TENDER ADDENDUM

Culverts Reconstruction and Lining - Gatineau Parkway – North Loop - Gatineau Park

NCC tender file # AL1584
April 23, 2015
ADDENDUM NO: 1

The following shall be read in conjunction with and shall form an integral part of the Tender/Proposal and Contract Documents:

1. Attached (1 page) is the sign in sheet from the April 21st non mandatory site visit.

2. Response to inquiry with regards re-use of material :

   “It should generally be possible to re-use the excavated embankment material to re-construct the embankment following the placement of the culvert and bedding materials. However, any organics, fine sand, alluvium or silty clay that may be encountered should not be re-used and any volume deficiency should be made up with MG-112. Under the roadway, the type of material placed in the frost zone (between subgrade level and 1.8 metres depth) should match the material exposed in the excavation slopes for frost heave compatibility. Embankment backfill should be placed in maximum 300 millimetre thick lifts and should be compacted to at least 90 percent of its modified Proctor maximum dry density using suitable compaction equipment”

   See attached geotechnical report.

3. In section 33 42 13-B (Culvert Relining)

   Replace 1.1 Scope with : This special provision covers the requirements to supply and install the following culvert liners into the existing culverts. The required lining method is cured-in-place pipe (CCIP). Culverts are listed in table 1. The work will include minor vegetation clearing to access the culvert ends. Prior to commencing the work or ordering any material, the Contractor shall validate culvert diameter and length and

ADDENDA À LA SOUMISSION

Reconstruction de ponceaux et chemisage – Promenade de la Gatineau – Boucle Nord – Parc de la Gatineau

Dossier de soumission de la CCN no. AL1584
Le 23 avril 2015
ADDENDA NO: 1

Ce qui suit doit être interprété comme faisant partie intégrante de la proposition/appel d'offres et des documents relatifs au contrat :

1) En annexe (1 page), la feuille de présence de la visite de site non obligatoire le 21 avril.

2) Réponse à la demande en ce qui concerne la réutilisation des matériaux :

   "Il devrait généralement être possible de réutiliser le matériau de remblai excavé pour reconstruire le remblai après le placement du ponceau et les matériaux de l’assise. Cependant, tout matériau organiques, sable fin, alluvium ou argile limoneuse qui peut-être être rencontrée ne devrait pas être réutilisé et tout déficit de volume devrait être composée avec le MG-112. Sous la route, le type de matériau placé dans la zone de gel (entre le niveau du sol de fondation et 1,8 mètres de profondeur) doit correspondre au matériel exposé dans les pentes de l'excavation pour la compatibilité de soulèvement dû au gel. Matériau de remblai doit être placé en couches épaisses de 300 millimètres (maximum) et doit être compacté au moins 90 pour cent de sa densité sèche maximale (*modified Proctor*), à l'aide de matériel de compactage adapté "

   Voir le rapport géotechnique en annexe (en anglais seulement).

3) Section 33 42 13-B (Gainage par chemisage)

   Remplacer 1.1 Étendue des travaux par : Cette disposition spéciale couvre les exigences pour la fourniture et l’installation des gaine de ponceaux suivants dans les ponceaux existants. La méthode de gainage requise est la réhabilitation par chemisage. Les ponceaux sont énumérés au tableau 1.Les travaux comprendront des travaux de déboisement conditions.

4. Section 33 42 13-B (Culvert Relining)

Replace 4.0. 1 Preliminary Work with: The work includes, without limitation, vegetation clearing in order to provide access to the culvert ends, culvert cleanout and reaming, water pumping and control, culvert ends replacement, riprap and site reinstatement.

mineures pour accéder à l'extrémité de ponceau. Avant de commencer les travaux ou de commander les matériaux, l'Entrepreneur doit valider le diamètre du ponceau et sa longueurs et ses conditions.

4) Section 33 42 13-B (Gainage par chemisage)

Remplacer 4.0.1 Travaux préliminaire par : Ces travaux comprennent, sans s'y limiter, déboisement mineures afin de fournir accès au ponceaux, le nettoyage et l'alésage de la conduite, les opérations de blocage et de pompage des effluents, le remplacement d'extrémités, l'enrochement et la remise en état des lieux.

Allan Lapensée
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Procurement Services / Services d'approvisionnement
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Pre-tender site visit / *Visite d'avant soumission*

Project title / ***Titre du projet*****:** GP - Parkway culverts (North Loop), Lining + Reconstruction.
Date: April 21/2015
Project / ***projet - DC #*** 3080-5-20, AL1584

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January 2014

REPORT ON

Geotechnical Investigation
Culvert Replacements along Promenade de la Gatineau and Promenade du Lac-Fortune
Gatineau Park
Chelsea, Quebec

Submitted to:
WSP Group
2611 Queensview Drive
Ottawa, Ontario
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Report Number: 13-1121-0159

Distribution:

2 copies - WSP Group
2 copies - Golder Associates Ltd.

REPORT

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Exova Report No. 1321366

1.0 INTRODUCTION

This report presents the results of a geotechnical investigation carried out for the proposed replacements of five culverts within Gatineau Park near Chelsea, Quebec.

This geotechnical investigation included an evaluation of the soil and groundwater conditions by means of a series of boreholes at each culvert location. Based on an interpretation of the factual information obtained, a general description of the subsurface conditions is presented. These interpreted subsurface conditions and available project details were used to prepare engineering guidelines on the geotechnical design aspects of the culvert replacements, including construction considerations which could influence design decisions.

The reader is referred to the "Important Information and Limitations of This Report", which follows the text but forms an integral part of this document.

2.0 DESCRIPTION OF SITE AND PROJECT

Plans are being prepared for the replacement of four culverts numbered 90, 91, 96, and 97 located along Promenade de la Gatineau and one culvert (105) located along Promenade de Lac Fortune within Gatineau Park near Chelsea, Quebec. The approximate locations of the sites are shown on the Key Plan, Figure 1.

The existing culverts are all corrugated steel pipe (CSP) culverts. The following table summarizes the dimensions, invert elevations, flow direction and other information on the existing culverts.

Culvert Number	**Dimensions**	**Invert Elevation (m)**		**Flow Direction**	**Approximate Top of Embankment Elevation (m)**	**Cover (m)**	**Approximate Side Slope Angles**
		Upstream	**Downstream**				
90	Single pipe – 610 mm	150.69	149.65	East to West	160.9	10.1	1.6H:1V
91	Single pipe – 914 mm	158.28	157.37	North to South	168.1	9.4	2.4H:1V & 2.7H:1V
96	Single pipe – 457 mm	163.51	162.78	North to South	171.2	7.6	1.6H:1V & 1.9H:1V
97	Twin pipes – 914 mm	163.10 / 163.14	162.82 / 162.86	West to East	165.4	1.6	1.6H:1V & 1.4H:1V
105	Single pipe – 610 mm	241.34	240.70	East to West	243.2	1.6	-

The existing culverts are planned to be replaced with corrugated steel pipe-arch (ACSP) culverts of varying sizes. At the time of this report, the design for the replacement of Culvert 105 had not begun. Therefore, no design information was available at the time of this report for this culvert, but it has been assumed that the culvert would be replaced with a similar culvert as the other four (i.e., ACSP). The following table summarized the proposed replacements and the difference in invert elevations from the existing culvert to the proposed culvert.

Culvert Number	**Dimensions**	**Proposed Upstream Invert (m) / Difference (m)**	**Proposed Downstream Invert (m) / Difference (m)**	**Flow Direction**
90	Single ACSP – 1200 mm	150.48 / - 0.21	149.26 / - 0.39	East to West
91	Single ACSP – 1200 mm	158.09 / - 0.19	156.25 / - 1.12	North to South
96	Single ACSP – 1400 mm	163.51 / 0.0	162.78 / 0.0	North to South
97	Twin ACSP – 1200 mm	162.90 / -.20, - 0.24	162.70 / - 0.12, -0.16	West to East
105	TBD	TBD	TBD	East to West

It is understood that no wingwall/headwall structures are proposed for the ends of the culverts, only a below grade precast concrete cut off wall and rip rap channel lining at both ends of the culverts are proposed as the culvert end treatment. It is also understood that the embankments will be reinstated to the existing roadway elevations and the side slopes of the embankments will be armoured with a layer of rip rap.

Based on published geologic mapping, the subsurface conditions at this site are expected to consist of shallow bedrock, but with a variable surface elevation. Based on a previous investigation carried out in 2011 for a washed out culvert located nearer to Meech Lake Rd, the valleys located between rocky hills in this area could be filled with soft or loose overburden soils not indicated in the published mapping.

The site also falls within the Western Quebec Seismic Zone (WQSZ) according to the Geological Survey of Canada. The WQSZ constitutes a large area that extends from Montreal to Témiscaming, and which encompasses the Ottawa area. Within the WQSZ recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. Historical seismicity within the WQSZ from 1900 to 2000 includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2 and the 1944 Cornwall-Massena event which had a magnitude of 5.6. More recently, the 2010 earthquake centered in Val-des-Bois, Québec had a magnitude of 5.0. In comparison to other seismically active areas in the world (e.g., California, Japan, New Zealand), the frequency of earthquake activity within the WQSZ is significantly lower but there still exists the potential for significant earthquake events to be generated.

3.0 PROCEDURE

The field work for this investigation was carried out between September 3, 2013 and September 10, 2013. At that time, sixteen boreholes (numbered 13-1 to 13-14 and 13-14A and 13-14B) and four augerholes (numbered AH 13-103, AH 13-106, AH 13-107 and AH 13-111) were put down at the approximate locations shown on the site plans, Figures 2, 4, 6, 8 and 10.

Boreholes 13-1, 13-2, 13-4, 13-5, 13-9 and 13-10 were advanced using portable drilling equipment supplied and operated by OGS Inc. of Almonte, Ontario. These boreholes were located near the ends of the existing culverts and near the toe of the existing embankments. These boreholes were terminated at sampler refusal depth, which varied from 1.2 to 4.7 metres below the existing ground surface.

Boreholes 13-3, 13-6, 13-7, 13-8, 13-11, 13-12, 13-13, 13-14, 13-14A, and 13-14B and the four augerholes were advanced using a truck-mounted hollow stem auger drill rig supplied and operated by George Downing Estate Drilling Ltd. of Grenville-sur-la-Rouge, Quebec. These boreholes were terminated at a depths ranging from 1.1 to 14.8 metres. Within the boreholes, standard penetration tests were carried out at regular intervals of depth and samples of the soils encountered were recovered using drive-open sampling equipment.

The augerholes were advanced adjacent to the boreholes 13-3, 13-6, 13-7 and 13-11 within the roadway to obtain the existing pavement structure at these locations.

Groundwater observations were noted at the completion of each borehole.

The field work was supervised by experienced technicians from our staff who located the boreholes, directed the drilling, sampling and in situ testing operations, logged the boreholes, and took custody of samples.

Upon completion of drilling, soil samples and rock core were transported to our laboratory for further examination by the project engineer and for laboratory testing. Index and classification tests, such as water content determinations, Atterberg Limits and grain size distribution testing were carried out on select soil samples.

Five samples of soil, one from each culvert location were submitted to EXOVA Laboratories Ltd. for chemical analysis related to potential corrosion of buried steel elements and potential sulphate attack on buried concrete elements.

The borehole locations were selected by Golder Associates and located in the field in relation to the existing site features. The location and ground surface elevation at boreholes 13-2, 13-4, 13-5, 13-9 and 13-10 were surveyed by National Capital Commission (NCC) surveyors after the completion of the drilling. The location of the remaining eleven boreholes was determined using existing site features and surveyed using a handheld GPS unit. The ground surface elevation at these boreholes was later interpreted from the NCC survey information.

4.0 SUBSURFACE CONDITIONS

A detailed description of the subsurface conditions encountered in the boreholes advanced for this investigation are shown on the Record of Borehole sheets in Appendix A. The results of the laboratory testing on select soil samples from this investigation are provided on the Record of Borehole sheets and on Figures 11 to 14. The results of the basic chemical analysis on soil samples from select boreholes are provided in Appendix B.

4.1 Culvert No. 90

Three boreholes and one augerhole were advanced at the location of the existing culvert. Two boreholes (BH 13-4 and 13-5) were advanced near the ends of the culvert at the toe of the roadway embankment and the third borehole (BH 13-6), located just north of the culvert, was advanced through the shoulder of the roadway embankment. One augerhole (AH 13-106) was advanced within the southbound travel lane. The locations of the boreholes and augerhole are shown on Figure 2.

The boreholes near the ends of the culvert (boreholes 13-4 and 13-5) encountered surficial organic silt and clayey silt overlying silty clay and were terminated when sampler refusal was encountered at depths of 2.7 metres (elevation 147.1 metres) and 4.7 metres (elevation 146.5 metres), respectively. Standard penetration tests carried out within the surficial organic silt and clayey silt gave an ‘N’ value of 1 blow per 305 millimetres of penetration, indicating a very loose state of packing. The results of in situ vane testing carried out within the silty clay gave undrained shear strengths ranging from 57 to 69 kilopascals. Standard penetration tests carried out within the silty clay gave ‘N’ values ranging from 2 to 6 blows per 305 millimetres of penetration. The results of this in situ testing indicate that the silty clay has a firm to stiff consistency. The results of Atterberg limit testing carried out on one sample of the silty clay gave plastic limit value of 14 and liquid limit value of 27 reflecting low plasticity. The measured water content of the silty clay ranges from approximately 28 to 40 percent.

Augerhole AH 13-106 encountered 110 millimetres of asphaltic concrete overlying 140 millimetre of granular road base consisting of gravelly sand.

At borehole 13-6, the roadway embankment appears to consist of sand and gravel with cobbles and boulders (possible rock fill). Rock fill is suspected because of the heavy grinding noted during the drilling. The fill extends to a depth of about 9.9 metres (elevation 150.8 metres) and is underlain by poorly graded sand (possible fill) to about 11.7 metres depth (elevation 149.1 metres). A grain size distribution was carried out on a select sample of the poorly graded sand (possible fill) and the results are shown on Figure 12. Auger refusal was encountered at this depth and the borehole was advanced deeper using rock coring techniques. Standard penetration test ‘N’ values within the embankment fill range from 3 to in excess of 100 blows per 305 millimetres of penetration, indicating a very loose to very dense state of packing, although the higher ‘N’ values could reflect the presence of cobbles and boulders, rather than the state of packing of the soil matrix. Granitic and gneiss boulders were encountered at 6.1 to about 7.3 metres depth within the embankment fill.

Granitic bedrock was encountered below the refusal depth of 11.7 metres (elevation 149.1 metres) in borehole 13-6 and the borehole was extended into the underlying bedrock to about 14.8 metres depth (elevation 146.0 metres). The Rock Quality Designation (RQD) values ranged from 95 to 98 percent indicating a very good quality rock. At boreholes 13-4 and 13-5, sampler refusal was encountered elevations 147.1 metres and 146.5 metres, respectively, which may indicate the bedrock surface, however, it could also represent cobbles and/or boulders. The boreholes suggest that bedrock may be higher under the roadway embankment than at the ends of the culvert or the toe of the embankment. However, intrusive bedrock, such as granitic bedrock, does exhibit significant changes and the bedrock surface should be expected to vary. A cross-section through the embankment and along the culvert alignment is shown on Figure 3.

4.2 Culvert No. 91

Three boreholes and one augerhole were advanced at the location of the existing culvert. Two boreholes (BH 13-1 and 13-2) were advanced near the ends of the culvert at the toe of the roadway embankment and the third borehole (BH 13-3), located just west of the culvert, was advanced through the shoulder of the roadway embankment. One augerhole (AH 13-103) was advanced within the northbound travel lane. The borehole and augerhole locations are shown on Figure 4.

The boreholes near the ends of the culvert (boreholes 13-1 and 13-2) encountered sand, silty sand and sandy gravel and were terminated when sampler refusal was encountered at depths of 1.2 metres (elevation 157.3 metres) and 2.3 metres (elevation 155.0 metres) respectively. Standard penetration tests carried out within these granular soils gave ‘N’ values ranging from 1 to 13 blows per 305 millimetres of penetration, indicating a very loose to compact state of packing. One standard penetration test within the sandy gravel gave an ‘N’ value of 75 blows per 305 millimetres of penetration, which could reflect the presence of larger gravel or cobbles, rather than the state of packing of the soil matrix. A grain size distribution was carried out on a select sample of the sandy gravel and the results are shown on Figure 11.

Augerhole 13-103 encountered 100 millimetres of asphaltic concrete overlying 160 millimetre of granular road base consisting of gravelly sand.

At borehole 13-3, the roadway embankment appears to consist of sand and gravel with cobbles and boulders (possible rock fill). Rock fill is suspected because of the heavy grinding noted during the drilling. The fill extends to a depth of about 7.6 metres (elevation 160.9 metres) and is underlain by peat and silty sand to about 8.2 metres (elevation 160.3 metres). Auger refusal was encountered at this depth and the borehole was advanced deeper using rock coring techniques. Standard penetration test ‘N’ values within the embankment fill range from 7 to in excess of 100 blows per 305 millimetres of penetration, indicating a very loose to very dense state of packing, although the higher ‘N’ values could reflect the presence of cobbles and boulders, rather than the state of packing of the soil matrix. A granitic boulder was encountered at 6.9 to about 7.3 metres depth within the embankment fill.

Gneiss bedrock was encountered below the refusal depth in borehole 13-3 and the borehole was extended into the underlying bedrock to about 11.2 metres depth (elevation 157.4 metres). The RQD values ranged from 90 to 95 percent indicating a very good quality rock. At boreholes 13-1 and 13-2, sampler refusal was encountered at elevation 157.3 metres and 155.0 metres, respectively, which may indicate the bedrock surface; however, it could also represent cobbles and/or boulders. This indicates that bedrock may be higher under the roadway embankment than at the ends of the culvert or the toe of the embankment. However, intrusive bedrock, such as gneiss, does exhibit significant changes and the bedrock surface should be expected to vary. A cross-section through the embankment and along the culvert alignment is shown on Figure 5.

4.3 Culvert No. 96

Three boreholes and one augerhole were advanced at the location of the existing culvert. Two boreholes (BH 13-9 and 13-10) were advanced near the ends of the culvert at the toe of the roadway embankment and the third borehole (BH 13-11), located just west of the culvert, was advanced through the shoulder of the roadway embankment. One augerhole (AH 13-111) was advanced within the westbound travel lane. The borehole and augerhole locations are shown on Figure 6.

The boreholes near the ends of the culvert (boreholes 13-9 and 13-10) encountered organic silt and silty sand overlying silty clay and were terminated upon sampler or dynamic cone penetration refusal encountered at depths of 4.5 metres (elevation 158.0 metres) and 3.6 metres (elevation 160.6 metres), respectively. Standard penetration tests carried out within the surficial organic silt and silty sand gave ‘N’ values ranging from 1 to 17 blows per 305 millimetres of penetration, indicating a very loose to compact state of packing. Standard penetration tests carried out within the silty clay gave ‘N’ values ranging from 8 to 46 blows per 305 millimetres of penetration, indicating a very stiff consistency. The results of Atterberg limit testing carried out on one sample of the silty clay gave plastic limit value of 20 and liquid limit value of 39 reflecting medium plasticity. The measured water content of the silty clay ranges from approximately 22 to 33 percent.

Augerhole 13-111 encountered 110 millimetres of asphaltic concrete overlying 140 millimetre of granular road base consisting of gravelly sand.

