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Baseline Hydrogeological Characterization Concrete Gravity Structure Graving Dock Site Argentia, NL

Prepared for

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EXECUTIVE SUMMARY

Acting at the request of Husky Energy (Husky), Stantec Consulting Ltd. (Stantec) carried out a baseline hydrogeological characterization of the proposed Concrete Gravity Structure (CGS) graving dock site in Argentia, Newfoundland and Labrador (NL), herein referred to as the "site". This hydrogeological characterization was required to gain a better understanding of the hydrogeological conditions at the proposed CGS graving dock site, and in particular to provide information on potential impacts to groundwater quality and quantity in the site area related to the construction and operation of the graving dock facility.

The hydrogeological characterization provided herein is based primarily on information obtained from several previous studies conducted by Stantec and others, including a detailed geotechnical borehole drilling program (Golder, 2012, a & b) and a water well drilling and hydraulic testing program (Stantec, 2013). Relevant geological and hydrogeological information from publically-available mapping and from other consulting and Public Works Government Services Canada (PWGSC) studies completed in the immediate area were also researched, and integrated into this assessment.

Site Description & Project Overview

The proposed CGS graving dock site is located in the northeast portion of the Argentia Northside peninsula. The Northside peninsula is a roughly triangular-shaped low-lying peninsula that is surrounded on all sides by the ocean, and is connected to the mainland by a narrow isthmus at the south end in the area of Sandy Cove. The approximately 20 hectares of land comprising the site is currently owned by the Argentia Management Authority (AMA), and is under lease to Husky for the proposed construction of a graving dock to be used for the construction of a Concrete Gravity Structure for the White Rose Extension Project.

Based on information provided by Husky, the graving dock will measure approximately 153.5m x 153.5 m at the floor, and will be excavated behind a natural coastal berm to a depth of approximately -18mCD. A cut-off wall, approximately 900 mm thick, will be constructed to minimize the ingress of water into the graving dock. The wall is designed with a permeability of 10^{-8} m/s to a depth of -28 mCD at the sea bund side, and will continue landwards approximately half way around the sidewalls and to a depth of -10 mCD.

Conclusions

Based on the findings of the current study, the following conclusions are made with respect to hydrogeological characterization of the CGS graving dock site:

Hydrogeological Properties of CGS Graving Dock Area

Based on a variety of hydraulic testing and statistical analysis techniques, the site area is characterized as an unconfined to leaky, highly stratified unconsolidated aquifer with interbedded silt, clay, fine to coarse-grained sand and gravels in excess of 42 m thick. Based on hydraulic testing of test well PW1, the aquifer has a geometric mean transmissivity of 222.7 m^2/d, a geometric mean coefficient of storage of 3.5E-03 and a geometric mean hydraulic conductivity of 1.8E-4 m/s. The soils exhibit a wide range of K from 4E-11 m/s for clay-silt to 2.1E-1 m/s for clean gravel, with a geometric mean in the order of 6E-4 m/s (slug tests) to 9.6E-6 m/s (sieve analysis).

Water levels range in depth from 1.0 to 9.4 mbgs, and 2.9 to 4.6 mCD. The dominant direction of groundwater flow is southeastward from the vicinity of the main runways to the coastline at an average horizontal hydraulic gradient of 1.2 percent and an average velocity of 0.02 to 0.75 m/day. Small downward vertical hydraulic gradients (<1%) are expected in the vicinity of the Northside runways, and small upward gradients (<1%) are suspected in the vicinity of the CGS graving dock site and near the coastline.

Drawdown Area of Influence of CGS Graving Dock Dewatering

Using the mean transmissivity (222.7 m^2/d) and storage coefficient (4.5E-03) from the hydraulic testing of PW1, the potential drawdown interference is predicted at various distances from the site for a variety of pumping times and pumping rates using the modified Cooper-Jacob non-equilibrium method (Cooper et al, 1946). A 100-day time frame is selected as this is typical of seasonal minimum (extreme dry summer) and maximum (extreme wet spring or fall) recharge conditions. Preliminary calculations of drawdown area of influence suggests 100 day radii of influence (ROI) varying from 400 m at 454 L/min (100 Igpm) to greater than 2,000 m (i.e., the extent of the peninsula) at sustained pumping rates of 2,273 L/min (500 Igpm) or more. Under sustained pumping required to dewater the graving dock to elevation -18 mCD (i.e., minimum of 5,683 L/min), it is estimated that the groundwater table will experience approximately 10 m of drawdown (i.e., approach sea level) in the runway area approximately 600 m northwest of the site, and approximately 5 m of drawdown will occur in the vicinity of the Pond, located approximately 1,300 m northwest of the site.

Groundwater Baseline Chemistry

The groundwater quality is characterized as a clear, very hard (hardness 215 mg/L), slightly alkaline (190 mg/L, mean pH 8.1), calcium bicarbonate water type of moderate dissolved solids (conductance 520 uS/cm, est. TDS 350 mg/L). All analyzed parameters meet applicable environmental groundwater guidelines. With the exception of traces of toluene (5 µg/L), phenanthrene (0.024 µg/L) and petroleum hydrocarbons in several wells, no BTEX, TPH, VOCs, PAHs or PCBs were detected during the pumping test program.

Water Quality Impact Potential from Contaminated Sites

A review of recent monitoring of remediated sites known to occur northeast, northwest and southwest of the site suggests that concentrations of petroleum, PAHs, PCBs, metals, and VOCs continue to decline, and that there does not appear to be any residual major sources of free product in the area. Based on the reported low levels of petroleum hydrocarbons, PAHs, metals, PCBs and VOCs and the general absence of free product in groundwater at the historical contaminated sites, no significant problems with inducing impacted groundwater into the CGS graving dock site are anticipated.

Impacts to Groundwater Users

No groundwater users are known to be present on the Northside Peninsula. It is assumed all activities are serviced by water pipeline from the mainland. No dewatering impacts to groundwater users are therefore anticipated on the Northside Peninsula associated with the CGS graving dock site. Because the Placentia Bay acts as a recharge boundary, no impacts to well users on the Southside are anticipated.

Effects on Surface Waters

With the exception of small wetlands, no surface water bodies are present in proximity to the CGS graving dock site. The closest major surface water body, the Pond, is located 1,200 to 1,500 m northwest of the site. While it is possible that the area of drawdown influence of the CGS graving dock could reach the Pond, the degree of interaction would depend on the duration of pumping, the rate of pumping, and the degree of hydraulic isolation of the Pond for the underlying aquifer (e.g., bottom sediment permeability). No effects are anticipated on surface waters located off the Northside Peninsula.

Groundwater Monitoring Plan

As indicated in the White Rose Extension Project Scoping Document (C-NLOPB, 2012), a monitoring strategy is required during the CGS graving dock dewatering and operation stage. This strategy should build on the baseline monitoring work currently on-going, using similar sampling protocols and QA/QC procedures. A general framework for a groundwater flow and quality monitoring plan for the CGS graving Dock site is provided herein based on results of this baseline hydrogeological site characterization.

The statements made in the executive summary are subject to the same limitations included in the Closure Section 9.0 and are to be read in conjunction with the remainder of this report.

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LIST OF ACRONYMS AND UNITS

Acronym/Unit	Definition
µg/L	microgram per litre
µS/cm	micro Siemens per centimetre
ACOA	Atlantic Canada Opportunities Agency
AMA	Argentia Management Authority
BTEX	Benzene, toluene, ethylbenzene and toluenes
CBR	California Bearing Ratio Test
CCV-DSS	consolidated constant volume direct simple shear test
CD	Chart Datum
CGS	Concrete gravity structure
CIU	consolidated undrained triaxial compression test
cm	centimetres
C-NLOPB	Canada-Newfoundland Offshore Petroleum Board
CoCs	chemicals of concern
ESA	Environmental Site Assessment
HHERA	Human Health and Ecological Risk Assessment
i	horizontal hydraulic gradient
Igpm	imperial gallons per minute
K	hydraulic conductivity
L/min	litres per minute
m	metre
m/day	metres per day
m/s	metres per second
m2	square metre
m2/day	square metres per day
m3	cubic metre
m3/day	cubic metre per day
m3/year	cubic metre per year

masl	metres above sea level
mbgs	metres below ground surface
mbgs	metres below ground surface
mg/L	milligram per litre
mm	millimetre
MOE	Ontario Ministry of the Environment
n	effective porosity
NAVFAC	United States Naval Facility
NB77	Northside Building 77
NBFF	Northside Bulk Fuel Farm
NFSA	Northside Fuel Storage Area
NFSB	Northside Fuel Storage and Buildings
NFTA/ACRP/NSSP	Northside Salvage Yard, Fire Training Area and Road near the Pond
NLFB	Northside Landfill B
NOAS	Northside Old Arena Site
NSRF	Northside Ship Repair Facility
NYDB	Northside Yard Dump and Building 606
OW	observation wells
PAH	Polycyclic aromatic hydrocarbon
PCBs	Polychlorinated biphenyls
PIRI	Partnership in RBCA Implementation
ppt	parts per thousand
PVC	Polyvinyl chloride
PW	pumping well
PWGSC	Public Works and Government Services Canada
RBCA	Risk-based Corrective Action
ROI	Radius of Influence
SVOC	Semi-volatile organic compounds
T	transmissivity
TDS	total dissolved solids
TPH	Total petroleum hydrocarbon
Usgpm	United States gallon per minute
VOC	Volatile organic compound
WREP	White Rose Extension Project

1.0 INTRODUCTION

Acting at the request of Husky Energy (Husky), Stantec Consulting Ltd. (Stantec) carried out a baseline hydrogeological characterization of the proposed Concrete Gravity Structure (CGS) graving dock site in Argentia, Newfoundland and Labrador (NL), herein referred to as the "site" (Drawing No. 121412512-EE-01 in Appendix A). A hydrogeological characterization was required to gain a better understanding of the hydrogeological conditions at the proposed CGS graving dock site, and in particular to provide information on potential impacts to groundwater quality and quantity in the site area related to the construction and operation of the graving dock facility.

This site characterization is based primarily on information obtained from several previous studies conducted by Stantec and others, including a detailed geotechnical borehole drilling program (Golder, 2012, a & b) and a water well drilling and hydraulic testing program (Stantec, 2013). Relevant geological and hydrogeological information from publically-available mapping and from other consulting and Public Works Government Services Canada (PWGSC) studies completed in the immediate area were researched, and integrated into this assessment.

1.1 Site Description & Project Overview

The proposed CGS graving dock site is located in the northeast portion of the Argentia Northside peninsula, as shown on Drawing Nos. 121412512-EE-01 and -EE-02 in Appendix A. The Northside peninsula is a roughly triangular-shaped low-lying peninsula that is surrounded on all sides by the ocean, and is connected to the mainland by a narrow isthmus at the south end in the area of Sandy Cove. The site is bordered to the north, west and south by vacant land and to the east by the waters of Argentia Harbour. Access to the site is via Provincial Highway Route 100, which ends at the Marine Atlantic Ferry Terminal at the south end of the peninsula, followed by a series of paved and gravel roads on the peninsula remaining from historical operations.

The approximately 20 hectares of land comprising the site is currently owned by the Argentia Management Authority (AMA), and is under lease to Husky for the proposed construction of a graving dock to be used for the construction of a Concrete Gravity Structure for the White Rose Extension Project. Based on information provided by Husky, the graving dock will measure approximately 153.5m x 153.5 m at the floor, and will be excavated behind a natural coastal berm to a depth of approximately -18mCD. A cut-off wall, approximately 900 mm thick, will be constructed to minimize the ingress of water into the graving dock. The wall is designed with a permeability of 10^{-8} m/s to a depth of -28 mCD at the sea bund side, and will continue landwards approximately half way around the sidewalls and to a depth of -10 mCD. The graving dock construction site plan is provided in Drawing No. 121412512-EE-03 in Appendix A, and shows the layout of the proposed graving dock facility and associated site infrastructure.

1.2 Background & Historical Contamination

The Northside peninsula was formerly part of a United States Naval Facility (NAVFAC) that was constructed during the Second World War and occupied until 1994. The Northside peninsula was the site of the airport, main dock facilities and main fuel storage for the NAVFAC. The proposed CGS graving dock site overlies the southwest portion of the former Bulk Fuel Tank Farm area, known as the Northside Fuel Storage Area (NFSA) (see Drawing No. 121412512-EE-02 in Appendix A). The southwest portion of NFSA contained barracks and recreational buildings for enlisted personnel, as well as numerous warehouses, aircraft maintenance hangars, and general support and administration buildings. The NAVFAC Argentia property officially closed in October 1994, and the facility was reverted to the Government of Canada. At this time Public Works and Government Services Canada (PWGSC), as custodians for the Crown, assumed ownership and administrative control of the property. In 2001, PWGSC transferred the Government of Canada property in Argentia to the Argentia Management Authority (AMA), a group established in 1995 by the Atlantic Canada Opportunities Agency (ACOA) to redevelop the former base.

Property-wide environmental investigations of the former NAVFAC were carried out under the direction of PWGSC from 1993 to 1995, and included Phase I through Phase IV Environmental Site Assessments (ESAs) and human health and ecological risk assessments (HHERA). These studies identified various contaminated sites on the Argentia Northside Peninsula due to former military operations and waste disposal activities. During the environmental investigations, the contaminated sites were given letter codes (e.g., NFSA) based on the local site names used formerly at the Argentia NAVFAC property. These letter codes were used by PWGSC in naming the monitoring wells, and are referred to in this report. For reference, the contaminated sites within the study area are labeled along with their corresponding letter codes on Drawing No. 121412512-EE-02 in Appendix A (Dillon Consulting Ltd., 2010).

Results of the ESAs and HHRAs carried out by PWGSC from 1993 to 1995 identified eleven (11) Northside sites as “areas of environmental concern” containing unacceptable risks based on observed levels of contaminants (primarily in soils). These included:

- Northside Fuel Storage Area (NFSA);
- Northside Bulk Fuel Farm (NBFF);
- Northside Salvage Yard, Fire Training Area and Road near the Pond (NFTA/ACRP/NSSP);
- Northside Yard Dump and Building 606 (NYDB);
- Northside Landfill B (NLFB);
- Northside Building 77 (NB77);
- Northside Fuel Storage and Buildings (NFSB);
- Northside Old Arena Site (NOAS); and,
- Northside Ship Repair Facility (NSRF).

The principal contaminant types identified in soil at these sites was petroleum hydrocarbons, and to a lesser extent metals, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). Site remediation involving tank and pipeline removal, excavation, product removal, containment, and capping was undertaken from 1998 to 2010 at these sites. In particular, a large-scale soil remediation program was completed at the NFSA from 2005 to 2007 involving aeration/land-farming of approximately 175,000 m^3 of petroleum hydrocarbon-impacted soil. With respect to groundwater, results of the risk assessments concluded that, with the exception of petroleum hydrocarbons, no other chemicals of concern detected in groundwater at the Argentia sites posed a significant human health or ecological risk based on the specific land use scenario assumed for each site (i.e., residential, commercial/industrial and limited land use).

A long-term groundwater-monitoring program at the Argentia property was initiated by PWGSC in 1997 to monitor changes in groundwater quality associated with various site remediation activities. Details pertaining to long-term groundwater monitoring at the Argentia property are discussed further in Section 4 of this report.

1.3 Study Objectives and Scope

The objective of this report is to characterize the hydrogeology of the CGS graving dock site area. This information is derived from previous studies, and on-going geotechnical and hydrogeological investigations at the site.

1.4 Assessment Limitations

Because work is underway at the site, the information presented herein is limited to site specific and historical data available at the time of writing. It is anticipated that a second aquifer testing program currently underway at a test well, PW2, located in the seaward portion of the site will augment the data obtained from hydraulic testing of test well PW1 completed in January – February, 2013, and reported herein.

1.5 Report Structure

The report is laid out in 5 sections. Section 1 describes the Project and study objectives, and provides various background information about the site. Section 2 describes the methods and procedures utilized in the collection and interpretation of relevant information. Section 3 provides a baseline interpretation of the hydrogeological conditions in the vicinity of the CGS graving dock site. Section 4 discusses environmental issues associated with the Project. Section 5 summarizes relevant conclusions, and Section 6 provides general recommendations for the collection of site-specific hydrogeological information going forward.

2.0 FIELD PROGRAMS

The following sections summarize the work completed in 2011 and 2012 at the CGS graving dock site. Further information and a detailed interpretation of hydrogeological conditions are provided in Stantec (2013).

