PAVEMENT INVESTIGATION REPORT

BATH AND MILLHAVEN CORRECTIONAL FACILITY – ROADWAY RESURFACING
BATH, ONTARIO

Submitted to:

Public Works and Government Services Canada
294 King Street East
Kingston, Ontario, K7L 3B2
Canada

Submitted by:

Amec Foster Wheeler Environment & Infrastructure,
a Division of Amec Foster Wheeler Americas Limited
900 Maple Grove Road
Cambridge, Ontario, N3H 4R7
Canada

17 May 2018
Project Reference Number: TPB176179.R212.3

TABLE OF CONTENTS

LIST OF FIGURES

RECORD OF BOREHOLES

LIST OF APPENDICES

1.0 INTRODUCTION

Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited ("Amec Foster Wheeler"), was retained by Public Works and Government Services Canada (PWGSC), on behalf of Correctional Service Canada (CSC), to conduct a pavement investigation for the proposed rehabilitation of approximately 6 km of local roads within the Institutions of Bath and Millhaven, located in Bath, Ontario. The project site location is shown in Figure No. 1.

The purpose of the pavement investigation was to obtain information on the sub-surface and existing pavement conditions along the investigated road section by means of a limited number of boreholes, in-situ tests and laboratory tests of selected soil samples. Based on Amec Foster Wheeler's interpretation of the data obtained, recommendations are provided on the geotechnical aspects of the project with respect to the detail design of pavement for rehabilitation of the investigated road section.

This report contains the findings of Amec Foster Wheeler's pavement investigation, together with recommendations and comments. These recommendations and comments are based on factual information, and are intended only for use by Design Engineers. The number of boreholes may not be sufficient to determine all the factors that may affect construction methods and costs. Sub-surface and groundwater conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of site investigation. The anticipated construction conditions are also discussed, but only to the extent that they may influence design decisions. Construction methods discussed, however, express Amec Foster Wheeler's opinion only and are not intended to direct the Contractors on how to carry out the construction. Contractors should also be aware that the data and their interpretation presented in this report may not be sufficient to assess all the factors that may have an effect upon the construction.

The report is prepared with the condition that the design will be in accordance with all applicable standards and codes, regulations of authorities having jurisdiction, and good engineering practice. Further, the recommendations and opinions in this report are applicable only to the proposed project as described above.

On-going liaison with Amec Foster Wheeler during the final design and construction phase of the project is recommended to confirm that the recommendations in this report are applicable and/or correctly interpreted and implemented. Also, any queries concerning the geotechnical aspects of the proposed project should be directed to Amec Foster Wheeler for further elaboration and/or clarification.

1.1 Project Description

The site is accessed from Highway 33 by an entrance with a side lane for west bound traffic to slow and enter the property. The asphalt roads on the property are configured in a loop layout, with branch roads providing access to a firing range, water reservoir, stores building, and a loop around Millhaven for security vehicle use. The road also has branches designated for security vehicle use next to the perimeter fence of Bath Institution.

The investigated roads within Bath and Millhaven Institution consist of circular and branch roads that stretch to approximately 6.0 km in length. The circular roads are mainly for security vehicles to observe the facility perimeters within the Bath Institution, and branch roads are for security vehicles to observe and travel between Bath and Millhaven Institution, and to allow visitors and delivery vehicles to access the Institutions.

The roads of the Institutions are two lanes (single lane in each direction) with asphalt-paved road way structure with a posted limit of 30 km/hr. The paved roadway generally has gravel or grass shoulders with a ditch located on one or both sides.

1.2 Geology

Based on Chapman, L. J., and Putnam, D. F., (1984), The Physiography of Southern Ontario the site is located at the physiographic region of Limestone Plains. A review of the Surficial Geology of Southern Ontario (2003) Ontario Geological Survey, shows that the site is located on Paleozoic bedrock (limestone with minor shales in upper part). The study area is underlain by limestone, dolostone, shale, arkose and sandstone bedrock of the Ottawa Group and Simcoe Group, Shadow Lake Formation according to the Bedrock Geology of Ontario Map 2544 (Southern Sheet).

2.0 INVESTIGATION PROCEDURE

The following tasks were carried out for the pavement investigation:

- Visual pavement condition survey of the existing road;
- Ground Penetration Radar (GPR) survey;
- Pavement investigation by shallow boreholes of the existing pavement structure and shoulders; and
- Laboratory testing, including soil and water content.

Prior to drilling, utility locates were carried out to obtain clearances for existing underground utilities. The borehole drilling activities for this investigation was carried out from 20 to 22 March 2018. Boreholes were advanced at 25 locations (BH1 to BH20, and BH1S to BH5S, inclusive) to depths ranging from 0.5 m to 2.1 m below ground surface (bgs).

All the boreholes were located and marked by our geotechnical engineering staff. Our staff arranged for underground utility locates for all borehole locations. The NAD 83 coordinates borehole locations were recorded by Amec Foster Wheeler, using a Sokkia GSR 2700 ISX GPS Global Navigation Satellite System receiver, with triple-frequency GPS and Russian based GLOSNASS satellite tracking capability. The ground surface elevations, NAD 83 coordinates, and detailed subsurface conditions encountered in the boreholes, are provided on the borehole logs attached. The boreholes were advanced in alternating driving lanes and shoulders of the roadway where possible to supplement existing data.

The boreholes were advanced utilizing a track-mounted Geo-probe 7822DT drill rig equipped with solid stem auger, direct push, and conventional soil sampling tools. Typically, soil samples were obtained at 0.75-m intervals via the Standard Penetration Test (STP) method, ASTM D1586. Where no to low recovery was encountered from SPT, auger soil sample was collected. The results of the penetration tests are reported as ‘N’ values on each borehole log at the corresponding depths and have been used to infer the conditions of the subsurface soils.

The soil stratigraphy within each borehole was visually examined and classified at the time of drilling in accordance with the modified Unified Soil Classification System (USCS) and for presence of visible environmental impact. Retrieved soil sample was placed in a sealed plastic bag and was immediately scanned in the field for the presence of organic / hydrocarbon vapours using a portable photo-ionization detector (PID) and combustible gas detector (e.g. Eagle II instrument).

The borehole details are shown in Table 2.1 and the locations are provided in Figure 2.

Table 2.1 – Borehole Details

Borehole No.	GPS Co-ordinates (UTM/NAD 83)		Ground Elevation (m)	Depth (m)	Remarks
	Easting	Northing			
BH1	839676	4901594	83.7	1.6	Asphalt borehole
BH2	839630	4901719	90.7	1.1	Asphalt borehole
BH3	839345	4901729	92.6	1.7	Asphalt borehole
BH4	839223	4901851	96.8	0.9	Asphalt borehole
BH5	839195	4902089	97.0	1.8	Asphalt borehole
BH6	839306	4902227	96.4	1.1	Asphalt borehole
BH7	839509	4902165	99.1	1.9	Asphalt borehole
BH8	839668	4902037	91.0	1.6	Asphalt borehole
BH9	839607	4901892	91.3	1.6	Asphalt borehole
BH10	839719	4901863	91.5	1.7	Asphalt borehole
BH11	839831	4901997	92.4	0.5	Asphalt borehole
BH12	839786	4902195	92.1	2.1	Asphalt borehole
BH13	839648	4902311	94.0	1.2	Asphalt borehole
BH14	839476	4902345	95.4	2.1	Asphalt borehole
BH15	839288	4902430	96.2	1.3	Asphalt borehole
BH16	839302	4902676	97.5	0.6	Asphalt borehole
BH17	839457	4902799	97.1	0.8	Asphalt borehole
BH18	839645	4902667	94.5	0.9	Asphalt borehole
BH19	839559	4902465	95.1	1.7	Asphalt borehole
BH20	839386	4902389	95.6	1.4	Asphalt borehole
BH1S	839410	4901709	91.7	2.1	Paved Shoulder borehole
BH2S	839128	4902004	96.8	1.6	Paved Shoulder borehole
BH3S	839436	4902222	95.8	1.5	Paved Shoulder borehole
BH4S	839287	4902580	97.1	1.0	Granular Shoulder borehole
BH5S	839625	4902483	94.2	1.0	Granular Shoulder borehole

Soil samples were transported to Amec Foster Wheeler's Soil Laboratory in Richmond Hill for further review and laboratory testing, which consisted of water content determination, grain size analysis, and Atterberg Limits on selected samples.

The soil and groundwater conditions and the results of in-situ and laboratory tests are presented on the corresponding borehole logs. Results of the laboratory testing on soil samples, including water content, grain size distribution curves, and plasticity chart, are included in Appendix A.

3.0 PAVEMENT INVESTIGATION

3.1 Pavement Evaluation

3.1.1 Visual Pavement Condition Survey

Amec Foster Wheeler completed a visual pavement condition survey of the existing road surface within the project area to identify any distresses. The identification and classification of the pavement distresses were carried out in accordance with MTO's "*Flexible Pavement Condition Rating Manual – Guidelines for Municipalities*", SP-022. The roads were divided into stations for sole purpose of identification during the condition survey. Bath extends from Station 1+000 to 3+750 and Millhaven from 4+000 to 5+500. The stations were divided into 250 m sections, and the stations are plotted in Figures 3A and 3B.

Generally, the existing asphaltic concrete surface condition was rated in 'Poor to Fair" to 'Fairly Good" condition. Such pavement condition reflects its age and lack of recent routine/systematic maintenance that has resulted in the pavement condition progressively deteriorating with time.

A summary of the pavement condition surveys, including predominant surface defects, surface deformation and cracking is tabulated in Table 3.1 and selected photographs showing the existing condition of the investigated road section is presented in Appendix B.

Table 3.1 - Summary of Pavement Condition

From - To	Predominant Distress	2018 Condition
KM 1+000 to 1+250	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Transversal (Half, Full and Multiple) - Slight / Frequent	Fair
KM 1+250 to 1+500	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Pavement Edge (Alligator) - Very Severe / Intermittent	Poor
KM 1+500 to 1+750	• Ravelling and Coarse Aggregate Loss – Severe / Throughout • Longitudinal Wheel Track Cracking (single and multiple) – Moderate / Frequent • Transverse Cracking (half, full and multiple) - Moderate / Frequent • Wheel Track Rutting – Moderate / Frequent	Poor
KM 1+750 to 2+000	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Transverse Cracking (half, full and multiple) - Moderate / • Longitudinal Wheel Track (Single and Multiple) - Moderate / Few • Pavement Edge (Alligator) - Very Severe/Intermittent • Transverse Longitudinal Meander (Half, Full Multiple) - Moderate / Intermittent	Poor
KM 2+000 to 2+250	• Ravelling and Coarse Aggregate Loss – Severe / Throughout Pavement Edge (Alligator) - Very Severe / Intermittent • Transverse (Half, Full and Multiple) - Slight / Frequent	Fair to Poor

From - To	Predominant Distress	2018 Condition
KM 2+250 to 2+500	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout Transverse (Full and Multiple) - Severe / Few • Center Line (Single and Multiple)-Slight/Intermittent • and Pavement Edge (Single and Multiple) - Slight / Intermittent	Fair
KM 2+500 to 2+750	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Center Line Cracking (single and multiple) – Severe / Extensive	Poor
KM 2+750 to 3+000	• Ravelling and Coarse Aggregate Loss – Moderate / Extensive • Center Line (Single and Multiple) - Slight / Throughout • Transverse (Half, Full and Multiple) - Slight / Intermittent	Poor to Fair
KM 3+000 to 3+250	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout Center Line (Single and Multiple) - Slight / Frequent • Transverse (Half, Full and Multiple) - Slight / Intermittent	Fair
KM 3+250 to 3+500	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Longitudinal Wheel Track (Single and Multiple) - Slight / Frequent • Center Line (Single and Multiple) - Slight / Intermittent • Transverse (Half, Full and Multiple)-Slight/Intermittent	Fair
KM 3+500 to 3+750	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Pavement Edge Cracking (alligator) – Very Severe / Intermittent	Very Poor
KM 3+750 to 4+000	• Ravelling and Coarse Aggregate Loss – Severe / Throughout • Longitudinal Wheel Track (Single and Multiple) - Moderate / Intermittent • Pavement Edge (Alligator) - Slight / Few • Transverse (Half, Full and Multiple) - Slight / Intermittent	Fair
KM 4+000 to 4+250	• Longitudinal Wheel Track Single and Multiple)-Very Severe/Few • Center Line (Single and Multiple) - Moderate/Few • Pavement Edge (Alligator) - Severe / Few	Very Poor
KM 4+250 to 4+500	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Center Line (Single and Multiple) - Moderate / Throughout • Transverse (Half, Full and Multiple) - Moderate / Extensive	Fair to Poor
KM 4+500 to 4+750	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Center Line Cracking (single and multiple) – Very Severe / Frequent • Transverse Cracking (half, full and multiple) - Severe / Frequent	Poor to Fair
KM 4+750 to 5+000	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Center Line Cracking (single and multiple) –Severe / Extensive • Transverse Cracking (half, full and multiple) - Moderate / Extensive	Poor to Fair
KM 5+000 to 5+250	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Transversal and Longitudinal Crack Sealing	Fair
KM 5+250 to 5+500	• Ravelling and Coarse Aggregate Loss – Moderate / Throughout • Center Line Cracking (single and multiple) – Severe / Extensive • Center Line Cracking (alligator) – Moderate / Frequent	Very Poor

3.1.2 Ground Penetration Radar Survey

Amec Foster Wheeler retained MultiVIEW as a Sub-Consultant to undertake the Ground Penetration Radar (GPR) survey. High speed collection of GPR data was performed on the selected road lanes using a high-speed multi-channel ground-coupled GPR system. The RoadMap GPR survey was designed to include a minimum of one pass per road lane. Two 1000 MHz GPR antennas were used at the left and centre channels, and one 500 MHz antenna on the right position for shallow and deep road condition assessment up to ~1.5m depth. GPS data were collected synchronously with the GPR data using a Trimble RTK-8 receiver mounted on RoadMap system. Data were collected using nominal GPR/GPS settings at posted travel speeds. The GPR report is included in Appendix D.

Colour contour plan maps and profile cross-sections illustrating the interpreted road structure along the GPR scanned profiles are presented in Figure 4-2 to Figure 4-31 of the GPR report in Appendix D.

Table 3.2 presents a summary of the interpreted GPR results of the thickness of existing asphalt, granular and sub-base layers.

Table 3.2 – Summary of Thickness of Asphalt, Granular and Sub-Base Layers

HMA Thickness	Granular Base	Granular Subbase	Total Thickness
Bath Road			
Range (46-226) mm Av. (105) mm	Range (40-371) mm Av. (175) mm	Range (24-494) mm Av. (227) mm	Range (214-729) mm Av. (507) mm
Millhaven Road			
Range (80-338) mm Av. (113) mm	Range (35-364) mm Av. (159) mm	Range (28-496) mm Av. (212) mm	Range (269-743) mm Av. (484) mm

Based on the results of the GPR survey, the average asphalt thickness in the Bath and Millhaven surveyed roads is about 105 mm and 113 mm, respectively. In general, asphalt thickness showed fair consistency with GPR and borehole/core data with typical thickness 30 percent higher than that measured from borehole/cores. The granular base and sub-base thicknesses based on GPR data and those based on borehole data had poor correlation likely due high moisture content of the soils.

3.2 Sub-Surface Conditions

The soil profile in the shoulder and asphalt boreholes consisted predominantly of existing asphaltic concrete or surficial granular fill (shoulder boreholes) overlying base and subbase granular fill and non-cohesive fill soils underlain by native silty clay. Additional information is provided in the Borehole Log Data.

Two methods were used to assess the existing pavement structure. In-situ structure number ("SN") and in-situ Granular Base Equivalency ("GBE") were estimated from the borehole data using the equivalency factors for various material types, as shown in Table 3.3.

Table 3.3: Typical Structural Layer Coefficient

Material Type	Typical AASHTO-Ontario Structural Layer Coefficient (SLC), ai (mm) [1]		Granular base Equivalency Factors [2]
Rehabilitation	**Drainage**	**Structural**	
Existing HL Existing Gran Base Existing Gran Sub-base Existing Gran Base/Sub-base	Acceptable **1.0** Questionable 0.9 Inadequate 0.8 to 0.5	0.14 to 0.28 0.10 to 0.14	1.25 0.75 0.50 0.625
Pulverization CIR RAP/Gran A blended stabilized with EAM	1.0 1.0 1.0	0.10 to 0.14 0.28 to 0.38 0.20 to 0.25	1.0 1.6 – 1.8 1.0

Notes:

(1) MTO Report MI-183 -. MTO Report MI-183 "Adaptation and Verification of AASHTO Pavement Design Parameters for Ontario Conditions" - Table 4-5.

(2) MTO Pavement Design Rehabilitation Manual 1990 – Table 3.5.

Table 3.4a, Table 3.4b and Table 3.4c display the total average pavement structural thickness of the existing asphaltic concrete pavement, granular base and sub-base, as well as the average existing structure number 'SN' and 'GBE' before rehabilitation. An asphalt core Photo Record is included in Appendix 'C'.

Table 3.4a: Summary of Pavement Structure Thickness of Bath Road

Total Thickness (mm)					
BH#[1]	**Approx. Station**	**Asphalt**	**Base / Subbase**	**Total**	**Underlying Material**
Bath Road					
BH1	KM1+100	76	1,324	1400	Sand
BH2	KM1+265	51	849	900	Silty Clay
BH3	KM1+555	76	1,024	1100	Silty Clay
BH4	KM1+725	102	298	400	Silty Clay
BH5	KM2+060	76	1,424	1,500	Sandy Silty Clay
BH6	KM2+240	51	1,049	1,100	Possible Bedrock
BH7	KM2+510	51	1,849	1900	Possible Bedrock
BH8	KM2+710	51	549	600	Silty Clay
BH9	KM2+900	76	224	300	Silty Clay
BH10	KM3+170	127	373	500	Silty Clay
BH11	KM3+350	127	373	500	Possible Bedrock
BH12	KM3+620	51	2,049	2,100	Fill - Sand and Gravel
BH13	KM3+800	51	1,149	1,200	Possible Bedrock
BH14	KM3+990	76	1,024	1,100	Silty Clay
	Minimum Maximum Average	**51 mm 127 mm 74 mm**	**224 mm 2,049 mm 968 mm**	**300 mm 2,100 mm 1,043 mm**	
Shoulder (Paved)					
BH1S[2]	KM1+485	51	1,049	1,100	Silty Clay
BH2S[2]	KM1+955	76	1,324	1,400	Silty Clay
BH3S[2]	KM2+410	51	549	600	Silty Clay
	Minimum Maximum Average	**51 mm 76 mm 59 mm**	**549 mm 1,324 mm 974 mm**	**600 mm 1,400 mm 1,033**	

Notes:

(1) Boreholes 1 to 14 were drilled along Bath road areas.

(2) Boreholes located on the asphalt shoulder

Table 3.4b: Summary of Pavement Structure Thickness of Millhaven

Total Thickness (mm)					
BH#[1]	**Approx. Station**	**Asphalt**	**Base / Subbase**	**Total**	**Underlying Material**
Millhaven Road					
BH15	KM4+275	76	724	800	Clayey Silt
BH16	KM4+525	76	524	600	Silt and Sand
BH17	KM4+725	101	699	800	Possible Bedrock
BH18	KM5+060	75	825	900	Possible Bedrock
BH19	KM5+310	76	724	800	Clayey Silt
BH20	KM5+500	76	724	800	Silty Clay

Total Thickness (mm)					
BH#[1]	**Approx. Station**	**Asphalt**	**Base / Subbase**	**Total**	**Underlying Material**
	Minimum **Maximum** **Average**	**75 mm** **101 mm** **80 mm**	**524 mm** **825 mm** **703 mm**	**600 mm** **900 mm** **783 mm**	
Shoulder (Unpaved)					
BH4S	KM4-425	-	1,000	1,000	Possible Bedrock
BH5S	KM5-240	-	1,000	1,000	Possible Bedrock
	Minimum **Maximum** **Average**	**-**	**1,000 mm**	**1,000 mm**	

Table 3.4b - Summary of Existing Pavement Structure on Asphalt Paved Roads and Shoulders

Number of Boreholes	Thickness (mm)		GBE	SN
	HMA	Base/Sub-Base	(mm)	
Bath Road				
@ **Road** # of BHs = 14 (BH1 - 20)	Range (51 - 127) mm Average 74 mm	Range (224 – 2,049) mm Average 968 mm	Range (235-1,344) mm Average 698 mm	Range (43-234) mm Average 123 mm
@ **Shoulders** # of BHs = 3 (BH1S – 3S)	Range (51 - 76) mm Average 59 mm	Range (549 – 1,324) mm Average 974 mm	Range (407-923) mm Average 683 mm	Range (72-162) mm Average 120 mm
Millhaven Road				
@ **Road** # of BHs = 5 (BH15 - 20)	Range (75 - 101) mm Average 80 mm	Range (524 – 825) mm Average 703 mm	Range (423-609) mm Average 540 mm	Range (76-108) mm Average 96 mm
@ **Shoulders** # of BHs = 5 (BH4S – 5S)	-	1,000	625	108

3.3 Environmental Soil Screening

Upon retrieving the soil samples from the boreholes, the soil samples were placed in a plastic bag for scanning for the presence of total organic vapours (TOV) / combustible organics vapours (COV) using a portable photo-ionization detector (PID) and a combustible gas detector instrument (e.g. RKI Eagle II). COV/TOV concentrations were measured using an RKI Eagle 2 (Eagle) combustible vapour analyzer calibrated to a known hexane/isobutylene standard and operated in methane elimination mode. Due to technical problems, TOV and COV was not recorded in all of the boreholes and some of the COV readings are provided in parts per million (ppm) rather than in lower explosive level (LEL). Table 3.5 below provides the maximum TOV and COV readings encountered in each borehole. Readings are shown in the respective Borehole Logs.

Table 3.5 – Summary of Maximum TOV and COV Readings

BH#	Maximum Reading		BH#	Maximum Reading	
	TOV (ppm)	COV (LEL)		TOV (ppm)	COV (LEL)
BH1	2	0	BH13	-[2]	-[2]
BH2	1	0	BH14	1	0
BH3	2	0	BH15	23	0[1]
BH4	2	0	BH16	1	0[1]
BH5	13	0	BH17	1	0
BH6	2	2	BH18	2	20[1]
BH7	1	0	BH19	4	0[1]
BH8	1	0	BH20	9	0[1]
BH9	1	0	BH1S	1	0
BH10	0	0	BH2S	1	0
BH11	2	0	BH3S	1	0
BH12	3	0[1]	BH4S	5	0[1]
			BH5S	-[2]	-[2]

Notes: 1 LEL is approximately 110 ppm for petroleum related vapour

(1) Unit was in ppm.

(2) Readings were not recorded.

As per standard operating procedures, during a field investigation, all soil samples were screened for odour and visual indication (i.e., staining or colour change) of impacts. Typically, an odour, visual impacts and/or indications, high total organic vapour levels, or high organic content (and thus the potential for methane generation) will yield higher levels of combustible hydrocarbon vapours or COV. During this field investigation, the soils encountered did not exhibit any visual or olfactory evidence indicative of higher levels of combustible hydrocarbon vapours.

The vapours readings indicate a negligible potential of hydrocarbon impacted soils at the borehole locations scanned with PID except at BH6 where the COV LEL reading was 2, or approximately 220 ppm.

If any excess fill / soil generated during earth works is to be disposed at a landfill or re-used at another site, additional soil quality testing will be required to determine the concentrations of any suspected contaminants of potential concern that may be present in the soil (i.e., BH6) relative to the Table 1 Background Site Conditions Standards set forth under Ontario Regulation 153/04 – Records of Site Condition. The Table 1 Background Site Conditions Standards are used currently by the Ministry of the Environmental and Climate Change to define inert fill that may be used without restriction throughout the province. Such potential contaminants include but are not necessarily limited to metals, petroleum hydrocarbons (PHC) and polynuclear aromatic hydrocarbons (PAH) as these contaminants are commonly found in poor quality fill and have the potential to accumulate in industrialized and/or urban and rural developed areas. Additional testing may also be required depending on the timing of the project with respect to the enactment of Ontario's proposed Excess Soil Regulation. Soil disposal at a landfill will also require testing in accordance with Ontario Regulation 347 General, Waste Management to determine the soil waste classification.

3.4 Laboratory Soil Testing

Laboratory tests were performed on selected samples from the boreholes. The laboratory tests were performed according to ASTM standards and the results are summarized in Tables 3.6 and presented in Appendix 'A'.

Table 3.6- Summary of Test Results and Soil Classification

Sample #	Gradation, % Passing			Soil Classification
	Gravel (>4.75 mm)	Sand (75µm to 4.75 mm)	Fines Silt/Clay [1] (< 75µm)	
BH11 - AS (base/sub-base)	31	50	19	Sand and gravel FILL, trace silt Sample met OPSSMUNI1010 Granular B-1, except marginally high sieve 200
BH17 - AS (base/sub-base)	48	42	10	Sand and gravel FILL, trace silt Sample met OPSSMUNI1010 Granular B-1 and B-2
BH5 – SS2	6	34	32 / 28	**CL**: Sandy Silty Clay
BH8 –SS1	4	6	33 / 57	**CH:** Silt Clay (Fat Clay)
BH16 – SS1	55	36	9	Sand and Gravel FILL, trace silt
BH1S – SS1	41	42	17	Sand and Gravel Fill, some silt

Notes:

(1) When shown in the form of, e.g. 19, it indicates the combination percent passing for silt and clay. When shown in the form of, e.g. 32 / 28, it indicates the percent passing for silt and clay, respectively.

4.0 FLEXIBLE STRUCTURAL PAVEMENT DESIGN

4.1 Existing and Forecasted Traffic Data

The institutions primarily receive light vehicle traffic composed of institutional staff, civilians visiting inmates, and correctional services transport vehicles. There are also commercial deliveries made by way of small and large trucks, and occasionally heavy civil construction equipment delivered on highway tractors and trailers.

Traffic data was not available for the project area. For local roads, such as Bath and Millhaven, it can be assumed that the Average Annual Daily Traffic (AADT) is less than 1000 vehicles per day.

The traffic data was used to calculate the projected traffic for an additional 20 year period. The traffic loading represented in equivalent single axle loads (ESALs) was calculated cumulatively over 20 years as described in the Ministry of Transportation Report "Procedures For Estimating Traffic Loads For Pavement Design, 1995".

Table 4.1 – Traffic Data

AADT 2019(1)	Growth Rate (2) (%)	Comm. Vehicles (2) (%)	Design ESALs @ 20 Years	Traffic Category
1,000	1.0%	5%	344,720 ~0.5 x 10^6	**Category B**

Notes:

(1) 2019 is the anticipated construction year.
(2) Assumed.

4.2 Pavement Design for New Construction

The minimum pavement structural design for Bath and Millhaven roads is presented in Tables 4.2a and 4.2b, as determined in accordance with the 1993 American Association of State Highway and Transportation Officials ('AASHTO') Guide for the Design of Pavement Structures using the Darwin Software Program and compared to the MTO Rehabilitation Design Manual. Darwin output Analysis is in Appendix E.

The AASHTO Pavement Design is considered to be a function of estimated future traffic in both directions (equivalent single axle loads (ESALs)), reliability (R), which is a function of road classification, overall standard deviation (S_o), resilient modulus (M_r), as well as initial and terminal serviceability (P_o, P_t). From these parameters, the structure number (SN) is calculated. The SN is defined in the AASHTO Guide as a number which provides a measure of the pavement strength and thickness needed to avoid overstressing the subgrade. The following design parameters were chosen to calculate the required structural design of the flexible pavement for 20 years for a base year 2019 using the AASHTO method:

- Design ESAL's = (20 year structural design) — Refer to Table 4.1
- Initial serviceability, P_i — 4.5
- Terminal serviceability, P_t — 2.5
- Mean subgrade resilient modulus, Mr — 30 MPa
- Reliability level, R — 90%
- Overall standard of deviation, S_o — 0.49
- HMA layer coefficient, a_i — 0.42
- Granular 'A' layer coefficient, a_i — 0.14
- Granular 'B' Type II layer coefficient, a_i — 0.14
- Drainage coefficient for all layers, m_i — 1.0

Table 4.2 - Recommended Minimum Structural Pavement Design Note (1) for Reconstruction

Material Description	**AASHTO'93 for 20 Years** Bath Rd and Millhaven Rd ESALs = ~0.5X10^6
Hot Mix Asphalt Concrete – PGAC 58-28/B	

Material Description	**AASHTO'93 for 20 Years** Bath Rd and Millhaven Rd ESALs = ~$0.5X10^6$
HL3 or SP12.5 - 40 mm	**110 mm**
HL 8 or SP 19.0 – 70 mm	
Granular Base 'A' Note (2, 3)	150 mm
Granular Subbase 'B' Type I Note (2, 3)	450 mm
Design Structure Number (SN) mm	95 mm
Selected Structure Number (SSN) mm	104 mm
Total Pavement Thickness (mm)	**710 mm**
GBE (mm)	**670 mm**

Notes:

(1) Pavement structure shall be over approved subgrade.

