APPENDIX B

GEOTECHNICAL REPORT

**GEOTECHNICAL INVESTIGATION
PROPOSED WASHROOM DEVELOPMENTS
WASKESIU, SASKATCHEWAN**

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1.0 INTRODUCTION

This report presents the results of a geotechnical investigation conducted by Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler) for two washroom facilities to be constructed in Prince Albert National Park (PAPN), Saskatchewan (the 'Site').

1.1 Scope of Work

The Scope of Work (SOW) for this project was presented to Mr. Travis Cooke, 1x1 Architectural Inc., in Amec Foster Wheeler Proposal S17-P4357 dated 5 May 2017. Authorization to conduct this investigation was provided to Amec Foster Wheeler on 15 September 2017.

1.2 Project Description

Amec Foster Wheeler understands that development will consist of two replacement washroom facilities. Washroom # 1 is approximately 35 m x 8 m and will be located near the south side of the beach area. Washroom # 2 is approximately 17 m x 6 m and will be located near the north end of the beach area.

1.3 Site Description

The Sites are bordered by beach and Waskesiu Lake to the west and several large paved parking lots to the east.

2.0 GEOTECHNICAL INVESTIGATION PROGRAM

2.1 Ground Disturbance Checks and Safety

Ground disturbance checks were completed on 10 October 2017. Sask 1st Call marked the location of underground services owned by Saskatchewan crown corporation (i.e. SaskPower, SaskTel, SaskEnergy, etc.). Private utility locates were provided by Hundseth Powerline Locators (HPL)

2.2 Field Investigation

Amec Foster Wheeler's field investigation was conducted on 10 October 2017 and consisted of four (4) test holes, numbered TH17-01 to TH17-04, inclusive and located as shown on Figures 2 and 3, Appendix A. The test holes were drilled to depths of 9.1 to 9.5 m below the existing ground surface using a truck mounted drill rig that was equipped with 150 mm solid stem, continuous flight augers.

Amec Foster Wheeler's field representative logged the test holes at the time of drilling according to the Modified Unified Soil Classification System. Disturbed soil samples were obtained from auger cuttings or from a split spoon sampler at regular depth intervals. Standard Penetration Tests (SPT's) were performed in conjunction with split spoon sampling.

The test holes were left open for approximately five minutes after the completion of drilling in order to observe short term groundwater seepage and sloughing conditions. The test holes were then backfilled with auger cuttings.

2.3 Laboratory Testing

Visual classification and moisture content tests were performed on all soil samples. Laboratory test results and other relevant subsurface information are summarized on the test hole logs, Appendix B.

3.0 SUBSURFACE CONDITIONS

3.1 Soil Profile

The soil types encountered at the test hole locations generally consists of a layer of topsoil overlying sand, organic clay and clay till.

3.2 Soil Properties

A brief description of each general soil type is presented below. For more detailed information regarding depths and thicknesses of strata see the test hole logs in Appendix B.

Sand

Sand extending either from grade or just below the surficial organic layer to depths of 3.0 to 4.7 m was encountered in each of the test holes. The sand contained some silt, was moist being wet below a depth of about 1.8 m, loose to compact, poorly graded, fine grained, and brown. The sand was a source of seepage and sloughing.

Organic Clay

An organic clay layer was encountered below the sand in test holes 17-01 and 17-02 and within the sand in test hole 17-03. The clay was generally moist to wet, low plastic, very soft and brown becoming grey.

Clay Till

Clay till was encountered below the clay or sand. The clay till was characterized as being silty, sandy with trace gravel, moist, firm to stiff, low plastic, and grey.

3.3 Seepage and Sloughing Conditions

Seepage and sloughing conditions during field test drilling are shown on the test hole logs, and are also summarized in Table 1.

TABLE 1 RECORDED GROUNDWATER AND SLOUGHING CONDITIONS

Test Hole	**Surface Elev.**[1] (m)	**Drilling Depth** (m)	**Depth to Slough/Water Immediately after Drilling**[1] (m)
TH17-01	534.3	9.5	1.8
TH17-02	534.1	9.5	1.8
TH17-03	533.8	9.1	1.8
TH17-04	533.9	9.1	1.8/1.6

1. At the completion of test drilling

4.0 GEOTECHNICAL RECOMMENDATIONS

4.1 Design Considerations

The soils at the Site #1 consisted of 4.5 m of sand overlying a one (1) meter thick organic layer. The above soils were underlain by clay till. The soils at the Site #2 consisted of 3 to 4 m of sand overlying clay till. The sand is considered low to moderately frost susceptible. The average depth of frost penetration in the Waskesiu area is expected to be in the order of 2.5 m.

Seepage and sloughing conditions were encountered within the sand stratum at each site, and at a depth of about 1.8 m below existing grade. The depth at which seepage and sloughing was encountered corresponds closely to the surface elevation of Waskesiu Lake (Elevation ~532.3 m, Per 1x1 Architectural Inc., Drawing Nos A0.1 and A0.2).

A pile and grade beam foundation is recommended for support of the washroom buildings, and in this regard, helical screw piles (HSPs) are recommended. HSPs can be sized according to the design load and are not susceptible to sloughing sands. However, boulders within the glacial clay till should be anticipated. Other foundation options include an insulated shallow strip footing foundation and an insulated grade supported thickened edge concrete slab.

A grade supported concrete slab bearing on a prepared granular base should perform satisfactorily in a heated building, but may experience some frost heave during the winter and early spring periods if the structures are unheated over the winter months. To minimize potential frost heave, consideration could be given to the installation of insulation below and adjacent to grade supported structures exposed to freezing. An alternate would be to design and construct the buildings with a pile and grade beam, or footing foundation, and a crawlspace.

Design recommendations are provided for site preparation; excavation, backfilling and dewatering; shallow spread footing foundations; thickened edge concrete slab on grade; helical screw piles; foundation concrete; and quality assurance and quality control. Where additional recommendations are required, Amec Foster Wheeler should be consulted.

4.2 Final Site Grading and Drainage

Site grading should provide positive drainage away from the washroom buildings at a minimum gradient of 4 percent for gravel surface driveways and landscaped areas within 3 m of the perimeter of the building. Further to surfaces grades, all downspouts from the roof of the structures should be discharged away from the foundations, and proper measures (i.e. splashguards) should be provided where necessary to reduce the potential for erosion and ponding water at the perimeter of the structure.

Excavations at the perimeter of the structures (raft, grade beams, footings, etc.) should be backfilled with moderately to well compacted fill, and topped with a clay cap a minimum of 0.3 m thick to reduce the amount of surface water infiltration into the slab subgrade or granular backfill against grade beams. As a recommended minimum, the clay cap in landscaped areas along the perimeter of the foundation should extend a minimum of 3.0 m from the foundation perimeter. Where pavement and/or concrete slabs meet the structure, these should be sealed against abutting structural components with a flexible seal, such as an asphaltic bead, to minimize surface water infiltration into the granular layer below the floor slab.

Amec Foster Wheeler understands that the proposed building will not have a basement or crawl space, and in this regard, recommendations for a sub drainage system are not required. If during subsequent design phases a crawlspace or basement are incorporated into design, a sub drainage system would be recommended in which case this office should be contact for recommendations.

4.2.1 Fill Selection

It is expected that select native sand will be used for general backfill, while imported granular base and sub-base will be used in cases where the performance of fill is critical, such as deep fill areas, roadways, slab on grade, etc.

Table 2 summarizes the recommended structural fill gradation for 18 mm minus granular base course and 50 mm minus granular sub-base course, based on Saskatchewan Ministry of Highways and Infrastructure (SMHI) standard gradation specifications for Type 32, 33 and Type 8 aggregates, respectively. Table 3 provides gradation requirements for ‘pitrun’ gravel.