2.1 Previous Work

In June 2011, Stantec was retained by Husky to provide geotechnical and environmental engineering services related to the development of a Concrete Gravity Structure graving dock at the former NAVFAC Base in Argentia. The purpose of the work was to review the geotechnical and environmental conditions (i.e., environmental contamination) at two sites in Argentia identified by Husky, and to provide an interpretation regarding the conditions for each site in aid of final site selection. Stage I of this work involved a desktop review of available data for the two proposed sites, including Site A, located in the general vicinity of the current site on the Northside Peninsula, and Site B located on the southside of Argentia. This work included an overview of previous geotechnical and environmental investigations, identification of data gaps in the current knowledge of subsurface conditions, and recommendations for additional field investigation to further characterize the geotechnical and environmental conditions at the two proposed sites. The Stage I work is detailed in Stantec Report No. 121413435 "*GBS Site Selection Study Stage I – Desktop Review, Argentia, NL*" dated October 11, 2011. Stage 2 of this work involved a geotechnical and environmental site investigation comprised of borehole drilling, soil sampling, monitor well installation and water quality sampling, and was carried out from November 2011 to January 2012. The results of the Stage 2 investigation are detailed in Stantec Report No. 121613435 "*Geotechnical and Environmental Services Stage 2 - Geotechnical / Environmental Site Investigation, Proposed GBS Construction Site, Argentia, NL*" dated March 23, 2012, and additional environmental investigation to delineate the extent of petroleum hydrocarbon impacted soil identified during the Stage 2 geotechnical and environmental investigation in March 2012 is detailed in Stantec report No. 121613435 "*Phase II Environmental Site Assessment, Site A, Proposed GBS Construction Site Argentia, NL*" dated April 5, 2012.

In September 2012, a test pit excavation and soil sampling program was carried out at a new proposed location for the CGS graving dock site to assess environmental conditions at the site to determine what, if any, environmental impacts exist. The current location for the CGS graving dock site is located immediately south of former Site A. The results of the 2012 test pit program are detailed in Stantec Draft Report No. 121613435 "*Test Pit Program, Revised Concrete Gravity Structure Casting Basin Site Argentia, NL*" dated November 1, 2012.

The September 2012 test pit program consisted of excavation of ten (10) test pits with related soil sampling at locations distributed to provide full coverage across the site. The test pits were excavated to the groundwater table and terminated at depths ranging from between 3.5 m below ground surface (mbgs) to 6.0 mbgs. Soil samples were collected from each test pit and analyzed for petroleum hydrocarbon indicator parameters, including benzene, toluene, ethylbenzene, and xylenes (BTEX), and total petroleum hydrocarbons (TPH), as well as

polychlorinated biphenols (PCBs), polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), metals, and dioxins/furans. Results of the investigation indicated no free phase petroleum hydrocarbon product or other field evidence of impacts in any of the test pits, and concentrations of petroleum hydrocarbons, PCBs, VOCs, metals, dioxins/furans and PAHs were either non-detect or detected at levels below the applicable assessment criteria in the soil samples analyzed.

In the Fall 2012, Husky Energy commissioned geotechnical, and hydrogeological site investigations in support of design and development of the graving dock site (Golder, 2012 a & b, and Stantec, 2013). These investigations are summarized below.

2.2 Geotechnical Borehole Drilling and Testing

From October 9 to November 24, 2012, Golder Associates oversaw the drilling of nine (9) geotechnical boreholes (i.e., BHA6 to BHA10, and BHA12 to BHA15) completed as monitor wells. Details regarding the drilling of these geotechnical boreholes are provided in Golder (2012a), along with borehole logs presenting subsurface conditions encountered at the borehole locations, as well as specific monitor well construction details. Table C.1 in Appendix C summarizes the borehole and monitor well construction details. The locations of geotechnical boreholes completed as part of Golder's 2012 geotechnical program are shown on Drawing No. 121412512-EE-03 in Appendix A. The geotechnical boreholes were advanced using sonic drilling techniques, and with the exception of BHA6 (26 m deep), were advanced to an average depth of 41.2 m below ground surface (mbgs). The boreholes were 203 mm (8") in diameter, and each was instrumented with a 51 mm diameter PVC monitoring well with No. 10 slot casing screened over the bottom 3.0 to 6.1 m.

A program of geotechnical laboratory testing of numerous sonic core (bag samples) and 5 Shelby tube samples was performed by Golders Associates Ltd. (Golders, 2013) using the Golders, Gemtec, TerrAtlantic and Maxxam laboratories. Geotechnical testing included: 52 Atterberg limits, 51 water contents, 11 bulk and dry densities, 110 grain size analyses (including 51 hydrometer tests), 9 particle size tests on 9 subsamples taken from the Shelby tube samples. Chemical testing included: 3 sulphate ion concentration tests, 3 pH tests. Mechanical behavior and strength testing included: 13 standard proctor density tests, 7 California bearing ratio (CBR) tests 6 consolidated undrained triaxial compression (CIU) tests and 6 consolidated constant volume direct simple shear (CCV-DSS) tests. The results were used to characterize the geotechnical properties of the materials at the site.

2.3 Observation Well Construction

A total of nine observation wells (OW) were drilled and completed as monitor wells by Golder Associates between November 24 and December 21, 2012 for use during the hydrogeological investigation. Details regarding the drilling of these observation wells are provided in Golder (2012a), along with borehole logs presenting subsurface conditions encountered at the borehole locations, as well as specific monitor well construction details. Table C.1 in Appendix C summarizes the borehole and monitor well construction details. The locations of the observation wells completed as part of Golder's 2012 geotechnical program are shown on

Drawing No. 121412512-EE-03 in Appendix A. Two well depths were installed, including six (6) wells (OW1, 3, 4, 5, 9 and 10) to an average depth of 21.3 m to monitor conditions near the base of the proposed excavation, and three (3) wells (OW6, 7 and 8) to an average depth of 41.1 m to monitor conditions below the CGS graving dock excavation and supplement the geotechnical borehole wells. With the exception of OW6 (6.1 m screen), each well was constructed with 51 mm diameter, fully-penetrating, No. 10 Slot PVC screens ranging in depth from 18.2 m to 22.9 m, set in silica sand packs in the 200 mm diameter boreholes.

2.4 Test Well PW1 Well Construction

The test well (PW1) was constructed between January 3 and 16, 2013 by P. Sullivan and Sons Ltd. of Paradise, NL. Test well PW1 is located towards the center of the graving dock approximately 60 m southeast of the northwest limit of the proposed excavation (Drawing No. 121412512-EE-03 in Appendix A). The borehole logs for nearby boreholes OW1, OW3, OW4 and OW5 were used to select a suitable screen for test well PW1. Based on the alternating fine to coarse grained strata, a screen slot size of No. 40 (0.040 inch) was selected to minimize the degree of borehole development needed to render the screen hydraulically efficient in alternating strata.

The construction details for well PW1 including depths and stratigraphic information recorded during drilling are provided in the Borehole Record in Appendix B. The borehole was drilled using a direct rotary drilling method with combined Symmetrix casing advancement systems to advance a 300 mm diameter steel well casing to a total depth of 24.3 mbgs. The aquifer materials within the casing were expelled as the casing was advanced, which provided a good check on expected stratigraphy. Once the casing had been advanced to 24.3 m depth, water and air were circulated to ensure that all residual material was removed.

A 200 mm diameter well screen assembly was welded together on surface and lowered down the borehole inside the 300 mm diameter casing. The well assembly included a 6.5 m long section of 200 mm diameter Johnson wire-wrapped stainless steel well screen with No. 40 slot (0.040 inch openings) set from 1.6 m to 19.8 m depth. Based on the finer grained material encountered in the lower section of the borehole, a 4.5 m length of solid well casing was set from 19.8 m to 24.3 m depth to limit the well screen to the coarser grain material. Once the well screen assembly was lowered in place, a filter pack comprised of No. 2 silica sand was installed in the annular space between the outside 300 mm casing and the 200 mm diameter well screen assembly in approximately 6 m sections. Following the installation of each filter pack section, the outside casing was retracted approximately 5 m to expose the filter pack to the natural sand material and allow the filter pack to settle. The upper 200 mm casing was grouted from the surface to approximately 1.2 mbgs.

The well screen was developed over a period of approximately 34 hours using a combination of surging and air lift pumping techniques.

2.5 Baseline Tidal Monitoring

On December 19, 2012, Stantec initiated a baseline tidal influence monitoring program at the site. This program was carried out to evaluate whether the groundwater system at the site was tidally influenced, and to determine preliminary estimates of the tidal response parameters for each affected well for use in detrending the tidal influence on hydraulic response data collected during subsequent aquifer testing programs.

Water levels were monitored using HOBO U20-001-02 water level loggers (Onset, Cape Cod, MA) with initial reference measurements collected using a Solinst Model 101 Water Level Meter. A total of ten (10) loggers were deployed, including eight (8) loggers in observation wells (i.e., OW1, OW8, OW9, OW10, BHA1, BHA7, BHA8 and BHA14) to record water levels and one (1) logger in observation well OW7 to record atmospheric pressure. Loggers were initially set to collect measurements at 30 min intervals. In addition, tidal water level data was obtained through the Canadian Hydrographic Service, Fisheries and Oceans Canada, Atlantic Tidal Water Level Network, which operates a tide gauge in Argentia, NL. On January 7, 2013, one (1) additional logger was installed in observation well BHA10.

Loggers were downloaded regularly throughout the water level monitoring program and water levels were verified at the time of downloading by collecting manual measurements using a water level meter.

Based on results, tidal influences were observed on groundwater levels in the majority of wells monitored across the site, with the exception of OW1, which is suspected to be damaged/blocked. In the wells where tidal effects were identified, groundwater levels fluctuated in an oscillatory pattern with the tides at amplitudes ranging from approximately 2 cm in well OW9 (i.e., approximately 1% tidal efficiency) up to 30 cm in borehole BHA8 (i.e., 15% tidal efficiency).

The tidal influence data collected from OW8, OW9, OW10, BHA7, and BHA8 during the baseline monitoring program, as well as subsequent baseline tidal data collected from PW1, OW1, OW3, OW4, OW5, and BHA10 was used in conjunction with a detrending program developed by the U.S. Geological Survey (Halford, 2006) to correct the time-drawdown data collected during aquifer testing of well PW1.

2.6 Water Level Monitoring

A continuous record of water levels was collected using data loggers from ten (10) monitor well locations at the site between December 19, 2012 and several days after completion of the PW1 pumping test. The background levels were collected at a 30 minute interval; the pumping test data were collected at a one minute interval.

2.7 Grain Size Analysis

Numerous soil samples were collected throughout the CGS graving dock site during Golder's 2012 geotechnical program. The distribution of grain size was used by Stantec to infer the

order of magnitude hydraulic conductivity of the unconsolidated material at the site. A summary of hydraulic conductivity (K) values derived from the grain size analysis is provided on Table C.4 in Appendix C. Based on 71 grain size analysis, a wide range of hydraulic conductivity is indicated for the saturated sediments at this site, ranging from 4.0E-11 m/s for clay dominated materials to 2.1E-01 m/s for clean gravel, with a geometric mean K of 9.6E-6 m/s, median 2.9E-05 cm/s. The majority of the values (19) fall between K = 1E-04 m/s and 1E-03 m/s.

2.8 Slug Test Analysis

Estimates of hydraulic conductivity were determined based on analysis of slug tests (rising/falling head) completed as part of Golder's 2012 geotechnical program. An analysis of a total of 16 rising head and falling head slug tests was carried out using a variety of methods applicable for confined/unconfined aquifers, including the Bouwer-Rice and KGS (Kanzas Geological Survey model, Hyder, et. A., 1994) methods with the aid of the computer program AQTESOLV® Version 4.50.002 (HydroSOLVE Inc., Reston, VA). Table C.5 in Appendix C provides a summary of hydraulic conductivity (K) or radial (horizontal) hydraulic conductivity (K_r) values based on analysis of slug test. A wide range of hydraulic conductivity is indicated for the saturated soils at this site, ranging from 8.1E-08 m/s (OW10) to 1.8E-4 m/s (BHA13 in gravelly sand), with a geometric mean K of 5.8E-6 m/s.

2.9 Aquifer Testing

A step drawdown test and two short term tests at higher pumping rates (i.e., Pump Test A at 204 minute duration and Pump Test B at 60 minute duration) were performed on PW1 between January 18, 2012 and February 8, 2013. Based on this testing, a 58.2 hour constant rate pumping test was performed on PW1 at a pumping rate of 454 L/min (120 USgpm) January 17 and February 8, 2013. The goal was to implement a 96 hour test, but the pump failed after 58.2 hours. The testing was performed by P. Sullivan and Sons Ltd. under the direction of Stantec. The pumping test details are described in Stantec, 2013.

Water level measurements were monitored in the pumping well and ten (10) adjacent observation wells (OW1, OW3, OW4, OW5, OW8, OW9, OW10, BHA7, BHA8 and BHA10) located 16 m to 168 m from the pumping well. Recovery measurements were recorded in all wells following cessation of pumping for up to 4.5 days using data loggers.

2.9.1 Step Test

A step drawdown pumping test was completed in test well PW1 on January 18, 2013 using a Goulds Pumps 18GS30 68 L/min (18 USgpm) submersible pump. Testing involved pumping the well at incrementally higher pumping rates of 42 L/min (11.1 USgpm) to 163 L/min (43.1 USgpm) over four (4) 60 minute steps. Subsequent short term tests were performed with larger pumps at rates of 404 L/min (107 USgpm) for 204 min duration (i.e., Pump Test A), and 530 L/min (140 USgpm) for 60 minute duration (i.e., Pump Test B). Table C.2 in Appendix C summarizes the step drawdown pumping test results. The 60 minute pumping period responses for the short term tests (i.e., Pump Test A & B), and the 58 hour constant rate test are also included, for comparison. Plots of drawdown versus time for the step drawdown test,

and short term Pump Test A and Pump Test B are shown in Figures A.1 to A.3 in Appendix A, respectively.

2.9.2 Constant Rate Pumping Test

A 58.2 hour constant rate pumping test was carried out in well PW1 between February 6, 2013 (12:05 pm) and February 8, 2013 (10:20 pm) at a rate of 454 L/min (120 USgpm). Water level measurements were recorded at pre-determined time intervals in the pumping well and ten (10) adjacent observation wells (OW1, OW3, OW4, OW5, OW8, OW9, OW10, BHA7, BHA8 and BHA10) located 16 m to 168 m from the pumping well. Following cessation of pumping at 58.2 hours due to a generator malfunction, recovery measurements were recorded in all wells for up to 4.5 days using data loggers.

The constant rate pumping test data was analyzed using a variety of methods applicable for confined/unconfined aquifers, including the Cooper-Jacob, Theis, and Residual Recovery (Theis and Jacob) methods, with the aid of the computer program AQTESOLV® Version 4.50.002 (HydroSOLVE Inc., Reston, VA). Table C.3 in Appendix C provides a summary of transmissivity (T) values based on analysis of the 58.2 hour constant rate pumping test data from PW1. Estimates of T based on analysis of time-drawdown data collected during the short-term constant rate pump test Pump Test A and Pump Test B are also provided.

2.10 Groundwater Quality Sampling

Water quality monitoring included field measurements of temperature, conductivity and salinity during the step drawdown and constant rate pumping tests to detect any changes in water quality indicative of seawater intrusion. Measurements were made from samples of well discharge using a YSI Professional-Plus handheld multi-parameter meter.

In addition, groundwater chemistry samples were collected from test well PW1 on February 9, 2013 following cessation of pumping, and baseline water samples were collected from observation wells OW1, OW8 and OW10 on December 19, 2012 during deployment of the data loggers. Prior to groundwater sampling, each well was purged by removing a minimum of three well volumes of water. The samples were collected into clean plastic bottles and were delivered to the Maxxam Analytics Inc. laboratory in Bedford, NS for chemical analysis. Groundwater samples were analyzed for general chemistry, as well as various chemicals of concern (COCs) detected in groundwater during historical groundwater monitoring in the site area, including petroleum hydrocarbons, dissolved metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs). In addition, previous results of groundwater sampling from former monitor well BH-A1 are also used herein to characterize baseline groundwater conditions at the site.

3.0 HYDROGEOLOGICAL CHARACTERIZATION

3.1 Climate

The Argentia area is located within the Maritime Barrens ecoregion which extends from the east to the west coast of Newfoundland along the south-central portion of the Island. This ecoregion has the coldest summers of the province, with frequent fog, strong winds and relatively mild winters. July and August are traditionally the warmest months, and January and February the coldest. Based on recent Canadian Climate Data for Argentia from 2004 to 2006, the mean annual precipitation is 1,134 mm (Environment Canada, 2012).

3.2 Topography and Drainage

Based on a review of topographic maps, the site is located on a low-lying (Northside) peninsula surrounded by Argentia Harbour to the east and Placentia Bay to the north and west. This physiographic region is characterized by very low relief and elevations ranging from 16 masl in the vicinity of the main runway to sea level, with a gentle slope from southwest to northeast. Elevations in the vicinity of the CGS graving dock site range from 4.27 mCD at BHA14 near the coastline south of the site to 11.7 mCD at OW1 in the northwestern portion of the site (Drawing No. 121412512-EE-03 in Appendix A). Note the elevation datum used during the current project is Chart Datum (CD), which based on information provided by Husky, is approximately -1.373 mean sea level. Existing regional elevation data cited in this report from areas outside the CGS graving dock site are referenced in m above sea level. With respect to the Northside peninsula, the highest elevation is in the vicinity of impacted area NBFF (24 masl), declining towards sea level to the north, east and south.

