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July 25, 2016

Amec Foster Wheeler File: LT164504.100

Public Works and Government Services Canada
1650, 635 - 8th Avenue, SW
Calgary, Alberta T2P 3M3

**Attention: Mr. Mark Burke, P.Eng.
Project Manager, Southern Alberta**

**RE: GEOTECHNICAL INVESTIGATION
Proposed Infrastructure Renewal
Waterton Lakes National Park (Townsite), Alberta**

1.0 INTRODUCTION

At the request of Public Works and Government Services Canada, Amec Foster Wheeler Environment & Infrastructure (Amec Foster Wheeler) has carried out a geotechnical investigation to support the design and construction of proposed watermain, sanitary sewer and surfacing upgrades throughout the northern portion of the Waterton Townsite.

This report summarizes the results of the field work and laboratory testing, and provides geotechnical discussion and recommendations to support the proposed project. This report has been revised to also include proposed storm sewer construction along the rear lane west of Evergreen Avenue.

2.0 METHODOLOGY AND RESULTS

2.1 Methodology

In order to assess the subsurface soil and groundwater conditions at the various streets indicated, Amec Foster Wheeler visited the sites on March 24, 2016 and monitored the drilling of seven boreholes. An additional seven boreholes were advanced at the site on July 14, 2016. The boreholes were drilled at the locations denoted on Figure 1 as BH16-01 to BH16-14, inclusive, at the following general locations.

- BH16-01 was drilled along Mountain View Road just west of Wind Flower Avenue;
- BH16-02 to BH16-04 were drilled along Cameron Falls Drive between Fountain Avenue and Wind Flower Avenue;
- BH16-05 was drilled along Clematis Avenue just east of Lupine Lane;
- BH16-06 was drilled along Harebell Road, just north of Lupine Lane;



- BH16-07 was drilled between Harebell Road and Wind Flower Avenue and North of Vimy Avenue; and
- BH16-08 to BH16-14 were drilled along the rear lane west of Evergreen Avenue.

The boreholes were advanced using a truck-mounted drill equipped with continuous flight solid stem augers operated by Chilako Drilling Services, and were terminated at depths ranging between of about 2.6 m and 3 m below existing grade. During the drilling, representative samples of the subsurface strata were recovered from the auger flights. Upon completion of the drilling, the boreholes were backfilled with the auger cuttings.

The drilling was carried out under the supervision of an Amec Foster Wheeler technician, who collected the soil samples and logged the subsurface conditions. The recovered soil samples were transported to Amec Foster Wheeler's Lethbridge laboratory for further review by a geotechnical engineer and selected laboratory classification testing. Laboratory testing for this project consisted of routine moisture content determinations, with results presented on the appended borehole logs.

Samples remaining will be stored for a period of three months following issuance of this report at which time they will be discarded unless we are requested otherwise by the Client.

2.2 Soil and Groundwater Conditions

The subsurface conditions encountered are detailed on the attached borehole logs and summarized in the following paragraphs.

Boreholes BH16-01 to BH16-07

Topsoil

With the exception of borehole BH16-04, the boreholes were each surfaced with layer of topsoil ranging between about 0.1 m to 0.15 m thick.

Crushed Gravel

Borehole BH16-04 was surface with a 0.2 m thick layer of crushed gravel.

Sand & Gravel

The predominant natural mineral soil encountered in each of the borehole was sand and gravel. The sand and gravel was described as fine grained and silty with occasional cobbles, brown, and compact (based on tactile observations and observed drilling resistance).

Based on laboratory testing, the *in situ* water content of the sand and gravel ranged between about 3 percent and 5.5 percent, generally indicative of moist to very moist soil conditions.



Boreholes BH16-08 to BH16-14

The boreholes along the rear lane west of Evergreen Avenue were each surface with a layer of asphalt, underlain by low plastic clay described as silty, sandy and gravelly. The clay was generally in a firm and moist condition, and extended to depths ranging between about 1.2 m and 3.0 m below the roadway surface. At boreholes BH16-09 to BH16-14, a layer of sand and gravel was encountered underlying the upper clay soils. The sand and gravel was described as medium to coarse grained, clayey, and moist to very moist.

Sloughing and Groundwater Conditions

The boreholes were each dry upon completion of the drilling. It is noted that the groundwater conditions are expected to fluctuate seasonally in response to spring thaw and periods of heavy precipitation, and may differ at the time of construction.

3.0 GEOTECHNICAL DISCUSSION AND RECOMMENDATIONS

As indicated previously, it is understood that watermain, sanitary sewer and surface upgrades are proposed throughout the northern portion of the Waterton Townsite, as well as storm sewer construction along the rear lane west of Evergreen Avenue. It is anticipated that the installation of underground utility pipe will generally be by conventional open cut techniques.

In general, the existing soil and groundwater conditions along the subject streets will support conventional open cut construction for the proposed pipe installation, followed by conventional roadway reconstruction.

Based on our understanding of the proposed development as discussed above in conjunction with the results of the current investigation, the following paragraphs provide geotechnical discussion and recommendations pertaining to site preparation, excavations, frost protection requirements, roadway reconstruction, and pavement construction.

3.1 Excavations and Dewatering

All excavations should conform to Part 32 of the 2009 Alberta Occupational Health and Safety Code.

Where spatial restrictions do not allow for the required safe trench sideslope inclinations, conventional shoring (i.e., trench boxes) can be considered. For shoring design, the following parameters can be used for the upper fill and native soils:



Table 1: Parameters for Shoring Design

Parameter	Natural Sand & Gravel Soils
Total Unit Weight, γ , kN/m ³	22
Active Earth Pressure Coefficient, k_a	0.29

The weight of the adjacent structures must also be considered in the calculation of the lateral earth pressures where these structures fall within a line drawn up at 45° from the base of the excavations. Where trench boxes or shoring are used, adjacent structures should be inspected prior to and following construction to ensure damage has not occurred to the foundations.

Based on the results of the investigation, groundwater accumulation is not generally anticipated within service trenches above 3.0 m depth. However, groundwater in the Waterton Townsite is known to fluctuate rather dramatically throughout the year and as a result of the level of water in the adjacent Upper Waterton Lake.

While minor groundwater accumulations within the services trenches can likely be accommodated by conventional sump pumping techniques, more extensive dewatering measures, such as the use of well points, would likely be required where excavation below the groundwater table is required. Amec can assist further in this regard, upon request.

3.2 Service Construction and Backfill

Bearing problems are not anticipated for pipes founded on the natural sand and gravel deposits.

The trenches above the service pipes should be backfilled with inorganic on-site soils placed in maximum 300 mm thick lifts and compacted to at least 98 percent of SPMDD. Bedding sand or gravel will be required for the pipe installations in accordance with the manufacturer's recommendations.

The natural on-site excavated sand and gravel can be generally used as trench backfill, provided the material is screened of boulders larger than about 150 mm, and moisture conditioned to within three percent of the optimum moisture content as determined by the Standard Proctor test. In this regard, some moisture conditioning of the soils should be anticipated.

