ranged from 20% to 61%, however, typical values ranged from 20% to 40%. The grain size distribution curves obtained for the samples of silty clay/clayey silt are included in Appendix B and indicate that the deposit contains 0% gravel, 0% to 18% sand, 38% to 70% silt and 30% to 47% clay. The results of the Atterberg Limits tests indicate that the deposit is typically of low plasticity with occasional intermediate plasticity zones.

A layer of peat was encountered underlying the silty clay in Borehole PR-04. The dark brown peat was fibrous with trace to some silt, trace sand and trace clay. The thickness of the peat was 0.8 m at the borehole location with a base at a depth of 3.8 m (Elevation 276.6). One SPT 'N' value recorded in the peat was 4 blows per 0.3 m penetration indicating a loose relative density. One recorded water content in the peat was 189%.



Underlying the peat in Borehole PR-04, and the silty clay to clayey silt deposit in the remaining boreholes, was a cohesionless silty sand till with trace to some clay and gravel and occasional cobbles and boulders. All boreholes were terminated in the till at depths ranging from 10.8 to 14.0 m (Elevations 270.7 to 266.5).

SPT N-values measured in the till ranged between 7 blows per 0.3 m penetration to more than 100 blows per 0.3 m penetration, indicating a loose to very dense relative density. The upper 2 m to 3 m of the deposit was typically loose to compact, and below that depth becoming very dense. The measured water contents of till samples ranged from 6% to 22%. The results of grain size distribution analyses performed on selected samples of the till are presented in Appendix B, and indicate that the till contains 0% to 7% gravel, 40% to 75% sand, 28% to 39% silt and 5% to 21% clay, as well as the combined content of silt and clay of 24%.

Groundwater levels in standpipe piezometers installed in Boreholes PR-02 and PR-04 were measured at depths of 2.5 m (Elev. 280.1) and 0.8 m (Elev. 279.6), respectively. Artesian groundwater condition was noted in the casing upon completion of boring in Borehole PR-03 with the water level at approximately a height of 1 m above the ground surface (Elev. 280.8). It is likely that this water level could be a result of a build-up of water pressure and blowing-back silt and sand in the tight casing during wash-boring procedure used to advance the borehole in this very dense and low permeability till.

The water level in Pike River was shown on the archive drawing (Geocres No. 42A-36) at Elevation 279.5 on November 17, 1982. Based on the survey information obtained from MMM, the water level in Pike River was at Elev. 279.5 at the location of Alternative 2 and at Elev. 279.2 at the location of Alternative 3 Alignment in June 2015.

## **4 STRUCTURE FOUNDATIONS**

The following discussion and recommendations are intended to support the selection of the most appropriate alignment for the replacement. More detailed design recommendations will be prepared for the selected alignment.

Given the soil stratigraphy encountered and the requirements of modular bridge design, the following alternatives could be considered for the new bridge foundations:

- spread footing (precast concrete slab) placed on engineered fill, and
- driven H-piles.

### **4.1 Alternative 1**

Alternative 1 involves replacement of the bridge on the existing alignment with a modular bridge of a slightly longer span.

The existing bridge is supported on timber cribs. As indicated earlier, “continuous” settlement/movement of the abutment walls, barrier post and bridge elements were observed at



the bridge site. Erosion of the river banks at the bridge location, including oversteepening of the fore slopes at the abutments and undermining/loss of ground below the cribs were evident.

No subsurface information is available at the existing bridge location. Heights of the existing embankments are not known. Outside and beneath of the embankments, the soils will probably consist of deposit of silty clay to clayey silt, which was present across the site. In the boreholes drilled in the vicinity of the existing bridge, the thickness of the silty clay/clayey silt was as much as 4 m. The silty clay was underlain by a silty sand till.

#### **4.1.1. Spread Footings on Engineered Fill Pads**

Placement of spread footings on an engineered granular pad is considered to be preferable from the foundation point of view, in light of relatively low loadings on the foundation soils imposed by the modular bridge, and ease of construction. Recommendations for design of the spread footings placed on the engineered granular pad is presented below.

New spread footings supporting the abutments will likely be located within the footprints of the existing timber cribs.

Since the details of the existing supports for the bridge are not known, the following construction sequence may be considered:

1. Excavate to remove all timber and other deleterious material from the footprint of the new foundation;
2. The minimum depth of excavation must accommodate the concrete foundation slab and at least 1.0 m of engineered fill below the slab, as described below;
3. Sand and gravel fill may be left in the base of the excavation, provided it is sufficiently compacted (100% of the material's SPMDD), otherwise the excavation should continue down to undisturbed, native soil;
4. The dimensions of the base of the excavation should be determined by assuming a granular pad 1.0 m wider than the footing at the level of the footing base and projecting outward at 2H:1V.

The new footings should be placed on the engineered fill pad consisting of OPSS Granular "A" or Granular B Type II placed in 150 mm lifts and compacted to 100% of its SPMDD at  $\pm 2\%$  of optimum moisture content. The top of the engineered fill pad should be at least 1 m wider than the footprint of the spread footing at the underside of the footing and the engineered fill should be at least 1.0 m thick.

Excavations for the engineered fill pad construction and footing placement will require the existing deck to be removed or temporarily supported during construction.



#### **4.1.2 Axial Resistance**

A foundation slab/spread footing approximately 1 m in width, constructed as described above may be designed using the following values:

Factored Geotechnical Resistance at ULS (kPa)	-	125 kPa
Geotechnical Reaction at SLS (kPa)	-	90 kPa.

These values are preliminary in nature and take account of the proximity of the river bank. The value of the Geotechnical Reaction at SLS given above is for up to 25 mm of settlement.

The values of a Factored Geotechnical Resistance at ULS was assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.5 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The Geotechnical Reaction at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The geotechnical resistance quoted above is for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as illustrated in the CHBDC 2014 Clause 6.10.3 and Clause 6.10.4.