Most of the peninsula is vegetated with grasses and low shrub. The former runways are paved with asphalt and/or concrete. Large areas of excavation and fill are present due to remediation work on contaminated sites (e.g., NBFF and the NFSA).

3.3 Overburden Geology

The Northside peninsula is characterized as an undulating, landform associated with eroded remnants of a raised marine terrace (Catto & Taylor, 1998). Peat deposits reportedly covered the area prior to development; and peat remains have been identified in low lying depressions along the coastline and near site NLFB during previous intrusive investigations for others by Stantec (as Jacques Whitford Environment Ltd.). Based on a review of surficial geology maps and borehole logs, as well as stratigraphic data obtained during the drilling of well PW1, the overburden material in the site area generally consists of sand and gravel glaciofluvial/marine deposits.

3.3.1 Thickness

Overburden thickness in the site area is expected to exceed 40 m. Drilling during the current program did not encounter bedrock to depths of 41.2 m.

3.3.2 Stratigraphy

The stratigraphy in the site area is very complex, consisting of alternating layers of clay, silty clay, fine to coarse-grained sand, and gravel, with varying percentages of cobbles and boulders. Grain-size analysis (sieve and hydrometer) conducted by Golder (2012b) on select samples of overburden material collected from the geotechnical boreholes indicate that the sand and gravel deposits at the site are typically well-graded with a wide span in grain sizes and have an appreciable fines content (i.e., often greater than 10% silt/clay).

3.3.3 Hydraulic Properties

The hydraulic conductivity of the overburden materials at the site have been assessed using a variety of methods, including statistical evaluation of grain size and hydrometer tests data, rising and falling head slug tests, and constant rate pumping tests using up to 10 observation wells.

Table 3.1 summarizes the range of K values determined from the various methods. More detailed summary tables for grain size, slug test and pumping test K are included in Tables in Appendix C. On a small scale (0.3 to 1.0 m radius), the slug testing and grain size analysis suggests a geometric mean K in the order of 5.8E-06 to 9.6E-06 m/s. The wide range of grain size estimates reflects the type of material (4E-11 m/s for a clay-silt to 2.0E-01 for sandy gravel).

On a larger scale (15 to 168 m radius), results of constant rate pumping tests suggest an aquifer transmissivity in the order of 222 m^2/day, a K in the order of 1.8E-04 m/s, and a coefficient of storage of 4.5E-03. The higher K range in the pumping tests reflects a larger representative volume of aquifer where highly permeable coarse sand and gravel zones can dominate the drawdown response.

Table 3.1 Summary of Hydraulic Conductivity Testing

Source	Range (m/s)	Geomean (m/s)
Sieve Analysis	4.0E-11 to 2.1E-01	9.6E-06
Slug Tests	8.1E-08 to 1.8E-04	5.8E-06
Pumping Tests[1]	1.0E-04 to 3.2E-04	1.8E-04 (PW1 = 1.2E-04)

1 – Divide observation well T by saturated screen thickness.

3.4 Bedrock Geology

The bedrock geology underlying and surrounding the site is reportedly comprised of Pre-Cambrian aged, wavy bedded, gray to green tuffaceous siltstone and arkose (Big Head Formation) belonging to the Musgravetown Group (King, 1988). Bedrock was not encountered in any of the boreholes or test wells in this or historical studies in the Northside area. Based on available geological information, there does not appear to be any significant geological structural features (i.e., faults, folds etc.) in the area immediately surrounding the site.

3.5 Groundwater Flow Conditions

The Northside Peninsula has been the subject of extensive subsurface investigation for over the past 15 years, with over 100 boreholes and groundwater monitoring wells completed at various contaminated sites on the peninsula (Dillon, 2012). In addition, Stantec (as Newfoundland Geosciences Limited (NGL) and Jacques Whitford Limited (JWL)) has carried out several intensive hydrogeological investigations in the Northside area for a variety of clients over the past 20 years, including development of two steady-state numerical groundwater models (NGL 1997, NGL 2003). The following general description of hydrogeological conditions in the Northside area and the CGS graving dock site are derived from this past experience and the current drilling and hydraulic testing programs.

3.5.1 Water Table Depth

A review of monitoring well information both on and off of the site provides a reliable indication of groundwater levels in the area. The groundwater table at the site ranges from 1.0 mbgs at BHA14 to 9.4 mbgs at OW4, averaging 5.5 m across the site (Table C.1 in Appendix C), with elevations ranging from 2.8 to 4.9 mCD. The water level depth is greatest on the up-gradient northeast edge of the graving dock footprint (mean 8.8 m), and shallowest at the southern seaward edge (mean 1.3 m), consistent with the inferred southeasterly groundwater flow direction.

Groundwater elevations increase in a northwesterly direction from the site towards the abandoned runway area which defines the assumed watershed divide on the peninsula. Groundwater elevation in this area is estimated to be approximately 10 m asl (i.e., ~ 11.373mCD).

Annual water table fluctuations are generally small (10 to 20 cm) based on historical monitoring.

3.5.2 Groundwater Flow Directions

Hydrogeologically, the Northside Peninsula is considered to be essentially an oceanic island that is hydraulically isolated from the mainland (e.g., Southside) by saline intrusion. The aquifer is described as an unconfined to leaky freshwater aquifer, the lateral and vertical extent of which is controlled by the surrounding ocean boundary of Placentia Bay. Groundwater recharge is expected to occur throughout the unconfined aquifer, and to move radially from the inferred watershed in the abandoned runway area towards the coastlines. Saline water is expected to occur at depth below this freshwater zone. The thickness of the freshwater “lens” is estimated to be in the order of 120 m below central portion of the peninsula, thinning towards the shorelines.

The dominant direction of groundwater flow at the site is assumed to follow topography, which is towards the southeast and Argentia Harbour. It is expected that the shallow groundwater system in the area will be largely controlled by surface runoff and local recharge, while at moderate depths the flow system may be influenced by seawater intrusion.

Based on Stantec's previous experience in the Northside area, rainwater recharging the peninsula area is expected to recharge vertically downward to the water table, and then flow radially from inferred recharge in the vicinity of the former runways towards discharge points along the coastlines, local wetlands and surface water features.

3.5.3 Horizontal Hydraulic Gradient

Assuming a mean groundwater elevation of 10 m asl in the vicinity of the runways, and essentially 0 m at the seacoast, the horizontal hydraulic gradient across the site is estimated to be in the order of 10 m / 825 m = 0.012 (1.2%).

3.5.4 Vertical Hydraulic Gradient

Historical monitoring in the Northside area suggests a downward vertical hydraulic gradient of 0.003 to 0.008 (0.3 to 0.8%) at monitor well pairs in the vicinity of the runways; upward vertical hydraulic gradients are anticipated near the shore line.

While no monitor well nests are present at the site, a comparison of shallow well OW10 with deep well BHA7 at similar topographic elevation (9.45 mCD and 9.48 mCD) suggests a small upward vertical hydraulic gradient of 0.003 from the deep zone (20 to 40 m depth) to the shallow zone (1.5 to 13.7 m depth), which is consistent with expected groundwater flow patterns. Stronger upward vertical gradients would be expected along the coastline.

3.5.5 Groundwater Velocity Estimates

Groundwater velocity is generally estimated using the Darcy approach (v = Ki/n, where "v" is average linear groundwater velocity, K is hydraulic conductivity, "i" is horizontal hydraulic gradient and "n" is effective porosity. Using a geometric mean K of 5.8E-06 to 1.8E-04 m/s (Table 3.1), a horizontal hydraulic gradient of 0.012 and an effective porosity of 0.25 for the saturated unconsolidated materials, the pre-construction (background) groundwater flow velocity across the site is estimated to be in the order of 0.02 m/day to 0.75 m/day.

3.5.6 Tidal Effect on Groundwater Levels

Tidal monitoring was carried out at the site between December 14, 2012 and January 3, 2013. Historical groundwater level monitoring on the Northside area suggested that tidal influences were restricted to 50 to 100 m from the shoreline. During the current testing, tidal responses ranged from approximately 2 cm in well OW9, a shallow well farthest from the coastline (approximately 1% tidal efficiency) to 30 cm in borehole BHA8, a deep well at a lower elevation (15% tidal efficiency). An average tidal efficiency of 3.5 % was noted for the site (Stantec 2013).

3.6 Groundwater Chemistry

Six manual measurements of temperature, conductivity and salinity during the PW1 pumping test indicted a water temperature range of 5.5 °C to 9.13 °C; relatively consistent conductivity

declining with time of pumping from 463 µS/cm to 429 µS/cm, and low salinity (average 0.33 parts per thousand (ppt), indicative of fresh water quality (Table D.1 in Appendix D).

A total of four (4) water samples were collected from monitoring wells during the current field program. Tables D.2 and D.3, Appendix D summarize the results of general chemistry and metals respectively. Water samples from PW1, OW1 and BHA1 are considered to be representative of the local groundwater chemistry conditions in the vicinity of the site; while the general chemistry of the remaining wells (i.e., OW8 and OW10) are considered to be influenced by drilling with salt water. PW1 is a post pumping sample, collected to evaluate potential changes to groundwater chemistry at the site resulting from pumping. The data for BH A1 is from the previous Stantec 2012 program but is included to characterize groundwater quality at the site, since it is located within the footprint of the graving dock.

Based on groundwater chemistry from PW1, which should exhibit the least bias from saline drilling water (after 58 hours of pumping), the groundwater is generally characterized as a clear, very hard (hardness 215 mg/L), slightly alkaline (190 mg/L, mean pH 8.1), calcium bicarbonate water type of moderate dissolved solids (conductance 520 uS/cm, est. total dissolved solids (TDS) 350 mg/L). Since there are no applicable NL provincial environmental guidelines for general chemistry and metals in groundwater, results are compared to the Ontario Ministry of the Environment (MOE) Soil, Groundwater, and Sediment Standards for Use Under Part XV.1 of the *Environmental Protection Act*: Table 3 - Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition for Industrial/Commercial Property Use, April 2011 (MOE, 2011). All general chemistry and metals parameters in the five (5) groundwater samples collected from the site meet MOE guidelines, where such criteria exist.

With the exception of traces (3 to 5 µg/L) of toluene in OW1 and PW1, no BTEX or total petroleum hydrocarbon was detected (Table D4 in Appendix D). Low level TPH in the C10 to C18 range was detected at OW8 and OW10 (i.e., 0.065 mg/L and 0.071 mg/L, respectively); however, no resemblance to petroleum hydrocarbons was noted. All parameters met respective Atlantic PIRI Tier I guidelines for petroleum hydrocarbon impacts in groundwater on a commercial/industrial site.

With the exception of toluene, no VOC compounds were detected (Table D.5, Appendix D). With the exception of a trace (0.024 µg/L) of phenanthrene at OW10 that is well below the 580 µg/L OMOE Guideline, no SVOCs were detected in PW1 (Table D.6, Appendix D). No PCBS were detected in any of the wells (Table D.7, Appendix D).

The general chemistry and field monitoring during the PW1 pumping test indicates no evidence of saline intrusion during the 58.4 hour pumping test period.

3.7 Groundwater Recharge & Discharge

Groundwater recharged by precipitation is expected to recharge freely into the unconfined sand and gravel aquifer over the entire peninsula, except in areas covered by runway, tarmac or buildings, which would promote direct runoff to the sea (assumed to be 20% of the land mass). Based on numerical modeling previously completed in the region, a preliminary estimate of

groundwater recharge (baseflow) discharging to the marine environment is about 640 m^3/day (233,600 m^3/year), which suggests a groundwater recharge rate of 5% based on 1,134 mm/year and the estimated total 400 hectare area of the Northside Peninsula (i.e., 4,536,000 m^3/yr).

Dewatering activities during construction and operation of the CGS graving dock site is expected to divert a considerable percentage of the natural discharge from the northeast area.

4.0 POTENTIAL ENVIRONMENTAL ISSUES

4.1 Saline Intrusion

While the sea water boundary is located only 45 m from the southern edge of the graving dock site (Drawing Nos. 121412512-EE-02 and 121412512-EE-03 in Appendix A), monitoring during the 58 hours of pumping at 120 USgpm indicated little evidence of saline intrusion. A review of the water levels during the 58.2 hours of pumping indicates a maximum drawdown to -1.94 mCD at PW1 (or -3.31 masl); while all the observation wells were generally at or above mean sea level (i.e., 1.2 mCD (-0.17 masl) to 4.5 mCD (3.13 masl)). The monitoring and post pumping chemistry are consistent with fresh groundwater.

While no saline intrusion occurred at the 454 L/min pumping rate, sustained pumping at much higher rates needed to dewater the graving dock to an average -18mCD may result in some degree of saline intrusion proportional to the ratio of fresh water capture and sea water capture.

4.1.1 Estimated Distance Drawdown & Radius of Influence

Using the mean transmissivity (222.7 m^2/d) and storage coefficient (4.5E-03) from the hydraulic testing of PW1, the potential drawdown interference can be predicted at various distances from the site for a variety of pumping times and pumping rates using the modified Cooper-Jacob non-equilibrium method (Cooper et al, 1946). Table C.6 (Appendix C) summarizes predicted 100 day distance drawdown for one or more wells pumping at rates between 454.6 L/min (100 Igpm) and 9,092 L/min (2,000 Igpm) (multiple wells). A 100-day time frame is selected as this is typical of seasonal minimum (extreme dry summer) and maximum (extreme wet spring or fall) recharge conditions. Drawdown at distances up to 2,000 m from the center of the CGS graving dock site is predicted. It should be noted that the theoretical estimates of distance-drawdown provided herein assume a simplified conceptual groundwater flow model throughout the Northside peninsula, with consistent aquifer hydraulic properties similar to that identified in PW1, and should be regarded as first-order estimates only. It is our understanding that detailed analysis of dewatering design and pumping requirements will be done by others.

Using the observed groundwater elevations (Table C.1, Appendix C), and assuming a graving dock bottom elevation of -18 mCD, the required drawdown will range from 20.9 to 22.0 m, mean 21.3 m throughout the CGS graving dock site area. Theoretical pumping rates that can achieve this degree of drawdown are shown in bold-hatched type in Table C.6 (Appendix C). It is also assumed that the dewatering pumps would be set at least 40 m below grade, resulting

in available drawdowns of 31.0 to 40.0 m, mean 34.5 m. The bold-shaded type in Table C.6 (Appendix C) indicate pumping rates that could reach the pump intake within 100 days.

A number of observations can be made using this simple approach. An order of magnitude pumping requirement of 5,683 to 6,819 L/min (i.e., 1,250 to 1,500 Igpm) is expected to be needed to dewater the graving dock excavation, likely accomplished from multiple screened wells. An initial inference of area of pumping influence of 450 to 500 m was indicated by PW1 pumping at 454 L/min for 2.5 days. Assuming a 1.0 m allowable drawdown in receptor wells, theoretical estimates provided in Table C.6 (Appendix C) suggest 100 day radii of influence (ROI) varying from 400 m at 454 L/min (100 Igpm) to greater than 2,000 m (i.e., the extent of the peninsula) at sustained pumping rates of 2,273 L/min (500 Igpm) or more. Under sustained pumping required to dewater the graving dock to elevation -18 mCD (i.e., minimum of 5,683 L/min), it is estimated that the groundwater table will experience approximately 10 m of drawdown (i.e., approach sea level) in the runway area approximately 600 m northwest of the site, and approximately 5 m of drawdown will occur in the vicinity of the Pond, located approximately 1,300 m northwest of the site. The locations of the predicted 5 m and 10 m drawdown ROI are shown on Drawing No. 121412512-EE-02 in Appendix A).

4.2 Interference with Existing Wells

No residential, commercial or industrial water supply wells are known to be present within the inferred capture areas of the CGS graving dock site. A total of 29 environmental monitor wells distributed among five (5) historical impacted sites (i.e., NBFF, NFSA, NFSB, NLFB, and NOAS as shown on Drawing No. 121412512-EE-02 in Appendix A) are currently included within PWGSC's long term groundwater monitoring network. A number of these monitor wells, particularly the 14 monitor wells at the NSFA, NFSB, and NOAS are located within the predicted 10 m drawdown ROI of the site, and may experience a reduction in water levels or possibly dewatering depending on their construction and screened depth. Since Placentia Bay will act as a recharge boundary, no effects of dewatering activities at the CGS graving dock site are anticipated to occur on the Southside.

4.3 Groundwater-Surface Water Interaction

No significant streams or wetlands are identified within the inferred capture areas of the site. The natural watershed divide (currently in the vicinity of the northwest runway) is expected to shift north and west due to sustained dewatering activities, possibly towards the Pond. The Pond is located 1200 to 1500 m northwest of the site. While preliminary distance drawdown predictions indicate that this area could be affected (3 to 5 m of drawdown), the actual degree of interaction will depend on the permeability of the bottom sediments, and surface drainage conditions. Further work would be required to further assess this.

