

Geotechnical Investigation Report

Proposed New Infrastructure
National Research Council (NRC)
Automotive and Surface
Transportation (AST) Campus,
2320 Lester Road Ottawa,
Ontario



Prepared for:
National Research Council
Canada
Ottawa, ON

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November 2017

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1.0 INTRODUCTION

1.1 GENERAL

The National Research Council Canada (NRC) is planning to relocate an existing generator, and install a new transformer, electrical tap box and panel, and duct bank at the NRC Automotive and Surface Transportation (AST) Campus located at 2320 Lester Road in Ottawa, Ontario. The NRC retained Stantec Consulting Ltd. (Stantec) to carry out a geotechnical investigation for this project.

This report has been prepared specifically and solely for the proposed generator relocation, new transformer, and related site works at 2320 Lester Road. It presents the factual results of the investigation and provides geotechnical recommendations for the design and construction of the proposed development.

Limitations associated with this report and its contents are provided in the Statement of Conditions included in Appendix A.

1.2 SITE LOCATION

The site is located at the eastern end of the NRC AST Campus at 2320 Lester Road in Ottawa, Ontario as shown on the Key Plan (Drawing No.1) contained in Appendix B.

The proposed location of the generator, transformer, and electrical unit infrastructure is approximately 30 m south of the existing U-91 Main Distribution building. This area is located on the east side of railway tracks leading to the building, and is surfaced with sand and gravel fill.

1.3 AVAILABLE SUBSURFACE INFORMATION

Boreholes from the Ontario Geological Survey advanced in the vicinity of the site suggest that the native soils in this area could consist of surficial peat deposits overlying sand to silty sand. Bedrock is anticipated to be at least 15 m below ground surface.

2.0 PROPOSED DEVELOPMENT

NRC Canada is planning to relocate an existing generator on to a new slab foundation, and to install a new transformer, a new electrical tap box and panel, and a new duct bank connecting to Building U-91. The proposed locations of these new facilities are shown on Drawing No. 2 in Appendix B.

3.0 SCOPE OF WORK

The scope of work for the geotechnical investigation is summarized below:

- Drill one borehole in the vicinity of the proposed generator pad foundation to 6 m depth;
- Perform Standard Penetration Tests (SPT) while collecting soil samples at regular intervals within the borehole;
- Complete geotechnical laboratory testing on samples retrieved from the borehole;
- Prepare a geotechnical report that includes the following:
 - Field investigation observations and results;
 - Laboratory test results;
 - Borehole location plan;
 - Sub-surface conditions and groundwater levels encountered in the borehole;
 - Site preparation recommendations
 - Recommendations for the design and construction of the proposed new foundations, including geotechnical bearing resistance values, based on the expected ground conditions;
 - Frost protection recommendations; and,
 - Excavation and backfill requirements.

4.0 INVESTIGATION PROCEDURES

4.1 DRILLING INVESTIGATION

Prior to carrying out the field investigation, Stantec contacted public utility authorities to confirm the borehole location would not impact public utilities.

The geotechnical field investigation consisted of advancing one borehole, designated as BH17-1, at the site on September 29, 2017. The approximate borehole location is shown on Drawing No. 2 in Appendix B.

The borehole was advanced using a CME truck-mounted drill rig. The subsurface stratigraphy encountered in the borehole was recorded in the field by Stantec geotechnical field personnel. Split spoon samples were collected at regularly spaced intervals in the borehole. All samples recovered were returned to Stantec's Ottawa laboratory for detailed classification and testing.

4.2 LOCATION AND ELEVATION SURVEY

The ground surface elevation and coordinates of the borehole were determined using a Trimble GeoXH Global Positioning System (GPS) navigation device. The survey data and borehole details are summarized in Table 4.1.

Table 4.1: Borehole BH15-1 Location and Field Testing Summary

MTM Zone 9 Coordinates Northing Easting	5019909 449655
Ground Surface Elevation, m	100.8
Total Depth Drilled, m	5.9
End of Borehole Elevation, m	94.9
Depth Augered, m	5.9
Number of Soil Samples	8

4.3 LABORATORY TESTING

All samples were taken to Stantec's Ottawa laboratory where they were subjected to a detailed visual examination by a Geotechnical Engineer.

The geotechnical laboratory testing program for the borehole samples is summarized in Table 4.2.

Table 4.2: Geotechnical Laboratory Testing Program

Test Description	Number of Tests
Moisture Content Test	8
Grain Size Distribution	1

Samples remaining after testing will be placed in storage for a period of one month after issuance of the final report. After this storage period, the samples will be discarded.

5.0 SUMMARY OF SUBSURFACE CONDITIONS

The approximate location of the borehole is shown on Drawing No. 2 in Appendix B. The subsurface conditions observed and the results of in situ and laboratory testing are presented on the Borehole Record provided in Appendix C. An explanation of the symbols and terms used to describe the Borehole Record is also provided in Appendix C.