The lateral resistance of the footings founded on engineered fill may be computed using an unfactored friction coefficient of 0.6 for cast-in-place concrete and 0.5 for pre-cast concrete. This is an “ultimate” value and requires a degree of sliding movement to occur to fully mobilize the resistance.

#### **4.1.3 Driven H-Piles**

Recommendations for the design of H-pile foundations presented below for Alternatives 2 & 3, could be considered for preliminary design of Alternative 1 pile foundations.

### **4.2 Alternative 2 and Alternative 3**

Alternative 2 and Alternative 3 involve, respectively, minor and major shifts in the Highway 572 alignment, and locating the replacement bridge some distance from the existing bridge and Highway 572 alignment.

#### **4.2.1 Spread Footings on Engineered Fill Pads**

Placement of spread footings on an engineered granular pad is considered to be feasible from the foundation point of view, in light of relatively low loading on the foundation soils imposed by the modular bridge, and ease of construction. Recommendations for design of the spread footings placed on the engineered granular pad is presented below.



In view of the presence of up to 4.1 m thick silty clay and the peat in borehole PR-04 for Alternative 3, consideration should be given to placing approach embankment fill 6 to 8 months ahead of bridge construction to preload the compressible layers.

The new footings should be placed on the engineered fill pad consisting of OPSS Granular "A" or Granular B Type II placed in 150 mm lifts and compacted to 100% of its SPMDD at  $\pm 2\%$  of optimum moisture content. At the end of the 6 to 8-month preload period, the approach fill should be removed to the base of the engineered fill pad. The top of the engineered fill pad should be at least 1 m wider than the footprint of the spread footing and the engineered fill should be at least 2.0 m thick.

#### **4.2.2 Axial Resistance**

A foundation slab/spread footing approximately 2 m in width, constructed as described above may be designed using the following values:

Factored Geotechnical Resistance at ULS (kPa)	-	200 kPa
Geotechnical Reaction at SLS (kPa)	-	125 kPa.

These values are preliminary in nature and take account of the proximity of the river bank. The value of the Geotechnical Reaction at SLS given above is for up to 25 mm of settlement.

The values of a Factored Geotechnical Resistance at ULS was assessed assuming a Consequence Factor equal to 1 (Typical), and a Resistance Factor equal to 0.5 (Typical degree of understanding of the subsurface conditions), as per CHBDC 2014. The Geotechnical Reaction at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The geotechnical resistance quoted above is for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance should be calculated as illustrated in the CHBDC 2014 Clause 6.10.3 and Clause 6.10.4.

The lateral resistance of the footings founded on engineered fill may be computed using an unfactored friction coefficient of 0.6 for cast-in-place concrete and 0.5 for pre-cast concrete. This is an "ultimate" value and requires a degree of sliding movement to occur to fully mobilize the resistance.

#### **4.2.3 Driven H-Piles**

The ground conditions at the site are considered to be suitable for the use of driven steel H-pile foundations at the bridge abutments. To develop required capacity, the piles should be driven into the very dense cohesionless till.

#### **Alternative 2 Alignment**



Based on the preliminary location plan provided by MMM, the replacement structure in Alternative 2 could be offset from the existing highway alignment by some 9 m at the north abutment and 14 m at the south abutment. The proposed structure will be a single span bridge. Subsurface information for this alternative is provided on the Record of Boreholes PR-01 and PR-02.

The following table provides axial geotechnical resistances at Ultimate Limit States and geotechnical reaction at Serviceability Limit States for a steel HP 310x110 pile. For the preliminary design, it was assumed that the underside of the pile caps will be located at approximately Elev. 281.5, near the existing ground surface and above the water level in the river.

Abutment Location/Reference Borehole	Approximate Pile Tip Elevation (m)	Approximate Pile Length (m)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Reaction at SLS (kN)
South / PR-01	272.0	9.5 <sup>*)</sup>	1200	1000
North / PR-02				

<sup>\*)</sup> For preliminary pile design, the underside of pile cap was assumed at Elev. 281.5.

The values of geotechnical resistances at SLS quoted above refer to 25 mm of settlement.

### Alternative 3 Alignment

The replacement structure in Alternative 3 will be offset to the east from the existing highway alignment by some 140 m. As shown on the preliminary alignment plan, the proposed structure could be a single-span and approximately 33 m long. PR-03 and PR-04 were drilled in the vicinity of the proposed abutments for this alternative.

For the preliminary design, it was assumed that the underside of the pile caps will be located at approximately Elev. 280.0.

The estimated geotechnical resistance at factored ULS and the geotechnical reaction at SLS are provided in the following table for a steel HP 310x110 pile.

Abutment Location/Reference Borehole	Approximate Pile Tip Elevation (m)	Approximate Pile Length (m)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Reaction at SLS (kN)
South / PR-03	269.0	11.0 <sup>*)</sup>	1200	1000
North / PR-04				

<sup>\*)</sup> For preliminary design, the underside of pile cap was assumed at Elev. 280.

The values of geotechnical resistances at SLS quoted above refer to 25 mm of settlement.





#### **4.2.3 Pile Installation**

The above pile tip elevations assume that piles are driven to effective refusal and penetrate a minimum 3 m into the very dense cohesionless till. Cobbles and boulders were encountered in the till deposit and should be expected during pile installation. Pile installation should be in accordance with OPSS 903.

#### **4.2.4 Downdrag Loads**

Driven H-piles could encounter practical refusal in the very dense till deposit. The weight of the new approach embankment fill to be placed for the realignment of Highway 572 will induce consolidation settlements of the underlying silty clay layer. As a result, downdrag forces will develop along the length of abutment piles embedded in this deposit.

For design purposes, an unfactored downdrag load of 120 kN per pile should be used to evaluate the impact of downdrag load on the bearing capacities of the abutment piles. This downdrag load should be multiplied by a load factor of 1.25 as per CHBDC Commentary Clause C6.8.4 to obtain a factored downdrag load. In accordance with Section in 6.8.4 of the CHBDC and Clause C6.8.4 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag.