4.3.1 Conditions below the CGS Graving Dock Excavation

The proposed graving dock will be excavated behind a natural coastal berm to a depth of approximately -18 mCD. A cut-off wall, approximately 900 mm thick, will be constructed to minimize the ingress of water into the graving dock. The wall is designed with a permeability of

10^{-8} m/s to a depth of -28 mCD at the sea bund side, and will continue landwards approximately half way along the sidewalls (i.e., 150 m) and to a depth of -10 mCD.

The aquifer below the graving dock site is anticipated to have the same hydraulic properties as the upper zones that will be excavated. A very small upward vertical hydraulic gradient is present in the vicinity of the site and the adjacent coastline. Once dewatering has reached elevation -18 mCD, the upward gradient on the floor of the graving dock may increase, depending on the cut-off wall design and degree of lateral dewatering away from the excavation. It is anticipated that the seaward gradients will gradually decrease on the northwest, northeast and southwest sides of the graving dock, however, by reason of proximity, the potential gradient from the sea coast to the excavation could be about 42% (e.g., -19.37 m head elevation divided by 45 m distance).

The dewatering design (by others) will address the upward vertical head potential on the seaward floor side of the graving dock.

4.4 Mobilization of Impacted Groundwater from Outlying Areas and Discharge Water Quality

A large amount of groundwater monitoring data is available for the Northside peninsula for a seventeen-year monitoring period extending from 1994 to 2011 that can be used to assess baseline groundwater quality conditions. The most significant source of groundwater monitoring data is the long-term Argentia groundwater monitoring program by PWGSC, which has been carried out on an annual basis since 1997. The long-term PWGSC groundwater monitoring program has included a network of approximately 425 monitoring wells from 13 sites, with monitoring primarily for petroleum hydrocarbons, and to a lesser extent metals, PCBs, PAHs, and VOCs. This sampling network was been reduced significantly as remediation programs have been completed at the sites, and only 29 monitor wells are currently included in the Northside Peninsula monitoring program distributed among five (5) sites (i.e., NBFF, NFSA, NFSB, NLFB, and NOAS). Table 4.1 summarizes the groundwater quality results for each of the five (5) sites based on the most recent PWGSC groundwater monitoring program in 2011 by Dillon Consulting (Dillon, 2012).

Table 4.1 Summary of 2011 Northside Groundwater Monitoring Results

Site	No. Monitor Wells	Chemical Parameter	2011 Monitoring Results
NBFF	6	• Petroleum hydrocarbons	• Concentrations ranging from 0.3 to 35 mg/L. • One sample (NBFF-905-MW) exceeded the provincial discharge criteria of 15 mg/L. • Atlantic PIRI Tier I guideline of 20 mg/L, returning a concentration of 35 mg/L. • No free product identified • Concentrations have shown a decreasing trend over the monitoring period.
NFSA	8	• Petroleum hydrocarbons	• Concentrations ranging from <0.1 to 1.1 mg/L. • All detected concentrations below provincial discharge criteria of 15 mg/L. • No free product identified • Concentrations have shown a decreasing trend over the monitoring period.
NFSB	2	• Petroleum hydrocarbons • PCBs	Petroleum Hydrocarbons • Concentrations ranging from 0.6 to 4.3 mg/L. • All detected concentrations below provincial discharge criteria of 15 mg/L. • No free product identified • Concentrations have shown a decreasing trend over the monitoring period. PCBs • Concentrations ranging from 3.1 to 35 ug/L • No applicable discharge guideline. • Concentrations have shown a decreasing trend over the monitoring period
NLFB	9	• PAHs • Metals	PAHs • Concentrations of total PAHs ranging from 0.04 to 1.7 ug/L. • Concentrations below applicable federal aquatic guidelines • Concentrations have shown a decreasing trend over the monitoring period. Metals • Monitored for lead (Pb) and cadmium (Cd). Concentrations ranging from non-detect to 1.9 ug/L & non-detect to 0.06 ug/L, respectively. • Concentrations below applicable federal aquatic guidelines • Concentrations have shown a decreasing trend over the monitoring period
NOAS	4	• Petroleum hydrocarbons • PCBs • PAHs	Petroleum Hydrocarbons • Concentrations ranging from non-detect to 0.3 mg/L. • All detected concentrations below provincial discharge criteria of 15 mg/L. • No free product identified

Site	No. Monitor Wells	Chemical Parameter	2011 Monitoring Results
			• Concentrations have shown a decreasing trend over the monitoring period. PCBs • Concentrations ranging from 0.002 to 0.005 ug/L • No applicable discharge guideline. • Concentrations have shown a decreasing trend over the monitoring period. PAHs • Concentrations of total PAHs ranging from 0.02 to 1.7 ug/L. • Concentrations below applicable federal aquatic guidelines • Concentrations have shown a decreasing trend over the monitoring period.

Based on long-term groundwater monitoring completed on the Northside peninsula, petroleum hydrocarbons, metals, PCBs, PAHs, and VOCs levels in groundwater have shown an overall decreasing trend over the monitoring period. Most recent groundwater sampling within the study area has indicated non-detectable to low concentrations of these parameters, that overall are below applicable federal and provincial aquatic guidelines, where such criteria exist.

It is anticipated that during the initial stages of the dewatering program, the water quality will be essentially fresh, and the main issues will be silt and sediment control. Based on the reported low levels of petroleum hydrocarbons, PAHs, metals, PCBs and VOCs and the general absence of free product in groundwater at the historical contaminated sites, no significant problems with inducing impacted groundwater into the CGS graving dock site are anticipated. While some low level dissolved parameters could theoretically be induced towards the site under sustained pumping, the large volumes of water produced are expected to afford some degree of dilution. Notwithstanding, monitoring should be considered of sump waters prior to discharge to the receiving environment (assumed to be Placentia Bay).

5.0 SUMMARY OF CONCLUSIONS

5.1 Hydrogeological Properties of CGS Graving Dock Area

Based on a variety of hydraulic testing and statistical analysis techniques, the site area is characterized as an unconfined to leaky, highly stratified unconsolidated aquifer with interbedded silt, clay, fine to coarse-grained sand and gravels in excess of 42 m thick. Based on hydraulic testing of PW1, the aquifer has a geometric mean transmissivity of 222.7 m^2/d, a geometric mean coefficient of storage of 3.5E-03 and a geometric mean hydraulic conductivity of 1.8E-4 m/s. The sediments exhibit a wide range of K from 4E-11 m/s for clay-silt to 2.1E-1 m/s for clean gravel, with a geometric mean in the order of 6E-4 m/s (slug tests) to 9.6E-6 m/s (sieve analysis).

Water levels range in depth from 1.0 to 9.4 mbgs, and are 2.9 to 4.6 mCD. The dominant direction of groundwater flow is southeastward from the vicinity of the main runways to the coastline at an average horizontal hydraulic gradient of 1.2 percent and an average velocity of 0.02 to 0.75 m/day. Small downward vertical hydraulic gradients (<1%) are expected in the vicinity of the Northside runways, and small upward gradients (<1%) are suspected in the vicinity of the CGS graving dock and near the coastline.

5.2 Drawdown Area of influence of CGS Graving Dock Dewatering

Preliminary calculations of drawdown area of influence suggests that drawdown in excess of 1.0 m could occur throughout the northern end of the Northside Peninsula under sustained pumping for dewatering.

5.3 Groundwater Baseline Chemistry

The groundwater quality is characterized as a clear, very hard (hardness 215 mg/L), slightly alkaline (190 mg/L, mean pH 8.1), calcium bicarbonate water type of moderate dissolved solids (conductance 520 uS/cm, est. TDS 350 mg/L). All analyzed parameters meet applicable environmental groundwater guidelines. With the exception of traces of toluene (5 µg/L), phenanthrene (0.024 µg/L) and petroleum hydrocarbons in several wells, no BTEX, TPH, VOCs, PAHs or PCBs were detected during the pumping test program.

5.4 Water Quality Impact Potential from Contaminated Sites

A review of recent monitoring of remediated sites known to occur northeast, northwest and southwest of the site suggests that concentrations of petroleum, PAHs, PCBs, metals, and VOCs continue to decline, and that there does not appear to be any residual major sources of free product in the area. Based on the reported low levels of petroleum hydrocarbons, PAHs, metals, PCBs and VOCs and the general absence of free product in groundwater at the historical contaminated sites, no significant problems with inducing impacted groundwater into the CGS graving dock site are anticipated.

5.5 Impacts to Groundwater Users

No groundwater users are known to be present on the Northside Peninsula. It is assumed all activities are serviced by water pipeline from the mainland. No dewatering impacts are therefore anticipated the Northside. Because the Placentia Bay acts as a recharge boundary, no impacts to well users on the Southside are anticipated.

5.6 Effects on Surface Waters

With the exception of small wetlands, no surface water bodies are present in proximity to the CGS graving dock site. The closest major surface water body, the Pond, is located 1,200 to 1,500 m northwest of the site. While it is possible that the area of drawdown influence of the CGS graving dock could reach the Pond, the degree of interaction would depend on the duration of pumping, the rate of pumping, and the degree of hydraulic isolation of the Pond for

the underlying aquifer (e.g., bottom sediment permeability). No effects are anticipated on surface waters located off the Peninsula.

6.0 GROUNDWATER MONITORING PLAN

6.1 Introduction

As indicated in the White Rose Extension Project Scoping Document (C-NLOPB, 2012), a monitoring strategy is required during the CGS graving dock dewatering and operation stage. This strategy should build on the baseline monitoring work currently on-going, using similar sampling protocols and QA/QC procedures. The following outlines a general framework for a groundwater flow and quality monitoring plan for the CGS graving Dock site based on results of this baseline hydrogeological site characterization.

6.2 CGS Graving Dock Discharge Monitoring Plan

An approximate volume of 1,200,000 m^3 of soil will be excavated from the CGS graving dock and large volumes of groundwater will be discharged from the CGS graving dock sumps as the excavation advances to the design depth elevation of -19m CD. The finished graving dock base will be built back up to -18m CD to allow for a drainage layer.

6.2.1 Monitoring Parameters

A settling pond will be installed as a means of sediment settlement in the discharge system. Routine discharge water quality monitoring will include: conductance (degree of salinity), total suspended solids (TSS), and petroleum hydrocarbon compounds to detect movement of any residual hydrocarbons from up-gradient and adjacent remediated areas. Other chemicals of concern (CoCs) will be analyzed during the early months to confirm absence of specific CoCs.

6.2.2 Monitoring Frequency

Monitoring will be done weekly for the initial phase of CGS graving dock construction until stable conditions are attained. The monitoring frequency for some parameters may decrease to monthly during facility operation; however, routine monitoring of conductivity will be done weekly and ground water levels will be monitored continuously using automated equipment.

6.2.3 Contingency Plan (Flooding)

An emergency response contingency plan will be established as part of the health and safety program to deal with sudden inrushes, extreme rainfall events, major storms (hurricane induced tidal surge) or major pump failures that could result in rapid flooding of the basin. Mitigative actions will include continuous monitoring, provision of spare pumps, back-up power and emergency escape routes.

6.3 Aquifer Monitoring Plan

The CGS graving dock dewatering will result in drawdown in the host aquifer that decreases with distance from the excavation. While preliminary estimates of drawdown extent exceed 2,000 m, the actual degree of drawdown will depend on the mitigative effects of the proposed interception walls. Monitoring of water levels in the aquifer adjacent to and at distance from the excavation also provides a good indication of the effectiveness of dewatering, and progression of hydraulic gradients and water pressure outside of the site.

6.3.1 Key Monitoring Well Locations

Monitor wells should be located immediately outside of the cut-off walls to monitor pressures on the walls; between the CGS graving dock and the coastline, and at distances inland from the site to monitor horizontal hydraulic gradient. Some of the existing BHA series and OW series wells may also be incorporated into the monitoring system. The objective will be to provide continuous surveillance on the configuration of the water table around the site, and vertical hydraulic gradients and pressures below the floor of the CGS graving dock.

In addition to the proximity wells, where possible, existing PWGSC monitor wells will be monitored in outlying areas of the site, particularly in the areas of the inferred water table divide near the runway, and between the runway and the Pond to detect changes in the watershed divide and groundwater flow patterns.

6.3.2 Monitor Well Design

The monitor wells should be conventional schedule 40, flush-threaded PVC pipe and No. 10 or 20 slot screens, similar to that used for the existing monitoring wells. Because the static water levels will be at or below elevation -18 mCD, the close-in perimeter wells should be constructed to depths of -25 to -40 mCD with short screens. At least two multi-level monitor well nests should be present with a shallow (elevation -22 to -25 mCD) screen and a deep (elevation -30 to -40CD) screen to monitor upward vertical hydraulic gradients.

Each new well should be thoroughly developed to render the screen hydraulically efficient, subjected to a falling head/rising head slug test to determine hydraulic conductivity, and surveyed into common datum (top of casing and grade).

6.3.3 Monitoring Procedures

The majority of monitoring wells should be measured at least monthly using an electric water level tape. The depth to water would be added to the cumulative database, and ultimately used to generate long-term water level hydrographs for select wells.

Selected wells should be instrumented with automated water level data loggers, set at reading intervals of 15 minutes to one hour. Cumulative hydrographs generated from monthly download of these data loggers will provide continuous record of water level conditions at key locations around the site.

6.3.4 Monitoring Frequency

A monthly manual water level monitoring frequency is recommended for the initial year of operation. Longer times may be warranted thereafter; depending on project life.

6.3.5 Sampling Parameters

Water quality monitoring in the monitoring wells is not strictly required, unless there is a concern about movement of a contaminant plume from one of the remediated areas. Nonetheless, water quality monitoring will be carried out as part of the project's Environmental Protection Plan (EPP). Because saline intrusion is the most likely water quality change, a quarterly conductivity profile of selected wells may be useful in establishing the fresh-saline water interface around the CGS graving dock site. This is usually done by lowering a SCT probe slowly through the water column and monitoring conductance, temperature and salinity at 1 m intervals.

For areas where petroleum hydrocarbon impacts are suspected, quarterly monitoring for TPH and BTEX parameters can be done using standard sampling protocols established for the adjacent PWGSC monitoring program.

6.3.6 Monitoring Network Maintenance

Monitor wells need little maintenance. The wells should be inspected on an annual basis, and any needed repairs such as casing covers, and flushing should be done.

6.4 Reporting

In order to maintain a consistent, accurate and useful monitoring program, all aspects of the sampling, analysis, and data management will be maintained and trended in a consistent manner so that ground water levels and water quality will be comparable over long time periods. Groundwater Monitoring reports will be prepared and submitted quarterly to the NL Department of Environment and Conservation over the life of the project.

6.4.1 Database Management

A database management system will be established for the CGS graving dock project. This will be populated with the baseline work currently underway, and added to the new monitoring data over the course of the project.

The database will include ground water levels, water chemistry, hydraulic testing works, borehole logs, inventory of relevant documentation and reports, and any other information deemed useful to regulators or Husky consultants who may need to evaluate the data. The databases will include tabular data in a master spreadsheet, specific summary tables generated from the spread sheets, cumulative water level hydrographs for each monitoring well, cumulative hydrochemical trend plots for key indicator compounds (e.g., electrical conductivity), and other outputs.

6.4.2 Monitoring Reporting

All information will be reviewed and interpreted by a qualified subject matter expert. Pending the stipulations of the regulators, these reports will likely form the support documentation for regulatory reports.

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8.0 CLOSURE

This report has been prepared for the sole benefit of Husky Energy. The report may not be relied upon by any other person or entity without the expressed written consent of Stantec Consulting Ltd. and Husky Energy.

Any uses that a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The recommendations and predictions contained in the above report are based solely on the scope of work completed to date, including the aquifer test data obtained during this investigation. While the recommendations and predictions of individual wells and aq uifer performance are based on sound hydrogeological principles, undetected hydraulic conditions may occur which were not apparent from limited duration aquifer tests. Since these could result in variations in predicted water levels over time, it is strongly recommended that wells be closely monitored over the initial year of operation. Any significant deviations from the predicted well performance should be immediately reported to Stantec Consulting Ltd.

This report was prepared by Michael Haverstock, M.Sc., P.Eng. and David MacFarlane, M.Sc., P.Geo. and was reviewed by Carolyn Anstey-Moore, M.A.Sc., M.Sc., P.Geo., and Robert MacLeod, M.Sc., P.Geo. We trust that this report meets your present requirements. If you have any questions or require additional information, please contact our office at your convenience.

Respectfully submitted,

STANTEC CONSULTING LTD.