The borehole record depicts conditions at a particular location and at the particular time indicated. Subsurface soil and groundwater conditions at locations away from the borehole could vary from those indicated on the borehole logs.

In general, the subsurface soil profile encountered in the borehole consists of a surficial layer of fill consisting of silty sand with varying amounts of gravel and pockets of silty clay overlying a native deposit of compact silty sand.

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5.1 FILL

Fill consisting of silty sand with varying amounts of gravel and pockets/clumps of silty clay was encountered at Borehole BH17-1 from ground surface to a depth of approximately 0.76 m below ground surface.

A Standard Penetration Test (SPT) blow count (N-value) of 17 blows per 0.3 m was measured within the fill indicating this material is compact.

Moisture content testing on a sample of the fill measured a moisture content of 7%, expressed as a percentage of the dry weight of the soil.

5.2 SILTY SAND

A silty sand deposit containing trace gravel was encountered in the borehole directly beneath the fill and extended to the termination depth of the borehole at approximately 5.9 m below ground surface. Grinding of the auger on a possible cobble or boulder was encountered at a depth of about 1.5 m below ground surface.

SPT N-values measured in the silty sand ranged between 16 and 26 blows per 0.3 m, indicating the silty sand is in a compact state.

Laboratory testing indicates that the moisture content of this material ranged from 10% to 21%.

One grain size analysis test carried out on a representative sample of the silty sand yielded the following results:

Gravel:	8%
Sand:	65%
Silt:	23%
Clay-sized particles:	4%

The grain size analysis results are included in Figure D1 of Appendix D. The Unified Soil Classification System (USCS) group symbol for the material is SM (silty sand).

5.3 GROUNDWATER

Groundwater was inferred based on observations made during the field investigation and the results of the laboratory testing to be at a depth of approximately 1.5 m below ground surface at the time of drilling.

Groundwater levels/elevations are subject to fluctuation due to seasonal variations and in response to precipitation events.

6.0 DISCUSSION AND RECOMMENDATIONS

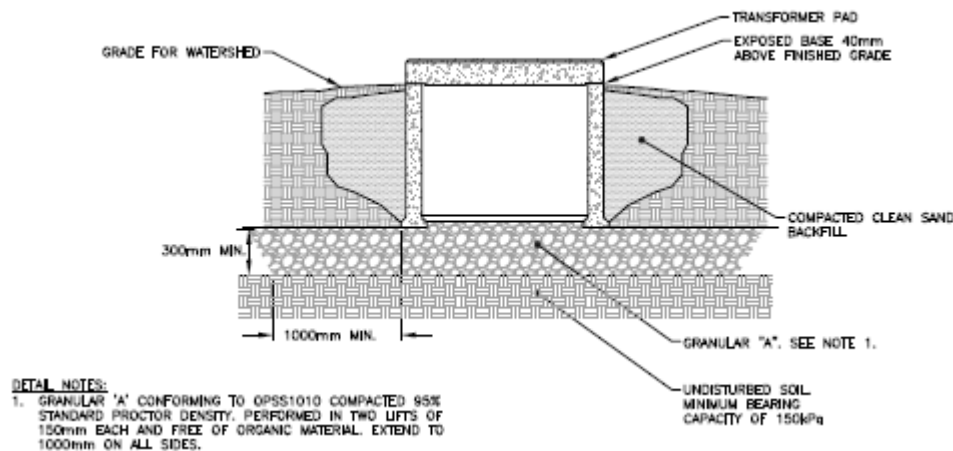
This section of the report provides input regarding geotechnical design aspects of the project. The geotechnical recommendations provided are based on our interpretation of the available subsurface information and on our understanding of the project requirements.

6.1 PROJECT DESCRIPTION

NRC Canada is planning to relocate an existing generator (including construction of a new pad/slab foundation), and install a new electrical panel and tap box on a new pad/slab foundation, a new transformer and a new duct bank connecting to building U-91.

Drawing Nos. 5452-E102 and 5452-E501, dated August 2017, provide details on the proposed new infrastructure. Based on these drawings, the transformer pad, electrical pad, and generator pad encompass footprints of approximately 1.9 m x 1.9 m, 1.6 m x 2.2 m, and 1.5 m x 3.8 m, respectively.

The new generator and electrical panel are anticipated to be supported on slab-on-grade pad foundations (i.e. concrete pads/slabs constructed at ground surface). The transformer pad is anticipated to be supported on a concrete pad resting on a square, concrete base comprised of cast-in-place concrete footings/walls as shown in the detail (excerpt from Drawing 5452-E501) below. This is understood to be a typical transformer pad design used by Hydro Ottawa and it is understood that these structures are not provided with insulation for frost protection purposes.



The subsurface stratigraphy in the borehole drilled at the proposed generator location consisted of approximately 0.8 m of fill consisting of silty sand with varying amounts of gravel and clumps of silty clay overlying a silty sand deposit that extended to the borehole termination depth of 5.9 m below ground surface.