#### **4.2.5 Pile Tips**

To prevent pile damage when setting the piles in the very dense till, which contains cobbles or boulders, piles should be equipped with tip protections.

The pile tip protection supplied by an approved manufacturer such as Titus Steel (Standard H-point), Skyline Steel or approved equivalent could be used at this site.

#### **4.3 Frost Cover**

The depth of frost penetration at this site is approximately 2.3 m. It is recommended that the base of pile caps be provided with a minimum 2.3 m of earth cover as protection against frost action.

### **5 APPROACH EMBANKMENTS**

No change in the vertical alignment has been indicated for Alternative 1 on the preliminary plans and sections.

Design Alternative 2 and Alternative 3 will require realignment of the highway embankments, including bridge approaches. The vertical alignments of the new highways indicate requirements for the embankments varying in height, and with approaches to the bridge as high as 6.5 m. It should be noted that the subsurface information at this stage of the project is limited to the



locations of the proposed new abutments; no subsurface information is available along the proposed embankment realignments.

Silty clay to clayey silt deposit varying in thickness from 1.5 m to 4 m was identified in the boreholes. In addition, a 0.8 m thick layer of fibrous peat was encountered beneath the silty clay in Borehole PR-04, drilled on the Alternative 3 alignment. The MTO report prepared in 1983 (Geocres No 39E-152) for the then proposed realignment of Highway 572 and the bridge on Line B indicates presence of “organics” in the silty clay in boreholes located on both sides of the river. Moreover, a layer of “black organics” was identified within the silty clay in one borehole located on the north side of the river. The exact locations of the boreholes or referenced in the report Line B cannot be established based on the MTO report; however, peat/organic matter should be expected to be present across the site, including the areas of the presently considered alignments.

Placement of embankment fill will induce consolidation settlement in the silty clay and peat. As the vertical alignments are not finalized yet, for the pre-design purposes, consolidation settlements in the silty clay layer and peat have been estimated for 4 m and 6 m in height approach embankments. The estimates are summarized in the table below.

Design Alternative	Approach Embankment/ Reference Borehole	Approximate Fill Height (m)	Estimated Consolidation Settlement (mm)
2	South/PR-01	4	70
		6	85
	North/PR-02	4	100
		6	150
3	South/PR-03	4	100
		6	150
	North/PR-04	4	300
		6	400

Based on the above settlement estimates, the settlements under the proposed embankments at the Alternative 3 are higher when compared to Alternative 2. It should be noted that buried peat was encountered in Borehole PR-04 at the Alternative 3 alignment.

The advantage of Alternative 3 is that it would involve shorter structure span. However, the settlements estimated at both Alternative 2 and Alternative 3 will need to be mitigated by constructing the approaches at least 6 to 8 months prior to the bridge construction and pile driving. The settlements induced by the construction of the approach fill should be monitored to determine substantial completion of the settlements.



Given the distance of the proposed structure in Alternative 2 from the existing bridge, the settlements under the new approach fill may impact the existing bridge and approaches. Monitoring of the existing bridge and a settlement mitigation plan should be in place to maintain the existing bridge in serviceable conditions.

A preliminary assessment of global stability for Alternative 3 indicates that for a 4 m high approach fill, the Factor of Safety for the end of construction conditions is in order of 1.3. The Factor of Safety reduces to below 1.2 for a 6 m high fill. Accordingly, for a 6 m high fill, the toe of the approach fill will need to be set back about 5 m from the crest of the river bank to attain a Factor of Safety of 1.3. This would imply a longer bridge for Alternative 3.

Detailed assessment of the stability of the approach embankments should be conducted when the alignment, structure design and approach embankment geometry are finalized.

Additional boreholes should be drilled to delineate the extent of the peat noted along the Alternative 3 alignment if selected in the detail design.



## 6 CLOSURE

The memorandum was prepared by Anna Piascik, P.Eng. and Keli Shi, P.Eng. and reviewed by 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 <sup>(1)</sup> '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.

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W <sub>L</sub> < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			



# RECORD OF BOREHOLE No PR-01

1 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 529.9 E 358 355.2 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.05 - 2016.03.05 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20   40   60   80   100	W <sub>P</sub> W      W <sub>L</sub>	WATER CONTENT (%)				
								SHEAR STRENGTH kPa						
								○ UNCONFINED      + FIELD VANE						
								● QUICK TRIAXIAL      × LAB VANE						
281.5	GROUND SURFACE													
0.0	Silty <b>CLAY</b> , trace sand, occasional rootlets Stiff Brown Moist to Wet		1	SS	12		281							
			2	SS	11									0   0   53   47
280.1							280							
1.4	Silty <b>SAND</b> , trace to some clay, trace gravel, occasional cobbles and boulders Compact to Very Dense Brown to Grey Moist (TILL)		3	SS	16									
			4	SS	18		279							
			5	SS	21		278							2   56   32   10
	150mm boulder at 4.3m		6	SS	112/ 0.150		277							
			7	SS	109/ 0.150		276							
			8	SS	106/ 0.150		275							
			9	SS	102/ 0.150		274							0   51   33   16
							273							
							272							

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PR-01

2 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 529.9 E 358 355.2 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.05 - 2016.03.05 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	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									
Continued From Previous Page							20	40	60	80	100	20	40	60			
270.7			10	SS	116/		271										
10.8	END OF BOREHOLE AT 10.8m. BOREHOLE OPEN TO 10.8m AND WATER LEVEL AT 1.4m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.				0.150												

# RECORD OF BOREHOLE No PR-02

1 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 589.3 E 358 371.8 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.08 - 2016.03.08 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
							20 40 60 80 100	20 40 60 80 100						
282.6	GROUND SURFACE													
0.0	Silty <b>CLAY</b> to Clayey <b>SILT</b> , trace sand, occasional rootlets Firm to Very Stiff Brown Wet		1	SS	21									
			2	SS	7									
			3	SS	12									
			4	SS	16									
	Becoming Grey		5	SS	6									
278.5														
4.1	Silty <b>SAND</b> , trace to some clay, trace gravel, occasional cobbles and boulders Compact to Very Dense Grey Moist (TILL)		6	SS	13									
	Cobbles from 5.5m to 6.1m		7	SS	24									
			8	SS	100/ 0.150									
			9	SS	111/ 0.150									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No PR-02