TABLE 2 GRADATION REQUIREMENTS FOR BASE AND SUBBASE AGGREGATES			
Metric Sieve Designation	**Percent by Dry Weight Passing Sieve Size**		
	SMHI Base Course Type		**SMHI Subbase Type 8**
	32	**33**	
50 mm	-	-	100
25 mm	100	100	-
18 mm	87 - 100	100	-
12.5 mm	72 - 93	75 - 100	-
5 mm	45 - 77	50 - 75	-
2 mm	29 - 56	32 - 52	0 - 90
900 µm	18 - 39	20 - 35	-
400 µm	13 - 26	15 - 25	0 - 60
160 µm	7 - 16	8 - 15	0 - 25
71 µm	6 - 11	6-11	0 - 15

Notes to Table 2:

1. Granular base course should be composed of sound, durable particles of crushed rock, stone, gravel, sand and fine soil. It should not contain thin elongated particles, sods, topsoil, roots or plants.

2. Base aggregates have the following additional SMHI material compliance requirements:
   - Material passing the 0.4 mm sieve: $0 \leq$ Plasticity Index ≤ 6
   - 50% of the total aggregate should be fractured (1 face)
   - Contain less than 5% lightweight particles
   - Can have up to 3% total oversize provided the maximum aggregate size does not exceed 22.4 mm (Type 33 aggregate)
   - The organic content of the material passing the 5 mm sieve shall not exceed 3.0 % by weight

3. Sub base should have the following additional material compliance requirements:
   - Material passing the 0.4 mm sieve: $0 \leq$ Plasticity Index ≤ 6
   - The organic content of the material passing the 5 mm sieve shall not exceed 3.0 % by weight
   - Can have up to 3% total oversize provided the maximum aggregate size does not exceed 63 mm

TABLE 3 REQUIREMENTS FOR GRANULAR PITRUN

Sieve Size (mm)	Percent (%) By Weight Passing Canadian Metric Sieve Series (by dry mass)
75	100
4.75	40 – 80
0.075	8 – 18

4.2.2 Fill Placement and Compaction

Fill placement shall consist of spreading fill materials in controlled, uniform horizontal lifts not exceeding the lesser of: the values specified in Table 4, or the ability of the compaction equipment to attain minimum specified density requirements. The recommended compaction requirements of the backfill material required for subgrade beneath open area grade fill (landscape areas) and access roads are also outlined in Table 4.

TABLE 4 REQUIREMENTS FOR COMPACTION

Location	Material	Compacted Layer Thickness (mm)	% of Maximum Dry Density (ASTM D698)	Moisture Content Range Relative to Optimum
Excavations	Select Sand Fill	150	96	-2% to +2%
All Applications	Structural Granular Fill	150	100	-3% to +1%

Qualified geotechnical personnel should monitor the quality and placement of all fill soils and the compaction of the fill should be monitored by field density testing at regular frequencies. The density of each compacted lift should be tested prior to placing the next lift to confirm that adequate compaction has been achieved. If the material fails to meet the required density, then the material must be reworked or replaced and construction methods altered as necessary to obtain the required density.

4.2.3 Fill Settlements

The quality of the fill material used and the fill compaction standards considered necessary from an engineering perspective is dependent on allowable settlements and the level of risk that the Owner is prepared to accept. Where fill settlements are to be minimized, a high quality fill such as well graded, crushed gravel should be selected and it should be uniformly compacted in thin lifts (150 mm maximum) to a minimum of 100 percent of standard Proctor maximum dry density (SPMDD). In other less critical areas, a lower standard of compaction and use of less select backfill materials may be acceptable.

The extent of fill settlement will be dependent on the type and quality of fill selected and the density to which it is compacted. Past experience has shown that the following *approximate* order of settlements may be expected for engineered fills, assuming that they have been compacted to a minimum density that is equal to 100 percent (granular) of standard Proctor maximum dry density (SPMDD):

Select Sand (Site)	1 % X H_f
Well graded gravel or gravelly sand	0.5 % X H_f

Where: H_f = total thickness of fill

4.3 Temporary Trench Excavations and Backfilling

4.3.1 Open Cut Excavations

The below grade soils within the anticipated depth of excavation consist of sand. For the purpose of design, the below grade soils should be treated as a Type 4 soil. In the case of a Type 4 soil, open excavation slopes should not be steeper than 3 horizontal to 1 vertical (3H:1V) or 19 degrees as measured from the toe of the excavated slope. If flowing sands and/or otherwise unstable conditions are encountered, relatively flat excavations of (4 to 6) H:1V would likely be required.

In general, all excavation work should be undertaken in compliance with the requirements of Saskatchewan Occupational Health and Safety regulations; should be undertaken by an experienced contractor who is familiar with the site conditions and difficulties that may arise; and, should be closely supervised by knowledgeable safety personnel.

Stockpiles of construction materials or other surcharge loads (e.g. equipment, wheel loads, etc.) should not be placed closer than the horizontal equivalent of the excavation depth from the top edge of any excavation. Site grading around the excavation should be such that surface runoff is prevented from entering the excavation.

4.3.2 Backfill (Trenches and Open Excavations)

Fill used to backfill trenching and open excavations should be compacted to a standard that is in keeping with the performance requirements of the area. If the area is not to be used for an end use requiring substantial subgrade support (such as for vehicular traffic, staging areas, etc.), a minimum compaction standard and common fill materials could be considered. Where fill subsidence is to be minimized, an increased compaction specification and select fill materials will be required.

The amount of future subsidence that will occur in trench and excavation areas cannot be accurately predicted because of the many variables involved (e.g. time, surface traffic conditions, type of material used, compactive effort, quality controls, etc.). In areas where fill subsidence is to be controlled, the fill should be placed in maximum 150 mm thick lifts and uniformly compacted to minimum 100 percent SPMDD.

4.4 Foundation Design

Foundation design recommendations are based on Limit States Design (LSD) in accordance with the 2010 National Building Code of Canada (NBCC). For purposes of this report, the following definitions have been adopted and are considered consistent with both the Canadian Foundation Engineering Manual (2006) and the NBCC.

Limit state design (LSD) refers to a design method used in structural engineering. A limit state is a condition of a structure beyond which it no longer fulfills the relevant design criteria. The condition may refer to a degree of loading or other actions on the structure, while the criteria refer to structural integrity, fitness for use, durability or other design requirements. A structure designed using LSD is proportioned to sustain all actions likely to occur during its design life, and to remain fit for use, with an appropriate level of reliability for each limit state. LSD requires the structure to satisfy two principal criteria: the ultimate limit state (ULS) and the serviceability limit state (SLS).

Ultimate limit state (ULS) with respect to soils and foundations is reached when the ultimate load carrying capacity of the soil is exceeded (due to compression, uplift, sliding or overturning), or when soil deformation causes an ULS in the structure without soil failure, or when overall stability is lost. A structure is deemed to satisfy the ULS criteria if all *factored loads* ($\Sigma\alpha\cdot P$) are less than the *factored resistances* ($\Sigma Ø\cdot R$).

To satisfy the serviceability limit state (SLS) criteria, a structure must remain functional for its intended use under unfactored operating loads.

4.5 Standard Strip or Spread Footings

4.5.1 Ultimate Limit State

Standard 0.6 m wide strip footings or 1 m square spread footings founded at a depth of 1.2 m on undisturbed sand may be designed based on ultimate bearing capacities of 380 and 525 kPa, respectively. A geotechnical resistance factor of Φ = 0.5 should be applied to the ultimate geotechnical resistance to obtain the available factored geotechnical resistance at the Ultimate Limit State (ULS). The factored ultimate geotechnical resistance is calculated as follows:

$$Q_{ult} = \Phi \times q_{ult} \times A_f \geq Q_t$$

Where

Q_{ult} = factored geotechnical resistance (kN)
Φ = resistance factor
Q_{ult} = factored structural compressive loading (kN) (compressive loads, moments, etc.)
A_f = Area of footing (m^2)

4.5.2 Serviceability Limit State

Based on an assumed movement tolerance of 25 mm (i.e., serviceability limit) for foundation elements (and an assumed maximum footing width of 1 m) AMEC recommends limiting the bearing pressure to 100 kPa . Where the footing is more than 1 m wide, a decrease in bearing pressure may be necessary to limit foundation settlement to 25 mm. Further if movements greater than 25 mm are permissible, a higher SLS value can be used.