6.2 FROST PENETRATION

The typical design frost penetration depth for Ottawa is 1.8 m. Therefore, all foundation elements that are sensitive to movements (i.e. heave and subsequent settlement) located in unheated areas should be provided with a minimum of 1.8 metres of earth cover, or equivalent insulation, for frost protection purposes.

Ottawa has a mean freezing index of 964 (Celsius (below 0 °C), Degree Days). This value should be used when developing an engineered insulation design. Additional input related to the use of the insulation is provided in Section 6.4.

6.3 SITE GRADING AND PREPARATION

Site Grading

The site grades are not expected to be raised by greater than 0.3 m above the existing grades. The proposed grade raise is not anticipated to cause significant settlement.

Site Preparation

All existing fill and any other soft/loose, disturbed or otherwise deleterious materials should be removed from beneath the footprints of the foundations for the generator, electrical panel and box, and transformer. The thickness of the fill materials was determined at a single location and may vary across the development area. Therefore, the prepared subgrade surfaces should be inspected by experienced geotechnical personnel to confirm all fill materials have been removed and the subgrade should be surface compacted/proof-rolled prior to placement of fill material or foundation construction. All soft or disturbed areas revealed during subgrade excavation or inspection should be removed and replaced with approved Structural Fill, as defined below.

Structural Fill should conform to the requirements of OPSS Granular B Type II or OPSS Granular A. Structural Fill placed beneath the foundations should contain no recycled materials such as concrete or asphalt and should be compacted in lifts no thicker than 300 mm to a minimum of 98% of the material's Standard Proctor Maximum Dry Density (SPMDD), as per ASTM D698.

As noted on the transformer pad detail included in Section 6.1, the transformer pad base is to be underlain by a minimum of 300 mm of OPSS Granular A materials placed in maximum 150 mm thick lifts that extend a minimum of 1 m beyond the outside edges of the pad base and which are compacted to a minimum of 95% of their SPMDD.

Imported fill materials should be tested and approved by a Geotechnical Engineering firm prior to delivery/use. Monitoring of fill placement and in situ compaction testing should be carried out to confirm that all fill is placed and compacted to the required degree.

6.4 FOUNDATIONS

The site soils are considered suitable for the support of the proposed pad/slab foundations provided that the foundation subgrade preparation work described in Section 6.3 above is carried out.

The base of all excavations should be inspected by a Geotechnical Engineer prior to placing concrete, Structural Fill or insulation to confirm the design pressures and to ensure that there is no disturbance of the founding soils. Temporary frost protection should be provided to protect subgrade materials from freezing if construction is carried out under winter conditions.

New pad/slab foundations and the concrete base for the transformer pad that are founded on the native silty sand or Structural Fill may be designed using a factored geotechnical resistance at Ultimate Limits States (ULS) and a geotechnical reaction at Serviceability Limits States (SLS) of 150 kPa. The factored geotechnical bearing resistance at ULS incorporates a resistance factor of 0.5. The geotechnical reactions at SLS were developed consistent with a total settlement of 25 mm.

The above geotechnical resistances are based on slab foundations resting on high density extruded polystyrene having a minimum compressive strength of 60 psi (414 kPa) such as Dow Chemical HI-60 or equivalent. The use of Dow Chemical HI-40 may be possible if the loads are sufficiently small; the insulation compressive strength and proposed loads should be compared and long term creep considered.

The insulation detail is a significant aspect of the slab-on-grade design. Figure No. 1 below provides guidance on the required insulation dimensions. The following are the recommended insulation details to be used for a thickened-edge slab:

- Freezing Index (Ottawa): 964 Degree-Days (Celsius), 1,735 Degree-Days (F)
- Insulation Type: HI-60, HI-40 may also be suitable depending on slab loads
- t: 0.075 m
- L: 2.44 m
- X: 1.07 m
- M: 0.30 m
- N: 0.10 m

