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GEOLOGICAL SURVEY OF CANADA
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Abstract

The Geological Survey of Canada (GSC) is investigating the hydrogeology of the Spiritwood buried valley aquifer in southwestern Manitoba as part of its Groundwater Geosciences Program. This Open File reports on a drilling program conducted in November 2010 in which one shallow and one intermediate depth piezometer were installed within separate boreholes at each of three sites near Killarney, Manitoba to complement existing deep wells monitored by Manitoba Conservation and Water Stewardship (Government of Manitoba, Ministry of CWS). Boreholes were advanced without drilling fluids by the cable tool method and by driving core tubes which allowed for accurate borehole logging and the collection of sample cores at selected depths. This Open File includes the geological logs of the boreholes, the piezometer construction details and the geotechnical data measured on sampled core. Geotechnical analyses included measurement of approximate shear strength using a pocket penetrometer (n=21), grain size distribution (n=8), gravimetric water content (n=91), and wet bulk density (n=22) from which dry bulk density (n=22) and volumetric water content (n=22) were calculated and porosity (n=22) estimated.

The drilling program was a collaborative effort between the Agri-Environmental Services Branch (AESB) of Agriculture and Agri-Food Canada (AAFC) and the Geological Survey of Canada of Natural Resources Canada (NRCan).

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Introduction

The Geological Survey of Canada (GSC) is investigating the hydrogeology of the Spiritwood buried valley aquifer in southwestern Manitoba as part of its Groundwater Geosciences Program. The Spiritwood buried valley aquifer is a cross-border aquifer extending from Manitoba, through North Dakota and into South Dakota (Figure 1). This aquifer has been studied extensively in North Dakota but is less known in Manitoba. The Water Resources Branch of Manitoba Natural Resources (currently Water Science and Management Branch of Manitoba Conservation and Water Stewardship, CWS) had previously drilled boreholes in the study area in 1974 and again in 2000-02. Eight monitoring wells drilled along the Spiritwood buried valley aquifer between Margaret, Manitoba, and the international border are currently being monitored by CWS. Most of these monitoring wells are screened at depth in confined units; interpretation of their water level fluctuations is problematic since there are no records of groundwater level response near the ground surface and at intermediate depths. A drilling program was undertaken in November 2010 to install piezometer nests at four sites with active CWS monitoring wells along the Spiritwood buried valley aquifer. One site was not accessible and, at the conclusion of fieldwork, two additional piezometers (one shallow, one intermediate depth) were installed at each of three existing sites. The purpose of this GSC Open File is to present the logs and geotechnical data collected from the six boreholes drilled near Killarney, Manitoba in November 2010.

The drilling program was a collaborative effort between Agriculture and Agri-Food Canada (AAFC) and Natural Resources Canada (NRCan). AAFC provided the drill rig with the field crew and technical support for geotechnical analysis of collected samples and compilation of field logs. NRCan selected the sites, ensured utility clearances before drilling, consulted with drillers to select piezometer installation depths, developed piezometers and installed water level recording dataloggers.

Study area

The study area is located in southwestern Manitoba near the town of Killarney (Figure 2). Four active CWS monitoring well sites were targeted for shallow piezometer installations: G05OA008, G05OA009, G05OA010, and G05OA011, however site G05OA011 was not accessible to the drill rig due to water ponding at the surface in a ditch. AAFC and GSC assigned their own site numbers to the new boreholes and the GSC also assigned new piezometer numbers to the completed piezometers. All borehole and piezometer designations are presented in Table 1 along with their GPS coordinates.

Previous and current studies

The groundwater resources of the Brandon map area were first mapped and summarized by Halstead (1959). By mapping the bedrock topography, he recognized the presence of deep valleys in the bedrock that were subsequently filled with glaciofluvial and glacial sediments. Although he acknowledged the potential of these buried valley aquifers for higher yield wells, there was minimal information available about them. More information existed for the shallower sand and gravel bodies found locally within the till. He observed that the volume of water recovered from these inter-till aquifers varied depending on their thickness, extent and interconnection with other aquifers and the ground surface.

Bedrock topography was subsequently mapped for all southern Manitoba by Klassen et al. (1970). Teller et al. (1976) similarly compiled bedrock topography and sediment thickness for southern Manitoba, whereas Sie and Little (1976) produced several maps and cross-sections of the Brandon

map area for the Groundwater Availability Map Series produced by Manitoba Natural Resources, Water Resources Branch. These maps indicate the presence of a broad buried valley that crosses the international border in a north-south direction just south of Cartwright, Manitoba, and then extends from Cartwright to the northwest towards the Souris River near Margaret.

The province of Manitoba has undertaken test drilling of the Spiritwood aquifer in 1961-62, 1974 and then installed 8 monitoring wells in 2000-02. The results of these drilling programs were never published, although the logs are available within the provincial water well records. In 2009, the province drilled 23 boreholes to specifically target buried valleys to the north and west of the current study area between Margaret and Brandon (Toop, 2010). Test drilling and a short-term pump test were conducted for the development of a groundwater supply for the Town of Killarney (Friesen Drilling Ltd., 2007; W. L. Gibbons & Associates Inc., 2009).

The Spiritwood buried valley aquifer was studied in greater detail in North Dakota where it is a significant water source for irrigation and municipal supply (Randich and Kuzniar, 1984; Shaver, 1984; Shaver and Pusc, 1992). Several cross-sections of mud-rotary holes were drilled at approximately one mile intervals to define the extent of the Spiritwood buried valley aquifer as well as the shallower inter-till aquifers in the area just south of the international boundary (Randich and Kuzniar, 1984).

As part of the GSC's Groundwater Geoscience Program, airborne and ground electromagnetic (Oldenborger, 2010b; Oldenborger, 2010a; Oldenborger et al., 2010; Oldenborger et al., 2011; Oldenborger et al., 2013), seismic reflection (Oldenborger et al., 2011; Oldenborger et al., 2013; Pullan et al., 2013; Pugin et al., 2014) and borehole (Crow et al., 2012a) geophysical surveys were conducted to help define the location, depth and composition of the Spiritwood buried valley aquifer in Manitoba. A borehole was cored to a depth of 97.5 m (320 feet) south of Cartwright, Manitoba, and two piezometers were installed at the site (Crow et al., 2012b).

Methods

All six boreholes were advanced with a B-12 cable tool rig owned and operated by the Agri-Environmental Services Branch (AESB) of AAFC without adding drilling fluids (water or mud; Figure 3 and Appendix B). A 3 ⅞″ diameter excavator bit was used to drill the initial borehole and bring cuttings to the surface for geological logging. Sediments were described and classified in the field using a modified unified soil classification system (USCS). A pocket penetrometer was used on site to provide estimates of unconfined compressive strength and assist sample descriptions. Intact cores were retrieved for selected intervals in 0.75 m length brass liner tubes driven into the sediment. Cores were sealed and stored for subsequent gravimetric water content and wet bulk density analysis in the laboratory. A core catcher was occasionally used at the base of the tube depending on the nature of the cored sediment. The upper portions of the borehole were usually reamed out using 5 ⅝″ and sometimes 7 ⅞″ bits to assist with the advance of a temporary 4″ casing to keep the borehole open in sandy sections and allow for installation of piezometers and filter sands. The 4″ casing was removed following piezometer installation. Piezometers were completed with 2″ nominal PVC pipe (schedule 40 thickness) fitted with 20-slot screens (20/1000″ slot width). Filter sand was emplaced adjacent to (and slightly above) screened intervals (Table 2). The borehole annulus was sealed with bentonite and followed by borehole cuttings. Lockable steel casing protectors (5′×6″×6″) were installed over each piezometer and extended approximately 0.75 m above ground surface (stick up). Locks on the wells were supplied by CWS and were keyed alike to all the CWS monitoring wells.

Cores were extruded from the tubes at AAFC laboratories in Regina to log the geology and obtain samples for geotechnical analysis. Samples were analyzed for gravimetric moisture content (ASTM Committee D18 on Soil and Rock, 2005), wet bulk density (AAFC internal method, described below), and compressive strength using a pocket penetrometer. Grain size analysis (ASTM Committee D18 on Soil and Rock, 2006; ASTM Committee D18 on Soil and Rock, 2007) was conducted to determine the sand and gravel fractions (>75 µm) of the non-till units. Particles passing through the 75 µm sieve (silt and clay sized particles) are reported in aggregate as "fines".

Wet bulk density is measured by weighing a wet sample sealed in wax both in air and in water, and includes the following steps (PFRA, no date):
1. The soil sample was coated with paraffin wax.
2. The waxed sample was weighed on a balance.
3. On the same balance, the sample was suspended into a large container of water and weighed while it was submerged in water.
4. The sample density was calculated using the following equation:

$$\rho_{wet} = \frac{m_a \cdot \rho_{water}}{m_a - m_w} \quad (1)$$

where
ρ_{wet} is wet bulk density (g/cm^3),
ρ_{water} is the density of water (g/cm^3), assumed to be 1 g/cm^3,
m_a is the sample weight in air (g), and
m_w is the sample weight in water (g).

From the measured values of gravimetric water content and wet bulk density, both the dry bulk density and volumetric water content were calculated by the following equations:

$$\rho_{dry} = \frac{\rho_{wet}}{(1+w)} \quad (2)$$

$$\theta = \frac{\rho_{wet} \cdot w}{\rho_{water}} \quad (3)$$

where
ρ_{dry} is dry bulk density (g/cm^3),

w is gravimetric water content (g water/g of soil), and

θ is volumetric water content (cm^3/cm^3).

Porosity was also estimated from the following equation by assuming a specific gravity of sediment particles of 2.65:

$$n = \frac{(G_s \cdot \rho_{wet}) - \rho_{dry}}{G_s \cdot \rho_{wet}} \quad (4)$$

where

n = porosity (cm^3/cm^3), and

G_s = specific gravity (g/cm^3 / g/cm^3).

Results

Two boreholes were advanced at each of three sites and a piezometer was constructed in each borehole for a total of six piezometers (Figure 4, Table 1). Piezometer construction is summarized in Table 2. Borehole logs for each borehole are presented graphically in Figures 5 to 10 and tabulated in Tables 3 to 8. The legend for borehole logs is shown in Figure 11. Borehole logs were based both on field observations of sediment samples during drilling and laboratory inspection of extruded cores. Field borehole descriptions are reproduced in Appendix A. Grain size distributions of non-till units are presented in Figures 12 to 19. Geotechnical results are compiled in Tables 9 to 11.

Site GSC-BH-SW-02 (CWS well G05OA010)

The well log for the mud-rotary drilled monitoring well G05OA010 (Table 12) corresponds closely with that obtained from borehole GSC-BH-SW-02A (Figure 6, Table 3). A shallow sand unit was encountered between 0.45 and 1.15 m and was instrumented with piezometer GSC-SW-02-p1 (in borehole GSC-BH-SW-02B) which will provide an effective measurement of the water table depth. The deepest observation of oxidation in borehole GSC-BH-SW-02A was 3.15 m whereas beige till was noted to a depth of 3.7 m (12′) for well G05OA010.

Although the borehole log for GSC-BH-SW-02A only indicates one deeper sand unit from 8.00 m to 8.60 m, another thinner sandy seam was encountered at 9.75 m (Appendix A1) and is also recorded in well G05OA010 from 33-34′ (10.1-10.4 m). The screen for piezometer GSC-SW-02-p2 straddles this thin sandy seam. Borehole GSC-BH-SW-02A was not extended deeper because there were no other sandy units reported above the deeper aquifer in well G05OA010 (Table 12) and drilling progress was hampered by a cobble at 9.1 m.

Grain size analyses of the shallow (Figure 19) and intermediate (Figure 18) sand units yielded similar size distributions that indicate a predominance of medium sand with 18% and 16% of fines (silt and clay sized sediment), respectively. Geotechnical data show fairly consistent measurements within the till (Table 9). Average values of wet and dry bulk densities (n=5) were 2.08±0.06 and 1.78±0.08 g/cm^3, respectively. Results showed consistency as the average volumetric water content (n=5) was 0.30±0.02, whereas the average estimated porosity (n=5) was 0.33±0.03. Pocket penetrometer readings indicated a very stiff to hard consistency. The sand at 8.0 to 8.6 m depth had higher gravimetric water contents than the till (Table 9), which suggests that the porosity of the sand is higher than that of the till and/or that the dry bulk density of the sand is lower than that of the till.

Site GSC-BH-SW-03 (CWS well G05OA009)

The well log for the mud-rotary drilled monitoring well G05OA009 (Table 13) indicates a clayey beige till (i.e. oxidized) to a depth of 5.5 m (18′) which is comparable to the observed maximum depths of 6.75 m of joint oxidation and the presence of gypsum in borehole GSC-BH-SW-03A (Figure 8, Table 5). The shallow piezometer GSC-SW-03-p1 is completed in a silty seam within the oxidized till of borehole GSC-BH-SW-03B and provides a measurement of the water table depth. The sand seam from 1.4 to 1.5 m depth would not have been suitable for piezometer installation since the water table is below this depth most of the time.

The numerous descriptions of "clay shale" within borehole GSC-BH-SW-03A either as fragments or as "shale' units are testimony to the high proportion of reworked shale within the till (Figure 8, Table 5, Appendix A3). The shale is present throughout much of the thickness of till as the first "clay shale" unit in borehole GSC-BH-SW-03A is recorded at 17.8-18.0 m depth (and at 18.6-19.2 m (61-63′) depth in G05OA009) and the depth of the true shale bedrock surface is recorded as 59.7 m (196′) in well G05OA009.

A five foot thick "sand and gravel layer" was recorded in well G05OA009 at a depth of 32.0-33.5 m (105-110′). In borehole GSC-BH-SW-03A only a few thin sandy and silty seams were encountered within the till between depths of 22.8 and 33.4 m. Piezometer GSC-SW-03-p2 straddles the lowermost of these thin sandy seams with a filter pack extending from 31.4 to 35.0 m depth.

The greater variability in the till was also observed in the geotechnical properties. Gravimetric water contents exhibited a wide range from 13.0 to 30.8 g of water/100 g of dry soil even below the water table with an average for all measurements of 21.3±4.9 g/100 g. Average values of wet and dry bulk densities (n=11) were 1.97±0.11 and 1.64±0.14 g/cm^3, respectively, whereas average volumetric water content and porosity were 0.33±0.04 and 0.38±0.05, respectively. Pocket penetrometer readings had the largest range of the three sites and indicated stiff to hard consistency.

Grain size analyses from the only non-till or clay shale units encountered characterize the sandy and silty seams. The sand seam is predominantly fine sand (75%), has no sediment coarser than medium sand (8%) and has 17% fines (24.0-24.1 m depth, Figure 16). The underlying sandy silt unit has only 1% medium sand, 44% fine sand and is predominantly (55%) fines (24.1-24.3 m depth, Figure 17).

Site GSC-BH-SW-04 (CWS well G05OA008)

The well log for the mud-rotary drilled monitoring well G05OA008 (Table 14) differs significantly with that obtained from borehole GSC-BH-SW-04A (Figure 10, Table 7). Whereas the well log for G05OA008 records brown coarse sand (0-5.5 m, 0-18′) and brown coarse gravel (5.5-6.7 m, 18-22′), the description of borehole GSC-BH-SW-04A makes no mention of sand or gravel and simply reports stiff to hard till with oxidized fractures or joints to a depth of 7.90 m. Similarly, the sandy non-till units in borehole GSC-BH-SW-04A (between 12.19 and 14.80 m depth) are offset from the gravel recorded in well G05OA008 (between 18.9 and 19.5 m, 62-64′). As the UTMs on well G05OA008 (Table 14) concur with those for GSC-SW-04-p1 and –p2 (Table 1), even though they were obtained independently, it is concluded that the correct well log for G05OA008 was likely used but that the site geology may have been misinterpreted in the mud-rotary borehole.

Piezometer GSC-SW-04-p1 was completed near the base of the oxidized zone (filter pack from 4.00 to 7.50 m depth), slightly below the water table (2.6-3.8 m deep). The intermediate depth piezometer GSC-SW-04-p2 straddles the sand and gravel units in borehole GSC-BH-SW-04A with a filter pack extending from 11.40-15.10 m depth.

Compared to borehole GSC-BH-SW-03A, the grain size distributions of non-till units in GSC-BH-SW-04A (Figures 12-15) are coarser and slightly less uniform (better graded). In particular, the sample at 13.4 m depth has 42% gravel, 49% sand and 9% silt and clay (fines; Figure 13). The presence of fines even in gravel units suggests that high hydraulic conductivities are unlikely within the inter-till sands and gravels of these boreholes.

Geotechnical data show considerable variability (Table 11). Gravimetric water contents are generally lower that for site GSC-BH-SW-03 with an average value of 16.3±3.8 g/100 g that may reflect the coarser grain size in borehole GSC-BH-SW-04A. Although average values and standard deviations of porosities and volumetric water contents are similar to those for borehole GSC-BH-SW-03A, the estimated porosities (0.37±0.06, n=6) are consistently higher than the calculated volumetric water contents (0.28±0.04, n=6) even if only those samples below the water table are considered (n=5). Average values of wet and dry bulk densities (n=5) were 1.96±0.13 and 1.68±0.15 g/cm^3, respectively. Pocket penetrometer readings indicated very stiff to hard consistency.

Additional work and installations

The piezometer nests are being used to assess groundwater conditions at these three sites as part of the investigation of the Spiritwood buried valley aquifer. These piezometers have also been developed, bail and slug tested and instrumented to allow for continuous monitoring. The piezometers have also been purged and sampled for groundwater geochemical and isotopic analyses. Soil moisture probes have been installed at sites GSC-BH-SW-02 and GSC-BH-SW-04 to provide data on the timing of infiltrating precipitation in relation to groundwater recharge.

Summary

This report documents geological, geotechnical and piezometer data collected during the drilling of six boreholes at three sites near Killarney, Manitoba. A piezometer was successfully installed in each borehole such that each monitoring site now has a vertical nest of three piezometers, including a shallow piezometer near the water table, an intermediate piezometer that straddles a sandy seam or layer, and a deeper Manitoba CWS monitoring well. As these boreholes were advanced without drilling fluids and cores were retrieved, the geology logs were expected to be more accurate than mud-rotary logger boreholes. The boreholes predominantly intercepted till with occasional gravel and sand or silt seams or thin layers. The depth of oxidation within the till varied from 3.15 m to 7.90 m. Till was mostly stiff to very hard. Geotechnical measurements were most uniform at site GSC-BH-SW-02 and most variable at site GSC-BH-SW-03. These piezometer installations will permit interpretation of the hydraulic relations between the groundwater table and the Spiritwood buried valley aquifer.

Acknowledgments

This work was conducted within the Groundwater Geosciences Program of Natural Resources Canada (NRCan). Collaboration with Agriculture and Agri-Food Canada (AAFC) was made possible by Victor Klassen (retired) of the former Agri-Environment Services Branch (AESB). Drilling and borehole logging was ably handled by Dale Gilchrist, Randy Darlington and Lane Scherger with an AAFC B-12 Cable tool rig. Core extrusion and geotechnical analyses were conducted at AAFC laboratories in Regina. Borehole logs were prepared by AAFC. Data transfer was enabled by Nadine Brossart of AAFC. Charles Logan of NRCan made GPS measurements and drafted Figure 1. Sam Alpay of NRCan provided helpful comments and Ross Knight of NRCan reviewed this Open File.

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Figures

Figure 1. Regional map of the approximate extent of the Spiritwood buried valley.