3.3 Roadway Reconstruction

It is understood that the excavations will generally encompass the full width of the various roadways. Accordingly, full width reconstruction of the roadway has been indicated.

Prior to placement of granular fill or asphalt, areas to be paved should be stripped of all existing deleterious material, scarified and moisture conditioned to 300 mm depth, and be recompacted to a minimum of 98 percent of SPMDD at a moisture content within two percent of optimum.



Any soft spots revealed by this or any other observations should be over-excavated and backfilled with approved material.

Provided the preceding recommendations are followed, the pavement thickness design requirements given in the following table are recommended for the anticipated traffic loading and subgrade conditions.

Table 2: Recommended Pavement Structure Thicknesses

Pavement Layer	Compaction Requirements	Medium Duty Pavement Structure Thicknesses
Asphaltic Concrete	93% Maximum Theoretical Density	100 mm Type III*
Granular Base Course*	100% SPMDD	75 mm
Reclaimed asphalt*	100% SPMDD	75 mm
<p>*Notes: * City of Lethbridge Specification * The reclaimed asphalt (millings) should be well graded with a maximum size of 25 mm. The subgrade must be moisture conditioned to a depth of 300 mm and compacted to 98% SPMDD.</p>		

The recommended pavement structure provided in the above table is based on the natural subgrade soil properties determined from visual examination and textural classification of the soil samples. Consequently, the recommended pavement structures should be considered for preliminary design purposes only, and should be verified during construction based on actual site subgrade conditions.

If construction is undertaken under adverse weather conditions (i.e., wet or freezing conditions) subgrade preparation and granular base requirements should be reviewed by the geotechnical engineer. As well, if only a portion of the pavement will be in place during construction, the granular base may have to be thickened, and/or the subgrade improved with a geotextile separator.

Samples of both the granular base aggregates and asphaltic concrete paving materials should be checked for conformance to the City of Lethbridge specifications prior to use on site, and during construction.

Good drainage provisions will optimize pavement performance. The pavement subgrade and the finished pavement surface should be free of depressions and should be sloped (preferably at



a minimum grade of two percent) to provide effective surface drainage toward catchbasins. Surface water should not be allowed to pond adjacent to the outside edges of pavement areas.

A program of in situ density testing must be carried out to verify that satisfactory levels of compaction are being achieved.



4.0 CLOSURE

The recommendations given in the above sections are based upon interpreted conditions found within the 14 boreholes drilled at this site. Should subsurface conditions other than those presented in this report be encountered during construction, the Client should notify our office so that these recommendations can be reviewed.

Soil conditions, by their nature, can be highly variable across a site. A contingency should be included in the construction budget to allow for the possibility of variations in soil conditions, which may result in modification of the design, and/or changes in the construction procedures.

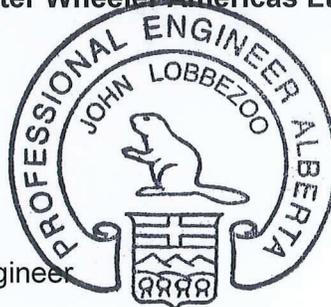
Amec Foster Wheeler requests the opportunity to review the design drawings and the installation of the foundations to confirm that the recommendations in this report have been correctly interpreted and implemented. If not afforded the opportunity to conduct this review, Amec Foster Wheeler will not accept responsibility for the interpretation of this report. Amec Foster Wheeler would be pleased to provide any further information that may be needed during design and to advise on the geotechnical aspects of specifications for inclusion in contract documents.

This report has been prepared for the exclusive use of Public Works and Government Services Canada and their designers for the specific application to the development described in this report. Any use that a third party makes of this report, or any reliance or decisions based on this report are the sole responsibility of those parties. This report has been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty, express or implied, is made.

Yours truly,

Amec Foster Wheeler Environment & Infrastructure
A division of Amec Foster Wheeler Americas Ltd.

John Lobbezoo, P.Eng.
Geotechnical Project Engineer



Co-Authored by:
Mohamadjavad Sheikhtaheri, M.A.Sc
Geotechnical EIT

Reviewed by:
Kevin Spencer, P.Eng.
Associate Geotechnical Engineer

APEGA PERMIT P04546

Attachments: Figure 1: Borehole Location Plan
Borehole Logs
Explanation of Symbols and Terms



Amec Foster Wheeler Environment & Infrastructure 469 - 40th Street South Lethbridge, Alberta CANADA T1J 4M1 Tel. (403) 327-7474 Fax (403) 327-7682				Public Works and Government Services Canada					
TITLE	BOREHOLE LOCATION PLAN			DWN BY:	BJ	DATUM:	NA	DATE:	JULY 2016
PROJECT	Waterton Townsite Streetworks PHASE C Waterton Lakes National Park, Alberta			CHK'D BY:	JS	PROJECT NO:	LT164504.100 FIGURE 1		
				SCALE:	NTS				

PROJECT: Waterton Townsite Infrastructure Renewal	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-01
CLIENT: Public Works and Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT154508.800
LOCATION: Mountain View Rd W of Wind Flower (refer to Figure 1)		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

Depth (m)	STANDARD PEN (N)		SOIL SYMBOL	SOIL DESCRIPTION	SPT (N)	SAMPLE TYPE	SAMPLE NO	OTHER TESTS COMMENTS	Depth (m)
	PLASTIC	M.C.							
0			 TOPSOIL GRAVELLY SAND - fine grained, coarse grained gravel, silty, sandy, moist						0
1							1S1		1
2									2
3									3
3	End of Borehole at 3.0 m depth								3
4	Notes:								4
5	1. Borehole log to be read in conjunction with Amec Foster Wheeler report LT154508.800. For definitions of terms and symbols used on logs refer to sheets following logs.								5
6	2. Borehole open and dry at completion of drilling.								6
7	3. Borehole backfilled with drill cuttings.								7
8									8
9									9
10									10

BHLOGS.GPJ 16/04/27 04:36 PM (BOREHOLE LOG)

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LOGGED BY: MG	COMPLETION DEPTH: 3.00 m
REVIEWED BY: JL	COMPLETION DATE: 24/3/16
	Page 1 of 1

PROJECT: Waterton Townsite Infrastructure Renewal	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-02
CLIENT: Public Works and Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT154508.800
LOCATION: Cameron Falls Dr between Fountain & Wind Flower (refer to Figure 1)		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

Depth (m)		SOIL SYMBOL	SOIL DESCRIPTION	SPT (N)	SAMPLE TYPE	SAMPLE NO	OTHER TESTS COMMENTS	Depth (m)
0			TOPSOIL					
0			GRAVELLY SAND - fine grained, coarse grained gravel, silty, sandy, moist			1S1		
1								
2								
2.6			End of Borehole at 2.6 m depth					
3			Notes: 1. Borehole log to be read in conjunction with Amec Foster Wheeler report LT154508.800. For definitions of terms and symbols used on logs refer to sheets following logs. 2. Borehole open and dry at completion of drilling. 3. Borehole backfilled with drill cuttings.					
4								
5								
6								
7								
8								
9								
10								