4.5.3 Design and Construction

The following criteria would also be applicable to the design and construction of strip or spread footings:

1. The footings should be steel reinforced and suitably designed by a structural engineer to act as rigid foundations.
2. A minimum width of 0.6 m is recommended for strip footings and a minimum plan dimension of 1 m is recommended for square footings.
3. The bearing surface of each footing base should be excavated using excavators with a smooth-edge trimming bucket to reduce the potential for disturbance of the subgrade. Final preparation of the bearing surfaces should be done by hand, with the removal of all loosened and disturbed soils.
4. All excavation works shall be constructed in accordance with Saskatchewan OH&S regulations. For design purposes, the sand encountered at the site is classified as a Type 4 soil.

5. Stockpiles of construction materials or other surcharge loads (e.g. equipment, wheel loads, etc.) should be kept a minimum horizontal distance of one excavation depth away from the crest of the excavation. All equipment should be removed from the top of the excavation when workers are present within the excavation.
6. Once the bearing surface has been prepared, it should be evaluated by qualified geotechnical personnel, to verify the suitability of the proposed bearing soils and to confirm that the soils are uniform and consistent with the conditions noted in the test hole logs presented in this report.
7. The exposed footing bearing surface should be protected from rain, snow, freezing temperatures and the ingress of free water. Where there is potential for significant degradation of a foundation bearing surface, it is recommended that a mud slab be placed to protect the bearing surface following the bearing surface inspection. The mud slab should consist of a 50 mm to 75 mm thickness of lean concrete.
8. Concrete should not be placed on frozen soil, nor should the soil beneath the footings be allowed to freeze after construction of the footing.
9. Rigid closed cell polystyrene insulation (such as Dow HI-40 or equivalent) around the perimeter of the building is recommended to mitigate the potential for frost penetrating beneath the footing. Insulation should also be placed alongside/over (vertically up) the exterior face of the wall to provide a continuous thermal barrier. If footings are to be insulated against frost action, the insulation details, particularly the thickness and lateral extension, should conform to the manufacturer's requirements and specifications to provide an equivalent soil coverage of not less than 2.5 m given the soil type and building heating conditions.
10. Footing excavations should be backfilled using select excavated sand soils placed and compacted in 200 mm lifts to 96% SPMDD at optimum moisture content. For backfill above the footing, a unit weight of greater than 18 kN/m³ is recommended for design purposes, as the natural groundwater table elevation at this site is expected to be below the base of the footing.

4.6 Thickened Edge Grade Supported Concrete Raft

A thickened edge grade supported reinforced concrete floor slab is a suitable foundation option for a lightly loaded building. Essentially, a rigid raft consists of a grade-supported slab that is poured monolithically with stiffened footing sections (i.e. spread footings) that support concentrated loading applied to the slab such as the structure envelop, column loads, etc. The un-thickened slab portions of the raft should be designed and constructed using the recommendations for grade supported slab.

4.6.1 Ultimate Limit State

A thickened edge grade supported reinforced concrete slab may be designed based on an ultimate bearing resistance of 250 kPa. A geotechnical resistance factor of 0.5 should be used to determine the geotechnical resistance at the ultimate limit state (ULS). The recommended bearing resistance assumes a minimum width of 0.6 m for all perimeter and internal stiffeners, and is subject to inspection and approval of all bearing surfaces by a qualified geotechnical engineer. It should be strictly noted that the recommended design bearing resistance has been provided assuming an Ultimate Limit State defined by plastic soil deformation and geotechnical failure of the footing. In other words, no reduction has been applied to the bearing pressure value to maintain deformations with a zone of elastic or elastic-plastic deformation, nor to ensure a maximum level of tolerable deflection. Reduced bearing pressures may be required where the ultimate limit state (ULS) of the footing is to be defined by a specified deformation of foundation subgrade that could lead to the ULS state being induced in the superstructure.

4.6.2 Serviceability Limit State

Based on an assumed movement tolerance of 25 mm (i.e., serviceability limit) for foundation elements (and an assumed thickened edge width of 1 m) AMEC recommends limiting the bearing pressure to 90 kPa (no load factor required for Serviceability Limit States (SLS)). Where the thickened edge is more than 1 m wide, a decrease in bearing pressure may be necessary to limit foundation settlement to 25 mm. Further if movements greater than 25 mm are permissible, a higher SLS value can be used.

4.6.3 Design and Installation

The following minimum requirements should be incorporated into the design and construction and a thickened edge grade supported concrete floor slab.

1. Excavate to the design subgrade elevation while ensuring that all organic soils are fully removed. All softened, weak and/or disturbed soils should also be removed from the final sub-grade surface. Excavated soils intended for re-use as backfill and/or in restoring grades should be closely monitored by knowledgeable and experienced geotechnical personnel. All suitable soils should be stockpiled separately for re-use. Care should be taken to ensure that the bearing surface is not disturbed by construction equipment, subject to freezing conditions, inundation, or excessive drying or wetting prior to, during, and after construction. Once the final surface has been prepared reached, the exposed sand soils should be evaluated by Amec Foster Wheeler geotechnical personnel to confirm that the soils are uniform and consistent with those observed at the borehole locations.

2. Compact the exposed subgrade with a smooth drum compactor to 96 percent of SPMDD, at close to optimum moisture content. Moisture conditioning (addition of water) may be necessary to achieve compaction and density.
3. Place and compact a minimum of **300 mm** of compacted, crushed granular base course material (Type 31 or 33) between the compacted sand surface and the underside of the thickened portion of the concrete floor slab. Add additional granular base course as required to elevate the subgrade to the underside of the unthickened portion of the floor slab.
4. All granular base course fill should be placed in 150 mm thick lifts and compacted to 100 percent SPMDD at optimum moisture content.
5. Reinforce the concrete slab and articulate the slab at regular intervals to provide for controlled cracking.
6. For a heated building, place rigid polystyrene insulation around the perimeter of the building to reduce the potential for frost penetrating beneath the perimeter of the concrete floor slab. Although actual dimensions will depend on the construction details, as a minimum guideline, the insulation should be 150 mm thick and extend out a minimum of 2.4 metres from the edge of the slab. The insulation should be covered with minimum of 300 mm granular fill (protective layer) and should be sloped away from the building. Insulation should also be placed alongside/over (vertically up) the exterior face of the thickened edge portion of the slab to provide a continuous thermal barrier. The insulation should be capable of supporting the design loading of the protective fill layer and any surcharge loads.
7. For an unheated building, place rigid polystyrene insulation beneath the entire structure. of the building to reduce the potential for frost penetrating beneath the building. Although actual dimensions will depend on the construction details, as a minimum guideline, the insulation should be 150 mm thick and extend out a minimum of 2.4 metres from the edge of the slab. The insulation should be covered with minimum of 300 mm granular fill (protective layer) and should be sloped away from the building. The insulation should be capable of supporting the design loading of the protective fill layer and any surcharge loads associated with the building.

4.7 Helical Screw Piles

4.7.1 Ultimate Limit State

HSPs may be designed as end bearing only in accordance with Limits States design approach and the recommended methodology presented below. Geotechnical resistance factors, Φ, of 0.4 and 0.3 should be applied to the ultimate skin friction values for compression and uplift resistance, respectively, to obtain the factored resistance at the ultimate limit state.

For single helix screw piles with a helix embedded into the clay till, the approximate ultimate compressive axial capacity, Qc, may be determined by the following:

$$\mathbf{Qc = Cu \cdot Ab \cdot Nc}$$

Where:

Qc	=	ultimate compressive load capacity (kN)
Cu	=	undrained shear strength at the depth of the helix
		Use **35 kPa** for end bearing for firm to stiff clay till below **6 m** depth
Ab	=	total area of helix (m^2) at the bottom = π D2/4
Nc	=	bearing capacity factor
		for deep embedment, H/D > 4, Nc = 9
		for shallow embedment H/D < 4, Nc = 5.6 to 9
		Nc varies linearly between 5.6 at H/D = 0, to 9 at H/D = 4

HSPs are well suited to resisting tensile loads. The uplift resistance of a screw pile can be considered as the "pullout" resistance of a cylindrical mass of soil projected above the circumference of the helix, with resistance calculated on the basis of the combined effective weight of the pile and soil above the helix. For sustained load conditions, the ultimate uplift resistance of a screw pile may be determined by the following:

$$\mathbf{Qt = C_u \cdot A_e \cdot N_u + Ae \cdot H \cdot \gamma'}$$

Where:

Qt	=	ultimate uplift resistance
Ae	=	Effective area of helix in uplift (m^2)
	=	π (D2 – d2)/4
γ'	=	effective soil unit weight (assume buoyant unit weight = 10 kN/m3)
H	=	depth to helix (meters)
D	=	diameter of the helix (meters)
d	=	diameter of the shaft (meters)
N_u	=	Uplift bearing capacity factor in cohesive soils
	=	1.2 (H/D) ≤ 9

4.7.2 Serviceability Limit State

The settlement of a single pile depends on the applied load, strength-deformation properties of the foundation soils, load transfer mechanism, load distribution over the pile embedment depth, and the relative proportions of the load carried by shaft friction and end-bearing. For a single helix screw pile with the helix embedded into the clay till, movements in the range of 1% of the helix diameter should be expected for loads up to the factored ultimate geotechnical resistance provided that good workmanship is followed. If this is acceptable, no reduction of the factored ultimate resistance is recommended for serviceability.