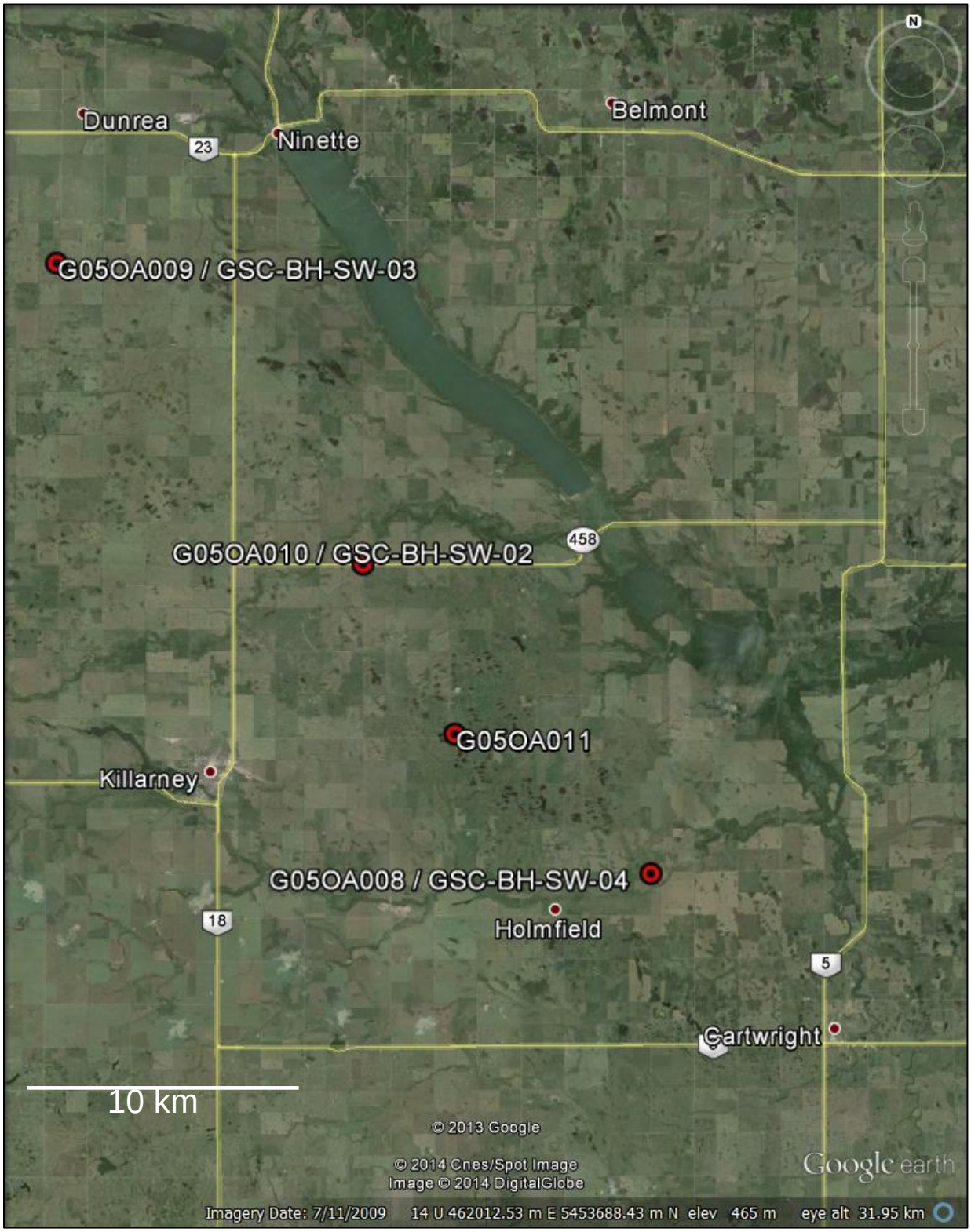


Figure 2. Satellite image (source Google Earth) of the proposed and actual drill sites. First identifiers are the Manitoba Water Stewardship well numbers, second identifiers are the GSC borehole site numbers.

Figure 3. B-12 cable tool rig and field core logging trailer at site G05OA010 (GSC-BH-SW02), November 2010.

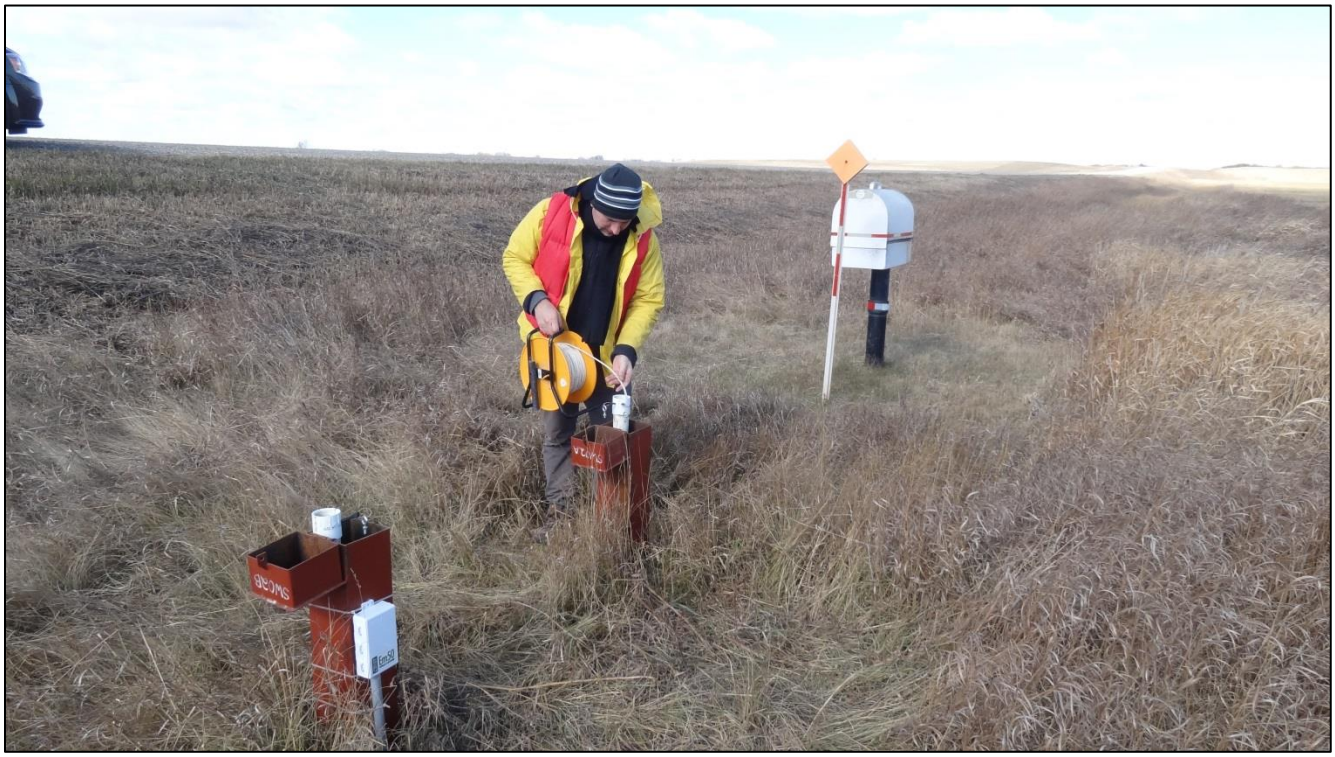


Figure 4. Photographs of piezometer sites.
a) GSC-SW-02-p1 (foreground), GSC-SW-02-p2 (middle) and G05OA010 (distant), facing NNW.

b) GSC-SW-03-p1 (left), GSC-SW-03-p2 (middle) and G05OA009 (right), facing NNE.

c) G05OA008 (left), GSC-SW-04-p2 (middle), GSC-SW-04-p1 (right), facing south.

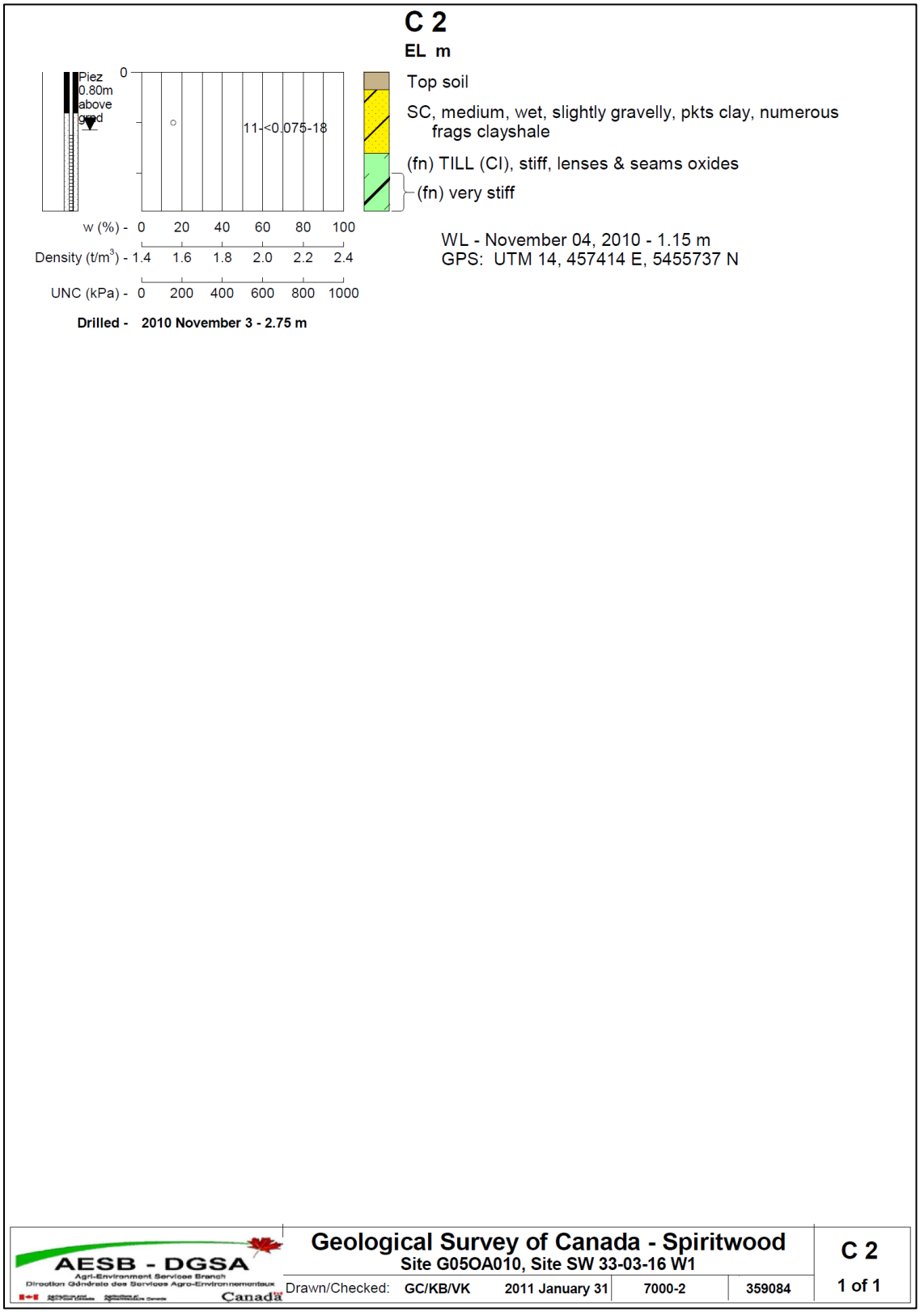


Figure 5. Borehole log for GSC-BH-SW-02B completed with piezometer GSC-SW-02-p1.

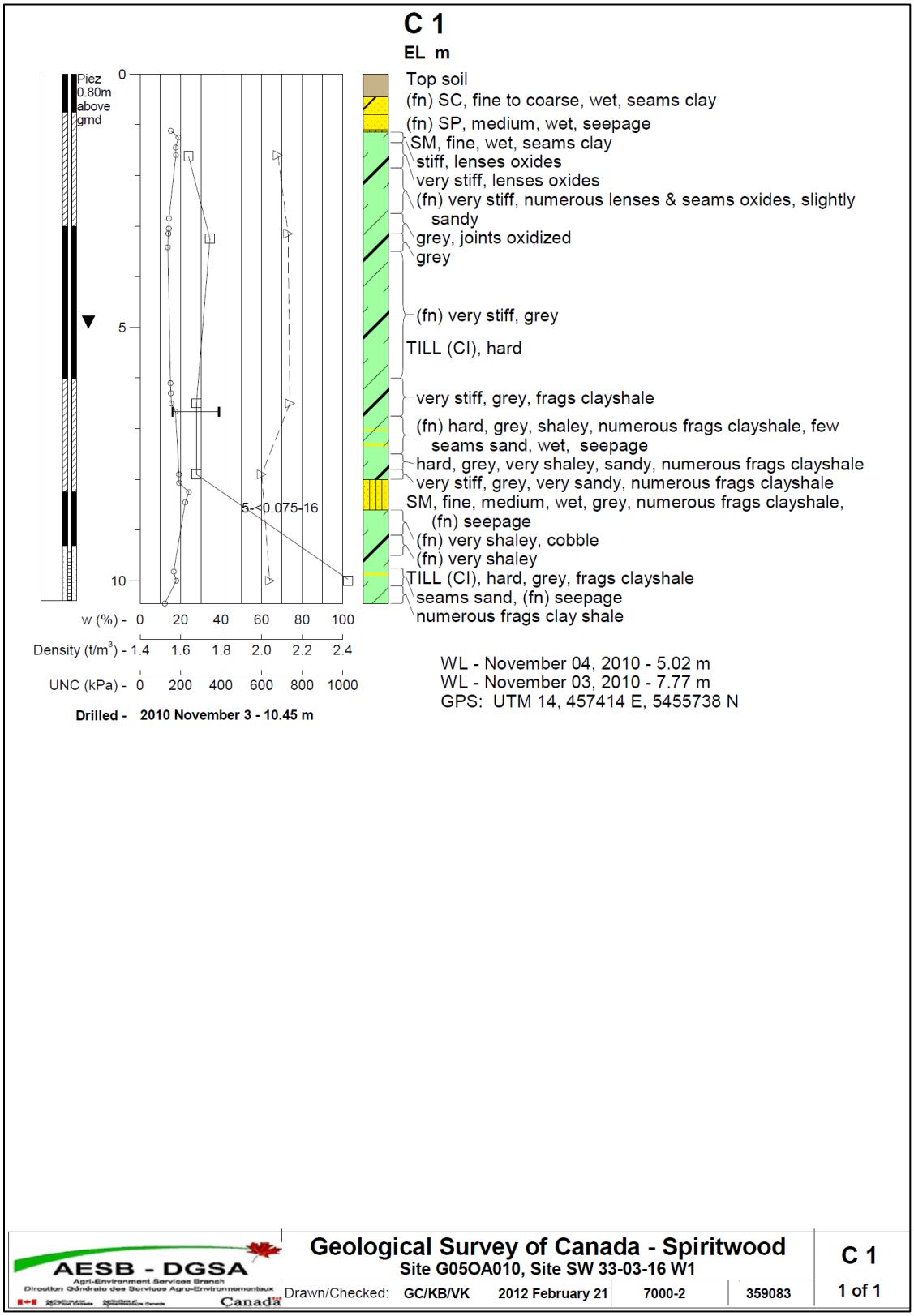


Figure 6. Borehole log for GSC-BH-SW-02A completed with piezometer GSC-SW-02-p2.

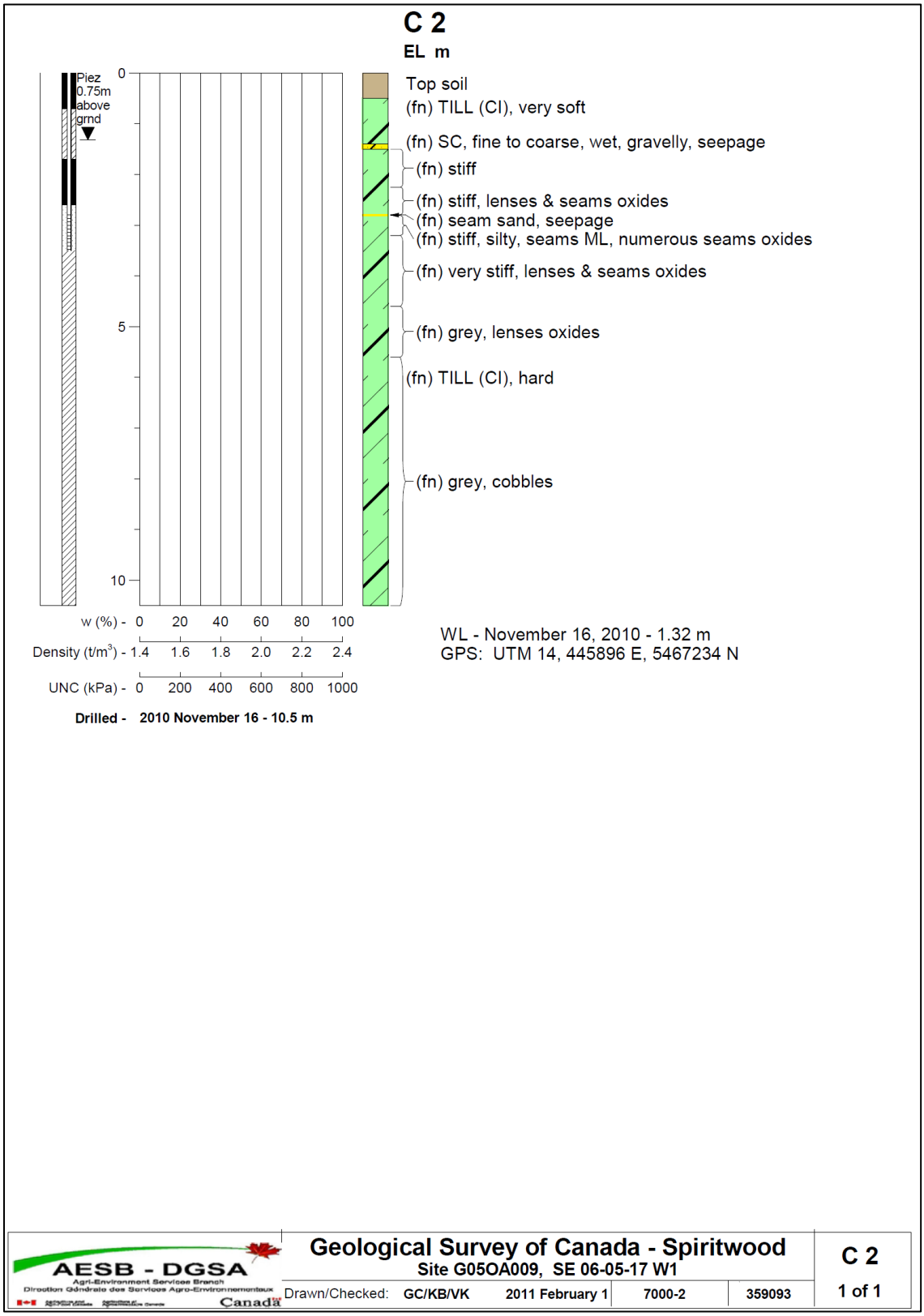


Figure 7. Borehole log for GSC-BH-SW-03B completed with piezometer GSC-SW-03-p1.