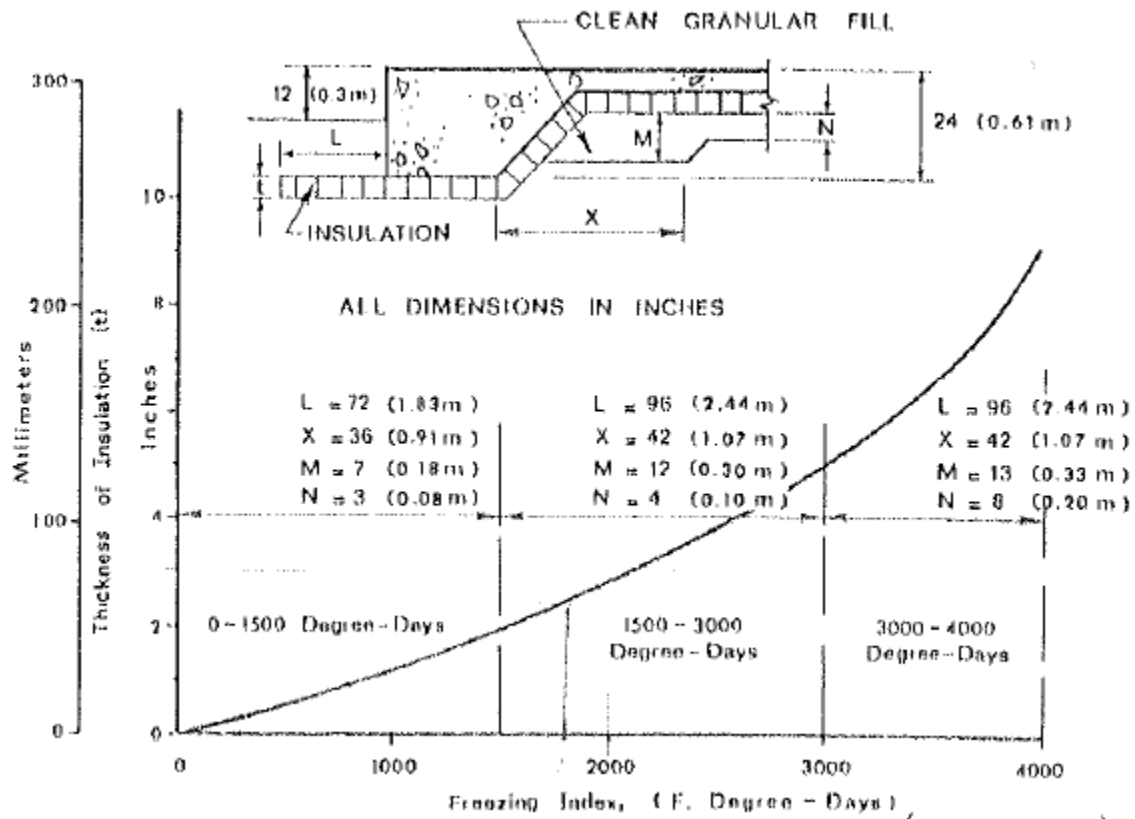


Figure 1: Design Curve for Foundation Insulation (Unheated Structure on Sandy Soil)

Source: Design of Insulated Foundations – Journal of Soil Mechanics and Foundations Division (September 1973)

6.5 EXCAVATION AND BACKFILLING

6.5.1 Excavations in Soil

All temporary excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects and care should be taken to direct surface water away from the open excavations.

Excavations at the site are anticipated to extend through fill materials and compact silty sand soils. Conventional hydraulic excavating equipment is considered suitable for developing excavations in these materials.

Provided that appropriate groundwater control is provided to maintain the water level below the base of the excavation, these overburden soils are classified as Type 3 soils as defined by Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. Within Type 3 soils, temporary open cut excavations must be sloped at 1 horizontal to 1 vertical from the base of the excavation per the requirements of OHSA. Excavation side slopes below the groundwater level in the sandy overburden soils would slough to a flatter inclination. Saturated granular soils would be classified as Type 4 soil in accordance with the Occupational Health and

Safety Act of Ontario and excavation side slopes in these materials would need to be sloped at 3 horizontal to 1 vertical. Alternatively, appropriate temporary support systems could be used.

Excavated materials should not be stockpiled adjacent to excavations. The sideslopes of the excavations should be inspected for signs of instability and flattened as required.

6.5.2 Groundwater Control

Groundwater control will be required to allow placement of concrete and/or Structural Fill under dry conditions. Groundwater was inferred to be at a depth of approximately 1.5 m below ground surface at the borehole location. Control of groundwater seepage into excavations above this level is expected to be possible using conventional sump and pump techniques. However, it should be noted that groundwater elevations may fluctuate seasonally.

Significant groundwater inflows should be expected for excavations extending below the groundwater table (if required) within the sandy soils at this site. More extensive dewatering systems (e.g. external dewatering system using well points or other dewatering wells) would be required for such excavations. Such dewatering is expected to require either registration in the Ministry of the Environment and Climate Change (MOECC) Environmental Activity and Sector Registry (EASR) or obtaining a Permit to Take Water (PTTW) from the MOECC. A separate hydrogeological assessment should be completed if such excavations are required.

6.5.3 Pipe Bedding and Trench Backfill

Bedding for utilities should be placed in accordance with the pipe or duct design requirements. It is recommended that a minimum of 150 mm of OPSS Granular A materials be placed below utility inverts as bedding material. Pipe/duct bank backfill and cover materials should also consist of OPSS Granular A material. A minimum of 300 mm vertical and side cover should be provided. These materials should be compacted to at least 95% of the material's SPMDD in lifts no greater than 300 mm.

Trench backfill above the pipe/duct cover materials should also be placed in maximum 300 mm thick lifts and should be compacted to at least 95 percent of the material's SPMDD using suitable vibratory compaction equipment. The type of material placed within the frost zone (i.e. between finished grade and about 1.8 metres depth) should match the soil exposed on the trench walls for frost heave compatibility in areas where trenches will be covered with hard surfaced materials. A 3H:1V frost taper is required in order to minimize the effects of differential frost heaving if materials different than those present in excavation sidewalls are used as backfill.