2 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 589.3 E 358 371.8 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.08 - 2016.03.08 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa													
								20 40 60 80 100													
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)									
							20 40 60 80 100					20 40 60									
	Continued From Previous Page																				
	225mm boulder at 11.0m		10	SS	102/ 0.150		272														
							271														
			11	SS	119/ 0.150		270														
							269														
268.6			12	SS	138											7 40 32 21					
14.0	END OF BOREHOLE AT 14.0m. BOREHOLE OPEN TO 14.0m AND WATER LEVEL AT 3.1m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m)  2016.03.09      2.5      280.1																				

ONTMT4S 19-5161-251.GPJ 2015TEMPLATE(MTO).GDT 5/13/16

# RECORD OF BOREHOLE No PR-03

1 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 427.0 E 358 409.2 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.06 - 2016.03.06 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub>	W	W <sub>L</sub>		
279.8	GROUND SURFACE							20 40 60 80 100						
0.0	Silty <b>CLAY</b> to Clayey <b>SILT</b> , trace sand, occasional wood fibres Very Stiff to Stiff Grey Wet to Moist		1	SS	18		279	○ UNCONFINED + FIELD VANE						
			2	SS	9		278	● QUICK TRIAXIAL × LAB VANE						
			3	SS	10		277							
277.6			4	SS	50/ 0.150		276							
2.2	Silty <b>SAND</b> , trace to some clay, trace to some gravel, occasional cobbles Loose to Very Dense Grey Moist (TILL)  100mm cobble at 2.4m		5	SS	7		275							
			6	SS	41		274							
			7	SS	107		273							
			8	SS	103/ 0.150		272							
			9	SS	112/ 0.150		271							
							270							

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
15  
10  
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PR-03

2 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 427.0 E 358 409.2 ORIGINATED BY GA  
HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
DATUM Geodetic DATE 2016.03.06 - 2016.03.06 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	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									
	Continued From Previous Page																
	300mm boulder at 10.4m		10	SS	111/ 0.150		269									0 52 34 14	
267.5			11	SS	119/ 0.150		268										
12.3	END OF BOREHOLE AT 12.3m BOREHOLE OPEN TO 12.3m AND ARTESIAN PRESSURE AT 1.0m ABOVE GROUND SURFACE IN NW CASING UPON COMPLETION OF BOREHOLE. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.				0.150												

# RECORD OF BOREHOLE No PR-04

1 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 461.4 E 358 415.3 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.07 - 2016.03.07 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE		WATER CONTENT (%) W <sub>P</sub> W W <sub>L</sub>			
280.4	GROUND SURFACE												
0.0	TOPSOIL: (150mm)												
0.2	Silty <b>CLAY</b> , some sand, trace gravel in upper zone, occasional rootlets and wood fibres Stiff to Soft Grey Moist		1	SS	14								
			2	SS	6								
			3	SS	4								
			4	SS	3								
277.4													
3.0	<b>PEAT</b> , fibrous, trace to some silt, trace sand, trace clay Loose Dark Brown Wet		5	SS	4								
276.6													
3.8	Silty <b>SAND</b> , trace gravel, trace to some clay, occasional cobbles and boulders Compact to Very Dense Grey Moist (TILL)		6	SS	20								
	125mm cobbles at 5.3m												
			7	SS	20								
			8	SS	103								
			9	SS	105/ 0.150								

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
15  
10  
(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No PR-04

2 OF 2

METRIC

GWP# 5196-13-00 LOCATION Pike River Bridge N 5 373 461.4 E 358 415.3 ORIGINATED BY GA  
 HWY 572 BOREHOLE TYPE NW Casing/NQ Coring/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2016.03.07 - 2016.03.07 CHECKED BY AMP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	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					WATER CONTENT (%) W <sub>p</sub> W W <sub>L</sub>				
	Continued From Previous Page																
			10	SS	111/ 0.150		270									3 42 39 16	
							269										
			11	SS	106/ 0.150		268										
							267										
266.5 13.9	END OF BOREHOLE AT 13.9m. BOREHOLE OPEN TO 13.9m AND WATER LEVEL AT 1.5m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2016.03.08 0.9 279.5 2016.03.09 0.8 279.6		12	SS	116/ 0.150												