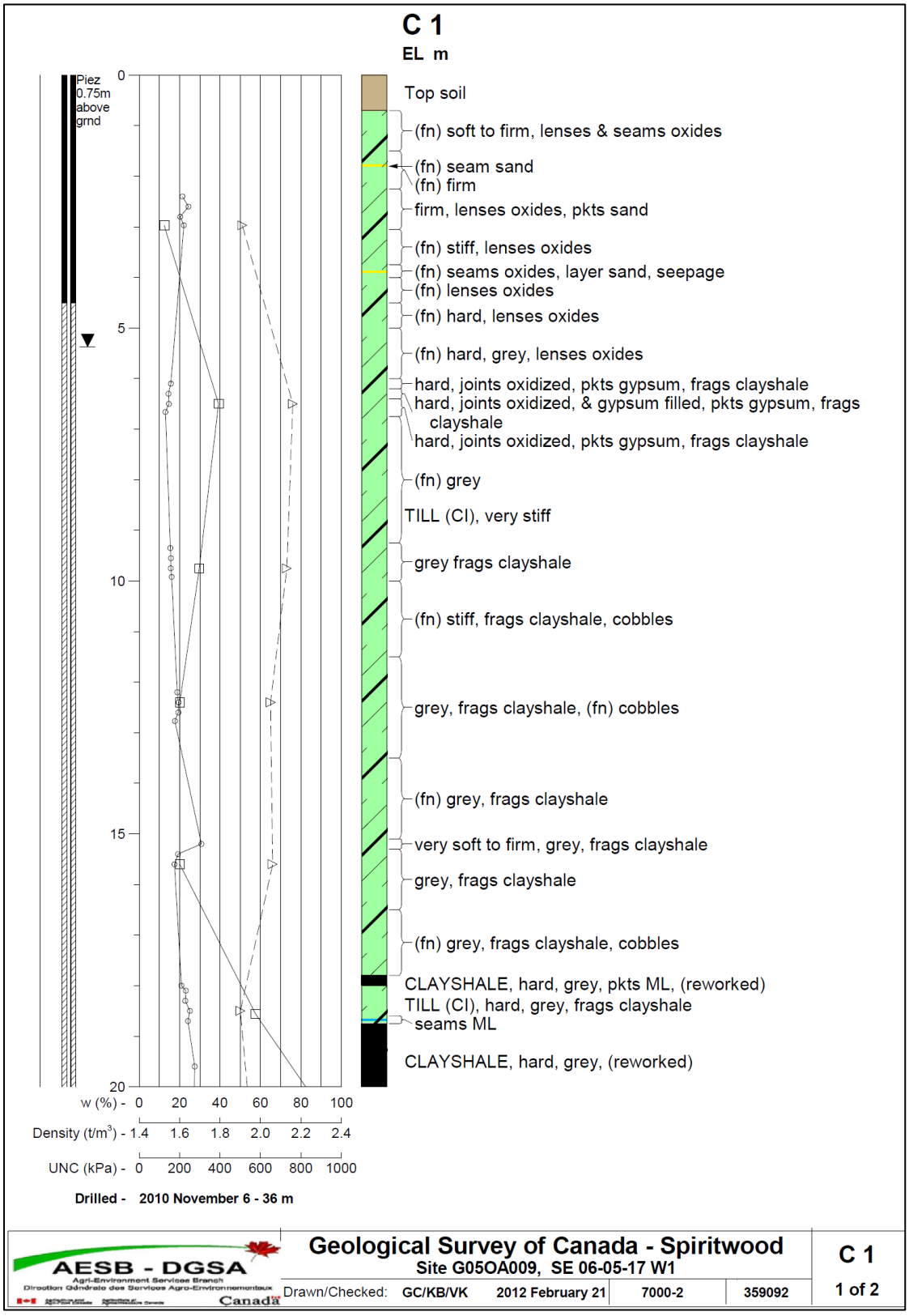


Figure 8a. Borehole log for GSC-BH-SW-03A completed with piezometer GSC-SW-03-p2, 1 of 2.

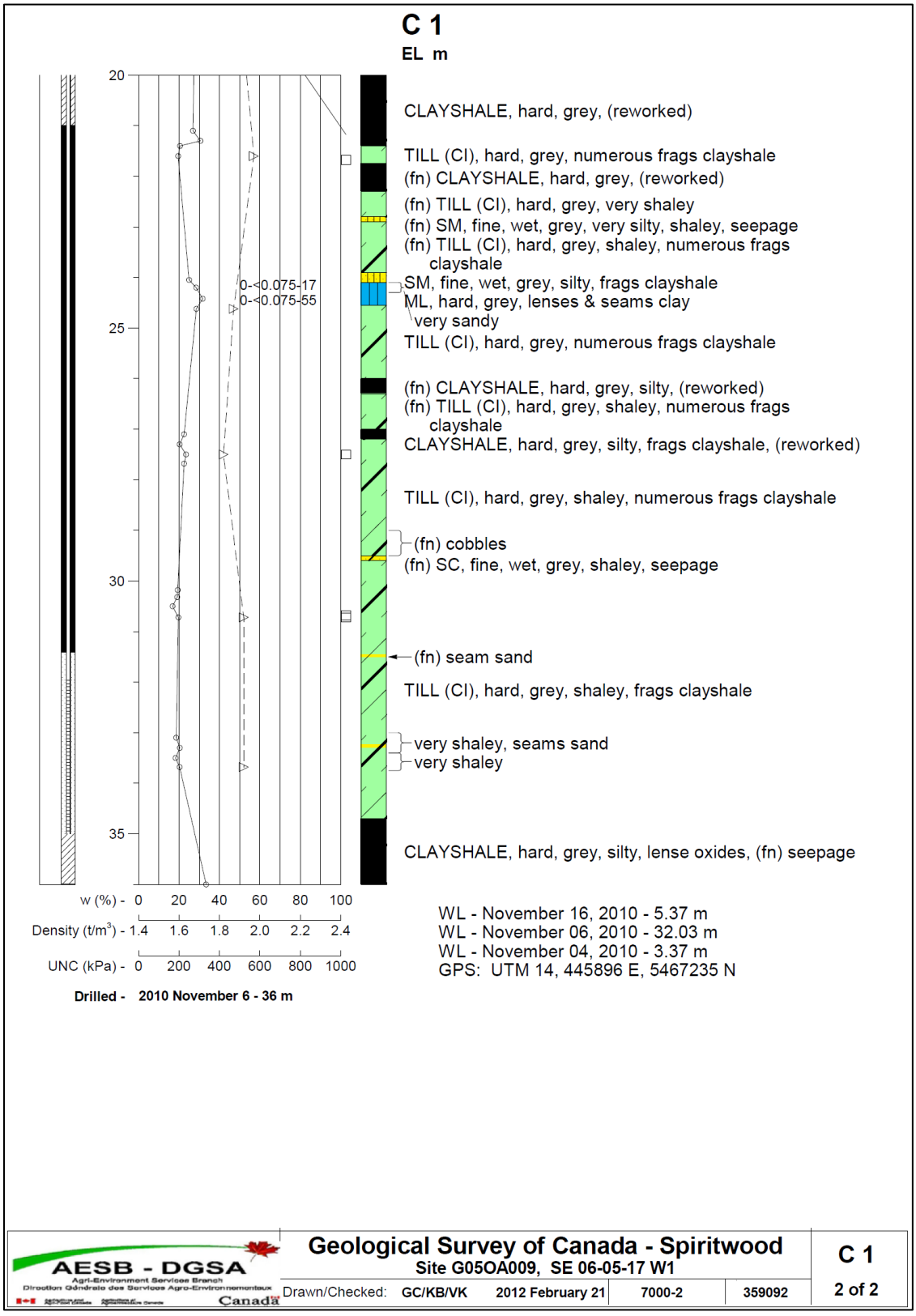


Figure 8b. Borehole log for GSC-BH-SW-03A completed with piezometer GSC-SW-03-p2, 2 of 2.

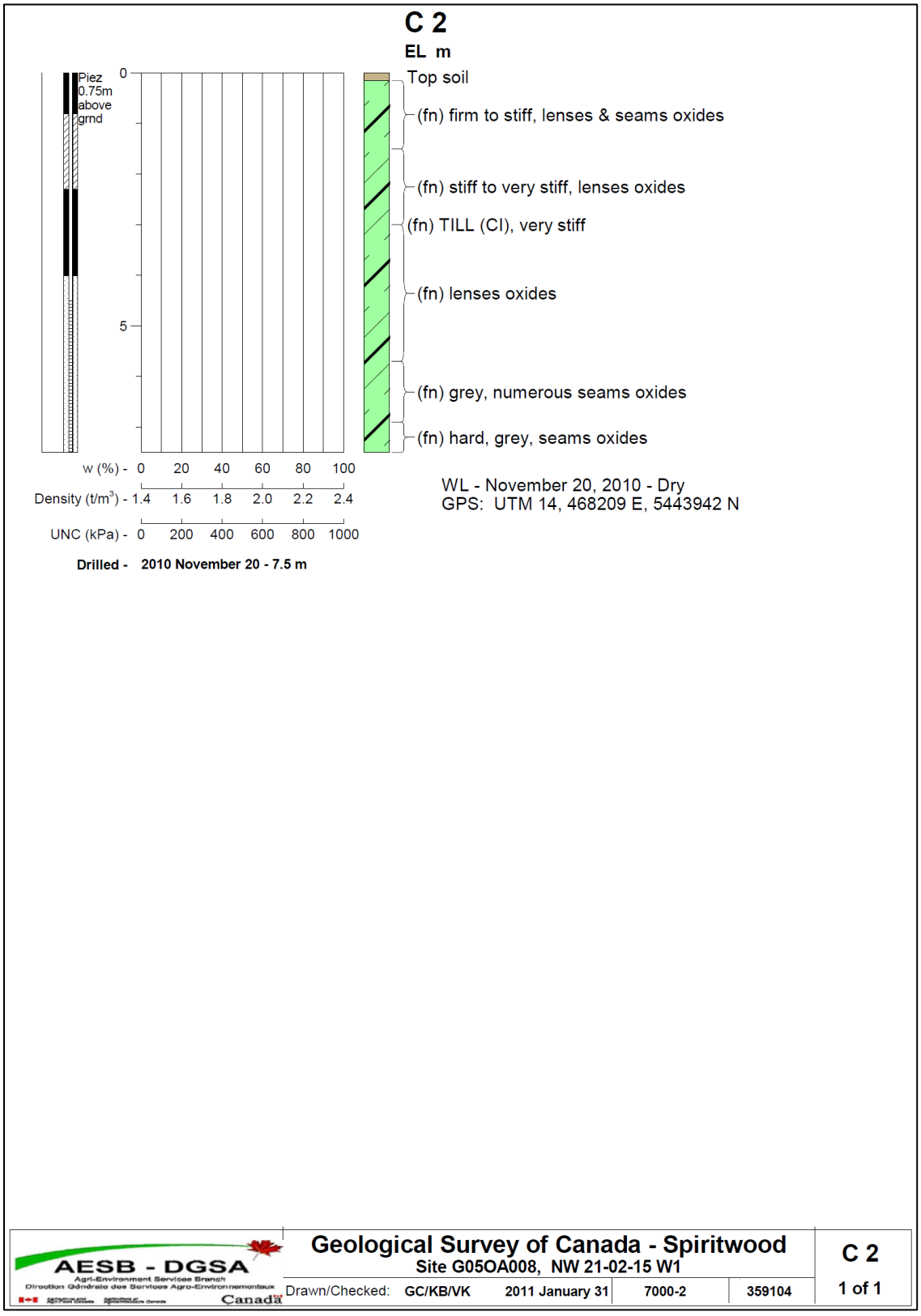


Figure 9. Borehole log for GSC-BH-SW-04B completed with piezometer GSC-SW-04-p1.

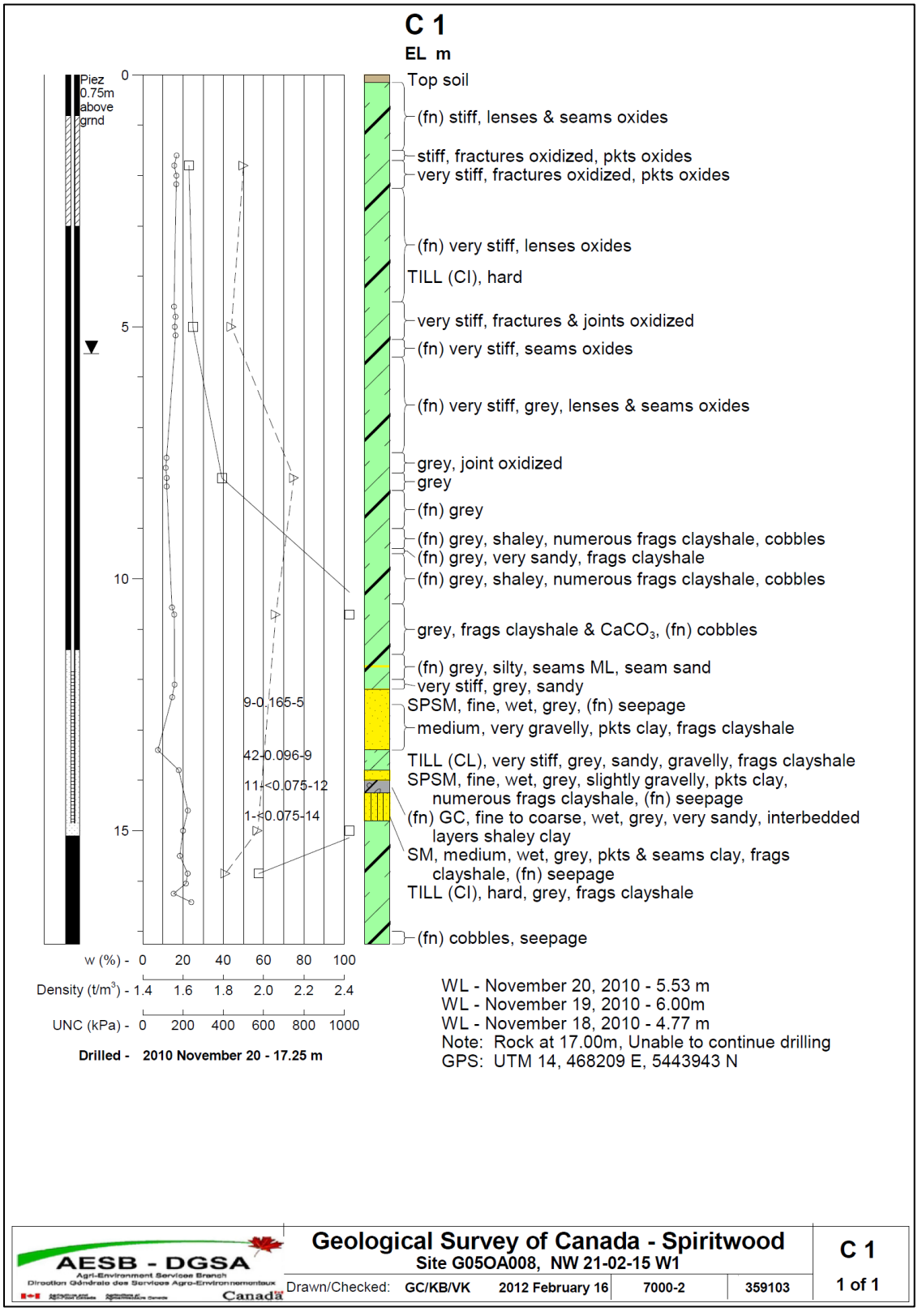


Figure 10. Borehole log for GSC-BH-SW-04A completed with piezometer GSC-SW-04-p2.

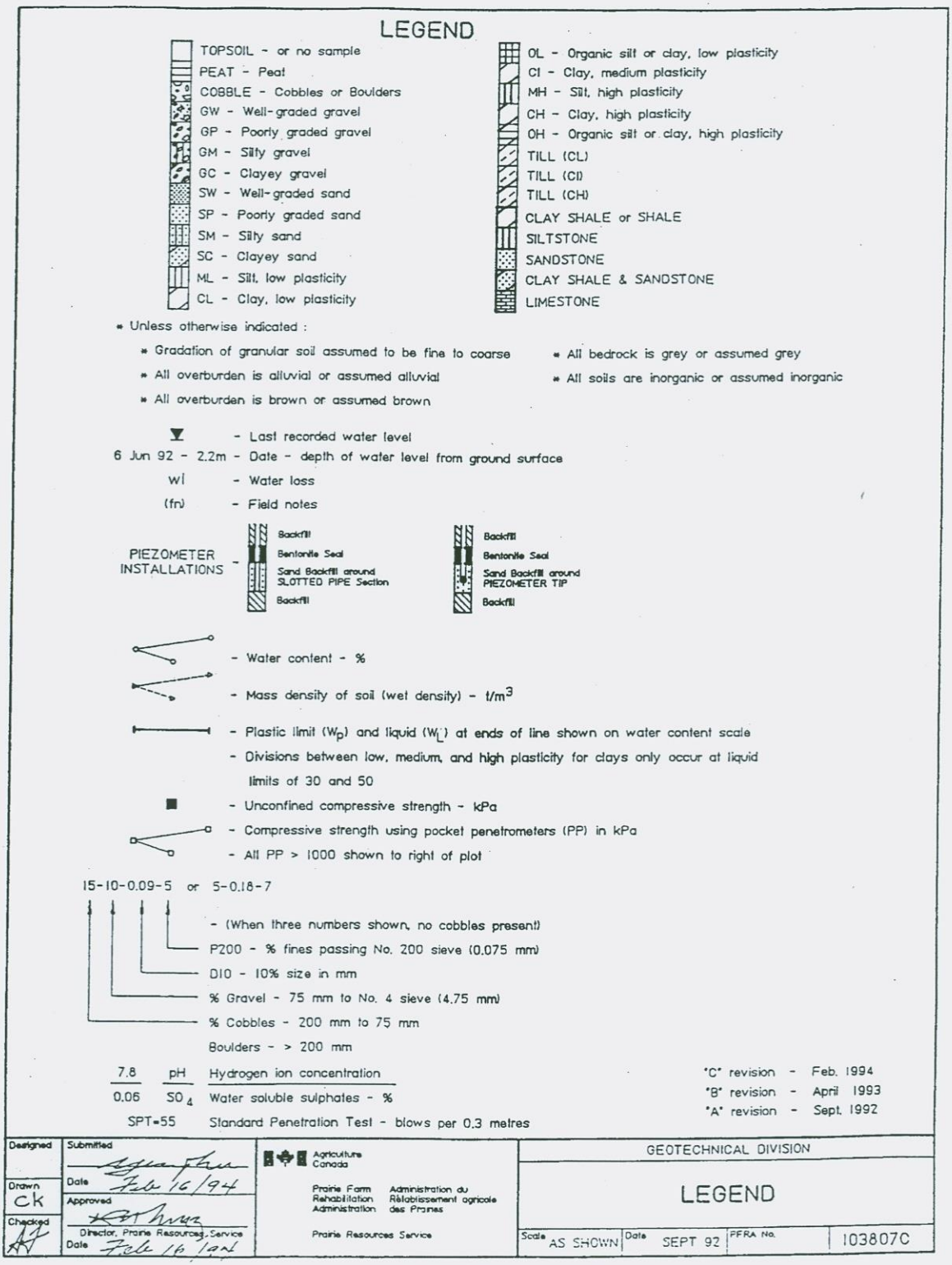


Figure 11. Legend for borehole logs in Figures 5-10 (provided by AAFC).

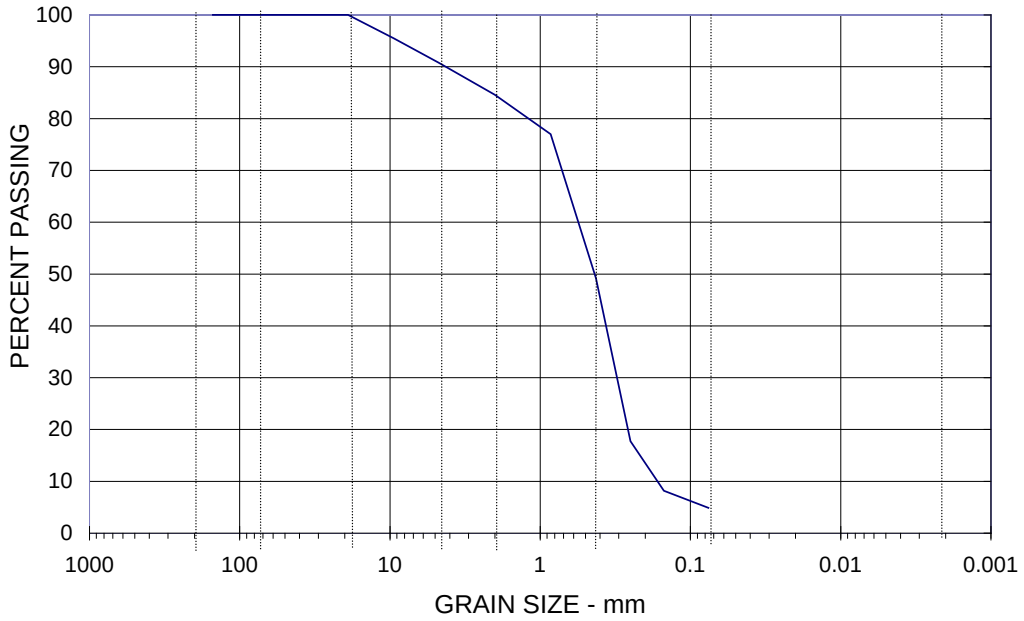
Grain Size Analysis

ASTM D422, D1140, C117, C136

D60=	0.557	D30=	0.308	SPSM, fine, wet, dark grey
D10=	0.165	Cc=	1.028	
Cu=	3.365	D15=	0.216	
		D85=	2.127	

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	0	9	6	36	44	5

COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	



AESB - DGSA Agri-Environment Services Branch Direction Générale des Services Agro-Environnementaux Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada Canada	GSC Spiritwood G05OA008, NW 21-02-15 W1 January 24, 2011 Depth: 12.19 - 12.50m	C 1 5B

Figure 12. Grain size analysis, borehole GSC-BH-SW-04A, 12.19-12.50 m depth.