(2) Granular A and B Type II: Compaction as per OPSS Form 1010 (100% SPMDD).

(3) The granular thicknesses of the widening given in the table is a minimum thickness and should be increased, as required, to match the adjacent existing pavement granular thickness to promote positive lateral drainage (refer to the Borehole Log Data). Also, the thicknesses can be increased depending on grading requirements.

4.3 Rehabilitation Strategies

The selected rehabilitation strategies were based on Amec Foster Wheeler's geotechnical investigation and analysis, including a visual pavement condition assessment, subgrade condition, laboratory test results, calculated ESALs and the requirements of Bath and Millhaven Project Brief – rev. 1. Consideration was also given to user delay, cost and/or disruption of traffic and an anticipated construction year of 2018.

Three (3) proposed rehabilitation strategies for Bath and Millhaven roads are as follows:

Option 1 - Total Removal of the Existing Asphalt and Replace with 110 mm of HMA

This strategy involves the total removal of the existing asphalt thickness, followed by repaving with 110 mm of hot mix (40 mm of HL3 and 70 mm of HL8) with PGAC 58-28. The advantages of this option are the elimination of the surface defects and reflection cracking.

Material Specification should be as per OPSS 1150 for Marshall mixes and for aggregates, the material specification should be as per OPSS MUNI 1003. In all areas, asphaltic concrete should be compacted as per OPSS 310, Table 10 (November 2012).

Once the existing asphalt is removed, the exposed granular should be prepared under dry weather conditions, proof-rolled with a heavy rubber-tired vehicle (such as a grader or loaded dump truck) or a 10 tons smooth roller without vibration in the presence of the geotechnical consultant. Any loose, soft or unstable areas detected by the proof-rolling must be sub-excavated and replaced with approved granular A materials thoroughly compacted to a minimum of 100% of Standard Proctor Maximum Dry Density (SPMDD). If wet weather conditions prevail at the time of construction, adjustments to this design may be required (i.e. if the granular base becomes excessively wet or rutted during construction activities, replacement of the base/subbase material may be required. This option will not raise the vertical profile and will exceed the target design structure number (137 mm). Expected service life is 8-12 years.

Option 2 - In-Place Pulverization, Remixing and Resurface with 110 mm of HMA

This option will involve pulverizing the remaining asphalt concrete thickness into an equivalent depth of granular base material to a total depth of 150 mm. Therefore, the pulverization depth shall be 75 mm in the existing pavement plus 75 mm in the granular.

The resulting mixture of asphalt concrete materials and granular is then graded to cross fall and compacted and used as a base. The advantages of this option include the elimination of surface defects and reflection cracking and the reuse of the existing material efficiently. Typically, the GBE for Bituminous crushed recovered material is in the order of 1.0. In-place pulverization should be graded and compacted, and resurfaced with 110 mm of HMA. This will raise the vertical profile by 110 mm and will exceed the target design structure number (148 mm). Expected service life 12 to 15+ years.

Option 3 - Partial Depth Re-construction

This option involves excavating 200 mm of asphalt and granular, complete base repair where needed, regrade, compact, add new granular A, compact, and resurface with hot mix. This option will improve drainage and the structural capacity of the pavement and it will have lower maintenance cost over the pavement service life. In addition, it will not change the existing vertical profile and will exceed the target design structure number (141 mm). Expected service life 15 to -17 years.

4.4 Life Cycle Cost Analysis

Life cycle cost analysis (LCCA) was conducted using the Net Present Worth Method (NPW), in accordance with the MTO Materials Engineering and Research Report "Guidelines for the Use of Life Cycle Cost Analysis on MTO Freeway Projects – MERO-018", 2005.

The analysis period was for 30 years and the discount rate was 5.0% as determined by the Ministry of Finance. The life cycle cost analysis does not include the cost of any associated work for the project such as drainage improvements including ditch cleanout, ditching or sub-drain installation. The Pay items and unit costs used in the analysis are presented in Table 4.3 below and reflect the relatively short lengths of pavement rehabilitation. Table 4.4 presents a summary of LCCA findings.

Table 4.3 - Pay Item Price, $

Material/Activity	Unit Cost ($)	Material/Activity	Unit Cost ($)
Milling (25 - 50 mm depth)	$1.5/m^2	Rout & Seal	$6.65/m
Milling (75 - 100 mm depth)	$1.75/m^2	Pulverize	1.7/m^2
Milling (100 - 150 mm depth)	$2.25/m^2	Re-Surface SP12.5	$95.42/t
Milling (175 - 200 mm depth)	$2.50/m^2	Binder SP 19.0 mm	$75.0/t
Tack Coat	$0.5/m^2	Patch with SP12.5 FC2	$125/t
Excavation	$20/m^3	Granular 'A'	$15.0/t

Table 4.4 – Rehabilitation Strategies and LCCA for Bath and Millhaven Roads

Rehabilitation Alternative	Activity	Net Present Worth ($)/Lane-km	Ranking
Option 1: Total Removal of the Existing Asphalt and Replace with 110 mm of HMA **(No increase in grade)**.	Pave HMA = 110 mm (40+70 mm)	$205,570	2
Option 2: In-Place Pulverization, Remixing and Resurface with 110 mm of HMA **(110 mm increase in grade)**.	Pulverize total depth of 150 mm Pave HMA = 110 mm (40+70 mm)	$190,860	1
Option 3: Partial Depth Re-construction **(No increase in grade)**.	Excavate 200 mm Place 100 mm of New Gran A Pave HMA = 110 mm (40+70 mm)	$271,387	3

Detouring: No long term detouring is anticipated. Therefore, no special treatment will be required.

5.0 RECOMMENDATIONS AND CONSTRUCTION FEATURES FOR PAVEMENT

5.1 Rehabilitation Strategies and LCCA

The net present worth (NPW) analyses for 30 years revealed that Option 2 In-Place Pulverization, Remixing and Resurface with 110 mm of HMA is the most cost cost-effective option as presented in Table 4.4. Option 2 In-Place Pulverization will provide good structure adequacy represented in high structure number and also will provide high environmental sustainability due to the reduction of the greenhouse gas (GHG) emissions and savings of the natural resources.

5.2 Transition Treatments

At the limits of the project, a butt joint with the existing pavement is recommended. The butt joint between successive lifts of hot mix should be staggered for a distance not less than 5 m, in accordance with OPSS 313. It should be ensured that no joint location corresponds with a joint location in any other layer, along both the mainline and the sideroads.

5.3 Subgrade/Road Base Preparation and Compaction

The pavement design recommended for roads is applicable, provided the subgrade is prepared under dry weather conditions and proof-rolled with a heavy rubber-tired vehicle (such as a grader or loaded dump truck) in the presence of Geotechnical Consultant. Any loose, soft or unstable areas, if detected during proof-rolling, should be sub-excavated, replaced with approved granular materials and compacted. Any additional engineered fill, if required, should be placed in thin layers not exceeding 200 mm and compacted to a minimum of 98% of Standard Proctor Maximum Dry Density (SPMDD). Granular materials (base/sub-base) should be placed in thin layers not exceeding 200 mm, with ± 2% of its optimum moisture content, and thoroughly compacted to a minimum of 100% of SPMDD.

The subgrade should be provided with adequate drainage. If wet weather conditions prevail at the time of construction, adjustments to this design may be required (i.e., if the subgrade becomes excessively wet or rutted during construction activities, additional sub-base material may be required). The need for additional sub-base material is best determined during construction.

5.4 Drainage

Prior to completing the re-construction or rehabilitation, it is recommended that adequate drainage be provided both laterally and longitudinally along the length of the project.

To meet the design requirements for the pavement life, the road subgrade and granular courses should be well drained at all times.

The existing granular material appears to be in moist condition along the road areas based on moisture content testing on selected samples, except for BH-5S and BH-7 where saturated conditions were observed. At this areas, drainage improvement should be considered. This can be accomplished by ensuring proper grading of the subgrade and positive lateral drainage of the granular base daylighting at the ditch.

Alternatively, full-length perforated subdrain pipes of 150 mm diameter could be installed along the road, below the roadbed level, to promote effective drainage in accordance with OPSD 216.021. The sub-drain pipes, if used, should be wrapped in suitable knitted sock geotextile with an FOS of 500 µm according to OPSS 1860, and surrounded by a minimum drainage zone of 19 mm size clear stone of minimum 150 mm thickness. A minimum slope of 2% should be maintained across the paved sections (finished road surface) for proper surface drainage. New pavement should slope towards gutter/ditch.

5.5 Frost Depth

A minimum depth of 1.2 m should be used for frost protection as per OPSD 3090.101.

5.6 Hot Mixes and PGAC Type

The following hot mixes should be used on roadways: HL7 mm binder course and HL3 surface course mix should be used to provide the roadway with high durability. Material Specifications for Superpave hot mix asphalt shall be as per OPSS 1150 and Specifications for asphalt paving, materials, sampling, and testing.

Typically, performance graded asphalt cement PGAC 58-28 would be specified for this region. This PGAC has to satisfy the requirements of MP1 of SHRP Specifications for Superpave. It should be noted that PGAC is engineered asphalt cement with additives such as polymers or modifiers so as to accommodate a wide range of pavement temperatures. When PGAC is used, it is recommended that the steel-wheel rollers are thinly coated with light application of non-petroleum based wetting agent (soap solution) to reduce sticking of the mix to the compaction equipment.

Transition Treatments at Limits of Paving: At the limits of the project, a butt joint with the existing pavement is recommended. The butt joint between successive lifts of hot mix should be staggered at a distance of not less than 5 m, in accordance with OPSS 313. It should be ensured that no joint location corresponds with a joint location in any other layer.

The transition treatment from earth cut to earth fill should be in accordance with OPSD 205.010.

5.7 In-Situ Compaction for Hot Mix

In all areas, asphaltic concrete should be compacted as per OPSS 310, Table 10 (April 2011). As noted earlier, that the granular base and sub-base materials should be compacted to 100% SPMDD.

Field Quality Assurance: Plate samples of loose hot mix should be obtained for each paving day, and extraction/gradation and full superpave hot mix compliance testing should be carried out on these samples. The binder and surface courses should be free from deviations exceeding 6 mm and 3 mm, respectively, as measured in any direction with a 3 m straight edge, placed parallel to the road centreline.

5.8 Asphalt Removal and Recycled Materials

The milled/reclaimed asphalt may be recycled and blended with granular materials to be used on the shoulders during the new construction for widening. The maximum amounts (%) of reclaimed asphalt pavement to be incorporated in the pavement are included in the OPS.MUNI 1010.

RAP containing steel slag aggregates shall not be allowed.

6.0 CLOSURE

The sub-soil information contained in this report should be used solely for the purpose of the geotechnical investigation of this project.

The attached Report Limitations is an integral part of this report.

Sincerely,

Amec Foster Wheeler Environment & Infrastructure,
a Division of Amec Foster Wheeler Canada Limited

Report prepared by:

Name: Ken Chi, M. Eng., P. Eng.	Name: Mauro Cortes, P. Eng.
Title: Geotechnical Engineer	Title: Associate Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
M. CORTES
100043905
May 16, 2018
PROVINCE OF ONTARIO

Report reviewed by:

Name: Hoda Seddik, M.A.Sc., P.Eng.
Consulting Engineer
Title: Principal Pavement Engineer

Amec Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Canada Limited

REPORT LIMITATIONS

The conclusions and recommendations given in this report are based on information determined at the test hole locations. The information contained herein in no way reflects on the environmental aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. It is recommended practice that the Geotechnical Engineer be retained during the construction to confirm that the subsurface conditions across the site do not deviate materially from those encountered in the test holes.

The design recommendations given in this report are applicable only to the project described in the text, and then only if constructed substantially in accordance with the details stated in this report. Since all details of the design may not be known, Amec Foster Wheeler recommends that we be retained during the final design stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

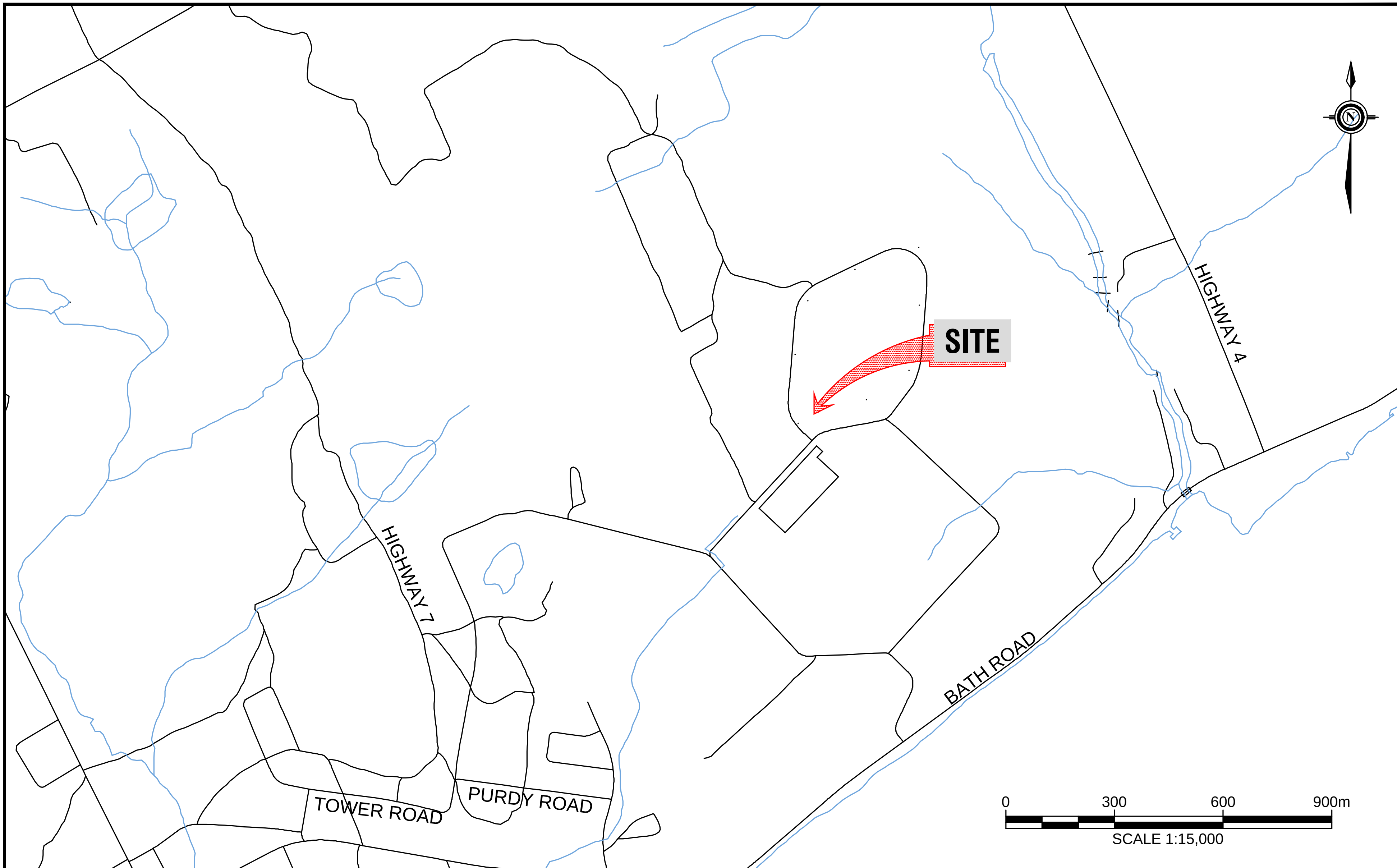
The comments made in this report relating to potential construction problems and possible methods of construction are intended only for the guidance of the designer. The number of test holes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices. No other warranty is expressed or implied.

The benchmark and elevations mentioned in this report were obtained strictly for use by this office in the geotechnical design of the project. They should not be used by any other party for any other purpose. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Amec Foster Wheeler accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

TM-GEO-03-02

Appendix ‘Figures’

Site Location Plan
Borehole Location Plan



CLIENT		DWN BY: ZF	PROJECT	REV. NO.: A
PUBLIC WORKS AND GOVERNMENT SERVICES CANADA		CHK'D BY: KC	BATH AND MILLHAVEN CORRECTIONAL FACILITY - ROADWAY RESURFACING	DATE: APRIL 2018
Amec Foster Wheeler Environment & Infrastructure 50 Vogell Road, Units 3 and 4 Richmond Hill, Ontario L4B 3K6	amec foster wheeler	DATUM:	TITLE	PROJECT NO: TPB176179
		PROJECTION:	KEY PLAN	FIGURE No. 1
		SCALE: AS SHOWN		

R:\2018\Projects_Other\TPB176179\TPB176179.dwg – Figure 1 – Apr. 11, 2018 10:40am – zhanna.furman

0 65 195 325m

SCALE 1:6,500

CLIENT:

PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

Amec Foster Wheeler Environment & Infrastructure
160 Traders Boulevard East, Unit #110
Mississauga, Ontario L4Z 3K7

amec foster wheeler

DWN BY: ZF

CHK'D BY: KC

DATUM:

PROJECTION:

SCALE: AS SHOWN

PROJECT

BATH AND MILLHAVEN CORRECTIONAL FACILITY ROADWAY RESURFACING

TITLE

BOREHOLE LOCATION PLAN
BATH ONTARIO

DATE: APRIL 2018

PROJECT NO: TPB176179

REV. NO.: A

FIGURE No. 2

R:\2018\Projects_Other\TPB176179\TPB176179.dwg – Figure 2 – Apr. 11, 2018 10:38am – zhanna.furman

LEGEND:

PAVEMENT CONDITION SURVEYED ROAD

0 30 90 150m

SCALE 1:3,000

CLIENT:

PUBLIC WORKS AND
GOVERNMENT SERVICES CANADA

Amec Foster Wheeler
Environment & Infrastructure
160 Traders Boulevard East, Unit #110
Mississauga, Ontario L4Z 3K7

amec foster wheeler

DWN BY:	ZF
CHK'D BY:	KC
DATUM:	
PROJECTION:	
SCALE:	AS SHOWN

PROJECT
BATH AND MILLHAVEN CORRECTIONAL FACILITY
ROADWAY RESURFACING

TITLE
SITE PLAN
MILLHAVEN INSTITUTION
BATH ONTARIO

DATE:	APRIL 2018
PROJECT NO:	TPB176179
REV. NO.:	A
FIGURE No.	3A

R:\2018\Projects_Other\TPB176179\TPB176179.dwg – Figure 3A – Apr. 11, 2018 10:38am – zhanna.furman

LEGEND:

PAVEMENT CONDITION SURVEYED ROAD

0 50 100 150 200m

SCALE 1:4,000

CLIENT:

PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

Amec Foster Wheeler
Environment & Infrastructure
160 Traders Boulevard East, Unit #110
Mississauga, Ontario L4Z 3K7

amec foster wheeler

DWN BY:	ZF
CHK'D BY:	KC
DATUM:	
PROJECTION:	
SCALE:	AS SHOWN

PROJECT

BATH AND MILLHAVEN CORRECTIONAL FACILITY
ROADWAY RESURFACING

TITLE

SITE PLAN
BATH INSTITUTION
BATH ONTARIO

DATE:	APRIL 2018
PROJECT NO:	TPB176179
REV. NO.:	A
FIGURE No.	3B

R:\2018\Projects_Other\TPB176179\TPB176179.dwg – Figure 3B – Apr. 11, 2018 10:37am – zhanna.furman

Appendix ‘Record of Boreholes’

Explanation of BH logs
Borehole Log Data

EXPLANATION OF BOREHOLE LOG

This form describes some of the information provided on the borehole logs, which is based primarily on examination of the recovered samples, and the results of the field and laboratory tests. Additional description of the soil/rock encountered is given in the accompanying geotechnical report.

GENERAL INFORMATION

Project details, borehole number, location coordinates and type of drilling equipment used are given at the top of the borehole log.

SOIL LITHOLOGY

Elevation and Depth

This column gives the elevation and depth of inferred geologic layers. The elevation is referred to the datum shown in the Description column.

Lithology Plot

This column presents a graphic depiction of the soil and rock stratigraphy encountered within the borehole.

Description

This column gives a description of the soil stratums, based on visual and tactile examination of the samples augmented with field and laboratory test results. Each stratum is described according to the *Modified Unified Soil Classification System*.

The compactness condition of cohesionless soils (SPT) and the consistency of cohesive soils (undrained shear strength) are defined as follows *(Ref. Canadian Foundation Engineering Manual)*:

Compactness of Cohesionless Soils	SPT N-Value
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of Cohesive Soils	Undrained Shear Strength kPa	Undrained Shear Strength psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very stiff	100 to 200	2000 to 4000
Hard	Over 200	Over 4000

Soil Sampling

Sample types are abbreviated as follows:

SS	Split Spoon	TW	Thin Wall Open (Pushed)	RC	Rock Core
AS	Auger Sample	TP	Thin Wall Piston (Pushed)	WS	Washed Sample

Additional information provided in this section includes sample numbering, sample recovery and numerical testing results.

Field and Laboratory Testing

Results of field testing (e.g., SPT, pocket penetrometer, and vane testing) and laboratory testing (e.g., natural moisture content, and limits) executed on the recovered samples are plotted in this section.

Instrumentation Installation

Instrumentation installations (monitoring wells, piezometers, inclinometers, etc.) are plotted in this section. Water levels, if measured during fieldwork, are also plotted. These water levels may or may not be representative of the static groundwater level depending on the nature of soil stratum where the piezometer tips are located, the time elapsed from installation to reading and other applicable factors.

Amec Foster Wheeler Environment & Infrastructure
900 Maple Grove Road, Unit 10
Cambridge, ON N3H 4R7
Ph: (519) 650-7100
Fax: (519) 653-6554
www.amecfw.com

amec foster wheeler

MODIFIED * UNIFIED CLASSIFICATION SYSTEM FOR SOILS

*The soil of each stratum is described using the Unified Soil Classification System (Technical Memorandum 36-357 prepared by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S Army. Vol. 1 March 1953.) modified slightly so that an inorganic clay of "medium plasticity" is recognized.

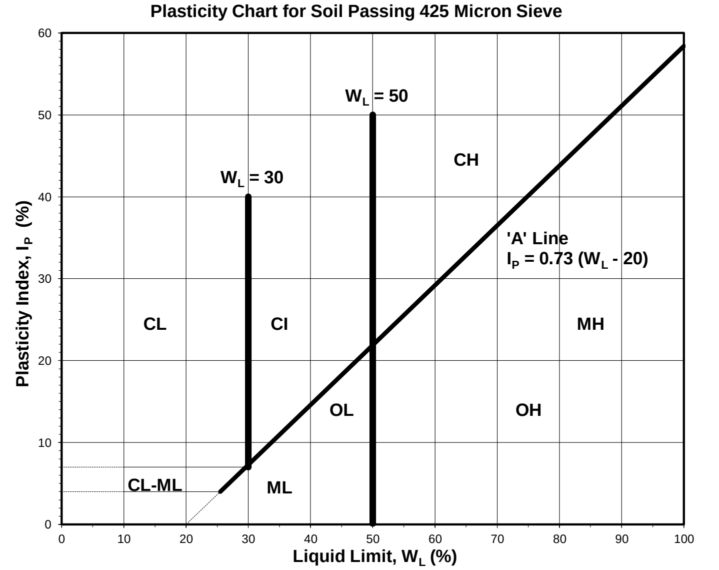
MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (TRACE OR NO FINES)	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 4$; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY GRAVELS (WITH SOME OR MORE FINES)	GM	SILTY GRAVELS, GRAVEL-SAND- SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 4
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 7
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (TRACE OR NO FINES)	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 6$; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3
			SP	POORLY GRADED GRAVELS, GRAVEL- SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY SANDS (WITH SOME OR MORE FINES)	SM	SILTY SANDS, SAND-SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 4
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR P.I MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)
		$W_L < 50\%$	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS	
	CLAYS ABOVE "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY OR SILTY CLAYS, LEAN CLAYS	
		$30\% < W_L < 50\%$	CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS	
		$W_L < 50\%$	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	
	ORGANIC SILTS & CLAYS BELOW "A" LINE	$W_L < 50\%$	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINES CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G SF IS A MIXTURE OF SAND WITH SILT OR CLAY
		$W_L < 50\%$	OH	ORGANIC CLAYS OF HIGH PLASTICITY	
HIGH ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR, AND OFTEN FIBROUS TEXTURE

SOIL COMPONENTS

FRACTION		U.S STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
		PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL	COARSE	75 mm	19 mm	35-50	AND
				20-35	Y/EY
	FINE	19 mm	4.75 mm	10-20	SOME
SAND	COARSE	4.75 mm	2.00 mm	1-10	TRACE
	MEDIUM	2.00 mm	425 µm		
	FINE	425 µm	75 µm		
FINES (SILT OR CLAY BASED ON PLASTICITY)		75 µm			

OVERSIZED MATERIAL	
ROUNDED OR SUBROUNDED: COBBLES 75 mm to 300 mm BOULDERS > 300 mm	NOT ROUNDED: ROCK FRAGMENTS > 76 mm ROCKS > 0.76 CUBIC METRE IN VOLUME

Plasticity Chart for Soil Passing 425 Micron Sieve



Amec Foster Wheeler Environment & Infrastructure
900 Maple Grove Road, Unit 10
Cambridge, ON N3H 4R7
Ph: (519) 650-7100
Fax: (519) 653-6554
www.amecfw.com

amec foster wheeler

Note 1: Soils are classified and described according to their engineering properties and behaviour.

Note 2: The modifying adjectives used to define the actual or estimated percentage range by weight of minor components are consistent with the Canadian Foundation Engineering Manual (3rd Edition, Canadian Geotechnical Society, 1992.)

Rev. 6 Jan '09

RECORD OF BOREHOLE No. BH 1

Project Number:	TPB176179	Drilling Location:	N: 4901594 E: 839676
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18
		Date Completed:	21 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING | COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Field testing legend: Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact, ▲ Remould; Nilcon Vane*: ◇ Intact, ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab testing legend: Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Grain size columns: GR SA SI CL

Geodetic Ground Surface Elevation: 83.7 m

Description	Elevation / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Comments
About 76 mm ASPHALT	83.6 / 0.1					
Light brown to light grey FILL - SAND and GRAVEL some silt, dry to moist		SS	1	54	39	
SAND some silt	82.3 / 1.4					
FRACTURED BEDROCK - SHALE	82.1 / 1.6	SS	2	100	50 / 10cm	Note: When N-Value is in the format, e.g. 50/10 cm, N-Value is 50 blows for 10 cm penetration.
Borehole terminated in BEDROCK	1.6					

Depth scale: 1; Elevation scale: 83. Lab testing moisture contents: 2 (sample 1), 1 (sample 2).