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Amec Foster Wheeler Environment & Infrastructure	LOGGED BY: MG	COMPLETION DEPTH: 2.60 m
	REVIEWED BY: JL	COMPLETION DATE: 24/3/16
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PROJECT: Waterton Townsite Infrastructure Renewal	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-03
CLIENT: Public Works and Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT154508.800
LOCATION: Cameron Falls Dr between Fountain & Wind Flower (refer to Figure 1)		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

Depth (m)	STANDARD PEN (N)		SOIL SYMBOL	SOIL DESCRIPTION	SPT (N)	SAMPLE TYPE	SAMPLE NO	OTHER TESTS COMMENTS	Depth (m)
	PLASTIC	M.C.							
0			TOPSOIL						
0.5			GRAVELLY SAND - fine grained, coarse grained gravel, silty, sandy, moist				3S1		
1									
2									
3									
3			End of Borehole at 3.0 m depth						
4			Notes: 1. Borehole log to be read in conjunction with Amec Foster Wheeler report LT154508.800. For definitions of terms and symbols used on logs refer to sheets following logs. 2. Borehole open and dry at completion of drilling. 3. Borehole backfilled with drill cuttings.						
5									
6									
7									
8									
9									
10									

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LOGGED BY: MG	COMPLETION DEPTH: 3.00 m
REVIEWED BY: JL	COMPLETION DATE: 24/3/16
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PROJECT: Waterton Townsite Infrastructure Renewal	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-04
CLIENT: Public Works and Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT154508.800
LOCATION: Cameron Falls Dr between Fountain & Wind Flower (refer to Figure 1)		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

Depth (m)	STANDARD PEN (N)		SOIL SYMBOL	SOIL DESCRIPTION	SPT (N)	SAMPLE TYPE	SAMPLE NO	OTHER TESTS COMMENTS	Depth (m)
	20	40							
0				CRUSHED GRAVEL GRAVELLY SAND - fine grained, coarse grained gravel, silty, sandy, moist					0
1							2S1		1
2				End of Borehole at 2.0 m depth					2
3				Notes: 1. Borehole log to be read in conjunction with Amec Foster Wheeler report LT154508.800. For definitions of terms and symbols used on logs refer to sheets following logs. 2. Borehole open and dry at completion of drilling. 3. Borehole backfilled with drill cuttings.					3
4									4
5									5
6									6
7									7
8									8
9									9
10									10

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LOGGED BY: MG
REVIEWED BY: JL

COMPLETION DEPTH: 2.00 m
COMPLETION DATE: 24/3/16

PROJECT: Waterton Townsite Infrastructure Renewal	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-05
CLIENT: Public Works and Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT154508.800
LOCATION: Clematis Ave W of Lupine (refer to Figure 1)		ELEVATION:
SAMPLE TYPE	<input type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

Depth (m)	STANDARD PEN (N)		SOIL SYMBOL	SOIL DESCRIPTION	SPT (N)	SAMPLE TYPE	SAMPLE NO	OTHER TESTS COMMENTS	Depth (m)
	PLASTIC	M.C.							
0			TOPSOIL						0
0.5	20	40	GRAVELLY SAND - fine grained, coarse grained gravel, silty, sandy, moist			1S1			0.5
1									1
2									2
3									3
3			End of Borehole at 3.0 m depth						3
4			Notes: 1. Borehole log to be read in conjunction with Amec Foster Wheeler report LT154508.800. For definitions of terms and symbols used on logs refer to sheets following logs. 2. Borehole open and dry at completion of drilling. 3. Borehole backfilled with drill cuttings.						4
5									5
6									6
7									7
8									8
9									9
10									10

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LOGGED BY: MG	COMPLETION DEPTH: 3.00 m
REVIEWED BY: JL	COMPLETION DATE: 24/3/16
	Page 1 of 1

PROJECT: Waterton Townsite Infrastructure Renewal	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-06
CLIENT: Public Works and Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT154508.800
LOCATION: Harebell Rd N of Lupine (refer to Figure 1)		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

Depth (m)	STANDARD PEN (N)		SOIL SYMBOL	SOIL DESCRIPTION	SPT (N)	SAMPLE TYPE	SAMPLE NO	OTHER TESTS COMMENTS	Depth (m)
	20	40							
0				TOPSOIL					
0.5				GRAVELLY SAND - fine grained, coarse grained gravel, silty, sandy, moist			1S1		
1									
2				... occasional cobbles below 2.4 m depth					
2.7				End of Borehole at 2.7 m depth					
3				Notes: 1. Borehole log to be read in conjunction with Amec Foster Wheeler report LT154508.800. For definitions of terms and symbols used on logs refer to sheets following logs. 2. Borehole open and dry at completion of drilling. 3. Borehole backfilled with drill cuttings.					
4									
5									
6									
7									
8									
9									
10									

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Amec Foster Wheeler Environment & Infrastructure	LOGGED BY: MG	COMPLETION DEPTH: 2.70 m
	REVIEWED BY: JL	COMPLETION DATE: 24/3/16
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PROJECT: Waterton Townsite Infrastructure Renewal	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-07
CLIENT: Public Works and Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT154508.800
LOCATION: Between Harebell & Wind Flower, N of Vimy (refer to Figure 1)		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