Grain Size Analysis

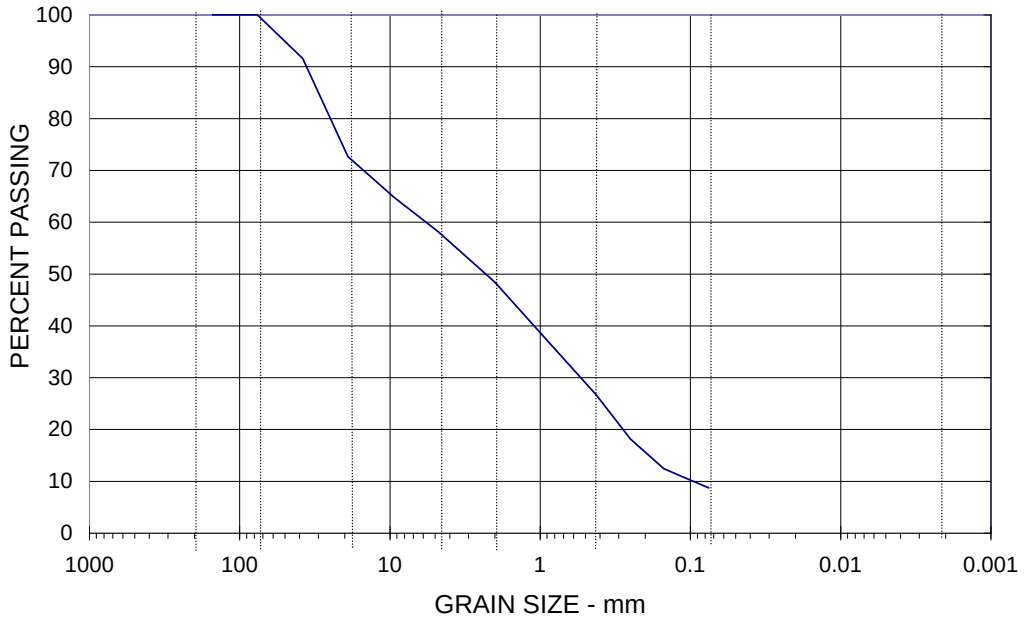
ASTM D422, D1140, C117, C136

D60=	5.773	D30=	0.536
D10=	0.096	Cc=	0.518
Cu=	60.024	D15=	0.189
		D85=	29.904

SPSM, medium, wet, grey, very gravelly, pkts clay, frags Clay Shale

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	27	15	10	21	18	9

COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	



AESB - DGSA Agri-Environment Services Branch Direction Générale des Services Agro-Environnementaux Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada Canada	GSC Spiritwood G05OA008, NW 21-02-15 W1 January 24, 2011 Depth: 13.40m	C 1 6

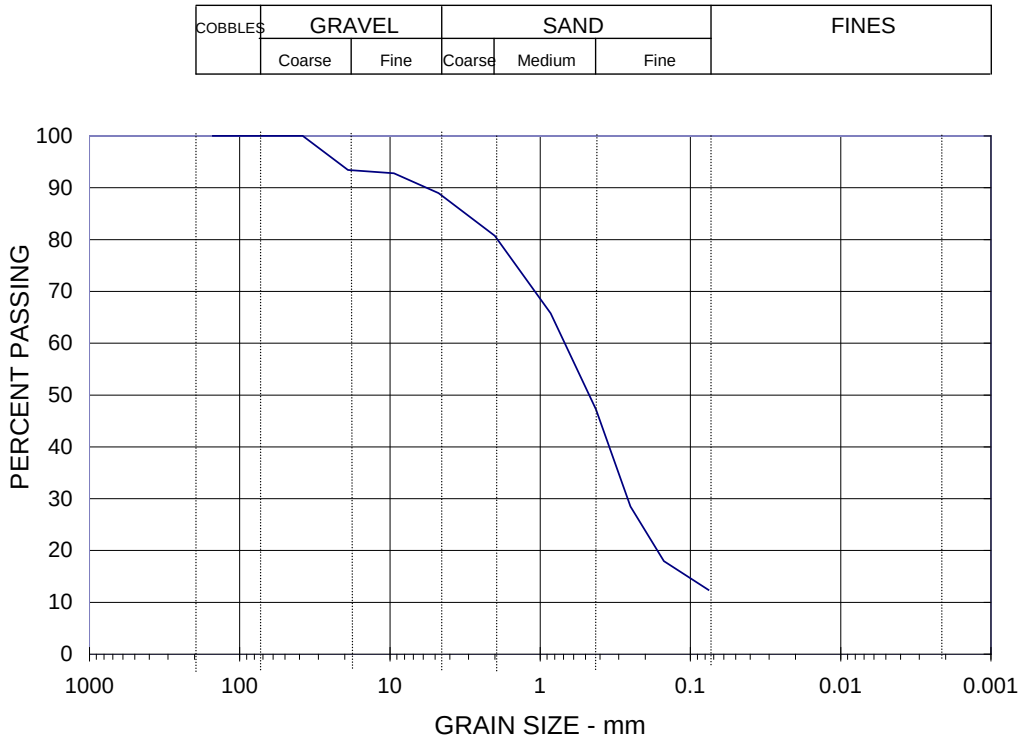
Figure 13. Grain size analysis, borehole GSC-BH-SW-04A, 13.40 m depth.

Grain Size Analysis

ASTM D422, D1140, C117, C136

D60=	0.686	D30=	0.261	SPSM, fine, wet, slightly gravelly,
D10=	#N/A	Cc=	#N/A	pkts clay, numerous frags Clay Shale
Cu=	#N/A	D15=	0.105	
		D85=	3.132	

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	7	4	8	34	35	12



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Canada

GSC Spiritwood
G05OA008, NW 21-02-15 W1
January 24, 2011 Depth: 14.00m

C 1
8

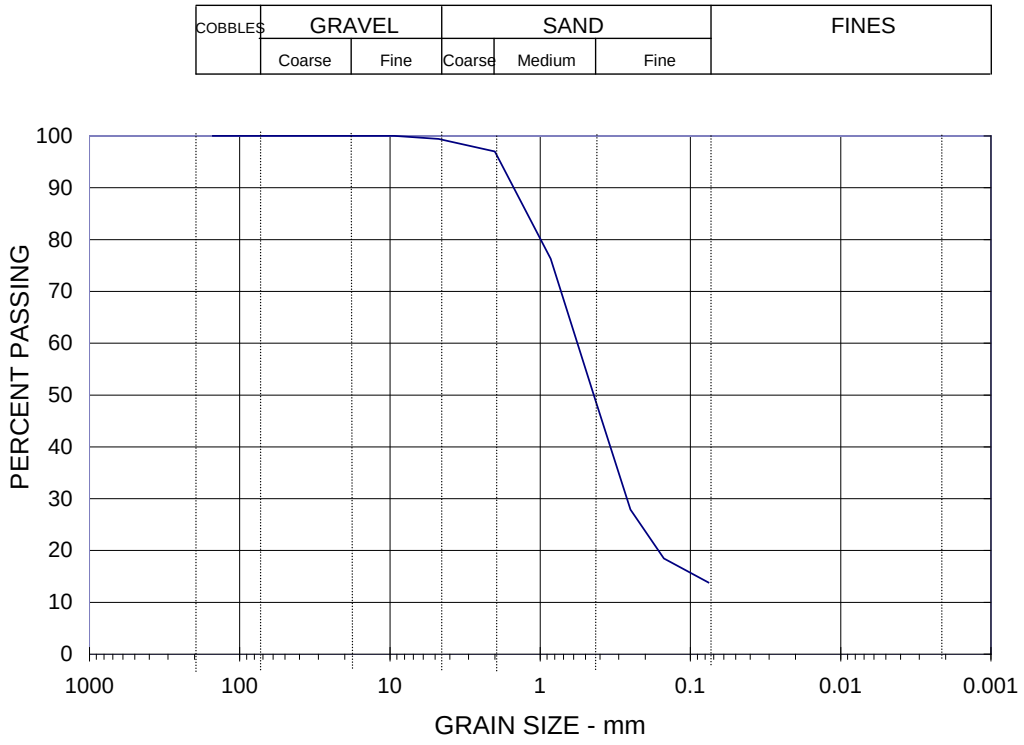
Figure 14. Grain size analysis, borehole GSC-BH-SW-04A, 14.00 m depth.

Grain Size Analysis

ASTM D422, D1140, C117, C136

D60=	0.565	D30=	0.264	SM, medium, wet, very dark grey, pkts & seams clay,
D10=	#N/A	Cc=	#N/A	frags Clay Shale
Cu=	#N/A	D15=	0.090	
		D85=	1.219	

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	0	1	2	48	35	14



AESB - DGSA Agri-Environment Services Branch Direction Générale des Services Agro-Environnementaux Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada Canada	GSC Spiritwood G05OA008, NW 21-02-15 W1 January 24, 2011 Depth: 14.60m	C 1 9

Figure 15. Grain size analysis, borehole GSC-BH-SW-04A, 14.60 m depth.

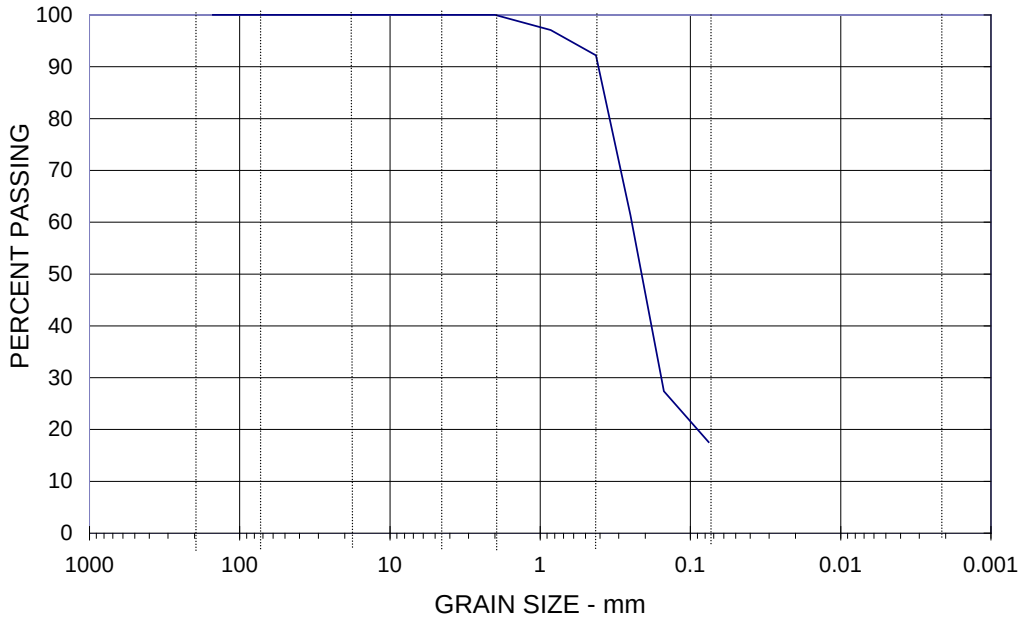
Grain Size Analysis

ASTM D422, D1140, C117, C136

D60=	0.245	D30=	0.156	SM, fine, wet, dark grey, frags Clay Shale,
D10=	#N/A	Cc=	#N/A	slightly silty
Cu=	#N/A	D15=	#N/A	
		D85=	0.376	

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	0	0	0	8	75	17

COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	



AESB - DGSA Agri-Environment Services Branch Direction Générale des Services Agro-Environnementaux Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada Canada	GSC Spiritwood G050A009, SE 06-05-17 W1 January 25, 2001 Depth: 24.00 - 24.10m	C 1 10A

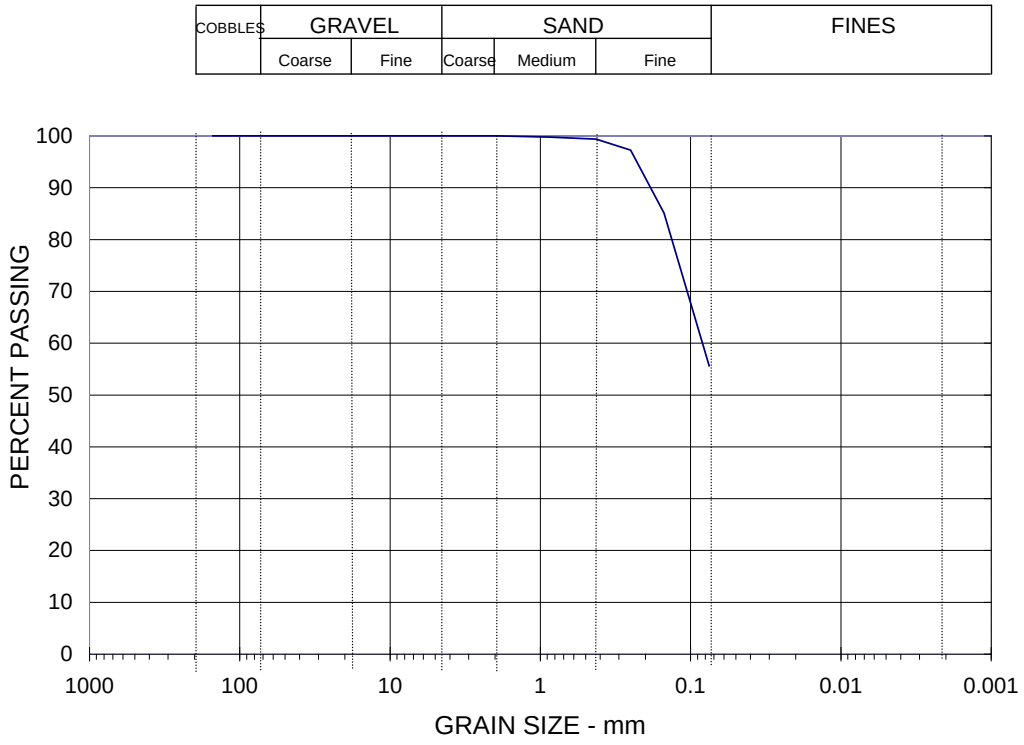
Figure 16. Grain size analysis, borehole GSC-BH-SW-03A, 24.00-24.10 m depth.

Grain Size Analysis

ASTM D422, D1140, C117, C136

D60=	0.083	D30=	#N/A	ML, hard, very dark grey, very sandy,
D10=	#N/A	Cc=	#N/A	lenses & seams clay
Cu=	#N/A	D15=	#N/A	
		D85=	0.150	

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	0	0	0	1	44	55



AESB - DGSA Agri-Environment Services Branch Direction Générale des Services Agro-Environnementaux Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada Canada	GSC Spiritwood G05OA009, SE 06-05-17 W1 January 25, 2011 Depth: 24.10 - 24.30m	C 1 10B

Figure 17. Grain size analysis, borehole GSC-BH-SW-03A, 24.10-24.30 m depth.

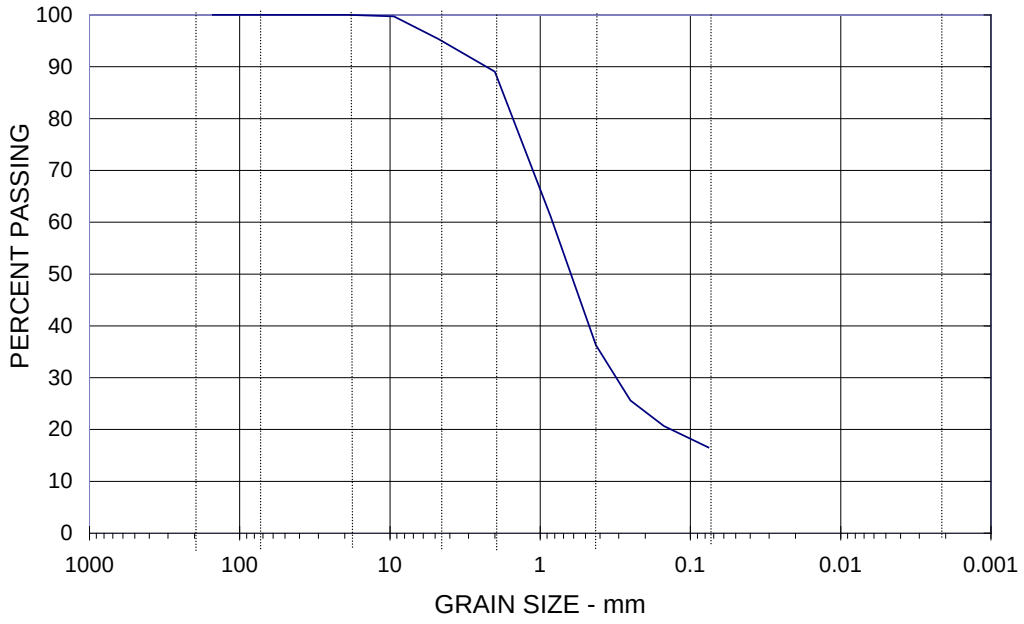
Grain Size Analysis

ASTM D422, D1140, C117, C136

D60=	0.825	D30=	0.311	SM, medium, wet, grey,
D10=	#N/A	Cc=	#N/A	numerous frags clayshale
Cu=	#N/A	D15=	#N/A	
		D85=	1.767	

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	0	5	6	53	20	16

COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	



AESB - DGSA Agri-Environment Services Branch Direction Générale des Services Agro-Environnementaux Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada Canada	GSC - Spiritwood G05OA010; SW 33-3-16 W1 January 26, 2011 Depth: 8.35 - 8.55 m	C 1 4D

Figure 18. Grain size analysis, borehole GSC-BH-SW-02A, 8.35-8.55 m depth.