At borehole 13-11, the roadway embankment appears to consist of gravelly sand with occasional cobbles and boulders. The fill extends to a depth of about 8.5 metres (elevation 162.6 metres) and is underlain by topsoil, silty clay and silty sand to about 10.7 metres (elevation 160.4 metres). Auger refusal was encountered at this depth and the borehole was advanced deeper using rock coring techniques. Standard penetration test ‘N’ values within the embankment fill range from 12 to 56 blows per 305 millimetres of penetration, indicating a compact to very dense state of packing, although the higher ‘N’ values could reflect the presence of cobbles and boulders, rather than the state of packing of the soil matrix.

Gneiss bedrock was encountered below the refusal depth in borehole 13-11 and the borehole was extended into the underlying bedrock to about 13.2 metres (elevation 157.9 metres). The RQD values ranged from 88 to 96 percent indicating a good to very good quality rock. At boreholes 13-9 and 13-10, sampler refusal and dynamic cone penetration refusal was encountered at elevation 158.0 metres and 160.6 metres, respectively, which may indicate the bedrock surface, however, it could also represent cobbles and/or boulders. The boreholes suggest that bedrock is below the invert of the existing culvert. A cross-section through the embankment and along the culvert alignment is shown on Figure 7.

4.4 Culvert No. 97

Two boreholes and one augerhole were advanced at the location of the existing culvert. Boreholes 13-7 and 13-8 were advanced along the shoulders of the roadway embankment on either side of the existing culvert. One augerhole (AH 13-107) was advanced within the westbound travel lane. The locations of the boreholes are shown on Figure 8.

The boreholes encountered roadway embankment fill consisting of gravelly sand. The embankment fill extends to a depth of about 4.9 metres (elevation 160.2 metres) and about 3.5 metres (elevation 162.1 metres), respectively. Standard penetration test ‘N’ values within the embankment fill range from 7 to 42 blows per 305 millimetres of penetration, indicating a loose to dense state of packing. The lower ‘N” values were at depth which could be an indication of poor compaction or placement under submerged conditions.

The fill is underlain by silty clay to about 5 metres depth (elevation 160.0 metres). The result of one in situ vane test carried out within the silty clay gave an undrained shear strength of 31 kilopascals. Standard penetration tests carried out within the silty clay gave ‘N’ values ranging from 5 to 6 blows per 305 millimetres of penetration. The results of this in situ testing indicate that the silty clay has a firm to stiff consistency. Submerged silty sand and sandy silt was encountered below the silty clay and extends to depths of 13.1 metres and 8.7 metres at the bottom of boreholes 13-7 and 13-8, respectively. Standard penetration test ‘N’ values within the silty sand and sandy silt range from weight of rod (less than 1 blow) to 13 blows per 305 millimetres of penetration, indicating a very loose to compact state of packing. Grain size distribution testing was carried out on 2 samples of the silty sand and sandy silt, the results of which are provided on Figures 13 and 14.

Augerhole 13-107 encountered 120 millimetres of asphaltic concrete overlying 100 millimetre of granular road base consisting of gravelly sand.

Auger refusal was encountered in borehole 13-7 at 13.1 metres (elevation 152.0 metres) and is assumed to be the bedrock surface. A cross-section through the embankment and along the culvert alignment is shown on Figure 9.

4.5 Culvert No. 105

Five shallow boreholes were advanced at this culvert location. Two boreholes (13-12 and 13-13) were advanced along the shoulder of the roadway or edge of pavement and boreholes 13-14, 13-14A and 13-14B were advanced just south of the existing culvert within the center of southbound travel lane. The purpose of boreholes 13-14, 13-14A, and 13-14B was to determine the possible cause(s) for the pavement distortion. The location of the boreholes is shown on Figure 10. These boreholes ranged from 1.1 to 2.5 metres in depth. These boreholes, except borehole 13-12, encountered pavement structure at the ground surface. At borehole 13-12, topsoil was encountered at the ground surface.

The boreholes within the pavement encountered 90 to 130 millimetres of asphaltic concrete overlying granular fill.

Below the topsoil and pavement structure, fill was encountered consisting of gravelly sand and poorly graded sand. Trace amounts of organics were also encountered within various layers within this fill. Standard penetration test ‘N’ values within the embankment fill range from 4 to in excess of 50 blows per 305 millimetres of penetration, indicating a loose to very dense state of packing, although the higher ‘N’ values could reflect the presence of cobbles and boulders, rather than the state of packing of the soil matrix.

Auger refusal was encountered below the fill in all but one borehole (borehole 13-13). The auger refusals are considered to represent the top of bedrock. Borehole 13-13 encountered a thin layer of peat and organic silt below the fill underlain by gravelly sand and then auger refusal. The auger refusal was encountered at a depth of 2.5 metres (elevation 240.1 metres).

5.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides engineering guidelines on the geotechnical design aspects of this culvert replacements based on our interpretation of the borehole information and project requirements, and is subject to the limitations in the "Important Information and Limitations of This Report" attachment which follows the text of the report.

The following sections highlight particular geotechnical issues, design and construction guidelines for each individual culvert. The general guidelines are also relevant for each culvert as well.

5.2 Culvert No. 90

The existing culvert is a 610 millimetre diameter corrugated steel pipe (CSP) with an invert elevation varying from 150.69 to 149.85 metres and the flow is from east to west. It is our understanding, from the drawings provided, that the proposed construction will consist of a new 1200 millimetre corrugated steel pipe-arch (ACSP) constructed at the same location as the existing culvert and will have an invert elevation varying from 150.48 to 149.26 metres, with flows still from the east to the west. The new culvert will be founded about 0.2 to 0.6 metres deeper than the existing culvert.

5.2.1 Bedding

Borehole 13-6, within the roadway embankment, indicates that bedrock surface could vary and be encountered near the proposed culvert invert. The culvert should be founded on a bedding of 300 millimetres of MG-20. However, if bedrock is encountered at or above the bedding level, then the bedrock should be removed to a depth of 600 millimetres below the invert of the culvert to provide a uniform foundation. This subexcavation should be filled with MG-20 compacted in 300 millimetre thick lifts. Refer to Section 5.7 for additional bedding and backfill guidelines.

Rock removal will most likely be localized and thus mechanical methods, such as hoe ramming will likely be feasible. This methodology is anticipated to be slow and tedious; therefore, some contingency allowance for rock removal should be included in the tender documents to address this possible subsurface condition.

5.2.2 Temporary Excavation

Excavation for the new culvert may be carried out either by unsupported excavations or using temporary shoring.

No unusual problems are anticipated in trenching (unsupported excavation) in the roadway embankment using conventional hydraulic excavating equipment. However, the contractor should be prepared to handle boulder and rock fill excavation by means of hoe ramming or ripping. Side slopes within the embankment fill should be stable in the short term at 1 horizontal to 1 vertical. Since the total depth of the excavation, from road surface to culvert bedding is anticipated to be on the order of 11.5 metres, and since this exceeds the range of typical excavation equipment, at least two benching levels will likely be required to complete the installation. This will add significantly to the size of the excavation and the total length of pavement to be reinstated.

If unsupported excavation side slopes cannot be accommodated, then temporary excavation shoring will be required. Due to the possible presence of rock fill and the depth of the excavation, soldier pile and lagging would be a practical method of shoring if the contractor chooses to shore the excavation rather than using an unsupported excavation. However, the piles would most likely be required to be advanced by preboring the pile locations due to possible boulders within the fill and the bedrock near the toe of the excavation. If not, the contractor should anticipate pile damage and/or piles that divert from their planned alignment and location. Due to the depth of the excavation, tie backs would likely be required as part of the shoring system. Additional recommendations can be provided if and when required. However, the design of the temporary shoring system should be entirely the responsibility of the contractor. Trench box type shoring could also be considered, however, the trench box should be wide enough to facilitate the removal of the rock fill from within the box.

5.3 Culvert No. 91

The existing culvert is a 914 millimetre diameter CSP with an invert elevation varying from 158.28 to 157.37 metres and the flow is from north to south. It is our understanding, from the drawings provided, that the proposed construction will consist of a new 1200 millimetre ACSP constructed at the same location as the existing culvert and will have an invert elevation varying from 158.09 to 156.25 metres, with flows still from the north to the south. This will be about 0.2 to 1.1 metres deeper than the existing culvert.

5.3.1 Bedding

Borehole 13-3 within the roadway embankment indicates bedrock could be as much as 3.1 metres higher than the proposed culvert invert under the roadway embankment. Therefore, the existing culvert and the proposed culvert may be at least partially founded within a bedrock valley. The new culvert should be founded on a bedding of 600 millimetres of MG-20 to provide sufficient bedding within the unyielding bedrock and to provide a uniform foundation across the entire culvert. Refer to Section 5.7 for additional bedding and backfill guidelines.

Rock removal, if required, will most likely be localized under the embankment to deepen or widen the trench. Mechanical methods, such as hoe ramming will be the most practical. This methodology is anticipated to be slow and tedious within this bedrock, therefore, an allowance for rock removal should be included in the tender documents to address this possible subsurface condition.

5.3.2 Temporary Excavation

Excavation for the new culvert may be carried out either by unsupported excavations or using temporary shoring.

No unusual problems are anticipated in trenching (unsupported excavation) in the roadway embankment using conventional hydraulic excavating equipment. However, the contractor should be prepared to handle boulder and rock fill excavation by means of suitable large size excavating equipment. Side slopes within the embankment fill should be stable in the short term at 1 horizontal to 1 vertical. Since the total depth of the excavation, from road surface to culvert bedding is anticipated to be on the order of 12 metres, and since this exceeds the range of typical excavation equipment, at least two benching levels will likely be required to complete the installation. This will add significantly to the size of the excavation and the total length of pavement to be reinstated. Groundwater control measures may be needed, which could include diversion dams and temporary pumping of surface water during construction.

If unsupported excavation side slopes cannot be accommodated, then temporary excavation shoring will be required. Due to the possible presence of rock fill and the depth of the excavation, soldier pile and lagging would be a practical method of shoring if the contractor chooses to shore the excavation rather than using an unsupported excavation. However, the piles would most likely be required to be advanced by preboring the pile locations due to possible boulders within the fill and the bedrock near the toe of the excavation. If not, the contractor should anticipate pile damage and/or piles that divert from their planned alignment and location. Due to the depth of the excavation, tie backs would likely be required as part of the shoring system. Additional recommendations can be provided if and when required. However, the design of the temporary shoring system should be entirely the responsibility of the contractor. Trench box type shoring could be considered, however, the trench box should be wide enough to facilitate the removal of the rock fill from within the box.

5.4 Culvert No. 96

The existing culvert is a 457 millimetre diameter CSP with an invert elevation varying from 163.51 to 162.78 metres and the flow is from north to south. It is our understanding, from the drawings provided, that the proposed construction will consist of a new 1400 millimetre ACSP constructed at the same location as the existing culvert with the new invert elevation matching the existing culvert.

5.4.1 Bedding

The boreholes indicate that bedrock is lower than the proposed invert and the new culvert will most likely founded on the existing culvert bedding or native silty clay. Existing organics at the culvert ends will need to be removed prior to placing any new bedding. The proposed culvert should be founded on a 600 millimetre bedding consisting of MG-20 to provide uniform bedding across the entire culvert. If the depth and quality of the existing culvert bedding can be demonstrated and if it has sufficient thickness, this existing bedding could be retained in place. Refer to Section 5.7 for additional bedding and backfill guidelines.

5.4.2 Temporary Excavation

Excavation for the new culvert may be carried out either by unsupported excavations or using temporary shoring.

No unusual problems are anticipated in trenching in the roadway embankment using conventional hydraulic excavating equipment. However, the contractor should be prepared to handle boulder and rock fill excavation. Side slopes within the embankment fill should be stable in the short term at 1 horizontal to 1 vertical. Since the total depth of the excavation, from road surface to culvert bedding is anticipated to be on the order of 11.5 metres, and since this exceeds the range of typical excavation equipment, at least two benching levels will likely be required around mid-height to complete the installation. This will add significantly to the size of the excavation and the total length of pavement to be reinstated. Groundwater control measures may be needed, which could include diversion dams and temporary pumping of surface water during construction.

If unsupported excavation side slopes cannot be accommodated, then temporary excavation shoring will be required. Due to the possible presence of rock fill and the depth of the excavation, soldier pile and lagging would be a practical method of shoring if the contractor chooses to shore the excavation rather than using an unsupported excavation. However, the piles may require to be advanced by preboring the pile locations due to possible boulders within the fill. If not, the contractor should anticipate pile damage and/or piles that divert from their planned alignment and location. Due to the depth of the excavation, tie backs would likely be required as part of the shoring system. Additional recommendations can be provided if and when required. However, the design of the temporary shoring system should be entirely the responsibility of the contractor. Trench box type shoring could be considered, however, the trench box should be wide enough to facilitate the removal of the rock fill from within the box.

5.5 Culvert No. 97

The existing culverts are twin 914 millimetre diameter CSP culverts with invert elevations varying from about 163.1 to 162.8 metres, and the flow is from west to east. It is our understanding, from the drawings provided, that the proposed construction will consist of two new 1400 millimetre ACSP constructed at the same location as the existing culverts and will have an invert elevation varying from 162.90 to 162.70 metres, with flows still from the west to east. This will be about 0.2 to 0.1 metres deeper than the existing culverts.

5.5.1 Bedding

The boreholes indicate that the existing culvert is founded within the roadway embankment fill and the new culverts will most likely be founded on the existing culvert bedding or roadway embankment fill. If organics are encountered at the culvert ends then it will need to be removed prior to placing any new bedding. The proposed culvert should be founded on a bedding consisting of 300 to 600 millimetres of MG-20, depending on the culvert size, to provide uniform bedding across the entire culvert. If the depth and quality of the existing culvert bedding can be demonstrated and if it has sufficient thickness, this existing bedding could be retained in place. Refer to Section 5.7 for additional bedding and backfill guidelines.

5.5.2 Temporary Excavation

No unusual problems are anticipated in trenching in the roadway embankment using conventional hydraulic excavating equipment. Side slopes within the embankment fill above the groundwater table should be stable in the short term at 1 horizontal to 1 vertical. Trench box type shoring could also be considered, however, the design of the temporary shoring system should be entirely the responsibility of the contractor. Groundwater control measures will be needed, which may require diversion dams and temporary pumping of surface water during construction.

5.5.3 Other Findings

A liquefaction assessment of the foundation soils was carried out and the results of this assessment are discussed in Section 5.9 of this report.

5.6 Culvert No. 105

The existing culvert is a 610 millimetre CSP with invert elevations of 241.34 to 240.70 metres, which is about 1.8 to 2.0 metres below the existing pavement surface. At this time no construction documents are available, but it is assumed that a new culvert invert would be at or very close to the existing culvert invert.

The existing culvert is jacking upward towards the pavement surface. This jacking is likely being caused by frost heave within the organics during freezing conditions. The existing fill and buried organics will need to be excavated and replaced with suitable granular material. Also, it appears that no frost tapers are in place at this location and that the culvert is likely constructed at least partially in a bedrock trench, since auger refusal depths varied from 1.1 to 2.5 metres below the existing pavement surface and the culvert inverts are 1.8 to 2.0 metres below the pavement surface. Therefore, additional bedrock removal is likely needed at this culvert location to allow construction of proper frost tapers and adequate pipe bedding for the new culvert. The frost tapers or transition from a bedrock subgrade to the granular trench fill should be constructed at a slope of 5H:1V from the bedrock surface to the underside of the pavement structure on both sides of the culvert.

Bedding of this new culvert should follow the general bedding guidelines outlined in Section 5.7 of this report.

Groundwater control measures may be needed, which could include diversion dams and temporary pumping of surface water during construction.

5.7 General Culvert Bedding, Backfill and Erosion Protection

The following general bedding, backfill and erosion protection guidelines apply to all proposed culvert replacements.

5.7.1 Bedding

The bedding for the new culvert should consist of a layer of MG-20 (NQ 2560-114) with a minimum thickness of 150 millimetres for culvert pipes less than 650 millimetres in diameter. Culvert pipes greater than 650 millimetre diameter should have a bedding layer with a minimum thickness of 300 millimetres unless otherwise noted. The bedding should be compacted to at least 90 percent of its modified Proctor maximum dry density. Due to the difficulties in placing the first lifts of pipe-surround backfill under the haunch of large diameter pipe, it is advantageous to compact and shape the bedding and surround up the quarter-height point prior to placing the pipe section. Further, for pipes larger than 750 millimetres in diameter, 2560-114 recommends an un-compacted key beneath the center-invert to prevent the concentration of stress that that point. All bedding, surround and cover material, up to 300 millimetres above the top of the new pipe should consist of 100 percent crushed stone, MG-20, placed in lifts with a maximum thickness of 300 millimetres and compacted to at least 90 percent of its modified Proctor maximum dry density. The use of 100 percent crushed material will provide a slightly higher resistance to washing out over crushed sand and gravel. If the bottom of the excavation is loose or soft, it may be necessary to thicken the bedding or to place a layer of MG-56 to provide a more stable working platform and bedding.

Under no circumstances should clear stone be used as bedding and cover in this application, therefore, fairly complete de-watering of the trench bottom will be required to permit proper compaction of the graded granular material. This may require additional pumping from well filtered sumps established in the floor of the excavation, depending on the success of the other de-watering operations.

5.7.2 Backfill

It should generally be possible to re-use the excavated embankment material to re-construct the embankment after the placement of the culvert and bedding materials. However, any organics, fine sand, alluvium or silty clay that may be encountered should not be re-used and any volume deficiency should be made up with MG-112 (NQ 2560-114). Under the roadway, the type of material placed in the frost zone (between subgrade level and 1.8 metres depth) should match the material exposed in the excavation slopes for frost heave compatibility. Embankment backfill should be placed in maximum 300-millimetre thick lifts and should be compacted to at least 90 percent of its modified Proctor maximum dry density using suitable compaction equipment.

If the embankment is to be reconstructed using existing rock fill then the fill should be constructed by placing the rock fill the full width of the embankment in successive and in uniform layers. Layers should not exceed 1.5 metres in thickness prior to compaction. Each layer of rock fill should be fully compacted before the succeeding layer is placed. Each rock fill layer should be compacted with a tractor bulldozer, crawler type. Materials shall be placed in final position by blading. End dumping or depositing of rock over the end of any layer by hauling equipment should not be allowed. Each layer should be levelled in place and compacted to minimize voids and bridging of large rock fragments within the embankment.

Rocks fragments exceeding a maximum dimension of 1 metre shall be well distributed throughout the embankment. Rock fragments up to a maximum size of 3 metres in size may be incorporated into the embankment provided that the rock fragments are less than two-thirds the remaining embankment height, when measured from the bottom of the oversized rock fragment at the point of placement to the top of the rock embankment, and are sufficiently spaced to allow free access of the specified equipment to compact the intervening fill.

Voids on the top surface of the embankment should be minimized to prevent migration of the roadway subbase and base into the rock fill embankment by chinking the top surface with rock fragments and spalls to form the subgrade prior to the placement of the roadway subbase.

5.7.3 Erosion Protection

If the water flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextile and rip rap) in the culvert area.

In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert and should extend to a depth of 1 metre below the scour level and to a minimum horizontal distance of 2 metres on either side of the culvert inlet opening, and a minimum vertical height equivalent to 0.3 metres above the high water level. A clay cut-off should be a minimum of 1.5 metres in thickness parallel to the culvert.

In addition, sediment control such as silt fences and/or erosion control blankets may be required during construction to mitigate migration of fine soil particles into the water courses.