The excavated overburden soils are generally considered suitable for re-use as trench backfill. However, some of the overburden materials (e.g. fill materials containing silty clay) may be too wet to compact. In that case, the wet materials should be wasted (and drier materials imported) or these materials should be placed only in the lower portions of the trench, recognizing that some future settlement of the ground surface may occur.

7.0 REFERENCES

- ASTM 4.08. Standard D422-63: Standard Test Method for Particle-Size Analysis of Soils.
- ASTM 4.08. Standard D1586-99: Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.
- ASTM 4.08. Standard D2216-98: Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
- ASTM 4.08. Standard D2487-00: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
- ASTM 4.08 Standard D698-07: Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³)).
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- Cement Association of Canada. 2011. Design and Control of Concrete Mixtures: The Guide to Application, Methods, and Materials. Ottawa, Ontario
- Ministry of Labour. Occupational Health and Safety Act and Regulations for Construction Projects. Toronto, Ontario: Publications Ontario, 2012.
- Robinsky, E. I., & Besspflug, K. E. (September 1973). Design of Insulated Foundations. Journal of Soil Mechanics and Foundations Division, pp. 665.

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8.0 CLOSURE

Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of National Research Council (NRC) Canada who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

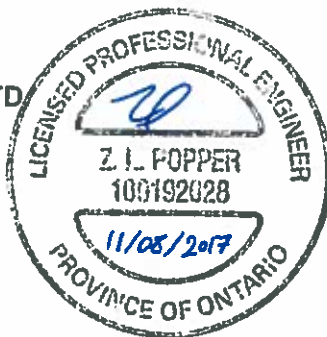
We trust the above meets your present requirements. Should you require any further information, please do not hesitate to contact us.

Respectfully submitted,

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APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or subsurface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

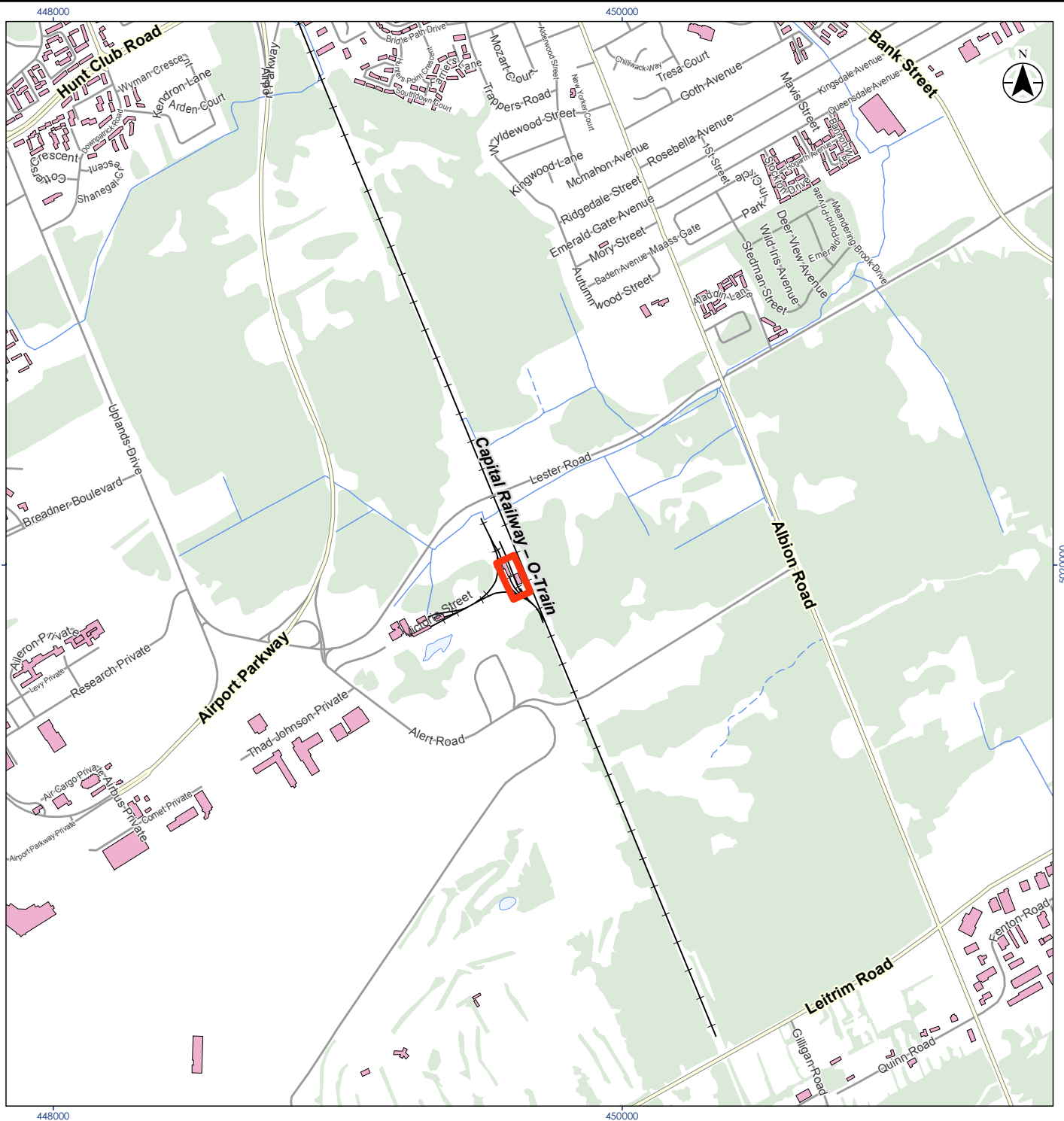
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APPENDIX B