ONTMT4S 19-5161-251.GPJ 2015TEMPLATE(MTO).GDT 5/13/16



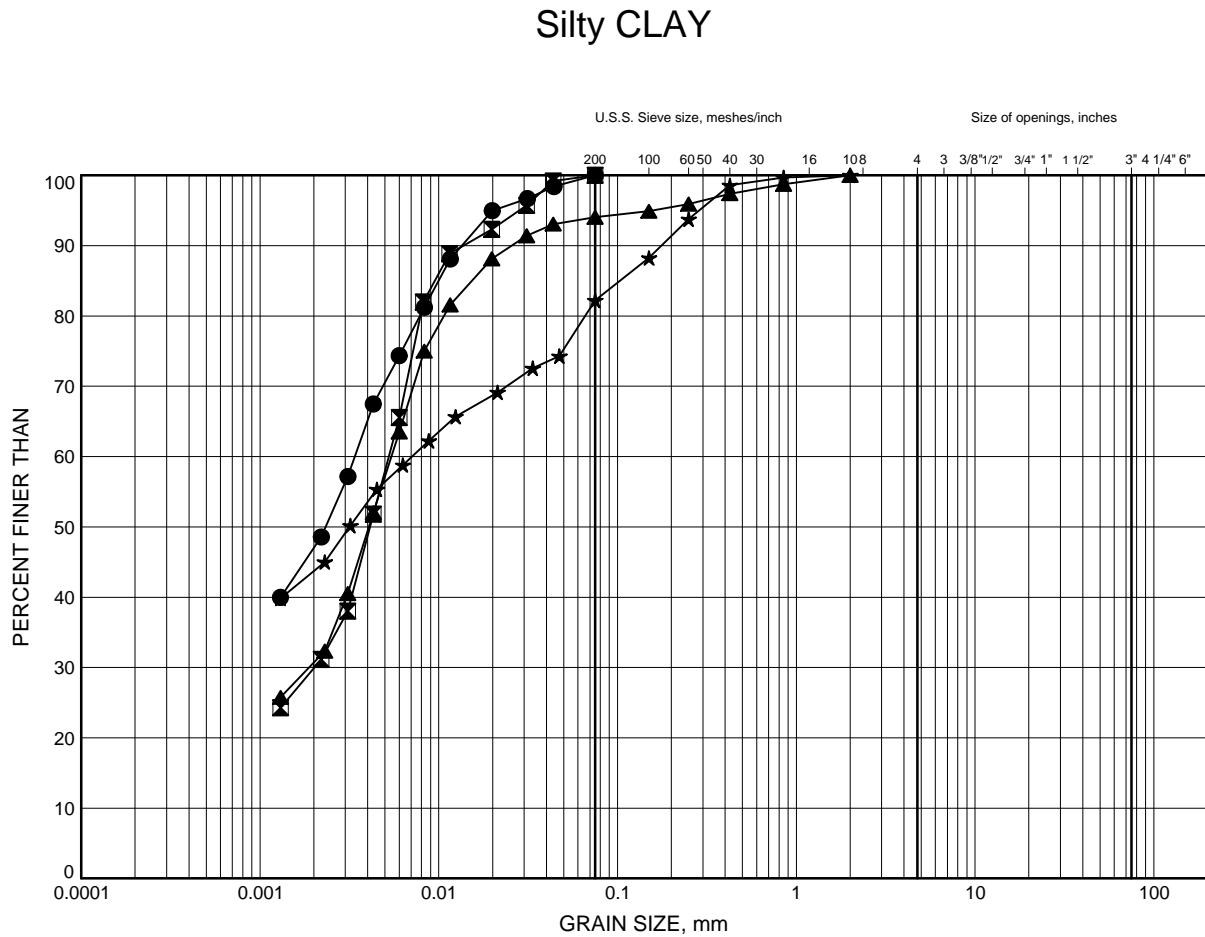
## **Appendix B**

### **Geotechnical Laboratory Test Results**

# Pike River Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B1



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR-01	1.07	280.43
⊠	PR-02	1.83	280.77
▲	PR-03	1.83	277.97
★	PR-04	1.83	278.57

Date May 2016

GWP# 5196-13-00



Prep'd AN

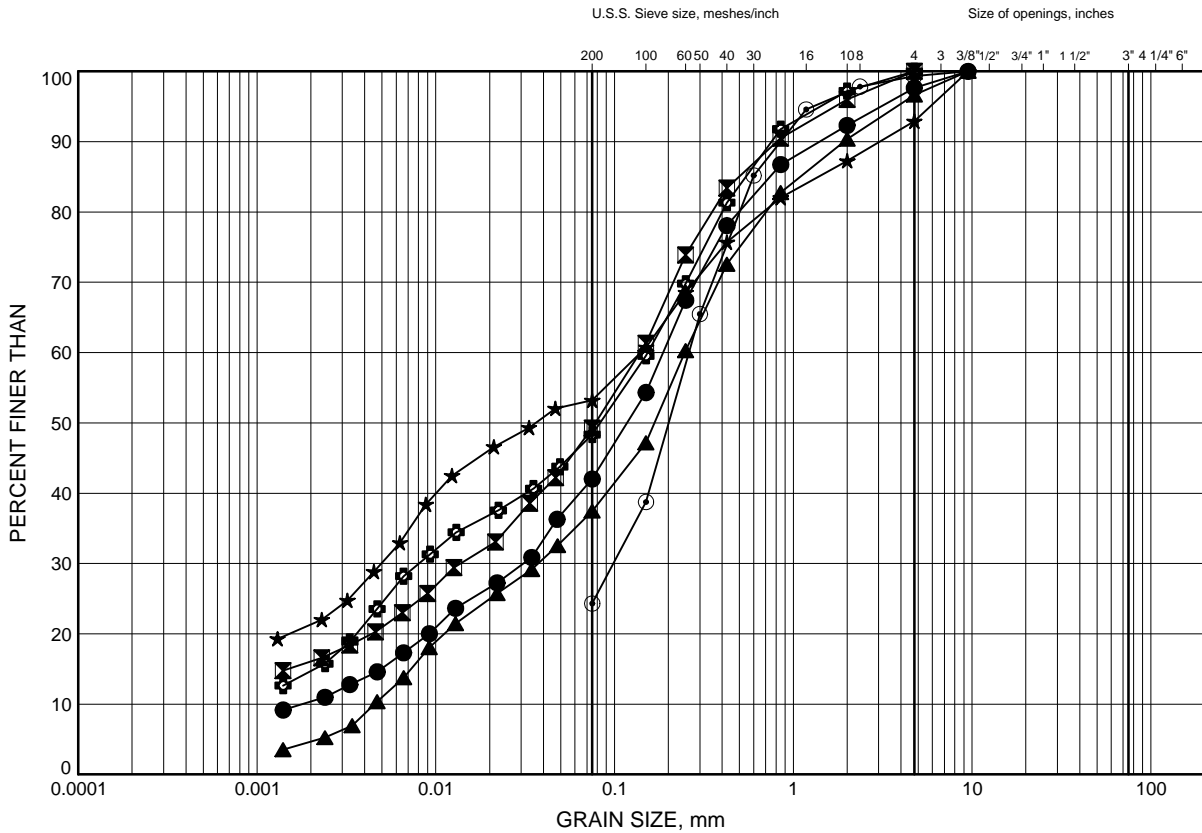
Chkd. DJP

# Pike River Bridge

## GRAIN SIZE DISTRIBUTION

FIGURE B2

### Silty SAND TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR-01	3.35	278.15
⊠	PR-01	7.70	273.80
▲	PR-02	4.88	277.72
★	PR-02	13.87	268.73
⊙	PR-03	4.88	274.92
⊕	PR-03	10.74	269.05