4.7.3 Design and Installation

The following criteria would also be applicable to the design and construction of helical screw piles:

1. The minimum bearing depth for HSPs should be 6 m below the final ground surface in naturally deposited clay till.
2. Neighbouring piles should be spaced no closer than a minimum 1 m edge-to-edge spacing between adjacent helixes, and founded at the same elevation provided that the helix diameter is less than 670 mm.
3. Pile installations should be continuously monitored by the geotechnical consultant acting independently of the contractor during construction.
4. Traditionally, torque measurements have been used in predicting the vertical capacities of helical piles. However, various researchers have indicated that torque correlations with vertical capacities can be unreliable, with deviations as much as 300 percent between the predicted and actual capacities from load tests. Hence, the use of torque measurements alone as a design tool in the absence of a pile load test is not recommended.

4.8 Grade Beam and Pile Caps

Pile caps and grade beams should be constructed with adequate reinforcement. A void space (minimum of 150 mm) should be constructed below all pile caps and grade beams. The void form material should be a low compressive strength, biodegradable material, or an alternate purpose- manufactured void form.

4.9 Grade-Supported Concrete Slabs (Interior)

Soil conditions at the site are considered suitable for grade supported concrete floor slabs, recognizing that some differential movements due to non-uniform subgrade support could occur, or in the case of unheated buildings and exterior slabs, heave and associated movements of the slab could occur if the sub-grade were to freeze. Movements associated with frost are difficult to assess; however if required, Amec Foster Wheeler can provide an estimate on request. The potential for frost induced movement can be mitigated by either constructing the buildings with a crawlspace or strategically placed insulation.

Assuming that some differential movement is acceptable, the following minimum requirements should be incorporated into their design and construction of grade supported floor slabs.

1. Excavate to design subgrade elevation, which for grade supported slabs should be taken as the top of slab minus the slab thickness and the recommended minimum gravel structures outlined in. Further excavation should be conducted as required to remove topsoil or otherwise unsuitable soils. Based on the test hole logs, subgrade conditions are expected to consist of sand.
2. Stripping and excavation should be completed in such a manner as to minimize disturbance of the exposed subgrade. In this regard, Amec Foster Wheeler recommends that excavation be completed using a backhoe equipped with a smooth bladed bucket operating from the edge of the excavation to limit potential disturbance of the underlying soil. Further, no construction equipment should be allowed on the exposed subgrade until an assessment of the subgrade has been completed by knowledgeable and experienced geotechnical personnel.
3. Excavated soils intended for re-use as backfill and/or in restoring grades should be closely monitored by knowledgeable and experienced geotechnical personnel. All suitable soils should be stockpiled separately for re-use.
4. Once stripping and excavation as outlined above is complete; and prior to trafficking the subgrade and/or prior to fill operations; an assessment of the subgrade shall be completed by knowledgeable and experienced geotechnical personnel in order to identify any scarification and/or compaction requirements to remediate disturbance, as well as to assess the feasibility of proof-rolling of the subgrade as recommended to identify any localized loose, ‘weak’, or zones of poor quality fill.

5. Ground conditions permitting, and depending on the exposed subgrade elevation relative to design subgrade elevation, proof-rolling should consist of multiple passes of a fully loaded tandem (preferred) or an otherwise acceptable sheepsfoot roller. If, in the opinion of qualified geotechnical personnel proof-rolling of the subgrade would be, or if during the course of proof-rolling becomes, detrimental to the subgrade, then such effort should be halted. Loose, 'weak', or zones of poor quality fill; identified either visually or by proof-rolling; should be sub-excavated below design subgrade as required to achieve a competent subgrade stratum up to a maximum of 400 mm below subgrade, and replaced with engineered fill material as directed by the engineer at the time of construction. In the event that loose, 'weak', or zones of poor quality fill below a depth of 400 mm below subgrade, Amec Foster Wheeler should be contacted so that supplementary recommendations can be provided
6. Fill materials, if required between the depth of stripping and excavation and the design subgrade elevation, should consist of additional granular subbase. The fill material should be placed in 150 mm thick lifts and uniformly compacted to 98% of SPMDD.
7. Interior grade-supported concrete slabs should be underlain by a minimum gravel structure thickness of 300 mm consisting of 100 mm of crushed gravel base course compacted to 100% of SPMDD at ±2 percent of optimum moisture content, underlain by 200 mm of crushed subbase compacted to 98% of SPMDD at ±2 percent of optimum moisture content. It is recommended that the gravel base course and gravel subbase materials should meet the material and gradation requirements for 18 mm minus granular base course and 50 mm minus granular sub-base course, based on Saskatchewan Ministry of Highways and Infrastructure (SMHI) standard gradation specifications for Type 32, 33 and Type 8 aggregates, respectively. Other gradations may be suitable but should be reviewed by the geotechnical engineer prior to use.
8. For the purposes of determining concrete slab thicknesses, grade-supported concrete slabs designed on an approved subgrade the gravel structure outlined above may be designed assuming a subgrade reaction modulus (k) of 30 MPa/m.
9. Interior floor slabs should be provided with joints or saw cuts at regular intervals to control and reduce random cracking. All partition walls or equipment founded on the slabs should have a minimum 150 mm thick void space at the top to mitigate damage if the slabs should heave. Interior floor slabs should be free floating, and should be structurally separated from the foundation walls, columns, and foundation walls, except possibly at doorways.

4.10 Frost Design Considerations

4.10.1 Frost Penetration Depth

The upper stratigraphy at the test hole locations, and across the site, is considered low to moderately frost susceptible in the presence of water, and as such, frost effects should be considered for foundations or surface structures sensitive to movement. A design frost penetration may be taken as 2.5 m below final grade along the exterior perimeter of structures and in unheated areas that will not have regular snow or vegetative ground cover. Where the superstructure is heated and there is beneficial heat loss into the soil, the depth of frost penetration may be reduced; however, the heat loss from the structure and the resulting reduction in frost penetration adjacent to the perimeter of the structure should reviewed on a case-by-case basis once the foundation insulation and building heating conditions are known.

4.10.2 Frost Forces

Potential frost forces acting on foundations elements include frost heave forces acting on the underside of structural elements (i.e. raft, footing, grade beams, pile caps, etc.) embedded within the depth of frost penetration, as well as adfreeze pressures acting along the sides of that portion of foundation elements located within the depth of frost penetration.

With respect to frost heave, frost heave forces in the range of 200 kPa to greater than 800 kPa have been determined from case studies. In this regard, it is most often impractical to design foundations to resist frost heave pressure, and instead, foundation design should adopt an approach to mitigate either (or both) the depth of frost penetration beneath the foundation element using insulation, and/or reduce the frost heave pressure by installing a void-forming product or compressible medium beneath the underside of foundation elements within the frost zone.

With respect to adfreeze, an average adfreeze stress of 65 kPa should be applied along foundation and structural elements located within the depth of frost penetration, which should be taken as recommended in Section 4.10.1. This adfreeze stress value is applicable to both concrete/soil and steel/soil interfaces. A load factor, $\alpha = 1.25$ should be applied to determine the factored adfreeze force. Adfreeze stresses along the sides of pile caps and buried substructures can be reduced by the installation of a ‘bond-break’ or ‘friction reducer’ within the zone of frost penetration. Friction reducers could consist of a system of poly wrapped sono-tubes. A smooth geosynthetic liner material, fixed to the shaft of the pile or to the sides of the pile cap would also be a suitable bond-break.