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 1S

Project Number:	TPB176179	Drilling Location:	N: 4901709 E: 839410
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18 — Date Completed: 21 Mar 18
Logged by:	KC	Compiled by:	KC
Reviewed by:	MC	Revision No.:	0, 11/5/18

amec foster wheeler

Geodetic Ground Surface Elevation: 91.7 m

Description	Elevation / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Depth (m)	Elevation (m)	Field Testing	Lab Testing (Moisture %)	Comments & Grain Size Distribution (%) GR / SA / SI / CL
About 51 mm ASPHALT	91.7 / 0.1									
Dark brown to grey **FILL - SAND and GRAVEL** some silt, moist							91		3	41 / 42 / (17)
Dark brown to dark grey **SILTY CLAY** trace sand and gravel, soft to very stiff	90.6 / 1.1	SS	1	54	3	1		SPT	36	
		SS	2	88	17		90	SPT	26	
Borehole terminated on possible BEDROCK	89.6 / 2.1					2				

Field testing legend: Penetration Testing — ○ SPT, □ PPT, ● DCPT; MTO Vane* — △ Intact, ▲ Remould; Nilcon Vane* — ◇ Intact, ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab testing legend: Soil Vapour Reading — □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic — Liquid 20 40 60 80

INSTRUMENTATION INSTALLATION

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

▽ No freestanding groundwater measured in open borehole on completion of drilling.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 2

Project Number:	TPB176179	Drilling Location:	N: 4901719 E: 839630
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18
		Date Completed:	21 Mar 18
Logged by:	KC	Compiled by:	KC
Reviewed by:	MC	Revision No.:	0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING

Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Geodetic Ground Surface Elevation: 90.7 m

Description	Elev./Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Depth (m)	Elevation (m)	Field Testing	Lab Testing	Instrumentation Installation	Comments & Grain Size Distribution (%) GR SA SI CL
About 51 mm ASPHALT	90.7 / 0.1										
Light brown to light grey **FILL - SAND and GRAVEL** some silt, dry to moist	89.8 / 0.9						90		2		
Brown to dark brown **SILTY CLAY** trace sand and gravel, soft to firm	89.6 / 1.1	SS	1	79	54 / 18cm	1			26		Note: When N-Value is in the format, e.g. 54/18 cm, N-Value is 54 blows for 18 cm penetration.
Borehole terminated on possible BEDROCK											

No freestanding groundwater measured in open borehole on completion of drilling.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 2S

Project Number:	TPB176179	Drilling Location:	N: 4902004 E: 839128
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	22 Mar 18
		Date Completed:	22 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

Geodetic Ground Surface Elevation: 96.8 m

LITHOLOGY PROFILE – DESCRIPTION	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Field Testing (DCPT / SPT)	Lab Testing (W)	Comments & Grain Size Distribution (%) GR SA SI CL
About 76 mm ASPHALT	96.8							
Dark grey to grey **FILL - GRAVELLY SAND** some silt, dry to moist	96.8 / 0.1	SS	1	42	17	○	3	
Light brown **SILTY CLAY** trace sand and gravel, stiff	95.4 / 1.4	SS	2	100	50 / 10cm	○	20	Note: When N-Value is in the format, e.g. 50/10 cm, N-Value is 50 blows for 10 cm penetration.
Borehole terminated on possible BEDROCK	95.2 / 1.6							

Legend: Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80. Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80. Depth (m): 1. Elevation (m): 96. Instrumentation Installation.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 3

Project Number:	TPB176179	Drilling Location:	N: 4901729 E: 839345
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18 Date Completed: 21 Mar 18

Logged by: **KC** Compiled by: **KC** Reviewed by: **MC** Revision No.: **0, 11/5/18**

Geodetic Ground Surface Elevation: 92.6 m

Elevation / Depth (m)	Description	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Lab Testing (Soil Vapour Reading)
92.5 / 0.1	**About 76 mm ASPHALT**					
91.5 / 1.1	Dark brown to grey **FILL - GRAVELLY SAND** some silt, moist	SS	1	71	6	4
90.9 / 1.7	Brown to light brown **SILTY CLAY** trace sand and gravel, soft to stiff	SS	2	57	51 / 18cm	30, 24
	Borehole terminated on possible BEDROCK					

Comments & Grain Size Distribution (%): GR SA SI CL

Note: When N-Value is in the format, e.g. 51/18 cm, N-Value is 51 blows for 18 cm penetration.

Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane* △ Intact ▲ Remould; Nilcon Vane* ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Instrumentation Installation

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 3S

Project Number:	TPB176179	Drilling Location:	N: 4902222 E: 839436
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	22 Mar 18
		Date Completed:	22 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

Geodetic Ground Surface Elevation: 95.8 m

Elevation / Depth (m)	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Lab Testing (Water content)	COMMENTS & GRAIN SIZE DISTRIBUTION (%)
95.7 / 0.1	**About 51 mm ASPHALT**						
95.1 / 0.6	Light brown **FILL - SAND and GRAVEL** some silt and clay, wet						
94.2 / 1.5	Dark grey to light brown **SILTY CLAY** trace sand, soft to firm	SS	1	50	4	40	
		SS	2	100	50 / 3cm	24	Note: When N-Value is in the format, e.g. 50/3 cm, N-Value is 50 blows for 3 cm penetration.

Borehole terminated on possible BEDROCK

Field Testing legend: Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

INSTRUMENTATION INSTALLATION

Grain size: GR SA SI CL

Groundwater depth during drilling on 22/03/2018 at a depth of: 0.3 m.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 4

Project Number:	TPB176179	Drilling Location:	N: 4901851 E: 839223
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18
		Date Completed:	21 Mar 18

Logged by: **KC** Compiled by: **KC** Reviewed by: **MC** Revision No.: **0, 11/5/18**

amec foster wheeler

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING** | **COMMENTS & GRAIN SIZE DISTRIBUTION (%)**

Field Testing legend: Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Geodetic Ground Surface Elevation: 96.8 m

Lithology Plot	DESCRIPTION	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Field Testing	Lab Testing	Instrumentation Installation	Comments (GR SA SI CL)
	About 102 mm ASPHALT	96.7 / 0.1										
	Dark brown to grey **FILL - GRAVELLY SAND** some silt, moist	96.5 / 0.4										
	Grey to brown **SILTY CLAY** trace sand, stiff	95.9 / 0.9	SS	1	100	53 / 15cm		96	○	○ 30		Note: When N-Value is in the format, e.g. 53/15 cm, N-Value is 53 blows for 15 cm penetration.
	Borehole terminated on possible BEDROCK											

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

▽ No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 4S

Project Number:	TPB176179	Drilling Location:	N: 4902580 E: 839287
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18 — Date Completed: 20 Mar 18
Logged by:	KC	Compiled by: KC	Reviewed by: MC — Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | SOIL SAMPLING | FIELD TESTING | LAB TESTING | COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Field testing legend: Penetration Testing: ○ SPT, □ PPT, ● DCPT; MTO Vane*: △ Intact, ▲ Remould; Nilcon Vane*: ◇ Intact, ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab testing legend: Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Grain size: GR SA SI CL

Geodetic Ground Surface Elevation: 97.1 m

Elevation / Depth (m)	Description	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Soil Vapour	Comments
96.9 / 0.2	Brown to light brown **FILL - SAND** trace silt and organics, moist						
96.2 / 1.0	Grey to drak grey **FILL - SAND and GRAVEL** trace to some silt, dry to wet	SS	1	63	33	4	
		SS	2	25	61 / 18cm	7	Note: When N-Value is in the format, e.g. 61/18 cm, N-Value is 61 blows for 18 cm penetration.
	Borehole terminated on possible BEDROCK						

Elevation scale mark: 97

▽ Groundwater depth during drilling on 20/03/2018 at a depth of: 0.3 m.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 5

Project Number:	TPB176179	Drilling Location:	N: 4902089 E: 839195
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18
		Date Completed:	21 Mar 18
Logged by: KC	Compiled by: KC	Reviewed by: MC	Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING**

Field Testing legend: Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Geodetic Ground Surface Elevation: 97.0 m

Description	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Water content (%)	Comments & Grain Size Distribution (%) GR / SA / SI / CL
About 76 mm ASPHALT	96.9 / 0.1						
Light brown to light grey **FILL - SANDY GRAVEL** some silt, trace clay, moist to dry		SS	1	42	22	3	
	95.4 / 1.5						
Light brown **SANDY SILTY CLAY** trace gravel, stiff to very stiff		SS	2	100	61 / 30cm	11	6 / 34 / 32 / 28
	95.1 / 1.8						
Borehole terminated on possible BEDROCK							

Depth scale: 1 m; Elevation scale: 96 m

Note: When N-Value is in the format, e.g. 61/30 cm, N-Value is 61 blows for 30 cm penetration.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 5S

Project Number:	TPB176179	Drilling Location:	N: 4902483 E: 839625
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18 — Date Completed: 20 Mar 18

Logged by: KC   Compiled by: KC   Reviewed by: MC   Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING** | **COMMENTS & GRAIN SIZE DISTRIBUTION (%)**

Field Testing legend: Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Grain size: GR SA SI CL

Geodetic Ground Surface Elevation: 94.2 m

Description	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Depth (m)	Elevation (m)	Field Testing	Lab Testing (W)	Comments
About 25 mm ORGANICS	94.2 / 0.0									
Dark brown **FILL - GRAVELLY SILTY CLAY** trace sand		SS	1	54	7		94	○ (SPT)	14	
Light brown **FILL - SILTY CLAY** trace sand and gravel	93.3 / 0.8	SS	2	100	50 / 13cm	1		○ (SPT)	34	Note: When N-Value is in the format, e.g. 50/13 cm, N-Value is 50 blows for 13 cm penetration.
Last 5 cm, soil became black	93.1 / 1.0									

Borehole terminated on possible BEDROCK

No freestanding groundwater measured in open borehole on completion of drilling.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 6

Project Number:	TPB176179	Drilling Location:	N: 4902227 E: 839306
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18 Date Completed: 21 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE		SOIL SAMPLING						FIELD TESTING	LAB TESTING		COMMENTS & GRAIN SIZE DISTRIBUTION (%)
Lithology Plot	DESCRIPTION Geodetic Ground Surface Elevation: 96.4 m	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Penetration Testing: ○ SPT □ PPT ● DCPT MTO Vane*: △ Intact ▲ Remould Nilcon Vane*: ◇ Intact ◆ Remould * Undrained Shear Strength (kPa) 20 40 60 80	Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8 △ COV (ppm) ▲ TOV (ppm) 100 200 300 400 W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	GR SA SI CL
	About 51 mm ASPHALT — 96.3 / 0.1										
	Dark brown to grey **FILL - SAND and GRAVEL** some silt, dry to moist						96				
		SS	1	62	56 / 18cm	1		○	△○ 4 ■		Note: When N-Value is in the format, e.g. 56/18 cm, N-Value is 56 blows for 18 cm penetration.
	95.4 Soil became FILL - SILTY SAND and GRAVEL — 95.3 / 1.1					▽					
	Borehole terminated on possible BEDROCK										

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

▽ Groundwater inferred from soil conditions during drilling

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 7

Project Number:	TPB176179	Drilling Location:	N: 4902165 E: 839509
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	22 Mar 18
		Date Completed:	22 Mar 18

Logged by: KC | Compiled by: KC | Reviewed by: MC | Revision No.: 0, 11/5/18

Elevation / Depth (m)	DESCRIPTION	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Field Testing	Lab Testing	Comments
	Geodetic Ground Surface Elevation: 99.1 m									
99.0 / 0.1	About 51 mm ASPHALT						99			
	Dark grey to dark brown **FILL - SAND and GRAVEL** some silt, dry to moist									
		SS	1	67	20	1	98	○	○ 15	
		SS	2	93	80 / 20cm			○	3	Note: When N-Value is in the format, e.g. 80/20 cm, N-Value is 80 blows for 20 cm penetration.
97.2 / 1.9	**Borehole terminated on possible BEDROCK**									

Field Testing: Penetration Testing — ○ SPT □ PPT ● DCPT; MTO Vane* (△ Intact, ▲ Remould); Nilcon Vane* (◇ Intact, ◆ Remould); * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing: Soil Vapour Reading — □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%) — GR SA SI CL

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 8

Project Number:	TPB176179	Drilling Location:	N: 4902037 E: 839668
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	22 Mar 18 — Date Completed: 22 Mar 18

Logged by: KC — Compiled by: KC — Reviewed by: MC — Revision No.: 0, 11/5/18

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING** | **COMMENTS & GRAIN SIZE DISTRIBUTION (%)**

Field Testing: PenetrationTesting ○ SPT □ PPT ● DCPT; MTO Vane* △ Intact ▲ Remould; Nilcon Vane* ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing: Soil Vapour Reading □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Geodetic Ground Surface Elevation: 91.0 m

Elev. / Depth (m)	Description	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Depth (m)	Elevation (m)	Field Testing	Lab Testing	Instrumentation Installation	GR	SA	SI	CL
90.9 / 0.1	About 51 mm ASPHALT													
90.4 / 0.6	Light brown **FILL - SAND and GRAVEL** some silt, moist													
	Light brown **SILTY CLAY** trace sand and gravel, stiff	SS	1	100	11	1	90		27		4	6	33	57
89.4 / 1.6		SS	2	100	50 / 8cm				10					
	Borehole terminated on possisble BEDROCK													

Note: When N-Value is in the format, e.g. 50/8 cm, N-Value is 50 blows for 8 cm penetration.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 9

Project Number:	TPB176179	Drilling Location:	N: 4901892 E: 839607
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	22 Mar 18 — Date Completed: 22 Mar 18

Logged by: KC — Compiled by: KC — Reviewed by: MC — Revision No.: 0, 11/5/18

amec foster wheeler

Geodetic Ground Surface Elevation: 91.3 m

Description	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Water Content (%)	Comments
About 76 mm ASPHALT	91.2 / 0.1						
Dark grey **FILL - SAND and GRAVEL** some silt, moist	91.0 / 0.3						
Light brown **SILTY CLAY** trace sand and gravel, very stiff	89.7 / 1.6	SS	1	8	21	17	
		SS	2	100	50 / 5cm	22	Note: When N-Value is in the format, e.g. 50/5 cm, N-Value is 50 blows for 5 cm penetration.

Borehole terminated on possible BEDROCK

Column headings: LITHOLOGY PROFILE (Lithology Plot, DESCRIPTION); SOIL SAMPLING (Sample Type, Sample Number, Recovery (%), SPT 'N' / RQD (%)); DEPTH (m); ELEVATION (m); FIELD TESTING (Penetration Testing: ○ SPT, □ PPT, ● DCPT; MTO Vane*: △ Intact, ▲ Remould; Nilcon Vane*: ◇ Intact, ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80); LAB TESTING (Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L, Plastic — Liquid 20 40 60 80); INSTRUMENTATION INSTALLATION; COMMENTS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

Depth scale: 1; Elevation scale: 91, 90

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 10

Project Number:	TPB176179	Drilling Location:	N: 4901863 E: 839719
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18
		Date Completed:	21 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING**

Penetration Testing: ○ SPT ☐ PPT ● DCPT; MTO Vane*: △ Intact, ▲ Remould; Nilcon Vane*: ◇ Intact, ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Soil Vapour Reading: ☐ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Geodetic Ground Surface Elevation: 91.5 m

Description	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Water content (%)	Comments
About 127 mm ASPHALT	91.4 / 0.1						
Light brown **FILL - SANDY GRAVEL** some silt, moist	91.0 / 0.5						
Light brown **SILTY CLAY** trace sand and gavel, firm	90.1 / 1.4	SS	1	17	7	9	
Ligh brown **SAND** some silt and gravel, moist	89.8 / 1.7	SS	2	100	50 / 13cm	5	Note: When N-Value is in the format, e.g. 50/13 cm, N-Value is 50 blows for 13 cm penetration.

Borehole terminated on possible BEDROCK

Depth (m): 1; Elevation (m): 91, 90

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 11

Project Number:	TPB176179	Drilling Location:	N: 4901997 E: 839831
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18
		Date Completed:	21 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE		SOIL SAMPLING						FIELD TESTING	LAB TESTING		COMMENTS & GRAIN SIZE DISTRIBUTION (%)			
Lithology Plot	DESCRIPTION (Geodetic Ground Surface Elevation: 92.4 m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80	Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	GR	SA	SI	CL
	About 127 mm ASPHALT 92.3													
	Dark brown FILL - GRAVELLY SAND some silt, moist 92.3 / 0.1 – 92.0 / 0.5	AS	1				92		4		31	50	(19)	
	Auger hit refusal on possible BEDROCK													

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 12

Project Number:	TPB176179	Drilling Location:	N: 4902195 E: 839786
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18 Date Completed: 20 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

Lithology Plot	DESCRIPTION (Geodetic Ground Surface Elevation: 92.1 m)	Elev./Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Field Testing	Lab Testing	Instrumentation Installation	Comments & Grain Size Distribution (%) GR SA SI CL
	About 51 mm ASPHALT	92.0 / 0.1						92				
	Dark brown to grey **FILL - SAND and GRAVEL** trace clay and silt, dry to moist		SS	1	58	30			○	3		
			SS	2	13	9	1	91	○	1		
			SS	3	4	7			○	19		
	Soil became wet	89.9 / 2.1					2 ▽	90				
	End of borehole											

Field Testing legend: PenetrationTesting: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

▽ Groundwater inferred from soil conditions during drilling

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 13

Project Number:	TPB176179	Drilling Location:	N: 4902311 E: 839648
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18 Date Completed: 21 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE		SOIL SAMPLING						FIELD TESTING	LAB TESTING		COMMENTS & GRAIN SIZE DISTRIBUTION (%)
Lithology Plot	DESCRIPTION Geodetic Ground Surface Elevation: 94.0 m	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Penetration Testing: ○ SPT □ PPT ● DCPT MTO Vane*: △ Intact ▲ Remould Nilcon Vane*: ◇ Intact ◆ Remould * Undrained Shear Strength (kPa) 20 40 60 80	Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8 △ COV (ppm) ▲ TOV (ppm) 100 200 300 400 W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	GR SA SI CL
	About 51 mm ASPHALT 93.9 / 0.1										
	Dark brown to dark grey **FILL - SAND and GRAVEL** some silt, moist	SS	1	78	61 / 30cm	1	93	○	○ 3		Note: When N-Value is in the format, e.g. 61/30 cm, N-Value is 61 blows for 30 cm penetration.
	92.7 / 1.2										
	Borehole terminated on possible BEDROCK										

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 14

Project Number:	TPB176179	Drilling Location:	N: 4902345 E: 839476
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	21 Mar 18
		Date Completed:	21 Mar 18

Logged by: KC   Compiled by: KC   Reviewed by: MC   Revision No.: 0, 11/5/18

amec foster wheeler

Geodetic Ground Surface Elevation: 95.4 m

Field Testing legend: Penetration Testing ○ SPT □ PPT ● DCPT; MTO Vane* △ Intact ▲ Remould; Nilcon Vane* ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Elevation (m) / Depth (m)	Description	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Instrumentation Installation	Comments & Grain Size Distribution (%) GR SA SI CL
95.3 / 0.1	**About 76 mm ASPHALT**						
94.4 / 0.9	Dark brown to dark grey **FILL - GRAVELLY SAND** some silt, moist						
94.3 / 1.1	Light grey to light brown **FILL - SANDY GRAVEL** some silt, dry to moist	SS	1	75	21		
93.2 / 2.1	Light brown **SILTY CLAY** trace sand, firm to very stiff at 1.6 m, encountered 10 cm pocket of SAND	SS	2	83	17		
	End of Borehole						

Moisture contents (W, %): 3, 2, 31, 4, 21

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 15

Project Number:	TPB176179	Drilling Location:	N: 4902430 E: 839288
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18 — Date Completed: 20 Mar 18

Logged by: KC   Compiled by: KC   Reviewed by: MC   Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** | **LAB TESTING**

Field Testing legend: PenetrationTesting: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

INSTRUMENTATION INSTALLATION

COMMENTS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Geodetic Ground Surface Elevation: 96.2 m

DESCRIPTION	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Lab Testing
About 76 mm ASPHALT	96.1 / 0.1					
Dark grey **FILL - SAND and GRAVEL** trace clay and silt, moist		SS	1	63	28	4
	95.4 / 0.8					
Brown to light brown **SILTY CLAY** stiff		SS	2	80	9	29
	94.9 / 1.3					

Depth (m): 1; Elevation (m): 96, 95

Borehole terminated on possible BEDROCK

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 16

Project Number:	TPB176179	Drilling Location:	N: 4902676 E: 839302
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18
		Date Completed:	20 Mar 18

amec foster wheeler

Logged by: KC | Compiled by: KC | Reviewed by: MC | Revision No.: 0, 11/5/18

LITHOLOGY PROFILE			SOIL SAMPLING						FIELD TESTING	LAB TESTING		COMMENTS & GRAIN SIZE DISTRIBUTION (%)
Lithology Plot	DESCRIPTION Geodetic Ground Surface Elevation: 97.5 m	Elev./Depth	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane* △ Intact ▲ Remould; Nilcon Vane* ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80	Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	GR SA SI CL
	About 76 mm ASPHALT	97.4 0.1										
	Grey **FILL - SAND and GRAVEL** trace silt, dry to moist	96.9	SS	1	71	76 / 28cm		97	○	3		Note: When N-Value is in the format, e.g. 76/28 cm, N-Value is 76 blows for 28 cm penetration. 55 36 (9)
	Black **SILT and SAND** moist **Borehole terminated on possible BEDROCK**	96.9 0.6										

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 17

Project Number:	TPB176179	Drilling Location:	N: 4902799 E: 839457
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18 — Date Completed: 20 Mar 18
Logged by:	KC	Compiled by:	KC
Reviewed by:	MC	Revision No.:	0, 11/5/18

amec foster wheeler

Geodetic Ground Surface Elevation: 97.1 m

Lithology Plot	DESCRIPTION	Elev. / Depth	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	FIELD TESTING	LAB TESTING	INSTRUMENTATION INSTALLATION	GR	SA	SI	CL
	About 101 mm ASPHALT	97.0 / 0.1						97							
	Light brown **FILL - SAND and GRAVEL** trace silt, moist		AS	1						6		48	42	(10)	
		96.3 / 0.8	SS	1	0	50 / 3cm									
	Borehole terminated on possible BEDROCK														

Legend: PenetrationTesting: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80. Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80.

COMMENTS & GRAIN SIZE DISTRIBUTION (%)

Note: When N-Value is in the format, e.g. 50/3 cm, N-Value is 50 blows for 3 cm penetration.

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 18

Project Number:	TPB176179	Drilling Location:	N: 4902667 E: 839645
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18
		Date Completed:	20 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE			SOIL SAMPLING						FIELD TESTING	LAB TESTING		COMMENTS & GRAIN SIZE DISTRIBUTION (%)
Lithology Plot	DESCRIPTION (Geodetic Ground Surface Elevation: 94.5 m)	Elev. / Depth	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	DEPTH (m)	ELEVATION (m)	Penetration Testing: ○ SPT □ PPT ● DCPT; MTO Vane*: △ Intact ▲ Remould; Nilcon Vane*: ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80	Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80	INSTRUMENTATION INSTALLATION	GR SA SI CL
	About 75 mm ASPHALT	94.4 / 0.1										
	Black to dark grey **FILL - SAND and GRAVEL** some silt and clay, moist							94				
		93.5 / 0.9	SS	1	57	75 / 18cm			○	▲○ 7		Note: When N-Value is in the format, e.g. 75/18 cm, N-Value is 75 blows for 18 cm penetration.
	Borehole terminated on possible BEDROCK											

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 19

Project Number:	TPB176179	Drilling Location:	N: 4902465 E: 839559
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18
		Date Completed:	20 Mar 18

Logged by: KC Compiled by: KC Reviewed by: MC Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE: Description (Geodetic Ground Surface Elevation: 95.1 m)	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Lab Testing: W (%)	Comments & Grain Size Distribution (%) GR SA SI CL
About 76 mm ASPHALT	95.0 / 0.1						
Brown to grey **FILL - SAND and GRAVEL** trace clay and silt, dry to moist		SS	1	58	28	2	
Dark grey to dark green **SILTY CLAY** trace sand, gravel, and organics, stiff	94.3 / 0.8	SS	2	71	9	26	
	93.4 / 1.7	SS	3	75	54 / 20cm	29	Note: When N-Value is in the format, e.g. 54/20 cm, N-Value is 54 blows for 20 cm penetration.
Borehole terminated on possible BEDROCK							

Field Testing legend: Penetration Testing ○ SPT □ PPT ● DCPT; MTO Vane* △ Intact ▲ Remould; Nilcon Vane* ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80

Lab Testing legend: Soil Vapour Reading □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L Plastic Liquid 20 40 60 80

Instrumentation Installation

Amec Foster Wheeler
Environment & Infrastructure
300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

RECORD OF BOREHOLE No. BH 20

Project Number:	TPB176179	Drilling Location:	N: 4902389 E: 839386
Project Client:	Public Works and Government Services Canada	Drilling Method:	150 mm Solid Stem Augers
Project Name:	Bath/Millhaven Correctional Facility - Roadway Resurfacing	Drilling Machine:	Track Mounted Drill
Project Location:	Bath/Millhaven, ON	Date Started:	20 Mar 18
		Date Completed:	20 Mar 18

Logged by: KC | Compiled by: KC | Reviewed by: MC | Revision No.: 0, 11/5/18

amec foster wheeler

LITHOLOGY PROFILE | **SOIL SAMPLING** | **FIELD TESTING** (PenetrationTesting: ○ SPT □ PPT ● DCPT; MTO Vane* △ Intact ▲ Remould; Nilcon Vane* ◇ Intact ◆ Remould; * Undrained Shear Strength (kPa) 20 40 60 80) | **LAB TESTING** (Soil Vapour Reading: □ COV (LEL) ■ TOV (LEL) 2 4 6 8; △ COV (ppm) ▲ TOV (ppm) 100 200 300 400; W_P W W_L, Plastic – Liquid, 20 40 60 80) | INSTRUMENTATION INSTALLATION | **COMMENTS & GRAIN SIZE DISTRIBUTION (%)** GR SA SI CL

Geodetic Ground Surface Elevation: 95.6 m

Description	Elev. / Depth (m)	Sample Type	Sample Number	Recovery (%)	SPT 'N' / RQD (%)	Water Content (%)
About 76 mm ASPHALT	95.5 / 0.1					
Dark grey to grey **FILL - SAND and GRAVEL** trace clay and silt, moist	95.3 / 0.3					3
Dark grey to dark green **FILL - SILTY CLAY** trace sand and gravel	94.8 / 0.8	SS	1	58	10	31
Light brown **SILTY CLAY** very stiff	94.2 / 1.4	SS	2	86	15	30

Depth (m) scale: 1. Elevation (m) scale: 95.

Borehole terminated on possible BEDROCK

Amec Foster Wheeler
Environment & Infrastructure

300-210 Colonnade Road South
Ottawa, Ontario, K2E 7L5
Canada
Tel. No.: (613) 727-0658
amecfw.com

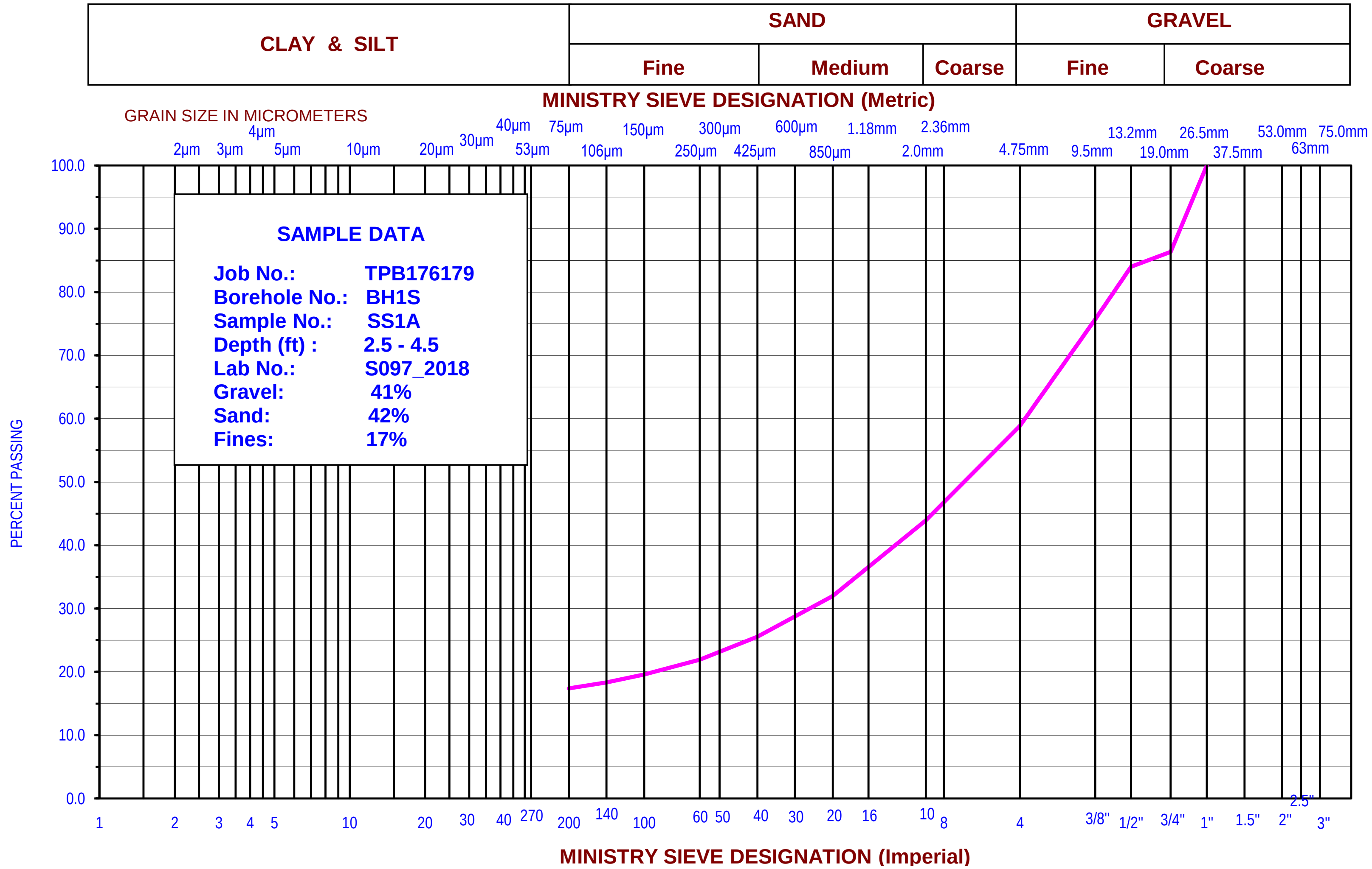
No freestanding groundwater measured in open borehole on completion of drilling.