Key Plan

Borehole Location Plan



Notes
 1. Coordinate System: NAD 1983 UTM Zone 18N.
 2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2016.

- Legend**
- Approximate Site Location
 - + Railway
 - Major Road
 - Minor Road
 - Watercourse (Intermittent)
 - Watercourse (Permanent)
 - Buildings
 - Waterbody
 - Wooded Area



Project Location: 2320 Lester Road, Ottawa, Ontario
 Project No. 121621336
 Prepared by Gliceria Briones on 2017-10-12

Client/Project: NATIONAL RESEARCH COUNCIL
 PROPOSED NRC AST CAMPUS GENERATOR

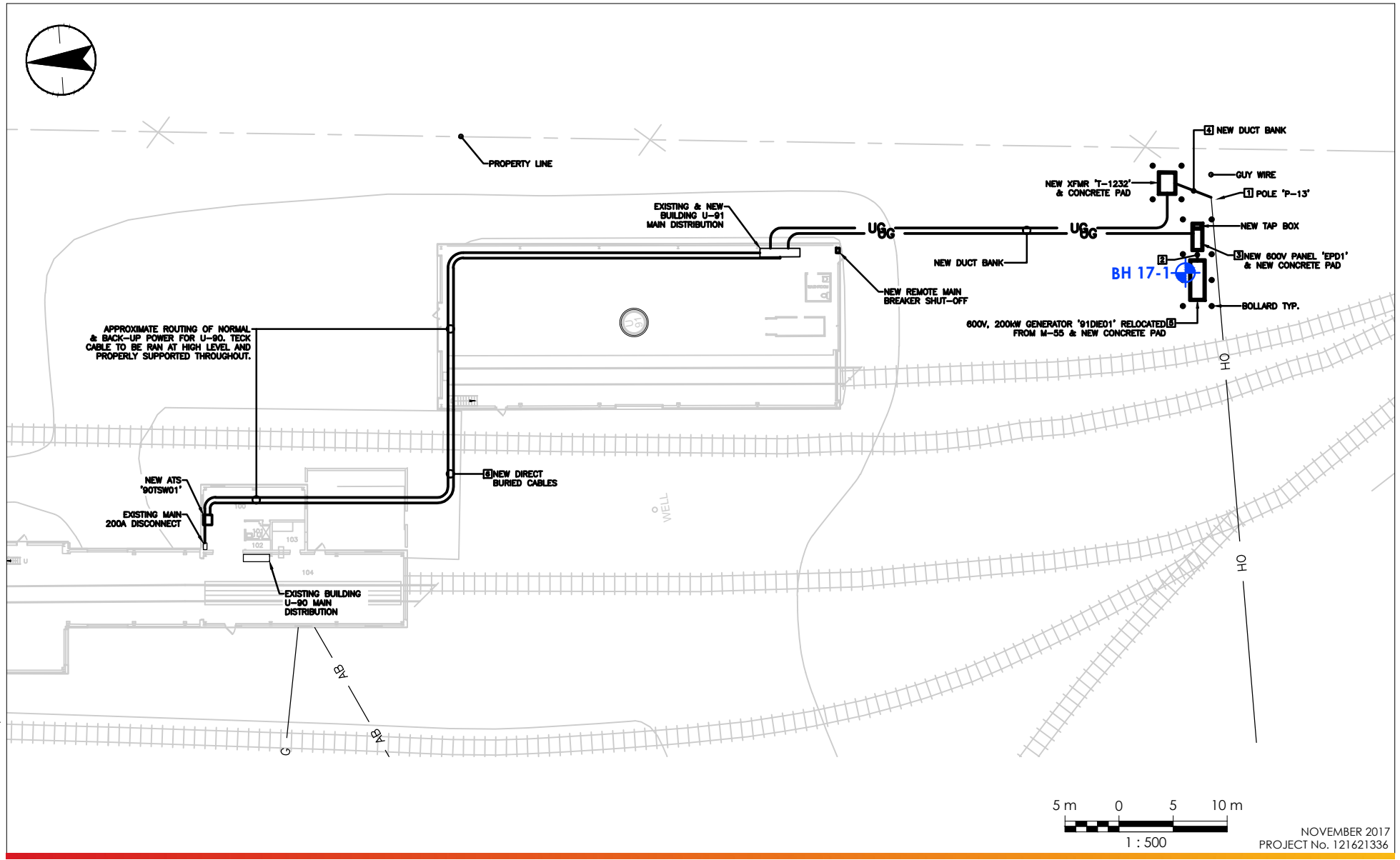
Drawing No.