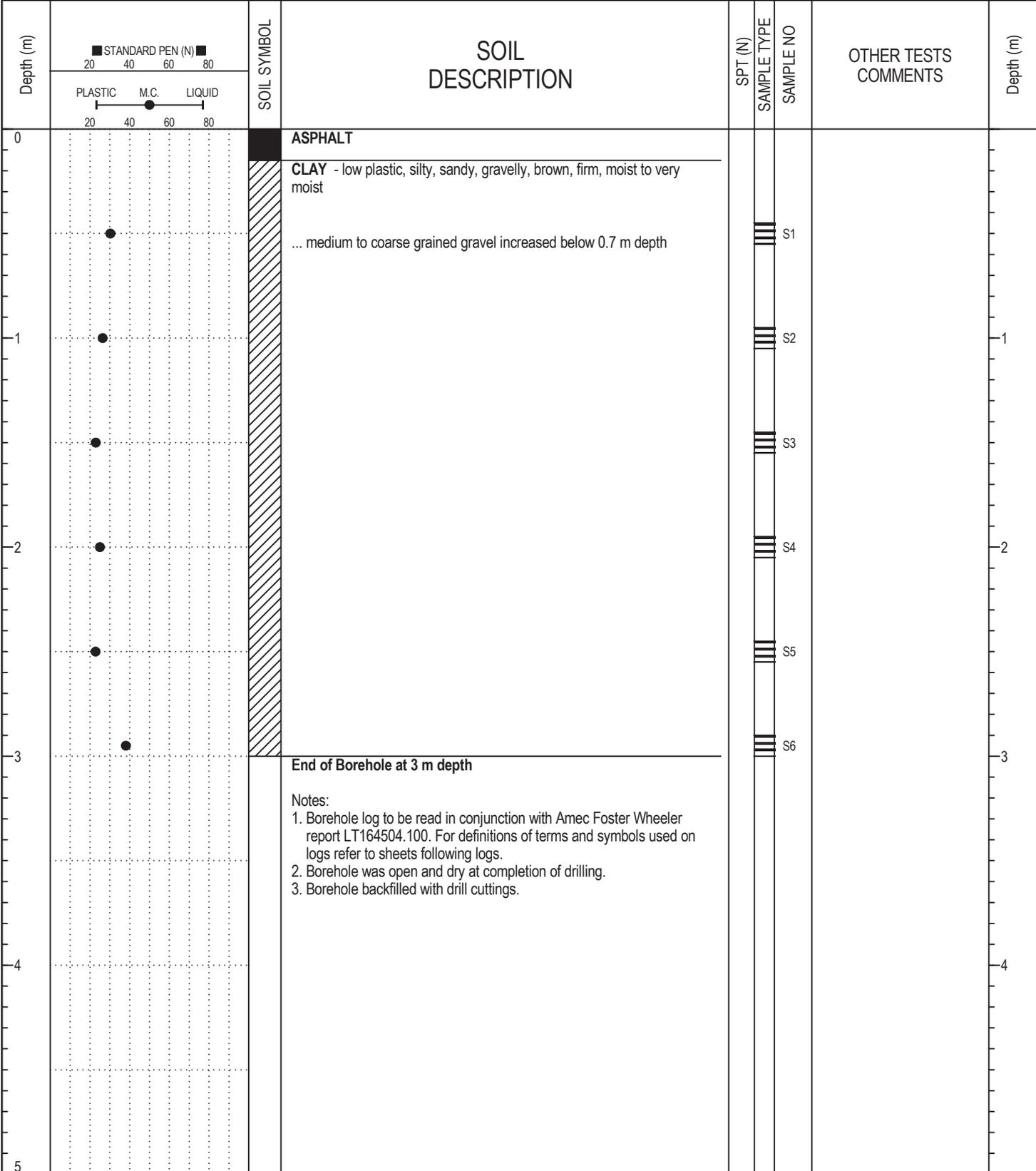
Depth (m)		SOIL SYMBOL	SOIL DESCRIPTION	SPT (N)	SAMPLE TYPE	SAMPLE NO	OTHER TESTS COMMENTS	Depth (m)
0			TOPSOIL					
0			GRAVELLY SAND - fine grained, coarse grained gravel, silty, sandy, moist			1S1		
1								
2								
2.8			End of Borehole at 2.8 m depth					
3			Notes: 1. Borehole log to be read in conjunction with Amec Foster Wheeler report LT154508.800. For definitions of terms and symbols used on logs refer to sheets following logs. 2. Borehole open and dry at completion of drilling. 3. Borehole backfilled with drill cuttings.					
4								
5								
6								
7								
8								
9								
10								

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LOGGED BY: MG	COMPLETION DEPTH: 2.80 m
REVIEWED BY: JL	COMPLETION DATE: 24/3/16
	Page 1 of 1

PROJECT: Waterton Townsite Street Works	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-08
CLIENT: Public Works & Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT164504.100
LOCATION: Rear lane west of Evergreen Avenue; Refer to Figure 1		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

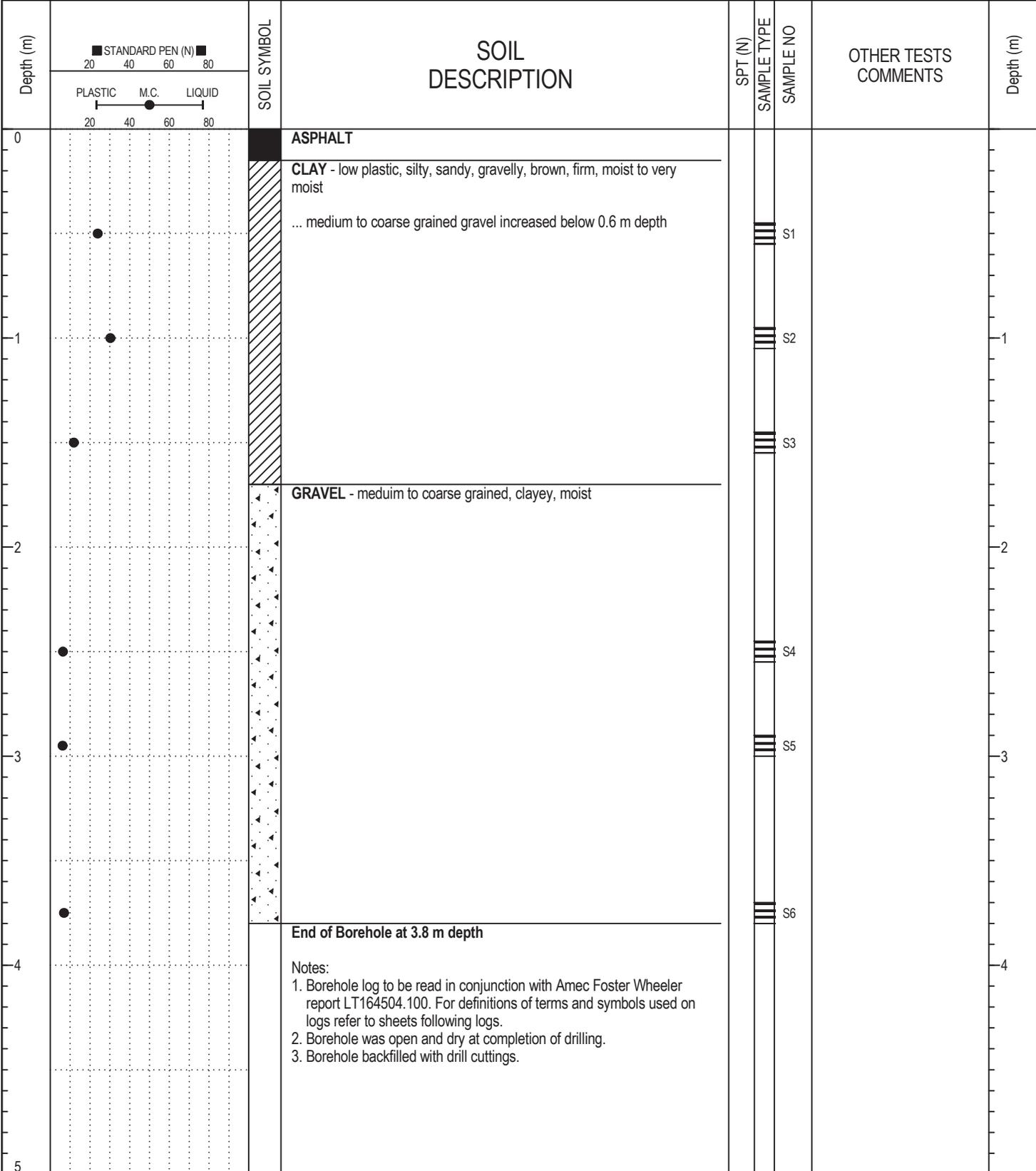


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LOGGED BY: MS	COMPLETION DEPTH: 3.00 m
REVIEWED BY: JL	COMPLETION DATE: 14/7/16
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PROJECT: Waterton Townsite Street Works	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-09
CLIENT: Public Works & Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT164504.100
LOCATION: Rear lane west of Evergreen Avenue; Refer to Figure 1		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