5.8 Embankment Design and Construction

5.8.1 Embankment Stability

A verification of the stability of the embankment slopes at Culvert 90, 91, 96 and 97 was carried out. For these assessments, the slope geometries used in the analyses were based on the topographic survey data provided by the NCC. The geology within each slope was inferred from the results of the boreholes. For the culvert embankments, a Factor of Safety of 1.3 or greater was calculated against static deep-seated slope instability and Pseudo-static seismic slope stability analysis also indicates that the culvert embankment side slopes will have a factor of safety greater than 1.1 against deep-seated slope instability based on an acceleration of 0.1g. Normal water conditions represented as a phreatic line was used these analyses. A rapid drawdown condition where the embankment is partially saturated on the upstream side was also evaluated. This condition could occur just after a heavy rain event or during spring flooding where the water raises above the culvert level and was analysed by a phreatic line placed approximately 3 metres above the culvert obvert elevation. Since a rapid drawdown condition is an extreme event a factor of safety greater than 1.1 is considered acceptable.

Under these conditions, the existing slopes exhibited factor of safeties greater that the criteria established for this analysis. However, there were shallow failure surfaces noted along the side slopes of these steep embankments in the analysis. Therefore, the side slopes of the embankments should be armored with a 1.2 metre layer of rip rap to retard the shallow sloughing.

The slope stability analyses for the above embankment were carried out using the following parameters:

Soil Layer / Deposit	Bulk Unit Weight (kN/m^3)	Effective Friction Angle, ϕ' (degrees)	Cohesion (kPa)
Culvert 90			
Existing Embankment Fill	22	36	2
Silty Clay, firm to stiff	17	0	60
Bedrock	Impenetrable		
Culvert 91			
Existing Embankment Fill	22	32	2
Silty Sand, loose to compact	19.5	30	0
Bedrock	Impenetrable		
Culvert 96			
Existing Embankment Fill	21	36	2
Upper Silty Sand and Silt, very loose to compact	18	30	5
Silty Clay, very stiff	17	0	80
Lower Silty Sand, dense to very dense	20	32	0
Bedrock	Impenetrable		
Culvert 97			
Existing Embankment Fill	21	34	2
Silty Clay, firm to stiff	17	0	50
Silty Sand, loose to very loose	18	28	0
Bedrock	Impenetrable		

For the purpose of the analyses, it was assumed that the subgrade was properly prepared and proper placement and compaction of the engineered fill embankment was performed. Existing embankment materials (i.e., granular earth fill) was assumed to be used for the engineered fill for the reconstruction of the fill embankments. The piezometric conditions used in the analyses were based on the groundwater levels noted during drilling in the boreholes.

5.8.2 Embankment Settlement

Based on the roadway grades not changing from the existing grades and the assumption that the existing embankment materials would be stockpiled at each culvert location and reused to reconstruct the roadway embankments; the settlements of the foundation soils would be negligible. Some settlement of the rock fill embankments should be anticipated. Rock fill embankments constructed in the manner outlined in this report will undergo internal consolidation and settlement of about 0.4 percent of the embankment height.

It is noted that these settlements are conditional based on the actual composition and consistency of the proposed embankment fill materials.

Considering the embankments are underlain by relatively thin overburden soils consisting of firm to stiff silty clay or compact silty sand overlying bedrock, settlements caused by seismic liquefaction of the foundation soils is not considered to be a significant concern with the expectation of Culvert 97. The settlements that may be the result from the liquefaction of the very loose to loose foundation soils at Culvert 97 is discussed in Section 5.9.

5.9 Seismic Considerations

5.9.1 Liquefaction Assessment

During the field investigation at Culvert 97, underlying loose to very loose saturated silty sands and sandy silts were observed that have the potential to liquefy during a seismic event and have therefore been evaluated.

Seismic liquefaction occurs when earthquake induced vibrations cause an increase in pore water pressure within the soil. The presence of excess pore water pressures reduces the effective stress between the soil particles and the soil’s frictional resistance to shearing. This phenomenon, which leads to a temporary reduction in the shear strength of the soil, may cause:

- Large lateral movements of even gently sloping ground, referred to as ‘lateral spreading’. This strength loss can also result in instability of slopes, approach embankments, and retaining structures (i.e., deep-seated shear failure through the underlying soil).
- Reduced shear resistance (i.e., bearing capacity) of soils which support foundations, as well as reduced resistance to sliding of shallow foundations.
- Reduced shaft resistance for deep foundations as well as reduced resistance to lateral loading.

In addition, ‘seismic settlements’ may occur once the vibrations and shear stresses have ceased. Seismic settlement is the process whereby the soils stabilize into a denser arrangement after an earthquake, causing potentially large surface settlements. If seismic settlements occur, down drag-loads would also be induced on deep foundation elements; the design of the foundations would have to consider this additional load which would result in the requirement for higher capacity piles or a higher number of piles.

The following conditions are more prone to experiencing seismic liquefaction:

- Coarse grained soils (i.e., more probable for sands than for silts);
- Soils having a loose state of packing; and,
- Soils located below the groundwater level.

An assessment of the liquefaction potential of the loose to very loose saturated silty sands and sandy silts was carried out using the Seed and Idriss (1971) simplified procedure based on SPT N_{60} values from the boreholes. The SPT N values reported on the borehole records were corrected for the overburden stress, rod length during sampling, and hammer energy efficiencies.

5.9.2 Liquefaction Assessment Results

The results of this assessment suggest that a portion of the loose to very loose saturated silty sands and sandy silts (about 8 metres in thickness) could be classified as liquefiable under an earthquake with a magnitude of 6.2 (Ottawa area specified design value) and a peak ground acceleration of 0.2 g (recognizing that the 'design' earthquake has a return period of 1 in 500 years). Liquefaction of these soils would result in subsidence of the culverts and the roadway embankment itself.

Our assessment indicates significant seismic settlements in the order of 250 millimetres of settlements could occur at the founding level of the culvert. Estimates of seismic liquefaction settlements are expected to have an accuracy of within 25 to 50 percent of actual values typically. Due to the depth of these soils it is not practical to remove them, and most likely too expensive to treat by either deep soil mixing or dynamic compaction in order to prevent liquefaction during a seismic event. Therefore, the NCC should create a contingency plan to temporary close this road and reconstruct the roadway and culvert at this location if, after a significant seismic event occurs, the roadway does subside.

5.10 Surface Water and Groundwater Management during Construction

Depending on the time of the year that the work takes place, control of surface water will be necessary in order for culvert construction to be carried out in dry conditions. Depending on the flows at the time of construction, the flows could be passed through the culvert area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam.

Some groundwater inflow into the excavations should be expected, particularly for excavations extending into the native surficial sands where encountered. However, it should be possible to handle the groundwater inflow by pumping from well filtered sumps established in the floor of the excavation.

Surface water should be directed away from the excavation area, to prevent ponding of water that could result in disturbance and weakening of the subgrade soils. It is expected that, provided the contractor has sufficient pumping capacity and strategically located sumps, then pumping from within the excavation should be a feasible dewatering method. The selection of the dewatering method and groundwater control requirements (i.e., numbers of pumps/sumps and the pumping rate) should entirely the responsibility of the contractor.

5.11 Pavement Reinstatement

The new pavement structures at culverts should match the existing materials.

Based on the observations in the augerholes along Promenade de la Gatineau at Culverts 90, 91, 96 and 97, the existing pavement structure is comprised of 100 to 120 millimetres of asphaltic concrete on approximately 100 to 160 millimetres of base (20 millimetres minus crushed stone) placed on the sand and gravel embankment fill. In the boreholes at Culvert 105 located along Promenade de Lac Fortune, the existing pavement structure is comprised of 90 to 130 millimetres of asphaltic concrete on granular fill.

We therefore recommend the following structure for all the repaired areas:

100 millimetres of hot mix hot laid asphaltic concrete

150 millimetres of NQ 2560-114-II MG-20, Granular Base

300 millimetres of NQ 2560-114-II MG-56, Granular Subbase

The granular base should be uniformly compacted to at least 98 percent of the modified Proctor maximum dry density using suitable vibratory compaction equipment. The asphaltic concrete should be compacted to between 93 and 98 percent of the maximum (Rice) density or MRD.

The composition and thickness of the asphaltic concrete should consist of the following:

EB-10S or ESG-10 – surface course	40 millimetres
EB-14 or ESG-14 – base course	60 millimetres

The asphaltic concrete should meet the requirements of Transports Québec's C.C.D.G. specification, Tome VII – Materiaux, Table 4201-1 for the "EB" type mixes, or Table 4202-1 for the "ESG" type mixes.

The asphaltic concrete used on this project should to be made with PG 58-34 asphalt cement or better on all lifts.

The existing asphaltic concrete at the outer limits of each culvert replacement should be saw-cut and milled to a depth of the new surface course asphaltic concrete for a distance of 300 millimetres back from the joint and the new surface course overlapped onto this platform. A tack-coat should be provided on the milled surface.

To maintain frost heave compatibility between the new and existing pavements frost tapers should be provided at the end of the new pavement. The frost tapers should be sloped to a 5 horizontal to 1 vertical angle within the granular layers either up or down to match existing.

At Culvert 105 and any other areas where bedrock is encountered within frost penetration zone, frost tapers or transition from a bedrock subgrade to the granular trench fill should be constructed at a slope of 5 horizontal to 1 vertical angle from the bedrock surface to the underside of the pavement structure on both sides of the culvert.

5.12 Cement Type and Corrosion

Five samples of the soil, one from each culvert location, was submitted to Exova Laboratories Ltd. for basic chemical analysis related to potential corrosion of buried steel elements and sulphate attack on buried concrete elements. The results of this testing are provided in Appendix B. The results indicate that concrete made with Type GU Portland cement should be acceptable for substructures at all five culvert locations. The results also indicate a moderate to corrosive environment for exposed buried ferrous metal at each of the culvert locations. That potential should be considered in the selection of pipe materials and in the design of substructures.

6.0 CONSTRUCTION CONSIDERATIONS

All subgrade areas should be inspected by Golder Associates prior to placement of granular bedding.

The placing and compaction of granular bedding, granular surround and pavement components should be inspected to make sure that the materials used conform to the specifications from a gradation and compactive point of view.

The placement of rock fill should be observed by Golder Associates to make sure that placement methods and materials conform to the requirements of this report.

Golder Associates should be retained to review the final drawings and specifications for this project prior to tendering to make sure that the guidelines in this report have been adequately interpreted.

7.0 CLOSURE

We trust this report contains sufficient information for your present requirements. If you have any questions concerning this report, or if we can be of further service to you on this project, please call us.

GOLDER ASSOCIATES LTD.

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IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

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Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client, WSP. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

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The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

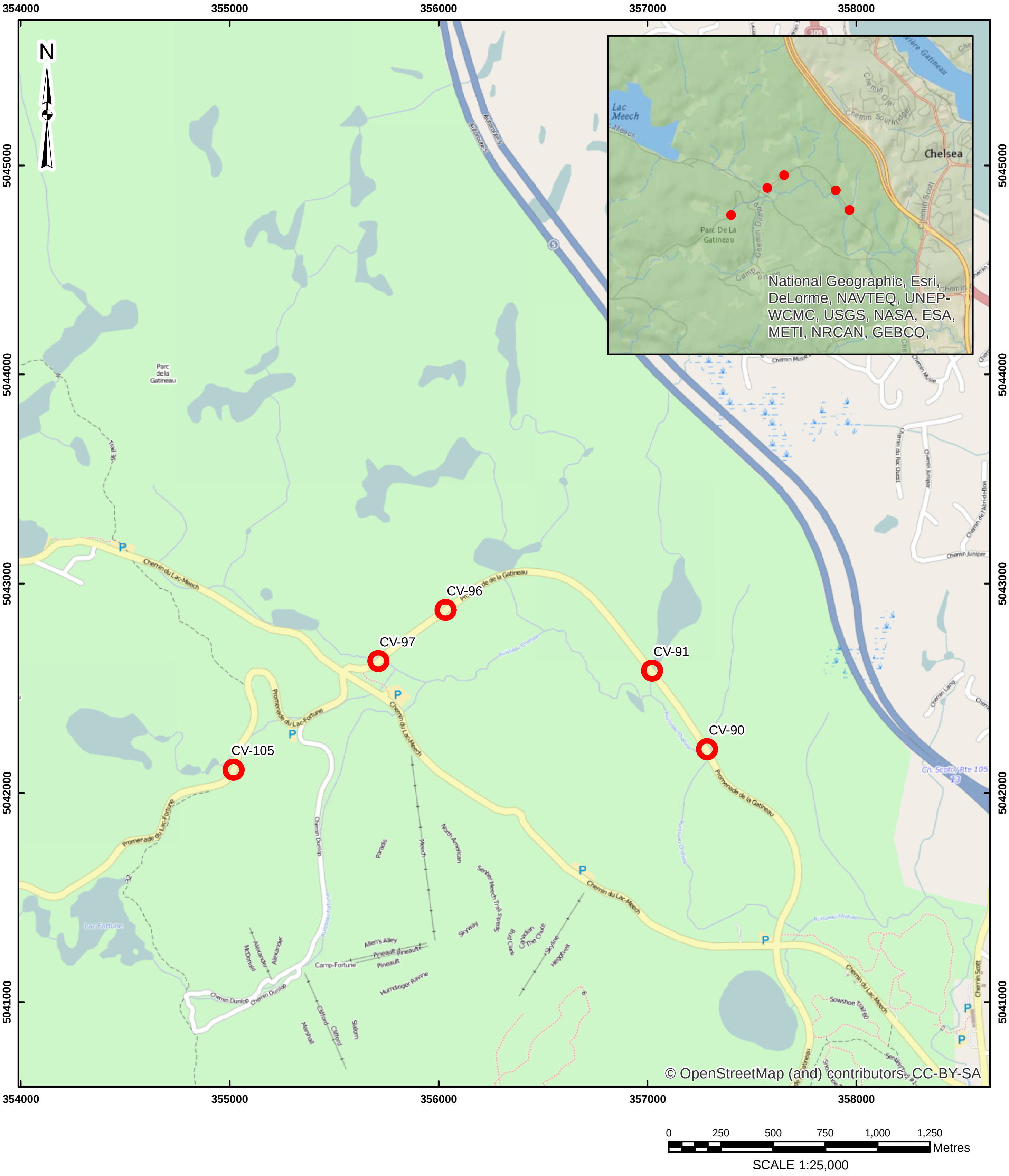
Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

TABLE 1
RECORD OF AUGERHOLES
GENIVAR / NCC CULVERTS / GATINEAU PARK

Augerhole Number	Depth (metres)	Description
AH 13-103	0.00 – 0.10	ASPHALTIC CONCRETE
	0.10 – 0.26	(SW) fine, angular gravelly SAND, fine to coarse grained; trace silt; brown, moist (GRANULAR BASE)
	0.26 – 1.52	(SW) fine, angular to subrounded gravelly SAND, fine to coarse grained; trace silt; brown, moist (GRANULAR SUB-BASE)
	1.52	End of Augerhole
AH 13-106	0.00 – 0.11	ASPHALTIC CONCRETE
	0.11 – 0.25	(SW) fine, angular gravelly SAND, fine to coarse grained; trace silt; brown, moist (GRANULAR BASE)
	0.25 – 1.52	(SW) fine to coarse, angular to subrounded gravelly SAND, fine to coarse grained; trace silt; brown, with cobbles and boulders, moist (FILL)
	1.52	End of Augerhole Sample Depth (m) 1 0.11 – 0.25 2 0.50 – 0.65
AH 13-107	0.00 – 0.12	ASPHALTIC CONCRETE
	0.12 – 0.22	(SW) fine, angular gravelly SAND, fine to coarse grained; trace silt; brown, moist (GRANULAR BASE)
	0.22 – 1.52	(SW) fine, angular to subrounded gravelly SAND, fine to coarse grained; trace silt; brown, with cobbles and boulders, moist (FILL)
	1.52	End of Augerhole Note: Cobbles encountered at 0.75 to 0.85 metres depth.
AH 13-111	0.00 – 0.11	ASPHALTIC CONCRETE
	0.11 – 0.25	(SW) fine, angular gravelly SAND, fine to coarse grained; trace silt; brown, moist (GRANULAR BASE)
	0.25 – 1.52	(SW) fine, angular to subrounded gravelly SAND, fine to coarse grained; trace silt; brown, with cobbles and boulders, moist (FILL)
	1.52	End of Augerhole Sample Depth (m) 1 0.11 – 0.25 2 0.45 – 0.60

n:\active\2013\1121 - geotechnical\13-1121-0159 genivar culverts - gatineau park\reporting\13-1121-0159 record of augerholes.docx



National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

TITLE

KEY PLAN

Golder Associates

PROJECT No. 13-1121-0159			SCALE AS SHOWN	REV. 0.0
DESIGN	BDG	2013-11-22	FIGURE 1	
GIS	JEM	2013-12-19		
CHECK	BDG	2013-12-19		
REVIEW	TJN	2013-12-19		

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

REFERENCE

DATUM: NAD 83, COORDINATE SYSTEM: MTM ZONE 9

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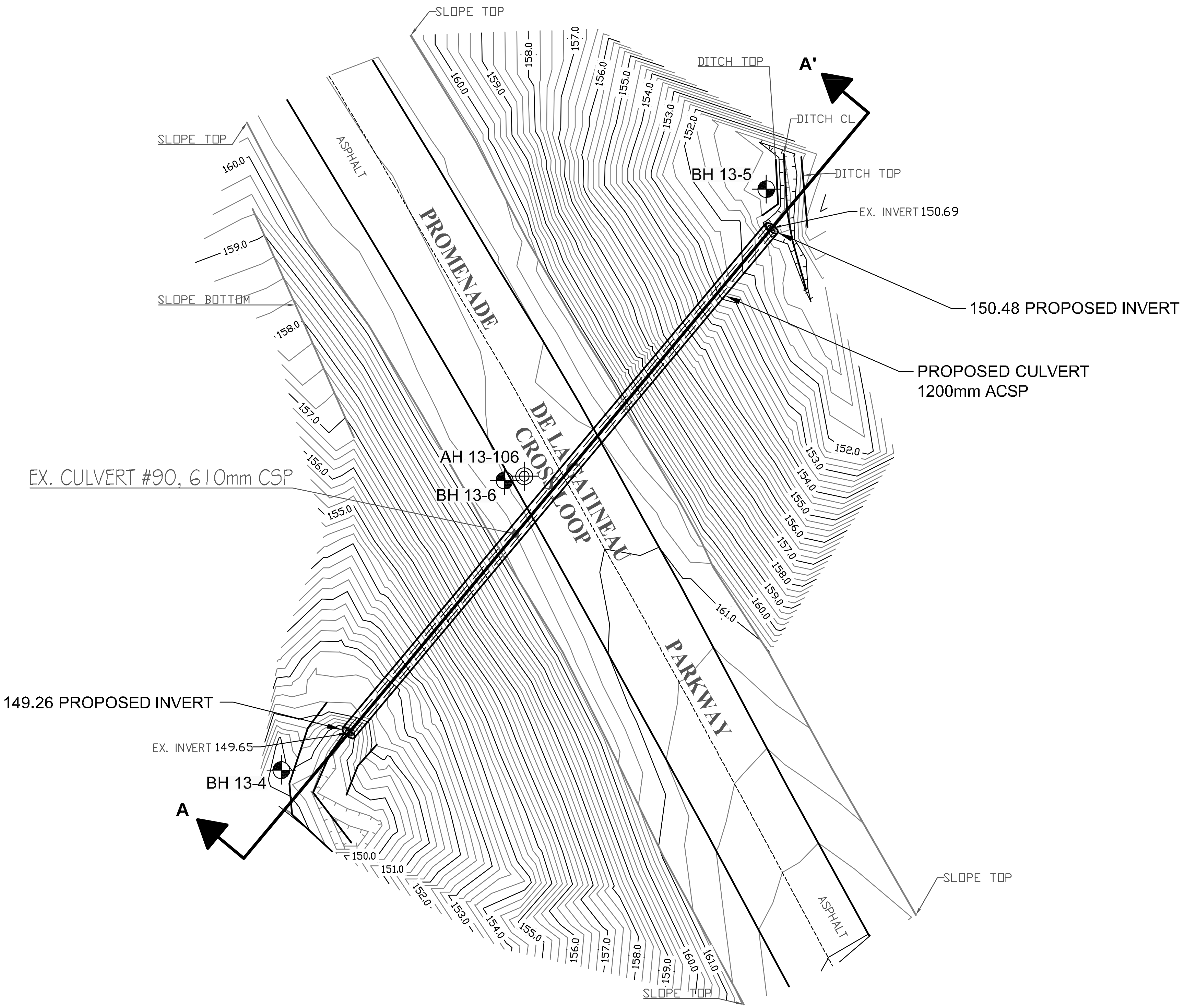
PLOT DATE: January 21, 2014
FILENAME: N:\Active\2013\1121 – Geotechnical\13-1121-0159 Genivar Culverts – Gatineau Park\Spatial IM\CAD\Phase 1000\1311210159-1000-02.dwg