Date May 2016

GWP# 5196-13-00



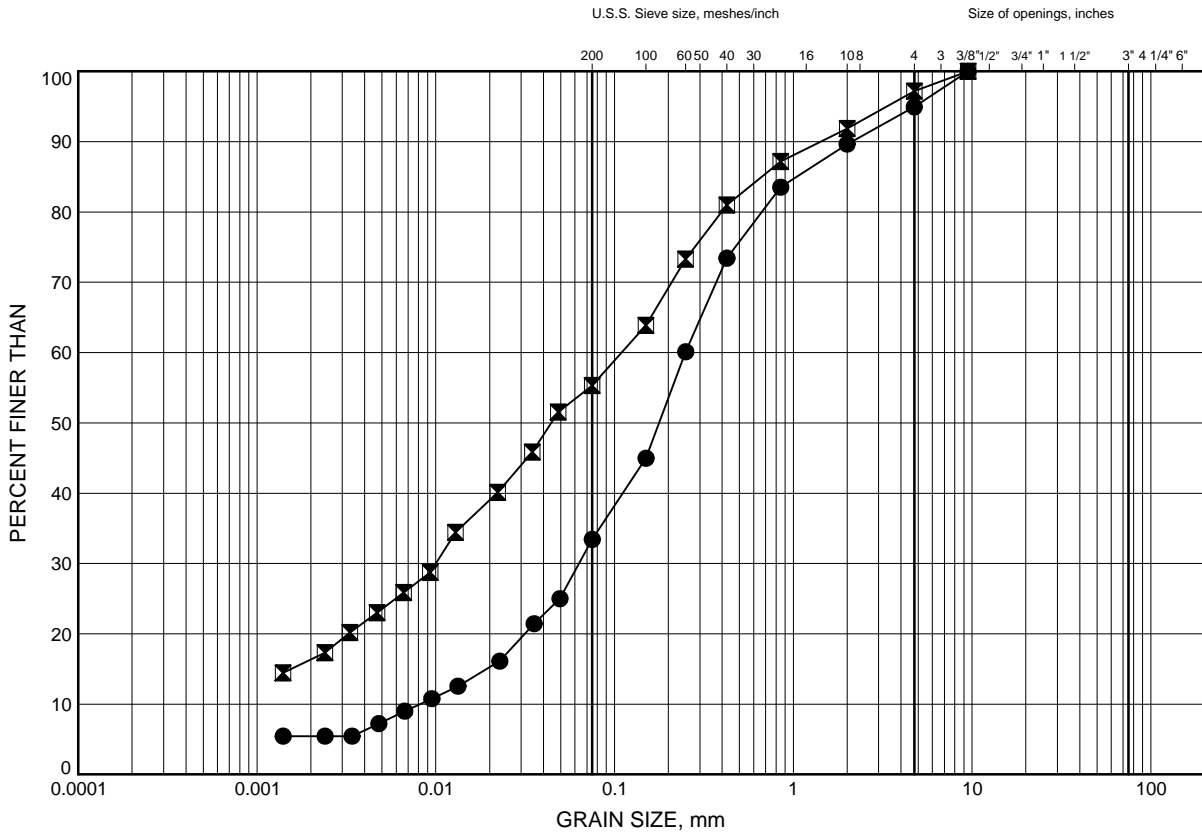
Prep'd AN

Chkd. DJP

# Pike River Bridge GRAIN SIZE DISTRIBUTION

FIGURE B3

## Silty SAND TILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR-04	6.40	274.00
⊠	PR-04	10.74	269.65

Date May 2016  
GWP# 5196-13-00

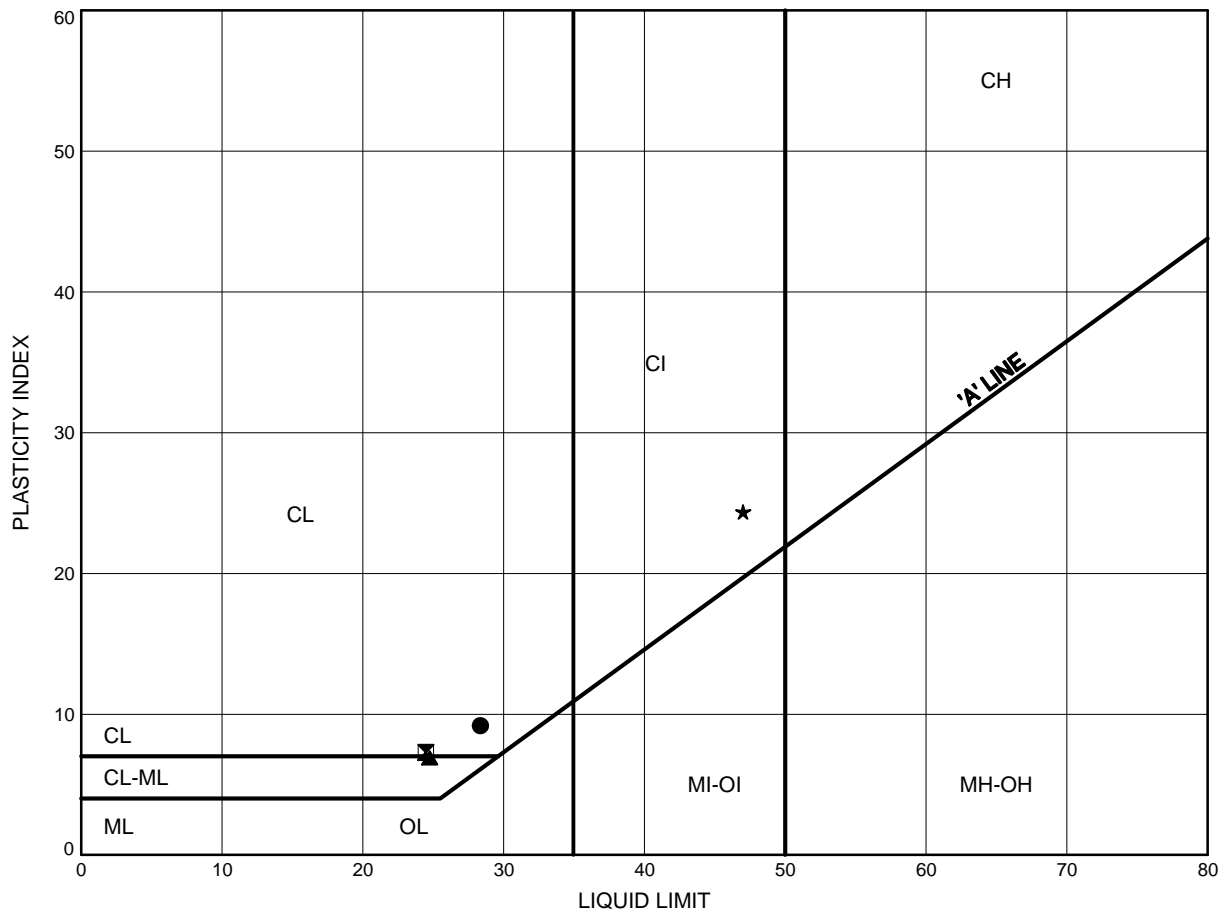


Prep'd AN  
Chkd. DJP

Pike River Bridge  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B4

Silty CLAY



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PR-02	1.83	280.77