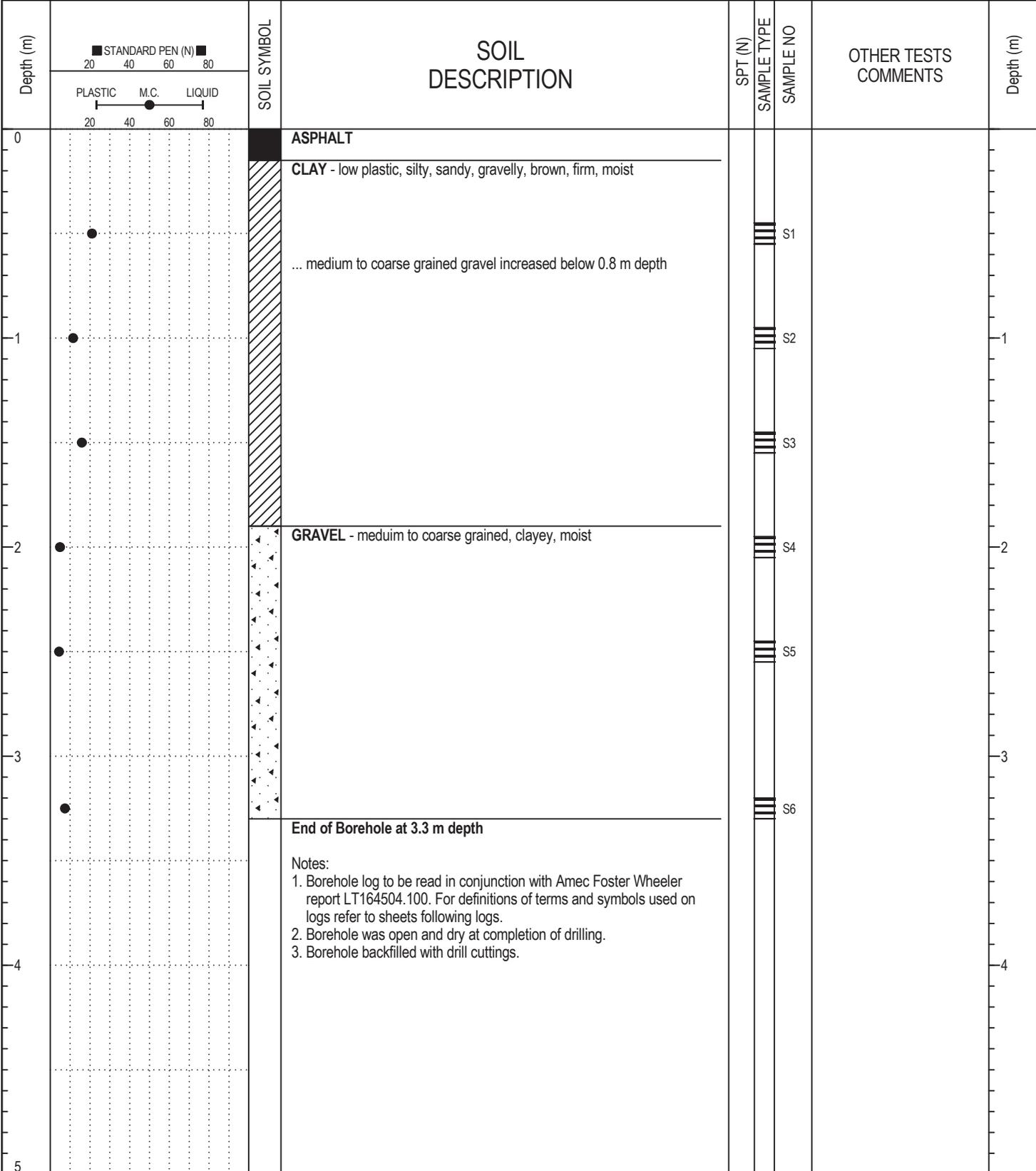


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LOGGED BY: MS	COMPLETION DEPTH: 3.80 m
REVIEWED BY: JL	COMPLETION DATE: 14/7/16
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PROJECT: Waterton Townsite Street Works	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-10
CLIENT: Public Works & Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT164504.100
LOCATION: Rear lane west of Evergreen Avenue; Refer to Figure 1		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