Borehole details as presented, do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified Geotechnical Engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying'Explanation of Borehole Log'.

Scale: 1 : 21

Appendix ‘A’

Laboratory test Results



Amec Foster Wheeler Environment & Infrastructure Units 3 & 4, 50 Vogell Road Richmond Hill, Ontario, Canada, L4B 3K6 Tel +1 (905) 415-2632, Fax +1 (647) 689-4876 amecfw.com	GRAIN SIZE DISTRIBUTION	Client :- Public Works & Government Services Canada Project:- Bath/Millhaven Correctional Facility Roadway Resurfacing
	CRUSHED LIMESTONE	Location:- Bath/Millhaven, ON. Lab No. :- S097_2018 Date :- 28 Mar 2018

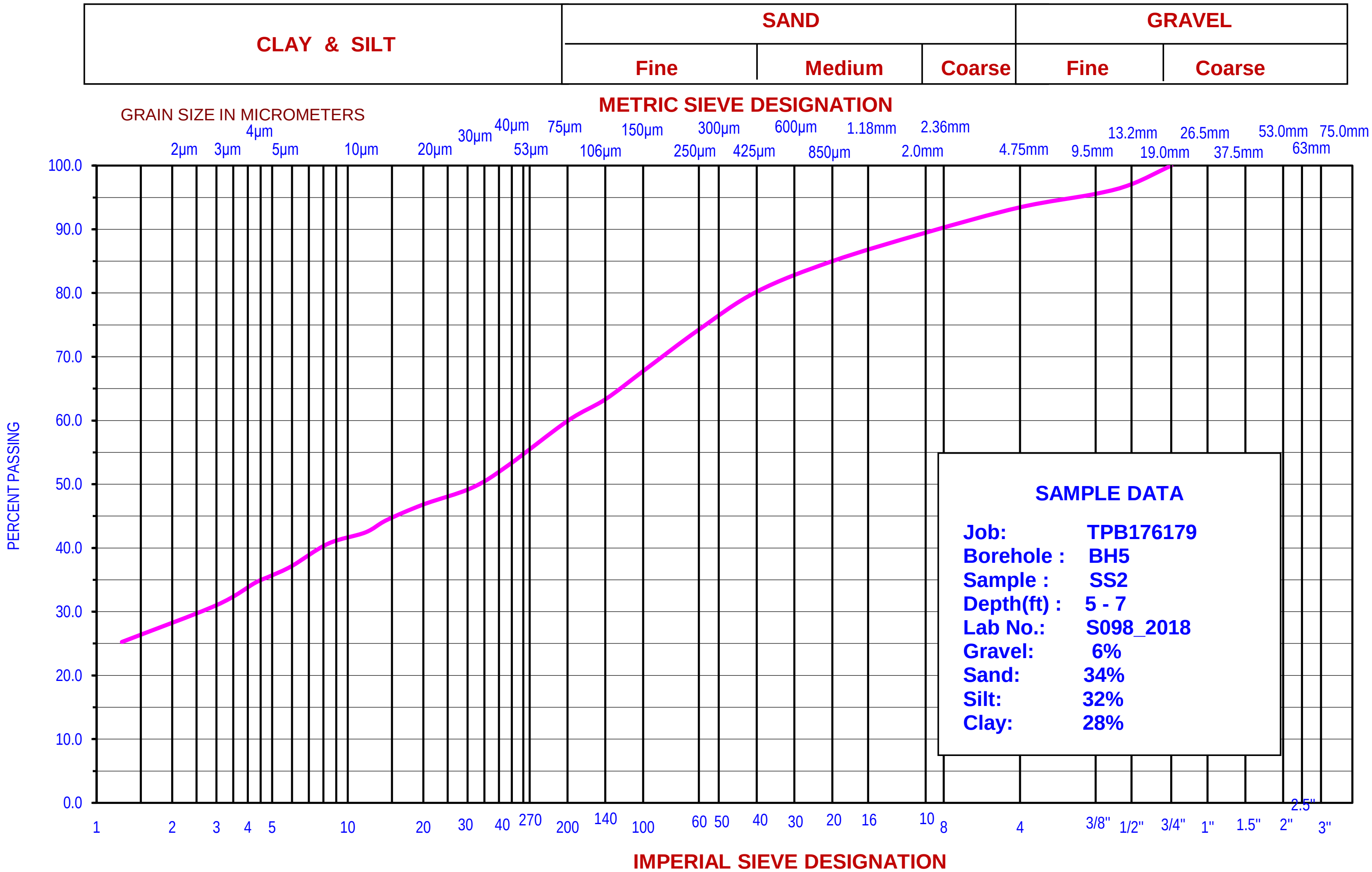
Grain Size Analysis

Client :- Public Works & Government Services Canada **Job# :-** TPB176179
Project:- Bath/Millhaven Correctional Facility – Roadway Resurfacing
Location:- Bath/Millhaven, ON. **Date :-** 28-Mar-18
Borehole # :- BH1S **Tested By :-** CZ
Sample ID # :- SS1A **Lab No. :-** S097_2018
Depth (ft): 2.5- 4.5 **Checked By :-** SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
26.5	0.00	100.0
19	36.45	86.4
13.20	42.77	84.0
9.5	64.99	75.7
4.75	110.03	58.8
2.00	149.88	43.9
0.85		32.0
0.425		25.6
0.250		21.9
0.150		19.6
0.106		18.3
0.075		17.4

Total Wt. (g)		267.37
FINES		
116.82 g		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.85	31.78	72.8%
0.425	48.87	58.2%
0.250	58.48	49.9%
0.150	64.71	44.6%
0.106	68.05	41.7%
0.075	70.58	39.6%
Pan	70.78	

UNIFIED SOIL CLASSIFICATION SYSTEM



SAMPLE DATA

Job:	TPB176179
Borehole :	BH5
Sample :	SS2
Depth(ft) :	5 - 7
Lab No.:	S098_2018
Gravel:	6%
Sand:	34%
Silt:	32%
Clay:	28%

Amec Foster Wheeler Environment & **Infrastructure**
Units 3 & 4, 50 Vogell Road, Richmond Hill, Ontario
Canada, L4B 3K6
Tel +1 (905) 415-2632, Fax +1 (647) 689-4876
amecfw.com

GRAIN SIZE DISTRIBUTION

SANDY LEAN CLAY

trace gravel

Client :-	**Public Works & Government Services Canada**
Project:-	**Bath/Millhaven Correctional Facility – Roadway Resurfacing**
Location:-	**Bath/Millhaven, ON**
Lab No. :- S098_2018	**Date :- 28 Mar 2018**

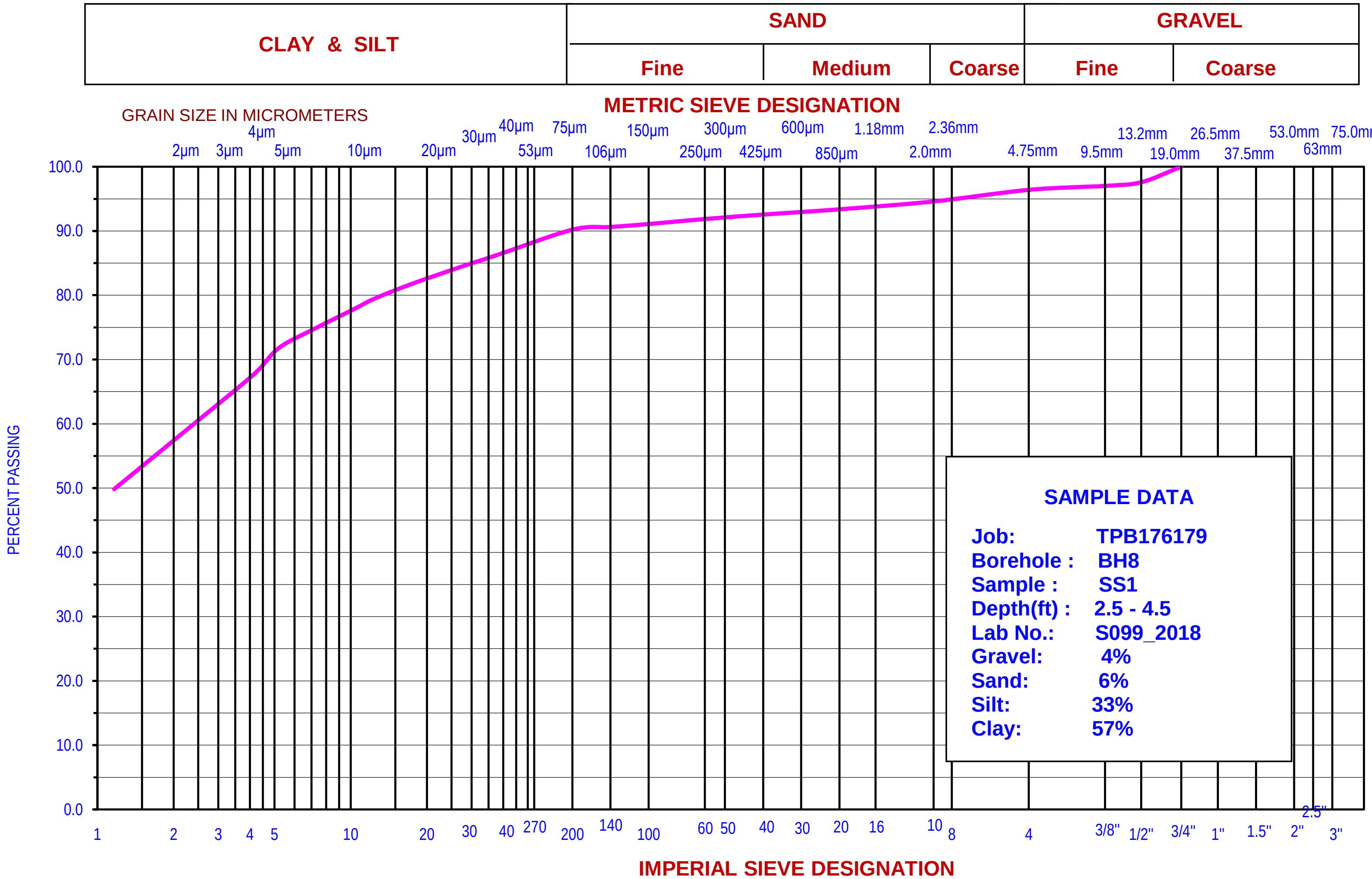
Grain Size Analysis

Client :-	Public Works & Government Services Canada	**Job# :-**	TPB176179
Project:-	Bath/Millhaven Correctional Facility – Roadway Resurfacing		
Location:-	Bath/Millhaven, ON	**Date :-**	28-Mar-18
Borehole # :-	BH5	**Tested By :-**	CZ
Lab No. :-	S098_2018	**Sample # :-**	SS2
Depth(ft):	5' - 7'	**Checked By :-**	SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
19	0.00	100.0
13.2	8.18	97.1
9.5	12.41	95.6
4.75	18.31	93.5
2.00	29.45	89.5
0.85		85.0
0.425		80.2
0.25		74.3
0.150		67.7
0.106		63.3
0.0750		59.9
0.0435		53.0
0.0312		49.4
0.0200		46.8
0.0143		44.4
0.0117		42.4
0.0084		40.7
0.0060		37.2
0.0049		35.6
0.0043		34.5
0.0030		31.0
0.0013		25.2

Total Wt. (g)		281.09
Wt used for Hydrometer (g)		
50.46		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.850	2.52	95.0%
0.425	5.22	89.7%
0.250	8.58	83.0%
0.150	12.25	75.7%
0.106	14.75	70.8%
0.075	16.66	67.0%
Pan	16.87	

UNIFIED SOIL CLASSIFICATION SYSTEM



SAMPLE DATA

Job:	TPB176179
Borehole :	BH8
Sample :	SS1
Depth(ft) :	2.5 - 4.5
Lab No.:	S099_2018
Gravel:	4%
Sand:	6%
Silt:	33%
Clay:	57%

Amec Foster Wheeler Environment & **Infrastructure**
Units 3 & 4, 50 Vogell Road
Richmond Hill, Ontario, Canada, L4B 3K6
Tel +1 (905) 415-2632, Fax +1 (647) 689-4876
amecfw.com

GRAIN SIZE DISTRIBUTION

FAT CLAY

trace gravel and sand

Client :-	**Public Works & Government Services Canada**
Project:-	**Bath/Millhaven Correctional Facility Roadway Resurfacing**
Location:-	**Bath/Millhaven, ON**
Lab No. :- S099_2018	**Date :- 28 Mar 2018**

Grain Size Analysis

Client :-	Public Works & Government Services Canada	**Job# :-**	TPB176179
Project:-	Bath/Millhaven Correctional Facility – Roadway Resurfacing		
Location:-	Bath/Millhaven, ON	**Date :-**	28-Mar-18
Borehole # :-	BH8	**Tested By :-**	CZ
Lab No. :-	S099_2018	**Sample # :-**	SS1
Depth(ft):	2.5 - 4.5	**Checked By :-**	SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
19	0.00	100.0
13.2	6.07	97.6
9.5	7.48	97.0
4.75	9.03	96.4
2.00	13.56	94.6
0.85		93.4
0.425		92.5
0.25		91.9
0.150		91.1
0.106		90.6
0.0750		90.2
0.0379		86.3
0.0271		84.4
0.0173		81.7
0.0124		79.5
0.0102		77.8
0.0073		74.9
0.0053		71.9
0.0044		68.5
0.0038		66.4
0.0027		61.7
0.0012		49.8

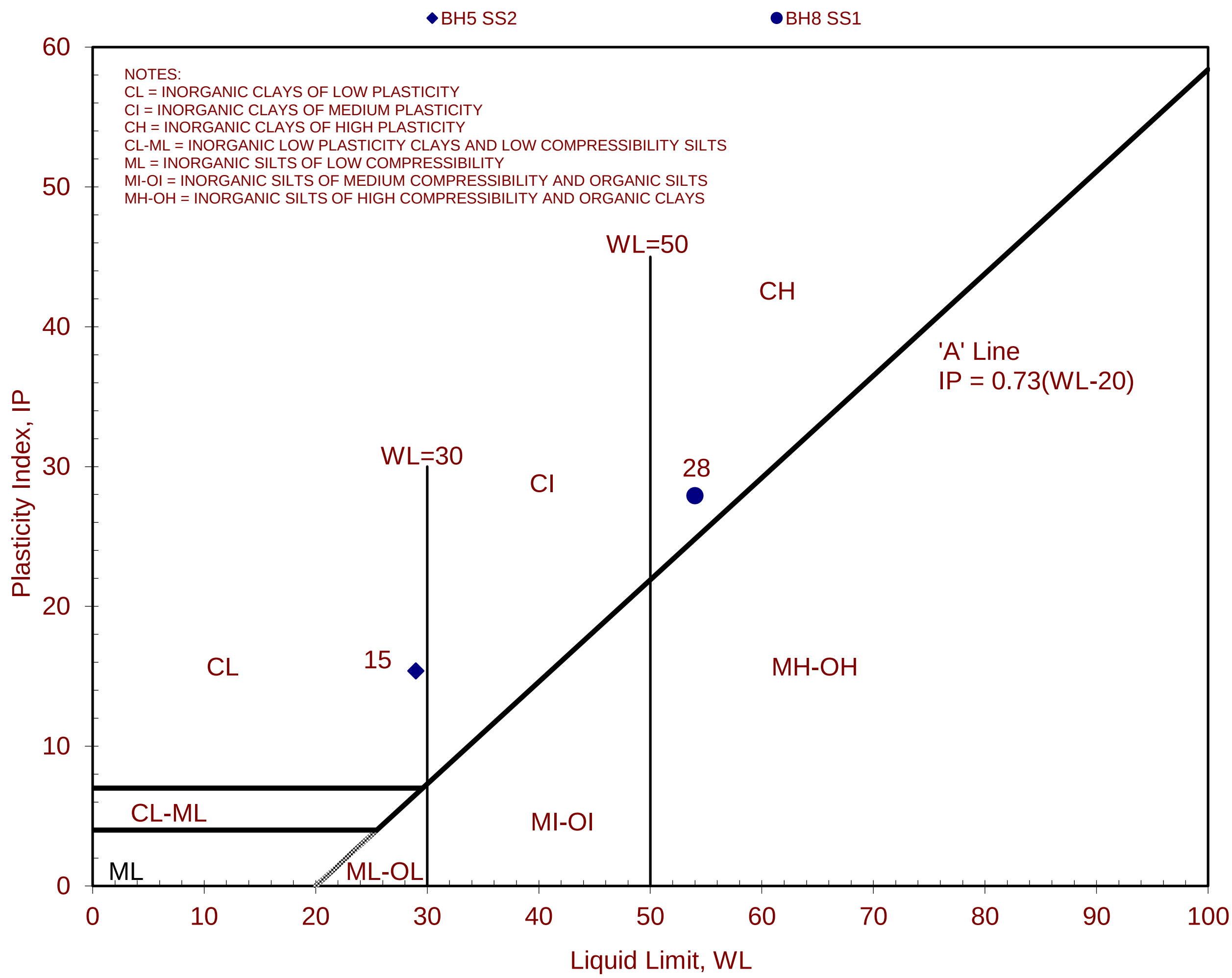
Total Wt. (g)		254.41
Wt used for Hydrometer (g)		
49.55		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.850	0.64	98.7%
0.425	1.07	97.8%
0.250	1.43	97.1%
0.150	1.84	96.3%
0.106	2.08	95.8%
0.075	2.30	95.4%
Pan	2.30	

ATTERBERG LIMITS
D 4318

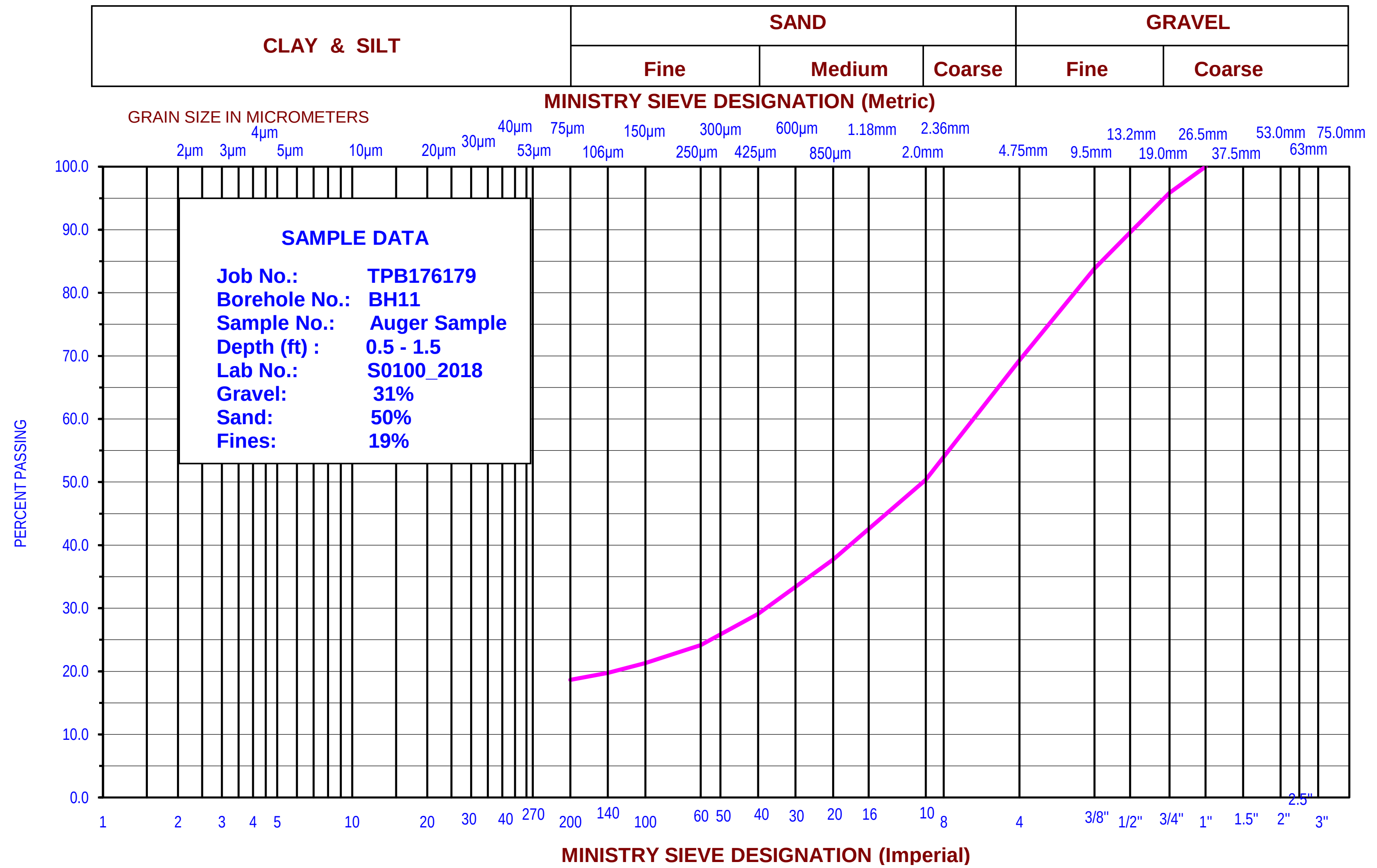
Project Title:	Bath/Millhaven Correctional Facility – Roadway Resurfacing	**Project No.:**	TPB176179
Project Client:	Public Works & Government Services Canada	**Sampled By:**	-
Project Location:	Bath/Millhaven, ON	**Date Tested:** 29-Mar-2018	**Tested By:** CZ

TEST RESULTS

Borehole No.	BH5	BH8		
Sample No.	SS2	SS1		
Depth	5'- 7'	2.5'- 4.5'		
Liquid Limit	29	54		
Plastic Limit	14	26		
Plasticity Index	15	28		
Soil Classification	CL	CH		
Natural Moiture Content %	11	27		



Laboratory Sheet No.:	Att-01	Signed By:	SB



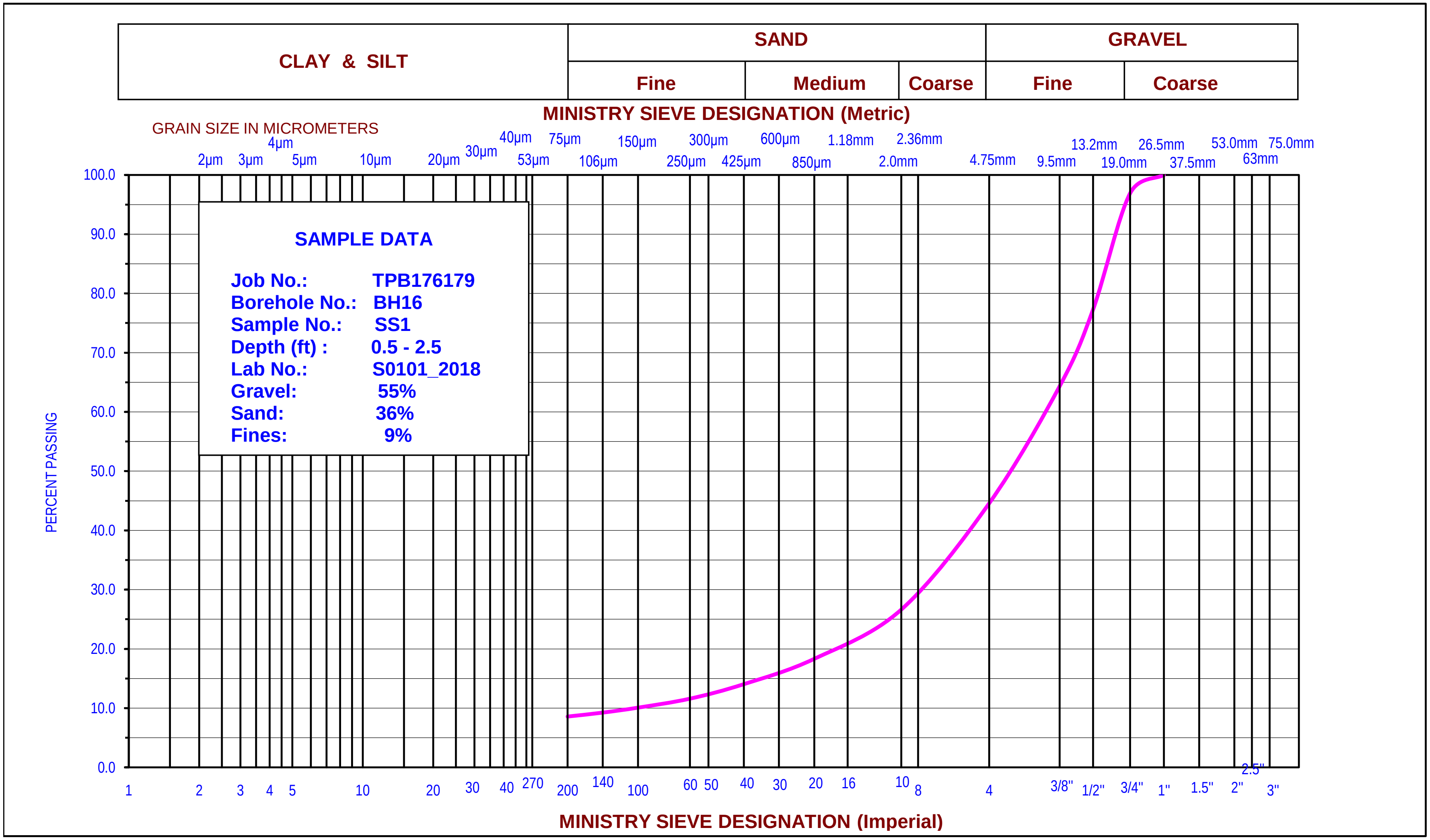
Amec Foster Wheeler Environment & Infrastructure Units 3 & 4, 50 Vogell Road Richmond Hill, Ontario, Canada, L4B 3K6 Tel +1 (905) 415-2632, Fax +1 (647) 689-4876 amecfw.com	**GRAIN SIZE DISTRIBUTION**	**Client :-** Public Works & Government Services Canada **Project:-** Bath/Millhaven Correctional Facility Roadway Resurfacing
	CRUSHED LIMESTONE	**Location:-** Bath/Millhaven, ON **Lab No. :-** S0100_2018 — **Date :-** 28 Mar 2018

Grain Size Analysis

Client :-	Public Works & Government Services Canada	**Job# :-**	TPB176179
Project:-	Bath/Millhaven Correctional Facility – Roadway Resurfacing		
Location:-	Bath/Millhaven, ON	**Date :-**	28-Mar-18
Borehole # :-	BH11	**Tested By :-**	CZ
Sample ID # :-	Auger Sample	**Lab No. :-**	S0100_2018
Depth (ft):	0.5 - 1.5	**Checked By :-**	SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
26.5	0.00	100.0
19	15.91	95.8
13.20	39.75	89.6
9.5	61.62	83.8
4.75	116.96	69.3
2.00	189.28	50.4
0.85		37.7
0.425		29.1
0.250		24.2
0.150		21.3
0.106		19.7
0.075		18.6

Total Wt. (g)		**381.36**
FINES		
104.70 g		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.85	26.30	74.9%
0.425	44.19	57.8%
0.250	54.48	48.0%
0.150	60.43	42.3%
0.106	63.67	39.2%
0.075	65.94	37.0%
Pan	66.12	