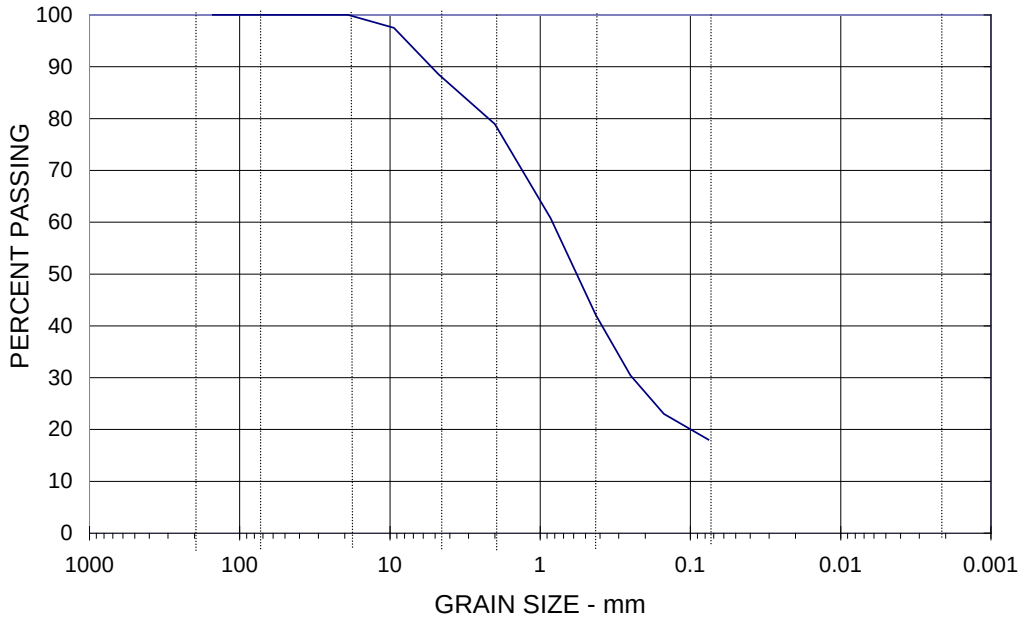
Grain Size Analysis

ASTM D422, D1140, C117, C136

D60=	0.828	D30=	0.243	SC, medium, wet, slightly gravelly,
D10=	#N/A	Cc=	#N/A	pkts clay, numerous frags clayshale
Cu=	#N/A	D15=	#N/A	
		D85=	3.459	

COBBLES	GRAVEL		SAND			FINES
	COARSE	FINE	COARSE	MEDIUM	FINE	
0	0	11	10	37	24	18

COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	



AESB - DGSA Agri-Environment Services Branch Direction Générale des Services Agro-Environnementaux Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada Canada	GSC - Spiritwood G05OA010; SW 33-3-16 W1 January 26, 2011 Depth: 1.00 m	C 2 1

Figure 19. Grain size analysis, borehole GSC-BH-SW-02B, 1.00 m depth.

Tables

Table 1. Borehole and piezometer designations and locations.

AAFC borehole ID	Nearby CWS monitoring well ID	GSC borehole ID	GSC piezometer ID	UTM E NAD83, Zone 14	UTM W NAD83, Zone 14	Quarter section
G05OA010 C1	G05OA010	GSC-BH-SW-02A	GSC-SW-02-p2	457414.6	5455734.3	SW33-3-16-W1
G05OA010 C2	G05OA010	GSC-BH-SW-02B	GSC-SW-02-p1	457414.7	5455732.9	SW33-3-16-W1
G05OA009 C1	G05OA009	GSC-BH-SW-03A	GSC-SW-03-p2	445897.5	5467233.2	SE6-5-17-W1
G05OA009 C2	G05OA009	GSC-BH-SW-03B	GSC-SW-03-p1	445895.5	5467232.9	SE6-5-17-W1
G05OA008 C1	G05OA008	GSC-BH-SW-04A	GSC-SW-04-p2	468211.5	5443940.0	NW21-2-15-W1
G05OA008 C2	G05OA008	GSC-BH-SW-04B	GSC-SW-04-p1	468209.8	5443939.9	NW21-2-15-W1

GPS data were collected in October 2011 using a Trimble Pathfinder ProXT GPS receiver with an integrated SBAS (Satellite Based Augmentation Systems) to provide 2 to 5 meter horizontal accuracy.

Table 2. Piezometer installations.

GSC piezometer	Stick up (mags)	Depth to screen top (mbgs)	Depth to screen bottom (mbgs)	Mid-screen depth (mbgs)	Screen length (m)	Total casing depth (mbgs)	Measured depth from measuring point to bottom (m)	Approx. length of pipe at installation (m)
GSC-SW-02-p2	0.771	9.43	10.40	9.92	0.97	10.396	11.167	11.15
GSC-SW-02-p1	0.737	1.25	2.75	2.00	1.50	2.733	3.47	3.50
GSC-SW-03-p2	0.690	31.96	34.95	33.46	2.99	34.967	35.657	35.70
GSC-SW-03-p1	0.690	2.80	3.50	3.15	0.70	3.553	4.243	4.25
GSC-SW-04-p2	0.767	11.85	14.85	13.35	3.00	14.442	15.209	15.60
GSC-SW-04-p1	0.730	4.51	7.50	6.01	2.99	7.437	8.167	8.25

GSC piezometer	Approx. elevation top of casing (masl)	Filter pack material	Depth to top of filter pack (mbgs)	Depth to bottom of filter pack (mbgs)	Type of seal	Top of seal (mbgs)	Bottom of seal (mbgs)
GSC-SW-02-p2	470.461[a]	sand	9.30	10.45	Hole Plug bentonite 1/4" pellets Hole Plug bentonite chips	8.25 3.00	9.30 6.00
GSC-SW-02-p1	470.427[a]	sand	0.80	2.75	Native material	0.00	0.80
GSC-SW-03-p2	468.137[b]	sand	31.40	35.00	Hole Plug bentonite 1/4" pellets and Econo Hole Plug	21.00	31.40
GSC-SW-03-p1	468.137[b]	sand	2.60	3.50	Hole Plug bentonite chips	1.70	2.60
GSC-SW-04-p2	470.987[c]	sand	11.40	15.10	Hole Plug bentonite chips	3.00	11.40
GSC-SW-04-p1	470.950[c]	sand	4.00	7.50	Hole Plug bentonite chips	2.30	4.00

Table 2. Piezometer installations (continued).

GSC piezometer	Piezometer material	Piezometer diameter, nominal (in)	Piezometer inside diameter (cm)	Slot size "/1000	Screen material	Method of drilling	Drilling fluid	Date drilling start	Date completion
GSC-SW-02-p2	PVC, sch 40	2	5.17	20	PVC	B14 cable-tool rig	none	02-Nov-10	03-Nov-10
GSC-SW-02-p1	PVC, sch 40	2	5.17	20	PVC	B14 cable-tool rig	none	03-Nov-10	03-Nov-10
GSC-SW-03-p2	PVC, sch 40	2	5.17	20	PVC	B14 cable-tool rig	none	04-Nov-10	06-Nov-10
GSC-SW-03-p1	PVC, sch 40	2	5.17	20	PVC	B14 cable-tool rig	none	16-Nov-10	16-Nov-10
GSC-SW-04-p2	PVC, sch 40	2	5.17	20	PVC	B14 cable-tool rig	none	17-Nov-10	20-Nov-10
GSC-SW-04-p1	PVC, sch 40	2	5.17	20	PVC	B14 cable-tool rig	none	20-Nov-10	20-Nov-10

[a] Not surveyed yet. Approximate elevation obtained by adding casing stick up to the reported ground surface elevation of 469.690 masl of Manitoba CWS well G05OA010.
[b] Not surveyed yet. Approximate elevation obtained by adding casing stick up to the reported ground surface elevation of 467.447 masl of Manitoba CWS well G05OA009.
[c] Not surveyed yet. Approximate elevation obtained by adding casing stick up to the reported ground surface elevation of 470.220 masl of Manitoba CWS well G05OA008.

Table 3. Borehole log descriptions, GSC-BH-SW-02A.

Top Depth (m)	Bottom Depth (m)	USCS description	Description
0.00	0.45	TOPSOIL	
0.45	0.80	SC	(fn) SC, fine to coarse, wet, seams clay
0.80	1.10	SP	(fn) SP, medium, wet, seepage
1.10	1.15	SM	SM, fine, wet, seams clay
1.15	8.00	TILL (CI)	TILL (CI), hard
1.15	1.35	TILL (CI)	stiff, lenses oxides
1.35	1.85	TILL (CI)	very stiff, lenses oxides
1.85	2.75	TILL (CI)	(fn) very stiff, numerous lenses & seams oxides, slightly sandy
2.75	3.15	TILL (CI)	grey, joints oxidized
3.15	3.50	TILL (CI)	grey
3.50	6.00	TILL (CI)	(fn) very stiff, grey
6.00	6.75	TILL (CI)	very stiff, grey, frags clayshale
6.75	7.50	TILL (CI)	(fn) hard, grey, shaley, numerous frags clayshale, few seams sand, wet, seepage
7.50	7.80	TILL (CI)	hard, grey, very shaley, sandy, numerous frags clayshale
7.80	8.00	TILL (CI)	very stiff, grey, very sandy, numerous frags clayshale
8.00	8.60	SM	SM, fine, medium, wet, grey, numerous frags clayshale, (fn) seepage
8.60	10.45	TILL (CI)	TILL (CI), hard, grey, frags clayshale
8.60	9.10	TILL (CI)	(fn) very shaley, cobble
9.10	9.50	TILL (CI)	(fn) very shaley
9.75	10.10	TILL (CI)	seams sand, (fn) seepage
10.10	10.45	TILL (CI)	numerous frags clay shale

Table 4. Borehole log descriptions, GSC-BH-SW-02B

Top Depth (m)	Bottom Depth (m)	USCS description	Description
0.00	0.35	TOPSOIL	
0.35	1.60	SC	SC, medium, wet, slightly gravelly, pkts clay, numerous frags clayshale
1.60	2.75	TILL (CI)	(fn) TILL (CI), stiff, lenses & seams oxides
2.00	2.75	TILL (CI)	(fn) very stiff

Table 5. Borehole log descriptions, GSC-BH-SW-03A

Top Depth (m)	Bottom Depth (m)	USCS description	Description
0.00	0.70	TOPSOIL	
0.70	17.80	TILL (CI)	TILL (CI), very stiff
0.70	1.50	TILL (CI)	(fn) soft to firm, lenses & seams oxides
1.50	2.25	TILL (CI)	(fn) firm
1.80		TILL (CI)	(fn) seam sand
2.25	3.05	TILL (CI)	firm, lenses oxides, pkts sand
3.05	3.75	TILL (CI)	(fn) stiff, lenses oxides
3.75	4.00	TILL (CI)	(fn) seams oxides, layer sand, seepage
4.00	4.50	TILL (CI)	(fn) lenses oxides
4.50	5.00	TILL (CI)	(fn) hard, lenses oxides
5.00	6.00	TILL (CI)	(fn) hard, grey, lenses oxides
6.00	6.20	TILL (CI)	hard, joints oxidized, pkts gypsum, frags clayshale
6.20	6.40	TILL (CI)	hard, joints oxidized, & gypsum filled, pkts gypsum, frags clayshale
6.40	6.75	TILL (CI)	hard, joints oxidized, pkts gypsum, frags clayshale
6.75	9.25	TILL (CI)	(fn) grey
9.25	10.00	TILL (CI)	grey frags clayshale
10.00	11.50	TILL (CI)	(fn) stiff, frags clayshale, cobbles
11.50	13.50	TILL (CI)	grey, frags clayshale, (fn) cobbles
13.50	15.10	TILL (CI)	(fn) grey, frags clayshale
15.10	15.30	TILL (CI)	very soft to firm, grey, frags clayshale
15.30	16.50	TILL (CI)	grey, frags clayshale
16.50	17.80	TILL (CI)	(fn) grey, frags clayshale, cobbles
17.80	18.00	SHALE	Clay shale, hard, grey, pkts ML, (reworked)
18.00	18.75	TILL (CI)	TILL (CI), hard, grey, frags clayshale
18.60	18.75	TILL (CI)	seams ML
18.75	20.01	SHALE	Clay shale, hard, grey, (reworked)
20.00	21.40	SHALE	Clay shale, hard, grey, (reworked)
21.40	21.75	TILL (CI)	TILL (CI), hard, grey, numerous frags clayshale
21.75	22.30	SHALE	(fn) CLAY SHALE, hard, grey, (reworked)
22.30	22.80	TILL (CI)	(fn) TILL (CI), hard, grey, very shaley
22.80	22.90	SM	(fn) SM, fine, wet, grey, very silty, shaley, seepage
22.90	23.90	TILL (CI)	(fn) TILL (CI), hard, grey, shaley, numerous frags clayshale
23.90	24.10	SM	SM, fine, wet, grey, silty, frags clayshale
24.10	24.55	ML	ML, hard, grey, lenses & seams clay
24.10	24.30	ML	very sandy
24.55	26.00	TILL (CI)	TILL (CI), hard, grey, numerous frags clayshale
26.00	26.30	SHALE	(fn) Clay shale, hard, grey, silty, (reworked)
26.30	27.00	TILL (CI)	(fn) TILL (CI), hard, grey, shaley, numerous frags clayshale
27.00	27.20	SHALE	Clay shale, hard, grey, silty, frags clayshale, (reworked)
27.20	29.50	TILL (CI)	TILL (CI), hard, grey, shaley, numerous frags clayshale
29.00	29.50	TILL (CI)	(fn) cobbles
29.50	29.60	SC	(fn) SC, fine, wet, grey, shaley, seepage

Table 5 (continued). Borehole log descriptions, GSC-BH-SW-03A

Top Depth (m)	Bottom Depth (m)	USCS description	Description
29.60	34.70	TILL (CI)	TILL (CI), hard, grey, shaley, frags clayshale
31.50		TILL (CI)	(fn) seam sand
33.00	33.40	TILL (CI)	very shaley, seams sand
33.40	33.75	TILL (CI)	very shaley
34.70	36.00	SHALE	Clay shale, hard, grey, silty, lense oxides, (fn) seepage

Table 6. Borehole log descriptions, GSC-BH-SW-03B

Top Depth (m)	Bottom Depth (m)	USCS description	Description
0.00	0.50	TOPSOIL	
0.50	1.40	TILL (CI)	(fn) TILL (CI), very soft
1.40	1.50	SC	(fn) SC, fine to coarse, wet, gravelly, seepage
1.50	10.50	TILL (CI)	(fn) TILL (CI), hard
1.50	2.25	TILL (CI)	(fn) stiff
2.25	2.79	TILL (CI)	(fn) stiff, lenses & seams oxides
2.80		TILL (CI)	(fn) seam sand, seepage
2.81	3.20	TILL (CI)	(fn) stiff, silty, seams ML, numerous seams oxides
3.20	4.60	TILL (CI)	(fn) very stiff, lenses & seams oxides
4.60	5.60	TILL (CI)	(fn) grey, lenses oxides
5.60	10.50	TILL (CI)	(fn) grey, cobbles

Table 7. Borehole log descriptions, GSC-BH-SW-04A.

Top Depth (m)	Bottom Depth (m)	USCS description	Description
0.00	0.15	TOPSOIL	
0.15	12.19	TILL (CI)	TILL (CI), hard
0.15	1.50	TILL (CI)	(fn) stiff, lenses & seams oxides
1.50	1.70	TILL (CI)	stiff, fractures oxidized, pkts oxides
1.70	2.25	TILL (CI)	very stiff, fractures oxidized, pkts oxides
2.25	4.50	TILL (CI)	(fn) very stiff, lenses oxides
4.50	5.25	TILL (CI)	very stiff, fractures & joints oxidized
5.25	5.60	TILL (CI)	(fn) very stiff, seams oxides
5.60	7.50	TILL (CI)	(fn) very stiff, grey, lenses & seams oxides
7.50	7.90	TILL (CI)	grey, joint oxidized
7.90	8.25	TILL (CI)	grey
8.25	9.00	TILL (CI)	(fn) grey
9.00	9.40	TILL (CI)	(fn) grey, shaley, numerous frags clayshale, cobbles
9.40	9.50	TILL (CI)	(fn) grey, very sandy, frags clayshale
9.50	10.50	TILL (CI)	(fn) grey, shaley, numerous frags clayshale, cobbles
10.50	11.50	TILL (CI)	grey, frags clayshale & $CaCO_3$, (fn) cobbles
11.50	12.00	TILL (CI)	(fn) grey, silty, seams ML, seam sand
12.00	12.19	TILL (CI)	very stiff, grey, sandy
12.19	13.40	SPSM	SPSM, fine, wet, grey, (fn) seepage
12.50	13.40	SPSM	medium, very gravelly, pkts clay, frags clayshale
13.40	13.80	TILL (CL)	TILL (CL), very stiff, grey, sandy, gravelly, frags clayshale
13.80	14.00	SPSM	SPSM, fine, wet, grey, slightly gravelly, pkts clay, numerous frags clayshale, (fn) seepage
14.00	14.25	GC	(fn) GC, fine to coarse, wet, grey, very sandy, interbedded layers shaley clay
14.25	14.80	SM	SM, medium, wet, grey, pkts & seams clay, frags clayshale, (fn) seepage
14.80	17.25	TILL (CI)	TILL (CI), hard, grey, frags clayshale
17.00	17.25	TILL (CI)	(fn) cobbles, seepage

Table 8. Borehole log descriptions, GSC-BH-SW-04B

Top Depth (m)	Bottom Depth (m)	USCS description	Description
0.00	0.15	TOPSOIL	
0.15	7.50	TILL (CI)	(fn) TILL (CI), very stiff
0.15	1.50	TILL (CI)	(fn) firm to stiff, lenses & seams oxides
1.50	3.00	TILL (CI)	(fn) stiff to very stiff, lenses oxides
3.00	5.70	TILL (CI)	(fn) lenses oxides
5.70	6.90	TILL (CI)	(fn) grey, numerous seams oxides
6.90	7.50	TILL (CI)	(fn) hard, grey, seams oxides

Table 9. Geotechnical data, site GSC-BH-SW-02 (G05OA010).

AAFC borehole ID	Sample	Depth (m)	Measured Gravimetric Water Content (g water /100g dry soil)	Measured Wet Density (g wet soil /cm^3 wet soil)	Measured Pocket Penetrometer (kPa)	Calculated Dry Density (g dry soil /cm^3 wet soil)	Calculated Volumetric water content (cm^3 water /cm^3 wet soil)	Estimated porosity (cm^3 void /cm^3 total volume)
G05OA010 C 1	1A	1.17	15.2					
G05OA010 C 1	1B	1.25	18.9					
G05OA010 C 1	1C	1.45	17.6					
G05OA010 C 1	1D	1.60	17.7	2.08	239	1.77	0.31	0.33
G05OA010 C 1	2A	2.85	14.3					
G05OA010 C 1	2B	3.05	14.2					
G05OA010 C 1	2C	3.25	14.0	2.13	345	1.87	0.26	0.29
G05OA010 C 1	2D	3.42	13.7					
G05OA010 C 1	3A	6.10	15.0					
G05OA010 C 1	3B	6.30	15.2					
G05OA010 C 1	3C	6.50	15.4	2.14	278	1.85	0.29	0.30
G05OA010 C 1	3D	6.66	17.4					
G05OA010 C 1	4A	7.90	19.2	2.00	278	1.68	0.32	0.37
G05OA010 C 1	4B	8.10	19.3					
G05OA010 C 1	4C	8.25	24.1					
G05OA010 C 1	4D	8.45	22.3					
G05OA010 C 1	5A	9.85	16.6					
G05OA010 C 1	5B	10.00	17.9	2.04	1036	1.73	0.31	0.35
G05OA010 C 1	6	10.45	12.2					
G05OA010 C 2	1	1.00	15.7					

Table 10. Geotechnical data, site GSC-BH-SW-03 (G05OA009).

AAFC borehole ID	Sample	Depth (m)	Measured Gravimetric Water Content (g water /100g dry soil)	Measured Wet Density (g wet soil /cm^3 wet soil)	Measured Pocket Penetrometer (kPa)	Calculated Dry Density (g dry soil /cm^3 wet soil)	Calculated Volumetric water content (cm^3 water /cm^3 wet soil)	Estimated porosity (cm^3 void /cm^3 total volume)
G05OA009 C 1	1A	2.40	21.4					
G05OA009 C 1	1B	2.60	24.4					
G05OA009 C 1	1C	2.80	20.3					
G05OA009 C 1	1D	2.97	22.1	1.91	124	1.56	0.35	0.41
G05OA009 C 1	2A	6.10	15.7					
G05OA009 C 1	2B	6.30	14.5					
G05OA009 C 1	2C	6.50	14.7	2.16	393	1.88	0.28	0.29
G05OA009 C 1	2D	6.68	13.0					
G05OA009 C 1	3A	9.35	15.4					
G05OA009 C 1	3B	9.55	15.7					
G05OA009 C 1	3C	9.75	15.6	2.13	297	1.84	0.29	0.30
G05OA009 C 1	3D	9.92	16.1					
G05OA009 C 1	4A	12.20	18.8					
G05OA009 C 1	4B	12.40	19.5	2.05	201	1.72	0.33	0.35
G05OA009 C 1	4C	12.60	19.4					
G05OA009 C 1	4D	12.78	17.7					
G05OA009 C 1	5A	15.20	30.8					
G05OA009 C 1	5B	15.40	19.2					
G05OA009 C 1	5C	15.60	17.5	2.06	201	1.75	0.31	0.34
G05OA009 C 1	6	18.00	20.9					
G05OA009 C 1	7A	18.10	23.1					
G05OA009 C 1	7B	18.30	22.8					
G05OA009 C 1	7C	18.50	25.1	1.90	576	1.52	0.38	0.43

Table 10 (continued). Geotechnical data, site GSC-BH-SW-03 (G05OA009).