Michael Haverstock, M.Sc., P.Eng.
Environmental Engineer

Carolyn Anstey-Moore, M.A.Sc., M.Sc., P.Geo.
Associate, Senior Environmental Geoscientist

PROVINCE OF NEWFOUNDLAND AND LABRADOR
PEG Newfoundland and Labrador
PERMIT HOLDER
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To practice Professional Geoscience in Newfoundland and Labrador.
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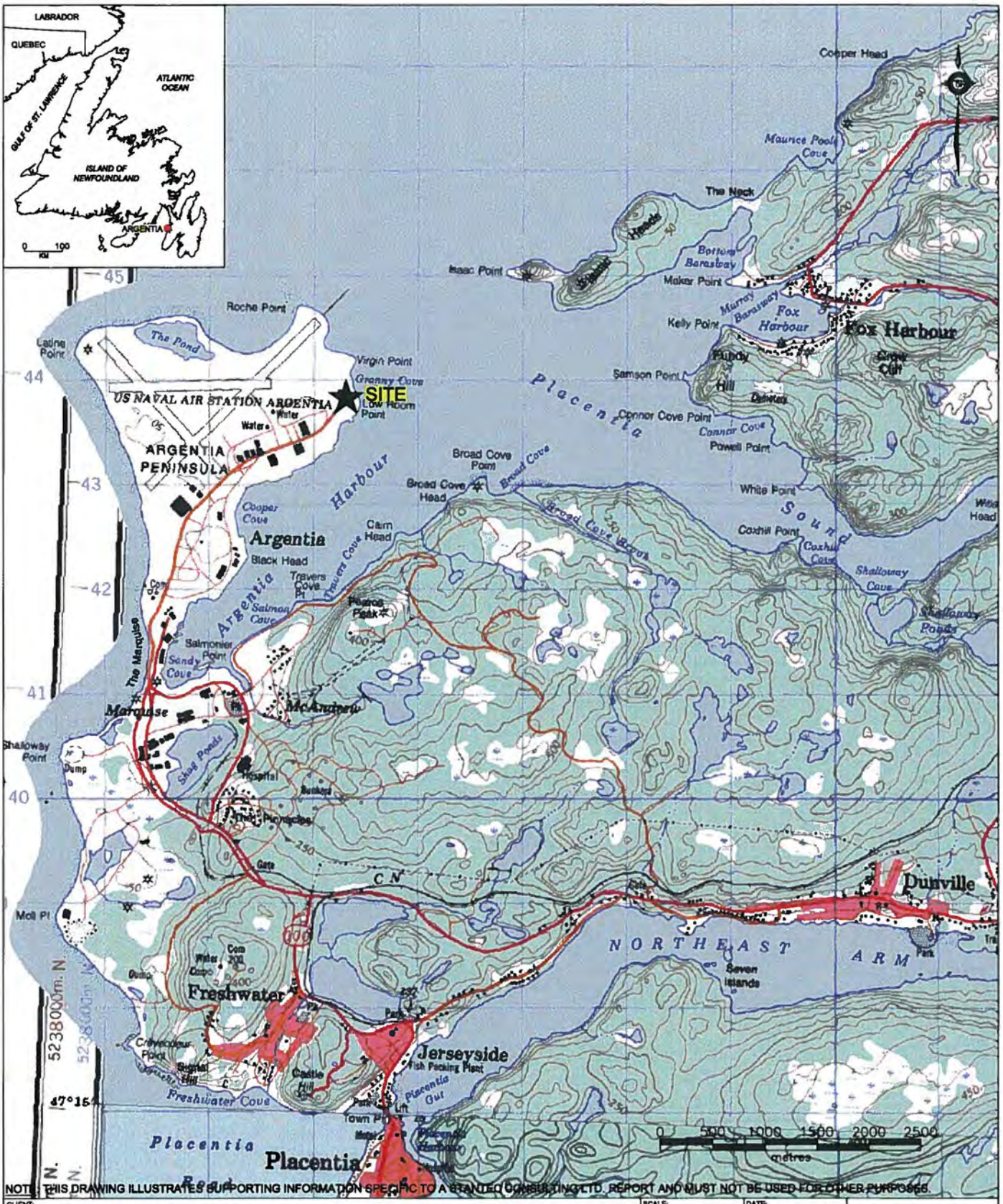
which is valid for the year 2013

REGISTERED PROFESSIONAL GEOSCIENTIST
CAROLYN ANSTEY-MOORE
SIGNATURE
04/10/13
DATE
NEWFOUNDLAND & LABRADOR

APPENDIX A

Drawings & Figures



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	EDITED BY: -	REV. No. 0	
DRAWING TITLE: SITE LOCATION PLAN	DRAWING No: 121412512-EE-01		
	CAD FILE: 121412512-EE-01.DWG		

28MAR13 10:00AM

Abbreviation	Site
ACND	Area of Concern Net Dipping
ACRP	Area of Concern Road Near The Pond
NB77	Northside Building 77
NBFF	Northside Bulk Fuel Farm
NDT1	Northside Day Tank
NFSA	Northside Fuel Storage Area
NFSB	Northside Fuel Storage associated with Buildings
NFTA	Northside Fire Training Area
NFTB	Northside Fire Training Area B
NGS1	Northside Gas Station
NIOT	Northside Irving Oil Tanks
NLFA	Northside Landfill A
NLFB	Northside Landfill B
NMGR	Northside Machine Gun Range
NOAS	Northside Old Arena Site
NQNP	Northside Quarry Near The Pond
NSCP	Northside Concrete Plant
NSRF	Northside Rifle Range
NSRR	Northside Rifle Range
NSSP	Northside Shore Property
NSUB	Northside Unknown Building
NYDB	Northside Yard Dump
PTHP	Pond; The Pond

CLIENT: **Husky Energy**

PROJECT TITLE: **Baseline Hydrological Characterization, Concrete Gravity Structure Graving Dock Site, Argentia, NL**

DRAWING TITLE: **Inferred Regional Groundwater Flow - Argentia Northside Peninsula**

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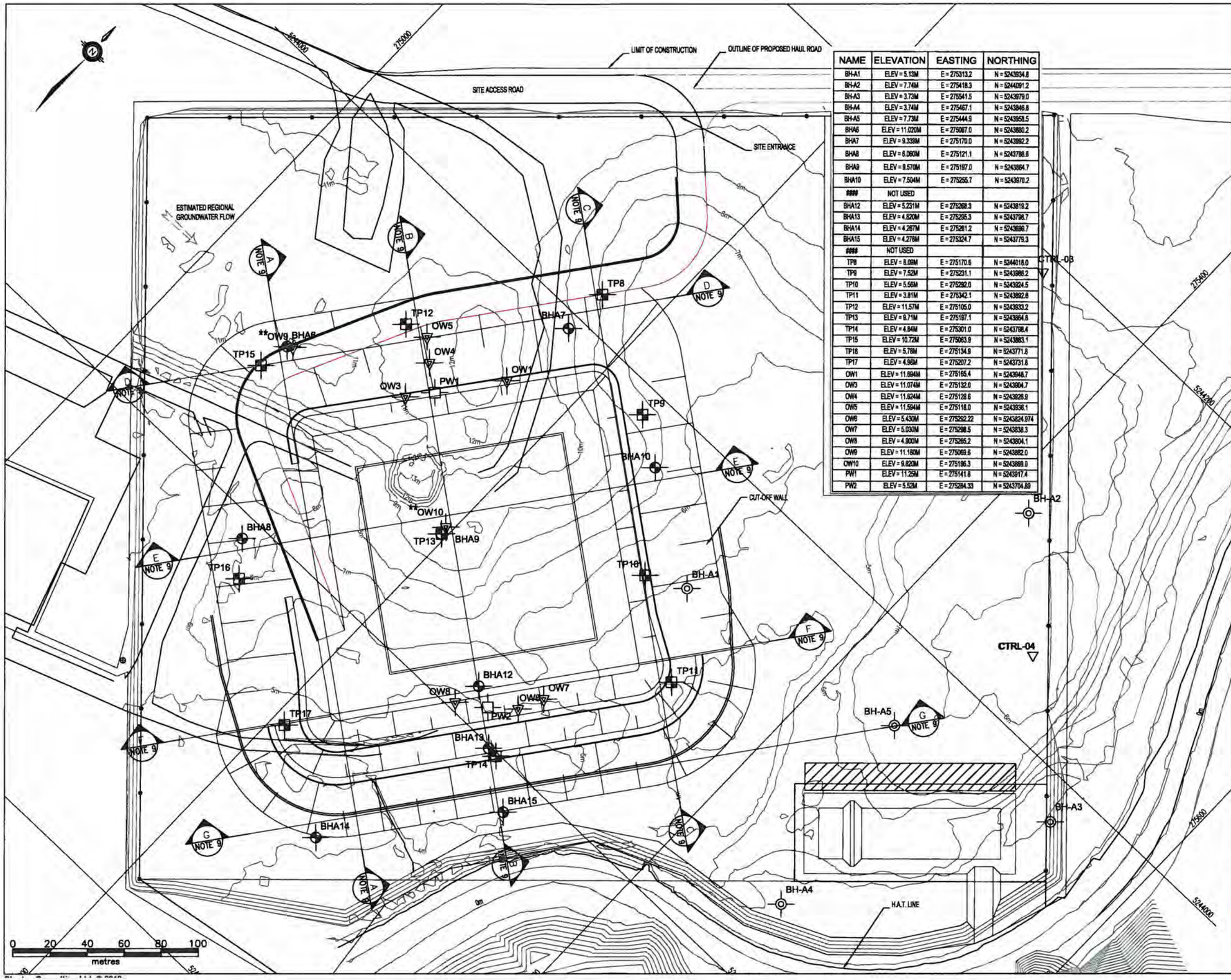
Stantec



NAME	ELEVATION	EASTING	NORTHING
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BH-A2	ELEV = 7.74M	E = 275418.3	N = 5244091.2
BH-A3	ELEV = 3.73M	E = 275541.5	N = 5243979.0
BH-A4	ELEV = 3.74M	E = 275467.1	N = 5243846.8
BH-A5	ELEV = 7.73M	E = 275444.9	N = 5243958.5
BHA6	ELEV = 11.020M	E = 275067.0	N = 5243880.2
BHA7	ELEV = 9.339M	E = 275170.0	N = 5243992.2
BHA8	ELEV = 8.060M	E = 275121.1	N = 5243788.6
BHA9	ELEV = 9.570M	E = 275197.0	N = 5243864.7
BHA10	ELEV = 7.504M	E = 275255.7	N = 5243970.2
####	NOT USED		
BHA12	ELEV = 5.231M	E = 275268.3	N = 5243819.2
BHA13	ELEV = 4.820M	E = 275295.3	N = 5243798.7
BHA14	ELEV = 4.267M	E = 275281.2	N = 5243699.7
BHA15	ELEV = 4.276M	E = 275324.7	N = 5243779.3
####	NOT USED		
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TP9	ELEV = 7.52M	E = 275231.1	N = 5243988.2
TP10	ELEV = 5.56M	E = 275292.0	N = 5243924.5
TP11	ELEV = 3.81M	E = 275342.1	N = 5243892.8
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TP15	ELEV = 10.72M	E = 275063.9	N = 5243883.1
TP16	ELEV = 5.78M	E = 275134.9	N = 5243771.8
TP17	ELEV = 4.96M	E = 275207.2	N = 5243731.8
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OW3	ELEV = 11.074M	E = 275132.0	N = 5243904.7
OW4	ELEV = 11.624M	E = 275128.6	N = 5243926.9
OW5	ELEV = 11.594M	E = 275118.0	N = 5243936.1
OW6	ELEV = 5.430M	E = 275292.22	N = 5243824.974
OW7	ELEV = 5.030M	E = 275298.5	N = 5243838.3
OW8	ELEV = 4.900M	E = 275265.2	N = 5243804.1
OW9	ELEV = 11.180M	E = 275069.6	N = 5243882.0
OW10	ELEV = 9.820M	E = 275196.3	N = 5243869.0
PW1	ELEV = 11.25M	E = 275141.8	N = 5243917.4
PW2	ELEV = 5.52M	E = 275284.33	N = 5243704.89

LEGEND

- NOVEMBER 2012 GEOTECHNICAL BOREHOLE LOCATION
- SEPTEMBER 2012 TEST PIT LOCATION
- 2011 INVESTIGATION EXISTING BOREHOLE LOCATION
- PROPOSED OBSERVATION WELL LOCATIONS (ONGOING)
- PROPOSED PUMPING WELL LOCATION (ONGOING)
- ESTIMATED REGIONAL GROUNDWATER FLOW

NOTES:
1. DRAWING BASED ON INFORMATION PROVIDED BY HUSKY ENERGY (CAD FILE No. WH-K-98W-K-LY-00005-001.DWG).
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CLIENT:

HUSKY ENERGY

PROJECT TITLE:

BASELINE HYDROGEOLOGICAL CHARACTERIZATION, CONCRETE GRAVITY STRUCTURE GRAVING DOCK SITE, ARGENTIA, NL

DRAWING TITLE:

SITE PLAN

Stantec Consulting Ltd.

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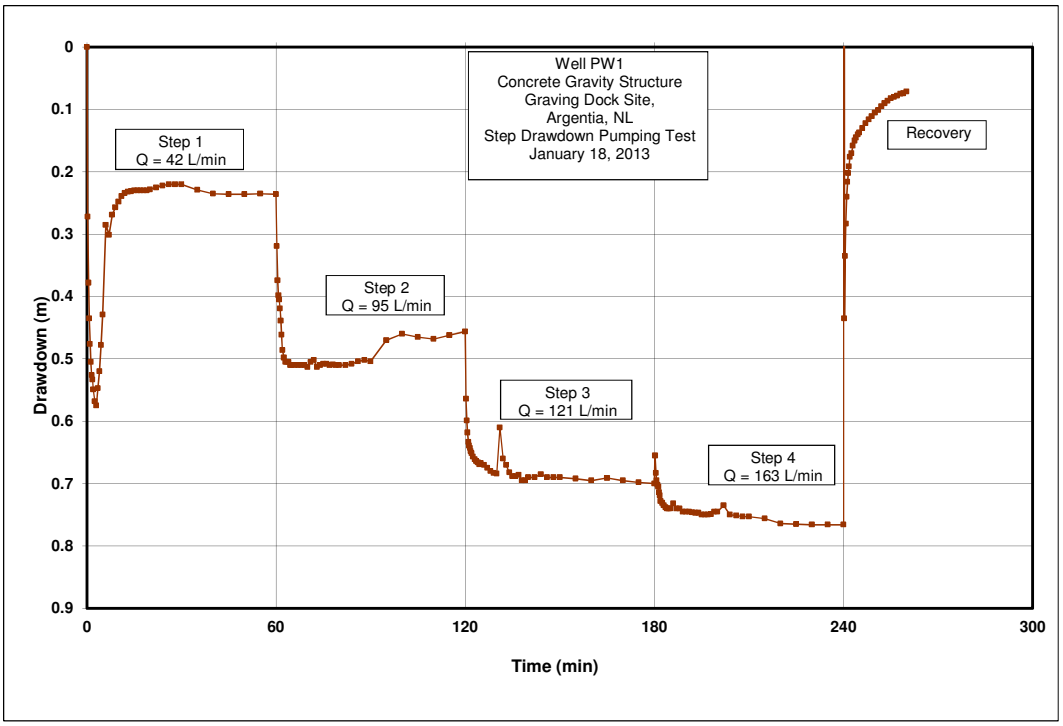