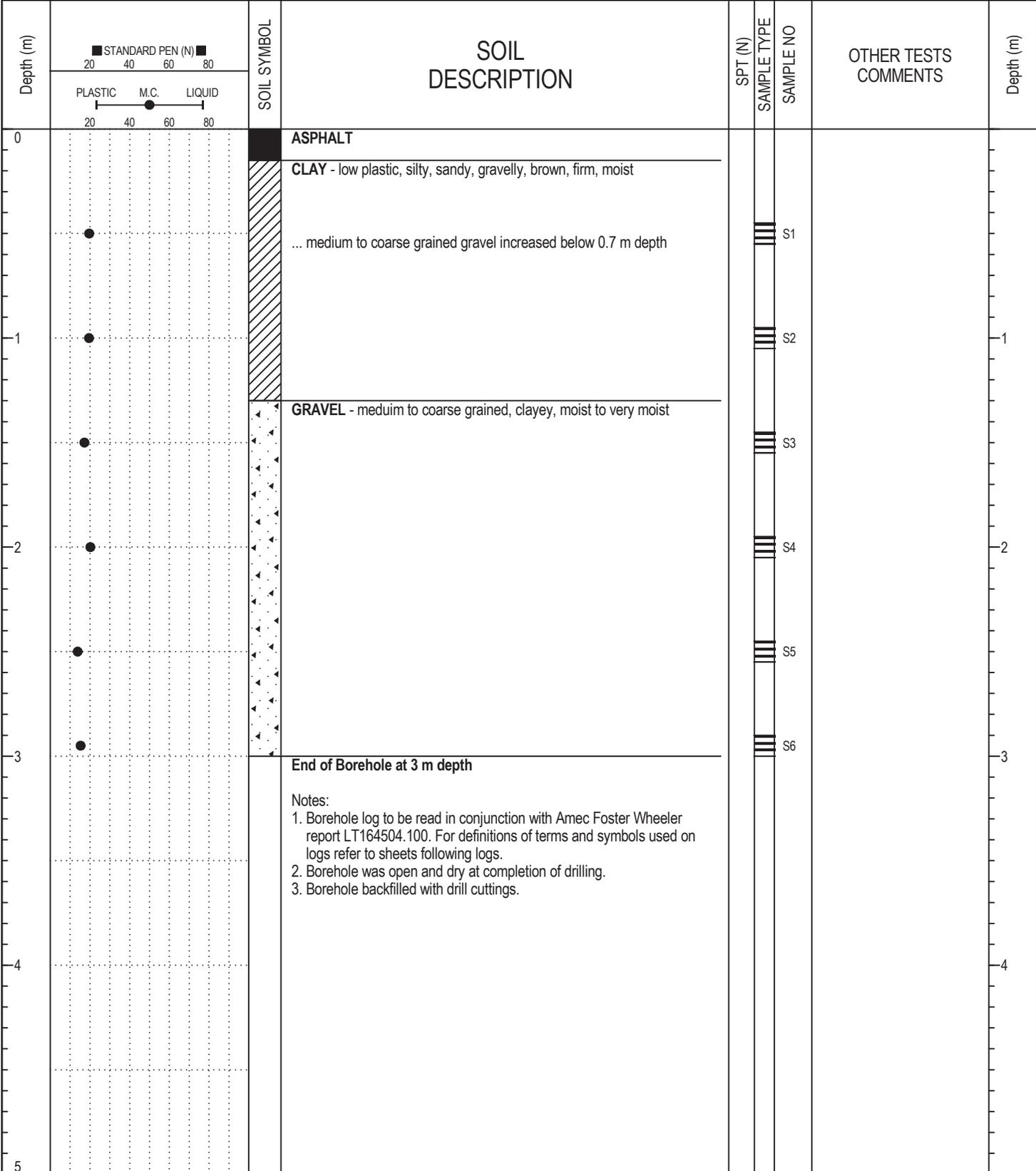


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LOGGED BY: MS	COMPLETION DEPTH: 3.30 m
REVIEWED BY: JL	COMPLETION DATE: 14/7/16
	Page 1 of 1

PROJECT: Waterton Townsite Street Works	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-11
CLIENT: Public Works & Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT164504.100
LOCATION: Rear lane west of Evergreen Avenue; Refer to Figure 1		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

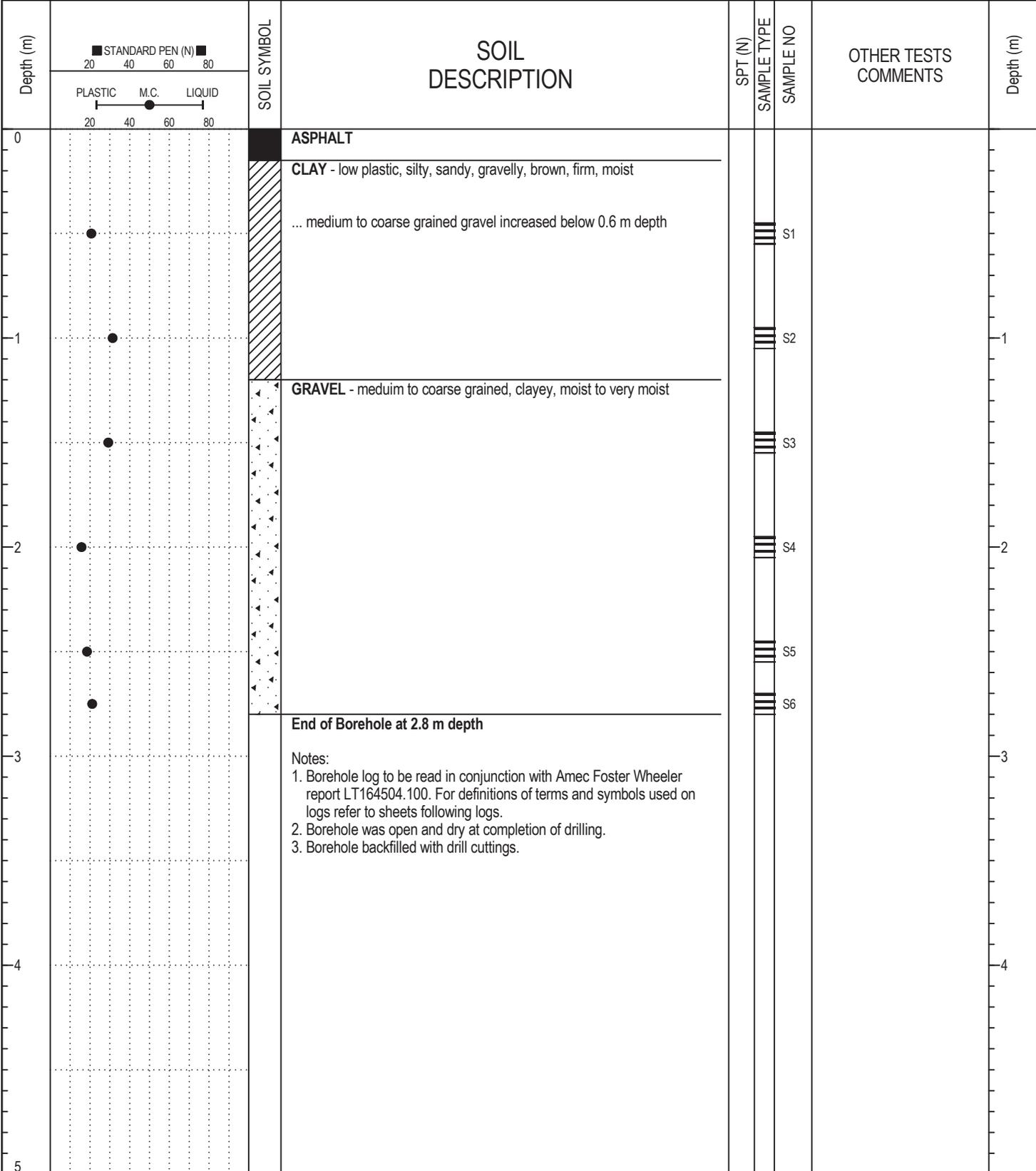


BHLOGS.GPJ 16/07/25 10:27 AM (BOREHOLE LOG)

Amec Foster Wheeler
Environment & Infrastructure

LOGGED BY: MS	COMPLETION DEPTH: 3.00 m
REVIEWED BY: JL	COMPLETION DATE: 14/7/16
	Page 1 of 1

PROJECT: Waterton Townsite Street Works	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-12
CLIENT: Public Works & Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT164504.100
LOCATION: Rear lane west of Evergreen Avenue; Refer to Figure 1		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