AAFC borehole ID	Sample	Depth (m)	Measured Gravimetric Water Content (g water /100g dry soil)	Measured Wet Density (g wet soil /cm^3 wet soil)	Measured Pocket Penetrometer (kPa)	Calculated Dry Density (g dry soil /cm^3 wet soil)	Calculated Volumetric water content (cm^3 water /cm^3 wet soil)	Estimated porosity (cm^3 void /cm^3 total volume)
G05OA009 C 1	7D	18.68	24.1					
G05OA009 C 1	8	19.60	27.5					
G05OA009 C 1	9A	21.10	26.9					
G05OA009 C 1	9B	21.30	30.6					
G05OA009 C 1	9C	21.50	20.5					
G05OA009 C 1	9D	21.68	19.6	1.97	1112	1.65	0.32	0.38
G05OA009 C 1	10A	24.05	25.0					
G05OA009 C 1	10B	24.20	28.5					
G05OA009 C 1	10C	24.42	31.7					
G05OA009 C 1	10D	24.62	28.6	1.87		1.45	0.42	0.45
G05OA009 C 1	11A	27.10	22.5					
G05OA009 C 1	11B	27.30	20.3					
G05OA009 C 1	11C	27.50	23.5	1.82	1036	1.47	0.35	0.44
G05OA009 C 1	11D	27.68	22.5					
G05OA009 C 1	12A	30.17	19.4					
G05OA009 C 1	12B	30.32	19.1					
G05OA009 C 1	12C	30.50	16.8					
G05OA009 C 1	12D	30.67	19.7	1.92	1532	1.60	0.32	0.39
G05OA009 C 1	13A	33.10	18.6					
G05OA009 C 1	13B	33.30	20.4					
G05OA009 C 1	13C	33.50	18.3					
G05OA009 C 1	13D	33.68	20.3	1.92	1492	1.60	0.32	0.40
G05OA009 C 1	14	36.00	33.4					

Table 11. Geotechnical data, site GSC-BH-SW-04 (G05OA008).

AAFC borehole ID	Sample	Depth (m)	Measured Gravimetric Water Content (g water /100g dry soil)	Measured Wet Density (g wet soil /cm^3 wet soil)	Measured Pocket Penetrometer (kPa)	Calculated Dry Density (g dry soil /cm^3 wet soil)	Calculated Volumetric water content (cm^3 water /cm^3 wet soil)	Estimated porosity (cm^3 void /cm^3 total volume)
G050A008 C-1	1A	1.60	16.8					
G050A008 C-1	1B	1.80	15.6	1.90	230	1.64	0.26	0.38
G050A008 C-1	1C	2.00	16.7					
G050A008 C-1	1D	2.17	16.6					
G050A008 C-1	2A	4.60	15.5					
G050A008 C-1	2B	4.80	16.3					
G050A008 C-1	2C	5.00	15.9	1.84	249	1.59	0.25	0.40
G050A008 C-1	2D	5.18	16.3					
G050A008 C-1	3A	7.60	11.8					
G050A008 C-1	3B	7.80	11.4					
G050A008 C-1	3C	8.00	11.9	2.15	393	1.92	0.23	0.27
G050A008 C-1	3D	8.18	11.9					
G050A008 C-1	4A	10.58	14.5					
G050A008 C-1	4B	10.72	15.6	2.06	1148	1.78	0.28	0.33
G050A008 C-1	5A	12.10	15.8					
G050A008 C-1	5B	12.40	14.6					
G050A008 C-1	6	13.40	7.5					
G050A008 C-1	7	13.80	17.9					
G050A008 C-1	9	14.60	22.4					
G050A008 C-1	10	15.00	20.0	1.97	1112	1.64	0.33	0.38
G050A008 C-1	11	15.50	18.4					
G050A008 C-1	12A	15.85	22.3	1.81	576	1.48	0.33	0.44

Table 11 (continued). Geotechnical data, site GSC-BH-SW-04 (G05OA008).

AAFC borehole ID	Sample	Depth (m)	Measured Gravimetric Water Content (g water /100g dry soil)	Measured Wet Density (g wet soil /cm^3 wet soil)	Measured Pocket Penetrometer (kPa)	Calculated Dry Density (g dry soil /cm^3 wet soil)	Calculated Volumetric water content (cm^3 water /cm^3 wet soil)
G050A008 C-1	12B	16.05	21.4				
G050A008 C-1	12C	16.25	15.3				
G050A008 C-1	12D	16.47	24.1				

Table 12. Borehole log, CWS well, G05OA010 as recorded in the CWS database.

Well PID: 116770

LOCATION: SW33-3-16W
UTMX:457411.7 UTMY:5455641.5 XY Accuracy:1 EXACT [<5M] [GPS]
UTMZ:469.69 (ground surface elevation) Z Accuracy:1 EXACT <10CM
Owner: WRB
Driller: Ralph Edwards & Sons Drilling LTd.
Well Name: G05OA010 KILCART #11
Date Completed: 2001 Aug 22
Well Use: OBSERVATION
Well Status: ACTIVE Aquifer: SAND AND GRAVEL

REMARKS:
PUMPED WITH AIR, EC=1990

WELL LOG (Imperial units)

From	To(ft.)	Log
0.0	2	TOPSOIL, BLACK
2.0	5	SAND AND GRAVEL, LIMESTONE
5.0	12	TILL, BEIGE, SAND
12.0	26	TILL, GREY, CLAYEY, STONY
26.0	27.5	SAND AND GRAVEL, MAINLY SHALE
27.5	33	TILL, GREY, CLAYEY, STONY
33.0	34	SAND AND GRAVEL, LAYER 50/50 SHALE AND LIMESTONE
34.0	80	TILL, DARK GREY, CLAYEY, STONY
80.0	85	SHALE, BALCK, RUBBLY, LOSING WATER
85.0	124	SAND AND GRAVEL, 80% SHALE & 20% LIMESTONE
124.0	140	SHALE, SOFT, BLACK

WELL CONSTRUCTION

From	To(ft)	Const.Method	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type	Material
0.0	115.0	CASING	5.0			INSERT	BLACK IRON
115.0	120.0	PERFORATIONS	5.0		0.010	WIRE WOUND	S. S.

Top of Casing: 3.0 ft. above ground

PUMPING TEST
Date : 2001 Aug 23 Pumping 10.0 Imp. gallons/minute
Water level before test : 6.0 ft below ground
Water level at end of test : 35.0 ft below ground
Test duration: 1:00:00
Test Zone: from 115.0 ft to 120.0 ft

Table 13. Borehole log, CWS well, G05OA009 as recorded in the CWS database.

Well PID: 116814

LOCATION: SE6-5-17W
UTMX:445899.6 UTMY:5467232.5 XY Accuracy:1 EXACT [<5M] [GPS]
UTMZ:467.447 (ground surface elevation) Z Accuracy:1 EXACT <10CM
Owner: WRB
Driller: Ralph Edwards & Sons Drilling LTd.
Well Name: G05OA009 KILCART #8
Date Completed: 2001 Jul 25
Well Use: OBSERVATION
Well Status: ACTIVE Aquifer: SAND AND GRAVEL

REMARKS:
PUMPED WITH AIR, EC=2320

WELL LOG (Imperial units)

From	To(ft.)	Log
0.0	18	TILL, BEIGE, CLAYEY
18.0	61	TILL, GREY, CLAYEY
61.0	63	SHALE LAYER,BLACK, BRITTLE
63.0	105	TILL, GREY, CLAYEY, SOME STONE
105.0	110	SAND AND GRAVEL LAYER
110.0	150	TILL, GREY, CLAYEY
150.0	175	SAND AND GRAVEL, 50% SHALE, 50% LIMESTONE
175.0	194	SAND AND GRAVEL, VERY COARSE, 1/2 TO 1 INCH DIAMETER
194.0	196	STONE
196.0	200	SHALE, HARD, BLACK

WELL CONSTRUCTION

From	To(ft)	Const.Method	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type	Material
0.0	163.0	CASING	5.0			INSERT	BLACK IRON
163.0	168.0	PERFORATIONS	5.0		0.010	WIRE WOUND	S. S.

Top of Casing: 2.5 ft. above ground

PUMPING TEST
Date : 2001 Jul 26 Pumping 20.0 Imp. gallons/minute
Water level before test : 23.0 ft below ground
Water level at end of test :
Test duration:
Test Zone: from 163.0 ft to 168.0 ft

Table 14. Borehole log, CWS well, G05OA008 as recorded in the CWS database.

Well PID: 116767

LOCATION: NW21-2-15W
UTMX:468210.4 UTMY:5443941.9 XY Accuracy:1 EXACT [<5M] [GPS]
UTMZ:470.22 (ground surface elevation) Z Accuracy:1 EXACT <10CM
Owner: WRB
Driller: Ralph Edwards & Sons Drilling LTd.
Well Name: G05OA008 KILCART #1
Date Completed: 2001 Sep 05
Well Use: OBSERVATION
Well Status: ACTIVE Aquifer: SAND AND GRAVEL

REMARKS:
PUMPED WITH AIR, EC=1490

WELL LOG (Imperial units)

From	To(ft.)	Log
0.0	18	SAND, COARSE, BROWN
18.0	22	GRAVEL, COARSE, BROWN
22.0	62	TILL, GREY, CLAYEY
62.0	64	GRAVEL, SHALE, SOME LIMESTONE
64.0	130	TILL, GREY, CLAYEY
130.0	140	ROCKY TILL, CARBONACEOUS
140.0	180	SAND AND GRAVEL, GREY, SAND, GRAVEL, 80 % SHALE, 20% LIMESTONE
180.0	198	TILL, GREY, VERY CLAYEY
198.0	200	TILL, GREY
200.0	220	SHALE, HARD, DARK GREY, VERY STIFF

WELL CONSTRUCTION

From	To(ft)	Const.Method	Inside Dia.(in)	Outside Dia.(in)	Slot Size(in)	Type	Material
0.0	175.0	CASING	5.0			INSERT	BLACK IRON
175.0	180.0	PERFORATIONS	5.0		0.010	WIRE WOUND	S. S.

Top of Casing:

PUMPING TEST
Date : 2001 Sep 12 Pumping Imp. gallons/minute
Water level before test : 50.0 ft below ground
Water level at end of test :
Test duration:
Test Zone: from 175.0 ft to 180.0 ft

Appendices

Appendix A: Field borehole descriptions.

A1. Field borehole description, GSC-BH-SW-02A, page 1 of 8.

Project GSC. Spritwood
Site G050A010
Hole No. C-1(SW02A) Elev. ____ m
Location SW 33-3-16-W1 GPS coordinates are Easting 14404574 14
Drilled by R.D. Date Started Nov 02/2010 Northing 5455738
Logged by D.G. Date Completed Nov 03/2010
Water Level Final 5.02 m Top Pipe ☒ Top Grd ☐ Time-Date Nov. 4/10 8:45 AM
Installation 2" P.V.C. sch 40 Pipe piezometer
Page 1 of 8
General B-14 cable tool rig

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	0-0.45	Topsoil	Black, organic, stiff fibers (roots)			3 7/8"	Excavator					
	0.45-0.80	SC	fine-coarse, brown, wet clay binder, with a few clay seams			3 7/8"	Excavator					
	0.80-1.10	SP	fine-coarse brown, wet med Predom, water coming into hole			"	"					
	1.10-1.85	SP	coarse-fine, Brown, wet some gravel Particles to			Brass liner with catcher			.75	.56	2.3	1
		CI	+up till, Brown, very stiff lenses of oxides									

A1. Field borehole description, GSC-BH-SW-02A, page 2 of 8.

Project G.S.C. Spiritwood
Site G050A010
Hole No. C-1 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 2 of 8
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
			Reamed hole out to 1.85m with 5 5/8" Excavator									
			Set 3.36m of 4" casing into hole									
			Drive casing down to 1.85m	1.85								
	1.85-2.25	CI	till, Brown, very stiff			3 7/8" Excavator					2.2	
	-2.75		numerous lenses + seams of oxides, slightly sandy									
				2.25								
	2.75-3.5	CI	till, dark grey, hard		Brassliner		21		.75	.75	4.5	2
			few lenses of oxides + shale Particles									
				3.36								
	3.5-4.0	CI	till, dark grey, very stiff, few shale particles			3 7/8" Excavator					2.2	

A1. Field borehole description, GSC-BH-SW-02A, page 3 of 8.

Project G.S.C. Spiritwood
Site GOSOA010
Hole No. C-1cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 3 of 8
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	4.0-5.0	CI	+wp till, dark grey, very stiff few shale particles and a few limestone pebbles + cobbles			3 7/8" Excavator					3.0	
	5.0-6.0	CI	+wp till, dark grey, very stiff few shale particles and limestone pebbles, occasional cobble			3 7/8" Excavator					2.75	
	6.0-6.75	CI	+wp till, dark grey, very stiff shale particles, and pebbles of limestone			Brass liner	13		-75	72	2.75	3
	6.75-7.5	CI	+wp till, Dark grey, Hard shaly, numerous shale particles wet sand seam at 7.3 and 7.5, water coming into hole									

Project G.S.C. Spiritwood
Site G050AQ10
Hole No. C-1 con't'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 4 of 8
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
			Took water level at Hole it is at 6.57m from grd. level									
			and is still coming into hole slowly									
			Install 3.10m + 2.90m of 4" casing into hole									
			Total casing is 9.36m									
			Drive casing down to 7.5m									
	7.5-7.8		CI-up till, dark grey, Hard very shaley, crumbly sandy, numerous shale Particles and limestone Pebbles				3 7/8" Excavator					

A1. Field borehole description, GSC-BH-SW-02A, page 5 of 8.

Project G. S. C. Spiritwood
Site G050A010
Hole No. C-1 con't'd Elev. ______ m
Location
Drilled by ______ Date Started ______
Logged by ______ Date Completed ______
Water Level Final ______ m Top Pipe ☐ Top Grd ☐ Time-Date ______
Installation
Page 5 of 8
General

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Description, Characteristics, Abnormal Conditions, Sample Type	Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Length – m Drive	Length – m Rec.	PP kPa Test	No.
	7.8-8.55	CI	-wp Till, dark grey, hard			Brass	shoe .75	26	.75	.75	>	4
	-8.60		crumbly, very shaley To									
			Broken shale Particles with									
			limestone Pebbles, water bearing									
			water coming into hole									
				8.60								
	8.6-9.1	CI	+wp Till, dark grey, hard			3⅞"	Excavator					
			limestone cobble at 9.1m									
			very shaley	9.1m								
			end of Day									
			Nov. 3/2010									
			G.W.L 7.77m									
	9.1-9.5	CI	-wp till, dark grey, hard				3⅞"	Excavator				
			crumbly, very shaley numerous									
			shale Particles + chunks + limestone Pebbles									

A1. Field borehole description, GSC-BH-SW-02A, page 6 of 8.

Project G.S.C. Spiritwood
Site G050A010
Hole No. C-1 con't'd Elev. _____ m
Location _____
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 6 of 8
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
			Bailed water out of hole	9.20								
	9.5-9.75	(Clay Shale Till) CI	Clay Till, dark grey, hard crumbley, very shaley numerous shale chunks and limestone Pebbles			3 7/8" Excavator						
				9.36								
			Tools Binding in hole due to cobble at 9.1m causing casing to go crooked Pulled casing back to 9.0 metres									
	9.75-10.1	Sm	Fine-coarse, grey, ucs mostly shale + limestone, to			Broaching			.35	.35	>	5
		(Clay Shale Till) CI	Clay Till, grey, hard crumbley, very shaley numerous shale chunks and limestone Pebbles water coming into hole			Note: No blow count Tools Binding due to rock above. Note: appears to be thin interbedded coal + sand layer within the clay shale Till						

A1. Field borehole description, GSC-BH-SW-02A, page 7 of 8.

Project G.S.C. SpiriTwood
Site GO50A0/0
Hole No. C-1 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 2 of 8
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	10.1-10.4	Clay Shale reworked	C.I. up Till, dark grey, hard crumbly, very shaly, numerous shale chunks + limestone Pebbles			3 7/8"	Excavator			Bag		6
			Bottom of hole, Prepare to install a 2" P.V.C. Plastic Pipe piez into hole.									
			Length of 2" sch. 40 slotted pipe is 0.97m. "20 slott size									
			Length of the 2" solid PVC pipe is 10.18 metres									
			Total length of Pipe in hole is 11.15 metres									
			Bottom of the slotted pipe is at 10.40 m. below grd. level									
			Top of the slotted pipe is at 9.43 m. below grd level									
			Top of the 2" P.V.C. pipe is 0.75 m. above grd level									
			Backfilled the hole around the slotted pipe with Filter sand, Top of sand pack is at 9.30m. from grd. level. Then Backfilled the hole with 1/4" Bentonite Pellets and Jarred casing at the same time									

A1. Field borehole description, GSC-BH-SW-02A, page 8 of 8.

Project G. S. C. Spiritwood

Site G050A010

Hole No. C-1 cont'd Elev. ______ m

Location ______

Drilled by ______ Date Started ______

Logged by ______ Date Completed ______

Water Level Final ______ m Top Pipe ☐ Top Grd ☐ Time-Date ______

Installation ______

Page 8 of 8

General ______

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Length – m Drive	Length – m Rec.	PP kPa Test	No.

Top of Bentonite Pellets is at 8.25 from grd level and
casing shoe is at 8.20 meter from grd level.
Pulled 6.0 meters of 4" casing out of hole. Bottom of
casing shoe is at 3.00 m Below grd level.
Hole caved in to 6.0 meters from grd level.
BackFilled hole from 6 meters to 3.0m with Bentonite
chips Then Pulled all remaining 4" casing out of the
hole. Backfilled remainder of the hole to 0.75m
with clay cuttings. Then put a steel Protective
Pipe around the 2" P.V.C pipe. The Protective
(1.5m x 15cm x 15cm)
Pipe is 5'x6"x6" with a locking lid. Top of
the Protective Pipe is 0.80m Above grd. level.
Pipe is marked and capped
end of Hole

A2. Field borehole description, GSC-BH-SW-02B, page 1 of 2

Project G.S.C. Spiritwood
Site G050A010
Hole No. C-2(SW02B) Elev. ____ m
Location SW 33-3-16-W2 and it is 1.5 meters south of hole C-1
Drilled by RD Date Started Nov 3/2010
Logged by DG Date Completed Nov 3/2010
Water Level Final 1.15 m Top Pipe ☒ Top Grd ☐ Time-Date Nov. 4/10 8:30 am
Installation 2" PVC sch. 40 Plastic Pipe Piez
Page 1 of 2
General

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop – m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	0 – 0.35	Top soil	Black, organic, Fibers (roots)	stiff		3 7/8" Excavator						
	0.35 – 1.0	SC	fine – coarse, brown, slight clay binder	wet		3 7/8" Excavator						Bag 1
	1.0 – 1.6	SC	fine – coarse, brown, wet with a few interbedded clay seams			"		"				
	1.6 – 2.0	CI	Till, Brown, stiff lenses + seams of oxide			"		"			1.50	
			Reamed hole out to 2.0 m with 5 5/8" Excavator									

A2. Field borehole description, GSC-BH-SW-02B, page 2 of 2

Project G.S.C. Spiritwood
Site GOSOA010
Hole No. C-2cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 2 of 2
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	2.0-2.75	CI	Top till, Brown, very stiff numerous seams of oxids more of a gr. brown colour at 2.65m				3 7/8" Excavator					
			Bottom of Hole, install a 2" PVC sch 40 Plastic pipe Plug into hole Length of the 2" P.V.C slotted pipe is 1.50m th 20 slott size Length of the 2" PVC solid pipe is 2.0 meters Total 2" pipe in hole is 3.50 meters Bottom of 2" slotted is at 2.75m from grd. level Top of the 2" slotted is at 1.25m from grd. level Top of the Filter sand pack is at 0.80m from grd. level. Top of the 2" Pipe is 0.75m above grd level. (1.5m x 15cm x 15cm) Then a 5"x6"x6" Protective Pipe was Put around the 2" P.V.C. Pipe for Protection. Top of Steel Pipe is 0.80 above grd. level Pipe is marked + Capped End of Hole.								