Figure A.1 Drawdown Responses in Step Drawdown test in PW1

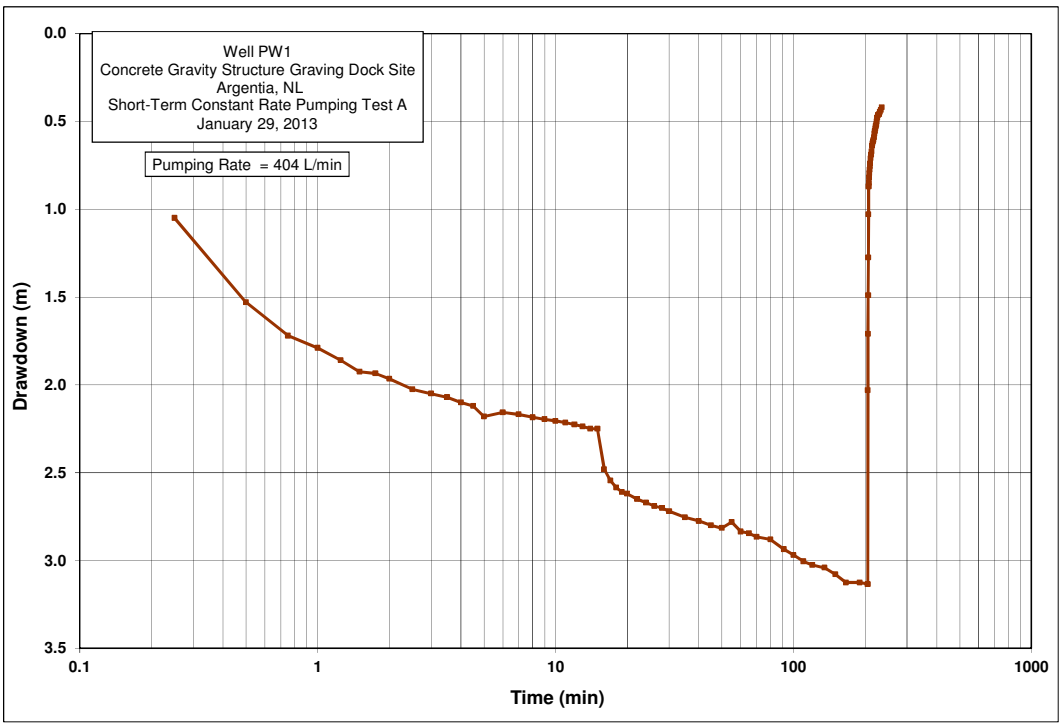

Figure A.2 Drawdown Responses for Short Term Pump Test A in PW1

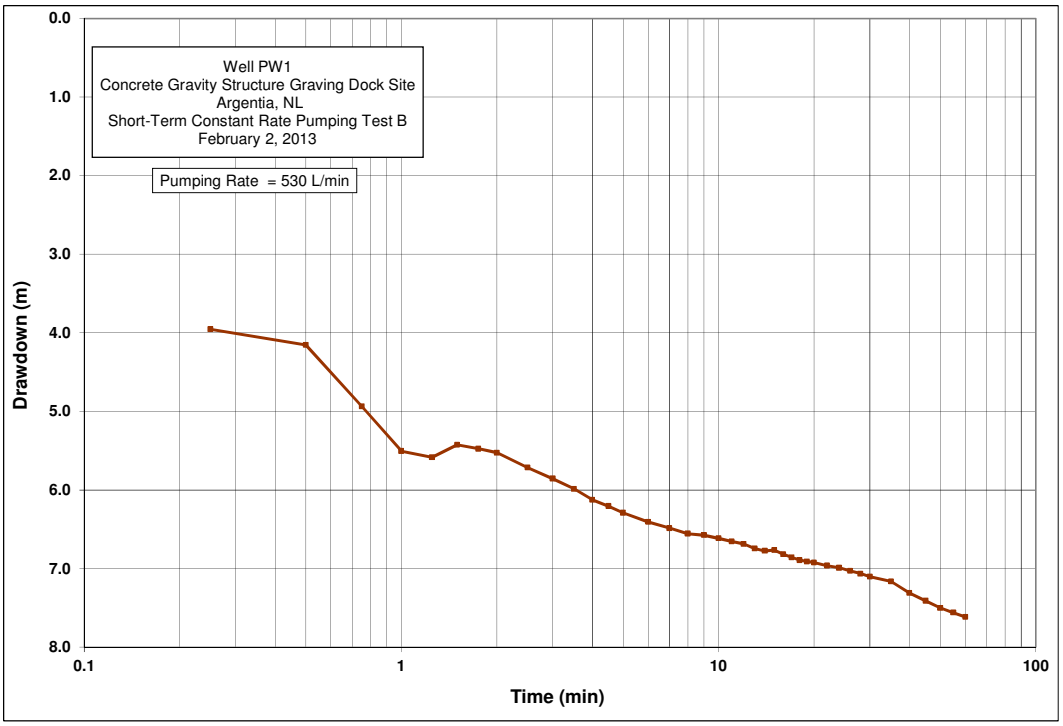

Figure A.3 Drawdown Responses for Short Term Pump Test B in PW1

APPENDIX B

Borehole Record – PW1

WELL RECORD

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BOREHOLE No. **PW1**
PAGE **1** of **3**
PROJECT No. **121412512**
DRILLING METHOD **Rotary Drill**
SIZE **300mm** **w/symmetrix**
DATUM **Chart Datum**

CLIENT **Husky Energy**
PROJECT **Hydrogeological Investigation, Test Well PW1 Concrete Gravity Structure,**
LOCATION **Graving Dock Site, Argentia, NL**
DATES (mm-dd-yy): BORING **1-4-13** to **1-6-13** WATER LEVEL **8.23m** **1-18-13**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY	SAMPLES N-VALUE OR RQD %	HYDROCARBON ODOUR	APPARENT MOISTURE CONTENT	PID (ppm)	TPH (ppm)	WELL CONSTRUCTION DETAILS (0.723 m STICK UP)
	11.25						mm						STAINLESS STEEL STICK-UP
0		Light brown, silty SAND with gravel (SM)			BS	1							BENTONITE
1													
2					BS	2							
3	8.20	Light brown, GRAVEL (GP)			BS	3							
4													
5					BS	4							200 mm DIAMETER No. 40 SLOT STAINLESS STEEL SCREEN IN No.2 SILICA SAND PACK
6	5.15	Light brown, GRAVEL with sand (GP)			BS	5							
7													
8				▼	BS	6							
9													
10					BS	7							

WELL RECORD

Stantec

BOREHOLE No. PW1
PAGE 2 of 3
PROJECT No. 121412512
DRILLING METHOD Rotary Drill
SIZE 300mm w/symmetrix
DATUM Chart Datum

CLIENT Husky Energy
PROJECT Hydrogeological Investigation, Test Well PW1 Concrete Gravity Structure,
LOCATION Graving Dock Site, Argentia, NL
DATES (mm-dd-yy): BORING 1-4-13 to 1-6-13 WATER LEVEL 8.23m 1-18-13

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY mm	SAMPLES N-VALUE OR RQD %	HYDROCARBON ODOUR	APPARENT MOISTURE CONTENT	PID (ppm)	TPH (ppm)	WELL CONSTRUCTION DETAILS
		Continued from Previous Page											
10													
11					BS	8							
12													
13					BS	9							
14					BS	10							200 mm DIAMETER No. 40 SLOT STAINLESS STEEL SCREEN IN No.2 SILICA SAND PACK
15													
16					BS	11							
17													
18	-7.04												
		Brown silty SAND (SM) to sandy SILT (ML)											
19					BS	12							
20													

WELL RECORD

Stantec

BOREHOLE No. PW1
PAGE 3 of 3
PROJECT No. 121412512
DRILLING METHOD Rotary Drill
SIZE 300mm w/symmetrix
DATUM Chart Datum

CLIENT Husky Energy
PROJECT Hydrogeological Investigation, Test Well PW1 Concrete Gravity Structure,
LOCATION Graving Dock Site, Argentia, NL
DATES (mm-dd-yy): BORING 1-4-13 to 1-6-13 WATER LEVEL 8.23m 1-18-13

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm)	SAMPLES N-VALUE OR RQD %	HYDROCARBON ODOUR	APPARENT MOISTURE CONTENT	PID (ppm)	TPH (ppm)	WELL CONSTRUCTION DETAILS
		Continued from Previous Page											
20					BS	13							
21													
22					BS	14							200 mm DIAMETER SOLID STAINLESS STEEL WELL CASING
23					BS	15							
24	-13.13												END CAP
		End of Borehole											
25													
26													
27													
28													
29													
30													

APPENDIX C

Summary Tables

Table C.1 Monitor Well Construction Details (MWs used in Hydraulic Testing)

Well	Drill Date	Depth (mbgs)	Diameter (mm)	Casing Stick-up (m)	Elevation		Static Water level		Screen Length (m)	Sand Pack		
					TOC (m)	Grade (m)	Depth (mbtoc)	Elevation (m)		From (m)	To (m)	Length (m)
PW1	16-Jan-13	24.30	200	1.00	12.25	11.25	8.23	4.02	18.20	1.20	19.8	18.60
OW1	3-Dec-12	21.34	51	1.08	12.79	11.71	8.20	4.59	20.00	1.34	21.34	20.00
OW3	27-Nov-12	21.34	51	1.07	12.10	11.03	8.96	3.14	20.00	1.34	21.34	20.00
OW4	28-Nov-12	21.34	51	1.05	12.62	11.57	9.36	3.26	20.00	1.34	21.34	20.00
OW5	4-Dec-12	21.34	51	0.98	12.65	11.67	9.28	3.38	20.00	1.34	21.34	20.00
OW6	2-Dec-12	41.1	51	1.04	6.16	5.43	3.00	3.14	6.10	32.50	40.3	7.80
OW7	14-Dec-12	36.5	51	0.36	6.21	5.03	2.30	3.14	22.90	11.25	35.9	24.65
OW8	8-Dec-12	41.15	51	1.11	6.05	4.94	3.11	2.94	20.00	21.15	41.15	20.00
OW9	16-Dec-12	22.90	51	1.08	12.22	11.14	8.80	3.42	21.40	1.50	22.90	21.40
OW10	15-Dec-12	13.70	51	1.40	10.85	9.45	7.60	3.25	12.20	1.50	13.70	12.20
BHA6	14-Nov-12	41.1	51	-	11.27	11.02	Well abandoned		3.05	21.40	26.3	4.90
BHA7	15-Nov-12	41.15	51	1.00	10.48	9.48	7.12	3.36	3.05	36.00	41.15	5.15
BHA8	23-Nov-12	41.15	51	0.94	7.09	6.15	4.02	3.08	3.05	32.90	41.15	8.25
BHA9	7-Nov-12	41.2	51	-	9.67	9.57	Well abandoned		3.05	37.20	41.2	4.00
BHA10	26-Nov-12	41.15	51	0.82	8.36	7.54	5.44	2.92	3.05	32.60	41.15	8.55
BHA12	26-Nov-13	41.2	51	1.23	6.52	5.23	2.10	3.13	6.10	33.00	40.4	7.40
BHA13	20-Nov-12	41.1	51	1.35	5.93	4.82	1.50	3.32	6.10	32.90	40.2	7.30
BHA14	16-Nov-12	41.1	51	0.64	5.22	4.27	1.00	3.27	6.10	32.60	39.9	7.30
BHA15	12-Nov-12	41.1	51	0.85	5.15	4.28	1.40	2.88	3.05	36.00	40.1	4.10
					Minimum	4.27	1.00	2.88	2.88			2.88
					Maximum	11.71	9.36	4.59	4.59			4.59
					Mean	8.50	5.72	3.33	3.33			3.33

No. 10 Slot PVC Screens

Table C.2 Step Test Response Summary - Test Well PW1 (18-Jan-13)

Step	Step Time	Pumping Rate			Water Level (m)	Drawdown (m)	Uncorr. Specific Capacity		Mean Q/s (m^2/d)
	(Min)	(USgpm)	(L/min)	(m^3/d)			m^2/d	L/min/m	
1	60	11.0	41.6	60.0	12.25	0.24	250	173	275
2	60	25.0	94.6	136.3	16.25	0.46	296	206	
3	60	32.0	121.1	174.4	22.59	0.70	249	173	
4	60	43.0	162.8	234.4	29.47	0.77	304	211	
PT1 (3.4 hr)	60	106.7	404	581.8	12.14	2.84	205	142	
PT2 (1 hr)	60	140.0	530	763.2	16.36	7.62	100	70	
PT3 (58 hr)	60	120.0	454.2	654.0		4.15	158	109	

Table C.3 Summary of Hydraulic Testing Data - PW1

Well	Pumping Rate (m^3/d)	Distance from Pumping Well (m)	Transmissivity (m^2/s)	Transmissivity (m^2/day)	Storage coefficient	Method
Short Term (3.5 hr) Pump Test A (29-Jan-13)						
PW1	582 (404 Lpm)	-	0.002675	226.8	1.2E-03	Cooper-Jacob
				313.0	-	Theis Recovery
Short Term (1 hr) Pump Test B (2-Feb-13)						
PW1	763 (530 Lpm)	-	0.003623	79.8	6.3E-02	Cooper-Jacob
				-	-	Theis Recovery
58.2 Hour constant Rate Pump Test (6-Feb-13 to 9-Feb-13)						
PW1	654 (454 Lpm)	-	0.001174	101.4	-	Cooper-Jacob
			0.001521	131.4	-	Theis
			0.001865	161.1	-	Theis Recovery
OW1		39	-	-	no response	Cooper-Jacob
OW3		16	0.002001	172.9	0.008152	Cooper-Jacob
			0.001904	164.5	0.01009	Theis
			0.001675	144.7	-	Theis Recovery
OW4		16	0.00216	186.6	0.00345	Cooper-Jacob
			0.002784	240.5	0.0004445	Theis
			0.002023	174.8	-	Theis Recovery
OW5		30	0.002405	207.8	0.002635	Cooper-Jacob
			0.002855	246.7	0.0008412	Theis
			0.002077	174.8	-	Theis Recovery
OW8		168	0.002542	219.6	0.005311	Cooper-Jacob
			0.002674	231.0	0.00587	Theis
			0.004647	401.5	-	Theis Recovery
OW9		80	0.002462	212.7	0.0156	Cooper-Jacob
			0.002167	187.2	0.02367	Theis
			0.002479	214.2	-	Theis Recovery
OW10		73	0.002197	189.8	0.004719	Cooper-Jacob
			0.002138	184.7	0.00538	Theis
			0.002114	182.6	-	Theis Recovery
BHA7		78	0.01052	908.928	0.04389	Cooper-Jacob
			0.006154	531.7056	0.06514	Theis
			0.005518	476.7552	-	Theis Recovery
BHA8		131	0.006385	551.7	0.008379	Cooper-Jacob
			0.004514	390.0	0.01207	Theis
			0.005881	508.1	-	Theis Recovery
BHA10		123	0.003717	321.1	0.001449	Cooper-Jacob
			0.005782	499.6	-	Theis
			0.003026	261.4		Theis Recovery
Composite			0.001762	152.2	0.01177	Cooper-Jacob
			0.001762	152.2	0.004995	Theis Recovery

Table C.3 Summary of Hydraulic Testing Data - PW1

Well	Pumping Rate (m^3/d)	Distance from Pumping Well (m)	Transmissivity (m^2/s)	Transmissivity (m^2/day)	Storage coefficient	Method
Distance Drawdown (t = 58 hrs)			0.001546	133.6	0.01215	Cooper-Jacob
		Apparent Well	**1.5E-03**	**131.3**	**-**	
		Aquifer Mean	**2.8E-03**	**239.7**	**7.4E-03**	
		Aquifer Geomean	**2.6E-03**	**222.7**	**4.5E-03**	

Table C.4 Summary of Grain Size Distribution K Analysis

Sample No.			Depth			
BH	Sample ID	Sample Type	From [m]	To [m]	Subsurface Unit	Est'd K [cm/s]
BH A10	26-B	SC-B	39.01	39.32	Sand (SP)	4.50E-06
BH A12	2-1-B	SC-B	1.83	2.21	Gravel (GW)	5.63E-05
BH A12	4-B	SC-B	5.18	5.49	Gravel (GW)	1.62E-02
BH A12	6-B	SC-B	7.92	8.23	Sand (SW)	7.04E-05
BH A12	7-B	SC-B	9.75	10.06	Gravel (GW)	1.00E-04
BH A12	8-B	SC-B	11.58	11.89	Silty Sand (SM)	2.94E-05
BH A12	12-B-2	SC-B	20.42	20.73	Silt (ML); Silty Sand (SM)	8.10E-08
BH A12	14-B	SC-B	23.16	23.47	Silt (ML); Silty Sand (SM)	6.97E-07
BH A12	16-B	SC-B	26.82	27.13	Sand (SW)	1.18E-04
BH A12	19-B	SC-B	31.09	31.39	Silty Sand	8.66E-08
BH A12	22-B	SC-B	35.43	35.74	Sand	1.45E-04
BH A12	24-B	SC-B	38.71	39.01	Gravelly Sand	1.90E-04
BH A13	3-B	SC-B	3.66	3.96	Silty-Gravel Sand	2.50E-05
BH A13	4-B	SC-B	5.18	5.49	Gravel	1.26E-05
BH A13	5-B	SC-B	7.01	7.32	Gravelly Sand	3.60E-03
BH A13	7-B	SC-B	9.75	10.06	Sand	1.44E-03
BH A13	9-B	SC-B	12.80	13.11	Sand	2.60E-04
BH A13	11-B	SC-B	15.85	16.15	Sand	4.00E-04
BH A13	13-B	SC-B	19.10	19.46	Silty Sand	2.56E-07
BH A13	15-B	SC-B	22.24	22.56	Silty Sand	2.56E-09
BH A13	17-B	SC-B	24.54	24.84	Gravelly Sand (SW)	4.00E-04
BH A13	19-B	SC-B	28.04	28.35	Sand (SP)	2.00E-05
BH A13	21-B	SC-B	31.45	31.88	Silty Sand (SM)	4.00E-09
BH A14	4-B	SC-B	5.18	5.49	Gravelly SAND	1.62E-03
BH A14	6-B	SC-B	8.59	8.84	Sandy GRAVEL	3.83E-04
BH A14	9-B	SC-B	12.50	12.80	Gravelly Sand	7.02E-05
BH A14	10-B	SC-B	14.02	14.33	Sandy GRAVEL	5.04E-07
BH A14	13-B	SC-B	18.90	19.20	Gravel	1.72E-04
BH A14	14-B	SC-B	20.73	21.03	Silty Sand (SM)	4.61E-08
BH A14	17-B	SC-B	24.84	25.15	Silty Sand (SM)	1.75E-04
BH A14	19-B	SC-B	28.04	28.35	Silty Gravel (GM)	5.76E-08
BH A14	22-B	SC-B	32.49	32.66	Sand	2.36E-04
BH A15	2-B	SC-B	2.44	2.74	Rootmat	2.25E-04
BH A15	5-B	SC-B	6.40	6.71	Sandy Gravel	1.60E-03
BH A15	6-B	SC-B	8.23	8.53	Gravel	2.11E-01
BH A15	8-B	SC-B	11.10	11.58	Sandy Gravel	1.69E-04
BH A15	11-B	SC-B	15.54	16.08	Fine Sand	1.01E-04
BH A15	16-B					2.56E-09
BH A15	17-B	SC-B	25.15	25.50	Silty Clay	3.60E-06
BH A15	18-B	SC-B	26.52	26.82	Clayey Silt	6.40E-08
BH A15	20-B	SC-B	29.57	29.87	gravelly silty sand	5.40E-06