1

Title

Key Plan

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LEGEND



APPROXIMATE BOREHOLE LOCATION

Client/Project

NATIONAL RESEARCH COUNCIL
PROPOSED NRC AST CAMPUS GENERATOR
2320 LESTER ROAD, OTTAWA, ONTARIO

Drawing No.

2

Title

BOREHOLE LOCATION PLAN

APPENDIX C

Symbols and Terms Used on Borehole Records

Stantec Borehole Record

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

<i>Rootmat</i>	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
<i>Topsoil</i>	- mixture of soil and humus capable of supporting vegetative growth
<i>Peat</i>	- mixture of visible and invisible fragments of decayed organic matter
<i>Till</i>	- unstratified glacial deposit which may range from clay to boulders
<i>Fill</i>	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

<i>Desiccated</i>	- having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
<i>Fissured</i>	- having cracks, and hence a blocky structure
<i>Varved</i>	- composed of regular alternating layers of silt and clay
<i>Stratified</i>	- composed of alternating successions of different soil types, e.g. silt and sand
<i>Layer</i>	- > 75 mm in thickness
<i>Seam</i>	- 2 mm to 75 mm in thickness
<i>Parting</i>	- < 2 mm in thickness

Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):

Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

<i>Trace, or occasional</i>	Less than 10%
<i>Some</i>	10-20%
<i>Frequent</i>	> 20%

Terminology describing compactness of cohesionless soils:

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
<i>Very Loose</i>	<4
<i>Loose</i>	4-10
<i>Compact</i>	10-30
<i>Dense</i>	30-50
<i>Very Dense</i>	>50

Terminology describing consistency of cohesive soils:

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
<i>Very Soft</i>	<0.25	<12.5	<2
<i>Soft</i>	0.25 - 0.5	12.5 - 25	2-4
<i>Firm</i>	0.5 - 1.0	25 - 50	4-8
<i>Stiff</i>	1.0 - 2.0	50 - 100	8-15
<i>Very Stiff</i>	2.0 - 4.0	100 - 200	15-30
<i>Hard</i>	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	Very Poor Quality
25-50	Poor Quality
50-75	Fair Quality
75-90	Good Quality
90-100	Excellent Quality

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	Crushed
Severely Fractured	Shattered or Very Blocky
Fractured	Blocky
Moderately Jointed	Sound
Intact	Very Sound

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

Spacing (mm)	Discontinuities	Bedding
>6000	Extremely Wide	-
2000-6000	Very Wide	Very Thick
600-2000	Wide	Thick
200-600	Moderate	Medium
60-200	Close	Thin
20-60	Very Close	Very Thin
<20	Extremely Close	Laminated
<6	-	Thinly Laminated

Terminology describing rock strength:

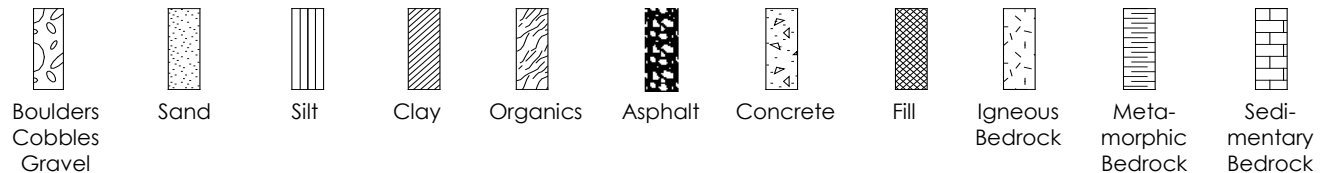
Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

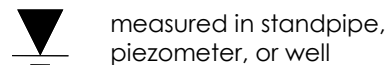
Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

WATER LEVEL MEASUREMENT



measured in standpipe, piezometer, or well



inferred

RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer

CLIENT National Research Council BOREHOLE No. BH17-1
 LOCATION NRC AST Campus Generator PROJECT No. 121621336
 DATES: BORING September 29, 2017 WATER LEVEL September 29, 2017 DATUM Geodetic