A3. Field borehole description, GSC-BH-SW-03A, page 1 of 18

Project Geological Survey OF Canada Spiritwood — PFRA TESTHOLE LOG

Site G05040009

Hole No. GS3 (SW03A) Elev. ____ m

Location SE 6-5-17-W1 GPS coordinates are

Drilled by R.D. Date Started Nov 4/2010

Logged by D.G. Date Completed Nov. 6/2010

Water Level Final 5.37 m Top Pipe ☐ Top Grd ☒ Time-Date Nov 16/10

Installation 2" PVC sch. 40 Plastic Pipe Rig 3

Page 1 of 18

General B-14 cable Tool rig Plan # 359092

Easting 14U 445896

Northing 5467235

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute

(B) Circulation fluid, Pump pressure, Volume % Loss

(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	0-0.70	Top soil, Black, organic, Firm	Fibers (roots)				3 7/8" Excavator					
	0.70-1.5	CT + up till, Brown, soft to Firm	Lenses + seams of oxides Hole is squeezing				3 7/8" Excavator					
		Reamed hole out to 1.5m with 5 5/8" excavator										
	1.5-2.25	C.T + up till, gy brown, Firm	wet sand seam at 1.80 m Hole squeezing, seams of oxides				3 7/8" Excavator					
		Reamed hole out To 2.0m with 7 7/8" Excavator										
		Set 1.69m of 6" casing with Drive shoe into hole										
		Drive casing down To	1.6m									

A3. Field borehole description, GSC-BH-SW-03A, page 2 of 18

Project G.S.C. Spiritwood
Site G050A009
Hole No. GSB cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 2 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	2.25 To 2.30-3.05	CI+wp Till, gr brown, soft to				Brass liner	8		.75	.75	1.5	2
		CI+wp Till, Brown, stiff				Note: no free water in hole						
		with lenses of oxides, trace										
		of water on sampler Barrel										
		Added 1.56m of 6" casing, Total casing is 3.25m										
		Drive casing down To	3.0 m									
	3.05-3.5	CI+wp till, Brown, stiff			3 7/8" Excavator							
	-3.75	lenses of oxides										
		Reamed hole out to 3.5m with 5 5/8" Excavator										
	3.75-4.0	CI+wp till, dark gr brown			3 7/8" Excavator						2.25	
		very stiff, seams of oxides			Note: water coming in to hole							
		and thin sand layer	3.8-3.9		from the sand layer							

Project G.S.C. Spiritwood
Site GOSOA009
Hole No. C-Scont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 3 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
			Static water level in hole after 40 min ave. 3.37m from ground level									
			Reamed hole out to 4.0 m with 5 5/8" excavator									
	4.0-4.5	CL ± sup till, dark gr brown very stiff, lenses + specks of oxides, few shale particles				3 7/8	4/5 Excavator				3.75	
		Added 1.0m of 6" casing, total casing is 4.25m Drive casing down to 4.25m										
	4.5-5.0	CL – sup till, dark gr brown Hard, few lenses + specks of oxides, Pebbly few shale Particles				3 7/8"	Excavator					

A3. Field borehole description, GSC-BH-SW-03A, page 4 of 18

PFRA TESTHOLE LOG

Project: G.S.C. Spiritwood
Site: G050A009
Hole No.: 3 cont'd Elev. ______ m
Location: C-1
Drilled by ______ Date Started ______
Logged by ______ Date Completed ______
Water Level Final ______ m Top Pipe ☐ Top Grd ☐ Time-Date ______
Installation ______
Page 4 of 18
General ______

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data Length – m: Drive	Rec.	PP kPa Test	No.
	5.0-6.0	CI	up Till, grey, hard lenses + specks of oxides few shale particles, very slight traces of water in a few oxidized Joints			3⅞" Excavator						
	6.0-6.75	CI	up Till, grey, hard few oxides, shale Particles few cobbles			Brassliner		18	.75	.75	>	2
						Note very slight amount of water seeping into hole from 3-3m Just above the 6" casing shoe						
	6.75-8.0	CI	up Till, grey, Hard to very stiff, few shale particles and cobbles (limestone)			3⅞" Excavator					4.0 To 3.75	

Reamed hole out to 8.0m with 5⅝" Excavator

Project G.S.C. Spiritwood

Site G050A009

Hole No. C-3 cont'd Elev. ______ m

Location C-1

Drilled by ______ Date Started ______

Logged by ______ Date Completed ______

Water Level Final ______ m Top Pipe ☐ Top Grd ☐ Time-Date ______

Installation ______

Page 5 of 8

General ______

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute

(B) Circulation fluid, Pump pressure, Volume % Loss

(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm^3/s / Drop-m	% Loss / Blows	Length – m Drive	Length – m Rec.	PP kPa Test	No.
	8.0-9.25	CI+	cup till, grey, very stiff			3 7/8" Excavator						
			few shale Particles									
	9.25-10m	CI+	cup, till, grey, stiff			Brassliner		12	.75	.75	2.5	3
			few shale Particles, trace			Note: sample Pulled out						
			of water seeping into hole			of liner. Put catcher on and retrieved sample.						
			no visual sand seems noticed									
	10m-11.5	CI+	cup till, grey, stiff			3 7/8" Excavator					2.5	
			few shale particles									
			and limestone cobbles									
			Reamed hole out to 11.5m with 5 5/8" Excavator									

A3. Field borehole description, GSC-BH-SW-03A, page 6 of 18

Project G.S.C. Spiritwood
Site GOSOA009
Hole No. 2-3 cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 6 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	11.5-12.1	CT+wp	till, grey, very stiff few limestone cobbles		3 7/8" Excavator						2.0	
	12.1-12.85	CT+wp	Till, dark grey, very stiff, few shale particles and limestone cobbles		Brassliner		16		.75	.75	2.5	4
	12.85-13.5	CT+wp	Till, As above, Limestone Cobble at 13.0 metres									
			Reamed hole out to 13.0 m with 5 5/8" Excavator									
	13.5-14.6	CT+wp	Till, dark grey, very stiff, few shale particles and limestone Pebbles		3 7/8" Excavator							
			Reamed hole out to 14.6 m with 5 5/8" Excavator									

Project G.S.C. Spiritwood
Site 2050A009
Hole No. C-3 cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 7 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	14.6-15.1	CI	till, dark gray, very stiff, few shale particles and limestone pebbles			3 7/8"	Excavate				3.0	
	15.1-15.85	CI	till, dark gray, very stiff, few shale particles and limestone pebbles			Brass liner	18	75-60			2.6	5
	15.85-16.1	CI	till, As above			3 7/8"	Excavate					
			Reamed hole out to 16.1m with 5 5/8" Excavate									
	16.1-16.5	CI	till, gray, very stiff, few limestone cobbles + shale particles									

A3. Field borehole description, GSC-BH-SW-03A, page 8 of 18

Project G.S.C. Spiritwood
Site G050A009
Hole No. 6-3 cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 3 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
			Set 3.27 with shoe + 3.38 + 3.23 + 3.12 + 2.90 + 1.48 = 17.38 m of 4" casing into hole, total 4" casing is 17.38 m									
			Drive casing down to end of Day	16.5 m								
			Nov. 5/2010									
			Drill out inside of casing to No. 5 m									
16.5-17.8		CI	Till, dark grey, very stiff, cobbles of limestone and shale particles			3 7/8" Excavator						
				17.35								
17.8-18		CI	Clay Shale, silty, dark grey med hard, few Mk Fissures			3 7/8" Excavator			Bag			6

A3. Field borehole description, GSC-BH-SW-03A, page 9 of 18

Project G.S.C. SpiriTwood
Site GO50A069
Hole No. GSC-3 cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 9 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	18.0-18.75		Clay shale, silty, Reworked with numerous limestone Pebbles, med hard, Dark grey			Bmssline		26	.75	.75	>	7
	18.75-19.6		Clay Shale, Reworked, Dark grey, hard silty, numerous, shale/stone concretions,				3⅞"	Excavator	Bag			8
			Removed 1.48m of casing, Added 3.38m of 4" casing Total casing 19.28m Drive casing down To 19.0m									

A3. Field borehole description, GSC-BH-SW-03A, page 10 of 18

Project GSC- SPiritwood
Site GOSOA009
Hole No. C-3 conT'd Elev. ______ m
Location C-1
Drilled by ______ Date Started ______
Logged by ______ Date Completed ______
Water Level Final ______ m Top Pipe ☐ Top Grd ☐ Time-Date ______
Installation ______
Page 10 of 18
General ______

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	19.6-21.0	Clay	Shale, Reworked, dark grey Hard, with shalestone concreations crumbley.			3 7/8" Excavator						
	21.0-21.75	Clay	Shale, Reworked, Hard silty, Crumbley, with a few limestone Pebbles @ 21.75 m			Brass liner		100	.75	.75	→	9
		Added 1.48 m of casing, total = 20.76 m										
				20.5 m								
	21.75-22.3	Clay	Shale Reworked, dark grey Hard, numerous limestone Pebble, appears till like			3 7/8" Excavator						
	22.3-22.8	CI	-cup Till, dark grey hard very shaly, crumbley, limestone Pebbles			3 7/8" Excavator						

Project G.S.C. Spiritwood
Site G050A069
Hole No. C-B conTd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
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General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	22.8-22.9	Sm	fine, grey, wet shaley very silty, very slight Trace of water in hole			3 7/8"	Excavator					
	22.9-23.0	CI	-wp Till, Dark grey, Hard very shaley, crumbley numerous shale chunks			3 7/8"	Excavator					
			Removed 1.48m of casing,	Added 3.34m, total = 22.62								
				22.6								
	23.0-23.75	CI	-wp till, dark grey, As above									
	-23.9m											
			Very slight water seepage coming into hole from the 22.8-22.9 layer									
			Added 1.48m of casing, total = 24.10m									
			Drive casing down To	23.75								

Project G.S.C. Spiritwood
Site G050A009
Hole No. GSC-3 cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
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General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	23.9-24.0	Sm	fine, silty, dark grey, wet clay binder			3 7/8" Excavator						
				24.m								
	24.0-24.75	SP SM	fine-med, grey, wet Shale Particles, To			Brass liner			.75	.69	> 10	
		CI	-up till, dark grey hard very shaley, numerous shale chunks water coming into hole									
			Removed 1.48m of casing, Added 3.24m, Total = 25.96m									
				24.75		Bailed water out of hole approx 3 gallons						
	24.75-25.96	CI	-up till, dark grey									
	-26.0		hard, very shaley numerous, shale chunks crumbley	25.9								

A3. Field borehole description, GSC-BH-SW-03A, page 13 of 18

PFRA TESTHOLE LOG

Project G.S.C. Spiritwood
Site C050A009
Hole No. 2-3 contd Elev. ____ m
Location C-1
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
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General ____

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	26.0-26.3		Clay Shale, silty, sandy, dark grey hard.			3 7/8" Excavator						
	26.3-27.0		CI-wp Till, dark grey, Hard very shaly, with numerous shale particles + chunks			3 7/8" Excavator						
			Added 1.48m of casing, total = 27.34m									
				27.0m								
	27.0-27.75		CI-wp Till, dark grey, hard very shaley, with limestone cobbles and numerous shale chunks, crumbley			Brass liner		50	.75	.75	>11	

Project G.S.C. Spiritwood
Site G050A009
Hole No. C-3 conPd Elev. ____ m
Location C-1
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 14 of 18
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	22.75-29.0	CI	-wp Till, dark grey, hard very shaley, limestone cobbles numerous shale partcles + chunks crumbley			3 7/8" Excavator						
			Removed 1.48m casing, Added 3.34m, total = 29.20m									
	29.0-29.5	CI	-wp Till, dark grey Hard, very shaley, limestone cobbles, numerous shale chunks	29.0m								
	29.5-29.6	SC	fine, dark grey, wet, very shaley, very slight trace of water in the hole			3 7/8" Excavator						
			Added 1.48m of casing, total casing 30.68m	29.6m								

A3. Field borehole description, GSC-BH-SW-03A, page 15 of 18

Project G.S.C. Spiritwood
Site G050A009
Hole No. GSC-BH-SW-03A cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 15 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	29.6-30m	CI	Cwp Till, dark grey, hard very shaley, shale chunks & limestone cobbles			3 7/8"	Excavator					
				30m								
	30.0m To 30.1-30.85	CI	Cwp Till, dark grey, hard very shaley, with shale chunks, limestone cobbles			Brassbuster		55	.75	.75	7	12
				30.5								
	30.85-32.6	CI	Cwp Till, dark grey, hard slightly sandy, shaley, with shale chunks, limestone cobbles			3 7/8"	Excavator					
			Thin sand seam, wet, at 31.5m			Note: very slight water seepage into the hole						
			Removed 1.48m of casing, Added 3.39, total = 32.59m									
			Drove casing down To	32.2m								

A3. Field borehole description, GSC-BH-SW-03A, page 16 of 18

Project G.S.C. Spiritwood
Site GO50A009
Hole No. GSC-3 cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 16 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
			Nov. 6/2010									
			Static water level in hole is at 32.03 m from grd. level									
	32.6-33.0	CI	Wp till, dark grey, hard very shaley, with shale Particles + chunks			3 7/8" Excavator						
	33.0-33.75	CI	Wp Till, dark grey, hard very shaley, with shale Particles + chunks			Brass liner	52		.75	.75	> 13	
	33.75-34.7	CI	Wp till, As above with a few limestone cobbles			3 7/8" Excavator						

Project GSC- Spiritwood
Site 6050A009
Hole No. C-B cont'd Elev. _____ m
Location C-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 17 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	34.7-36.6		Clay shale, dark gray, silty, Hard few oxides, slight trace of water at the shale contact			3 7/8"	Excavator		3.0			14
			After approx 30 min water level in the hole is 32.65m from grd level.									
			Backfill hole to 35.0m. with clay cuttings and tamped									
			Then installed a 2" PVC Plastic pipe preg into hole sch.40									
			Length the slotted 2 PVC Pipe is 2.99 metres #20 slot size									
			Total length of the 2" solid Pipe is 32.71 metres									
			Total 2" PVC Pipe + screen is 35.70 metres									
			Bottom of the 2" slotted pipe is at 34.95m from grd level									
			Top of the 2" slotted pipe is at 31.96 m from grd level									
			Top of the 2" PVC pipe is 0.75 m above grd level									
			Jarred 4" casing back to 32.0m from grd level									
			Then Pour Filter sand into hole to form a sand pack around the pipe									

A3. Field borehole description, GSC-BH-SW-03A, page 18 of 18

Project G.S.C. Spiritwood
Site GOSOA009
Hole No. GSC-BH-SW-03A Elev. _____ m
Location L-1
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 18 of 18
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
			Jarred casing and Poured Filter sand into hole at same time Top of the sand Pack is at 31.40 m. from ground level Then Poured ½" Bentonite Pellets into the hole and Jarred Casing out at the same time To Put the Bentonite Pellets is at 30.4m from ground level. Pulled all 4" casing out of hole. Then Sounded the hole with a steel surveyor chain. Hole is open to 30.3 m. Then Poured Two Bags of Grout Hole Plug into the hole Top of Hole Plug is at 21.0 meter from grd. level Backfilled the remainder of the hole with clay cuttings to 4.50 m from ground level. Then Pulled all 6" casing out of Hole. Backfilled hole to 0.70 m. with clay cuttings and Bentonite chips. Then Installed a 5"x6"x6" (1.5m x 15cm x 15cm) Protective steel pipe around the 2" P.V.C Pipe piez, Pipe is capped and Marked. END of Hole A Water level will be obtained later									

A4. Field borehole description, GSC-BH-SW-03B, page 1 of 5

PFRA TESTHOLE LOG

Project Geological Survey of Canada Spiritwood
Site G050A009
Hole No. C-2 (SW03B) Elev. ______ m
Location SE6-5-17-W1st it is 1.80 m west of Hole C-1 (SW03A)
Drilled by R.D. Date Started Nov 16/2010
Logged by D.G. Date Completed Nov16/2010
Water Level Final 1.32 m Top Pipe ☑ Top Grd ☐ Time-Date NOV 16 PM
Installation 2" PVC Plastic Pipe piez. (sch 40)
Page 1 of 5
General B-14 cable Tool rig Plan# 359093

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	0-0.5		Topsoil, Black organic, stiff			3 7/8" Excavator						
			Fibers (roots)									
	0.5-1.40		CI+wp, Till, Brown, very			3 7/8" Excavator						
			soft lacking pebbles									
	1.4-1.50		SC fine-coarse, brown wet			3 7/8" Excavator						
			gravelly, water seeping into									
			hole									
			Reamed hole out to 1.5 m with 7 7/8" excavator									
			Set 1.69 m of 6" casing in to hole									
			Drive casing down to 1.50 m									
	1.5-2.25		CI+wp till, Brown, stiff			3 7/8" Excavator						
			few seams of oxides									

A4. Field borehole description, GSC-BH-SW-03B, page 2 of 5

Project G.S.C. Spirit Wood
Site G050A009
Hole No. C-2 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 2 of 5
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
			Added 1.56 m of 6" casing, total = 3.25 m									
			Drive casing down to	2.25								
	2.25-2.8	CI	Till, Brown, stiff			3 7/8" Excavator						
			lenses + seams of sand,									
			wet sand seam at 2.8m									
			water coming into hole									
	2.8-3.0	CI	Till, Brown, stiff			3 7/8" Excavator						
	- 3.20		silty, with interbedded			Mt. water coming into hole						
			thin layers + seams of	Mt.		wet sandy						
			numerous seams of oxides									
			Reamed hole out to 3.0m with 5 5/8" Excavator									
			Drive casing down to	3.0m								
	3.20-3.70	CI	Till, grey brown, very stiff			3 7/8" Excavator						
			lenses + seams of oxide									

A4. Field borehole description, GSC-BH-SW-03B, page 3 of 5

Project G.S.C. Spiritwood
Site GO50A009
Hole No. C-2 Cont'd Elev. _____ m
Location _____
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 3 of 5
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
			Added 1.0m of 6" casing, total = 4.25m									
			Drive casing down to	3.70m								
			Bailed water out of Hole									
	3.70-4.60	CI-up Till, dark gr brown				3 7/8" Excavator						
			very stiff, lenses + seams									
			of oxides									
			Reamed hole out to 4.6m with 5 5/8" Excavator									
	4.60-5.0	CI-up Till, grey, hard			3 7/8" Excavator							
	- 5.6		lenses of oxides	4.20								
			Reamed hole out to 5.0m with 5 5/8" Excavator									

Project G.S.C. Spiritwood
Site G050A809
Hole No. C-2 cont'd Elev. _____ m
Location _____
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 4 of 5
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
	5.6 - 9.0	CI	-wp Till, grey, Hard few cobbles			3 7/8"	Excavator					
	9.0 - 10.5	CI	+wp Till dark grey, Hard few cobbles, cobble at 10 m and a other at 10.5 m			3 7/8"	Excavator					
			Bottom of hole, Prepare hole for a 2" sch40 PVC Plastic pipe piez									
			Backfill hole with clay cuttings and Bentonite chips and tamp it Tight into the hole with the rig Tool steel.									
			Hole was Backfilled to 4.20 metres from grd level									
			Pulled casing back To 3.5m. Then backfilled hole with									
			clay cuttings To 3.5 metres from ground level									
			Then set 2" P.V.C. Plastic Pipe piez into hole									
			Length of exposed slotted pipe is 0.70 metres #20 slot size									
			Length of Just 2" PVC Pipe is 3.55 metres									