Table C.4 Summary of Grain Size Distribution K Analysis

Sample No.			Depth			
BH	**Sample ID**	**Sample Type**	**From [m]**	**To [m]**	**Subsurface Unit**	**Est'd K [cm/s]**
BH A15	21-B	SC-B	31.09	31.45	Silty Sand	3.60E-06
BH A15	24-B	SC-B	35.36	35.66	silty clay	1.60E-08
BH A15	26-B	SC-B	38.71	39.01	silty sand	4.00E-07
BH A15	28-B	SC-B	40.23	40.54	silty sand	4.00E-07
BH A6	2-B	SC-B	2.13	2.36	FILL	6.30E-05
BH A6	12-B	SC-B	17.37	17.68	Sand	5.04E-04
BH A6	14-B	SC-B	20.02	20.32	Sand	2.70E-05
BH A6	16-B	SC-B	23.16	23.47	Sandy Gravel	6.85E-03
BH A6	17-B	SC-B	24.38	24.69	Silty Sandy Gravel	4.10E-04
BH A6	26-B	SC-B	38.79	39.09	Medium Sand	1.29E-04
BH A7	5-B	SC-B	6.71	7.01	Silty Clay	1.76E-08
BH A7	10-B	SC-B	14.02	14.33	Silty CLAY (CL)	3.14E-08
BH A7	12-B	SC-B	17.68	17.98	Clayey SILT (ML)	1.68E-06
BH A7	15-B	SC-B	21.34	21.64	Sandy Gravel (GW)	1.02E-03
BH A7	17-B	SC-B	24.64	25.04	Sand (SW)	1.41E-04
BH A7	19-B	SC-B	28.04	28.35	Silty Sand (SM)	1.08E-07
BH A7	21-B	SC-B	31.09	32.00	Silty Sand (SM)	1.28E-05
BH A7	24-B	SC-B	35.97	36.27	Sandy Silt (ML)	2.70E-08
BH A7	26-B	SC-B	38.10	38.40	Sandy Silt (ML)	1.54E-07
BH A8	4-B	SC-B	5.18	5.49	Gravelly Sand (SW)	2.80E-04
BH A8	11-B	SC-B	16.00	16.31	Silty Sand (SM)	8.00E-05
BH A8	14-B	SC-B	20.42	20.73	Gravelly Sand (SW)	3.60E-03
BH A8	18-B	SC-B	26.37	26.67	Sand (SW)	1.13E-06
BH A9	4-B	SC-B	5.18	5.49	Medium Sand	6.00E-07
BH A9	6-B	SC-B	8.84	9.14	Gravel	1.28E-05
BH A9	12-B	SC-B	17.07	17.53	Gravel	7.68E-05
BH A9	24-B	SC-B	35.66	36.12	Gravelly clayey Sand	2.56E-03
BH A9	25-B	SC-B	37.29	37.64	Silty Clay	3.60E-10
BH A9	26-B					4.00E-11
BH A9	27-B	SC-B	39.62	40.06	Silty Sand	1.60E-08
Summary:						
Geometeric Mean		-	16.57	17.06	-	9.61E-06
Median		-	20.58	20.96	-	2.94E-05
Minimum		-	0.61	0.91	-	4.00E-11
Maximum		-	40.23	40.54	-	2.11E-01
#		108	108	108		71

Table C.5 Summary of Slug Testing - CGS Graving Dock Site

Well	Test Date	Test Type	Screen From (m)	To (m)	Material	K (m/s)	Ss	Method
OW1	15-Dec-12	Rising Head	1.34	21.34		2.80E-06	-	Bouwer & Rice
OW3	15-Dec-12	Falling Head	1.34	21.34		5.15E-07	-	Bouwer & Rice
OW4	15-Dec-12	Rising Head	1.34	21.34		2.09E-06	7.6E-03	KGS
OW5	15-Dec-12	Falling Head	1.34	21.34		1.50E-06	-	Bouwer & Rice
OW6	15-Dec-12	Rising Head				2.72E-05	1.1E-01	KGS
OW7	15-Dec-12	Rising Head				1.10E-05	1.4E-03	KGS
OW8	15-Dec-12	Rising Head	21.15	41.15		3.53E-05	-	Bouwer & Rice
OW9	15-Dec-12	Rising Head	1.5	22.9		1.55E-05	-	Bouwer & Rice
OW10	15-Dec-12	Falling Head	1.5	13.7		8.07E-08	-	Bouwer & Rice
A7	15-Dec-12	Falling Head	36	41.15	clay-silt	6.16E-06	6.2E-06	KGS
A8	15-Dec-12	Falling Head	32.9	41.15	sand	1.05E-06	1.7E-04	KGS
A10	15-Dec-12	Rising Head	32.6	41.15	Sand	4.12E-05	2.6E-04	KGS
A12	15-Dec-12	Falling Head			Sd, Grav	5.09E-05	2.1E-04	KGS
A13	15-Dec-12	Falling Head			Grav-Sd	1.82E-04	1.9E-04	KGS
A14	15-Dec-12	Rising Head			Sd, Grav	1.87E-05	5.0E-06	KGS
A15	15-Dec-12	Falling Head			silty-Sd	6.45E-07	1.9E-03	KGS
		Minimum				**8.07E-08**		
		Maximim				**1.82E-04**		
		Mean				**5.83E-06**		

Table C.6 Predicted 100 Day Distance Drawdown at Various Combined Pumping Rates

Distance	igpm	100	250	500	750	1,000	1,250	1,500	1,750	2,000
(m)	L/min	455	1,137	2,273	3,410	4,546	5,683	6,819	7,956	9,092
1		3.80	9.49	18.99	**28.48**	**37.97**	**47.47**	**56.96**	**66.46**	**75.95**
10		2.72	6.80	13.60	**20.40**	**27.19**	**33.99**	**40.79**	**47.59**	**54.39**
25		2.29	5.73	11.45	17.18	**22.90**	**28.63**	**34.36**	**40.08**	**45.81**
50		1.97	4.91	9.83	14.74	19.66	**24.57**	**29.49**	**34.40**	**39.32**
75		1.78	4.44	8.88	13.32	17.76	**22.20**	**26.64**	**31.08**	**35.52**
100		1.64	4.10	8.21	12.31	16.41	**20.52**	**24.62**	**28.72**	**32.83**
150		1.45	3.63	7.26	10.89	14.52	18.14	**21.77**	**25.40**	**29.03**
200		1.32	3.29	6.58	9.88	13.17	16.46	19.75	**23.04**	**26.34**
300		1.13	2.82	5.64	8.45	11.27	14.09	16.91	19.72	**22.54**
400		0.99	2.48	4.96	7.44	9.92	12.40	14.88	17.37	19.85
500		0.89	2.22	4.44	6.66	8.88	11.10	13.32	15.54	17.76
600		0.80	2.01	4.01	6.02	8.02	10.03	12.04	14.04	16.05
700		0.73	1.83	3.65	5.48	7.30	9.13	10.95	12.78	14.61
800		0.67	1.67	3.34	5.01	6.68	8.35	10.02	11.69	13.36
900		0.61	1.53	3.06	4.59	6.13	7.66	9.19	10.72	12.25
1000		0.56	1.41	2.82	4.22	5.63	7.04	8.45	9.86	11.27
1100		0.52	1.30	2.59	3.89	5.19	6.48	7.78	9.08	10.37
1200		0.48	1.19	2.39	3.58	4.78	5.97	7.17	8.36	9.56
1500		0.37	0.93	1.87	2.80	3.73	4.67	5.60	6.54	7.47
2000		0.24	0.60	1.19	1.79	2.39	2.98	3.58	4.18	4.78

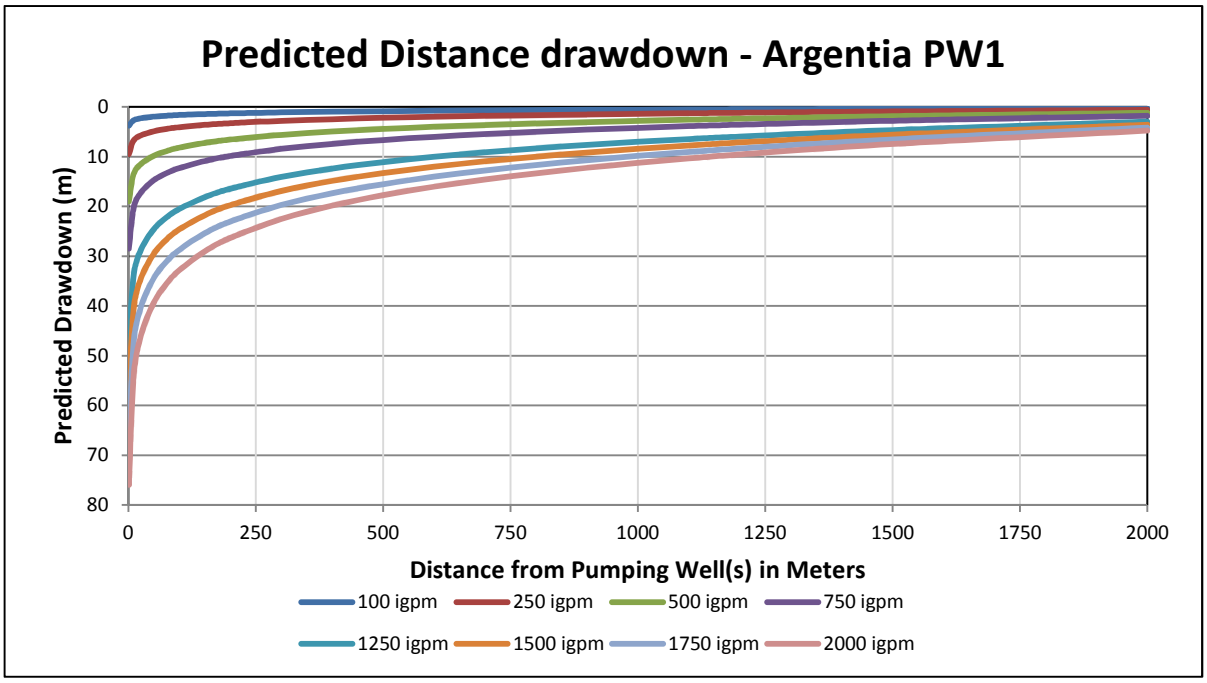
47.47 below 40 m pump setting

28.48 within dewatering window

Pump Setting: 40 m (available drawdown 31-40, meam 34.5 m

CSG Bottom elevation: -18 m

Pumping Level Required: 20.9 to 22.0, mean 21.3 m



APPENDIX D

Water Chemistry Summary Tables

Table D.1 Field chemistry - Pumping Test PW1

Time (minutes)	Salinity (o/oo)	pH (units)	Conductivity (µS/cm)	Temperature (^oC)
10	0.33	8.27	430	5.50
300	0.33	6.82	461	8.03
1180	0.33	7.15	449	7.91
1345	0.33	7.28	463	9.13
1575	0.32	6.70	450	8.33
2968	0.32	6.81	429	7.27
Mean	**0.33**	**7.17**	**447**	**7.70**

Notes: o/oo - parts per thousand; µS/cm - microseimens/centimetre; ^oC - degrees Celsius

Table D.2 Results of Laboratory Analysis of General Chemistry Parameters in Groundwater

Parameters	Units	RDL	Guideline[1]	BH A1	OW1	PW1	PW1 Lab-Dup	OW8	OW8 Lab Dup	OW10
Sodium (Na)	mg/L	0.1	2,300	78.0	156.0	25.2		693.0		**4,280**
Potassium (K)	mg/L	0.0		6.0	7.8	0.8		45.6		98.4
Calcium (Ca)	mg/L	0.1		69.7	87.1	63.7		128.0		552.0
Magnesium (Mg)	mg/L	0.1		22.5	34.5	13.6		137.0		516.0
Total Alkalinity (Total as CaCO3)	mg/L	25	-	330.0	170.0	190.0	-	130.0	-	80.0
Dissolved Sulphate (SO4)	mg/L	10	-	57.0	50.0	23.0	-	200.0	-	990.0
Dissolved Chloride (Cl)	mg/L	1.0	2,300	78.0	360.0	31.0	-	1500.0	-	**8,600**
Reactive Silica (SiO2)	mg/L	0.50	-	12.0	13.0	12.0	-	6.3	-	8.2
Orthophosphate (P)	mg/L	0.010	-	nd	nd	nd	-	nd	-	nd
Phosphorus (P)	mg/L	0.100		<0.1	<0.1	<0.1		<0.1		<0.1
Nitrate + Nitrite	mg/L	0.050	-	nd	4.30	2.10	-	0.21	-	1.00
Nitrite (N)	mg/L	0.010	-	0.01	0.04	nd	-	0.01	-	0.04
Nitrogen (Ammonia Nitrogen)	mg/L	0.050	-	0.35	nd	nd	-	0.79	-	0.14
Colour	TCU	5.0	-	20	nd	nd	-	nd	-	nd
Turbidity	NTU	0.50	-	170	52	6.1	-	0.8	-	51.0
Conductivity	uS/cm	1.0	-	930	1,500	520	520	5,000	5,000	24,000
pH	pH	N/A	-	7.60	7.67	8.1	8.11	7.85	7.87	7.73
Hardness				267	360	215		883	-	3502
Total Organic Carbon (C)	mg/L	5.0	-	13 (1)	nd	nd	-	nd	-	nd

Notes:

[1] = Ontario Ministry of the Environment (MOE) Soil, Groundwater, and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act: Table 3 - Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition for Industrial/Commercial Property Use

"-" = not analysed, not applicable or no applicable guideline

ND = Not Detected above the RDL

RDL = Reportable Detection Limit

Lab-Dup = Laboratory QA/QC duplicate sample

Bold/Shaded = value exceeds applicable criteria

Table D.3 Results of Laboratory Analysis of Dissolved Metals in Groundwater

Parameter	Units	RDL	Guideline[1]	BHA1	OW1	PW1	OW8	OW10
Aluminum (Al)	ug/L	5.0	-	nd	nd	nd	nd	nd
Antimony (Sb)	ug/L	1.0	20,000	nd	nd	nd	nd	nd
Arsenic (As)	ug/L	1.0	1,900	nd	nd	nd	nd	nd
Barium (Ba)	ug/L	1.0	29,000	109	109	28.4	128	123
Beryllium (Be)	ug/L	1.0	29	nd	nd	nd	nd	nd
Bismuth (Bi)	ug/L	2.0	-	nd	nd	nd	nd	nd
Boron (B)	ug/L	50	45,000	69	75	nd	238	1,130
Cadmium (Cd)	ug/L	0.017	2.7	nd	0.221	nd	0.135	0.59
Chromium (Cr)	ug/L	1.0	810	nd	nd	nd	nd	nd
Cobalt (Co)	ug/L	0.40	66	1.58	0.89	0.47	nd	nd
Copper (Cu)	ug/L	2.0	87	nd	nd	nd	nd	nd
Iron (Fe)	ug/L	50	-	296	nd	nd	72	nd
Lead (Pb)	ug/L	0.50	25	nd	nd	nd	nd	nd
Manganese (Mn)	ug/L	2.0	-	8,310	552	15.7	848	1,320
Molybdenum (Mo)	ug/L	2.0	9,200	nd	nd	nd	nd	nd
Nickel (Ni)	ug/L	2.0	490	nd	nd	nd	nd	nd
Selenium (Se)	ug/L	1.0	63	nd	nd	nd	nd	nd
Silver (Ag)	ug/L	0.10	1.5	nd	nd	nd	nd	nd
Strontium (Sr)	ug/L	2.0	-	316	395	130	1,330	2,210
Thallium (Tl)	ug/L	0.10	510	nd	nd	nd	nd	nd
Tin (Sn)	ug/L	2.0	-	nd	nd	nd	nd	nd
Titanium (Ti)	ug/L	2.0	-	nd	nd	nd	nd	nd
Uranium (U)	ug/L	0.10	420	0.38	0.38	2.21	4.31	nd
Vanadium (V)	ug/L	2.0	250	nd	nd	nd	nd	nd
Zinc (Zn)	ug/L	5.0	1,100	6.1	5.4	12.7	nd	nd

Notes:

[1] = Ontario Ministry of the Environment (MOE) Soil, Groundwater, and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act: Table 3 - Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition for Industrial/Commercial Property Use (April 2011)

"-" = not analysed, not applicable or no applicable guideline

ND = Not Detected above RDL

RDL = Reportable Detection Limit

Table D.4 Results of Laboratory Analysis of Petroleum Hydrocarbons in Groundwater

Sample I.D.	Sample Date	BTEX Parameters (mg/kg)				Total Petroleum Hydrocarbons (mg/kg)					Resemblance/Comment
		Benzene	Toluene	Ethylbenzene	Xylenes	C_6-C_{10}	>C_{10}-C_{16}	>C_{16}-C_{34}	>C_{34}-C_{50}	Modified TPH[2]	
BHA1	3-Feb-12	nd	nd	nd	nd	nd	nd	nd	-	nd	-
OW1	19-Dec-12	nd	0.003	nd	nd	nd	nd	nd	-	nd	-
PW1	9-Feb-13	nd	0.005	nd	nd	nd	nd	nd	-	nd	-
OW8	19-Dec-12	nd	nd	nd	nd	nd	0.065	nd	-	nd	No resemblance to petroleum hydrocarbons
OW10	19-Dec-12	nd	nd	nd	nd	nd	0.071	nd	-	nd	No resemblance to petroleum hydrocarbons
RDL		0.001	0.001	0.001	0.002	0.01	0.05	0.05	0.1	0.1	-
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-
Guidelines[1]		20	20	20	20	-	-	-	-	20	-

Notes:

1 = Atlantic Partners in RBCA (Risk-Based Corrective Action) Implementation (PIRI) Tier I Risk-Based Screening Levels (RBSLs) for a commercial/industrial site with non-potable groundwater, coarse grained soil, and fuel oil impacts (July 2012)

2 = TPH - C_6 - C_{32} (excluding BTEX).