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES				UNDRAINED SHEAR STRENGTH - kPa									
					TYPE	NUMBER	RECOVERY (mm)	N-VALUE OR QD	50 100 150 200 WATER CONTENT & ATTERBERG LIMITS DYNAMIC PENETRATION TEST, BLOWS/0.3m STANDARD PENETRATION TEST, BLOWS/0.3m 10 20 30 40 50 60 70 80 90									
0	100.81	FILL: brown silty sand with gravel to silty sand. Contains pockets/clumps of silty clay.			SS	1	360	17										
	100.1																	
1		Compact light brown to light grey SILTY SAND (SM), trace gravel			SS	2	390	16										
		Grinding of auger on cobble or boulder at 1.5 m depth.																
2					SS	3	380	21										
3					SS	4	410	26										
4					SS	5	470	21										
5					SS	6	470	18										
6	94.9	End of Borehole			SS	7	390	22										
7					SS	8	420	24										

▽ Inferred Groundwater Level

▼ Groundwater Level Measured in Standpipe

■ Field Vane Test, kPa

□ Remoulded Vane Test, kPa

▲ Pocket Penetrometer Test, kPa

App'd _____

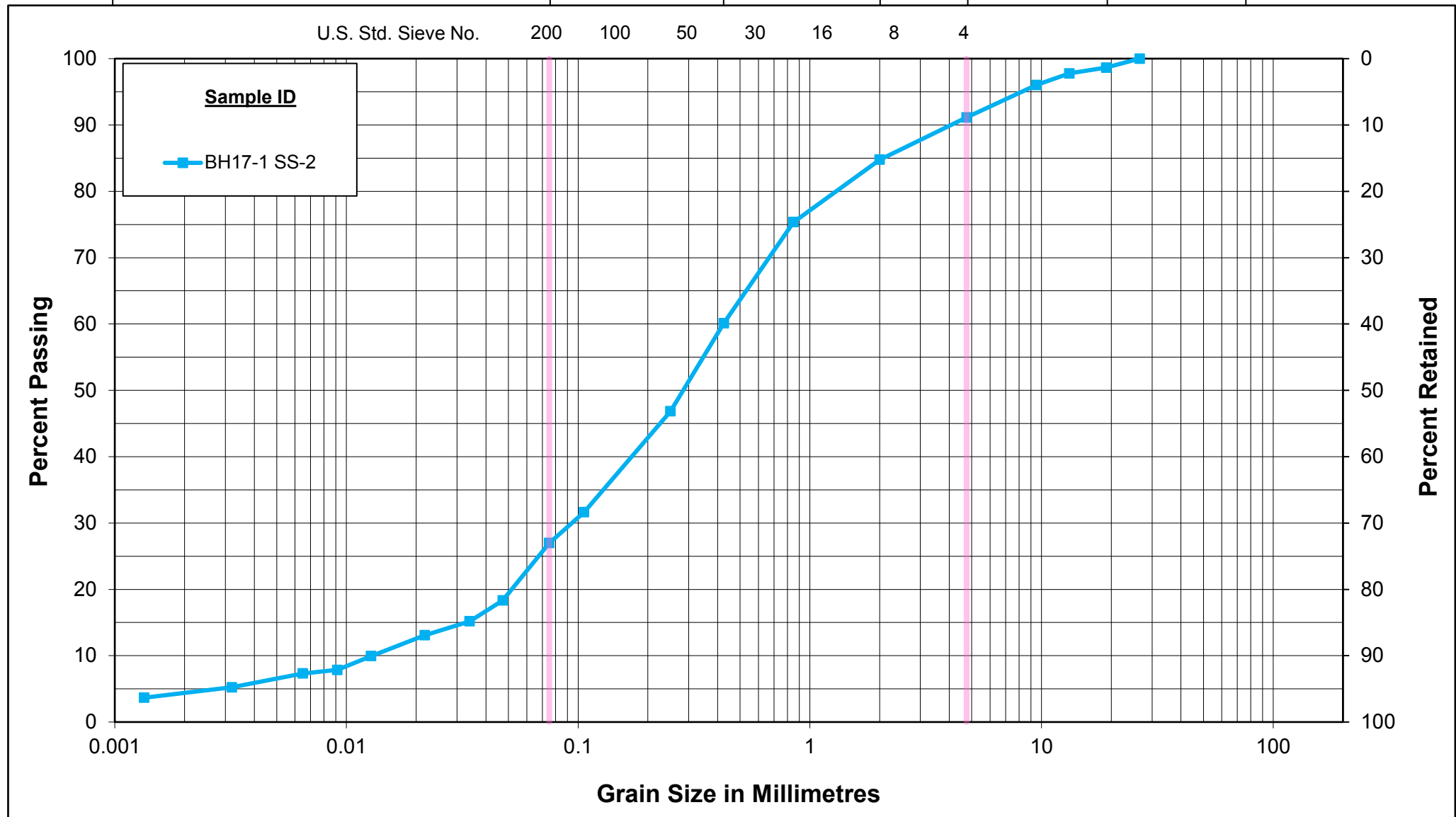
Date _____

APPENDIX D

Laboratory Test Results

Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



Silty Sand (SM)
National Research Council (NRC)
NRC AST Campus Generator

Figure No. D1

Project No. 121621336