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LEGEND

- APPROXIMATE BOREHOLE LOCATION IN PLAN
- APPROXIMATE AUGERHOLE LOCATION IN PLAN

REFERENCE

BASE PLAN SUPPLIED IN ELECTRONIC FORMAT BY NCC

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

8 0 8
SCALE 1:400 METRES

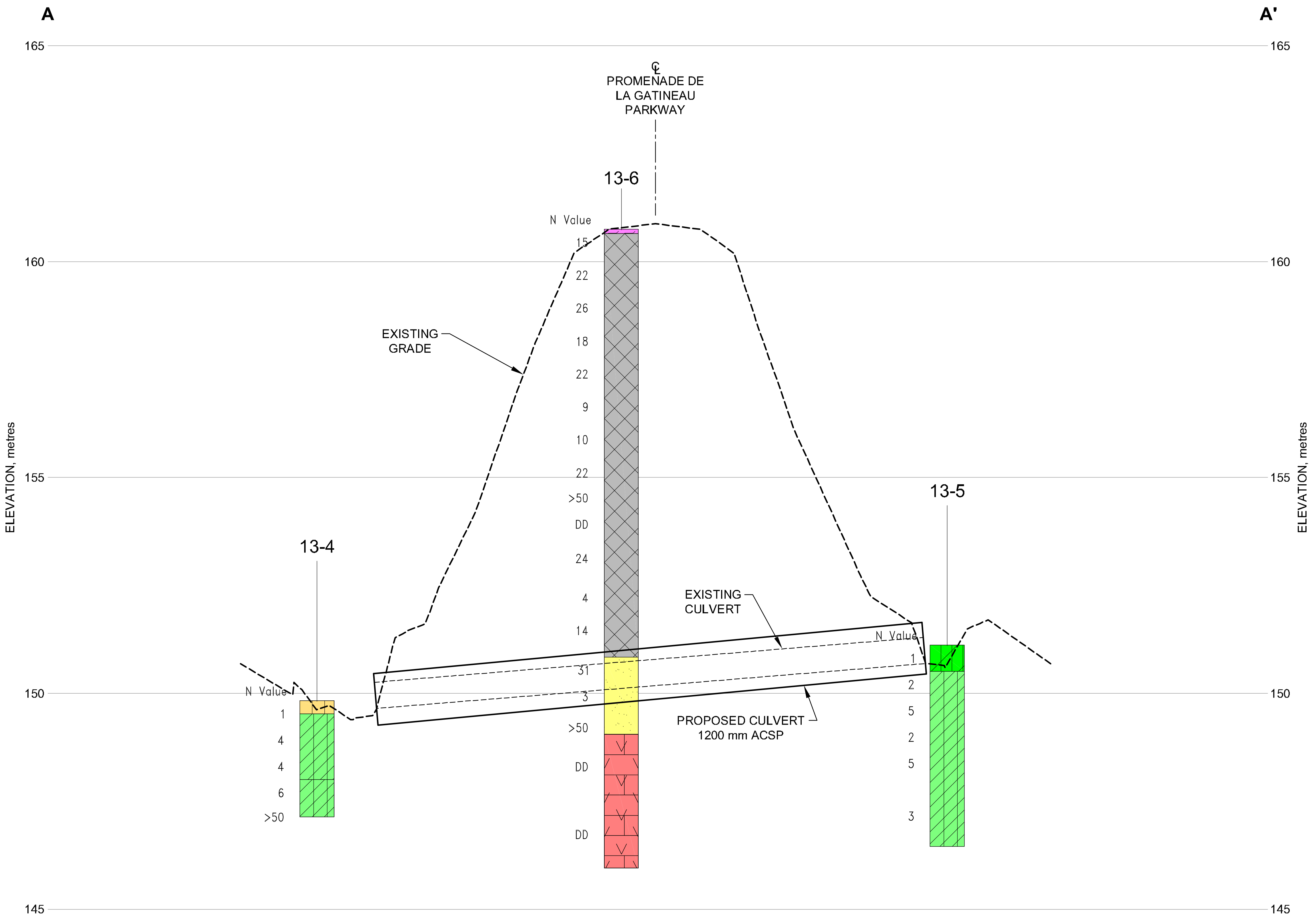
REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

TITLE
SITE PLAN
(CULVERT 90)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		13-1121-0159	FILE No. 1311210159-1000-02.dwg
DESIGN			SCALE 1:400 REV.
CAD	JM	Nov. 2013	FIGURE No.
CHECK	BDG	Dec. 2013	2
REVIEW	TJN	Dec. 2013	



SUBSURFACE STRATIGRAPHY

▨	TOPSOIL	▨	SILTY CLAY
▨	FILL	▨	CLAYEY SILT
▨	SAND	▨	GRANITE
▨	SILT		

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

HORIZONTAL
8 0 8
SCALE 1:400 METRES

VERTICAL
2 0 2
SCALE 1:100 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW
△						

PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

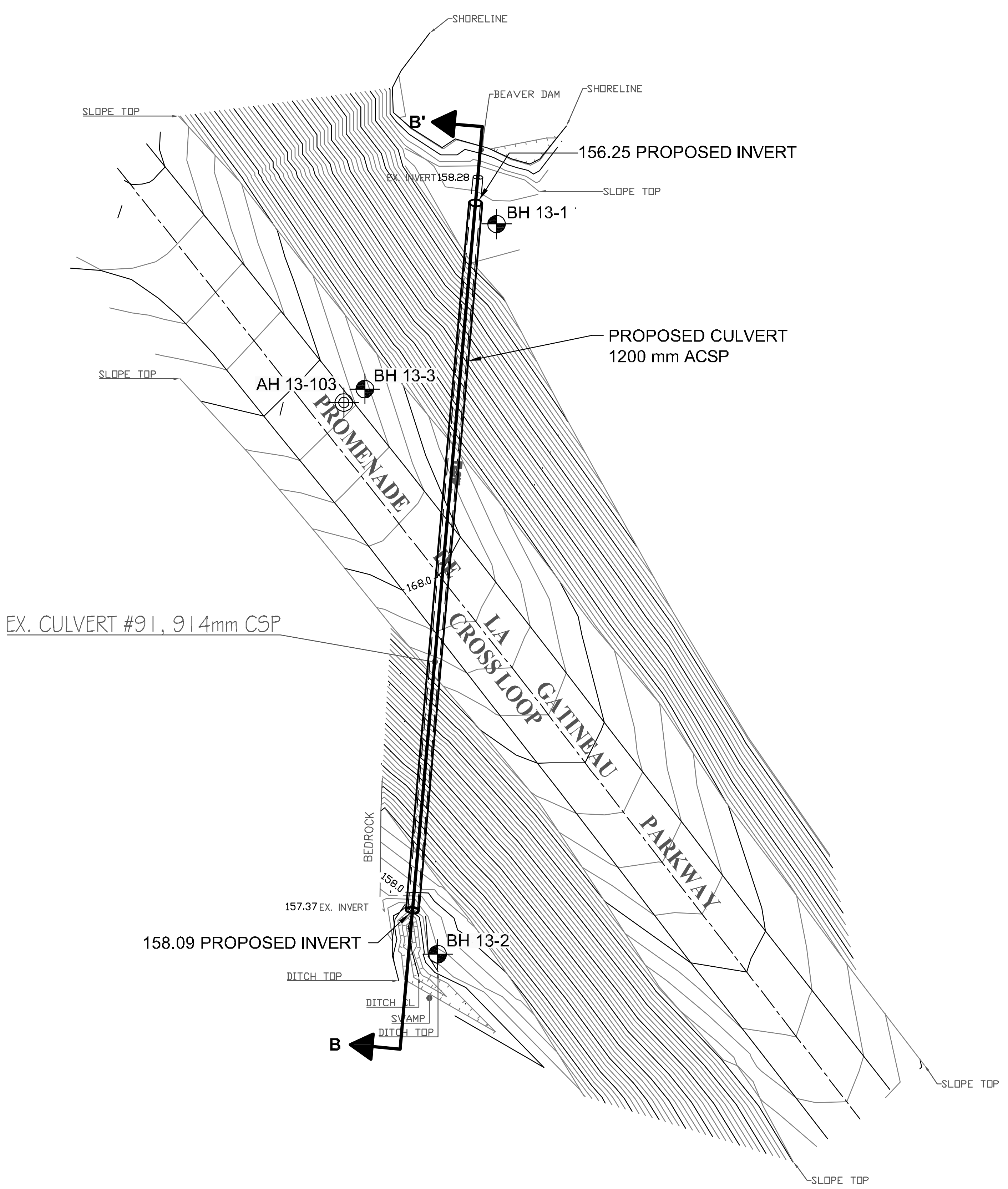
TITLE
CROSS-SECTION A-A'
(CULVERT 90)

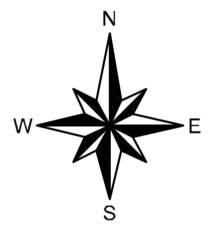
Golder Associates
Ottawa, Ontario, Canada

PROJECT No.	13-1121-0159	
DESIGN		
CAD	JM	Nov. 2013
CHECK	BDG	Dec. 2013
REVIEW	TJN	Dec. 2013

FILE No. 1311210159-1000-03.dwg
SCALE AS SHOWN REV.
FIGURE No.
3

PLOT DATE: January 21, 2014
FILENAME: N:\Active\2013\1121 - Geotechnical\13-1121-0159 Genivar Culverts - Gatineau Park\Spatial IM\CAD\Phase 1000\1311210159-1000-03.dwg





LEGEND

⊕	APPROXIMATE BOREHOLE LOCATION IN PLAN
⊚	APPROXIMATE AUGERHOLE LOCATION IN PLAN

REFERENCE

BASE PLAN SUPPLIED IN ELECTRONIC FORMAT BY NCC

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

10 0 10
SCALE 1:500 METRES

△						
REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

TITLE
SITE PLAN (CULVERT 91)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		13-1121-0159
DESIGN		
CAD	JM	Nov. 2013
CHECK	BDG	Dec. 2013
REVIEW	TJN	Dec. 2013

FILE No. 1311210159-1000-04.dwg
SCALE 1:500 REV.
FIGURE No.
4

PLOT DATE: January 21, 2014
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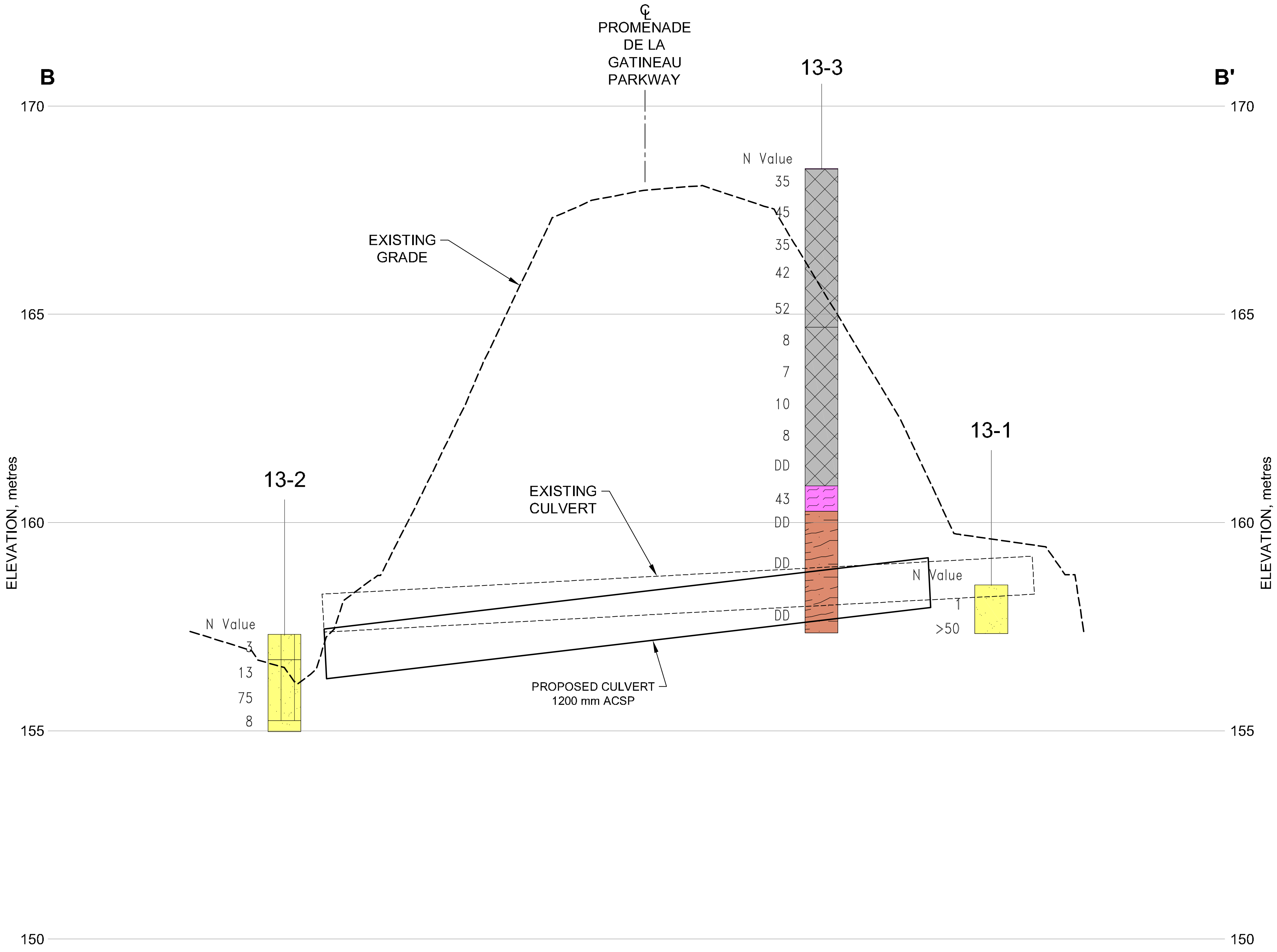
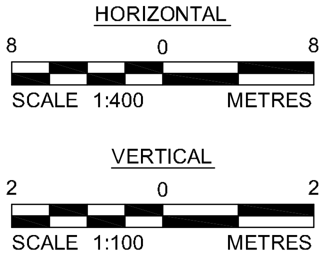


SUBSURFACE STRATIGRAPHY

- ▨ TOPSOIL
- ▨ FILL
- ▨ SAND
- ▨ SILTY SAND
- ▨ GNEISS

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159



REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT

GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

TITLE

CROSS-SECTION B-B'
(CULVERT 91)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		13-1121-0159
DESIGN		
CAD	JM	Nov. 2013
CHECK	BDG	Dec. 2013
REVIEW	TJN	Dec. 2013

FILE No. 1311210159-1000-05.dwg
SCALE AS SHOWN REV.
FIGURE No.
5

PLOT DATE: January 21, 2014
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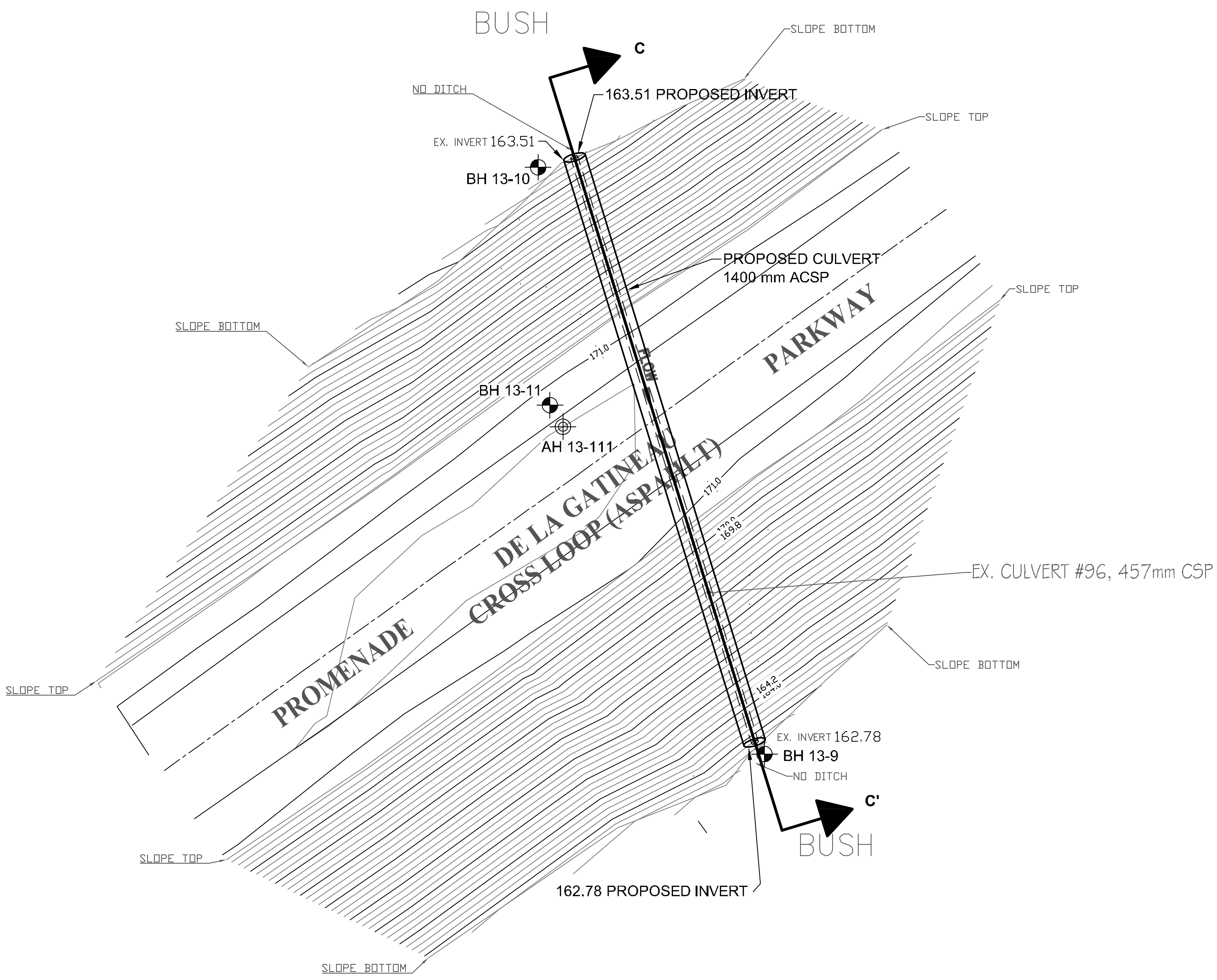