4.10.3 Frost Protection of Raft Foundations

In the case of shallow foundations, including rafts, the minimum depth of soil cover for shallow foundations located in unheated areas and along the perimeter of heated structures should be taken equivalent to the depth of frost penetration outlined previously. Where the recommended embedded depth is not desirable or practical; such as is the case for the proposed rigid raft foundations and shallow footings, rigid high density extruded polystyrene insulation (*Dow Styrofoam*) should be used to reduce the required thickness of soil cover.

4.10.4 Frost Protection of Piled Foundations

Resistance to adfreezing stresses on straight shaft piles will be provided by the skin friction below the depth of frost penetration, the weight of the pile, and by sustained vertical dead loads. For foundation design purposes, an unfactored adfreezing uplift pressure of 65 kPa applied over a depth of frost penetration of 2.5 m. In case of piles subjected to live uplift loads as well as to frost jacking forces, the live uplift load need not be additive to the frost jacking forces.

4.11 Foundation Concrete

General Use (GU) hydraulic cement may be used for concrete in contact with the existing native sand soils. Should any fine grained material be imported to the site for use as backfill, it should be tested for the presence of sulphate and the above recommendation modified accordingly.

4.12 Quality Assurance And Quality Control

The geotechnical recommendations presented within this report are based on the assumption that an adequate level of quality assurance and quality control will be provided during construction and that qualified contractors experienced in foundations and earthworks will carry out the construction. An adequate level of quality control is considered to be full time testing, with a qualified engineer's supervision and review, by a qualified materials testing laboratory during placement of all fills, sub base, base gravel; installation (i.e. drilling, excavation, casting and backfilling) of foundations; and, testing of hydraulic cement concrete. For pile foundations an adequate level of quality control is considered to be review of the geotechnical component of the pile design, and full time monitoring of pile installation.

Amec Foster Wheeler further requests the opportunity to review drawings and specifications related to any foundation, earthworks or other designs, based on the recommendations provided in this report, to confirm that Amec Foster Wheeler's geotechnical recommendations have been correctly interpreted.

5.0 CLOSURE

The findings and recommendations of this report were based on a geotechnical evaluation of subsurface conditions encountered at and within the depths of four (4) test holes located as shown on Figure 2, Appendix A. If conditions are observed or encountered during construction that appear to be different from those shown on the test hole logs and described in this report, or if the assumptions stated herein are not in keeping with the design, this office should be notified immediately in order that the recommendations can be reviewed and adjusted, if considered necessary by Amec Foster Wheeler.

Recommendations presented herein may not be valid if an adequate level of quality assurance and quality control is not provided during construction, or if relevant building code requirements are not met. Note that 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 variation in soil conditions, which may result in modification of the design and/or construction procedures.

This report has been prepared for the exclusive use of 1x1 Architectural Inc., and their agents, for specific application to the property identified in this report. Reliance on this report by any other party is not permitted without written authorization of Amec Foster Wheeler. The geotechnical investigation was conducted in accordance with generally accepted assessment practices. No other warranty, express or implied, is made.

Respectfully submitted,

Amec Foster Wheeler Environment & Infrastructure
A Division of Amec Foster Wheeler Americas Limited

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of Saskatchewan

CERTIFICATE OF AUTHORIZATION

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

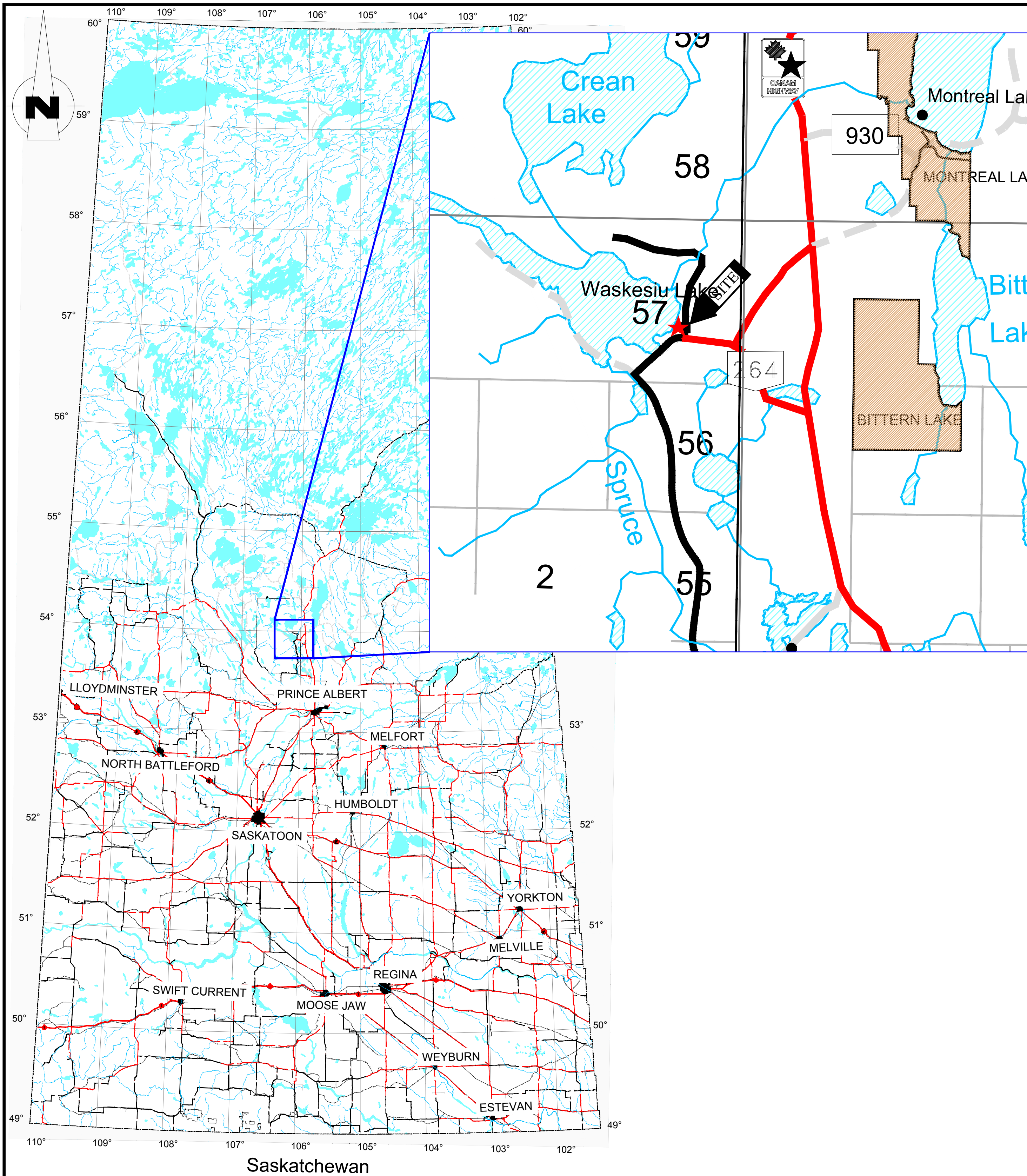
Number C0545

Permission to Consult held by:

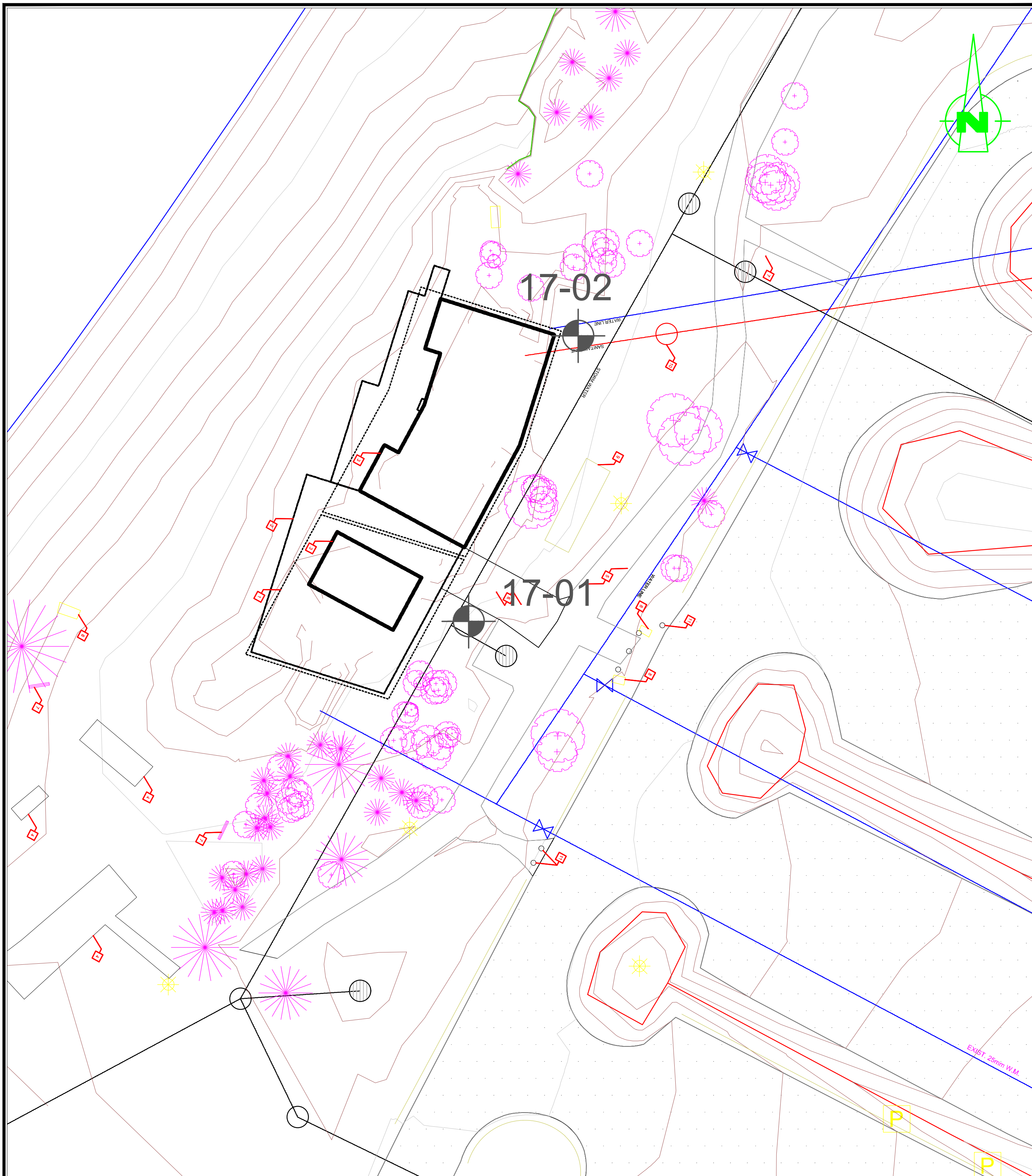
Discipline	SK. Reg. No.	Signature
Geoenvironmental	5296	

APPENDIX A

Project Site Location and
Test Hole Location



Amec Foster Wheeler Environment & Infrastructure	amec foster wheeler	CLIENT LOGO	CLIENT: PARKS CANADA	
PROJECT: GEOTECHNICAL INVESTIGATION PROPOSED WASHROOM DEVELOPMENT WASKESIU, SASKATCHEWAN		DWN BY: C.W.	DATUM: -	DATE: NOVEMBER 2017
		CHK'D BY: J.L.	REV. NO.: -	PROJECT NO.: WX18284
TITLE: KEY PLAN		PROJECTION: -	SCALE: N.T.S.	FIGURE NO.: FIGURE 1



LEGEND:		CLIENT LOGO:	CLIENT:
SAMPLING LOCATION	amec foster wheeler Environment & Infrastructure 4015 MILLAR AVENUE SASKATOON, SASKATCHEWAN S7K 2K6 TEL (306) 975-0444 www.amecfw.com		PARKS CANADA

PROJECT:	DWN BY:	DATUM:	DATE:
GEOTECHNICAL INVESTIGATION PROPOSED WASHROOM DEVELOPMENT WASKESIU, SASKATCHEWAN	C.W.	-	NOVEMBER 2017
	CHK'D BY: J.L.	REV.No.: -	PROJECT No. WX18284
TITLE: TEST HOLE LOCATION PLAN	PROJECTION: -	SCALE: N.T.S.	FIGURE No. FIGURE 2

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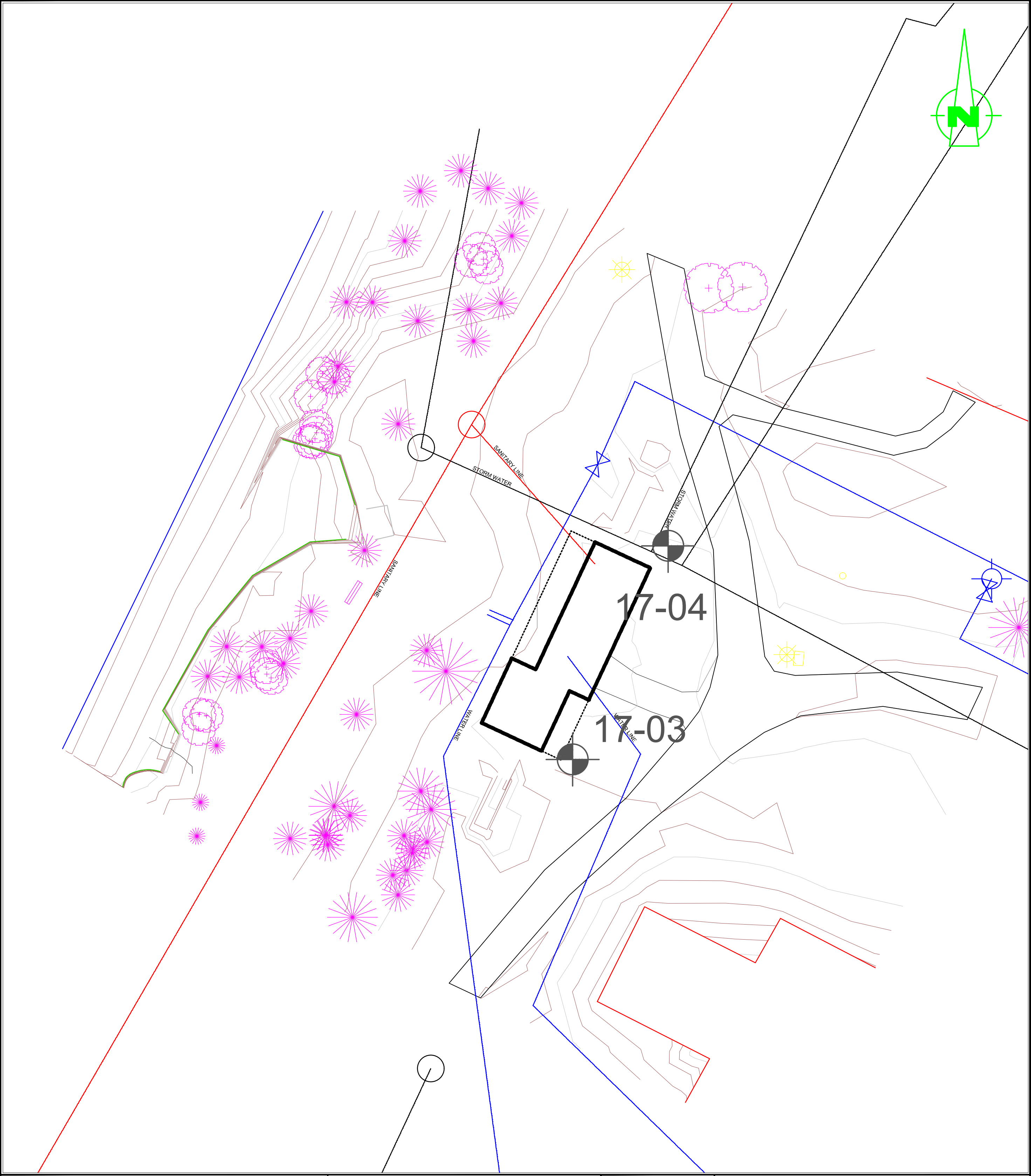