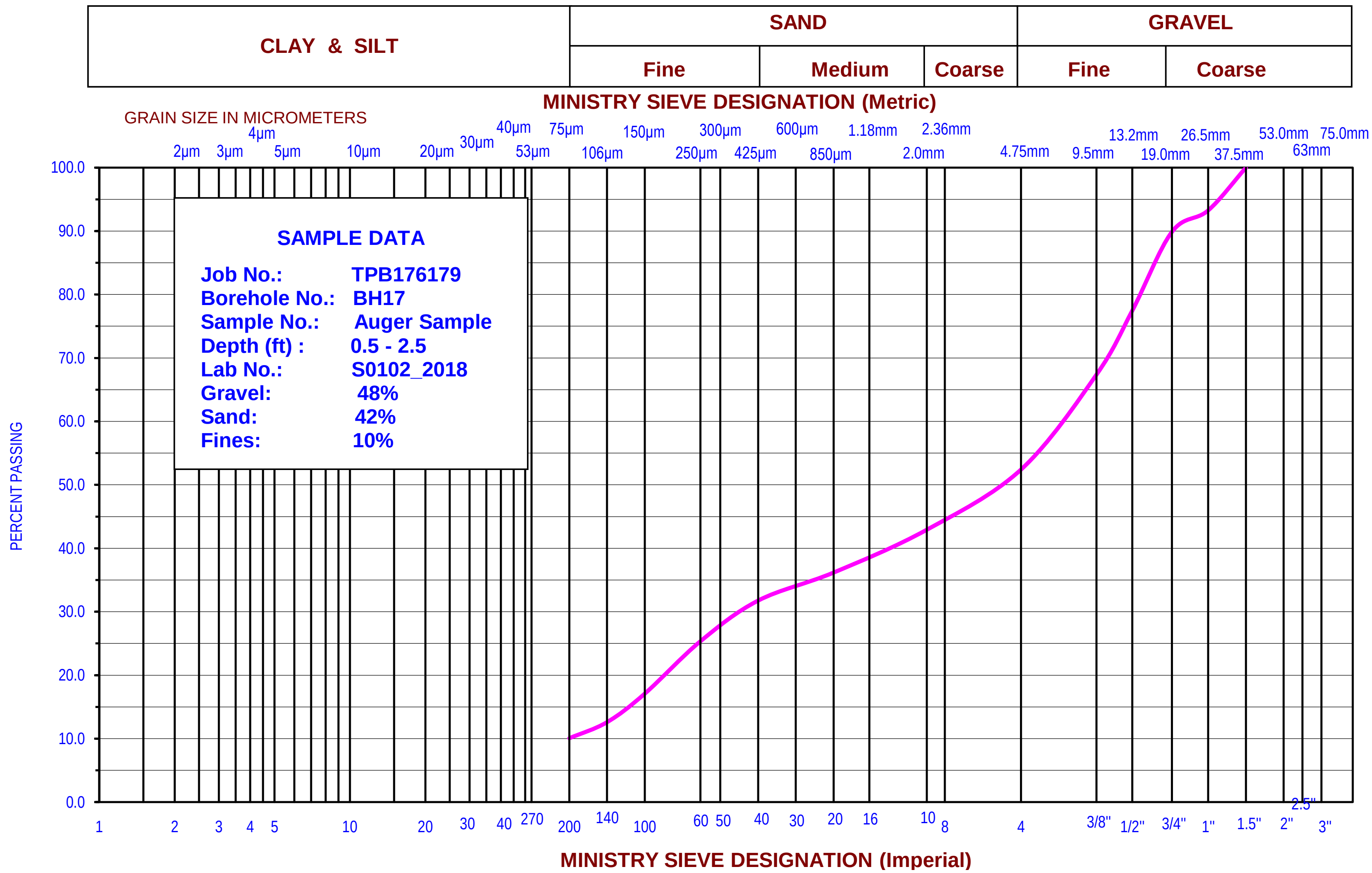
Amec Foster Wheeler Environment & Infrastructure Units 3 & 4, 50 Vogell Road Richmond Hill, Ontario, Canada, L4B 3K6 Tel +1 (905) 415-2632, Fax +1 (647) 689-4876 amecfw.com	GRAIN SIZE DISTRIBUTION	Client :- Public Works & Government Services Canada Project:- Bath/Millhaven Correctional Facility Roadway Resurfacing
	CRUSHED LIMESTONE	Location:- Bath/Millhaven, ON Lab No. :- S0101_2018 Date :- 28 Mar 2018

Grain Size Analysis

Client :-	Public Works & Government Services Canada	**Job# :-**	TPB176179
Project:-	Bath/Millhaven Correctional Facility – Roadway Resurfacing		
Location:-	Bath/Millhaven, ON	**Date :-**	28-Mar-18
Borehole # :-	BH16	**Tested By :-**	CZ
Sample ID # :-	SS1	**Lab No. :-**	S0101_2018
Depth (ft):	0.5 - 2.5	**Checked By :-**	SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
26.5	0.00	100.0
19	13.70	96.9
13.20	100.36	77.3
9.5	157.57	64.3
4.75	244.90	44.6
2.00	324.18	26.6
0.85		18.3
0.425		14.0
0.250		11.6
0.150		10.1
0.106		9.2
0.075		8.6

Total Wt. (g)		**441.85**
FINES		
117.25 g		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.85	36.59	68.8%
0.425	55.41	52.7%
0.250	66.22	43.5%
0.150	72.88	37.8%
0.106	76.57	34.7%
0.075	79.49	32.2%
Pan	79.73	



SAMPLE DATA

Job No.:	TPB176179
Borehole No.:	BH17
Sample No.:	Auger Sample
Depth (ft) :	0.5 - 2.5
Lab No.:	S0102_2018
Gravel:	48%
Sand:	42%
Fines:	10%

Amec Foster Wheeler Environment & Infrastructure
Units 3 & 4, 50 Vogell Road
Richmond Hill, Ontario, Canada, L4B 3K6
Tel +1 (905) 415-2632, Fax +1 (647) 689-4876
amecfw.com

GRAIN SIZE DISTRIBUTION

CRUSHED LIMESTONE

Client :-	Public Works & Government Services Canada
Project:-	Bath/Millhaven Correctional Facility Roadway Resurfacing
Location:-	Bath/Millhaven, ON
Lab No. :- S0102_2018	Date :- 28 Mar 2018

Grain Size Analysis

Client :-	Public Works & Government Services Canada	**Job# :-**	TPB176179
Project:-	Bath/Millhaven Correctional Facility – Roadway Resurfacing		
Location:-	Bath/Millhaven, ON	**Date :-**	28-Mar-18
Borehole # :-	BH17	**Tested By :-**	CZ
Sample ID # :-	Auger Sample	**Lab No. :-**	S0102_2018
Depth (ft):	0.5 - 2.5	**Checked By :-**	SB

Sieve size (mm)	Cumm. Wt. Retained (g)	%passing
37.50	0.00	100.0
26.5	45.34	93.3
19	68.06	89.9
13.20	151.52	77.5
9.5	219.34	67.4
4.75	319.90	52.4
2.00	383.64	42.9
0.85		36.2
0.425		31.8
0.250		25.3
0.150		17.1
0.106		12.6
0.075		10.1

Total Wt. (g)		672.15
FINES		
107.64 g		
Pass 2mm Retained 0.075mm		
Sieve size (mm)	wt. retained (g)	%passing
0.85	16.92	84.3%
0.425	28.00	74.0%
0.250	44.09	59.0%
0.150	64.79	39.8%
0.106	76.07	29.3%
0.075	82.41	23.4%
Pan	83.21	

Appendix ‘B’

Pavement Condition Survey

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 1

PHOTOGRAPH	1

Fair Condition

Date: 29 March 2018
SECT:KM 1-000 to 1-250
STN: KM 1-125, looking S direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout

Transversal (Half, Full and Multiple) - Slight / Frequent.

PHOTOGRAPH	2

Poor Condition

Date: 29 March 2018
SECT:KM 1-250 to 1-500
STN: KM 1-450, looking SW direction
Ravelling and Coarse Aggregate Loss – Moderate / Throughout

Longitudinal Wheel Track / Center Line (Signle and Multiple) - Slight / Frequent.

Pavement Edge (Alligator) - Very Severe / Intermittent

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 2

PHOTOGRAPH	3

Poor Condition

Date: 29 March 2018
SECT:KM 1-500 to 1-750
STN: KM 1-650, looking W direction

Ravelling and Coarse Aggregate Loss – Severe / Throughout

Longitudinal Wheel Track / Transverse (Single and Multiple) - Moderate / Frequent
Wheel Track Rutting - Moderate / Frequent

PHOTOGRAPH	4

Poor Condition

Date: 29 March 2018
SECT:KM 1-750 to 2-000
STN: KM 1-875, looking NW direction
Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Longitudinal Wheel Track (Single and Multiple) - Moderate / Few
Pavement Edge (Alligator) - Very Severe/Intermittent
Transverse Longitudinal Meander (Half, Full Multiple) - Moderate / Intermittent

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 3

PHOTOGRAPH	5

Fair to Poor Condition

Date: 29 March 2018
SECT:KM 2-000 to 2-250
STN: KM 2-175, looking NW direction

Ravelling and Coarse Aggregate Loss – Severe / Throughout

Pavement Edge (Alligator) - Very Severe / Intermittent

Transverse (Half, Full and Multiple) - Slight / Frequent

PHOTOGRAPH	6

Fair Condition

Date: 29 March 2018
SECT: KM 2-250 to 2-500
STN: KM 2-325, looking SE direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Transverse (Full and Multiple) - Severe / Few
Center Line (Single and Multiple)- Slight/Intermittent
and Pavement Edge (Single and Multiple) - Slight / Intermittent

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 4

PHOTOGRAPH	7

Poor Condition

Date: 29 March 2018
SECT: KM 2-500 to 2-750
STN: KM 2-625, looking SE direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Center Line (Single and Multiple) - Severe / Extensive
Pavement Edge (Alligator) - Slight / Frequent
Transverse (Half, Full and Multiple) - Moderate / Intermittent

PHOTOGRAPH	8

Poor to Fair Condition

Date: 29 March 2018
SECT: KM 2-750 to 3-000
STN: KM 2-800, looking NE direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Center Line (Single and Multiple) - Slight / Throughout
Transverse (Half, Full and Multiple) - Slight / Intermittent

PHOTOGRAPH	9

Fair Condition

Date: 29 March 2018
SECT: KM 3-000 to 3-250
STN: KM 3-200, looking SW direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Center Line (Single and Multiple) - Slight / Frequent
Transverse (Half, Full and Multiple) - Slight / Intermittent

PHOTOGRAPH	10

Fair Condition

Date: 29 March 2018
SECT: KM 3-250 to 3-500
STN: KM 3-450, looking E direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Longitudinal Wheel Track (Single and Multiple) - Slight / Frequent
Center Line (Single and Multiple) - Slight / Intermittent
Transverse (Half, Ful and Multiple)-

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 6

PHOTOGRAPH	11

Very Poor Condition

Date: 29 March 2018
SECT: KM 3-500 to 3-750
STN: KM 3-650, looking NE direction

Pavement Edge (Alligator) - Very Severe / Intermittent

PHOTOGRAPH	12

Fair Condition

Date: 29 March 2018
SECT: KM 3-750 to 4-000
STN: KM 3-950, looking NE direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Longitudinal Wheel Track (Single and Multiple) - Moderate / Intermittent
Pavement Edge (Alligator) - Slight / Few
Transverse (Half, Full and Multiple) - Slight / Intermittent

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 7

PHOTOGRAPH	13

Very Poor Condition

Date: 29 March 2018
SECT: KM 4-000 to 4-250
STN: KM 4-100, looking E direction

Longitudinal Wheel Tracek Single and Multiple)-Very Severe/Few
Center Line (Single and Multiple) - Moderate/Few
Pavement Edge (Alligator) - Severe / Few

PHOTOGRAPH	14

Fair to Poor Condition

Date: 29 March 2018
SECT: KM 4-250 to 4-500
STN: KM 4-375, looking NW direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Center Line (Single and Multiple) - Moderate / Throughout
Transverse (Half, Full and Multiple) - Moderate / Extensive

PHOTOGRAPH	15

Poor to Fair Condition

Date: 29 March 2018
SECT: KM 4-500 to 4-750
STN: KM 4-550, looking NE direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Center Line (Single and Multiple) - Very Severe / Frequent
Transverse (Half, Full and Multiple) - Sever / Frequent

PHOTOGRAPH	16

Poor to Fair Condition

Date: 29 March 2018
SECT: KM 4-750 to 5-000
STN: KM 4-950, looking N direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Center Line (Single and Multiple) - Severe / Extensive
Transverse (Half, Full and Multiple) - Moderate / Extensive

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 9

PHOTOGRAPH	**17**

Fair Condition

Date: 29 March 2018
SECT: KM 5-000 to 5-250
STN: KM 5-125, looking N direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout

PHOTOGRAPH	**18**

Very Poor Condition

Date: 29 March 2018
SECT: KM 5-250 to 5-500
STN: KM 5-375, looking S direction

Ravelling and Coarse Aggregate Loss – Moderate / Throughout
Center Line (Single and Multiple) - Very Severe / Extensive
(Alligator)-Slight/Frequent
Pavement Edge (Alligator) - Slight / Intermittent
Transverse (Half, Full and Multiple) - Slight/Frequent

APPENDIX B - CONDITION SURVEY

PROJECT NO. TPB176179 - Bath and Millhaven Correctional Facility - Roadway Resurfacing

LOCATION Bath, ON

ENCLOSURE 2

PHOTOGRAPH	3

Good Condition

Date: 29 March 2018
SECT:KM 1-500 to 1-750
STN: KM 1-650, looking W direction

Transversal (Half, Full and Multiple) - Slight / Frequent.

PHOTOGRAPH	4

Core #

Date: 29 March 2018
STN: KM 1-450, looking SW direction

Longitudinal Wheel Track / Center Line (Signle and Multiple) - Slight / Frequent.

Pavement Edge (Alligator) - Very Severe / Intermittent

Appendix ‘C’

Asphalt Core Photo Records

Core Number: BH2S

Location: Station KM1-955

Average Total Core Length: 80 mm

Description:

Tight bond between 1st and 2nd lift.

Estimated Lift Thicknesses:
Lift 1- lower course: 40 mm
Lift 2- top course: 40 mm

Core Number: BH4

Location: Station KM1-725

Average Total Core Length: 74 mm

Description:

Single length

Core Number: BH7

Location: Station KM2-510

Average Total Core Length:
50 mm

Description:

Single length

Core Number: BH9

Location: Station KM2-900

Total Core Length: 60 mm

Description:

Single length

Core Number: BH10

Location: Station KM3-170

Average Total Core Length:
122 mm

Description:

Tight bond between 1st and 2nd lift.

Estimated Lift Thicknesses:
Lift 1- lower course: 58 mm
Lift 2- top course: 64 mm

Core Number: BH13

Location: Station KM3-800

Average Total Core Length:
68 mm

Description:

Tight bond between 1st and 2nd lift.

Estimated Lift Thicknesses:
Lift 1- lower course: 25 mm
Lift 2- top course: 43 mm

Core Number: BH18

Location: Station KM5-060

Average Total Core Length:
96 mm

Description:

Tight bond between 1st and 2nd lift.

Estimated Lift Thicknesses:
Lift 1- lower course: 70 mm
Lift 2- top course: 26 mm

Core Number: BH20

Location: Station KM5-500

Average Total Core Length:
72 mm

Description:

Single length

Appendix 'D'

Ground Penetrating Radar (GPR)

Geophysical Interpretation Report

Regarding RoadMap Ground Penetrating Radar Survey for

Road Pavement and Structure Analysis

Bath and Millhaven Institution – Kingston, Ontario

Submitted to:

Wood

1240 Phillip Murray Ave, Units 4 and 5, Oshawa, Ontario, L1J 6 Z9
Mohammed Javeed, PMP, P.Eng., Senior Project Manager

Prepared by:

multiVIEW Locates Inc.

325 Matheson Blvd. East, Mississauga, ON, L4Z 1X8
Evelio Martinez del Pino, Senior Geophysicist, M.Sc., P.Geo., CESA

April 18, 2018

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

DIGITAL ARCHIVE CONTENT

Table 1: Digital Archive Content

Folder	Content
…//Deliverables/	Digital copy of the survey results, final documents and maps
…//Maps/	Grid and interpretation maps
…//Raw Data/	Acquired raw data and processing results
…//Reports/	Geophysical survey report

PROJECT SPECIFICATION LIST

Table 2: Project Specification List

Contract	
MLI Reference Number	39736
Report Date	April 18, 2018
Client	
Legal Name	Wood
Address	1240 Phillip Murray Ave, Units 4 and 5, Oshawa, Ontario, L1J 6 Z9
Phone	905-720-4100
Contact	
Client Representative:	Mohammed Javeed, PMP, P.Eng.
Qualifications:	Senior Project Manager
Email	Javeed, Mohammed <mohammed.javeed@woodplc.com>
Survey	
Survey Description	Road Pavement and Structure Analysis
Methodology	RoadMap Ground Penetrating Radar Survey
Location	Bath and Millhaven Institution – Kingston, Ontario
Execution Date	22/03/2018
Contractor	
Survey by:	multiVIEW Locates Inc.
Responsible	Evelio Martinez del Pino
Qualifications	Senior Geophysicist, M.Sc., P.Geo., CESA
Phone	905-601-5400
Email	emartinez@multiview.ca

CONTRACT RELEASE LETTER: 39736

April 18, 2018

Wood

1240 Phillip Murray Ave, Units 4 and 5, Oshawa, Ontario, L1J 6 Z9
Phone: 905-720-4100

Attention to: Mr. Mohammed Javeed, PMP, P.Eng., Senior Project Manager

Re: Geophysical Interpretation Report regarding Road Pavement and Structure Analysis for Bath and Millhaven Institution – Kingston, Ontario.

Dear Mr. Mohammed Javeed, PMP, P.Eng.:

Wood retained multiVIEW Locates Inc. to carry out RoadMap Ground Penetrating Radar Survey for Road Pavement and Structure Analysis for Bath and Millhaven Institution – Kingston, Ontario. The geophysical survey was undertaken during 22/03/2018. Included, you will find the following items:

Item	Description	Quantity
Geophysical Interpretation Report	Geophysical survey report describing the data acquisition, methodology, data quality, processing, interpretation results, conclusion and recommendations relevant to survey objectives, including appendices, tables and figures	1 Digital Copy of the Report
Digital Archive	Digital archive containing the acquired raw data and final processed results, digital maps, presentations and documents	1 Electronically Transferred Data Compilation

This represents the end of our contractual agreement regarding the aforementioned geophysical survey. Contact us if you need any additional material or information.

Thank you,

Signed by: ___________________

Evelio Martinez del Pino, Senior Geophysicist, M.Sc., P.Geo., CESA
multiVIEW Locates Inc.

1 INTRODUCTION

Wood retained multiVIEW Locates Inc. to carry out detailed RoadMap Ground Penetrating Radar Survey in support of Road Pavement and Structure Analysis for the geotechnical project at Bath and Millhaven Institution – Kingston, Ontario.

This Non-Destructive Testing (NDT) Report summarizes the GPR data collection logistics and methodology, processing results, tabulated data summaries and multi-parameter data interpretation associated with the Road Pavement and Structure Analysis.

The acquisition, processing and analysis of the RoadMap Ground Penetrating Radar Survey data were performed according to professionally regulated industry standards. The data interpretation contained in this report is based on the analysis of the responses recorded during the acquisition and processing stage.

Examples of the results are presented in screen captured figures, cross-sections and depth plan maps throughout the sections of this interpretation report. The images and figures in the body of the report are for referencing and illustration purposes only. Scaled and referenced maps and images of the road structure in plan and sectional views, along with and Excel format tables are available in the digital archive. The interpretation of the data obtained during this investigation is intended for guidance during road inspection, condition assessment and structure rehabilitation.

Interpretation and use of the GPR data during any subsequent programs is subject to the Law of Physics and Technical limitations of the exploration technique. The criteria and models used for the interpretation of the acquired GPR data are not unique and may not represent the actual objects present on site.

1.1 Survey Objectives

The primary objectives of the investigation were to:

- Collect RoadMap GPR data for road pavement and structure analysis of approximately 500m at Bath and Millhaven Institution – Kingston, Ontario. The data acquisition system for this project was setup with 3 GPR channels consisting of two high resolution 1000MHz GPR antennas on the left and central channels (LWP, CTR). One mid-resolution 500MHz GPR antenna was setup on the right channel (RTR) for deep structure analysis. All GPR scans used real time GPS synchronization, with a minimum of one profile scan per travel lane.
- Process and interpret the GPR data to determine asphalt pavement thickness, granular base and sub-base depth.
- Provide tabulated summary of GPR interpreted data; and digital drawings containing plan view and cross-section images of asphalt pavement thickness, granular bottom and sub-base depth.

2 PROJECT OVERVIEW

2.1 Site Location and Access

The geophysical project is located along Bath and Millhaven Institution – Kingston, Ontario. A RoadMap project general location map is presented in Figure 2-1.

2.2 Weather and Terrain Conditions

The survey was performed during 2017 winter season, in a dry day with average temperatures of ~-5 degrees Celsius. The GPR profiles were run over asphalt paved lanes. No significant obstructions and road construction zones were documented during the geophysical data acquisition.

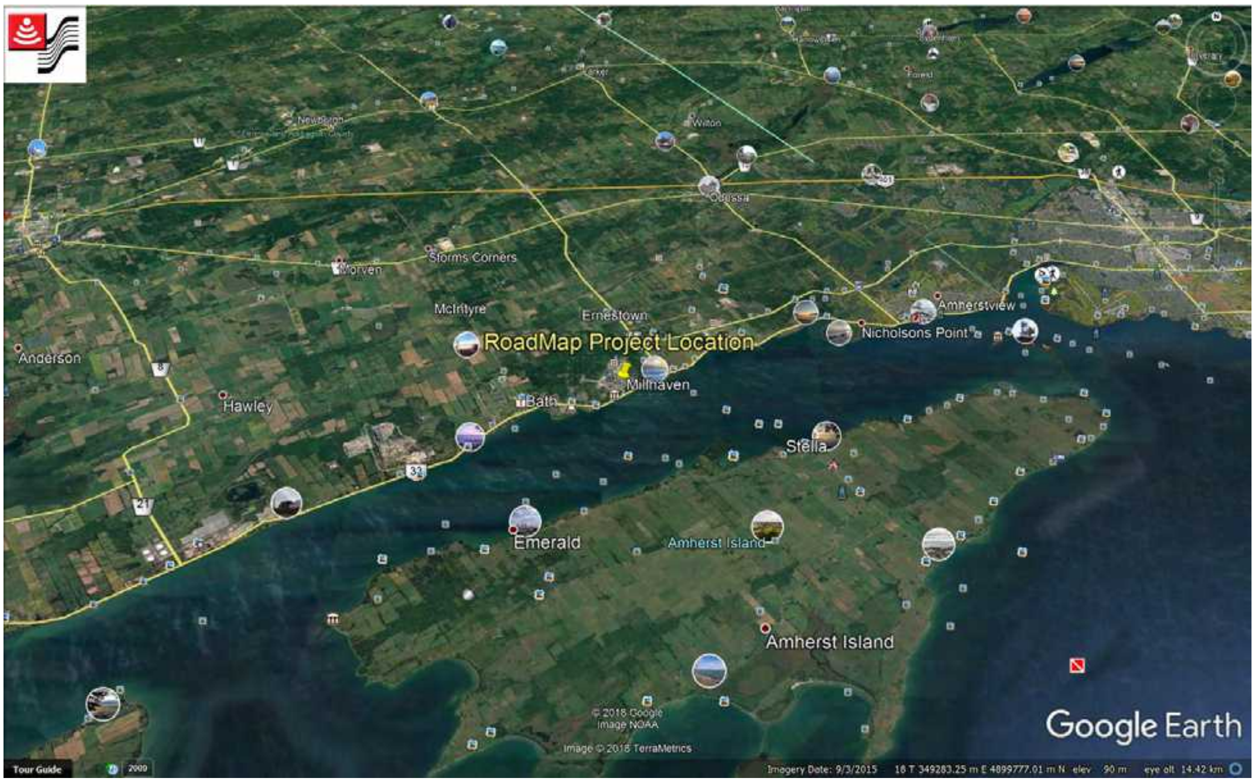


Figure 2-1: Geophysical Survey General Location Map

General Location Map captured from Google Maps. 22/03/2018

3 METHODOLOGY

The geophysical study was completed using RoadMap Ground Penetrating Radar Survey techniques. The GPR data acquisition was performed using Sensors & Software SPIDAR system. The geophysical exploration and acquisition phase of the survey was completed on 22/03/2018.

Field labor included the following activities:

- Geophysical survey grid installment;
- GPR Profile Imaging;
- Site Documentation;
- Data Interpretation and Results Presentation;

3.1 Survey Grid Installment

Survey profiles and reference stations for the RoadMap GPR data acquisition were established according to client's base maps and project requirements. Starting from the reference locations, the GPR survey profiles were installed with increasing stations on the north direction. Geographic Position System (GPS) data and elevations were acquired for each of the acquired profiles for the purpose of grid establishment and positioning correction.

A RoadMap project profile location map is presented in Figure 3-1.

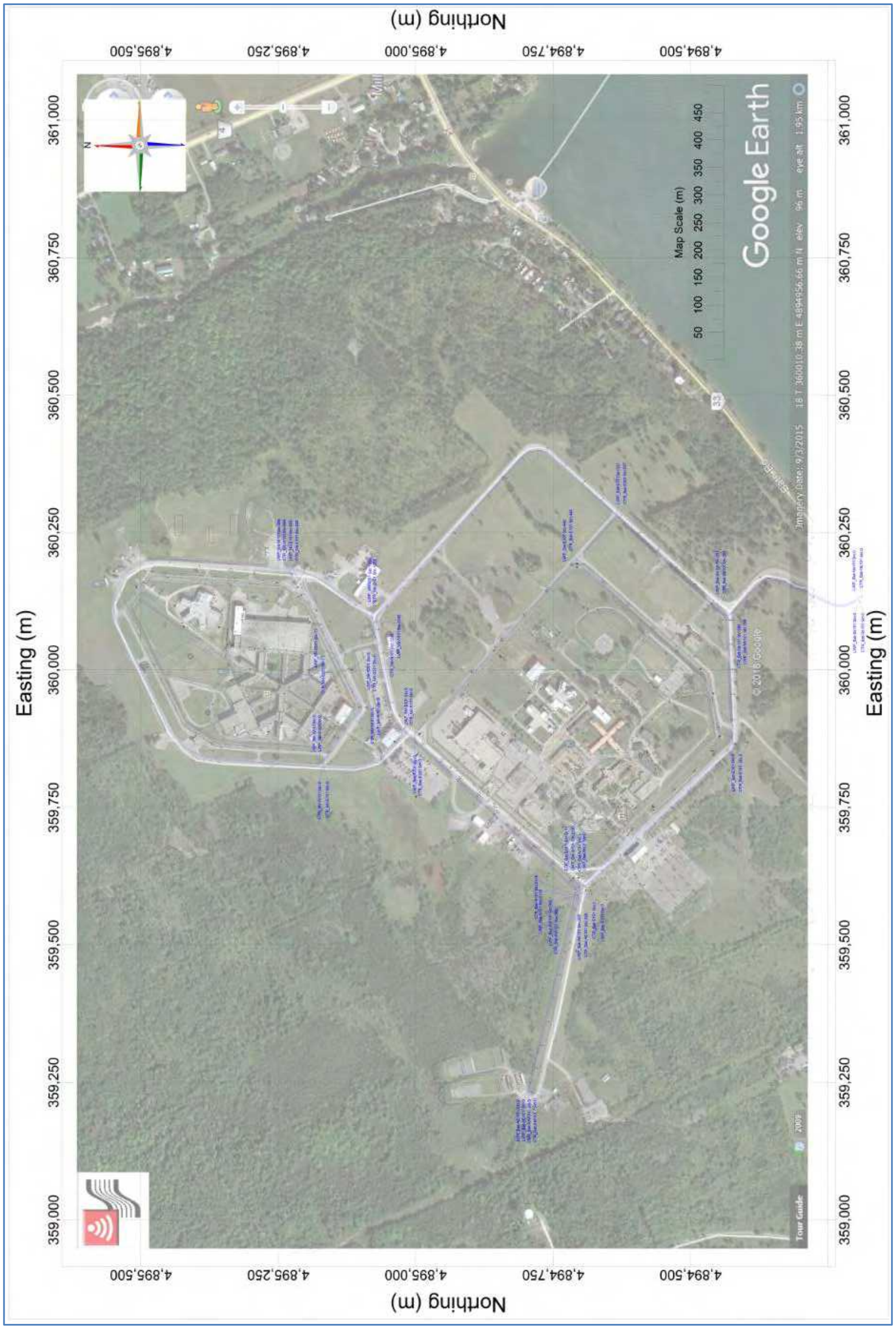


Figure 3-1: RoadMap GPR Profile Location Map

3.2 Ground Penetrating Radar Data Acquisition

High speed collection of GPR data was performed on the selected road lanes using a high-speed multi-channel ground-coupled GPR system shown in Figure 3-2.