N
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LEGEND

◈	APPROXIMATE BOREHOLE LOCATION IN PLAN
⊕	APPROXIMATE AUGERHOLE LOCATION IN PLAN

REFERENCE

BASE PLAN SUPPLIED IN ELECTRONIC FORMAT BY NCC

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

6 0 6
SCALE 1:300 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

TITLE
SITE PLAN (CULVERT 96)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		13-1121-0159
DESIGN		
CAD	JM	Nov. 2013
CHECK	BDG	Dec. 2013
REVIEW	TJN	Dec. 2013

FILE No. 1311210159-1000-06.dwg
SCALE 1:300 REV.
FIGURE No.
6

PLOT DATE: January 21, 2014
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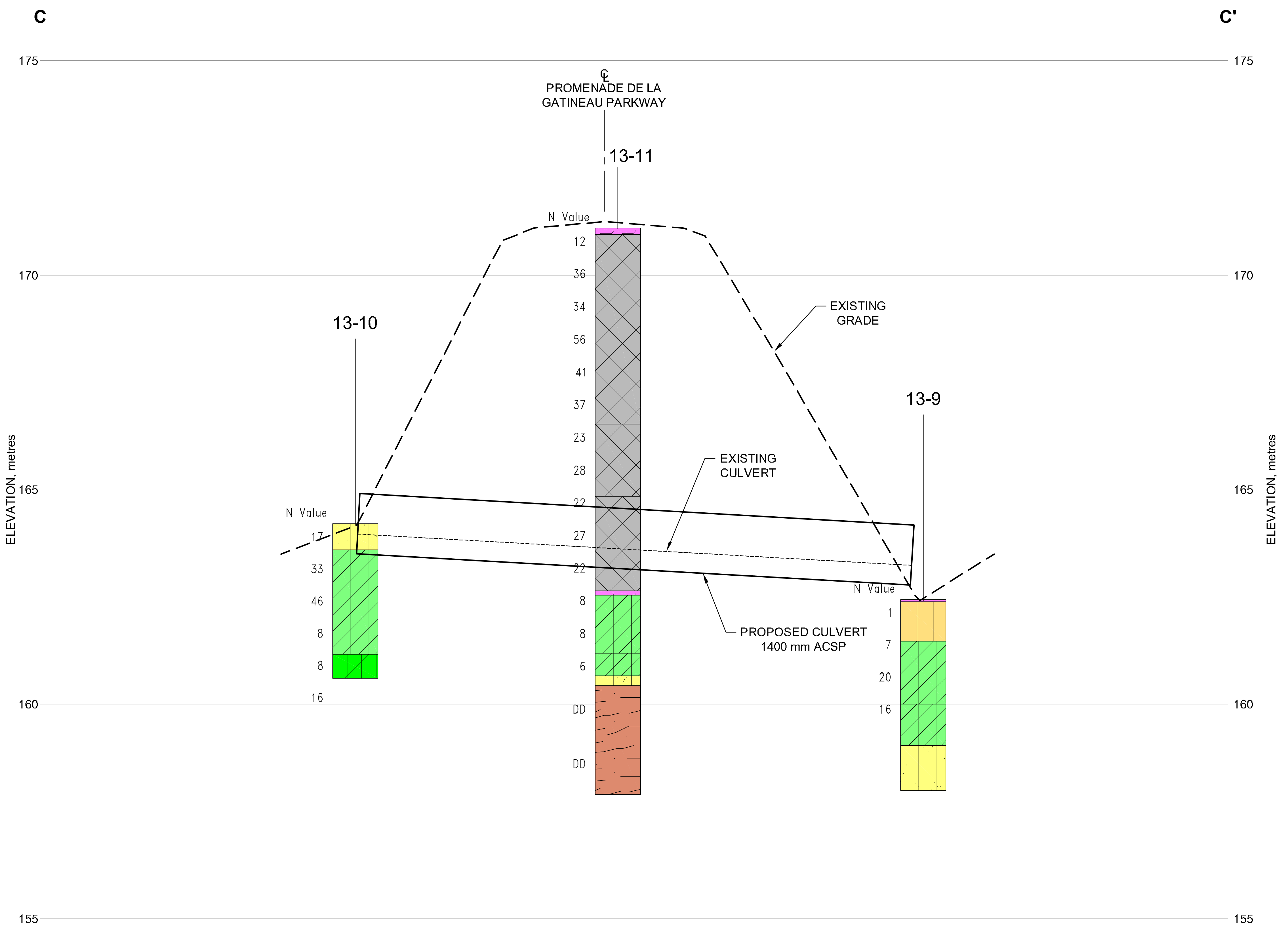

SUBSURFACE STRATIGRAPHY

▨	TOPSOIL	▨	SILTY CLAY
▨	FILL	▨	CLAYEY SILT
▨	SAND	▨	SILT
▨	SILTY SAND	▨	GNEISS

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

HORIZONTAL
6 0 6
SCALE 1:300 METRES

VERTICAL
2 0 2
SCALE 1:100 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW
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PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

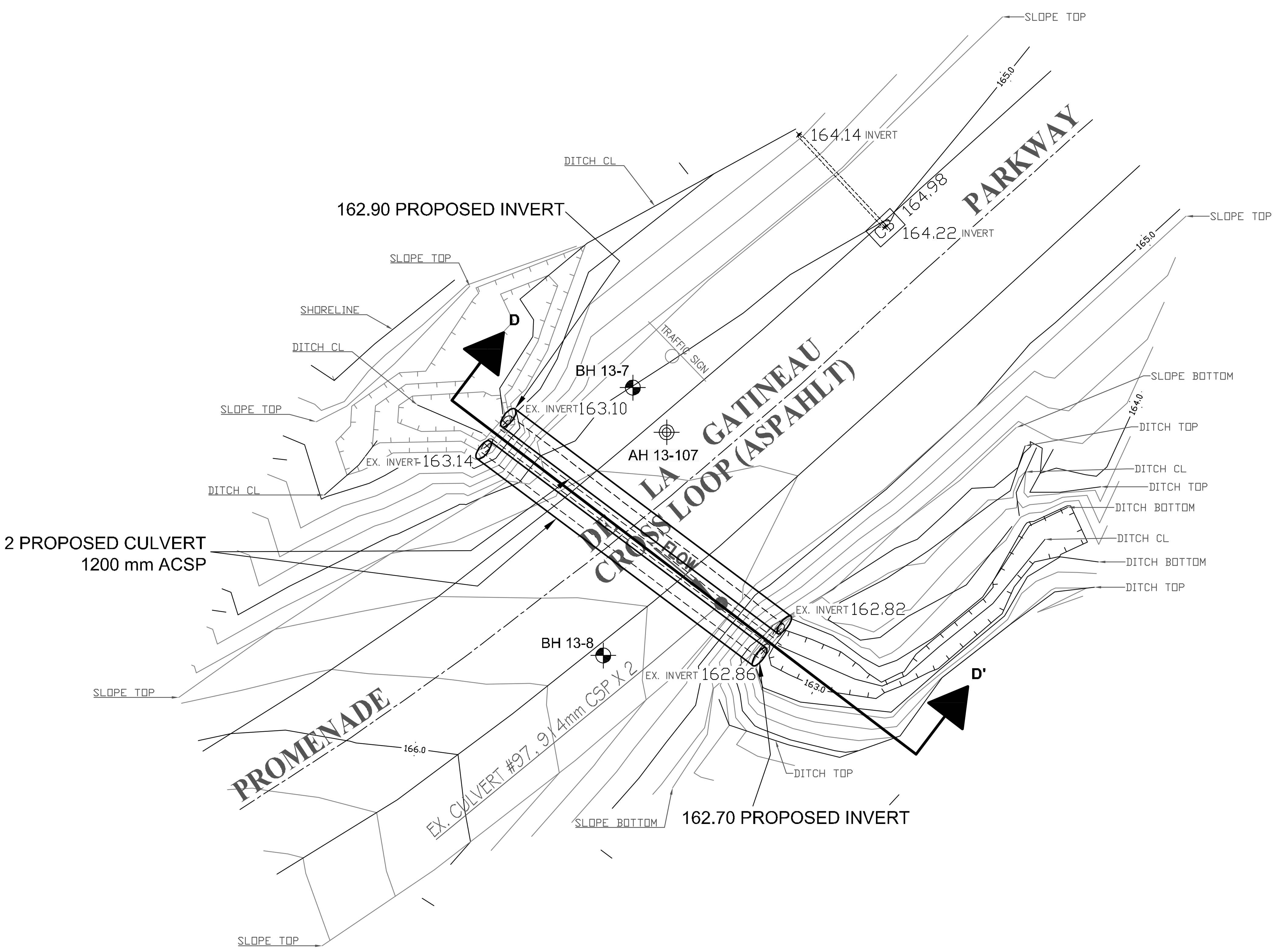
TITLE
CROSS-SECTION C-C' (CULVERT 96)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		13-1121-0159
DESIGN		
CAD	JM	Nov. 2013
CHECK	BDG	Dec. 2013
REVIEW	TJN	Dec. 2013

FILE No. 1311210159-1000-07.dwg
SCALE AS SHOWN REV.
FIGURE No.
7

PLOT DATE: January 21, 2014
FILENAME: N:\Active\2013\1121 – Geotechnical\13-1121-0159 Genivar Culverts – Gatineau Park\Spatial IM\CAD\Phase 1000\1311210159-1000-07.dwg



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LEGEND

⊕	APPROXIMATE BOREHOLE LOCATION IN PLAN
⊕	APPROXIMATE AUGERHOLE LOCATION IN PLAN

REFERENCE

BASE PLAN SUPPLIED IN ELECTRONIC FORMAT BY NCC

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

5 0 5
SCALE 1:250 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW
△						

PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

TITLE
SITE PLAN
(CULVERT 97)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		13-1121-0159
DESIGN		
CAD	JM	Nov. 2013
CHECK	BDG	Dec. 2013
REVIEW	TJN	Dec. 2013

FILE No. 1311210159-1000-08.dwg
SCALE 1:250 REV.
FIGURE No.
8

PLOT DATE: January 21, 2014
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PLOT DATE: January 21, 2014
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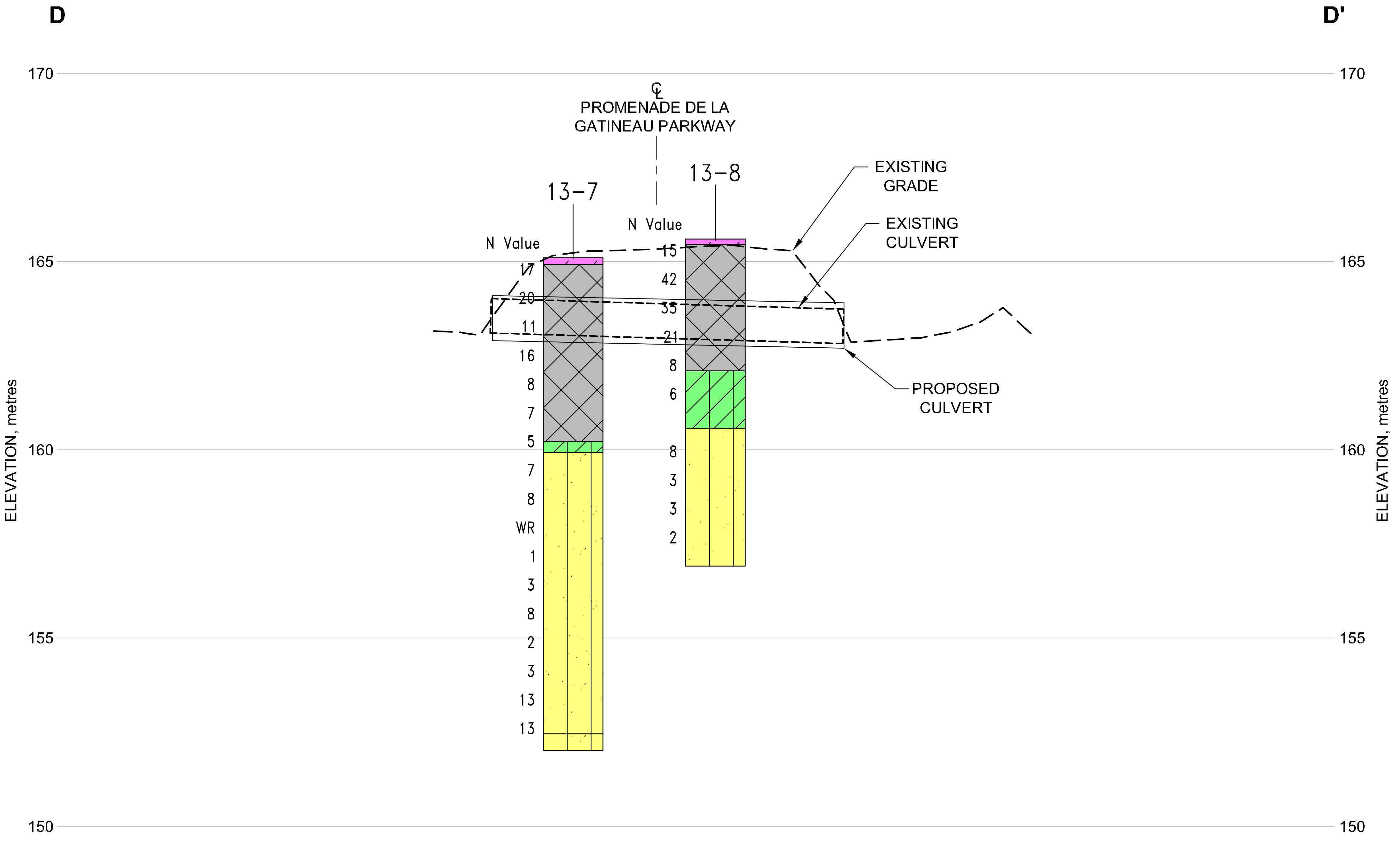
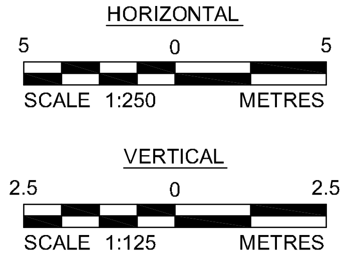


SUBSURFACE STRATIGRAPHY

▨	TOPSOIL
▨	SILTY CLAY
▨	FILL
▨	SAND
▨	SILTY SAND

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159



REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW
△						

PROJECT

GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

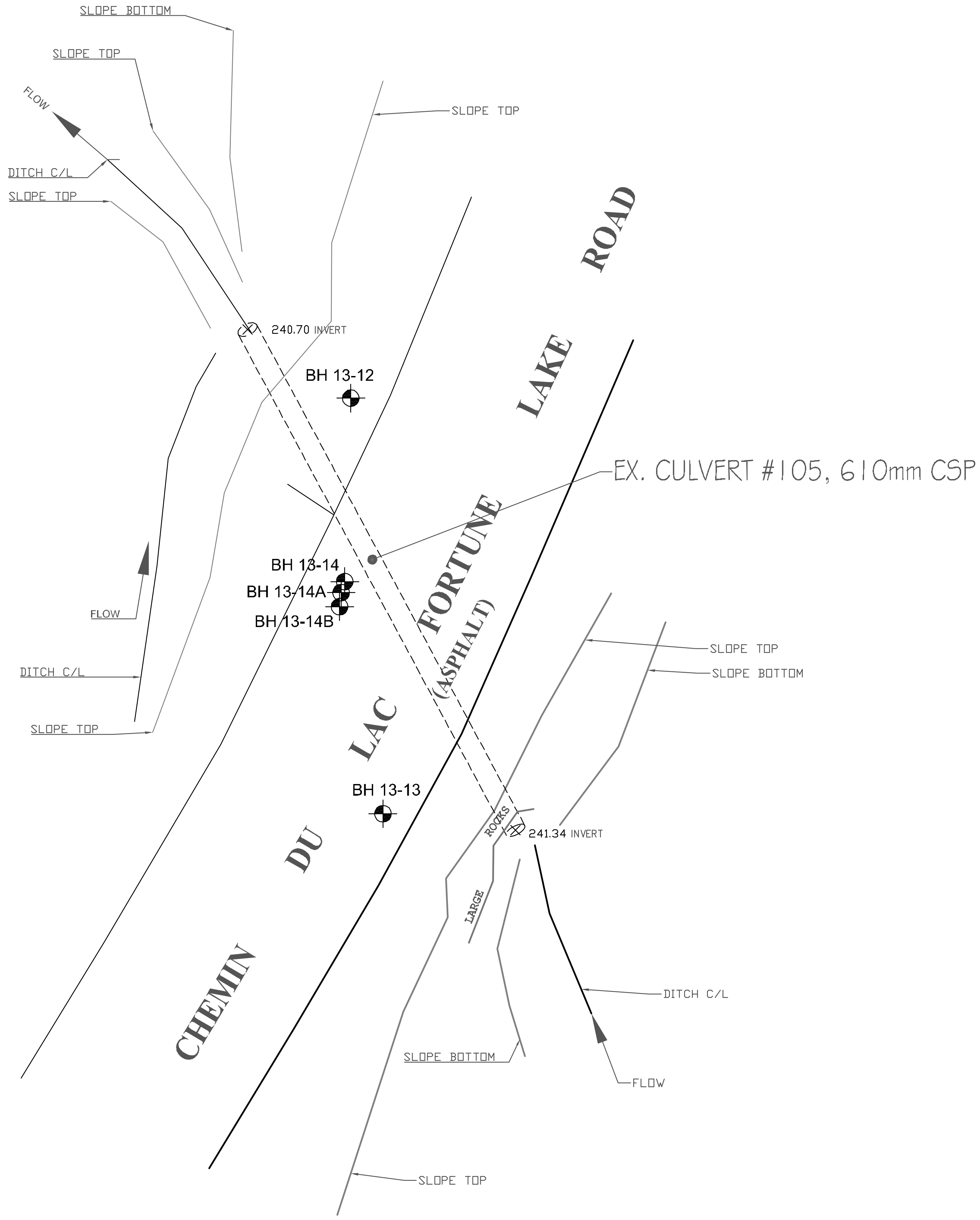
TITLE

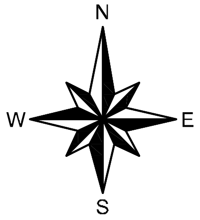
CROSS-SECTION D-D'
(CULVERT 97)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.		13-1121-0159
DESIGN		
CAD	JM	Nov. 2013
CHECK	BDG	Dec. 2013
REVIEW	TJN	Dec. 2013