LEGEND: SAMPLING LOCATION	amec foster wheeler Environment & Infrastructure 4015 MILLAR AVENUE SASKATOON, SASKATCHEWAN S7K 2K6 TEL (306) 975-0444 www.amecfw.com	CLIENT LOGO:	CLIENT: PARKS CANADA	
PROJECT: GEOTECHNICAL INVESTIGATION PROPOSED WASHROOM DEVELOPMENT WASKESIU, SASKATCHEWAN		DWN BY: C.W.	DATUM: -	DATE: NOVEMBER 2017
		CHK'D BY: J.L.	REV.No.: -	PROJECT No. WX18284
TITLE: TEST HOLE LOCATION PLAN		PROJECTION: -	SCALE: N.T.S.	FIGURE No. FIGURE 3

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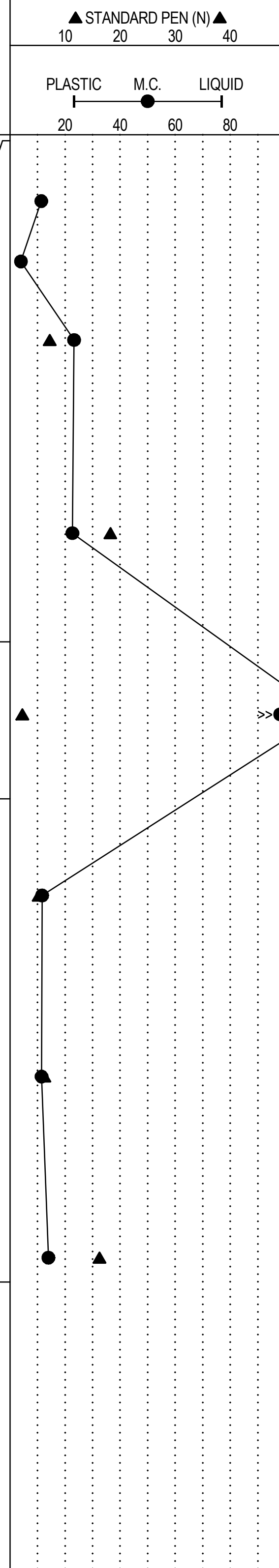
APPENDIX B
Test Hole Logs

WASHROOM FACILITIES	DRILLING METHOD: 150 MM SSA	TEST HOLE NO: **17-01**
PARKS CANADA		PROJECT NO: WX18284
PRINCE ALBERT NATIONAL PARK, SASKATCHEWAN		ELEVATION: 534.3 m

SAMPLE TYPE: THIN WALL TUBE, DISTURBED, SPT, A-CASING, HOLLOW STEM, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SAMPLE TYPE	SPT (N)	USCS	SOIL DESCRIPTION	COMMENTS	BACKFILL DETAILS	ELEVATION (m)
0			CL	ORGANIC CLAY (TOPSOIL)			
			SM	SAND- SOME SILT, SOME CLAY, MOIST, LOOSE, POORLY GRADED, FINE GRAINED, BROWN			534.0
1.0				- ROOTLETS TO 1.2 m			533.0
		7		- WET BELOW 1.5 m			
2.0							532.0
				- GREY BELOW 2.8 m			
				- BECOMING CLAYIER BELOW 2.8 m			
3.0		18		- COMPACT BELOW 3.1 m			531.0
4.0			OR	ORGANIC CLAY (PEAT) - VERY STILY, MOIST/WET, VERY SOFT, LOW PLASTIC, BROWN			530.0
		2		- BLACK, ORGANIC MOTTLING BELOW 4.5 m			
5.0				- TRACE SAND, GREY BELOW 4.9 m			529.0
			CL	CLAY (GLACIAL TILL) - SILTY, SANDY, TRACE GRAVEL, MOIST, FIRM, LOW PLASTIC, GREY			
6.0		5					528.0
7.0							527.0
8.0		6					526.0
				- SOME SAND, MEDIUM PLASTIC, VERY STIFF BELOW 8.5 m			
9.0		16					525.0
10.0				NOTES: WATER AND SLOUGH RECORDED AT 1.8 m BELOW GROUND LEVEL. TEST HOLE BACKFILLED WITH AUGER CUTTINGS.			524.0
11.0							523.0
12							



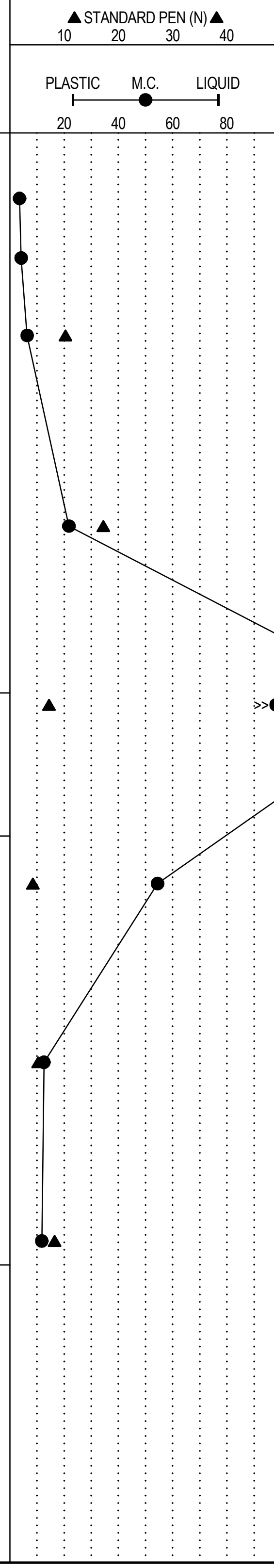
Amec Foster Wheeler Environment & Infrastructure Saskatoon, Saskatchewan	LOGGED BY: JL	COMPLETION DEPTH: 9.5 m
	REVIEWED BY: FH	COMPLETION DATE: 10 October 2017
	Fig. No: 4	Page 1 of 1

WASHROOM FACILITIES	DRILLING METHOD: 150 MM SSA	TEST HOLE NO: **17-02**
PARKS CANADA		PROJECT NO: WX18284
PRINCE ALBERT NATIONAL PARK, SASKATCHEWAN		ELEVATION: 534.1 m

SAMPLE TYPE: THIN WALL TUBE, DISTURBED, SPT, A-CASING, HOLLOW STEM, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SAMPLE TYPE	SPT (N)	USCS	SOIL DESCRIPTION	COMMENTS	BACKFILL DETAILS	ELEVATION (m)
0			SM	SAND- SOME SILT, SOME CLAY, MOIST, LOOSE, POORLY GRADED, FINE GRAINED, DARK BROWN		DRILL CUTTINGS	534.0
1.0	DISTURBED						533.0
1.8	SPT	10		- BROWN BELOW 1.5 m			
2.0				- WET BELOW 2.5 m		SLOUGH	532.0
3.0				- GREY BELOW 2.8 m			531.0
3.3	SPT	17					
4.0				- ORGANICS (ROOTS) FROM 4.3 m TO 4.6 m			530.0
4.8	SPT	7	OR	ORGANIC CLAY (PEAT) - VERY STILY, MOIST/WET, VERY SOFT, LOW PLASTIC, BROWN			
5.0				- TRACE SAND, GREY BELOW 5.5 m			529.0
6.0			CL	CLAY (GLACIAL TILL) - SILTY, SANDY, TRACE GRAVEL, MOIST, FIRM, LOW PLASTIC, GREY - ORGANICS AND SEA SHELLS TO 6.5 m			528.0
6.3	SPT	4					
7.0							527.0
7.8	SPT	5					
8.0							526.0
9.0							525.0
9.3	SPT	8					
10.0				NOTES: WATER AND SLOUGH RECORDED AT 1.8 m BELOW GROUND LEVEL. TEST HOLE BACKFILLED WITH AUGER CUTTINGS.			524.0
11.0							523.0
12							