Figure 3-2: Typical RoadMap GPR Acquisition System Setup

The RoadMap GPR survey was designed to include a minimum of one pass per road lane. Two 1000 MHz GPR antennas were used at the left and centre channels, and one 500 MHz antenna on the right position for shallow and deep road condition assessment up to ~1.5m depth.

GPS data were collected synchronously with the GPR data using a Trimble RTK-8 receiver mounted on RoadMap system. Data were collected using nominal GPR/GPS settings at posted travel speeds. No supplemental traffic management was required for the survey. Following the field survey, the GPS data were post processed and integrated with the GPR data.

3.3 Geophysical Data Interpretation and Presentation

GPR uses the physical principles of electromagnetic waves propagation throughout media. The GPR transmitted signal will be reflected, refracted and diffracted from the boundaries between objects with different dielectric properties. Structure mapping using GPR is possible due to the dielectric contrast between different man-made structures and host matrix.

The GPR anomaly identification was accomplished by examining the subsurface electromagnetic reflection characteristics such as continuous anomalous trending and high amplitude hyperbolic reflection identification and contour mapping.

All data collected in the field were digitally recorded and backed up on site. The data were then analyzed in-office using Sensors & Software processing and analysis tools. The GPR data processing was done according to the following steps:

- GPS and GPR Grid data referencing.
- GPR profile zero-time correction, total background subtraction, amplitude equalization.
- Dewow, migration, envelope signal processing and hyperbola velocity calibration.
- Gain equalization and enhancement.
- GPR Reflection identification, visual interpretation, event picking and data exporting.
- Grid Contouring, map creation, interpretation and reporting

Post processing of the GPR data was performed using EKKO_PROJECT Analysis software, a proprietary data processing package for viewing the GPR cross section images and defining profiles of the pavement interface depths. Identification of the interfaces or boundaries was based on their character in the cross-section image and knowledge of the pavement structure.

In order to determine depth of the GPR reflective interfaces (e.g. interface between the Asphalt Pavement, Concrete and Granular), it was necessary to determine the propagation velocity of the GPR launched electromagnetic pulse in the pavement structure. The velocity was calculated via analyzing hyperbolic reflections visually identified in the GPR raw data. For some road sections, core thickness and granular bottom depth data was available for correcting the velocity and thickness of the interpreted sections.

The raw data and survey results included in this report are:

- Geophysical interpretation report and appendices.
- Asphalt thickness, granular bottom and sub-base bottom depth contour grid maps.
- Cross-sections illustrating the road structure along the scanned GPR profiles (one section per road lane).
- Excel summary tables with estimated GPR asphalt thickness, granular base bottom and sub-base bottom plan maps.

4 RESULTS

Colour contour plan maps and profile cross-sections illustrating the interpreted road structure along the GPR scanned profiles are presented in Figure 4-2 to Figure 4-31.

The images presented are scaled to fit the page size. Plan maps and sections at scale adequate for the interpretation and visualization are available in the digital archive.

GPR sections of the asphalt pavement thickness, granular base and sub-base bottom depth were calculated from the RoadMap measurement points collected on each survey line above each of the profiles along the road. GPR interpretation and compilation was completed by comparing the characteristics of the acquired profiles to examples and results available at multiVIEW from historic field surveys.

The following Figure 4-1 illustrates the legend for interpreting the GPR profile sections.

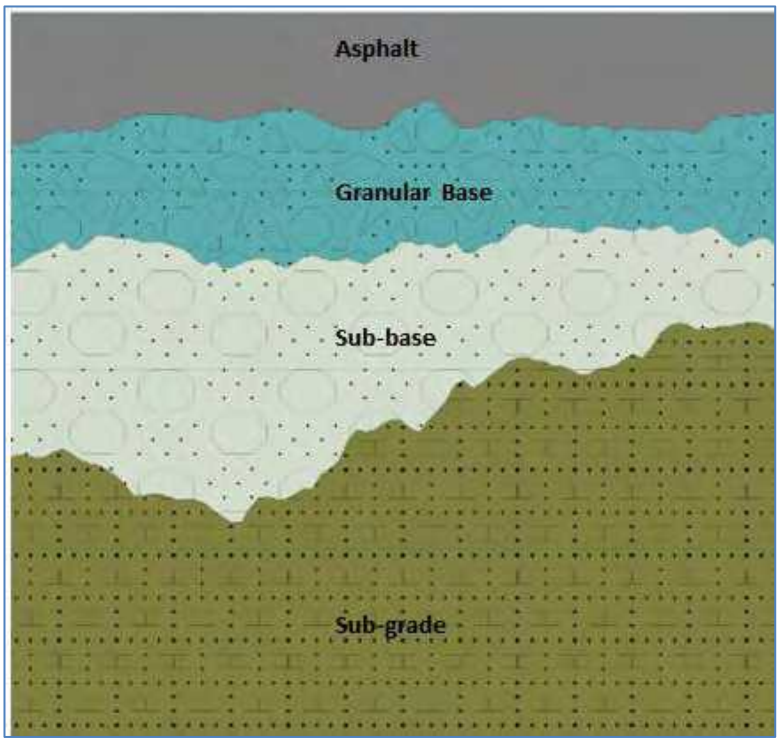


Figure 4-1: GPR Section Legend

4.1 Summary Statistics

Statistical information regarding the road structure estimated from GPR profile data is available in the Excel tables provided digitally along with this interpretation report. The data presented in the tables summarize the estimated parameters of the processed GPR profiles. Individual GPR profiles, interpreted road sections and maps are provided in the appendices of the report.