FILE No. 1311210159-1000-09.dwg
SCALE AS SHOWN REV.
FIGURE No.
9





LEGEND

⊕ APPROXIMATE BOREHOLE LOCATION IN PLAN

REFERENCE

BASE PLAN SUPPLIED IN ELECTRONIC FORMAT BY NCC

NOTE

THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT No. 13-1121-0159

3 0 3
SCALE 1:150 METRES

REV	DATE	DES	REVISION DESCRIPTION	CAD	CHK	RVW

PROJECT
GEOTECHNICAL INVESTIGATION
GATINEAU PARK CULVERT REPLACEMENTS
CHELSEA, QUEBEC

TITLE
SITE PLAN
(CULVERT 105)

Golder Associates
Ottawa, Ontario, Canada

PROJECT No.	13-1121-0159		FILE No. 1311210159-1000-10.dwg	
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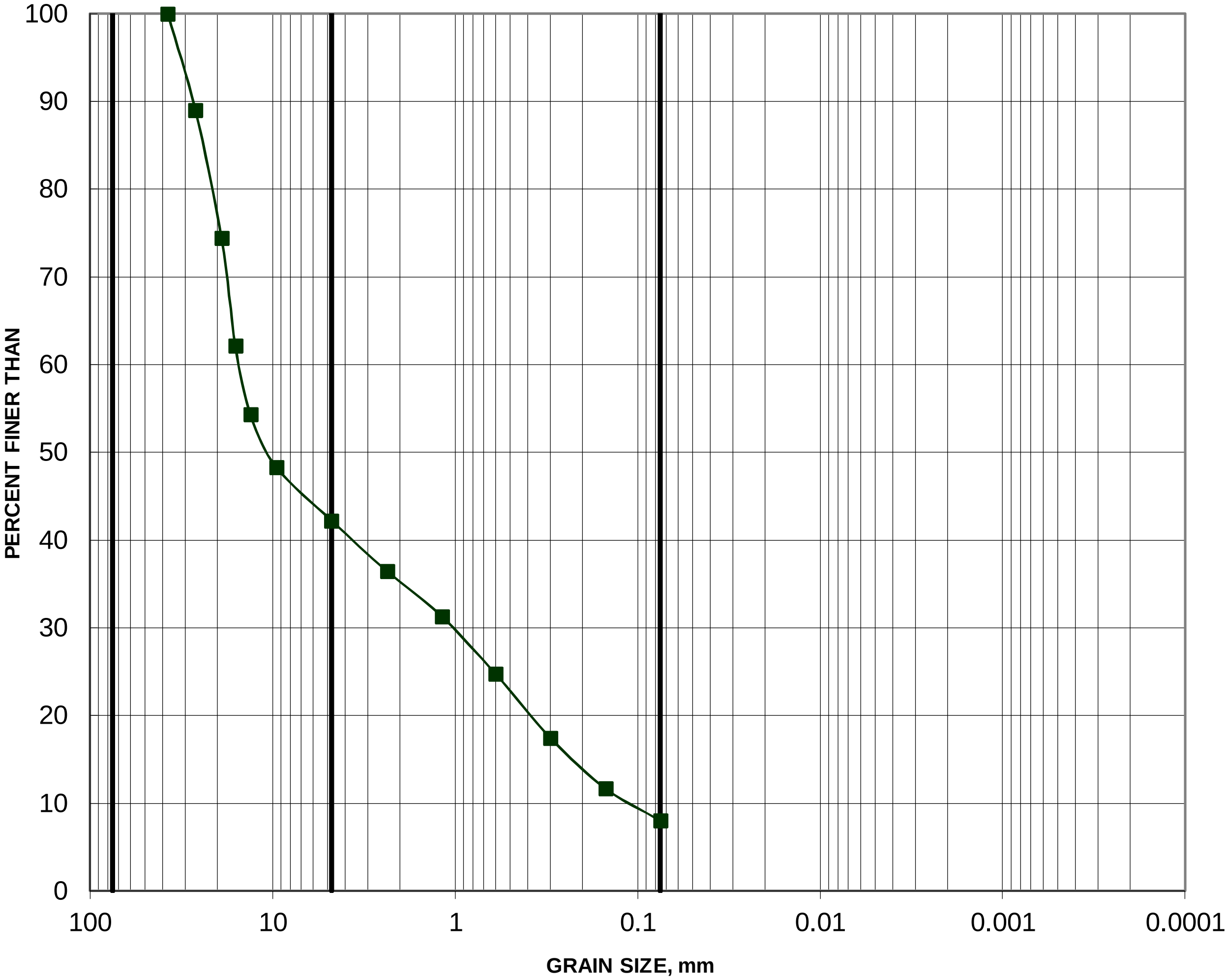
CAD	JM	Nov. 2013	FIGURE No.	
CHECK	BDG	Dec. 2013	10	
REVIEW	TJN	Dec. 2013		

PLOT DATE: January 21, 2014
FILENAME: N:\Active\2013\1121 - Geotechnical\13-1121-0159 Genivar Culverts - Gatineau Park\Spatial IM\CAD\Phase 1000\1311210159-1000-10.dwg

GRAIN SIZE DISTRIBUTION

FIGURE 11

(GP) Sandy poorly graded GRAVEL



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

	Borehole	Sample	Depth (m)
■	13-2	2	0.61-1.22

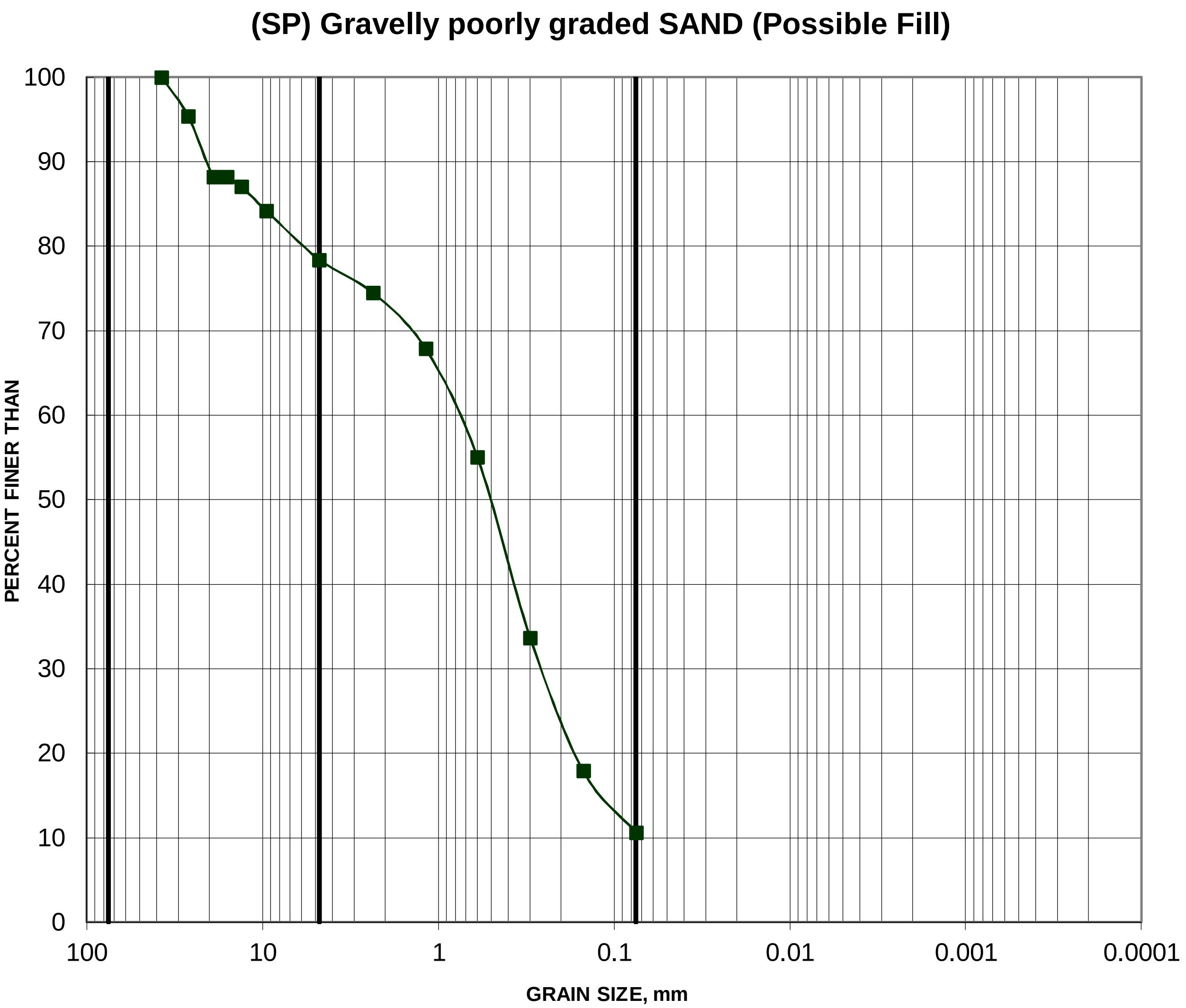
Created by: MI
Checked by: CNM

Project: 13-1121-0159

Golder Associates

GRAIN SIZE DISTRIBUTION

FIGURE 12



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

Borehole	Sample	Depth (m)
■ 13-6	14	9.91-10.52

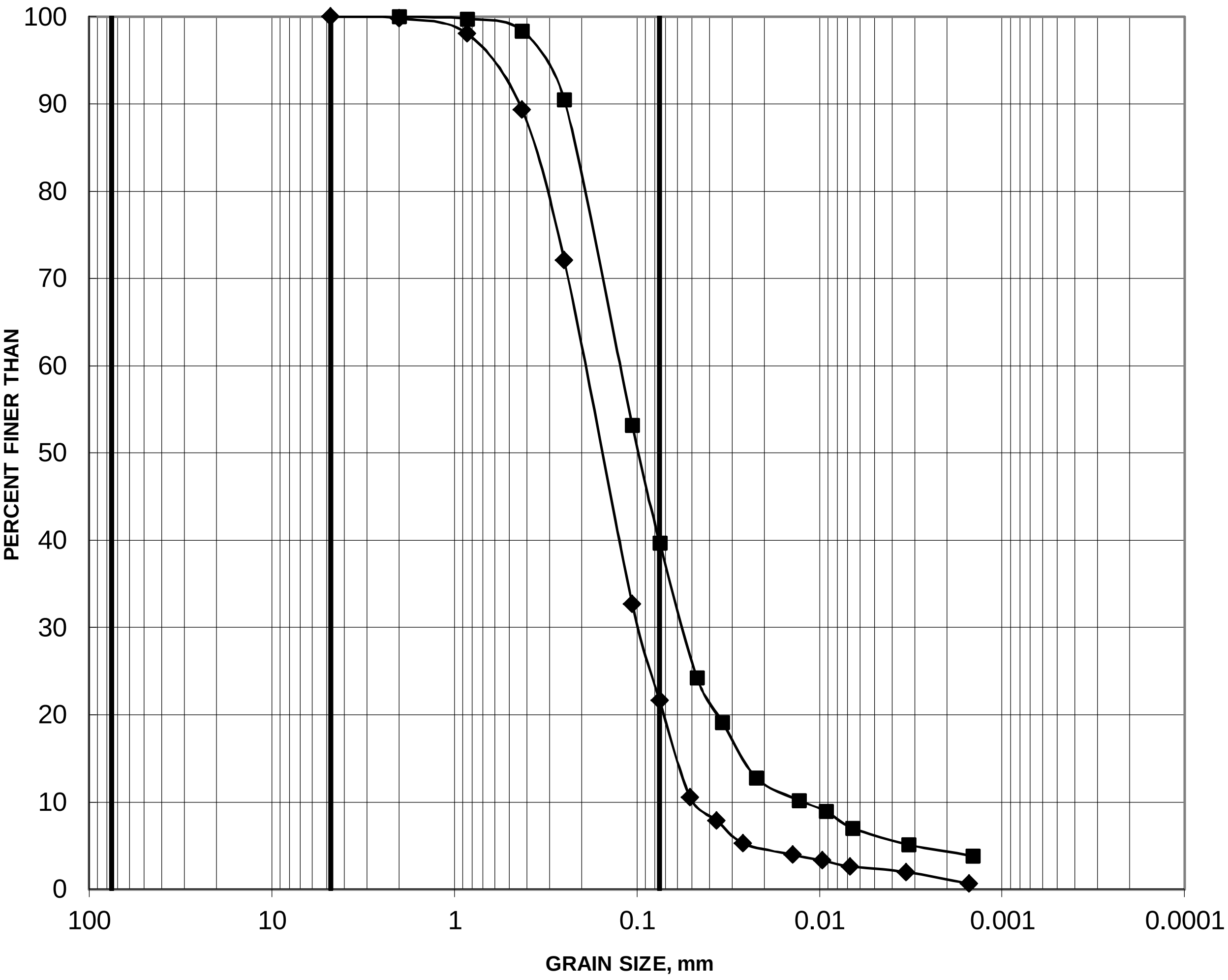
Project: 13-1121-0159

Golder Associates

Created by: MI
Checked by: CNM

GRAIN SIZE DISTRIBUTION	FIGURE 13

(SM) SILTY SAND



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

Borehole	Sample	Depth (m)
■ 13-7	14	9.15-9.76
◆ 13-7	16	11.43-12.04

Project: 13-1121-0159

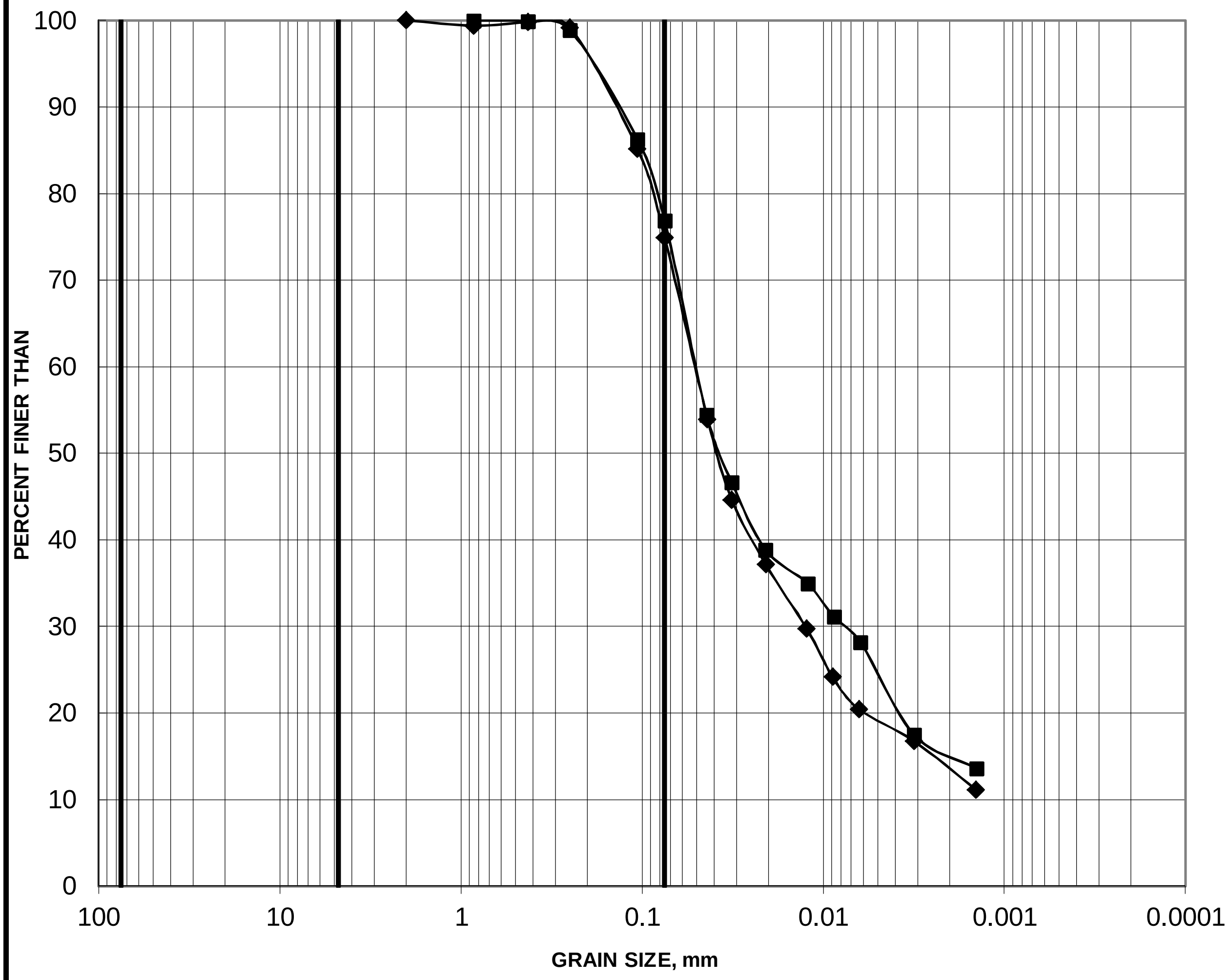
Golder Associates

Created by: CNM
Checked by: CW

GRAIN SIZE DISTRIBUTION

FIGURE 14

(ML) Sandy SILT



Cobble	coarse	fine	coarse	medium	fine	SILT AND CLAY
Size	GRAVEL SIZE		SAND SIZE			

Borehole	Sample	Depth (m)
─■─ 13-7	11	7.62-8.23
─◆─ 13-8	9	6.86-7.47

Created by: CNM
Checked by: CW

Project: 13-1121-0159

Golder Associates

APPENDIX A

List of Abbreviations and Symbols
Record of Borehole Sheets
Current Investigation

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures, and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open-ended, driven or pushed tube samplers
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample
DT	Dual tube sample
DD	Diamond drilling

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.).