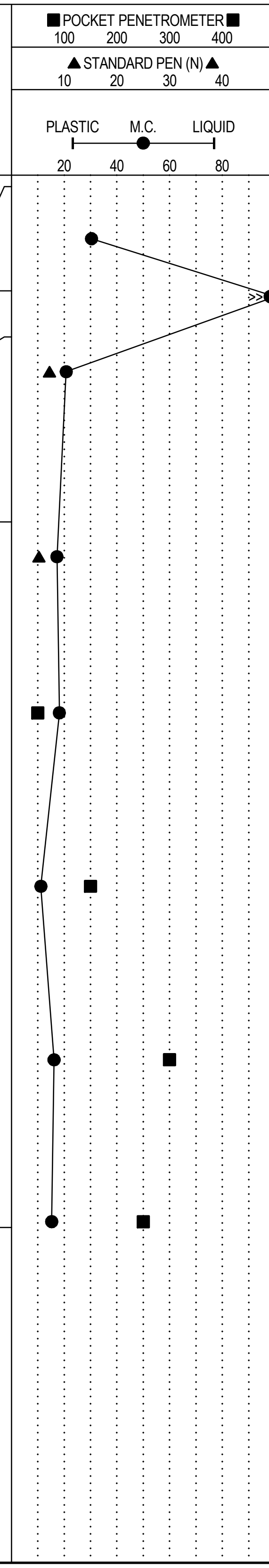
Amec Foster Wheeler Environment & Infrastructure Saskatoon, Saskatchewan	LOGGED BY: JL	COMPLETION DEPTH: 9.5 m
	REVIEWED BY: FH	COMPLETION DATE: 10 October 2017
	Fig. No: 6	Page 1 of 1

WASHROOM FACILITIES	DRILLING METHOD: 150 MM SSA	TEST HOLE NO: **17-03**
PARKS CANADA		PROJECT NO: WX18284
PRINCE ALBERT NATIONAL PARK, SASKATCHEWAN		ELEVATION: 533.8 m

SAMPLE TYPE: THIN WALL TUBE | DISTURBED | SPT | A-CASING | HOLLOW STEM | CORE

BACKFILL TYPE: BENTONITE | PEA GRAVEL | SLOUGH | GROUT | DRILL CUTTINGS | SAND

Depth (m)	SAMPLE TYPE	SPT (N)	USCS	SOIL DESCRIPTION	COMMENTS	ELEVATION (m)
0			CL	ORGANIC CLAY (TOPSOIL) 100 mm		
	DISTURBED		SM	SAND- SOME SILT, MOIST, LOOSE, POORLY GRADED, FINE GRAINED, BROWN WITH BLACK/ORGANIC MOTTLING		533.0
1.0	DISTURBED		OR	ORGANIC CLAY (PEAT) - VERY STILY, MOIST/WET, VERY SOFT, LOW PLASTIC, BROWN		
	SPT	7	SM	SAND- SOME SILT, WET, LOOSE, POORLY GRADED, FINE GRAINED, BROWN		532.0
2.0						531.0
3.0	SPT	5	CL	CLAY (GLACIAL TILL) - SILTY, SANDY, MOIST, FIRM, LOW PLASTIC, GREY		
				- GRAVELLY FROM 3.7 m TO 4.2 m		530.0
4.0	DISTURBED					529.0
5.0						528.0
6.0	DISTURBED			- STIFF BELOW 6 m		527.0
7.0	DISTURBED			- SOME SAND, TRACE GRAVEL BELOW 7.5 m		526.0
8.0						525.0
9.0	DISTURBED					524.0
10.0						523.0
11.0						522.0
12						



BACKFILL DETAILS

NOTES:
WATER AND SLOUGH RECORDED AT 1.8 m BELOW GROUND LEVEL.
TEST HOLE BACKFILLED WITH AUGER CUTTINGS.

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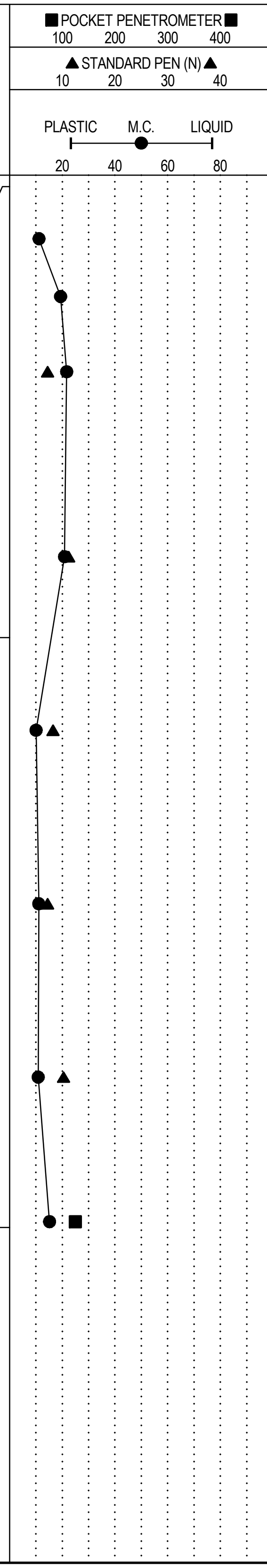
Amec Foster Wheeler Environment & Infrastructure Saskatoon, Saskatchewan	LOGGED BY: JL	COMPLETION DEPTH: 9.1 m
	REVIEWED BY: FH	COMPLETION DATE: 10 October 2017
	Fig. No: 7	Page 1 of 1

WASHROOM FACILITIES	DRILLING METHOD: 150 MM SSA	TEST HOLE NO: **17-04**
PARKS CANADA		PROJECT NO: WX18284
PRINCE ALBERT NATIONAL PARK, SASKATCHEWAN		ELEVATION: 533.9 m

SAMPLE TYPE: THIN WALL TUBE, DISTURBED, SPT, A-CASING, HOLLOW STEM, CORE

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	SAMPLE TYPE	SPT (N)	USCS	SOIL DESCRIPTION	COMMENTS	BACKFILL DETAILS	ELEVATION (m)
0			CL	ORGANIC CLAY (TOPSOIL) 100 mm		DRILL CUTTINGS	
	DISTURBED		SM	SAND- SOME SILT, TRACE GRAVEL, MOIST, LOOSE, POORLY GRADED, FINE GRAINED, DARK BROWN			
1.0	DISTURBED						533.0
	SPT	7		- NO GRAVEL, VERY MOIST, BROWN, OXIDIZED FROM 1.5 m TO 1.8 m			
2.0						SLOUGH	532.0
				- GRAVELLY FROM 2.3 m TO 2.6 m			
				- GREY FROM 2.6 m TO 3.0 m			
3.0				- SOME CLAY, FINE GRAINED BELOW 3.0 m			531.0
	SPT	11					
4.0			CL	CLAY (GLACIAL TILL) - SILTY, SOME SAND, TRACE GRAVEL, MOIST, STIFF, LOW PLASTIC, GREY			530.0
	SPT	8					529.0
5.0				- SANDY BELOW 5.0 m			
6.0							528.0
	SPT	7					
7.0							527.0
				- SOME SAND, TRACE GRAVEL BELOW 7.5 m			
	SPT	10					526.0
8.0							
9.0	DISTURBED						525.0
10.0				NOTES: TEST HOLE OPEN TO 1.8 m WITH WATER RECORDED AT 1.6 m BELOW GROUND LEVEL. TEST HOLE BACKFILLED WITH AUGER CUTTINGS.			524.0
11.0							523.0
12							522.0



Amec Foster Wheeler Environment & Infrastructure Saskatoon, Saskatchewan	LOGGED BY: JL	COMPLETION DEPTH: 9.1 m
	REVIEWED BY: FH	COMPLETION DATE: 10 October 2017
	Fig. No: 8	Page 1 of 1

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APPENDIX C
Site Photographs

Photo No. 1 – North End Bldg #2 Facing East

Photo No. 2 – Bldg#2 Facing South

Photo No. 3 – Bldg#2 Propane Line

Photo No. 4 – Piezometer Casing Near Bldg#2 Facing East

Photo No. 5 – Bldg #1 Facing West

Photo No. 6 – Propane Tank Bldg #1 Facing North

Photo No. 7 – East Side Bldg #1 Facing North

Photo No. 8 – Bldg #1 Facing West