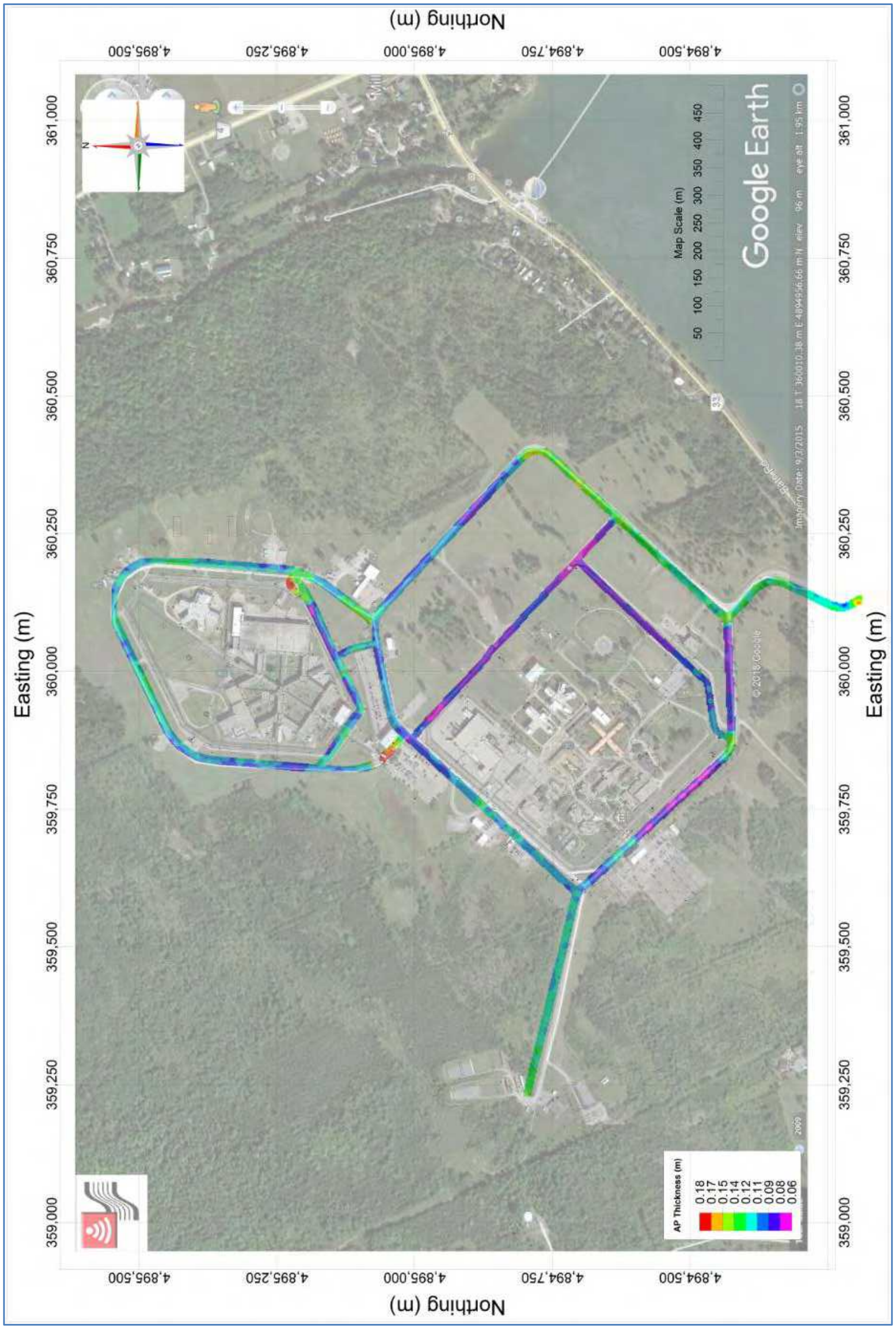


Figure 4-2: Asphalt Thickness Contour Grid Map

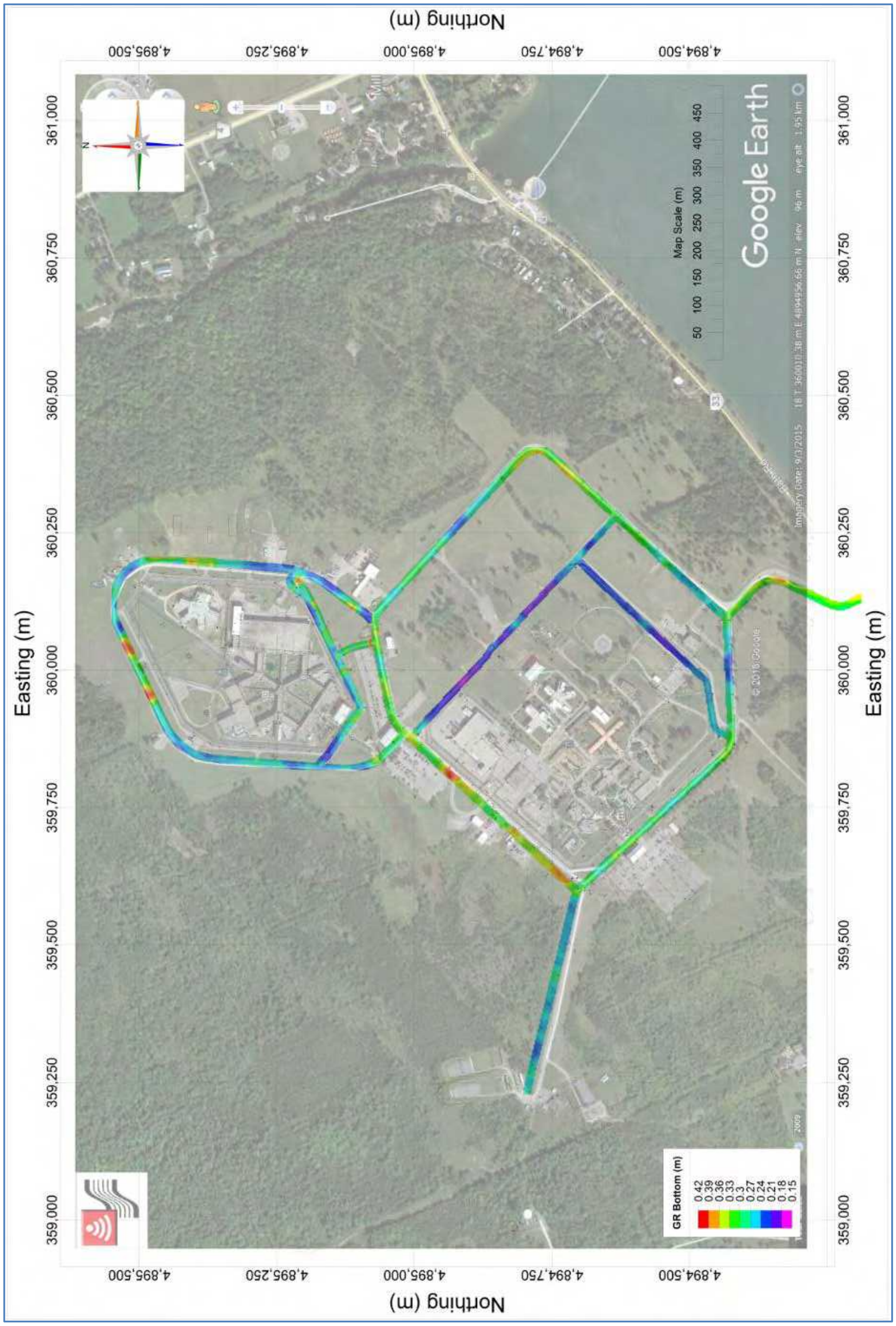


Figure 4-3: Granular Bottom Depth Contour Grid Map

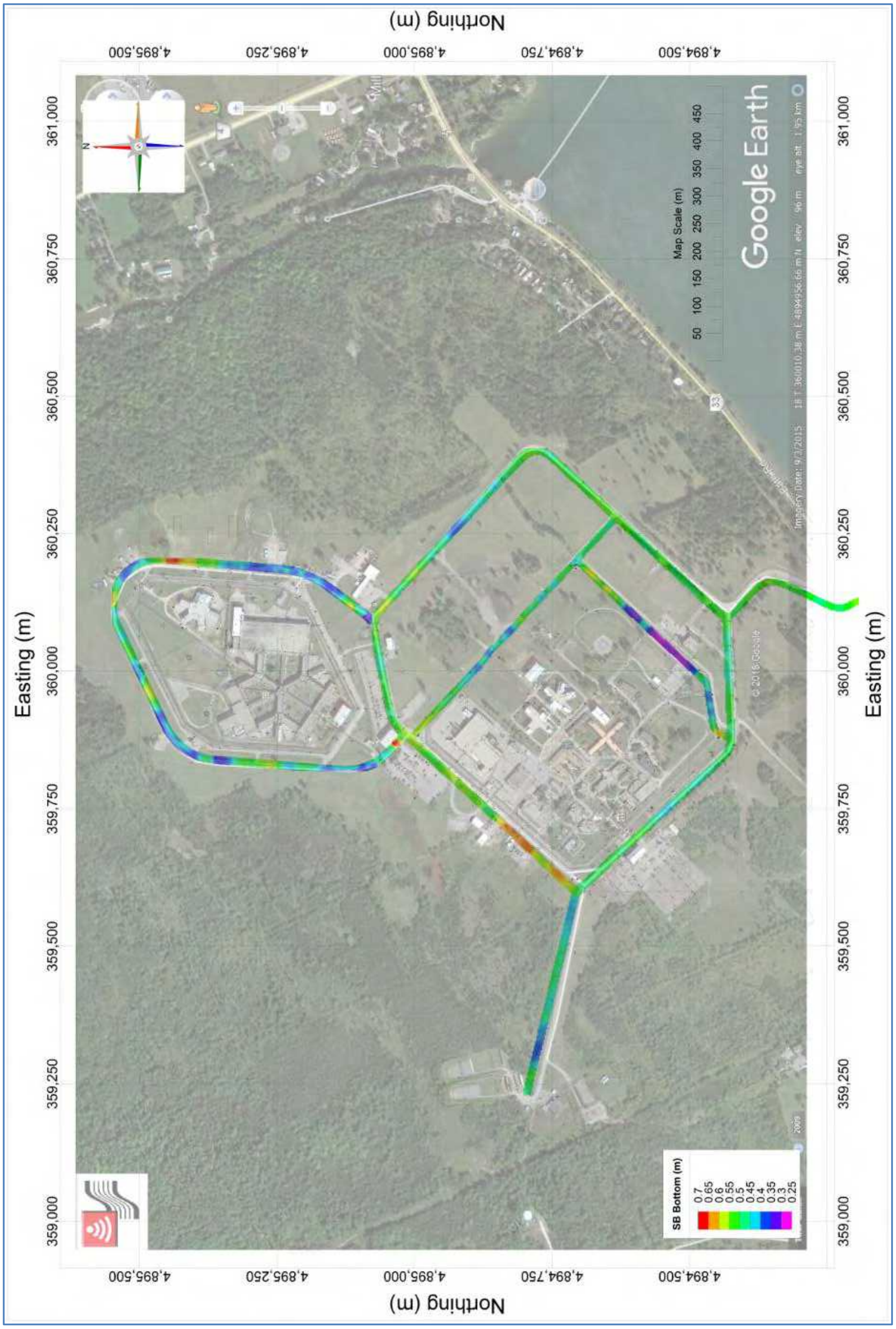


Figure 4-4: Sub-base Bottom Depth Contour Grid Map

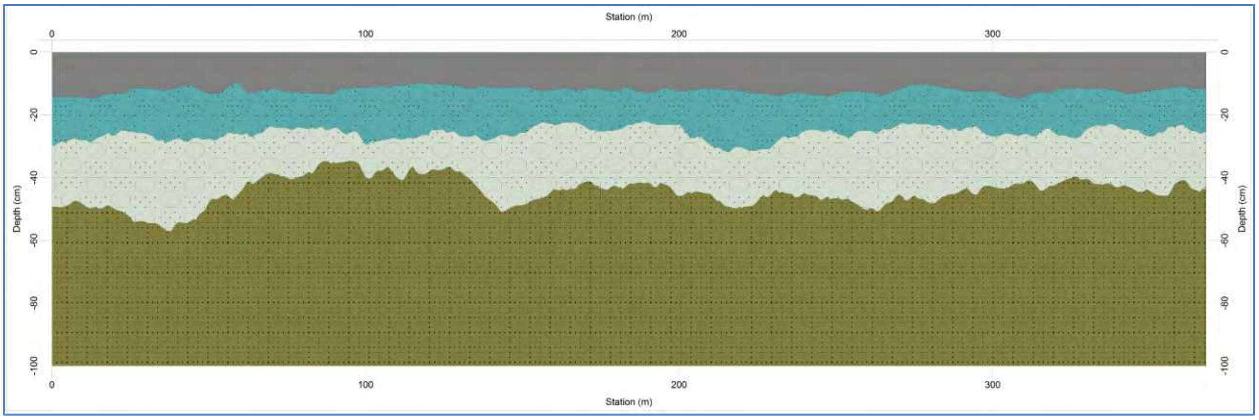


Figure 4-5: CTR_Bat-AE101 - Central Profile Section

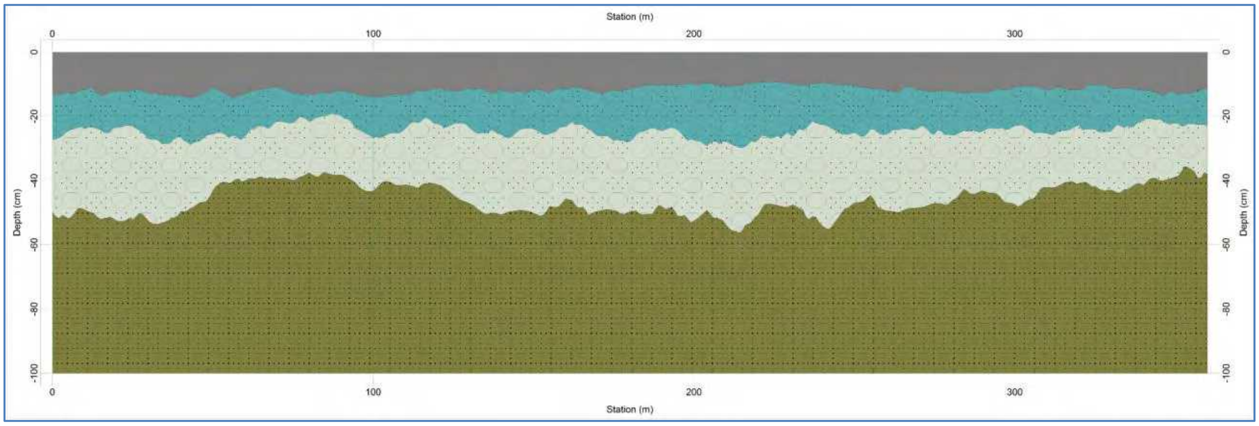


Figure 4-6: CTR_Bat-AW101 - Central Profile Section

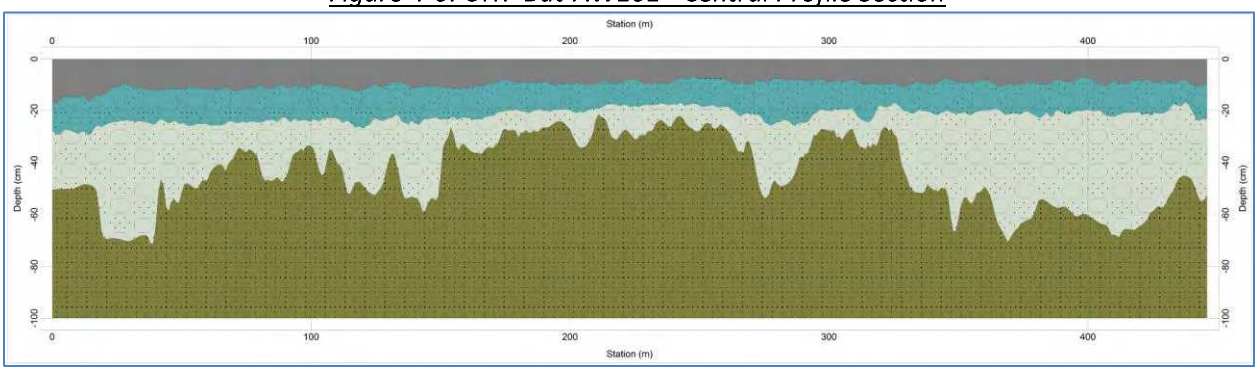


Figure 4-7: CTR_Bat-E101 - Central Profile Section

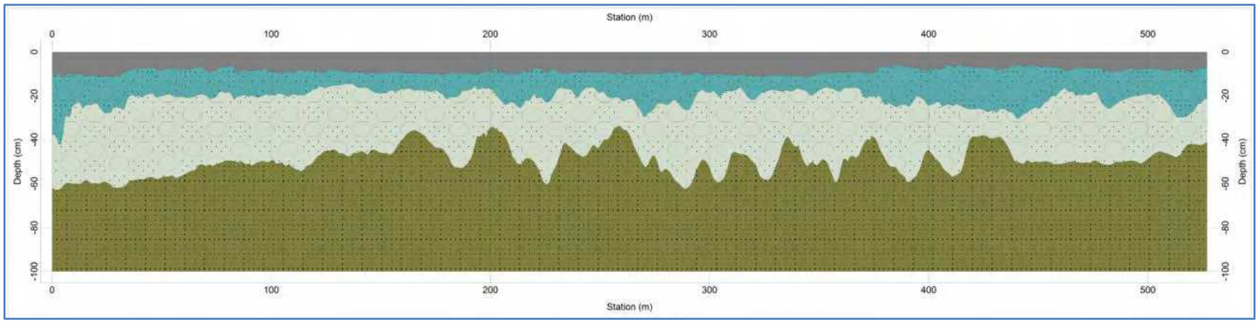


Figure 4-8: CTR Bat-E201 - Central Profile Section

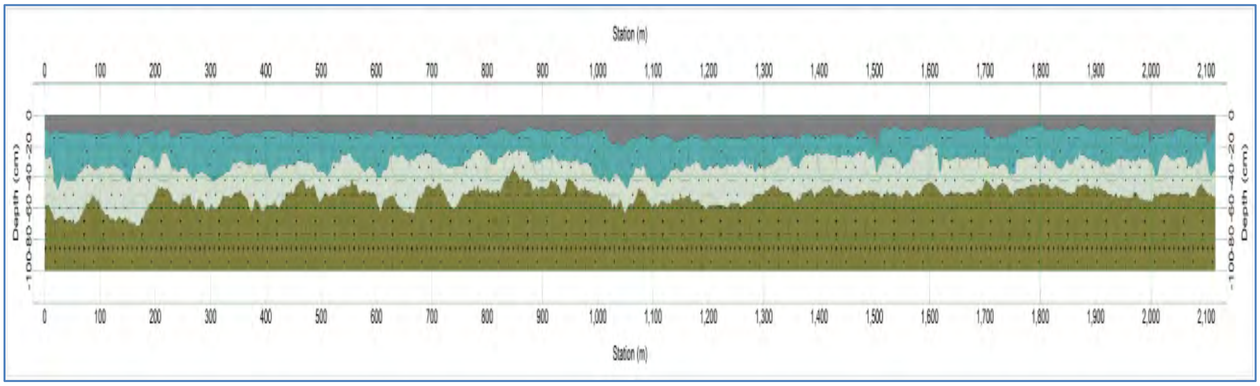


Figure 4-9: CTR Bat-N101 - Central Profile Section

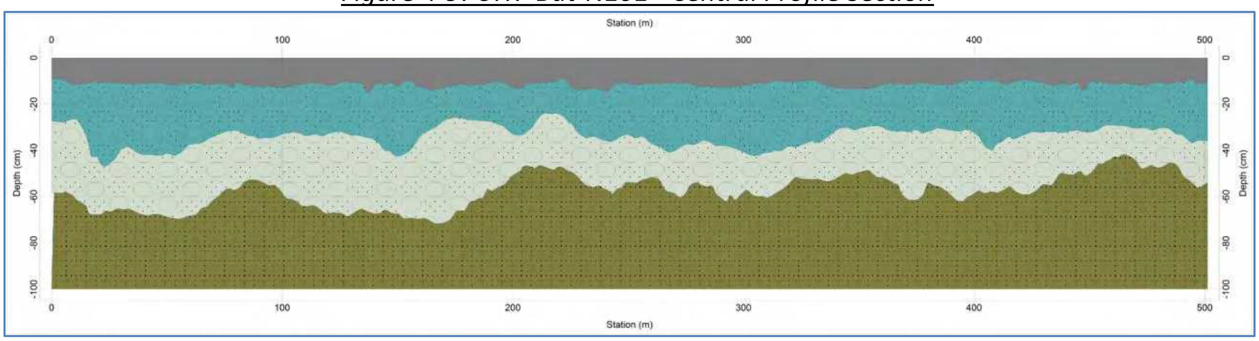


Figure 4-10: CTR Bat-N101 0-500 - Central Profile Section

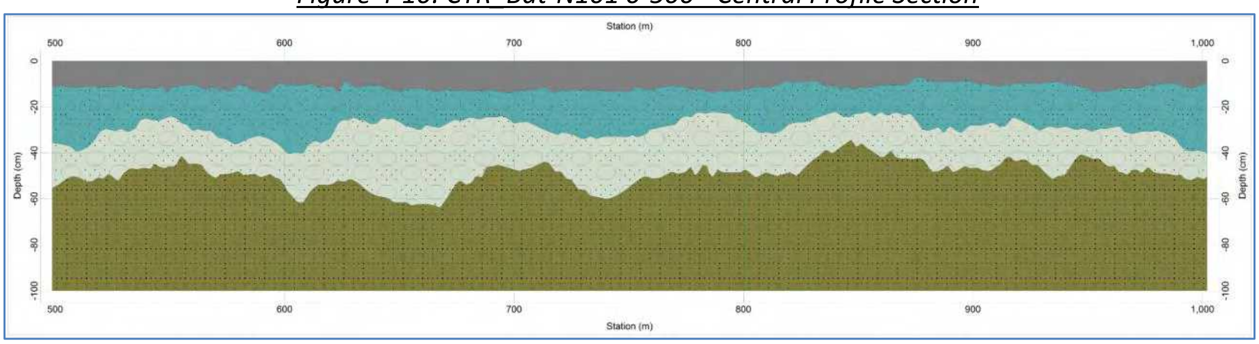


Figure 4-11: CTR Bat-N101 500-1000 - Central Profile Section

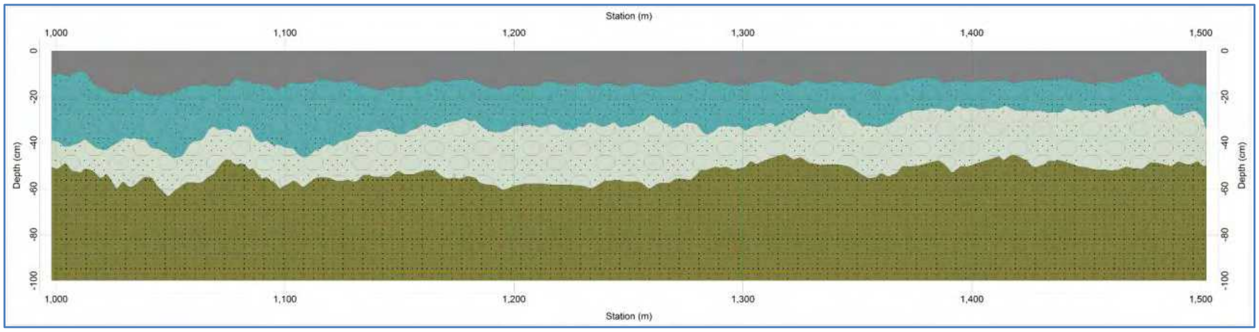


Figure 4-12: CTR_Bat-N101 1000-1500 - Central Profile Section

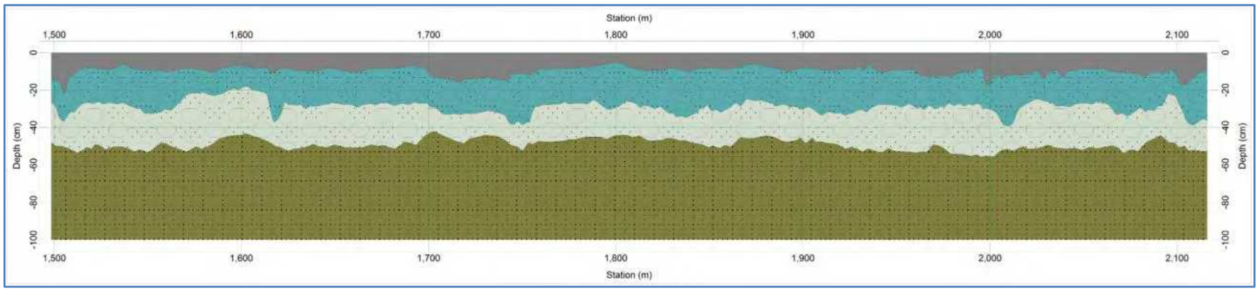


Figure 4-13: CTR_Bat-N101 1500-2100 - Central Profile Section

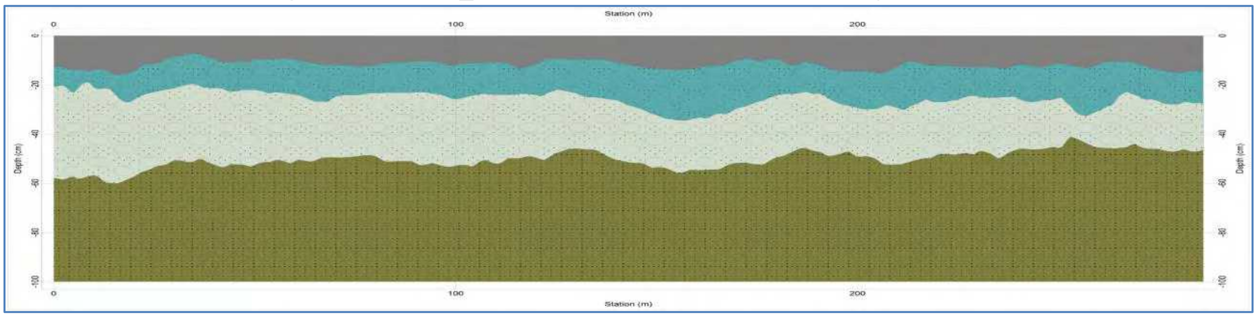


Figure 4-14: CTR_Bat-Nb101 - Central Profile Section

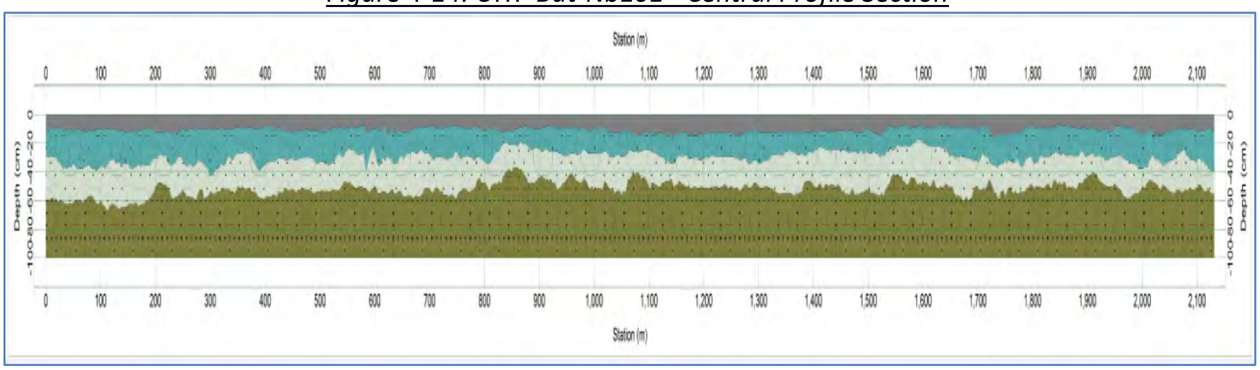


Figure 4-15: CTR_Bat-S101 - Central Profile Section

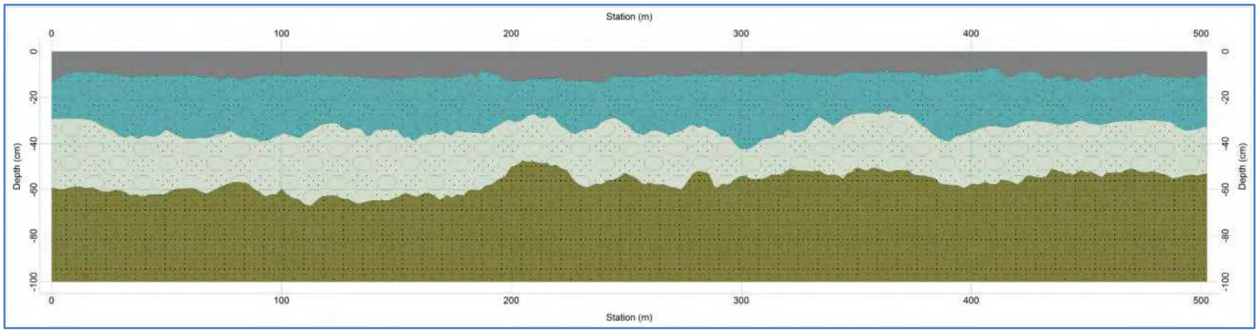


Figure 4-16: CTR_Bat-S101 0-500 - Central Profile Section

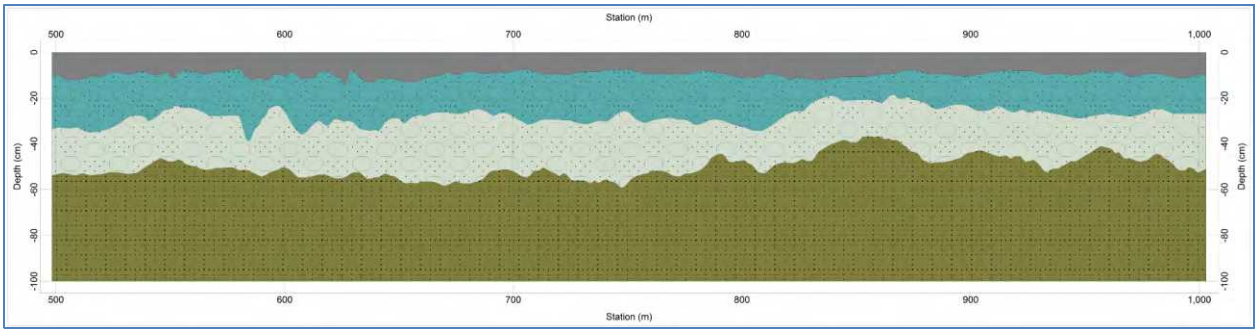


Figure 4-17: CTR_Bat-S101 500-1000 - Central Profile Section

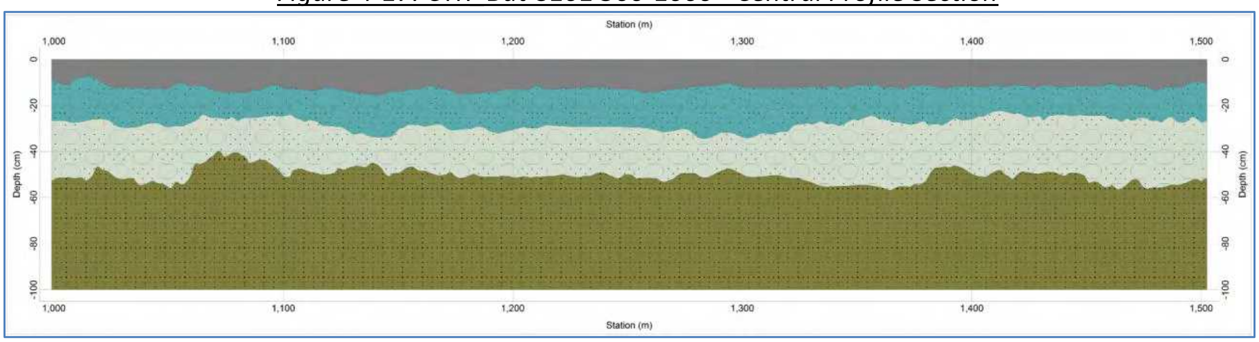


Figure 4-18: CTR_Bat-S101 1000-1500 - Central Profile Section

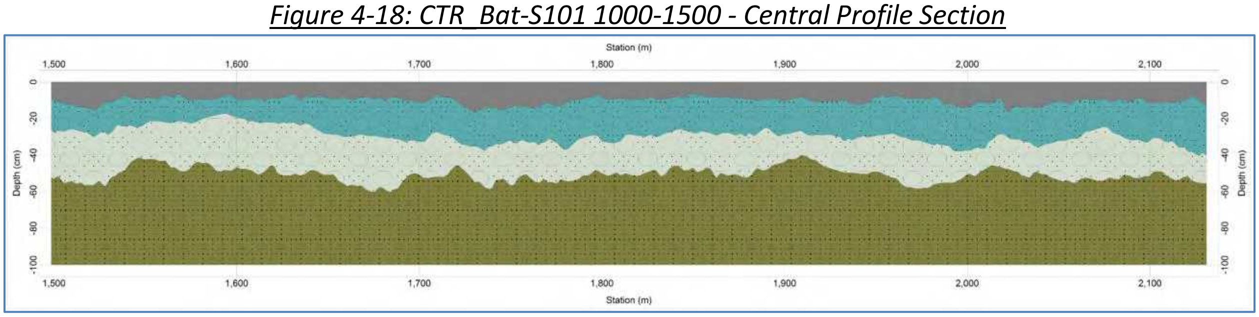


Figure 4-19: CTR_Bat-S101 1500-2100 - Central Profile Section

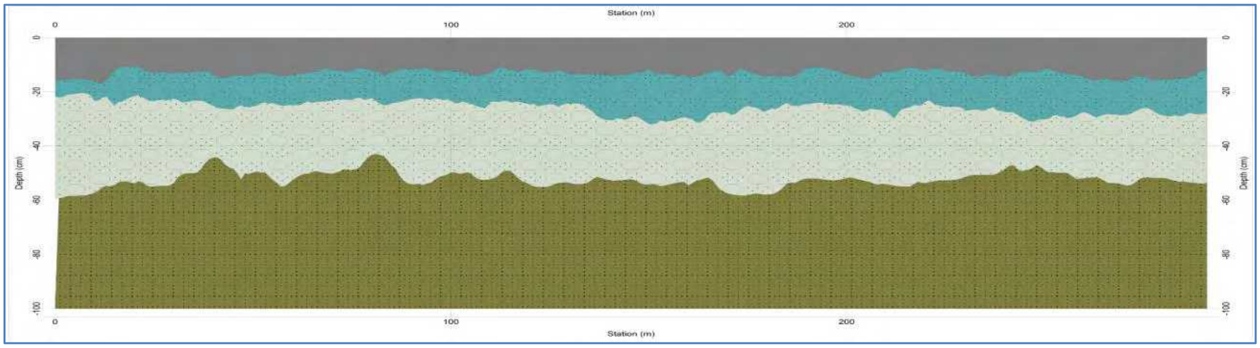


Figure 4-20: CTR_Bat-Sb101 - Central Profile Section

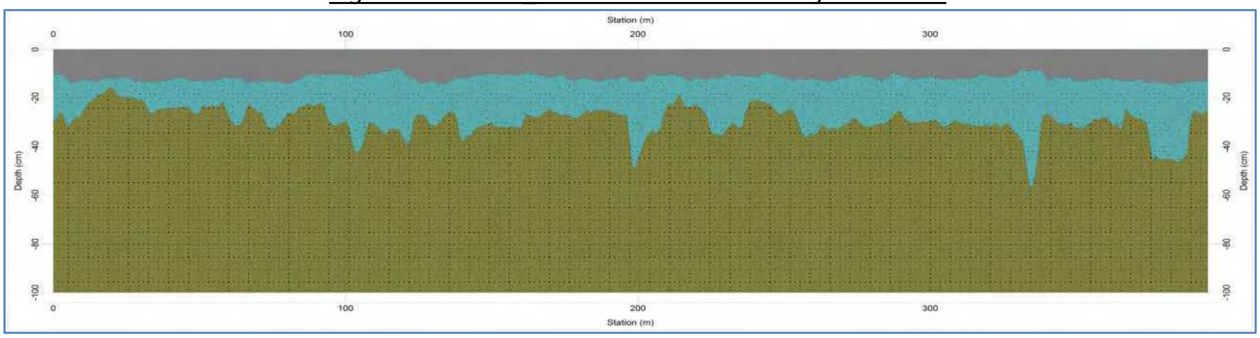


Figure 4-21: CTR_Mil-E101 - Central Profile Section

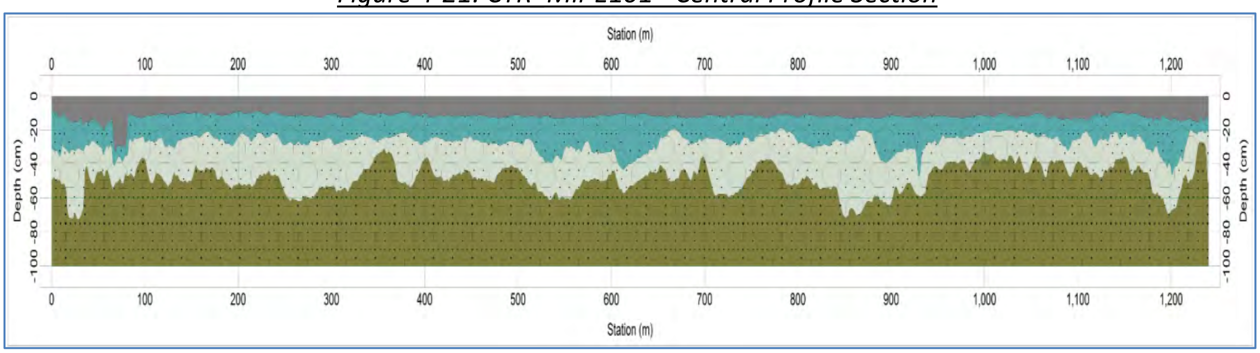


Figure 4-22: CTR_Mil-N101 - Central Profile Section

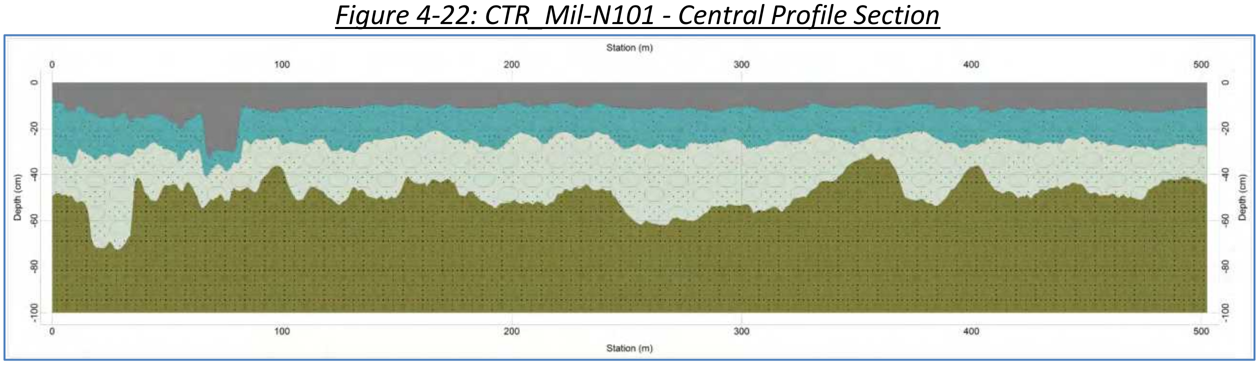


Figure 4-23: CTR_Mil-N101 0-500 - Central Profile Section

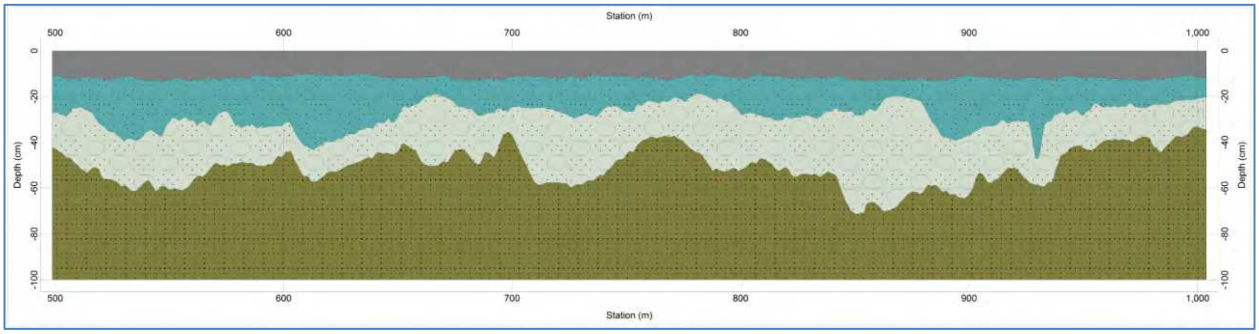


Figure 4-24: CTR_Mil-N101 500-1000 - Central Profile Section

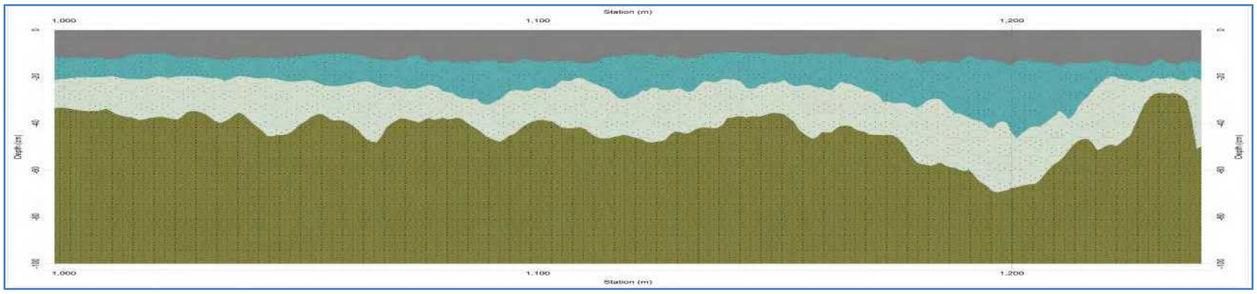


Figure 4-25: CTR_Mil-N101 1000-1300 - Central Profile Section

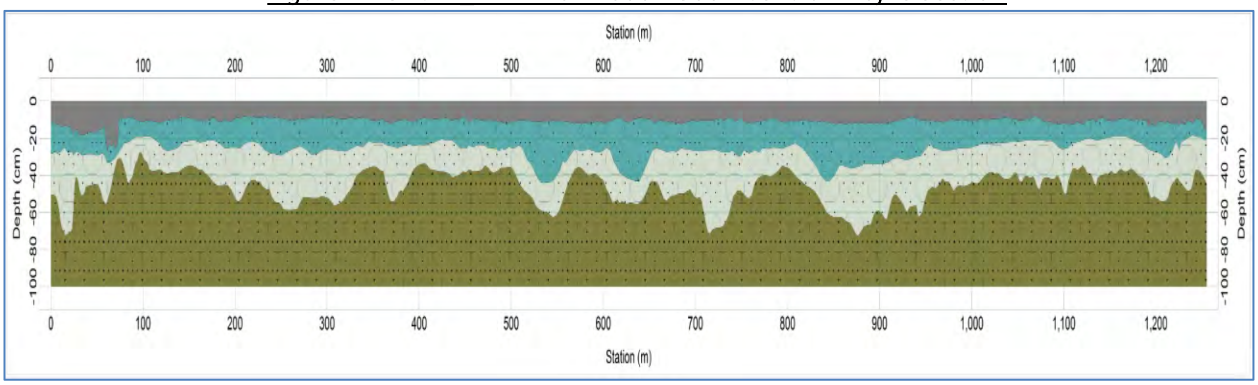


Figure 4-26: CTR_Mil-S101 - Central Profile Section

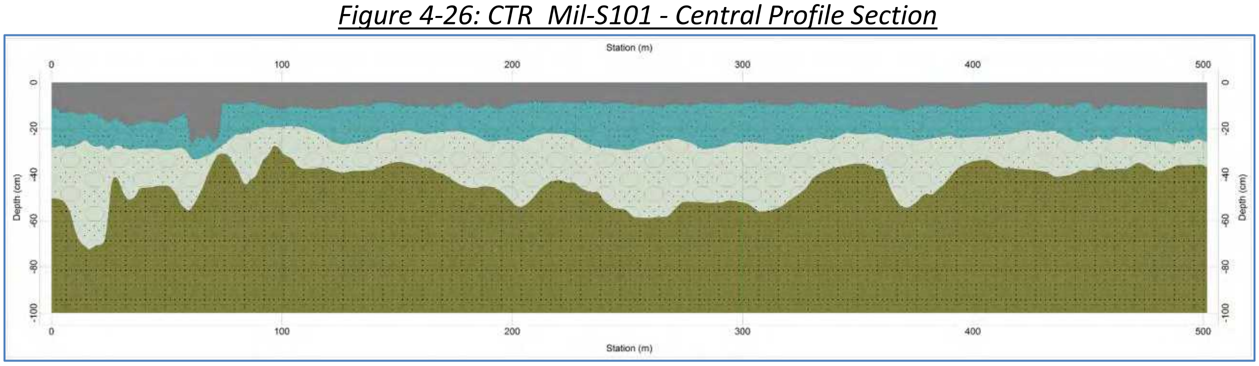


Figure 4-27: CTR_Mil-S101 0-500 - Central Profile Section

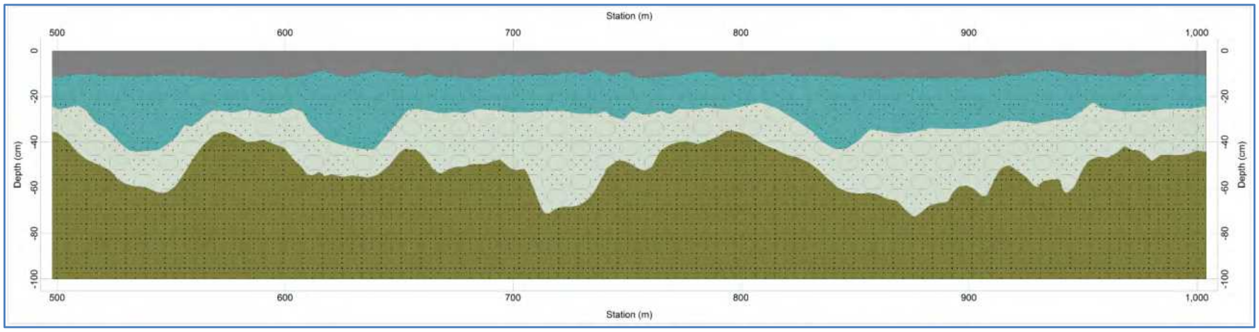


Figure 4-28: CTR_Mil-S101 500-1000 - Central Profile Section

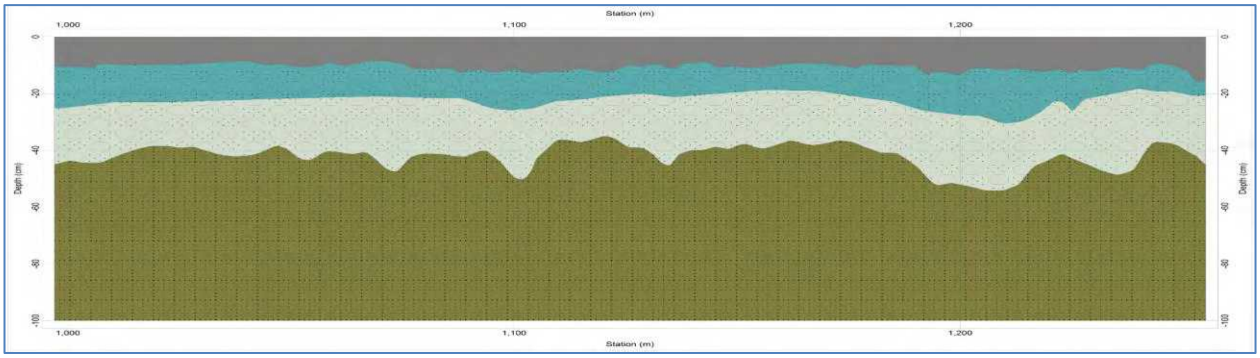


Figure 4-29: CTR_Mil-S101 1000-1300 - Central Profile Section

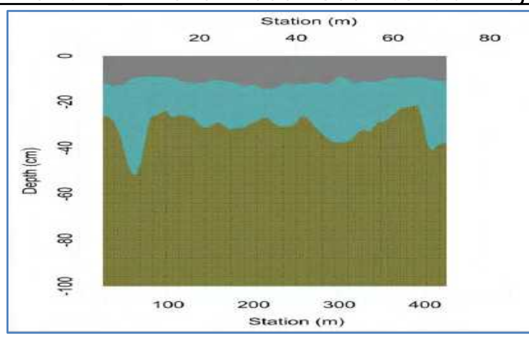


Figure 4-30: CTR_Mil-S201 - Central Profile Section

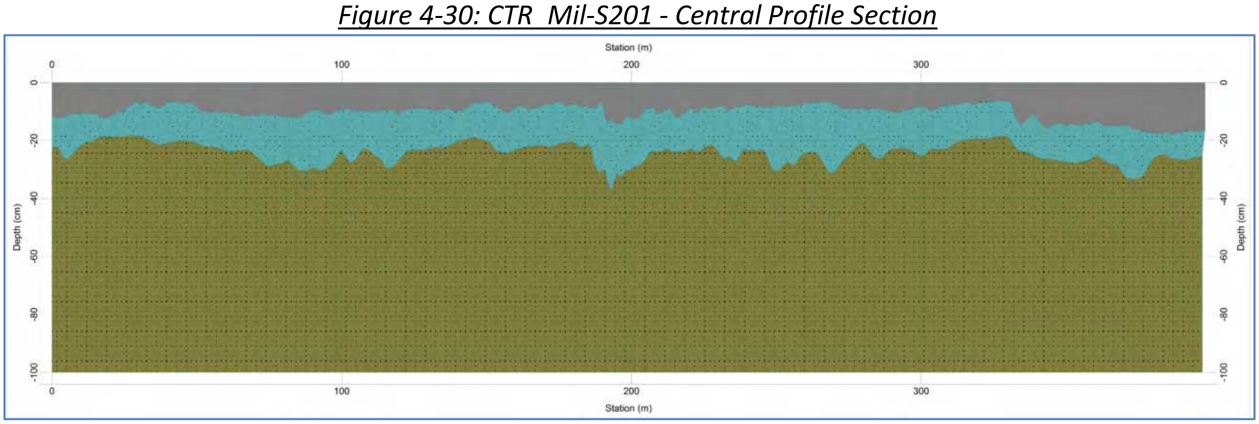


Figure 4-31: CTR_Mil-W101 - Central Profile Section

5 CONCLUSION

Wood retained multiVIEW Locates Inc. to carry out detailed RoadMap Ground Penetrating Radar Survey in support of Road Pavement and Structure Analysis for the geotechnical project located at Bath and Millhaven Institution – Kingston, Ontario.