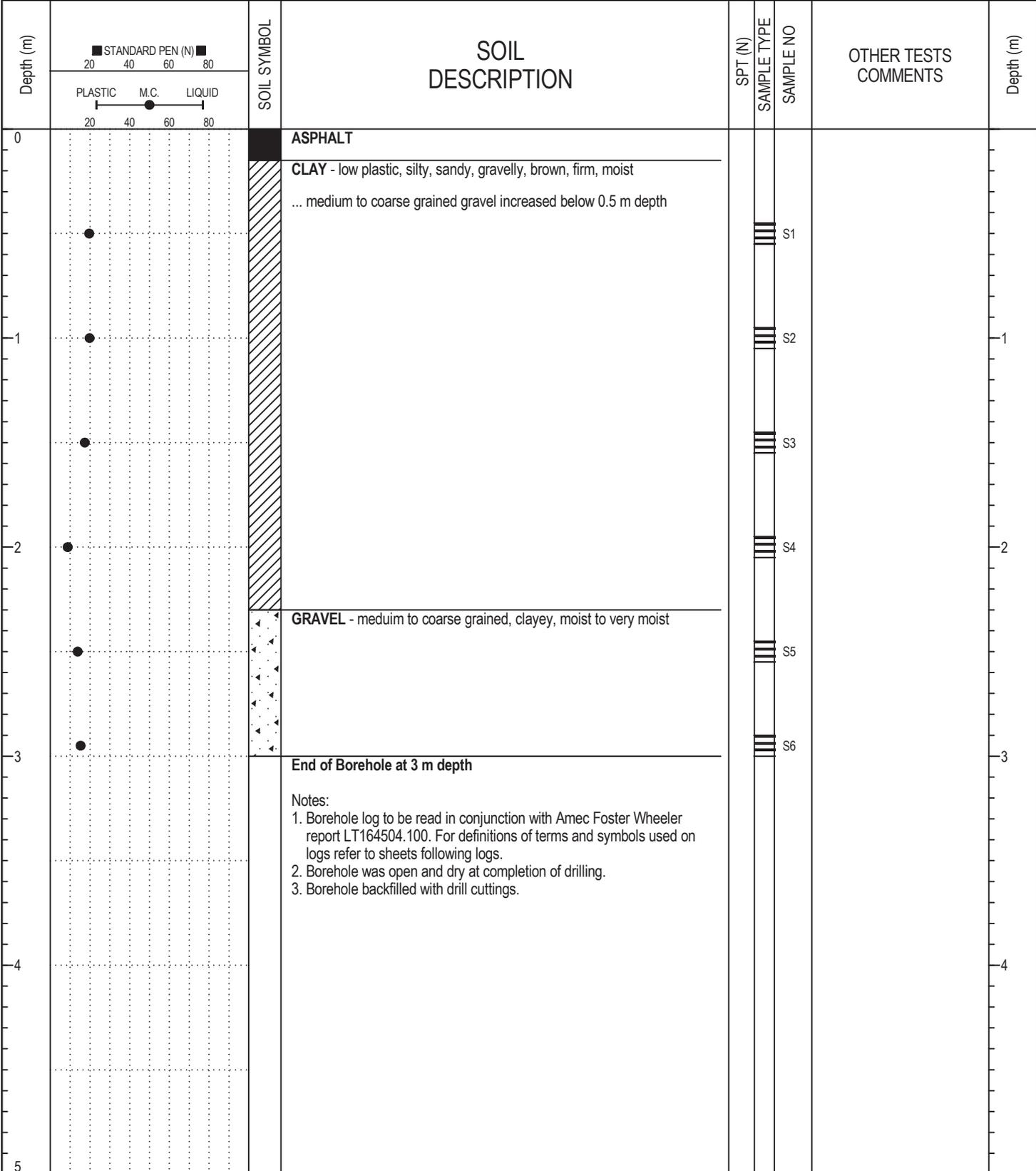


BHLOGS.GPJ 16/07/25 10:27 AM (BOREHOLE LOG)

Amec Foster Wheeler
Environment & Infrastructure

LOGGED BY: MS	COMPLETION DEPTH: 2.80 m
REVIEWED BY: JL	COMPLETION DATE: 14/7/16
	Page 1 of 1

PROJECT: Waterton Townsite Street Works	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-13
CLIENT: Public Works & Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT164504.100
LOCATION: Rear lane west of Evergreen Avenue; Refer to Figure 1		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	

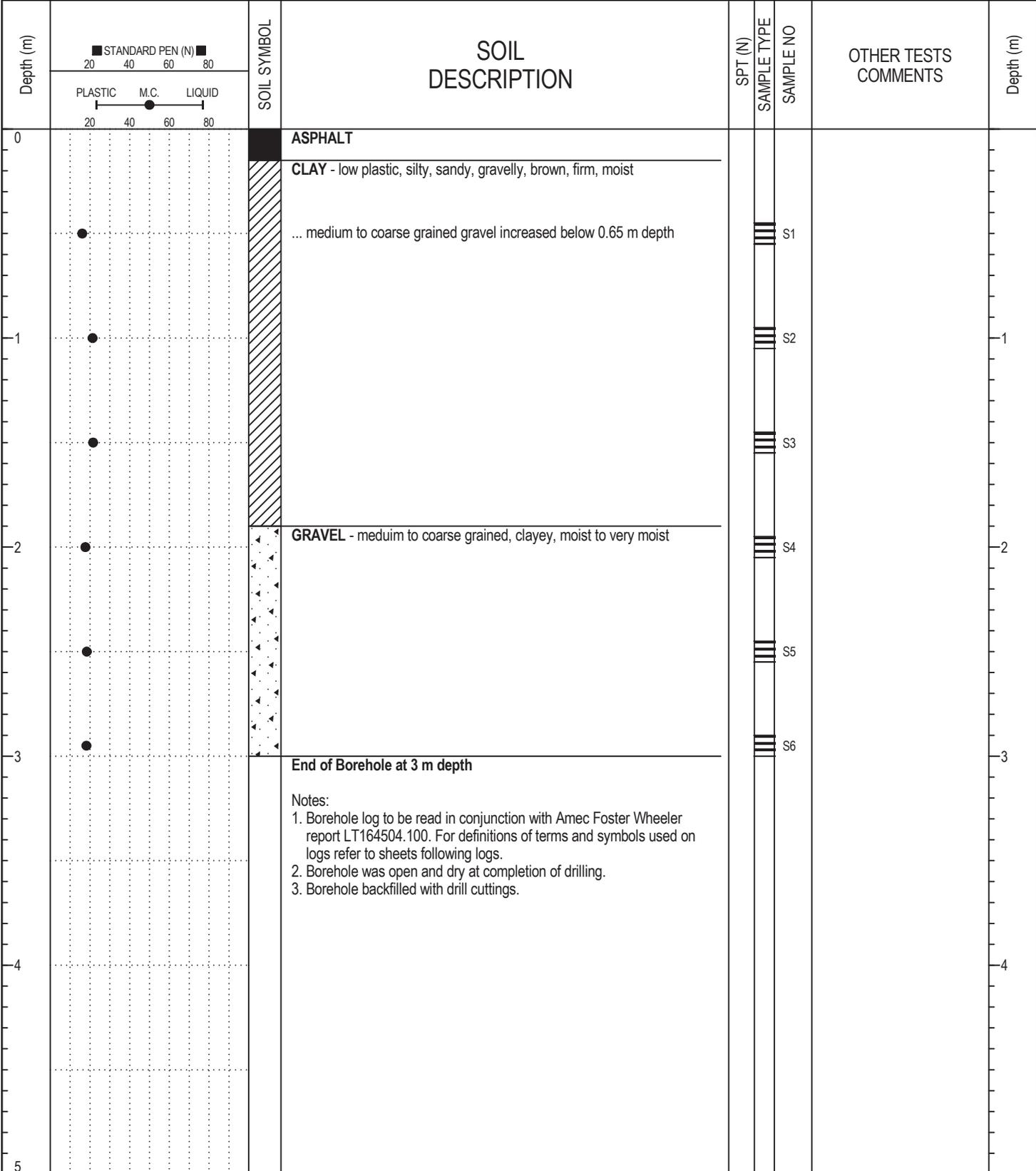


BHLOGS.GPJ 16/07/25 10:27 AM (BOREHOLE LOG)