A4. Field borehole description, GSC-BH-SW-03B, page 5 of 5

Project G.S.C. Spiritwood
Site G050A009
Hole No. C-2 con't'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 5 of 5
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
			Total length of 2" pipe in hole is 4.25 meters									
			Bottom of slotted pipe is at 3.5 metres from ground level									
			Top of the exposed slots is at 2.80 metres from ground level									
			Top of the 2" pvc pipe is 0.75 metres above grd. level									
			Then Poured Filter sand down the hole and pulled									
			the 6" casing out at the same time top of sandpack									
			is at 2.60m. 6" casing is at 2.6 metres. then									
			Pulled casing Back to 1.69m and Backfilled the									
			hole around the Piez. Pipe with Bentonite chips to									
			1.70m from grd level. There is 0.9m of Bentonite									
			chip in the hole to form a seal around the P.V.C. Pipe.									
			Pulled all 6" casing out of the hole. Backfilled									
			hole with clay cuttings to 0.70m. from grd level.									
			Placed a 5'x6"x6" (1.5m x 15cm x 15cm) Protective pipe around the 2" Pipe pipe.									
			Pipe is capped and marked.									
			End of Hole									

Project Geological Survey of Canada Spiritwood

Site G050A008

Hole No. C-1(SW04A) Elev. ____ m

Location NW21-2-15-W2 G.P.S. coordinates are Easting 14U0468209

Drilled by R.D. Date Started Nov 18/2010 Northing 5443943

Logged by D.G. Date Completed Nov 20/2010 Drill along the north side of the road in the R.M. Ditch

Water Level Final 5.53 m Top Pipe ☐ Top Grd ☒ Time-Date Nov 20/2010

Installation 2" sch 40 P.V.C. Plastic Pipe piez

Page 1 of 11

General B-14 cable Tool rig Pkn # 359103

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute

(B) Circulation fluid, Pump pressure, Volume % Loss

(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	0 - 0.15	Top	soil, Black Organic, stiff			3 7/8" Excavator						
	0.15 - 1.5	CI+cwp till, Brown, stiff				3 7/8" Excavator					1.25	
			lenses + seams of oxides									
	1.5 - 2.25	CI+cwp Till, Brown, stiff to				Brass liner	12	.75	.75	2.75	2	
		very stiff, lenses of oxides										
		few organic streaks										
		Reamed Hole out to 2.25 m with 5 5/8" excavator										
	2.25 - 4.0	CI+cwp till, Brown, very stiff				3 7/8" Excavator					2.5	
		few cobbles, lenses of										
		oxides, and a few organic streaks										

A5. Field borehole description, GSC-BH-SW-04A, page 2 of 11

Project G.S.C. Spiritwood
Site G050A008
Hole No. G-1 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 2 of 11
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
			Reamed hole out to 4.0 m with 5 5/8" excavator									
	4.0-4.5	CI till	gr. brown, very stiff lenses & seams of oxides			3 7/8" Excavator						
	4.5-5.25	CI till	Dark gr brown very stiff, lenses of oxides			Bureshina 19			.75	.75	3.0	2
	5.25-5.6	CI till	Dark gr brown, very stiff seams of oxides			3 7/8" Excavator					3.0	
	5.6-7.0	CI till	gr. grey, very stiff, lenses & seams of oxides			3 7/8" Excavator						

A5. Field borehole description, GSC-BH-SW-04A, page 3 of 11

Project G.S.C. Spiritwood
Site G050A008
Hole No. C-1 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 3 of 11
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
			Reamed hole out To 7.0 m with 5 5/8" Excavator									
	7.0-7.5	CI	till-up dark grey, very stiff seams of oxides			3 7/8" Excavator					2.5 to 3.5	
	7.5-8.25	CI	till-up dark grey, Hard numerous seams + lenses of oxides (oxidized Joints)			Brass bits		26	7.5	7.5	> 3	
	8.25-9.0	CI	till-up dark grey, Hard as above, cobble at 9.0m.			3 7/8" Excavator						
			Reamed hole out to 9.0m, with 5 5/8" Excavator									

A5. Field borehole description, GSC-BH-SW-04A, page 4 of 11

Project G.S.C. Spiritwood
Site GOSOA008
Hole No. C-1 con't'd Elev. _____ m
Location _____
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 4 of 11
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	9.0-9.4	CI	-cwp Till, dark grey, hard shaley, numerous shale chunks and limestone pebbles + cobbles			3 7/8" Excavator						
	9.4-9.5	CI	-cwp Till, dark grey, hard very sandy, shale partides			3 7/8" Excavator						
	9.5-9.7	CI	-cwp Till, dark grey, Hard shaley, with numerous shale chunks and limestone Pebbles			3 7/8" Excavator						
			Reamed hole out to 9.7m with 5 5/8" Excavator To help drill out the cobble at 9.0 metres									

Project G.S.C. Spiritwood
Site GOSOA008
Hole No. C-1 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 5 of 11
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
	9.7-10.5	CI	wp till, dark grey hard shaley, numerous limestone cobbles and shale particles			3 7/8" Excavator					>	
	10.5-10.8	CI	wp Till, dark grey, hard			Bounces/min			.30	.20	7	4
	-11.5		shale particles, and limestone Pebbles + cobbles			Note: cobble at 10.8m and caused tools to bind						
			Reamed hole out to 10.8m with 5 5/8" Excavator									
	11.5-12.0	CI	wp till, dark grey, hard silty, with a few, damp sandy silt seams, sand seam at 11.8m damp			3 7/8" Excavator					>	
						Reamed hole out to 11.8m with 5 5/8" Excavator						

A5. Field borehole description, GSC-BH-SW-04A, page 6 of 11

Project G.S.C. Spiritwood
Site G050A008
Hole No. C-1 con Td Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 6 of 11
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	12.0-12.5	CI	-up Till, dark grey, hard		Brosshole				.50	.50	—	5
			slightly sandy, to									
		SPSM	fine-coarse, grey, wet									
			water coming into hole									
			cobble at 12.5m									
			end of Day									
			Nov. 18/2010									
			Static water level is 4.70 m from ground level									
			Set 3.27m + 3.37m + 3.24m + 3.13m of 4" casing in hole									
			Total casing is 13.01m									
			Drive casing down to	12.5m								
			Bailed water out of	hole								
			Drilled sand out of Hole by Bit + Bail method									

A5. Field borehole description, GSC-BH-SW-04A, page 7 of 11

Project G.S.C. Spiritwood
Site G050A008
Hole No. C-1cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 7 of 11
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	12.5-13.4	GP GM	fine-coarse, grey, wet numerous cobbles water coming into hole			Sampler Barrel			Bag		—	6
			Added 1.48m of casing, total = 14.49m									
			(CL Till ground)	13.4								
	13.4-13.8	GC	fine-coarse, grey, wet slightly cemented, with numerous shale particles clay Binder			Sample Barrel			Bag		—	7
	13.8-14.0	S.P	S.M coarse-fine, grey wet, V. gravelly, cobbles water coming into hole			Sample Barrel			Bag		—	8
				14.0 m								

A5. Field borehole description, GSC-BH-SW-04A, page 8 of 11

Project G.S.C. Spiritwood
Site G050A00B
Hole No. C-1 con'td Elev. _____ m
Location _____
Drilled by _____ Date Started _____
Logged by _____ Date Completed _____
Water Level Final _____ m Top Pipe ☐ Top Grd ☐ Time-Date _____
Installation _____
Page 8 of 11
General _____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
			Lost approx. 1 meter of hole due to the formation sand coming up the hole with the water									
	14.0-14.25	GC	fine-coarse, grey, wet very sandy, cemented, with interbedded layers of shaley clay			Sampler Barrel						
			END OF Day Nov 19/2010									
			continue drilling									
	14.25-14.4	SM	fine-coarse, dark grey			Sampler Barrel			Bag-			9
	-14.8		wet, cemented, with a few thin interbedded clay layers, many shale and limestone Particles			water coming into hole Note: sample was one cemented Piece before it was Placed into the sample bag						

Project G.S.C. Spiritwood
Site G050A008
Hole No. C-1 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 9 of 11
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
			Removed 1.48m of casing, Added 2.90m, total casing - 15.91									
	14.8-15.0	CI	wp till, dark grey, hard shale particles	14.60m			Sampler Barrel		Bag		>	10
				15.0		Note: Bailed water out of Hole						
	15.0-15.5 - 15.75m	CI	wp till, dark grey, hard numerous shale particles			3⅞" Excavator			Bag		>	11
				15.5m								
	15.75-16.5	CI	wp till, dark grey, Hard crumbly, shaley, with numerous shale particles			Brass liner		30	.75	.73	>	12
	16.5-17.0	CI	wp till, As above cobble at 17.0 meters			3⅞" Excavator						
			Added 1.48m of casing, total = 17.39m.									

A5. Field borehole description, GSC-BH-SW-04A, page 10 of 11

PFRA TESTHOLE LOG

Project G.S.C. Spiritwood
Site G050A008
Hole No. C-1 con't'd Elev. ______ m
Location
Drilled by ______ Date Started
Logged by ______ Date Completed
Water Level Final ______ m Top Pipe ☐ Top Grd ☐ Time-Date
Installation
Page 10 of 11
General

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa (B) kPa (C) kg	rpm cm³/s Drop-m	% Loss Blows	Length – m Drive	Rec.	PP kPa Test	No.
			Slight water seepage into hole 17.0m									
			at 17.0 meters. Put 4" chisel Bit on to drill rock									
	17.0-17.25		Cobbles at 17m and another at 17.25m 4" chisel Bit									
			water coming into hole at 17.25									
			and very small amount of sand									
			Unable to drill Past 17.25m due to the cobbles at									
			17 and 17.25 meters, Bottom of hole									
			static water level after 35 mins 6.0m below grd level									
			Pulled 4" casing Back To 14.80m from ground level									
			Backfilled hole from 17.25m to 15.1 meter with Bentonite									
			chips to seal off the Bottom layer									
			Then Poured filter sand into hole Filter sand is from									
			15.1-14.8m from grd. level.									
			Then installed a 2" P.V.C.-Plastic Pipe piez into the									
			hole sch. 40 wall Thickness									

A5. Field borehole description, GSC-BH-SW-04A, page 11 of 11

Project G.S.C. Spiritwood
Site G050A008
Hole No. C-1cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 11 of 11
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length-m Drive	Length-m Rec.	PP kPa Test	No.
			Length of exposed slotted 2" pipe is 3.0 m #20 slot size									
			Total Length of Just 2" Pipe is 12.60 meters									
			Total Pipe in the hole is 15.60 meters									
			Bottom of the slotted pipe is at 14.85 m from gnd level									
			Top of the 2" slotted pipe is at 11.85 m from gnd level									
			Top of the 2" P.V.C. pipe is 0.75 m above gnd level									
			Pulled casing and Backfilled hole with Filter sand at the same time. Top of sand Pack is at 11.4 m from gnd level. Pulled all 4" casing out of hole and Backfilled hole to 3.0 m from ground level with Bentonite chips (5-50/16 bags of Hole Plug).									
			end of Day									
			Nov. 20/2010 complete P23 installation									
			Backfilled hole with clay cuttings to 0.8 m below gnd level (1.5m x 1.5 x 1.5)									
			Put a 5½ 6" x 6" Protective steel Pipe over the 2" P.V.C Plastic Pipe									
			Pipe is marked and capped. END OF Hole									

Project Geological Survey OF Canada Spiritwood — PFRA TESTHOLE LOG

Site G050A008

Hole No. C-2(SW04B) Elev. ____ m

Location NW21-2-15-W2 Drilled 1.8m west of hole C-1 drilled in north ditch of the east-west road

Drilled by RD Date Started Nov 20/2010

Logged by D.C Date Completed Nov 20/2010

Water Level Final Dry m Top Pipe ☐ Top Grd ☐ Time-Date Nov 20/2010

Installation 2" sch 40 P.V.C Plastic Pipe piez.

Page 1 of 3

General B-14 cable tool rig Plan #359104

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute

(B) Circulation fluid, Pump pressure, Volume % Loss

(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	0 – 0.15	Topsoil, Black, organic, stiff			3 7/8" Excavator							
	0.15 – 1.5	CI till, Brown, firm-stiff lenses & seams of oxides			"	"					1.25	
		Reamed hole out to 1.5m with 5 5/8" Excavator										
	1.5 – 3.0	CI till, Brown, stiff to very stiff, Lenses of oxides few organic streaks			3 7/8" Excavator							
		Reamed hole out to 3.0m with 5 5/8" Excavator										
	3.0 – 4.7	CI till, Brown, very stiff, lenses & specks of oxides			3 7/8" Excavator							

A6. Field borehole description, GSC-BH-SW-04B, page 2 of 3

Project G.S.C. Spiritwood
Site GOSOA008
Hole No. C-2 cont'd Elev. ____ m
Location ____
Drilled by ____ Date Started ____
Logged by ____ Date Completed ____
Water Level Final ____ m Top Pipe ☐ Top Grd ☐ Time-Date ____
Installation ____
Page 2 of 3
General ____

PFRA TESTHOLE LOG

LOCATION SKETCH

(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Formation and Water Data: Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa / (B) kPa / (C) kg	rpm / cm³/s / Drop-m	% Loss / Blows	Sample Data: Length – m Drive	Length – m Rec.	PP kPa Test	No.
	4.2 – 5.70	CI+sp	till, dark gr brown very stiff, lenses of oxides			3 7/8" Excavator						
	5.7 – 6.0 – 6.9	CI+sp	till, brownish grey to grey, very stiff numerous seam of oxides			3 7/8" Excavator						
			Reamed hole out To 4.5 m with 5 5/8" Excavator									
	6.9 – 7.5	CI+sp	Till, grey, Hard with seams of oxides a few cobbles			3 7/8" Excavator						
			Bottom of Hole, Install a 2" PVC Plastic Pipe pig into hole with a sch 40 wall Thickness									

A6. Field borehole description, GSC-BH-SW-04B, page 3 of 3

PFRA TESTHOLE LOG

Project GSC. Spiritwood
Site G050A008
Hole No. C-2contd Elev. ______ m
Location
Drilled by ______ Date Started
Logged by ______ Date Completed
Water Level Final ______ m Top Pipe ☐ Top Grd ☐ Time-Date
Installation
Page 3 of 3
General

LOCATION SKETCH

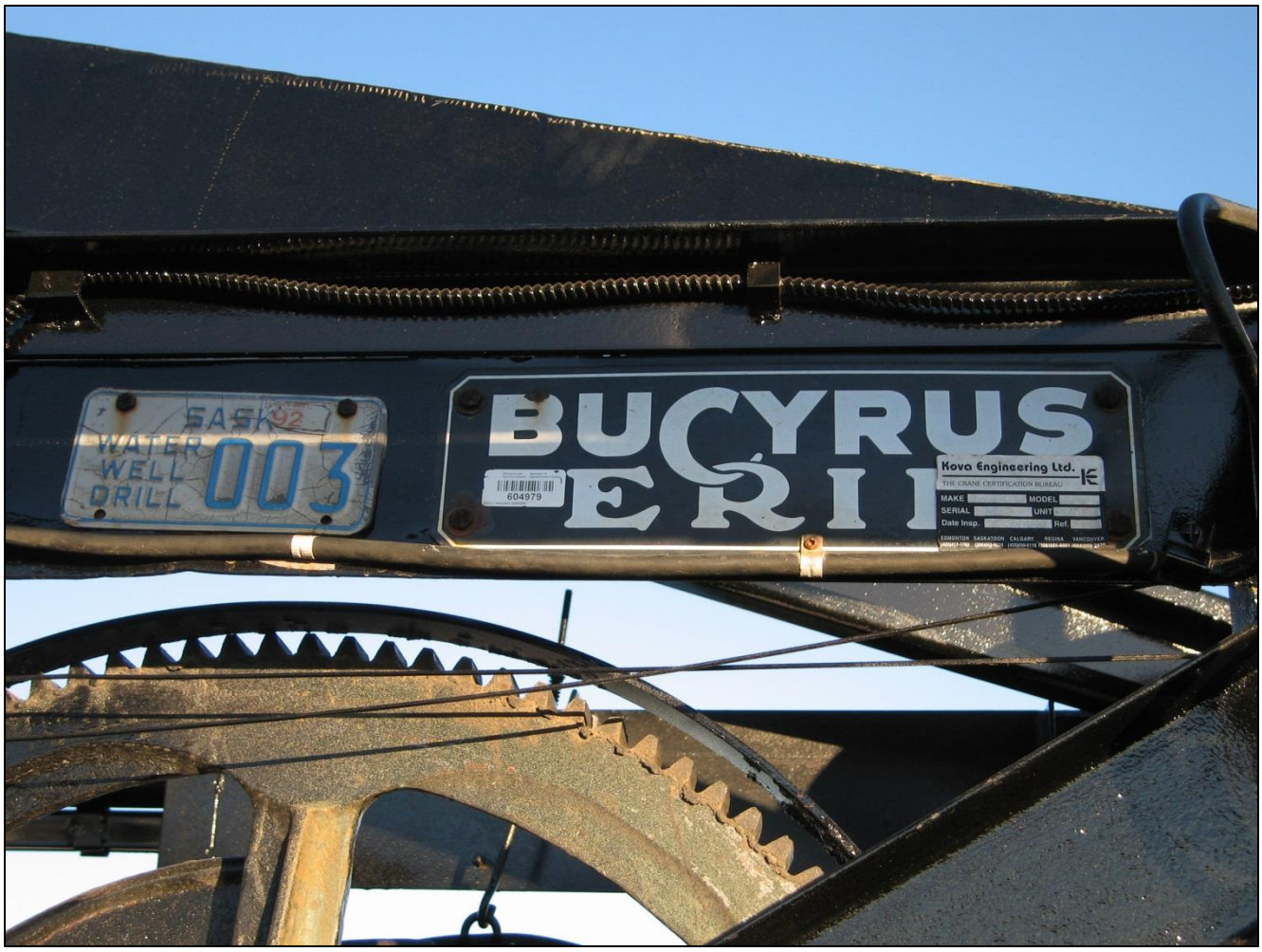
(A) Bit pressure, Revolutions per minute
(B) Circulation fluid, Pump pressure, Volume % Loss
(C) Drive sample weight, Drop distance, Blow count

Time	Depths – m (Underline sample drive)	Group	Formation and Water Data: Description, Characteristics, Abnormal Conditions, Sample Type	Drill Data and Remarks: Depth Casing Shoe m	Depth Hole Fluid m	(A) kPa (B) kPa (C) kg	rpm cm³/s Drop-m	% Loss Blows	Sample Data: Length – m Drive	Rec.	PP kPa Test	No.
			Length of 2" slotted pipe is 2.99 m with #20 slot size									
			Length of Just 2" PVC pipe is 5.26 meters									
			Total 2" Pipe in hole is 8.25 meters									
			Bottom of the slotted pipe is at 7.5 m below grd level									
			Top of the slotted pipe is at 4.51m below grd level									
			Then Poured Filter sand down hole to form a sand pack									
			around the 2" Pipe piez. top of sand pack is at 4.0 m									
			from ground level. Then backfilled the hole with									
			Bentonite chips to 2.30m from ground level.									
			Backfill the remainder of the hole with clay cuttings									
			to 0.80m from ground level.									
			(1.5m x 15cm x 15cm) Put a 5'x6"x6" Protective steel Pipe over the 2" P.V.C. Pipe piez.									
			Pipe is marked and capped.									
			AT this time the water table Piez is dry									
			0.75 above grd									
			END OF Hole									

Appendix B: Additional photographs.

Photograph B1. AAFC B-12 drill rig setup with crew.

Photograph B2. AAFC B-12 drill rig at site G05OA010/GSC-BH-SW-02, November 2010, facing east.



Photograph B3. AAFC B-12 drill rig name plate.

Photograph B4. Site G05OA010/GSC-BH-SW-02, October 2011, facing east.

Photograph B5. Site G05OA009/GSC-BH-SW-03, October 2012, facing north.

Photograph B6. Site G05OA009/GSC-BH-SW-03, October 2012, facing east with loading station well in the distance.