Asphalt thickness, granular bottom and sub-base depth estimates presented in this assessment report are based on the GPR reflective horizon depth calculation using multiVIEW processing platforms and methodology. The interpretation presented in the report should assist the senior geotechnical engineer to effectively conduct rehabilitation and maintenance activities over the analysed road sections.

Further analysis of the data collected in context with all available information, road structure documents and coring results should be consulted in order to corroborate the interpretation presented in this assessment report.

When physically locating the interpreted results for testing, coring and repair it is recommended to properly correlate the GPR grid stations with the survey stations presented on the digital maps and available drawings.

Additional information regarding advantages and limitations of this geophysical technique is provided in the appendices of this report.

Respectfully Submitted,

April 18, 2018

[signature and date]

Evelio Martinez del Pino
Senior Geophysicist, M.Sc., P.Geo., CESA
multiVIEW Locates Inc.

6 REFERENCES

- Lisa Dojack. 2012. Ground Penetrating Radar Theory, Data Collection, Processing, and Interpretation: A Guide for Archaeologists.
- Sensors & Software. 2007. EKKO Mapper User's Guide. Sensors & Software, Mississauga.
- Sensors & Software. 2007. GFP View & GFP Edit User's Guide. Sensors & Software, Mississauga.
- Sensors & Software. 2007. EKKO View Enhanced & EKKO View Deluxe User's Guide. Sensors & Software, Mississauga.
- Sensors & Software. 2007. Ground Penetrating Radar Survey Design. Sensors & Software, Mississauga.
- Sensors & Software. 2007. Velocity Analysis. Sensors & Software, Mississauga.

multiVIEW Insight, not hindsight®

HEAD OFFICE
325 MATHESON BLVD. EAST
MISSISSAUGA, ON L4Z 1X8
(905) 629-8959

LONDON
#20-570 CLARKE ROAD
LONDON, ON N5V 3K5
(226) 721-0211

KITCHENER
#3-38 MCBRINE PLACE
KITCHENER, ON N2R 1G8
(519) 279-1126

OTTAWA
#204-2 BEAVERBROOK RD.
KANATA, ON K2K 1L1
(613) 287-7005

INFO@MULTIVIEW.CA WWW.MULTIVIEW.CA

7 QUALIFICATIONS

I, Evelio Martinez del Pino, declare that:

I am a Senior Geophysicist with residence in Hamilton, Ontario and presently employed in this capacity with multiVIEW Locates Inc., Mississauga, Ontario.

I have obtained an Engineer's Degree (B.Sc.) in Geophysical Exploration at Gornii Mining Institute in St. Petersburg, Russia and at ISPJAE University in La Habana, CUBA in 1993.

I have obtained a Master's Degree in Applied Geophysics (M.Sc.) at International Institute for Geo-Information Science and Earth Observation (ITC) in Delft, The Netherlands, in 2000.

I am a registered geoscientist, since 2004, with license to practice in the Province of Ontario, (APGO License # 1058), and registered geoscientist, since 2010, with license to practice in the Province of Saskatchewan, (APEGS License # 20431).

I am a Certified Environmental Site Assessor (Phase I), with license to practice in the Province of Ontario since 2015, (AESAC License # 17770).

I am a member of the Society of Exploration Geophysicists (SEG), member of the American Geophysical Union (AGU), and the Canadian Exploration Geophysicists Society (KEGS).

I have practiced my profession continuously since September 1993 in Cuba, The Netherlands, Portugal, Canada, Botswana, DRC, Russia and Peru.

I am the Professional Geophysicist responsible for this project. I have acquired the field data and executed the Quality Control and Assurance of the geophysical results and interpretation. I have authored and compiled the final processed data and interpretation contained in this report. I can attest that the information and interpretation accurately and faithfully reflect the data acquired on site.

The statements made in this report represent my professional opinion based on the consideration of the information and professional experience available at the time of executing this project.

Mississauga, Ontario.

April 18, 2018

[signature and date]
Evelio Martinez del Pino
Senior Geophysicist, M.Sc., P.Geo., CESA
multiVIEW Locates Inc.

APPENDICES

HEAD OFFICE
325 MATHESON BLVD. EAST
MISSISSAUGA, ON L4Z 1X8
(905) 629-8959

LONDON
#20-570 CLARKE ROAD
LONDON, ON N5V 3K5
(226) 721-0211

KITCHENER
#3-38 MCBRINE PLACE
KITCHENER, ON N2R 1G8
(519) 279-1126

OTTAWA
#204-2 BEAVERBROOK RD.
KANATA, ON K2K 1L1
(613) 287-7005

INFO@MULTIVIEW.CA
WWW.MULTIVIEW.CA

APPENDIX A

Data Presentation

1. The electromagnetic point data were acquired at the station spacing and on the date as defined in the survey objectives.
2. Colour-contoured maps were created from the collected electromagnetic data and referenced to the survey grid coordinates
3. The images of the colour contoured maps presented in the body of the report are for display and review purposes only. The images are scaled to fit page sizes. Data acquired for QC/QA purposes (base station, background or auxiliary data) are available in the digital archive. The raw data and maps in the digital archive are properly referenced to the survey area, using either grid or UTM coordinates. The maps are presented at a scale to facilitate the accompanying interpretation.

Data Interpretation

Interpretation of the electromagnetic data is intended for guidance on environmental engineering and excavation purposes only. The user must be aware of the following interpretive restrictions:

4. Features shown on the interpretation map are related to the expression of subsurface man-made objects and other geological features and structures underground. The projection and location of these features on the surface is referenced to the grid coordinate system established at the time of the survey. All detected features are not necessarily shown due to the weak and non-relevance of the observed responses.
5. Interpretation of buried features or change in soil conditions cannot be made in areas where data were not collected.
6. The electromagnetic data were reviewed with respect to the position of the cultural features (i.e. man-made metallic objects) identified on site. The electromagnetic response observed in proximity to a known cultural feature is attributed to that feature.
7. Where known surface or subsurface metallic objects exist within 2 metres of the electromagnetic data observation station, it is possible that other metallic objects or a change in soil conditions may be present but not identified in the interpretation because the electromagnetic response is attributed to, or masked by, the known feature.
8. The spatial position of all interpreted electromagnetic anomalies (zones where electromagnetic fields are different than background) inferred to represent buried metallic objects are indicated in red on this figure.
9. If red anomalies are not present on this figure, no electromagnetic signatures were identified which could not reasonably be ascribed to known metallic objects and/or no isolated electromagnetic anomalies could be identified.
10. The spatial position of all interpreted electromagnetic anomalies inferred to represent unusual soil conditions is indicated in blue on this figure. These anomalies may represent local changes in soil type or geology, changes in soil moisture conditions; fill versus natural soils or contaminated areas.

11. If blue anomalies are not present on this figure, no electromagnetic signatures were identified which could not reasonably be ascribed to known changes in soil type or geology, changes in soil moisture conditions, fill versus natural soils or contaminated areas.

Comments for Subsequent Investigations

12. The electromagnetic anomalies identified within the survey area and as potential buried objects relevant to the survey objectives should be excavated to confirm the source of the electromagnetic response. The excavation point and/or area must be referenced to the site survey grid and located in the center of the anomaly.
13. The survey grid coordinates were established using survey tapes. The stations and lines were picketed and marked over the ground and left in-place upon completion of the survey. After survey completion, if markings are unclear, the survey grid should be reconstructed prior to excavation activities, using all the information provided in this report and in the digital archive (e.g. GPS locations, photographs and additional location maps).
14. In all cases, excavation should be extended to a minimum depth of 2 metres to allow confident identification of the anomaly source.
15. It is recommended that this document be retained on site during any excavation activities. Excavation may reveal features not identified in the interpretation process due to the limitations of the technique.

APPENDIX B

GPR Instrumentation

Noggin GPRs are complete radar systems in a single package. Noggin family members provide a balance between flexibility and simplicity.

Simple, but optimized to address the real day-to-day technical challenges, Noggin GPRs are the workhorses of many GPR survey companies. Available in operating frequencies of 100, 250, 500 and 1000 MHz, Noggins cover the most common range of depth and resolution needed by GPR applications.

Users choose the Noggin system and the configuration that best suits their specific application and survey environment needs. Application focused users generally find one unit will address all their requirements. System configurations frequently enable interchange of Noggins, allowing customers to leverage initial investments into other applications.

APPENDIX C

ELECTROMAGNETIC THEORY AND APPLICATION

The EM method is based on the induction of electrical currents in subsurface conductors by electromagnetic waves which are generated on the surface. The EM source is commonly a closed loop (transmitter) in which a controlled alternating current produces a time-varying magnetic field. The time-variant magnetic field induces alternating currents (often called eddy currents) in subsurface conductors which produce a secondary time-variant magnetic field that is measured at the surface with another closed loop of wire (receiver).

The secondary field is often not in phase with the primary (transmitted) field. The secondary field is divided into the portion of the field that is in phase and the portion that is out of phase with the primary field. These quantities may be referred to using a variety of names; in-phase and quadrature components, or real and imaginary components. The quadrature component is linearly related to terrain conductivity under normal subsurface conditions.

Electromagnetic measurements facilitate rapid determination of the average terrain conductivity because they do not require direct electrical contact with the ground. A disadvantage is that unless measurements are taken at different coil spacing, little vertical information is gained. However, EM profiling can be effective in investigations for locating lateral discontinuities such as landfill boundaries, changes in soil composition, or in the search for buried objects.

Terrain conductivity is defined as the conductivity that the instrument would report if located over a homogenous half-space with exactly that conductivity. As the earth is seldom well characterized as a homogenous half-space, the instrument simply integrates the effects of all the subsurface variations and indicates an "apparent conductivity" as terrain conductivity. The units are millisiemens/meter or inverse ohm-meters times 1000.

The conductivity measurement is dependent upon the density, porosity, moisture content, and presence or absence of electrolytes or colloids of the subsurface materials. Typically, clay soils have a high conductivity due to substantial cation exchange capacity. These cations contribute to the electrolyte concentration.

To a lesser extent, the amount and composition of colloids may also contribute to measured conductivity. Bedrock typically has a lower conductivity because of high density and the generally lower porosity present within the rock matrix. The irregular nature of landfilled material and the frequent presence of ferrous metals provide for an electromagnetic response that typically contrasts the more homogeneous natural materials in an area.

Electromagnetic methods (EM) are frequently used in the search for minerals and in shallow geophysical applications related to engineering, groundwater and environmental investigations.

Electrical Properties of Subsurface Materials

Conduction of electricity in materials takes place through electronic or ionic processes. Solid conductive materials can be divided into three classes: metals, electron semiconductors, and solid electrolytes. In the shallow groundwater environment, it is expected that the only metallic conductors are related to man-made objects such as pipes, tanks, and metallic landfill material rather than natural metallic bodies.

Nearly all materials which are not true metal are electron semiconductors to some extent. The silicate rock-forming minerals in sedimentary formations are in the class of solid electrolytes.

Porosity, saturation, and pore fluid chemistry are much more important to the bulk electrical properties of a soil or rock than the electrical properties of the solid matrix. Most pore fluids contain some salts in solution and electrolytic conduction is the dominant conduction mechanism. The relative ability of a material to conduct electricity when a voltage is applied is expressed as conductivity in units of Siemens/meter (S/m).

Ground Penetrating Radar

Ground Penetrating Radar (GPR) is the general term applied to techniques which employ radio waves, typically in the 1 to 1000 MHz frequency range, to map structures and features buried in the ground (or in man-made structures). Historically, GPR was primarily focused on mapping structures in the ground; more recently GPR has been used in non-destructive testing of non-metallic structures.

The concept of applying radio waves to probe the internal structure of the ground is not new. Without doubt the most successful early work in this area was the use of radio echo sounders to map the thickness of ice sheets in the Arctic and Antarctic and sound the thickness of glaciers. Work with GPR in non-ice environments started in the early 1970s. Early work focused on permafrost soil applications.

GPR applications are limited only by the imagination and availability of suitable instrumentation. These days, GPR is being used in many different areas including locating buried utilities, mine site evaluation, forensic investigations, archaeological digs, searching for buried landmines and unexploded ordnance, and measuring snow and ice thickness and quality for ski slope management and avalanche prediction, to name a few.

*Signal propagation**

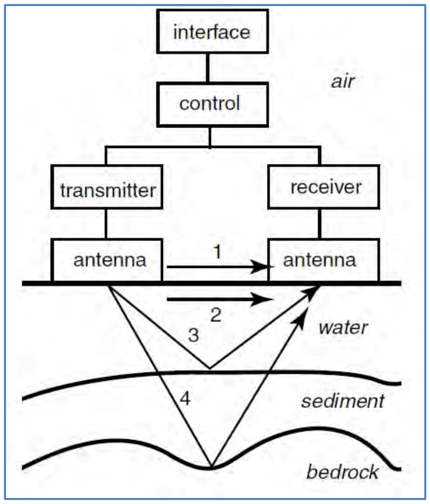
The strong relationship between the physical properties of materials (including water) and their electromagnetic properties enables the identification of physical structures in the subsurface using electrical methods (Davis & Annan, 1989; Dallimore & Davis, 1987; Delaney & Arcone, 1982; Scott et al., 1978).

Most geologic materials (in bulk form) are considered as semi-conductors, or dielectrics, thus they can be characterized by three electromagnetic properties: electrical conductivity, electric permittivity, and magnetic permeability. The electrical conductivity of a material is a measure of its ability to transmit a DC current and is inversely proportional to the voltage drop experienced across a given distance for a given DC current.

Magnetic permeability is defined as the ratio of the magnetic flux induction to the magnetizing force. The magnetic susceptibility of a material is a function of the permeability. Electrical permittivity is the ratio of the capacitance of an electrical condenser filled with a dielectric to the capacitance of the same condenser when evacuated. The movement of electromagnetic energy within the subsurface is governed by the propagation constant of the material it travels through.

*Signal reflection**

Ground penetrating radar principles are similar to those of reflection seismic, in that a pulse of energy is sent into the subsurface, and a portion of it is reflected back to the surface by interfaces between different materials. In contrast to seismic, GPR energy is electromagnetic, not vibrational, and the interfaces are dielectric, not sonic velocity interfaces. In water, the energy is transmitted with a near radial geometry (Davis & Annan, 1989). These results in several simple ray paths which the energy tends to follow, travelling between the transmitter and the receiver.



After the transmitter has emitted a signal, the first energy to arrive at the receiver is the direct air wave. This is the first because it travels directly from the transmitter to the receiver, through the air (at near the speed of light). As the travel time of the direct air wave is easily calculated and stays relatively constant, its arrival time is often used as a marker for static correction. The next return is the direct ground wave. It travels directly from the transmitter to the receiver through the top skin of the subsurface. The next returns are the reflections from the dielectric interfaces. They arrive in order of their depth (top first). The radar waves may also be refracted; however wide-angle reflection and refraction soundings have shown that refracted returns are not usually generated in normal profiling mode (Arcone & Delaney 1982). Due to the complexity of refracted radar waves, detailed analysis has yet to been done on refracted waves as it has in refraction seismic.

The three variables that affect the strength and arrival time of returns are: the strength of the reflections, the propagation velocity of the radar waves, and the rate of attenuation of the signal. Just as light is reflected from an interface between two substances with different refractive indexes, a portion of the energy in a radar energy pulse is reflected from an interface between two materials with different dielectric constants.

*Depth of penetration**

The depth to which GPR can image below the surface is dependent on three main factors:

1. the number of interfaces that generate reflections and the dielectric contrast at each interface,
2. the rate at which the signal is attenuated as it travels through the subsurface, and
3. the centre frequency of the antennas. As the GPR pulse arrives at each interface, a portion of it is returned to the surface and the rest continues into the next layer.

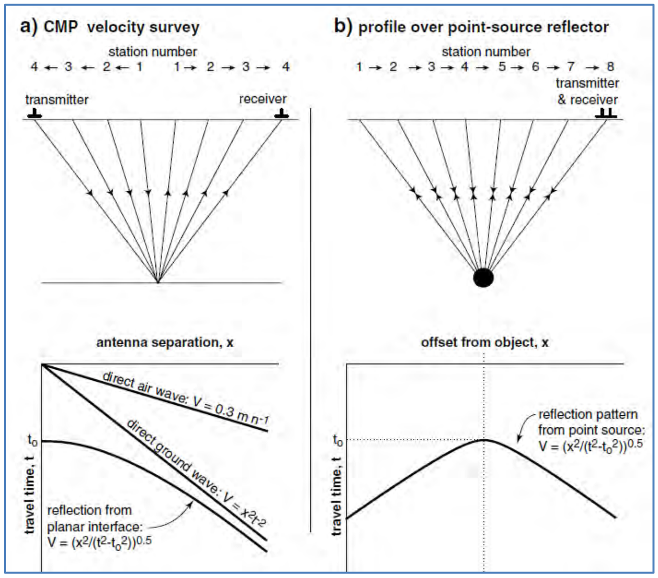
HEAD OFFICE
325 MATHESON BLVD. EAST
MISSISSAUGA, ON L4Z 1X8
(905) 629-8959

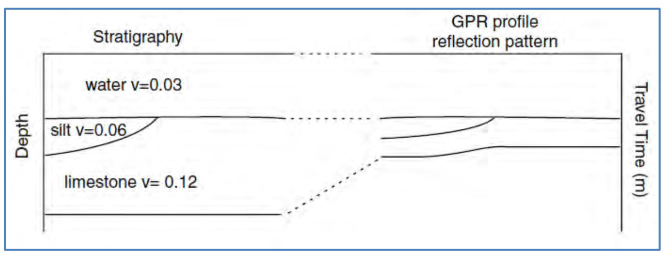
LONDON
#20-570 CLARKE ROAD
LONDON, ON N5V 3K5
(226) 721-0211

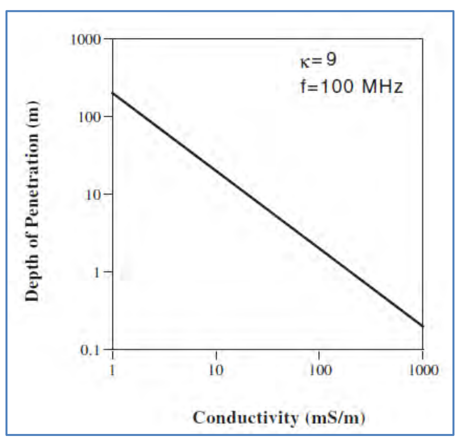
KITCHENER
#3-38 MCBRINE PLACE
KITCHENER, ON N2R 1G8
(519) 279-1126

OTTAWA
#204-2 BEAVERBROOK RD.
KANATA, ON K2K 1L1
(613) 287-7005

INFO@MULTIVIEW.CA
WWW.MULTIVIEW.CA







As the number of interfaces increases, the proportion of energy that propagates to depth is reduced. In addition, the greater proportion of energy that is reflected back to the surface at each interface, the less energy that is available to propagate deeper into the ground.

The conductivity of the material that a GPR signal is travelling through has a major influence on the depth to which the signal will penetrate. As the conductivity increases, the material acts more like a conductor than a semi-conductor. The conductive currents in a material are an energy dissipating mechanism for an EM field. In this case, energy is irreversibly extracted from the EM field and transferred to the medium it is in.

The frequency used is also of importance since the resolution of the system and the rate of signal attenuation is proportional to the frequency (Fig. 8) of the GPR system. With lower frequencies, the wavelength is longer and as a result there is less attenuation due to conductive losses and less scattering from the chaotic reflections from small clutter. The main disadvantage of using very low frequencies is that the resolution decreases, such that the thickness of small layers can no longer be measured and small objects are not detected.

A practical consideration is that, as the frequency decreases, the length of the antennas increase in size and become more difficult to work with. In fresh-water lakes it is reasonable to expect a depth of penetration of 20–30m and then a propagation of several metres into the subbottom, depending on the material type (Sellman et al., 1992; Moorman & Michel 1997).

*Feature detection and resolution**

The three main factors that determine where an object or a thin layer of material will be detected are the size of the object or layer thickness, the frequency of the GPR system, and the propagation velocity of the medium. Higher frequency antennas generate shorter waves and thus have finer resolution and can detect smaller objects. The propagation velocity of the medium is important because the size of the wavelet in the subsurface is not only determined by the frequency of the antenna that created it, but also the velocity at which it propagates through the subsurface. If a pulse is forced to slow down in a medium with a slower propagation velocity (e.g., water), the pulse is compressed to accommodate the slower velocity.

The precise vertical resolution can be determined by surveying two reflectors that intersect at a gentle angle (Sheriff, 1985), however wave theory suggests that the greatest vertical resolution that can be expected is 1/4 of the size of a wavelet (Sheriff & Geldart, 1982). The size of the wavelets that are recorded on a GPR profile is a function of the pulse width of the original transmitted pulse. The pulse width produced by the 100MHz and 50MHz antennae and the resultant maximum theoretical resolution in various geologic materials is displayed in the following table.

Material	100 MHz		50 MHz	
	Pulse width (m)	Theoretical resolution (m)	Pulse width (m)	Theoretical resolution (m)
water	0.33	0.08	0.66	0.16
ice	1.6	0.4	3.2	0.8
saturated sand	0.6	0.15	1.2	0.3
saturated clay	1.0	0.25	2.0	0.5
limestone	1.2	0.3	2.4	0.6
shale	1.0	0.25	2.0	0.5
granite	1.3	0.33	2.6	0.66

The horizontal resolution is a function of the spacing between traces and the footprint of the radar pulse. The wavelength, radiation pattern and, water depth determine the size of the footprint. For common dipole antennas, Annan (1992) provides a way to estimate the footprint using:

$$A = \frac{\lambda}{2} + \frac{d}{\sqrt{\kappa - 1}}.$$

Where *A* is the long axis diameter of the oval footprint, *d* is the distance (or depth), and *κ* is the dielectric constant of the medium (80 for water). The short axis of the oval footprint is roughly half the length of the long axis. For example, at a depth of 20 m, in water, the effective footprint of a 50MHz pulse has a mean diameter of approximately 10 m. This is a little smaller than the footprint of an acoustic subbottom profiler (Sellmann et al., 1992).

*Survey design-system parameters**

Most of the GPR systems currently on the market allow for the adjustment of many of the system parameters enabling the optimization of the system for the specific survey environment.

The main system parameters that can be adjusted include: operating frequency, time window, sampling interval, stacking, antenna spacing, antenna orientation. The frequency of antennas chosen influence the exploration depth that is possible, the resolution of the data, and the amount of clutter that is present on the profiles. As the frequency is lowered, the depth of penetration is increased and the amount of clutter present of the profiles decreases; however, the ability to detect and resolve smaller objects decreases.

*Survey design-profile parameters**

The profile parameters that need to be taken into consideration when designing a GPR survey include station spacing along the survey profile, spacing between profiles, and the type of survey grid desired. Ensuring that the station spacing is close to enable interpretation of the profile is very important when designing a survey. Station spacing is a function of the frequency used, the dielectric constant of the material, and the complexity of the subsurface. The profiles should be close enough that the footprint of the GPR overlaps from one profile to the next.

*Data processing and interpretation**

Compared to seismic data, relatively little processing is generally done to GPR data. A gain function is usually applied to the data to emphasize the weaker returns. There are a number of gain functions that can be applied depending of the data quality and the profile elements that you want to emphasize (e.g., automatic gain control (AGC), spherical and exponentially compensation (SEC) gain, user defined gain function). An example of the effects of different gain functions are displayed in Moorman & Michel (1997).

Temporal filtering involves filtering along the time axis of each trace. This can involve high-pass, low-pass filters or frequency filters such as Fourier analysis. These filters involve reduction or elimination of certain unwanted returns along each trace. For example by running mean along each trace, high frequency noise can be reduced (see Moorman & Michel, 1997).

As with temporal filtering, spatial filtering is employed to remove unwanted spatial variations. One technique is to perform a running mean of data points at the same time across traces. This type of trace to trace running mean is used to emphasize horizontal reflections while de-emphasizing sloping returns. Other types of spatial filters can be applied to emphasize sloping reflections such as trace-to-trace differential filters.

There are also a number of more advanced filtering techniques such as migration that are occasionally employed to solve a specific problem with the data set. However, these more complicated filtering techniques are generally too time consuming to be regularly applied to all data sets.

*Feature identification**

Feature identification is primarily accomplished by examining the reflection characteristics (e.g., continuous line, hyperbola, or multiple discontinuous chaotic reflections). By comparing the reflection character to known examples, one can construct a radar stratigraphic facies interpretation of the data. Radar stratigraphic examples have been published from a few environments to date (e.g., Beres&Haeni, 1991; van Heteren et al., 1994; Smith & Jol, 1997).

In some applications by studying the pulse polarity you can determine relative magnitude of the dielectric constant on either side of an interface (Arcone et al., 1995; Moorman & Michel, in press). However, this probably has limited use in studying lake basin sediments.

Along with identifying features of interest, the interpreter must be alert to the potential for the incorporation of unwanted returns into the GPR profile. Because the energy is being radially emitted from the antenna, in areas of very uneven topography there is the potential to recording a reflection from a feature that is not beneath the antennas, but off to the side or even nearby on the surface. These are called offline reflections. This is most evident when the profile is parallel to a very steep lake bottom slope (i.e., greater than 45 degrees). When the slope is greater than 45 degrees, reflections will not be directed back to the receiver, but off to the side. Similarly, if the profile runs near to a steep slope, unwanted offline reflections may be recorded from the slope off to the side.

*Applications**

Since the early work of Annan & Davis (1977) and Kovacs (1978), it has been apparent that GPR is an effective tool for mapping the depth of fresh water lakes. Using a 120MHz system, Trumen et al. (1991) found that water depth in a reservoir could be mapped with confidence. When the GPR profiles were correlated to measured depths, an R2 value was calculated to be 0.989. Kovacs (1991) showed that GPR was more effective at mapping bathymetry than sonar when the water depth was shallow and when the weed concentration is high. Sellman et al. (1992) & Delaney et al. (1992) demonstrated that 100MHz GPR has a resolution similar to a 7 kHz acoustic survey for measuring water depth, and that the GPR was far superior for imaging the bedding structure. Using 50MHz antennas, up to 30m of water can be mapped, with up to 7m of penetration into the bed (Sellman et al., 1992).

A number of authors have reported mapping the distribution and thickness of lacustrine sediments (Delaney et al. 1992; Moorman & Michel, 1997). Smith & Jol have under taken extensive work on mapping the structure of modern and ancient deltaic deposits (e.g., Jol & Smith, 1991, 1992; Smith & Jol, 1997). Lowe (1985) reported being able to discern multiple layers of lacustrine sediments and tephra up to 10m depth.

Various trials have been undertaken showing the capabilities of GPR for mapping the thickness and stratigraphy of organic deposits in ponds and bogs (Worsfold et al., 1986; Warner et al., 1990; Hanninen, 1992; Doolittle et al., 1992; Mellett, 1995).

Depending on how many the physical properties vary with depth, GPR results varied from just detecting the bottom of the peat to differentiating the actual peat stratigraphy. As ice enables radar pulses to propagate with little attenuation, GPR has been shown effective for imaging the thickness of lake, sea and river ice (Arcone et al., 1997; Kovacs, 1978; Kovacs & Morey, 1979, 1985, 1992). As the dielectric contrast between ice and water is much greater than that of ice and air, O'Niell &Arcone (1991) found that lake ice thickness could be detected from a helicopter.A number of technical issues complicate the collection of good quality data, however, in some situations, it is feasible.

*(*information captured from Brian J. Moorman, Ground-Penetrating Radar Applications, In Paleolimnology, 2001).*

Appendix ‘E’

AASHTO DARWin Pavement Design
and Analysis

1997 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

Flexible Structural Design

80-kN ESALs Over Initial Performance Period	500,000
Initial Serviceability	4.5
Terminal Serviceability	2.5
Reliability Level	90 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	30,000 kPa
Stage Construction	1
Calculated Design Structural Number	95 mm

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di)(mm)	Width (m)	Calculated SN (mm)
1	AC Surafce, Class A	0.42	1	100	7.5	42
2	Aggregate Base - crushed stone	0.14	1	150	7.5	21
3	Aggregate Subbase	0.09	1	450	7.5	41
Total	-	-	-	700	-	104

Layered Thickness Design

Thickness precision Actual

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Spec Thickness (Di)(mm)	Min Thickness (Di)(mm)	Elastic Modulus (kPa)	Width (m)	Calculated Thickness (mm)	Calculated SN (mm)
1	AC Surface, Class A	0.42	1	-	100	2,400,000	7.5	110	46
2	Agg. Base - crushed st...	0.14	1	-	150	210,000	7.5	150	21
3	Aggregate Subase - gr...	0.09	1	-	450	205,000	7.5	450	41
Total	-	-	-	-	-	-	-	710	108