RDL = Reportable Detection Limit.

ND = Not detected above standard RDL.

"-" = Not analyzed, not applicable or no applicable guideline.

Table D.4 Results of Laboratory Analysis of Petroleum Hydrocarbons in Groundwater

Sample I.D.	Sample Date	BTEX Parameters (mg/kg)				Total Petroleum Hydrocarbons (mg/kg)					Resemblance/Comment
		Benzene	Toluene	Ethylbenzene	Xylenes	C_6-C_{10}	>C_{10}-C_{16}	>C_{16}-C_{34}	>C_{34}-C_{50}	Modified TPH[2]	
BHA1	3-Feb-12	nd	nd	nd	nd	nd	nd	nd	-	nd	-
OW1	19-Dec-12	nd	0.003	nd	nd	nd	nd	nd	-	nd	-
PW1	9-Feb-13	nd	0.005	nd	nd	nd	nd	nd	-	nd	-
OW8	19-Dec-12	nd	nd	nd	nd	nd	0.065	nd	-	nd	No resemblance to petroleum hydrocarbons
OW10	19-Dec-12	nd	nd	nd	nd	nd	0.071	nd	-	nd	No resemblance to petroleum hydrocarbons
RDL		0.001	0.001	0.001	0.002	0.01	0.05	0.05	0.1	0.1	-
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	-
Guidelines[1]		20	20	20	20	-	-	-	-	20	-

Notes:

1 = Atlantic Partners in RBCA (Risk-Based Corrective Action) Implementation (PIRI) Tier I Risk-Based Screening Levels (RBSLs) for a commercial/industrial site with non-potable groundwater, coarse grained soil, and fuel oil impacts (July 2012)

2 = TPH - C_6 - C_{32} (excluding BTEX).

RDL = Reportable Detection Limit.

ND = Not detected above standard RDL.

"-" = Not analyzed, not applicable or no applicable guideline.

Table D.5 Results of Laboratory Analysis of Volatile Organic Compounds in Groundwater

Parameter	Units	RDL	Guideline[1]	BHA1	OW1	PW1	OW8	OW10
Chlorobenzenes								
1,2-Dichlorobenzene	ug/L	0.50	4,600	nd	nd	nd	nd	nd
1,3-Dichlorobenzene	ug/L	1.0	9,600	nd	nd	nd	nd	nd
1,4-Dichlorobenzene	ug/L	1.0	8	nd	nd	nd	nd	nd
Chlorobenzene	ug/L	1.0	630	nd	nd	nd	nd	nd
Volatile Organics								
1,1,1-Trichloroethane	ug/L	1.0	640	nd	nd	nd	nd	nd
1,1,2,2-Tetrachloroethane	ug/L	1.0	3.2	nd	nd	nd	nd	nd
1,1,2-Trichloroethane	ug/L	1.0	4.7	nd	nd	nd	nd	nd
1,1-Dichloroethane	ug/L	2.0	320	nd	nd	nd	nd	nd
1,1-Dichloroethylene	ug/L	0.50	1.6	nd	nd	nd	nd	nd
1,2-Dichloroethane	ug/L	1.0	1.6	nd	nd	nd	nd	nd
1,2-Dichloropropane	ug/L	1.0	16	nd	nd	nd	nd	nd
Benzene	ug/L	1.0	44	nd	nd	nd	nd	nd
Bromodichloromethane	ug/L	1.0	85,000	nd	nd	nd	nd	nd
Bromoform	ug/L	1.0	380	nd	nd	nd	nd	nd
Bromomethane	ug/L	3.0	5.6	nd	nd	nd	nd	nd
Carbon Tetrachloride	ug/L	1.0	0.79	nd	nd	nd	nd	nd
Chloroethane	ug/L	8.0	-	nd	nd	nd	nd	nd
Chloroform	ug/L	1.0	2.4	nd	nd	nd	nd	nd
Chloromethane	ug/L	8.0	-	nd	nd	nd	nd	nd
cis-1,2-Dichloroethylene	ug/L	2.0	1.6	nd	nd	nd	nd	nd
cis-1,3-Dichloropropene	ug/L	2.0	-	nd	nd	nd	nd	nd
Dibromochloromethane	ug/L	1.0	82,000	nd	nd	nd	nd	nd
Ethylbenzene	ug/L	1.0	2,300	nd	nd	nd	nd	nd
Ethylene Dibromide	ug/L	1.0	0.25	nd	nd	nd	nd	nd
Methylene Chloride(Dichloromethane)	ug/L	3.0	610	nd	nd	nd	nd	nd
o-Xylene	ug/L	1.0	-	nd	nd	nd	nd	nd
p+m-Xylene	ug/L	2.0	-	nd	nd	nd	nd	nd
Styrene	ug/L	1.0	1,300	nd	nd	nd	nd	nd
Tetrachloroethylene	ug/L	1.0	1.6	nd	nd	nd	nd	nd
Toluene	ug/L	1.0	18,000	nd	nd	5.8	nd	nd
trans-1,2-Dichloroethylene	ug/L	2.0	1.6	nd	nd	nd	nd	nd
trans-1,3-Dichloropropene	ug/L	1.0	-	nd	nd	nd	nd	nd
Trichloroethylene	ug/L	1.0	1.6	nd	nd	nd	nd	nd
Trichlorofluoromethane (FREON 11)	ug/L	8.0	2,500	nd	nd	nd	nd	nd
Vinyl Chloride	ug/L	0.50	0.5	nd	nd	nd	nd	nd
Total VOC	ug/L			0	0	5.8	0	0

Notes:

[1] = Ontario Ministry of the Environment

"-" = not analysed, not applicable or no applicable guideline

ND = Not Detected above RDL

RDL = Reportable Detection Limit

Table D.6 Results of Laboratory Analysis of Semivolatile Organic Compounds (incl. PAHs) in Groundwater

Parameter	Units	RDL*	Guideline[1]	BHA1	OW1	OW1 Lab-Dup	PW1	OW8	OW10
Acenaphthene	ug/L	0.2 (0.01)	600	nd	nd	nd	nd	nd	nd
Acenaphthylene	ug/L	0.2 (0.01)	1.80	nd	nd	nd	nd	nd	nd
Anthracene	ug/L	0.2 (0.01)	2.40	nd	nd	nd	nd	nd	nd
Benzo(a)anthracene	ug/L	0.2 (0.01)	4.70	nd	nd	nd	nd	nd	nd
Benzo(a)pyrene	ug/L	0.2 (0.01)	0.75	nd	nd	nd	nd	nd	nd
Benzo(b/j)fluoranthene	ug/L	0.2 (0.01)	0.75	nd	nd	nd	nd	nd	nd
Benzo(g,h,i)perylene	ug/L	0.2 (0.01)	0.20	nd	nd	nd	nd	nd	nd
Benzo(k)fluoranthene	ug/L	0.2 (0.01)	0.40	nd	nd	nd	nd	nd	nd
1-Chloronaphthalene	ug/L	1	-	nd	-	-	-	-	-
2-Chloronaphthalene	ug/L	0.5	-	nd	-	-	-	-	-
Chrysene	ug/L	0.2 (0.01)	1.00	nd	nd	nd	nd	nd	nd
Dibenz(a,h)anthracene	ug/L	0.2 (0.01)	0.52	nd	nd	nd	nd	nd	nd
Fluoranthene	ug/L	0.2 (0.01)	130	nd	nd	nd	nd	nd	nd
Fluorene	ug/L	0.2 (0.01)	400	nd	nd	nd	nd	nd	nd
Indeno(1,2,3-cd)pyrene	ug/L	0.2 (0.01)	0.20	nd	nd	nd	nd	nd	nd
1-Methylnaphthalene	ug/L	0.2 (0.01)	1,800	nd	nd	nd	nd	nd	nd
2-Methylnaphthalene	ug/L	0.2 (0.01)	1,800	nd	nd	nd	nd	nd	nd
Naphthalene	ug/L	0.2 (0.01)	1,400	nd	nd	nd	nd	nd	nd
Perylene	ug/L	0.2 (0.01)	-	nd	nd	nd	nd	nd	nd
Phenanthrene	ug/L	0.2 (0.01)	580	nd	nd	nd	nd	nd	0.024
Pyrene	ug/L	0.2 (0.01)	68	nd	nd	nd	nd	nd	nd
1,2-Dichlorobenzene	ug/L	0.5	4,600	nd	-	-	-	-	-
1,3-Dichlorobenzene	ug/L	0.5	9,600	nd	-	-	-	-	-
1,4-Dichlorobenzene	ug/L	0.5	8	nd	-	-	-	-	-
Hexachlorobenzene	ug/L	0.5	3.10	nd	-	-	-	-	-
Pentachlorobenzene	ug/L	0.5	-	nd	-	-	-	-	-
1,2,3,5-Tetrachlorobenzene	ug/L	0.5	-	nd	-	-	-	-	-
1,2,4,5-Tetrachlorobenzene	ug/L	0.5	-	nd	-	-	-	-	-
1,2,3-Trichlorobenzene	ug/L	0.5	-	nd	-	-	-	-	-
1,2,4-Trichlorobenzene	ug/L	0.5	180	nd	-	-	-	-	-
1,3,5-Trichlorobenzene	ug/L	0.5	-	nd	-	-	-	-	-
2-Chlorophenol	ug/L	0.3	3,300	nd	-	-	-	-	-
4-Chloro-3-Methylphenol	ug/L	0.5	-	nd	-	-	-	-	-
m/p-Cresol	ug/L	0.5	-	nd	-	-	-	-	-
o-Cresol	ug/L	0.5	-	nd	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	ug/L	0.5	-	nd	-	-	-	-	-
2,3-Dichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,4-Dichlorophenol	ug/L	0.3	4,600	nd	-	-	-	-	-
2,5-Dichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,6-Dichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
3,4-Dichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
3,5-Dichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,4-Dimethylphenol	ug/L	0.5	39,000	nd	-	-	-	-	-
2,4-Dinitrophenol	ug/L	10	11,000	nd	-	-	-	-	-
4,6-Dinitro-2-methylphenol	ug/L	7	-	nd	-	-	-	-	-
2-Nitrophenol	ug/L	0.5	-	nd	-	-	-	-	-
4-Nitrophenol	ug/L	1	-	nd	-	-	-	-	-
Pentachlorophenol	ug/L	1	62	nd	-	-	-	-	-
Phenol	ug/L	0.5	12,000	nd	-	-	-	-	-
2,3,4,5-Tetrachlorophenol	ug/L	0.4	-	nd	-	-	-	-	-
2,3,4,6-Tetrachlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,3,5,6-Tetrachlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,3,4-Trichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,3,5-Trichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,3,6-Trichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
2,4,5-Trichlorophenol	ug/L	0.5	1,600	nd	-	-	-	-	-
2,4,6-Trichlorophenol	ug/L	0.5	230	nd	-	-	-	-	-
3,4,5-Trichlorophenol	ug/L	0.5	-	nd	-	-	-	-	-
Benzyl butyl phthalate	ug/L	0.5	-	nd	-	-	-	-	-
Biphenyl	ug/L	0.5	1,000	nd	-	-	-	-	-
Bis(2-chloroethyl)ether	ug/L	0.5	300,000	nd	-	-	-	-	-
Bis(2-chloroethoxy)methane	ug/L	0.5	-	nd	-	-	-	-	-
Bis(2-chloroisopropyl)ether	ug/L	0.5	20,000	nd	-	-	-	-	-
Bis(2-ethylhexyl)phthalate	ug/L	2	140	nd	-	-	-	-	-
4-Bromophenyl phenyl ether	ug/L	0.3	-	nd	-	-	-	-	-
p-Chloroaniline	ug/L	1	400	nd	-	-	-	-	-
4-Chlorophenyl phenyl ether	ug/L	0.5	-	nd	-	-	-	-	-
Di-N-butyl phthalate	ug/L	2	-	nd	-	-	-	-	-
Di-N-octyl phthalate	ug/L	0.8	-	nd	-	-	-	-	-

Table D.6 Results of Laboratory Analysis of Semivolatile Organic Compounds (incl. PAHs) in Groundwater

Parameter	Units	RDL*	Guideline[1]	BHA1	OW1	OW1 Lab-Dup	PW1	OW8	OW10
2,4-Dinitrotoluene	ug/L	0.5	2,900	nd	-	-	-	-	-
3,3'-Dichlorobenzidine	ug/L	0.5	640	nd	-	-	-	-	-
Diethyl phthalate	ug/L	1	38	nd	-	-	-	-	-
2,6-Dinitrotoluene	ug/L	0.5	2,900	nd	-	-	-	-	-
Dimethyl phthalate	ug/L	1	38	nd	-	-	-	-	-
Diphenyl Ether	ug/L	0.3	-	nd	-	-	-	-	-
Hexachlorobutadiene	ug/L	0.4	0.44	nd	-	-	-	-	-
Hexachlorocyclopentadiene	ug/L	2	-	nd	-	-	-	-	-
Hexachloroethane	ug/L	0.5	94	nd	-	-	-	-	-
Isophorone	ug/L	0.5	-	nd	-	-	-	-	-
Nitrobenzene	ug/L	0.5	-	nd	-	-	-	-	-
Nitrosodiphenylamine/Diphenylau	ug/L	1	-	nd	-	-	-	-	-
N-Nitroso-di-n-propylamine	ug/L	0.5	-	nd	-	-	-	-	-
Total SVOC	ug/L			0	0	0	0	0	0.024

Notes:

[1] = Ontario Ministry of the Environment (MOE) Soil, Groundwater, and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act: Table 3 - Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition for Industrial/Commercial Property Use (April 2011)

"-" = not analysed, not applicable or no applicable guideline

ND = Not Detected above RDL

RDL = Reportable Detection Limit; RDL in brackets for OW series data

Table D.7 Results of Laboratory Analysis of Polychlorinated Biphenyls in Groundwater

Sample ID	Sampling Date	Total PCBs (ug/L)
BH A1	3-Feb-12	nd
OW1	19-Dec-12	nd
OW8	19-Dec-12	nd
OW10	9-Dec-12	nd
PW1	9-Feb-13	nd
PW1 Lab-Dup	9-Feb-13	nd
	RDL	0.05
	Guideline[1]	0.2

Notes:

1 = Ontario Ministry of the Environment (MOE) Soil, Groundwater, and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act: Table 3 - Full Depth Generic Site Condition Standards in a Non-Potable Groundwater Condition for Industrial/Commercial Property Use (April 2011)

ND = Not Detected above the RDL.

RDL = Reportable Detection Limit.

"-" = Not analysed, not applicable or no applicable guideline.

Lab-Dup = Laboratory QA/QC duplicate sample