⊠	PR-02	3.35	279.24
▲	PR-03	1.83	277.97
★	PR-04	1.83	278.57

Date May 2016  
 GWP# 5196-13-00



Prep'd AN  
 Chkd. DJP



**Appendix C**  
**Selected Site Photographs**





Photograph 1 – South Approach, Looking North



Photograph 2 – North Approach, Looking South





Photograph 3 – Looking at South Abutment



Photograph 4 – Looking at North Abutment





Photograph 5 – East Elevation, Looking South



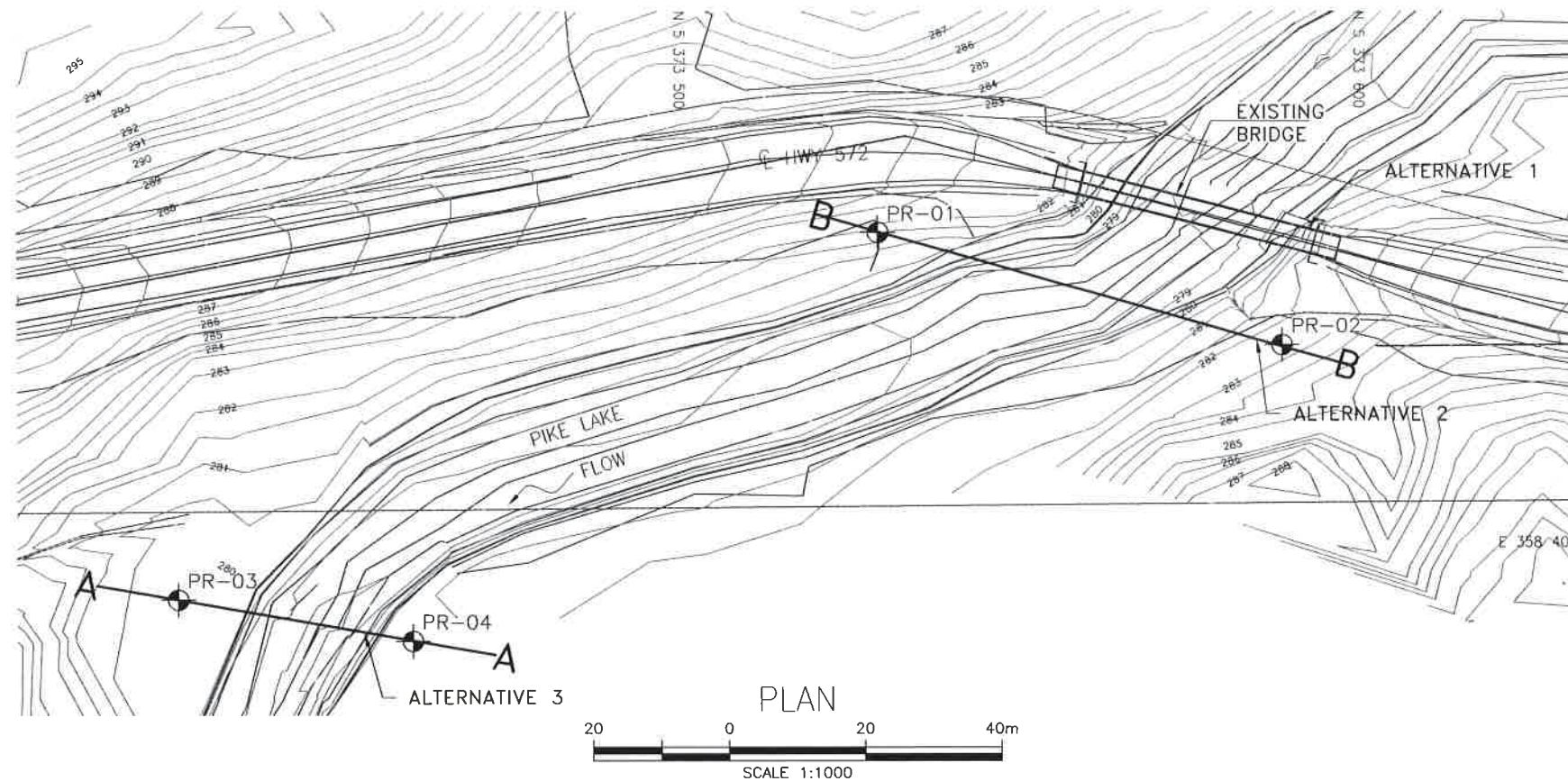
Photograph 6 – West Elevation, Looking North