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LOGGED BY: MS	COMPLETION DEPTH: 3.00 m
REVIEWED BY: JL	COMPLETION DATE: 14/7/16
	Page 1 of 1

PROJECT: Waterton Townsite Street Works	DRILLER: Chilako Drilling Services	BOREHOLE NO: BH16-14
CLIENT: Public Works & Government Services Canada	DRILL/METHOD: Truck Mounted C-1150 Drill/ SSA	PROJECT NO: LT164504.100
LOCATION: Rear lane west of Evergreen Avenue; Refer to Figure 1		ELEVATION:
SAMPLE TYPE	<input checked="" type="checkbox"/> Shelby Tube <input type="checkbox"/> No Recovery <input checked="" type="checkbox"/> SPT Test (N) <input type="checkbox"/> Grab Sample <input type="checkbox"/> Split-Pen <input type="checkbox"/> Core	
BACKFILL TYPE	<input checked="" type="checkbox"/> Bentonite <input type="checkbox"/> Pea Gravel <input type="checkbox"/> Slough <input type="checkbox"/> Grout <input checked="" type="checkbox"/> Drill Cuttings <input type="checkbox"/> Sand	



BHLOGS.GPJ 16/07/25 10:27 AM (BOREHOLE LOG)

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LOGGED BY: MS	COMPLETION DEPTH: 3.00 m
REVIEWED BY: JL	COMPLETION DATE: 14/7/16
	Page 1 of 1

EXPLANATION OF TERMS AND SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of field investigation and subsequent laboratory testing are described in these pages.

It should be noted that materials, boundaries and conditions have been established only at the borehole locations at the time of investigation and are not necessarily representative of subsurface conditions elsewhere across the site.

TEST DATA

Data obtained during the field investigation and from laboratory testing are shown at the appropriate depth interval.

Abbreviations, graphic symbols, and relevant test method designations are as follows:

*C	Consolidation test	*ST	Swelling test
D _R	Relative density	TV	Torvane shear strength
*k	Permeability coefficient	VS	Vane shear strength
*MA	Mechanical grain size analysis and hydrometer test	w	Natural Moisture Content (ASTM D2216)
N	Standard Penetration Test (CSA A119.1-60)	w _l	Liquid limit (ASTM D 423)
N _d	Dynamic cone penetration test	w _p	Plastic Limit (ASTM D 424)
NP	Non plastic soil	E _f	Unit strain at failure
pp	Pocket penetrometer strength (kg/cm ²)	γ	Unit weight of soil or rock
*q	Triaxial compression test	γ _d	Dry unit weight of soil or rock
q _u	Unconfined compressive strength	ρ	Density of soil or rock
*SB	Shearbox test	ρ _d	Dry Density of soil or rock
SO ₄	Concentration of water-soluble sulphate	C _u	Undrained shear strength
		→	Seepage
		▼	Observed water level

* The results of these tests are usually reported separately

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

The soil of each stratum is described using the Unified Soil Classification System¹ modified slightly so that an inorganic clay of "medium plasticity" is recognized.

The modifying adjectives used to define the actual or estimated percentage range by weight of minor components are consistent with the Canadian Foundation Engineering Manual².

Relative Density and Consistency:

Cohesionless Soils		Cohesive Soils		
Relative Density	SPT (N) Value	Consistency	Undrained Shear Strength c _u (kPa)	Approximate SPT (N) Value
Very Loose	0-4	Very Soft	0-12	0-2
Loose	4-10	Soft	12-25	2-4
Compact	10-30	Firm	25-50	4-8
Dense	30-50	Stiff	50-100	8-15
Very Dense	>50	Very Stiff	100-200	15-30
		Hard	>200	>30

Standard Penetration Resistance ("N" value)

The number of blows by a 63.6kg hammer dropped 760 mm to drive a 50 mm diameter open sampler attached to "A" drill rods for a distance of 300 mm.

¹ "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.

² "Canadian Foundation Engineering Manual", 4th Edition, Canadian Geotechnical Society, 2006.

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION		GROUP SYMBOL	GRAPH SYMBOL	COLOUR CODE	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 (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 4$; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
			GP		RED	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES		NOT MEETING ABOVE REQUIREMENTS
		DIRTY GRAVELS (WITH SOME FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12 %	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (LITTLE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 6$; $C_C = \frac{(D_{60})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$	
			SP		RED	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		NOT MEETING ABOVE REQUIREMENTS
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12 %	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7

FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	SILTS BELOW "A" LINE NEGLECTIBLE ORGANIC CONTENT	$W_L < 50\%$	ML		GREEN	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		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDS OR SILTY SOILS		
	CLAYS ABOVE "A" LINE NEGLECTIBLE ORGANIC CONTENT	$W_L < 30\%$	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS & CLAYS BELOW "A" LINE	$W_L < 50\%$	OL		GREEN	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		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
	HIGHLY ORGANIC SOILS			Pt		ORANGE		PEAT AND OTHER HIGHLY ORGANIC SOILS

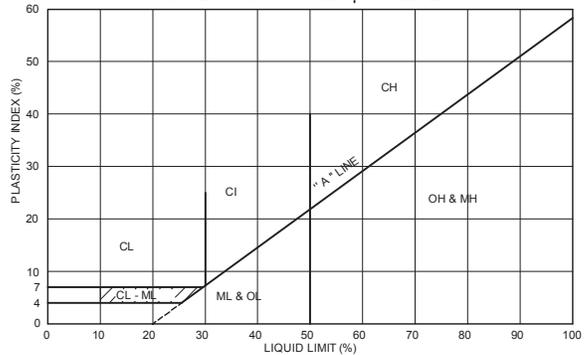
SPECIAL SYMBOLS

LIMESTONE		OILSAND	
SANDSTONE		SHALE	
SILTSTONE		FILL (UNDIFFERENTIATED)	

SOIL COMPONENTS

FRACTION	U.S. STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
	PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL	76mm	19mm	35-50	AND
	19mm	4.75mm		
SAND	4.75mm	2.00mm	20-35	Y/EY
	2.00mm	425µm	10-20	SOME
	425µm	75µm	1-10	TRACE
FINES (SILT OR CLAY BASED ON PLASTICITY)	75µm			

PLASTICITY CHART FOR SOILS PASSING 425 µm SIEVE



NOTES:

- ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD A.S.T.M. E.11
- COARSE GRAIN SOILS WITH 5 TO 12% FINES GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5 AND 12% FINES.

OVERSIZED MATERIAL

ROUNDED OR SUBROUNDED: COBBLES 76mm TO 200mm BOULDERS > 200mm	NOT ROUNDED: ROCK FRAGMENTS > 76mm ROCKS > 0.76 CUBIC METRE IN VOLUME
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amec foster wheeler