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive an uncased 50 mm (2 in.) diameter, 60^0 cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60^0 conical tip and a projected end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	**N** Blows/300 mm Or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

C_u or S_u

Consistency	kPa	Psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	Over 200	Over 4,000

IV. SOIL TESTS

w	Water content
w_p or PL	Plastic limited
w_1 or LL	Liquid limit
C	Consolidaiton (oedometer) test
CHEM	Chemical analysis (refer to text)
CID	Consolidated isotropically drained triaxial test[1]
CIU	Consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	Relative density
DS	Direct shear test
Gs	Specific gravity
M	Sieve analysis for particle size
MH	Combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	Organic content test
SO_4	Concentration of water-soluble sulphates
UC	Unconfined compression test
UU	Unconsolidated undrained triaxial test
V	Field vane test (LV-laboratory vane test)
γ	Unit weight

Note: [1] Tests which are anisotropically consolidated prior shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$ x or log x	logarithm of x to base 10
g	acceleration due to gravity
t	time
FOS	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma'$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$ - u)
σ'_{vo}	initial vertical effective overburden stress
$\sigma_1\sigma_2\sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3) / 3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_1 or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity Index = ($w_1 - w_p$)
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_c	consistency index = $(w_1 - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	overconsolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p or τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u or s_u	undrained shear strength (ϕ = 0 analysis)
p	mean total stress $(\sigma_1 + \sigma_3) / 2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3) / 2$
q	$(\sigma_1 - \sigma_3) / 2$ or $(\sigma'_1 - \sigma'_3) / 2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:
[1] $\tau = c' + \sigma' \tan \phi'$
[2] shear strength = (compressive strength) / 2

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-1

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: September 3, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		158.50							
0	Portable Drill	(SP) SAND, fine to medium, some silt, trace gravel; brown; moist to wet, very loose		0.00	1	SS	1				
1				157.33	2	SS	>50		○		
		End of Borehole Sampler Refusal		1.17							
2											
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-2

SHEET 1 OF 1

LOCATION: See Site Plan

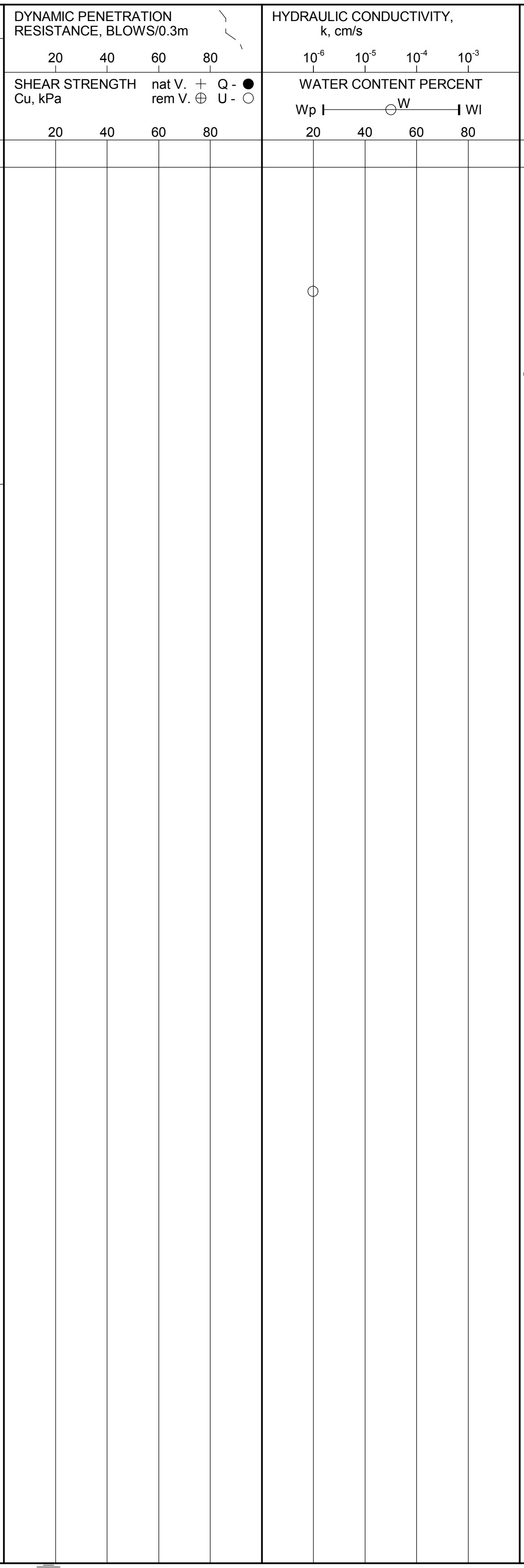
BORING DATE: September 3, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	157.32					
0	Portable Drill	(SM) SILTY SAND, fine to medium, some gravel, some organics, rootlets; brown; wet, very loose	0.00	1	SS	3		
1		(SM) SILTY SAND, fine to coarse, and (GP) sandy GRAVEL, fine to medium, some organics; grey; wet, compact to very dense	156.71 0.61	2	SS	13	M	
				3	SS	75	CHEM	
2		(SP) SAND, fine to medium, some gravel, organics; grey; wet, loose	155.24 2.08	4	SS	8		
		End of Borehole Sampler Refusal	154.98 2.34					
3								
4								
5								
6								
7								
8								
9								
10								



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-3

SHEET 1 OF 2

LOCATION: See Site Plan

BORING DATE: September 5, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
		GROUND SURFACE	168.50			
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) gravelly SILTY SAND, fine to coarse; dark brown, organics, roots; moist	0.02	1	SS	35
		FILL - (SP) SAND, fine to coarse, trace silt, and (GP) GRAVEL, angular to subrounded; brown, with cobbles and/or boulders and thin seams of grey silty clay; moist, dense to very dense Cobbles and/or boulders inferred from auger resistance from 0.76 m to 3.81 m				
1				2	SS	45
2				3	SS	35
				4	SS	42
3				5	SS	52
		FILL - (SP) SAND, fine to coarse, and (GP) GRAVEL; dark brown, with cobbles and boulders; moist, loose Cobbles and/or boulders inferred from auger resistance from 3.81 m to 7.62 m	164.69 3.81			
4				6	SS	8
5				7	SS	7
				8	SS	10
6				9	SS	8
	Rotary Drill NQ Core			10	SS	>50
7		- Gneiss boulder from 6.91 m to 7.33 m		11	RC	DD
		(PT) PEAT and (SM) SILTY SAND, fine; wet, dense	160.88 7.62			
8				12	SS	43
		Fresh, massive, black, grey and pink, medium grained GNEISS	160.27 8.23	C1	RC	DD
9				C2	RC	DD
10						

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MIS-BHS 001 1311210159.GPJ GAL-MIS.GDT 01/21/14 TB

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-3

SHEET 2 OF 2

LOCATION: See Site Plan

BORING DATE: September 5, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Rotary Drill NQ Core	Fresh, massive, black, grey and pink, medium grained GNEISS			C2	RC	DD				
					C3	RC	DD				
11				157.35							
		End of Borehole		11.15							
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF DRILLHOLE: 13-3

SHEET 1 OF 1

LOCATION: See Site Plan

DRILLING DATE: September 5, 2013

DATUM: Geodetic

DRILL RIG: CME 55

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Downing Drilling

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

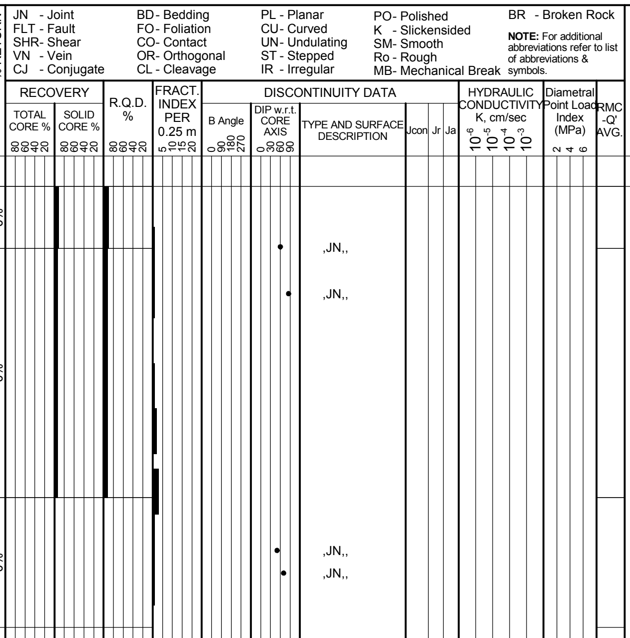
PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	FLUSH	TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE		160.27					
	Rotary Drill NQ Core	Fresh, massive, black, grey and pink, medium grained GNEISS		8.23	1		0%	,JN,,	
9					2		0%	,JN,,	
10					3		0%	,JN,, ,JN,,	
11				157.35					
		End of Drillhole		11.15					
12									
13									
14									
15									
16									
17									
18									



DEPTH SCALE
1 : 50

LOGGED: RI
CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-4

SHEET 1 OF 1

LOCATION: See Site Plan

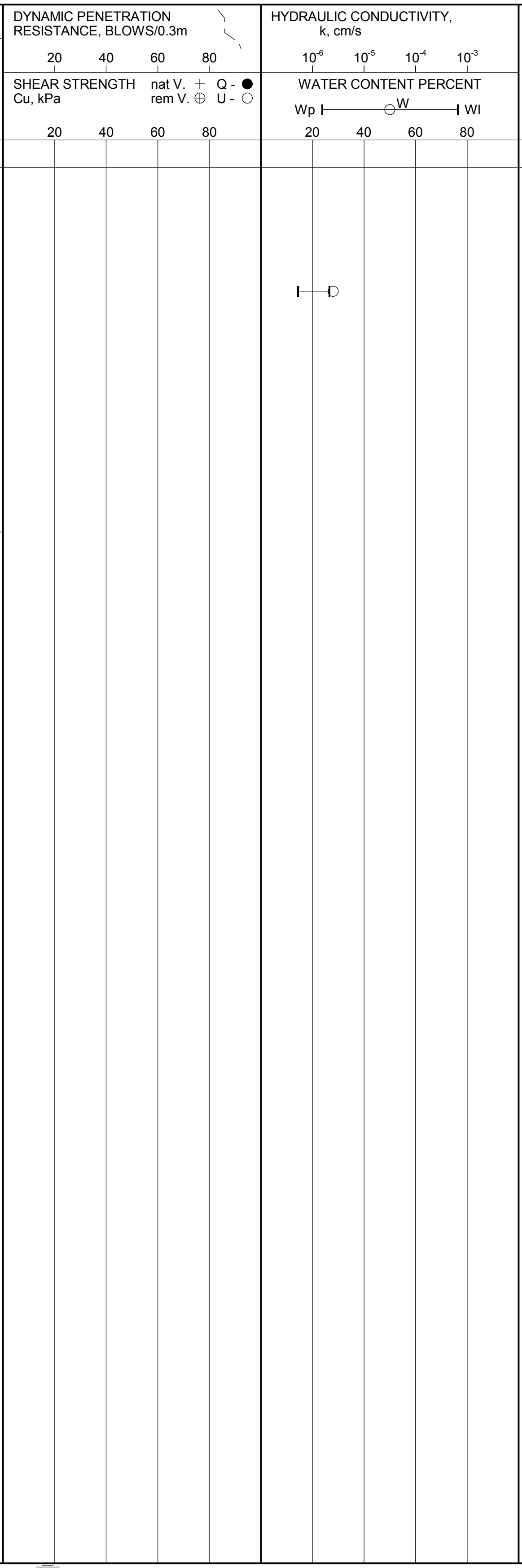
BORING DATE: September 3, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		149.83					
0	Portable Drill	(OH) SILT, some sand, fine, trace rootlets; moist, very loose		0.00					
		(CI) SILTY CLAY, some sand seams, fine, trace organics; grey; cohesive, firm		149.53 0.30	1	SS	1		
1					2	SS	4		
					3	SS	4		
2		(CI-CL) SILTY CLAY, layered silty sand seams; grey; cohesive, firm		148.00 1.83	4	SS	6		
					5	SS	>50		
		End of Borehole Sampler Refusal		147.14 2.69					
3									
4									
5									
6									
7									
8									
9									
10									



DEPTH SCALE
1 : 50

LOGGED: RI
CHECKED: BDG

MIS-BHS 001 131121O159.GPJ GAL-MIS.GDT 01/21/14 TB

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-5

SHEET 1 OF 1

LOCATION: See Site Plan

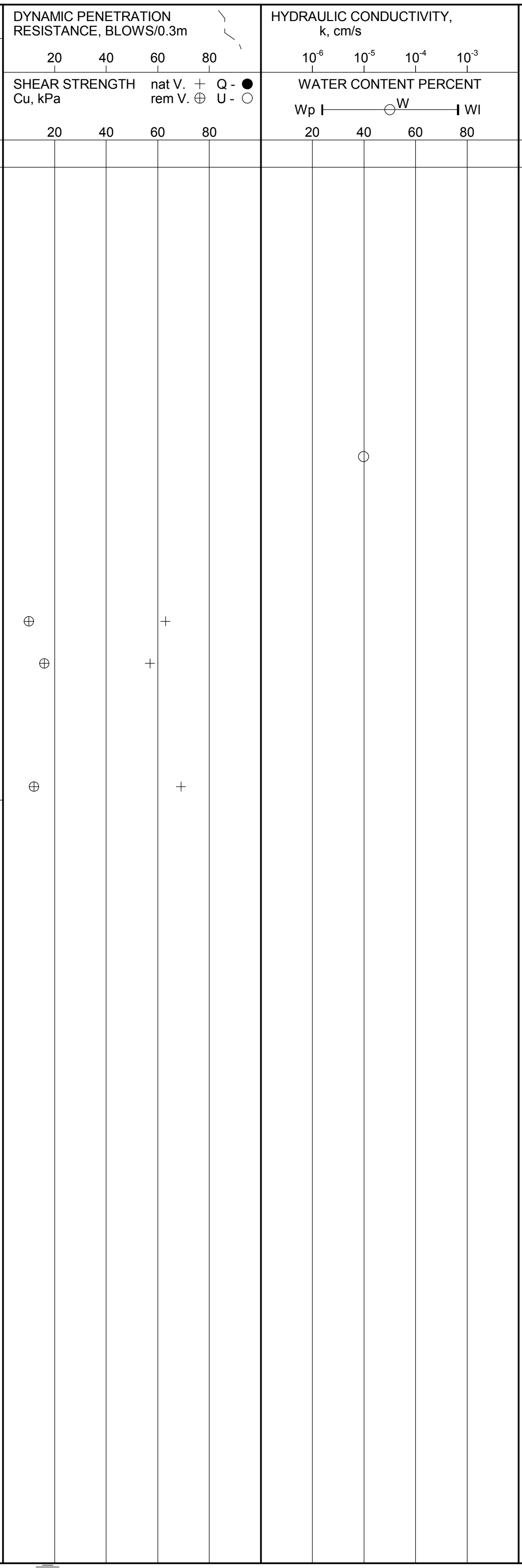
BORING DATE: September 3, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		151.12					
0	Portable Drill	(ML-CL) CLAYEY SILT, some sand, fine; grey; cohesive, soft	▨	0.00	1	SS	1		
		(CI-CL) SILTY CLAY, some sand, fine; grey; cohesive, stiff	▨	150.51 0.61	2	SS	2		
					3	SS	5	CHEM	
2					4	SS	2		
					5	SS	5		
4					6	SS	3		
		End of Borehole Sampler Refusal		146.45 4.67					



DEPTH SCALE

1 : 50

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-6

SHEET 1 OF 2

LOCATION: See Site Plan

BORING DATE: September 4, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		160.75							
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) SILTY SAND, fine to medium, trace gravel; dark, brown, organics, rootlets; non-cohesive, moist		0.00							
		FILL - (SP) SAND, fine to coarse, and (GP) GRAVEL, angular to subrounded, trace silt; brown, with cobbles and/or boulders; moist, loose to compact Cobbles and/or boulders inferred from auger resistance from 0.30 m to 9.91 m		0.10	1	SS	15				
1					2	SS	22				
					3	SS	26				
2					4	SS	18				
3					5	SS	22				
4					6	SS	9				
5					7	SS	10				
					8	SS	22				
6		- Granitic and gneiss boulders encountered from 6.10 m to 7.32 m depth			9	SS	>50				
	Rotary Drill NQ Core				10	RC	DD				
7					11	SS	24				
8					12	SS	4				
9					13	SS	14				
10				150.84 9.91	14	SS	31				
		CONTINUED NEXT PAGE									

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-6

SHEET 2 OF 2

LOCATION: See Site Plan

BORING DATE: September 4, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Rotary Drill NQ Core	(SP) SAND, fine to coarse, subrounded, some silt; brown, oxidation areas, thick laminations of brown fine sand; non-cohesive, wet, dense (Possible FILL)			14	SS	31		○	M	
					15	SS	3				
11					16	SS	>50				
		Fresh, massive, pink, medium grained GRANITE		149.05 11.70							
12					C1	RC	DD				
13											
14					C2	RC	DD				
		End of Borehole		145.95 14.80							
15											
16											
17											
18											
19											
20											

MIS-BHS 001 1311210159.GPJ GAL-MIS.GDT 01/21/14 TB

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF DRILLHOLE: 13-6

SHEET 1 OF 1

LOCATION: See Site Plan

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: September 4, 2013

DRILL RIG: CME 55

DRILLING CONTRACTOR: Downing Drilling

DATUM: Geodetic

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

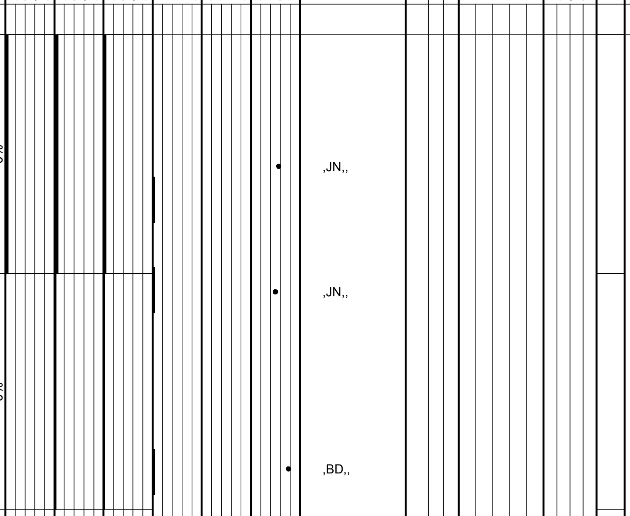
BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.



DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN FLUSH	TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE		149.09				
12	Rotary Drill NQ Core	Fresh, massive, pink, medium grained GRANITE		11.66	5	0%	,JN,,	
13					6	0%	,JN,,	
14				145.95 14.80			,BD,,	
		End of Drillhole						
15								
16								
17								
18								
19								
20								
21								

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RI
CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-7

SHEET 1 OF 2

LOCATION: See Site Plan

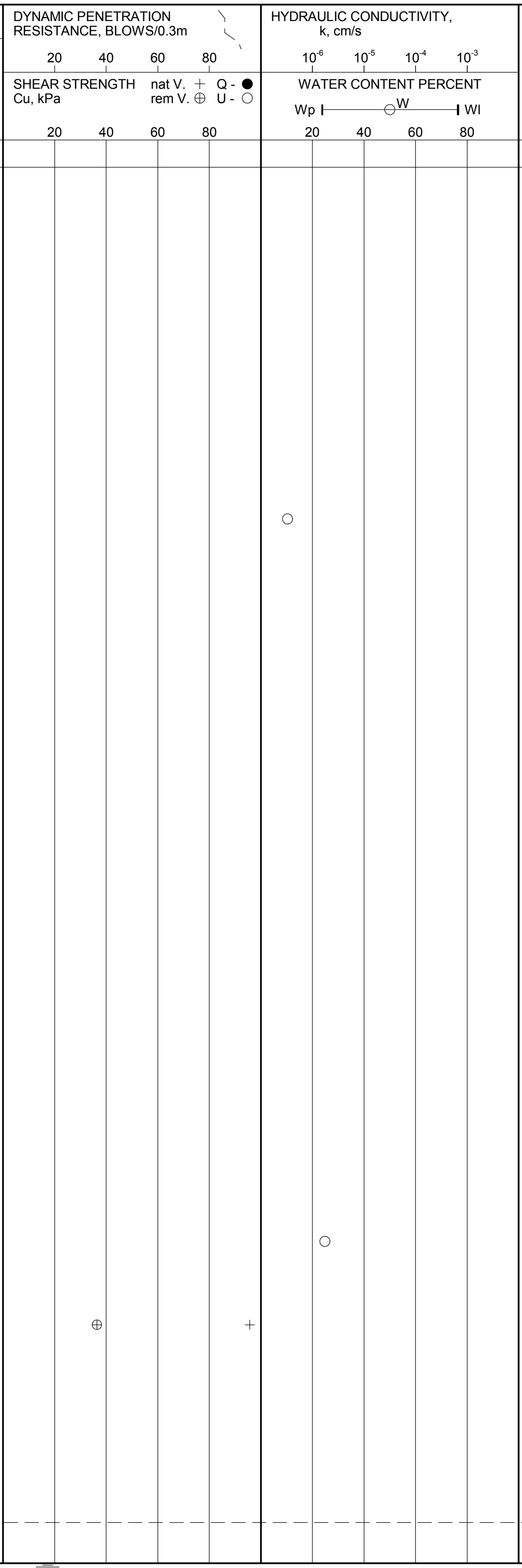
BORING DATE: September 9, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
	Power Auger 200 mm Diam. (Hollow Stem)	GROUND SURFACE	165.10				
0		TOPSOIL - (SP) SAND, fine to medium, some silt, trace gravel; dark brown; moist	0.00				
		FILL - (SP) gravelly SAND, fine to coarse, trace to some silt, with thin layers of grey silty sand, some clay; dark brown to brown; moist to wet, compact to loose	164.92 0.18	1	SS	17	
1				2	SS	20	
2				3	SS	11	
				4	SS	16	
3				5	SS	8	
4				6	SS	7	
5		(CI-CL) SILTY CLAY, trace sand; grey, thin laminations of fine sand, rootlets, moderately fissured; stiff	160.22 4.88	7	SS	5	
		(SM) SILTY SAND, fine, and (ML) sandy SILT, thin laminations of grey silty clay, thin laminations to thin beds of fine to medium sand; grey; wet, loose to very loose	159.92 5.18	8	SS	7	CHEM
6				9	SS	8	
7				10	SS	WR	
8				11	SS	1	M
				12	SS	3	
9				13	SS	8	
10				14	SS	2	



PIEZOMETER OR STANDPIPE INSTALLATION

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-7

SHEET 2 OF 2

LOCATION: See Site Plan

BORING DATE: September 9, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ : 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl : 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

--- *CONTINUED FROM PREVIOUS PAGE* ---

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
10	(SM) SILTY SAND, fine, and (ML) sandy SILT, thin laminations of grey silty clay, thin laminations to thin beds of fine to medium sand; grey; wet, loose to very loose	153.82 11.28
11	(SM) SILTY SAND, fine to medium; grey; wet, compact	152.45 12.65
12	(SM) SILTY fine SAND, thin laminations of grey silty clay, thin beds of brown fine to coarse sand, trace gravel; brown; wet, compact	152.01 13.09
13	End of Borehole Auger Refusal	

SAMPLE NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
14	SS	2	M
15	SS	3	
16	SS	13	M
17	SS	13	

Depth scale: 10 11 12 13 14 15 16 17 18 19 20

MIS-BHS 001 131121O159.GPJ GAL-MIS.GDT 01/21/14 TB

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-8

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: September 9, 2013

DATUM: Geodetic

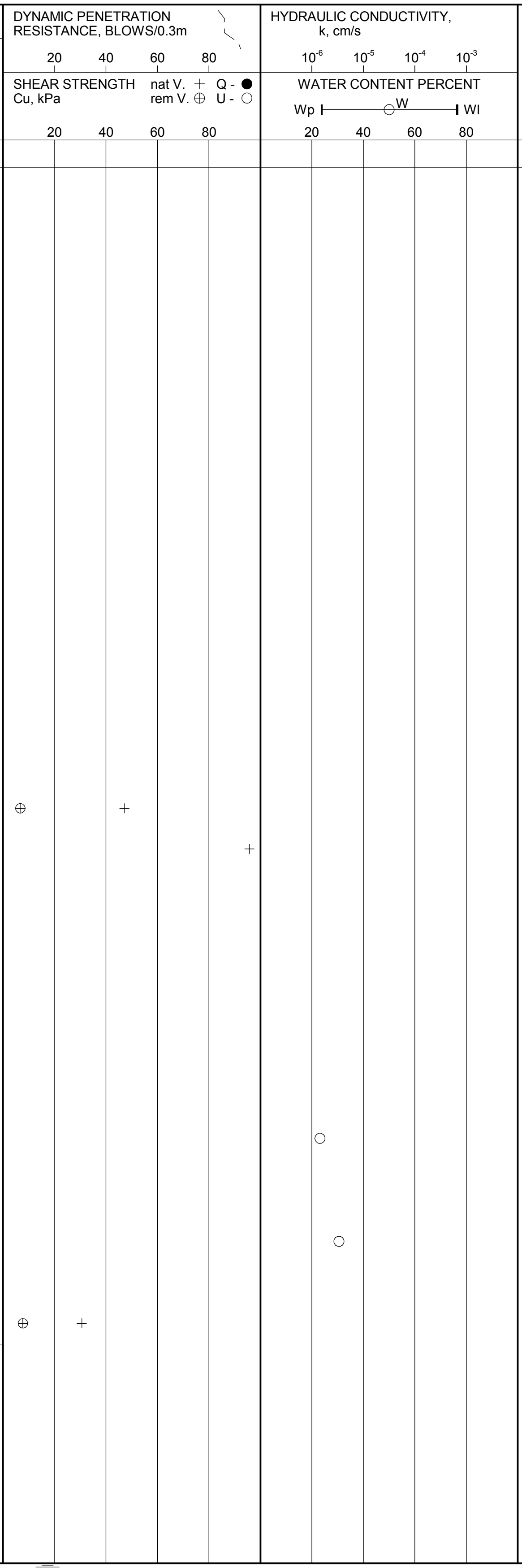
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	165.60
TOPSOIL - (SM) SILTY SAND, fine, trace gravel, organics; dark brown; moist	0.00
FILL - (SP) gravelly SAND, fine to coarse, trace to some silt; brown; moist to wet, dense to loose	0.15
(CI-CL) SILTY CLAY, moderately fissured, rootlets, thin laminations of fine sand; grey; very stiff to firm	162.09 3.51
(SM) SILTY SAND, fine, and (ML) sandy SILT, thin laminations of grey silty clay and fine to medium sand; grey; wet, loose to very loose	160.57 5.03
End of Borehole	156.91 8.69

SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
1	SS	15	
2	SS	42	
3	SS	35	
4	SS	21	
5	SS	8	
6	SS	6	
7	SS	8	
8	SS	3	
9	SS	3	M
10	SS	2	



Depth (m)	Shear strength rem V. ⊕ (kPa)	Shear strength nat V. + (kPa)	Water content W (%)
4.6	~10	~50	
4.9		>80	
7.2			~23
7.9			~30
8.4	~10	~30	

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE 1 : 50

LOGGED: RI

CHECKED: BDG

MIS-BHS 001 1311210159.GPJ GAL-MIS.GDT 01/21/14 TB

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-9

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: September 4, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

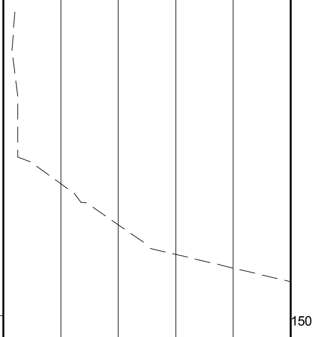
DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	162.44					
0	Portable Drill	TOPSOIL	0.05					
		(OL) SILT, some fine sand, organics, rootlets; very loose		1	SS	1		
				2	SS	7		
1		(CI-CL) SILTY CLAY, some fine sand seams; grey; very stiff	161.47 0.97					
				3	SS	20	CHEM	
2				4	SS	16		
		Inferred Silty Clay	160.00 2.44					
3		Inferred Silty Sand	159.04 3.40					
4		DPT Refusal	157.99 4.45					
5								
6								
7								
8								
9								
10								

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-10

SHEET 1 OF 1

LOCATION: See Site Plan

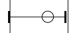
BORING DATE: September 4, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3}; WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		164.21							
0	Portable Drill	(SM) SILTY SAND, fine; brown; moist, compact		0.00	1	SS	17				
		(CI-CL) SILTY CLAY, trace fine sand; grey to brown (WEATHERED CRUST); very stiff		163.60 0.61	2	SS	33				
1					3	SS	46				
2					4	SS	8				
					5	SS	8				
3		(ML) CLAYEY SILT, some fine sand, some gravel; grey to brown; very stiff		161.16 3.05	6	SS	16				
		End of Borehole Sampler Refusal		160.60 3.61							
4											
5											
6											
7											
8											
9											
10											



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-11

SHEET 1 OF 2

LOCATION: See Site Plan

BORING DATE: September 6, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	171.10
TOPSOIL - (SP) SAND, fine to coarse, some silt, trace gravel, organics, rootlets; dark brown; moist	0.00
FILL - (SP) gravelly SAND, fine to coarse, trace silt; brown, with cobbles and boulders, with thin layers of fine sand; dense to very dense Cobbles and boulders inferred from auger resistance from 1.5 m to 3.0 m	0.15
FILL - (SP) SAND, fine to coarse, trace to some fine to coarse, subrounded gravel, trace silt; occasionally grey silty clay layer, possible cobbles/boulders; brown; moist, compact	166.53 4.57
FILL - (SP) SAND, fine to coarse, trace fine to coarse subrounded gravel, trace silt, occasional thin lamination of dark brown organics, possible cobbles/boulders; brown; moist to wet, compact to loose	164.84 6.26
TOPSOIL - (ML) CLAYEY SILT, trace to some fine sand, organics, rootlets; dark brown; moist	162.64 8.46
(CI-CL) SILTY CLAY, moderately fissured, thinly laminated with fine sand; grey-greenish; very stiff	8.56
	161.19 9.91

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	12
2	SS	36
3	SS	34
4	SS	56
5	SS	41
6	SS	37
7	SS	23
8	SS	28
9	SS	22
10	SS	27
11	SS	22
12	SS	8
13	SS	8
14	SS	6

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

WATER CONTENT PERCENT: Wp ⊢—○W—⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-11

SHEET 2 OF 2

LOCATION: See Site Plan

BORING DATE: September 6, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	Power Auger	(CL-ML) SILTY CLAY/CLAYEY SILT	▨	160.66 10.44	14	SS	6		○		
	Power Auger	(SM) SILTY SAND, trace gravel, some clay; grey brown to brown (Possible Glacial Till); wet, loose		160.43 10.67							
11	Rotary Drill NQ Core	Fresh, massive, black, grey and pink GNEISS			C1	RC	DD				
12	Rotary Drill NQ Core				C2	RC	DD				
13				157.89 13.21							
		End of Borehole									
14											
15											
16											
17											
18											
19											
20											

MIS-BHS 001 1311210159.GPJ GAL-MIS.GDT 01/21/14 TB

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF DRILLHOLE: 13-11

SHEET 1 OF 1

LOCATION: See Site Plan

DRILLING DATE: September 6, 2013

DATUM: Geodetic

DRILL RIG: CME 55

INCLINATION: -90°   AZIMUTH: ---

DRILLING CONTRACTOR: Downing Drilling

JN - Joint
FLT - Fault
SHR- Shear
VN - Vein
CJ - Conjugate

BD- Bedding
FO- Foliation
CO- Contact
OR- Orthogonal
CL - Cleavage

PL - Planar
CU- Curved
UN- Undulating
ST - Stepped
IR - Irregular

PO- Polished
K - Slickensided
SM- Smooth
Ro - Rough
MB- Mechanical Break

BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	RECOVERY TOTAL CORE % 80 60 40 20	RECOVERY SOLID CORE % 80 60 40 20	R.Q.D. % 80 60 40 20	FRACT. INDEX PER 0.25 m 5 10 15 20	DISCONTINUITY DATA B Angle 0 90 180 270	DIP w.r.t. CORE AXIS 0 30 60 90	TYPE AND SURFACE DESCRIPTION	Jcon	Jr	Ja	HYDRAULIC CONDUCTIVITY K, cm/sec 10^{-6} 10^{-5} 10^{-4} 10^{-3}	Diametral Point Load Index (MPa) 2 4 6	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		BEDROCK SURFACE		160.43																
11	Rotary Drill NQ Core	Fresh, massive, black, grey and pink GNEISS		10.67	1	100%							,JN,, ,JN,, ,JN,,							
12 13				157.89 13.21	2	100%														
14 15 16 17 18 19 20		End of Drillhole																		

DEPTH SCALE
1 : 50

LOGGED: RI
CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-12

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: September 10, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	SOIL PROFILE STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		243.30							
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) SILTY SAND, fine, organics, rootlets; dark brown; moist		0.00							
		FILL - (SP) gravelly SAND, fine to coarse, trace silt; brown; moist, compact Possible boulder or cobbles inferred from auger resistance between 0.76 m to 1.07 m	▨	0.15	1	SS	11				
					2	SS	>50				
1				242.23 1.07							
		End of Borehole Auger Refusal									
2											
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RI
CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-13

SHEET 1 OF 1

LOCATION: See Site Plan

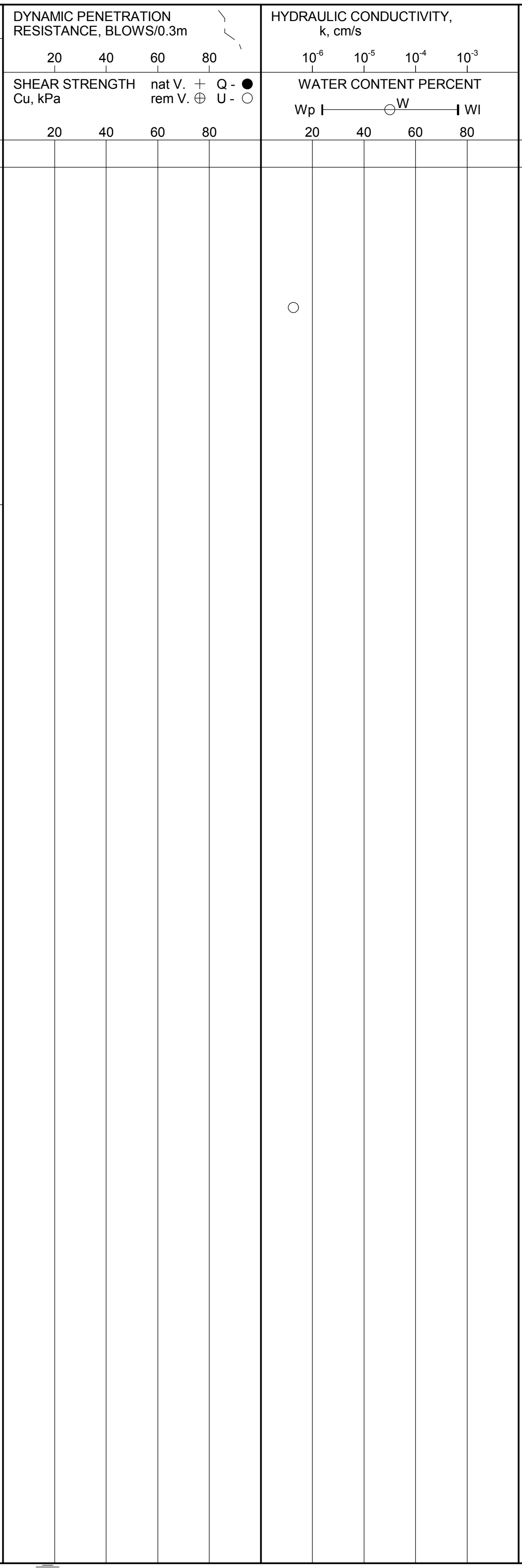
BORING DATE: September 10, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		242.50					
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALTIC CONCRETE	■	0.00					
		FILL - (SP) gravelly SAND, fine to coarse, trace to some silt; grey brown; moist, compact to dense	▨	0.13	1	SS	10		
1		FILL - (SM) SILTY SAND, some gravel, trace organics, with cobbles (inferred from auger resistance); dark brown to black; moist to wet, compact to loose	▨	241.56 0.94	2	SS	43		
					3	SS	4	CHEM	
2		(PT) PEAT and (OL) ORGANIC SILT, trace fine sand; black and brown; wet		240.45 2.05					
		(SP) gravelly SAND, fine to coarse, trace silt; dark brown; moist, dense		2.13	4	SS	>50		
		End of Borehole Auger Refusal		240.01 2.49					



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-14

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: September 10, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		243.25							
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALTIC CONCRETE	■	0.00							
		FILL - (SW) gravelly SAND, fine to coarse, trace silt and organics, thin layers fo grey silty clay; dark brown; moist, compact	▨	0.09	1	SS	14				
1		FILL - (SP) SAND, fine, trace to some silt, trace gravel; grey brown; moist, loose	▨	242.56 0.69	2	SS	9				
		FILL - (SM) SILTY SAND, fine to coarse, some gravel, trace organics; dark brown; moist to wet, loose	▨	241.88 1.37	3	SS	8				
					4	SS	>50				
2		End of Borehole		241.34 1.91							
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-14A

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: September 10, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		243.20							
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALTIC CONCRETE	■	0.00							
		BASE/FILL - (SW) gravelly SAND, fine to coarse, trace silt; brown; moist	▨	0.10	1	GS					
		FILL - (SP) SAND, fine, and SILTY SAND, trace to some gravel, trace organics, trace cobbles; dark brown, grey and black; moist	▨	0.25	2	GS					
		FILL - (SP) SAND, fine, some silt, trace gravel; grey brown; moist	▨	242.55 0.65	3 4	GS GS			 ○		
1											
		End of Borehole Auger Refusal		241.75 1.45							
2											
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

PROJECT: 13-1121-0159

RECORD OF BOREHOLE: 13-14B

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: September 10, 2013

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	SOIL PROFILE STRATA PLOT	SOIL PROFILE ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		243.15							
0	Power Auger 200 mm Diam. (Hollow Stem)	ASPHALTIC CONCRETE	■	0.00							
		BASE/FILL - (SW) gravelly SAND, fine to coarse; brown to grey brown; moist	▨	0.10							
		FILL - (SM) SILTY SAND and (SP) SAND, fine to medium, trace silt, trace some gravel, trace cobbles; dark brown to grey brown; moist	▨	242.81 0.34							
1											
		End of Borehole Auger Refusal		241.91 1.24							
2											
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RI

CHECKED: BDG

APPENDIX B

Results of Chemical Analysis
Exova Report No. 1321366

Certificate of Analysis

Client:	Golder Associates Ltd. (Ottawa) 32 Steacie Drive Kanata, ON K2K 2A9
Attention:	Mr. Bruce Goddard
PO#:	
Invoice to:	Golder Associates Ltd. (Ottawa)

Report Number:	1321366
Date Submitted:	2013-09-27
Date Reported:	2013-10-04
Project:	13-1121-0159
COC #:	777423

Group	Analyte	MRL	Units	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D. Guideline	1061245 Soil 2013-09-03 13-2 Sa 3	1061246 Soil 2013-09-03 13-5 Sa 3	1061247 Soil 2013-09-09 13-7 Sa 8	1061248 Soil 2013-09-04 13-9 Sa 3
Agri. - Soil	Electrical Conductivity	0.05	mS/cm		0.12	0.33	0.10	0.17
	pH	2.0			6.6	7.7	8.0	7.5
General Chemistry	Cl	0.002	%		0.010	0.006	0.004	0.005
	Resistivity	1	ohm-cm		8330	3030	10000	5880
	SO4	0.01	%		<0.01	0.01	<0.01	<0.01

Group	Analyte	MRL	Units	Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D. Guideline	1061249 Soil 2013-09-10 13-13 Sa 3
Agri. - Soil	Electrical Conductivity	0.05	mS/cm		0.34
	pH	2.0			5.8
General Chemistry	Cl	0.002	%		0.003
	Resistivity	1	ohm-cm		2940
	SO4	0.01	%		0.08

Guideline = *** = Guideline Exceedence**
** = Analysis completed at Mississauga, Ontario.
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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