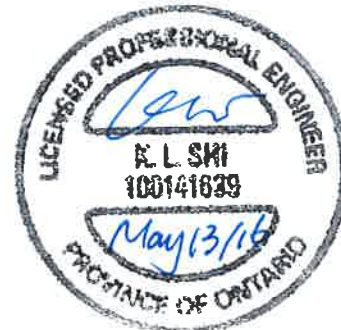
## **Appendix D**

### **Borehole Locations and Soil Strata Drawing**





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



CONT No  
GWP No 5196-13-00

HIGHWAY 572  
PIKE RIVER BRIDGE  
REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

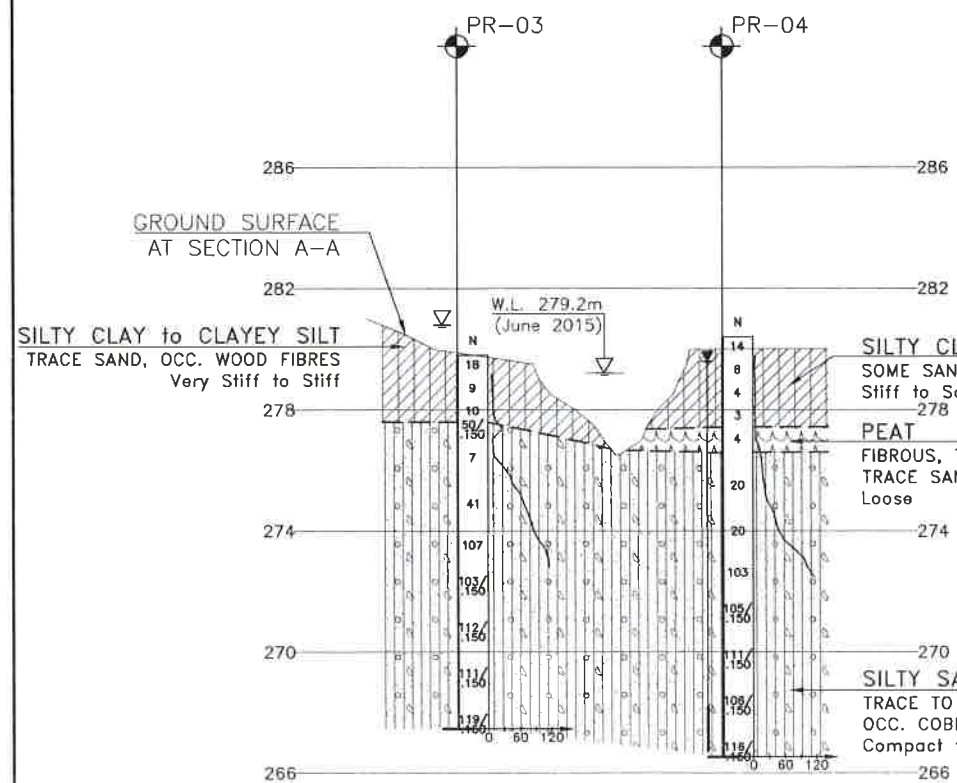
◆	Borehole
◆	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▽	Water Level in Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING (MTM)	EASTING (MTM)
PR-01	281.5	5 373 529.9	358 355.2
PR-02	282.6	5 373 589.3	358 371.8
PR-03	279.8	5 373 427.0	358 409.2
PR-04	280.4	5 373 461.4	358 415.3

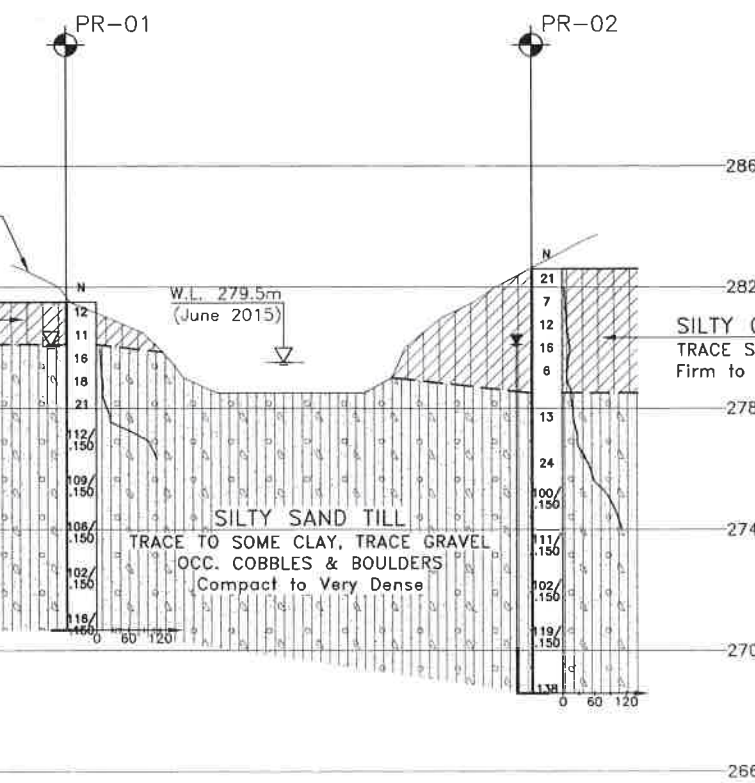
NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Survey data provided by MMM.
- MTM 83, Zone 12 coordinate system was used to obtain boreholes Northings and Eastings.

GEOCRES No. 42A-106



SECTION ALONG A-A



SECTION ALONG B-B

H 1:1000  
V 1:250

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	DJP	CHK	DJP
DRAWN	AN	CHK	AMP
CODE	LOAD	DATE	MAY 2016
STRUCT	DWG		